*Automated Guideway Transit: An Assessment of PRT and Other New Systems*

June 1975

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# Office of Technology Assessment

# Automated Guideway Transit

AN ASSESSMENT OF PRT
AND OTHER NEW SYSTEMS

PREPARED AT THE REQUEST OF

THE SENATE COMMITTEE ON APPROPRIATIONS
TRANSPORTATION SUBCOMMITTEE

MAY 1975

UNITED STATES CONGRESS
Office of Technology Assessment

# AUTOMATED GUIDEWAY TRANSIT

AN ASSESSMENT OF PRT AND
OTHER NEW SYSTEMS

INCLUDING

SUPPORTING PANEL REPORTS

PREPARED AT THE REQUEST OF THE

**SENATE COMMITTEE ON APPROPRIATIONS**

TRANSPORTATION SUBCOMMITTEE

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Congress of the United States

Office of Technology Assessment

Washington, D.C. 20510

## TECHNOLOGY ASSESSMENT BOARD



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## URBAN Mass TRANSIT ADVISORY PANEL



## OTA TRANSPORTATION ASSESSMENT STAFF MEMBERS




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**Congress of tbc United States**
**OFFICE OF TECHNOLOGY ASSESSMENT**
WASHINGTON, D.C. 20510



May **20, 1975**

The Honorable John L. McClellan
Chairman
Committee on Appropriate ions
U.S. Senate
Washington, D. C. 20510

Dear Mr, Chairman:

On behalf of the Technology Assessment Board, we are pleased to forward to you the following report on Automated Guideway Transit: An Assessment of PRT and Other New Systems. This report was prepared by the Office of Technology Assessment and is based upon the findings of five panels established to explore major topics. The report distinguishes three classes of Automated Guideway Transit and discusses the major institutional, technical, economic and social implications of each class.

This report is being made available to your Committee in accordance with Public Law 92-484, with appreciation and thanks to the many panelists who gave so generously of their time and energy.

| | |
|---|---|
| Sinc~ly, | Sincerely, |
| Olin E. Teague | Clifford P. Case |
| Chairman | Vice-Chairman |
| Technology Assessment Board | Technolo~y Assessment Board |

Congress of the United States
OFFICE OF TECHNOLOGY ASSESSMENT
WASHINGTON, D.C. 20510

EMILIO Q. DADDARIO
DIRECTOR
DANIEL V. DE SIMONE
DEPUTY DIRECTOR

May 16, 1975

The Honorable Olin E. Teague
Chairman of the Board
Office of Technology Assessment
United States Congress
Washington, D. C. 20510

Dear Mr. Chairman:

In response to the letter of September 27, 1974, from Senator John L. McClellan, Chairman, Senate Committee on Appropriations, the Office of Technology Assessment is pleased to forward this report, Automated Guideway Transit: An Assessment of Personal Rapid Transit (PRT) and Other New Systems.

This assessment was conducted by OTA'S Transportation Group, headed by Dr. Gretchen S. Kolsrud. The assessment was undertaken by five panels of experts who addressed the following five areas:

- Current Developments in the United States
- International Developments
- Operations and Technology
- Social Acceptability
- Economic Considerations

I am pleased to submit this report to you and to express my appreciation to all of the participants who contributed to it.

Sincerely,

Emilio Q. Daddario

EMILIO Q. DADDARIO
Director

United States Senate
COMMITTEE ON APPROPRIATIONS
WASHINGTON, D.C. 20510

September 27, 1974

The Honorable Edward M. Kennedy
Chairman
Technology Assessment Board
Washington, D. C. 20510

Dear Mr. Chairman:

On behalf of Senator Robert C. Byrd, Chairman of the Transportation Subcommittee, and Senator Clifford P. Case, the Subcommittee's Ranking Minority Member, I am transmitting an attached suggested revision to the Mass Transit Assessments you presently have underway.

With kindest personal regards, I am

Sincerely,

John L. McClellan
Chairman

JLM:cej

**United States Senate**
COMMITTEE ON APPROPRIATIONS
WASHINGTON, D.C. 20510

September 10, 1974

**Honorable John L. McClellan**
**Chairman**
**Committee on Appropriations**
**United States Senate**
**Washington, D. C. 20510**

**Dear Mr. Chairman:**

**We would like to enlist your support for an increase in the scope of the urban mass transportation assessments currently being conducted for the Committee by the Office of Technology Assessment. As you will recall, one of these assessments is concerned with the question of the degree of automation which is technically feasible, economically justifiable or otherwise appropriate to rail rapid transit. The second assessment addresses the process by which communities select, plan and implement a new transit system or modernize an existing one.**

**While the need for these studies of conventional rail transit remains unchanged, there have been significant developments since the date of our original request to the Office of Technology Assessment which indicate that the coverage of the assessments should be expanded in two directions.**

**--First, it seems clear that we will be required to deal with the issue of "personal rapid transit" and related high technology projects earlier and in greater depth than had been anticipated.**

**--Second, the increasingly serious condition of the economy suggests that these assessments should be expanded to consider the development and potential of urban mass transit under conditions in which federal funding may be severely decreased -- or greatly increased in the event that unemployment becomes an overriding problem.**

**To expand on the first point, communities (such as Minneapolis and Las Vegas) are showing increasing interest in new types of fixed guideway systems. Personal rapid transit (PRT) systems are increasingly discussed as alternatives to more conventional rail transit. Implementation of new technologies may be proposed such as magnetically levitated vehicles. The considerable effort underway in other countries to advance the state of the art in fixed guideway systems should be further investigated. The current assessments do address** some **of these issues. However, if addressed**

SENATE COMMITTEE ON APPROPRIATIONS
SEP 20 1974

they lie at the boundaries of the ongoing assessments rather than being fully included in the scope of work.

Concerning the second suggestion for expanding the assessments already underway, the economic picture has changed greatly since these assessments were initiated. As you know, a major purpose of a technology assessment is to identify policy alternatives and quantify the probable effects of such alternatives. Certainly, these assessments should address the full range of contingencies affecting policy alternatives and their impacts. Examples of varying economic outlooks that should be considered are as follows:

1. A revived fuel shortage leading to greatly increased (and funds for) mass transit. How much of the additional funds should be spent for fixed guideway transit, including personal rapid transit? How would R and D be affected? Would private industry have the capacity to support increased demands upon it?

2. A severe recession or actual depression. Should major

On the other hand, if funds for major transit projects were severely curtailed, how quickly could communities ,low planning or building new transit systems alter their plans? What are the probabilities associated with such a future? Are they sufficiently high that communities should be encouraged to place more emphasis on staging the development of new transit systems so that working subsystems are obtained if development of the entire system is interrupted?

To summarize, we feel the needs of the Committee will be best served by extending the current assessment efforts. These extensions would

--increase the range of technologies under assessment; and,

--permit assessment of the interrelationships between alternate economic futures and a variety of mass transit policy alternatives.

We appreciate your assistance in transmitting this request to the Chairman of the Technology Assessment Board.

Sincerely,

Robert C. Byrd, U.S.S.
Chairman, Transpor~ation
Appropriations Subcommittee

Clifford P. Case, U.S.S.
Ranking Minority Member
Transportation Appropriations
Subcommittee

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H. William Merritt, Transportation Consultant.
Leon M. Cole, The Library of Congress.

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Clark Henderson, Chairman Stanford Research Institute.
John K. Howell, Gerald D. Hines Interests (BRH Mobility).
John R. Jamieson, Twin Cities Area Metropolitan Transit Commission.
Thomas A. Lancaster, Rohr Industries, Inc.
Roy Lobosco, Port Authority of New York and New Jersey.

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J. Edward Anderson, University of Minnesota (on leave).
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Paul K. Dygert, Peat, Marwick, Mitchell and Company.
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Sumner Myers, Institute of Public Administration.

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Ralph Jackson, Denver Regional Transportation District.
Alain L. Kornhauser, Princeton University.
Rodney K. Lay, The MITRE Corporation.
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Vukan Vuchic, University of Pennsylvania.

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Thomas H. Floyd, Jr., D(IA International.
Howard R. Ross, Transportation Consultant.

# Preface

This assessment of Personal Rapid Transit and other forms of Automated Guideway Transportation has been prepared in response to a request from the United States Senate Committee on Appropriations on behalf of the Transportation Subcommittee.

The scope of this assessment complements two other studies conducted by the Office of Technology Assessment (OTA). The subjects of these other assessments are:

- The degree of automation which is technically feasible, economically justifiable, or otherwise appropriate to rail rapid transit; and
- The process by which communities plan, select or reject, and implement rail rapid transit systems in conjunction with other modes of transit.

The objectives of this assessment are threefold:

- To provide the Senate Appropriations Committee with information on the current status and the social and economic aspects of Automated Guideway Transit (AGT) developments,
- To assess the key problems associated with Automated Guideway Transit as perceived by potential riders, the communities, and the transit industry; and
- To identify major policy issues and automated guide~way transit program alternatives, and to explore their implications.

Dual-mode systems, moving walkways, and continuous flow systems are beyond the scope of this study. Other urban transportation options (e.g., electric automobiles) that might contribute to overcommg some of our current difficulties are covered, but only briefly.

The assessment was accomplished during a four-month period by a s ecial team of experts in the field representing divergent views on tEe subject. Study panels were organized to examine the current status of development and implementation. Consideration was given to the economic, social, and technical aspects of Automated Guideway Transit in the United States and foreign countries. The panels consulted with other interested and knowledgeable individuals, including representatives of urban planning organizations, transit operators, industry, and other groups who could make a significant contribution. The panel on social acceptability- invited a representative of organized labor to participate in discussions on the impact of automation.

Members of the assessment team made visits to important Automated Guideway Transit installations in the United States. Meetings were helcl with the urban Mass T'ransportation Administration. Advocates and opponents of Automated Guideway Transit presented their views to the assessment team. Research reports and technical data were obtained from a variety of domestic and foreign sources.

This report has been prepared b}~ the C)TA Transportation Assessments Group, based upon the fin&ngs and conclusions of the study panels and other information developed independently. The panel reports are included in this volume.

# Chapter 1: Summary

This report is a technology assessment of Automated Guideway Transit s stems, undertaken b The Office of Technology Assessment at t{ e request of the U.S. Senate Committee on Appropriations, Transportation Subcommittee. Detailed findings are presented in Chapters 2 through 5. Major findings and conclusions are summarized in this chapter, which is organized as follows. The first section contains definitions and brief descriptions of Automated Guideway Transit systems. The definitions are followed by a summary of the major technical, economic, social, and institutional issues associated with Automated Guideway Transit. Next is a review of current R & D programs, with emphasis on those sponsored by the Urban Mass Transportation Administration (UMTA). 1n the last section, four options are outlined for research and development activities by UMTA in the coming fiscal year.

## DEFINITIONS

Automated Guideway Transit (AGT) is a class of transportation systems in which unmanned vehicles are operated on fixed guideways along an exclusive right of way. The capacity of the vehicfes ranges from one or two up to 100 passengers. Single units or trains may be operated. Speeds are from 10 to +10 miles per hour. Headway (the time interval between vehicles moving along a main route) varies from one or two seconds to a minute. There may be a single route or branching and interconnecting lines.

This definition covers systems with a broad range of characteristics and includes many types of technology. To provide an organizing structure for the assessment, three major categories of AGT systems have been distinguished:

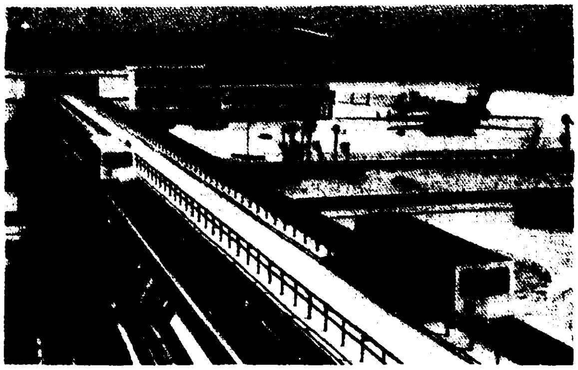
Shuttle-Loop Transit (SLT).
Group Rapid Transit (GRT).
Personal Rapid Transit (PRT).

Definitions and descriptions are given on page 3, with an illustration of each category on the facing age.

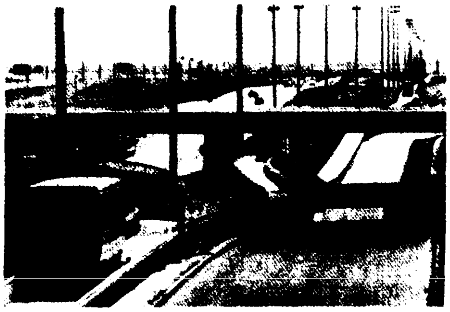
In selecting the terms empFeyed here, care was taken to use those which have already become established in the technical vocabulary. Automated Guideway Transit, Group Rapid Transit, and their acronyms are in general use b the Department of Transportation and the professional community. Personal Rapid Transit is a1'so a common term, but it causes confusion because PRT is sometimes used in a sense that is loosely synonymous with the whole AGT class. Restricting PRT in this report to mean a particular category of AGT is a return to the original definition, given in Tomorrow's *Transportation: New Systems for the Urban Future,* where the term was first used. Shuttle-Loop Transit is a new term, adopted here to describe a type of AGT system for which there is no generally accepted designation

CLASSES OF AUTOMATED GUIDEWAY TRANSIT

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



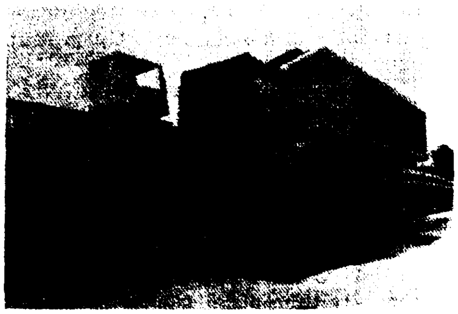
Passenger Shu



AIRTRANS-Dallas/Ft. Worth Airport

Group Rapid Transit
- more than six riders
- switching to shorten en route delays
- intermediate ***headway—three*** to *60* seconds

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



Cabinentaxi-Hagen, W. Germany

*Shuttle-Loop Transit* (SLT).—(Example: Tampa International Airport.) This is the simplest type of AGT system. Vehicles move along fixed paths with few or no switches, The vehicles of a simple *shuttle* system move back and forth on a single guideway, the horizontal equivalent of an automatic elevator. They may or may not make intermediate stops. Vehicles in a loop system move around a closed path, stopping at any number of stations. In both shuttle and loop systems, the vehicles may vary considerably in size and may travel singly or coupled together in trains.

*Group Rapid Transit* (GRT).—(Example: AIRTRANS, Dallas/Fort Worth Airport,) These systems serve groups of people with similar origins and destinations, The principal differences between GRT and the simpler SLT are that GRT tends to have shorter headways and a more extensive use of switching. GRT stations may be located on sidings off the main guideway, permitting through traffic to bypass. GRT guideways may merge or divide into branch lines to provide service on a variety- of routes. Vehicles with a capacity of 10 to 50 passengers may" be operated singly or in trains. Headways range from 3 to 60 seconds.

*Personal Rapid Transit* (PRT).—(Example: Cabinentaxi in Germany is a prototype.; there are no systems in passenger service,) The term PRT, as used in this study, is restricted to systems with small vehicles carrying either one person or groups of up to six usually traveling together by choice. Plans for PRT systems typically include off-line stations connected by a guideway' network. Under computer control, vehicles switch at guideway intersections so as to follow the shortest uncontested path from origin to destination without intermediate stops, Most proposed PRT systems call for vehicles to be operated at headways of three seconds or less.

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# SHUTTLE-LOOP TRANSIT (SLT)

## STATUS

In the United States there are nine SLT systems in operation and six more under construction. Two SLTs stems are operating abroad—one in Japan and the other in France. Five companies in the United States have been involved in producing vehicles for SLT systems. Westinghouse Electric and Ford Motor Company build fairly large vehicles (20 to 100 passengers each). Rohr and Universal Mobility build smaller and slower vehicles in the eight to 12 passenger range whch operate in trains of varying length. A fifth company, Stanray - Pacific, built one system for Baniff International at Love Field in Dallas, Texas.

None of these initial SLT systems serves the general public in the urban environment. All are found in airports, recreational centers, and private commercial establishments. However, SLT has several potential applications as an urban transportation system:

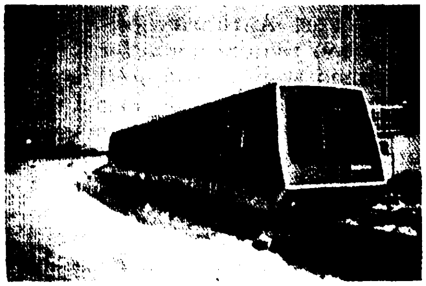
- Circulation in central business districts and other areas where surface congestion impedes movement;
- Collection and distribution of passengers from transit and commuter railway stations;
- Movement of people between remote parking facilities and centers of activity, such as terminals, central business districts or university campuses;
- Connection of two or more major activities, such as a hotel and a convention center;
- Intermediate capacity corridor service, where transfers are acceptable and no switching is involved.

## ISSUES

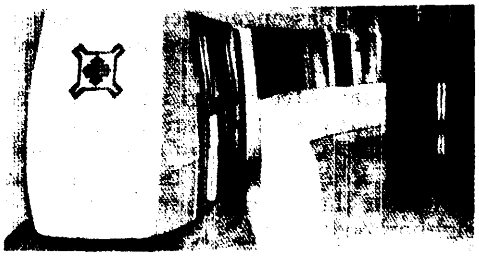
*Technical.* The SLT systems operating in the United States have provided highly satisfactory service. They have carried a proximately 200 million passengers with only one serious accident. The experience accumulated in building and operating the present systems has served to eliminate most of the technical problems. However, all systems developed so far have been used in special situation:, and there are some basic questions that must be addressed in considering SLT for deployment m an urban setting.

TYPICAL SLT SYSTEMS

Ford Motor Company
Vehicle for
Bradley International
Airport



Universal Mobility
Hershey Amusement Park
Hershey, Pennsylvania



Rohr Industries
Monotrain at Houston
Intercontinental Airport

- Can inexpensive and aesthetically pleasing guideways and stations be built?
- Can operational problems due to snow and ice be overcome inexpensively?
- How can reliability of components be improved at reasonable cost?
- What level of ride quality is required, and what is the trade-off between Guideway roughness and vehicle suspension?
- h ow is the evacuation of stalled vehicles best accomplished?

Economic.-SLT systems have been in operation long enough to enerat.e significant quantities of capital and operating cost data. However, because most existing installations are not intended to produce revenue, there has been little effort on the part of operators to keep detailed statistics. UMTA has only recently started to compile these data.

Preliminary indications are encouraging but not conclusive. SLT systems can operate with a total workforce (operational, maintenance, and administrative personnel) equivalent to one person or less. Conventional transit bus operations require about two persons per vehicle and specialty bus operations offering 24 hour service, as SLT does, could require as many as three to five persons per vehicle.

The tradeoffs between SLT and manned rail transit systems are less clear. A study conducted by the Port Authority of Allegheny County in Pittsburgh compared manpower requirements for a driverless SLT system with those for a manned trolley system. They SLT system was projected to achieve only a small reduction in manpower (12 positions in a workforce of about 225). Savings in manpower achieved by eliminating the on-board operator were largely offset by **a** requirement to provide station atteni'ants for the automated SLT line.

Capital costs are heavily dependent upon the amount of exclusive guideway to be constructed. However, to put this cost in perspective, It shoulJbe noted SLT guideway costs appear to be competitive with the construction of exclusive busways.

There are two major economic issues associated with SLT.

- What are the ranges of capital and operating costs for SLT?
- For what applications, and under what conditions, is SLT a cost-effective mode of urban transit compared to other transit options?

Social.-Patronage of existing SLT systems is high, suggesting good public acceptance. However, existing installations serve a captive clientele and do not face the same requirements as public transit. The controlled environment of an airport or a recreation park is far different from an urban center, where passenger security, susceptibility to vandalism and security of right of **way** are much greater problems.

The SLT guideway may be a visual intrusion in an urban area. Some SLT vehicles are large and heavy and require guideways of approximately eight to ten feet in width. he design of elevated guideways must be carefully considered, keeping mind that even small structures could be objectionable. On the other hand, there may be opportunities for enhancing neighborhoods through good urban design. Careful attention to the architectural features of guideways, introduction of linear parks, and urban development in the area of stations could create a positive and appealing environment.

It appears that further data on public acceptance in urban situations can best be gained from an urban demonstration project, perhap s in an activity center or downtown district. The basic issues to be addressed include:

- The acceptability of ride and service characteristics,
- Effects o !unmanned operation on passnger security,
- Aesthetics of guideway and station design.

*InStitutional.—* UMTA has not issued performance standards or criteria which would assist in qualifying the simple SLT systems for capital grants. Without such standards or adequate data for evaluating the economic and social characteristics of SLT, it is difficult to determine cost-effectiveness in relation to other transportation modes, and those reviewing grant applications will continue to be skeptical of their worth. Because UM A requires that system planners substantiate the cost-effectiveness of the mode selected in order to qualify for capital assistance grants, SLT system are placed at a distinct disadvantage.

As a comparatively new technology, SLT is under a second disadvantage. Product engineering and tooling form a large part of the manufacturer's initial costs. These costs must be recovered in the first project or two because a long-term market has not been established.

SLT system research and development to date has been largely financed by private industry. However, there is little incentive for industry to spend additional funds for follow-on development, testing and Product improvement without positive inducement in view of UMTA's negative attitude regarding capital grants for new systems. The government's R & D program also offers little encouragement to pursue SLT since most of the budget is devoted to the more complex classes of AGT.

## FINDINGS

- SLT systems appear worthy of careful consideration as transportation alternatives for many specialized urban transportation problems.
- UMTA'S research and development program does not emphasize improvement of technical operating characteristics and reduction of SLT system costs.
- UMTA'S technological R & D is not matched by a corresponding program to develop a better understanding of problems in the area of economics and public acceptance. SLT systems should receive emphasis in such a program.
- **An urban demonstration project for SLT appears justified. Such a project should concentrate on gathering economic and acceptance data and on improving the technical operation of the system.**
- **There is a lack of criteria for qualifyinir SLT systems for capital grant funding. There is no apparent m-echanisfi within UMTA for the trafisfer of R & D results to implementation under the capital grant program.**

## GROUP RAPID TRANSIT (GRT)

### STATUS

Two AGT s stems have been built in the United States—one at Morgantown, West Virginia, and the other at the Dallas/Fort Worth Airport. There are no operational GRT systems overseas. Three are under construction in Japan, and one was started in Canada but has been temporarily halted.

The Morgantown project is significant because it represents the most ambitious effort thus far to build a full-scale system capable of providing service on demand from origin to destination and to o crate vehicles on 15-second headways in a real life environment. '1he rime contractor, Boeing Aerospace Corporation, has delivered 18 0r the 45 vehicles required under the contract and expects to complete the prescribed acceptance testing in mid-1975.

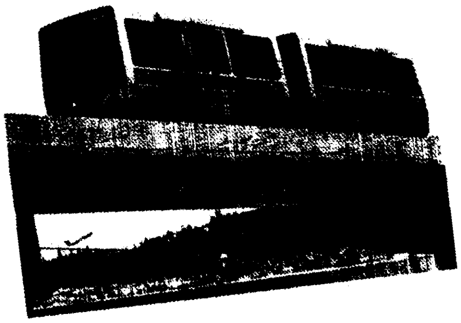
Vehicle and Guideway in Morgantown, West Virginia

The AIRTRANS system, built by the LTV Aeros ace Corporation at the Dallas/Fort Worth Airport, is the largest AGT project yet undertaken. It consists of 13 miles of guideways, 55 stations, 51 passenger vehicles and 17 utility vehicles. The system was designed to handle airline passengers, employees, interline baggage, supplies, airmail, and trash. It was opened to the public in January 1974 and is currently providing inter-terminal passenger and supply service. Most of the non-passenger movements are stall handled by alternate means.

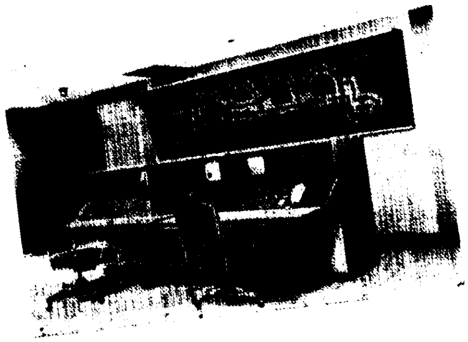
Two major studies in the United States are noteworthy. The Twin Cities Area Metropolitan Transit Commission has recommended AGT as one of three transportation alternatives to be selected for detailed planning . In Denver, the Regional Transportation District has selected GRT as the preferred system for regional deployment. Significant planning for the installation of GRT systems is also taking lace in Japan and Europe.

UMTA is seeking funds in fiscal ear 1976 to start construction of a prototype test facility which will carry forward the work accomplished at Morgantown and at Dallas/Fort Worth. This reject, designated by UMTA as "High Performance Personal Rapid Transit" ("HPPRT"), involves 12-passenger vehicles and is really an advanced version of GRT. Contracts for preliminary enginneering have been awarded to Boeing, Rohr and Otis-TTD. UMTA's current

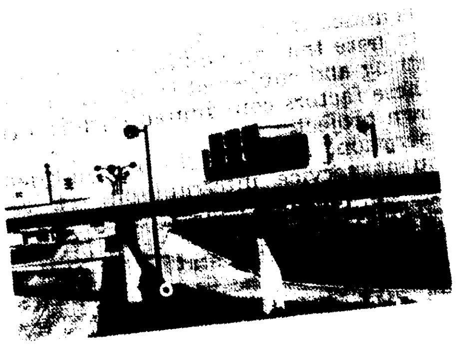
## AIRTRANS GRT SYSTEM DALLAS/FT. WORTH AIRPORT



Passenger Vehicles in Tandem



Control Panel Showing System Layout



Utility Vehicle for Baggage, Mail and Trash plan is to select one of the system concepts developed by these contractors for full-scale testing. A two-mile test track, five prototype vehicles and a sophisticated control system capable of achieving three-second headways will be built and evaluated over a four-year period.

Although the two GRT systems in place serve special transportation situations (an airport and a university), GRT is technically capable of providing basic urban transportation for low- to medium-density traffic. With headways of 15 seconds and capacities of 20 passengers per vehicle such systems could move a maximum of 4800 people per hour.

Along more heavily traveled routes, capacity can be increased by using larger vehicles, coupling two or more vehicles together, or by reducing headways. GRT is thus viewed as an intermediate capacity system, i.e., less capacity than rail rapid transit but more than typical bus operations. In this sense, GRT is much like light rail transit.

The potential for evolution to greater capacity and versatility through technological advances is an important consideration. A relatively simple GRT system can be installed at the outset and later expanded with off-line stations and shorter headways—using the same technology and without redesigning the basic guideway network.

## ISSUES

Technical.-Both the Morgantown project and the AIRTRANS system have experienced numerous technical problems. In the case of Morgantown, a complete redesign has recently been completed. AIRTRANS has not yet been finally accepted by the airport. Of course, problems should always be anticipated in the development and introduction of new technologies, but GRT has suffered from a lack of research and development prior to deployment, the restrictions of fixed rice contracts, and management problems.

The General Accounting Office has recently completed a detailed review of the cost, schedule and performance characteristics of the Morgantown Project. Since the GAO staff study has been transmitted separately to the Congress, it is unnecessary to cover the same ground in this report. It is sufficient to note that an ambitious R & D effort was attempted in an urban setting and subjected to unrealistic deadlines and design criteria. All these factors contributed significantly to the high cost of the Morgantown project.

During the first year of operation, AIRTRANS was plagued by equipment failures and frequent service interruptions. In recent months, however, reliability has improved significantly; and LTV has been able to cut the maintenance force in half. Nevertheless, the airport management keeps buses in standby status for use when service interruptions exceed 15 minutes. In the first three months of 1975 the buses were called out five times because of AIRTRANS failures.

The safety record of the system has been good. Reliability has steadily improved, with system availability at 100 percent during a recent six-week period. Originally, a maintenance force of 90 was anticipated for the project; but 120 are currently employed, down from a peak of about 250.

B asic technical issues cited earlier for SLT applv to GRT as well. There are also the following issues specific to GRT'~

- Does greater system complexity contribute to a more difficult reliability problem?
- Are there alternative engineering concepts that can reduce the cost of GRT systems?
- Can ride quality (particularly freedom from sway and jerk) be improved over that of AI RTRANS and Morgantown?

The advanced GRT program being undertaken by UMTA ("HPPRT") raises two additional technical concerns. "

. Reduced headways require demonstration of the feasibility of command and control systems.

. Software must be developed for managing a larger fleet of vehicles.

Economic.-The two GRT systems constructed have been expensive. AIRTRANS, originally projected at $35 million, is now reported to have cost over $53 million. The cost of the Morgantown system was initially estimated at $18 million by West Virginia University in 1970. The detailed estimate by the Jet Propulsion Laboratory in 1971 was $37 million. So far the project has cost $64 million for a system half as large as Initially contemplated. Even allowing a generous amount for one-time R & D charges, these systems have proved very costly for the amount of service that they can provide.

Conclusive data on operations and maintenance costs of GRT systems are not available. The first year of AIRTRANS has been a shake-down phase with costs substantially higher than could be expected for normal operation. At current manning levels, AIRTRANS averages about 2.5 people per vehicle, or 25 percent more than the Washington Metropolitan Area Transit Authority METROBUS operation.

The economic issues are straightforward.

- Is there a market for GRT systems or a transit "need" which they would serve?
- Assuming they fill a need, are GRT systems cost-effective competitors in the urban transit market?
- can the Morgantown and AIRTRANS projects be used by UMTA to gather data on GRT operating and maintenance costs?
- Is there any justification for hardware R & D (i.e., the "HPPRT" program) before first gathering economic data such as that described above?

Soctial.-GRT requires large, elevated, exclusive guideways that present the same problems of visual intrusion as SLT and offer the same opportunities for urban improvement. Because GRT is more complex than SLT, problems of safety- and security are accentuated.

The AIRTRANS experience suggests that automated systems, because of the inherent inflexibility of machine operations, require a higher degree of passenger understanding and cooperation than do manned systems. Airport employees and other AIRTRANS patrons have at times disrupted operations by opening doors, or holding them open, thereby causing the system to shut down. Also, the system lacks good human engineering. Information is so poorly conveyed that patrons become confused and frustrated. To compensate, it has been necessary to add attendants in stations.

Experience with Morgantown and AIRTRANS indicates the following needs.

- These two systems should be carefully monitored to obtain data relating to public acceptance.
- Human engineering principles must be applied to facilitate the patrons' use of the system.

1nstitutional.-UMTA has put nearly all of the total $95 million spent on AGT research and development into GRT. However, it has concentrated on technical hardware development with little consideration of social needs and economic considerations. As a result, understanding of the potential role of GRT is incomplete. UMTA does not have a demonstration program for GRT systems in an urban situation. This should be corrected, articularly if further investment in GRT system R & D is made. T fe discussion of the issues under SLT applies to GRT as well.

## FINDINGS

- **A number of localMes across the country have shown interest in installing GRT systems,**
- **Serious technical problems have arisen in the first two installations and neither is yet operating as planned. These technical problems have been exacerbated by unrealistic** deadlines and management problems.
- UMTA's R & D Program does not include **market and economic** research sufficient to evaluate the **need for** GRT and its cost-effectiveness as a solution to urban transportation problems.
- Monitoring efforts for AIRTRANS and Morgantown are required to obtain data useful in evaluating GRT. UMTA could perform this service and **has** initiated **such a program for AIRTRANS.**
- **Until the Morgantown system has been proved in actual operation, it would be premature to commit funds to expand the system. Additional funding does seem justified to complete the engineering work which is necessary to develop realistic cost estimates. Federal assistance for this interim operating period may be appropriate if the partial system places a greater financial burden on the university than the full system would have.**
- **No clear urban transportation need is apparent for the short three-second headway Performance ?mecified for the "HPPRT" mogram. The mogram should be reviewed to ~ee whether modifications wo~ld not incr_eas= its value.**

## POTENTIAL ROLE OF PERSONAL RAPID TRANSIT (PRT)

### STATUS

Since the term "Personal Rapid Transit" tit entered the transit vocabula~ in 1968, this high] innovative conce t has fascinated many transportation planners. $ RT offers personaYized service with small vehicles which rovide non-stop transportation from origin to destination at short feadways. To date, no systems which can be classfied as PRT are in revenue service or under construction in the United States, but several test traclc installations have been built in Europe and in Japan.

Proponents of PRT view this concept as a reasonable supplement to the private automobile in high density urban areas[1] and claim that PRT can provide a very much higher level of service than other modes of public transportation. Thus, it is argued that PRT systems would attract a significant percentage of the rides now being made in private automobiles and offer obvious benefits:

- less traffic congestion in urban areas.
- less land and fewer facilities used for automobile storage.
- reduced travel time under more comfortable circumstances.
- less noise and air pollution.
- reduction in consumption of petroleum-derived fuels.
- reduction in requirements for new arterial roads and urban freeways.

It is contended that PRT would provide greater mobility for the transportation disadvantaged, i.e., the young, the elderly, the poor, and the handicapped.

Proponents admit that the area-wide networks with closely spaced stations and large numbers of vehicles would be expensive to build and, perhaps, to operate. The initial capital cost might equal that of rail rapid transit systems, but levels of service are envisaged to be much higher than with conventional modes, except perhaps taxicabs. Proponents claim the higher service levels will attract significantly greater patronage than conventional transit. Automation is expected to allow the high service level to be delivered at a cost the public is willing to pay.

PRT capacity depends upon short headways. Except in downtown areas, headways need not be closer than those of GRT systems (i.e., three seconds). In downtown areas, headways on the order of ½ second would be needed to move 10,000 people per hour over a single PRT guideway at an average occupancy of 1.4 people per vehicle. This is roughly equivalent to the number of people moved on four freeway lanes.

Advocates of PRT estimated that there are 10,000 square miles of urban areas in the United States where PRT service might be appropriate. This would require about 20,000 miles of one-way guideways and about three million PRT vehicles.

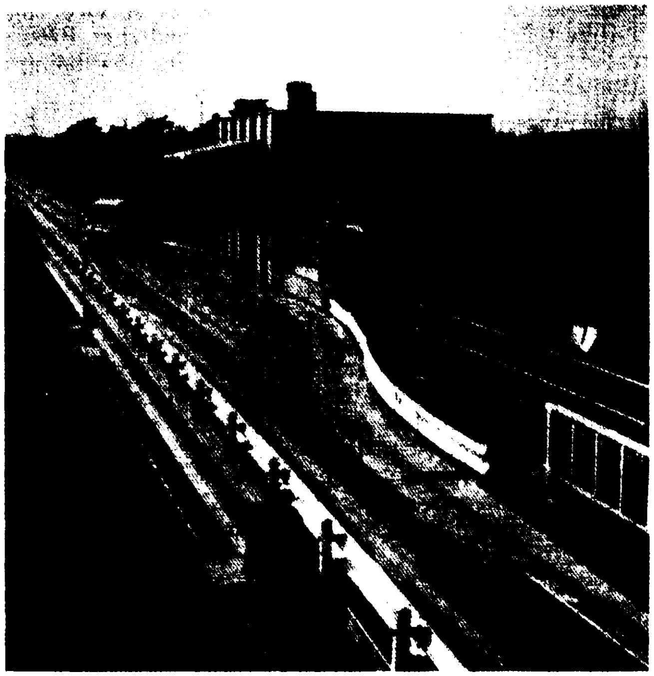
## ISSUES

Because there are no operating systems, there is no empirical evidence on PRT. Many of the studies reviewed were motivated by attempts to sell or reject the concept and were based upon largely arbitrary assumptions. Therefore, there are many detailed issues for which objective data are needed.

*Technical.*—With few exceptions, the engineers and manufacturers who have made serious studies of the PRT concept find that there are numerous technical problems that must be solved before PRT systems can be deployed. Technical solutions have been proposed but not validated, and a large program of development, testing and demonstration would be needed to implement a PRT system. Estimates of time and money required to achieve market-ready systems vary widely. However, there appears to be general agreement that at least 10 years would be required depending upon the level of funding provided.

[1] Greater than 3,000 people per square mile.

PRT TEST FACILITIES ABROAD



CVS, **Higashimurayamz Tokyo, Japan**

**ARAIMI~ Orly Airport, Paris, France**

The following technical problems need to be solved.

- Computer control systems must be developed to exercise command and surveillance over thousands of vehicles traveling between hundreds of stations at fractional-second headways. Vehicle management (particularly the storage of empty vehicles and their redistribution to satisfy changes in demand) further complicates this problem.
- Advanced control and braking systems must be perfected to insure that vehicles can be operated safely at very close intervals.
- Major improvements in reliability—far beyond those levels which have been achieved for any transit equipment in operation—are required. Engineering techniques from other fields may be applicable to this problem.
- Crash survivability should be demonstrated for PRT, possibly using techniques similar to those required for automobiles by the National Highway Traffic Safety Administration. Means for emergency evacuation should be provided to insure passenger safety in the event of a failure.
- Study of alternative engineering approaches is required to develop cost-effective systems and components.

Economic.—The economic characteristics of PRT are so unclear that meaningful analysis is difficult. Several analyses have been attempted, including one by the Aerospace Corporation for the Los Angeles area, a general study by the DOT Transportation Systems Center (TSC), and one of the Twin Cities area by De Leuw Cather. Cost assumptions vary reatly. Proponents' estimates for PRT vehicles, for example, are Based upon large production runs, and the estimated cost per unit presumably goes down with increased production. As another example, costs are related to solutions to potential social problems. If passenger security considerations require the installation of closed circuit T.V. throughout the system, including vehicles, then the ccsts would rise appreciably. Costs for operation and maintenance also vary. Proponents' estimates assume maintenance levels that are unrealistically low for transit.

- The major economic issue is whether research, without hardware development and urban demonstration, can answer the economic questions, or whether hardware development is necessary to assess the economic characteristics of PRT systems.

*Social.*—Public acceptance of PRT is open to question. Despite the many potential advantages of PRT in comparison to other transit modes, there is serious question that the associated proliferation of elevated guideways and stations would be acceptable to the public, particularly in residential neighborhoods. Also, the safety and security aspects of unattended small vehicles require careful evaluation.

Advocates contend that PRT should duplicate as closely as possible the service characteristics of the private automobile. The wisdom of attempting to provide such a high level of service at public expense is open to question. Whether the benefits of such a system would only accrue to the well-to-do, or whether they would also provide for the needs of the transit disadvantaged is worthy of exploration. An annual expenditure equal to the debt service on the capital cost of such a high technology system, when combined with traffic management systems designed to enhance conventional transit, might provide better service at lower cost over a larger service area than PRT. These observations may be equally true for other capital intensive systems. Such tradeoff studies should be undertaken and clear urban transit goals articulated by UMTA before the agency embarks on new systems for their own sake.

The major social issues of PRT are summarized below.

- What urban objectives will be served by a PRT system?
- What is the overall social acceptability of PRT, and what lessons can be learned from less sophisticated AGT systems?
- Can PRT systems offer adequate passenger security, particularly in numerous unattended stations?
- What environmental impact will guideways and stations have on the neighborhood?

*Institutional.*—Groups in Germany, Japan and France are actively engaged in PRT research and development. The possibility of cooperative arrangements between United States firms or the United States Government and their overseas counterparts thus exists. Such efforts, building upon United States experience and accomplishments in SLT and GRT and overseas research in PRT, could lead to stronger and more cost-effective development programs. On the other hand, the United States has pioneered much of the work in new transportation systems and could develop the technology if a need exists for PRT.

The effect on U.S. balance of payments must be considered if equipment licenses or royalty payments for the use of foreign patents are required. Such payments, however, will be only a small part of the costs for building a system because most transit system costs are for construction. Thus, potential foreign exchange savings are too small to justify a large investment in domestic R. & D.

PRT poses major institutional issues.

- Should PRT systems be a substantial part of UMTA's R & D effort?
- Should other arrangements be considered for PRT development and deployment?
- To what extent is international cooperation possible and beneficial?

### FINDINGS

- **Before major commitments of funds are made for detailed simulations or hardware developments, research is required to resolve the many uncertainties concerning the proper role of PRT systems, their social acceptability and their economic feasibility. These preliminary studies may involve expenditures of $4 to $6 million.**
- **There are possibilities for cooperation with foreign governments or overseas suppliers in research and development of PRT. UMTA has recognized these possibilities in starting negotiations with the West German Government.**

## U.S. Government Research and Development of AGT Systems

### R & D PROGRAMS

Since 1962, UMTA has spent about $95 million for R & D on AGT systems. Two-thirds of the Westinghouse Transit Expressway demonstration project was government-financed from 1963 onward. Federal R & D funds (about $4.5 million) assisted developments which ultimately led to installation of four SLT systems. The most expensive project undertaken by UMTA during this period was the Morgantown GRT demonstration project which has cost $64 million. Other significant undertakings were development of two prototype vehicles for the Dallas/Fort Worth Airport at about $1 million and demonstration and evaluation of four Transpo-72 peoplemover systems involving almost $10 million. Considering the substantial amounts expended since the establishment of UMTA, accomplishments in the form of fully developed systems in revenue service have been limited. Most of the systems now in operation did not receive direct federal R & D funding. Indirectly, however, the federal R & D program has stimulated major manufacturers to develop and demonstrate AGT systems.

In the budget request for fiscal year 1976, UMTA is seeking $14 million in R & D funds for AGT systems (about 40 percent of the total R & D budget of $37 million).

- $10 million is requested for detailed engineering, urban deployability studies, and the first phase of construction of a new prototype test and evaluation facility. This project, called "High Performance Personal Rapid Transit (HPPRT)", deals with an advanced form of Group Rapid Transit. The total cost for five prototype vehicles, the test facility, and a comprehensive evaluation program is estimated by UMTA at somewhat more than $30 million over a four year period.
- $4 million is requested for the "Automated Guideway Transit Technology Program". (To this will be added $4.4 million of reprogrammed FY 1975 funds, making a total of $8.4 million.) Unlike the "HPPRT" project, which deals with a specific new system, this program will provide for selective R & D on components and special problems which are common to a number of AGT systems.

Considering the substantial amount of transportation hardware being purchased under the capital grant program, the funds allocated for R & D to perfect alternative new solutions to urban transportation problems are small. In FY 1975, R & D expenditures by UMTA amounted to only 1.9 percent of total expenditures. For FY 1976, the $37 million requested is 2.1 percent of the projected total. In contrast, the total budget of the United States for FY 1976 allocates 5.7 percent of all federal spending to R & D. It is clear that UMTA lags well behind the government average. R & D for urban mass transportation amounts to only about 7 percent of all federally sponsored R & D for transportation, yet 76 percent of all passenger trips are in urban areas.

UMTA needs to clarify the scope and objectives of the AGT Technology Program. Solving all the problems posed by AGT would require several multiples of the proposed budget. Priorities have to be established to give proper balance to solving near-term technical problems in conventional transit modes and the simpler forms of AGT, while laying the groundwork necessary for advancing the basic technology of AGT.

## RELATIONSHIP OF (GOVERNMENT AND INDUSTRY R & D

Major manufacturers report aggregate expenditures from company funds of about $100 million for AGT research and development. Industry was willing to make this investment in anticipation of a substantial market for AGT equipment. However, no such market has developed, and most of the manufacturers are pessimistic about the future. Two major manufacturers, Bendix and Pullman, have withdrawn; and others are considering termination of their AGT programs. In this atmosphere it is unrealistic to expect that industry will make further substantial investments for product development and improvement.

Federally sponsored R & D has not included a coordinated program for conversion of successful products into operational systems. This may be partially due to uncertainty about the value of new systems. Another reason may be the complex requirements surrounding government-sponsored research. Finally, institutional failures may have hindered implementation. If broad application of AGT systems is desired, there are other mechanisms that could be employed.

- The provincial government of Ontario, has established the Urban Transportation Development Corporation (UTDC) to aggregate the market for system installations, license foreign developments, test prototypes, and market new urban transportation systems.
- In France, system suppliers are selected early in the planning process and work closely with public officials in planning and developing a system installation.
- System development in Japan is accomplished through a business-government cartel. Fixed facilities constructed on public streets are financed by gasoline taxes; other costs are shared by the participants.
- In the United States, the Communications Satellite Act of 1962 established a corporation (COMSAT) to develop, implement, and operate a telecommunications satellite system.
- Also in the United States, the Transit Development Corporation (TDC) has been formed as the scientific and educational agency of the transit industry. It could function much as the President's Conference Committee did in the 1930's in bringing operators and suppliers together on new developments.

### FINDINGS

- **UMTA's R & D programs for new systems have emphasized advancing the state of technology but have neglected near-term system improvements to perfect and apply simpler approaches to correct transit problems.**
- **Better results might be achieved from cooperative arrangements between government and industry.**
- **The scope and objectives of UMTA's AGT Technology Program need to be clarified.**
- **Transit research and development is receiving a disproportionately small share of federal R & D funds.**

## BUDGET ALTERNATIVES FOR FISCAL YEAR 1976

### BACKGROUND

Automated Guideway Transit has a variety of potential applications for urban transportation that are worth pursuing. The SLT systems are in a more advanced state of development than other classes of AGT systems. They are especially appropriate for activity centers and as circulation systems for downtown areas.

The GRT systems are less developed than the SLT systems. The two installations in Dallas/Ft. Worth Airport and Morgantown have been marred by technical and managerial problems. However, valuable experience can be obtained from both of these programs. The more advanced GRT systems, under development by UMTA through the "HPPRT" program, have potentially higher service levels than the AIRTRANS-Morgantown equipment, but their economic and technical feasibility remains to be demonstrated.

PRT has the highest potential service level and may have the highest patronage level of all AGT systems. However, it poses the most difficult technical problems and requires both hardware development and study concerning service level, patronage and economic feasibility.

Application of resources for the development of all three types of AGT is warranted. The distribution of funding among them, however, is a matter of debate. Four budget alternatives for the coming fiscal year are outlined below.

## ANALYSIS OF BUDGET ALTERNATIVES

The budget submitted by UMTA for FY 1976 contains provisions for a program of AGT research and development totaling $18.4 million, of which $14 million is new (NOA) funding and $4.4 million is carry-over funds. The proposed R & D program has two major elements: the "HPPRT" program ($10 million) and AGT Technology ($8.4 million). The program concentrates heavily on development of technology and feasibility demonstrations. Almost no effort is allocated to study the social and economic aspects of AGT.

Four courses of action on the program budgeted for FY 1976 are worthy of consideration by the Congress. They are listed below and summarized in tabular form. An analysis of each alternative is presented afterward.

Alternative A—Approve the program as submitted.

Alternative B—Provide no new funding and use carry-over funds for a reduced program of data gathering and analysis.

Alternative C—Approve the level of funding requested by UMTA but restructure the program.

Alternative D—Increase the level of funding and expand the scope of the proposed program.

*Funding Alternatives Fiscal Year 1976*

[In millions of dollars]

| | No change (A) | Reduce (B) | Restructure (C) | Expand (D) |
|---|---|---|---|---|
| HPPRT | 10.0 | | 6.0 | 15.0 |
| AGT technology: | | | | |
| New funds (NOA) | 4.0 | | | 12.0 |
| Carryover | 4.4 | 4.4 | ::: | 4.4 |
| Social/economic impact studies | | | 2.0 | 3.0 |
| Total funding level (NOA and carry-over) | 18.4 | 4.4 | 18.4 | 34.4 |

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### ALTERNATIVE A—APPROVE THE PROGRAM AS SUBMITTED

This alternative would provide a total funding level of $18.4 million (including $4.4 million of carry-over funds) of which $10 million would be allocated to the "HPPRT" program and $8.4 million to AGT Technology. This action would:

- Continue the current emphasis on high technology R & D, notably "HPPRT".
- Leave to private enterprise most of the cost of product improvement for near-term applications of SLT and GRT in urban environments.
- Require continuing appropriations to complete the "HPPRT" test program and to achieve market-ready status.
- Leave unresolved the social and economic issues relating to AGT systems, particularly PRT.

### ALTERNATIVE B—PROVIDE NO NEW FUNDING AND USE CARRY-OVER FUNDS FOR A REDUCED PROGRAM

This alternative would provide no new funding for AGT research and development and would restrict the budget to carry-over funds from FY 1975 and prior years. Carry-over funds would support a program of data gathering and analysis for existing AGT systems (SLT and GRT). This action would have the following consequences:

- Curtail the development of AGT technology and limit the options available to urban transportation planners.
- Cause more companies to restrict or abandon further AGT development.
- Make the United States dependent on foreign technology and manufacturers for new AGT systems.
- Give priority to analysis of data on existing systems before proceeding further with new technology development.

### ALTERNATIVE C—APPROVE THE REQUESTED LEVEL OF FUNDING BUT RESTRUCTURE THE PROGRAM

This alternative would approve the $18.4 million level of funding requested by UMTA ($14 million NOA, $4.4 million carry-over), but with restructuring of the R & D program. Funding for the "HPPRT" program would be reduced from the proposed $10 million to $6 million. The AGT Technology program would receive increased funding ($6 million NOA, $4.4 carry-over) to permit greater emphasis on evaluating AGT technologies. Two million dollars would be allocated for the study of social and economic factors, an area that has been neglected in UMTA R & D programs up to now. The restructuring of the program would:

- Redirect the emphasis of R & D toward exploiting existing technology.
- Involve UMTA in product development and improvement, which have traditionally been private industry activities.
- Provide data to further an understanding of the social and economic implications of AGT.

- Entail a commitment to continue substantial R & D funding for AGT systems.
- Require substantial expansion and improvement of R & D management capability in UMTA.
- Continue active participation by three manufacturers through the completion of the "HPPRT" prototype testing phase to facilitate urban applications.
- Require better coordination between the R & D and capital grants programs.
- Encourage industry to bear pre-production engineering and tooling costs.
- Probably stimulate more requests for capital assistance to plan and install AGT systems.
- Give adequate attention to the heretofore neglected social and economic impacts of AGT.

# Chapter 2: The Status and Potential of Automated Guideway Transit in Urban Areas

## THE CURRENT STATUS OF URBAN PASSENGER TRANSPORTATION

Urban transportation service and the location of urban activities are intimately related. Changing locations of people and jobs in urban areas, particularly in recent decades, has had significant effects on the supply and mix of urban transport services. Population within Standard Metropolitan Statistical Areas (SMSA) increased nearly 17 percent between 1960 and 1970, yet only 0.1 percent of the increase occurred within the central cities of those SMSAs. Urbanized areas outside of central cities, the suburbs, experienced a 33.1 percent increase in population in that decade.

One result of these population trends is a greater homogeneity of population density throughout a metropolitan area, with a concomitant greater dispersal in the location of economic activities, over ever larger urbanized areas.

Job locations have migrated outward from the central cities as well, causing a substantial loss in numbers of central city jobs in recent years. In SMSAs with a population over 250,000, for example, there were 41 million jobs in 1970, but only 23 million of these were in the central cities of those metropolitan areas. The rest were located in surrounding suburbs.

Such diffusion trends have had major impacts on the daily journey to work in metropolitan areas. Considering only SMSAs of a million or more population, the number of daily work trips with both origin and destination in the central city declined by 1.2 million between 1960 and 1970. Work trips into the central city from surrounding areas increased by nearly a million, as did the "reverse commute" work trip from the central city to the suburban ring. Work trips with both origins and destinations in the suburbs, however, trips which avoided the central city entirely, increased most of all, by 3.6 million daily trips. Thus, not only has total trip-making increased significantly in United States metropolitan areas, the origins and destinations have spread diffusely over a larger land area within larger metropolitan areas.

Diffuse trip patterns represent precisely the kinds of urban travel demand most difficult to serve effectively with conventional public transit systems. Transit service shortcomings, together with the trends toward more separated locations of economic activity and diffuse travel behavior, have together tended to reinforce, in the aggregate, dependence on the private automobile for the great majority of urban trips, even work trips. Yet the private automobile, too, has critical deficiencies in meeting demand for urban travel.

## THE AUTOMOBILE

Use of the automobile has contributed to the changes in urban form already described. It has allowed the diffusion of each type of activity to continue throughout the urban area. Traditional central business district functions have become more diffusd and, in some cases, have been replaced by suburban shopping and business centers.

The private automobile has encouraged an urban structure which favors individualized or small group transportation. Unfortunately, as more and more families have found it necessary to own one or more automobiles, the disadvantages of dependency on automobile transportation have increased. These disadvantages include increased traffic congestion, greater amounts of valuable urban space required for movement and parking, air pollution (50 percent or more of total air pollution is attibuted to the automobile), and high energy consumption (about 50 percent of the nation's petroleum is consumed by the automobile). The problems of the young, old, physically handicapped and other disadvantaged persons who cannot drive or do not own an automobile have also become increasingly apparent.

## PUBLIC TRANSPORTATION

In comparison with the automobile, public transportation has not provided an attractive alternative. The transit industry reports a steady decline in transit patronage over the past 30 years, despite a rapid increase in total urban travel demand. (See Figure 1 below.) Because trip origins and destinations are increasingly scattered

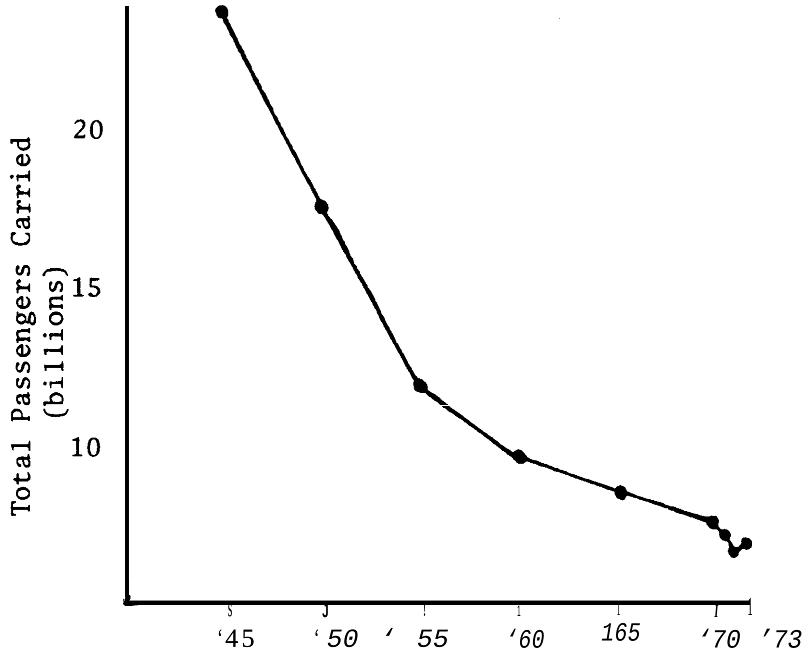



**Figure I.—Transit Patronage Trends 1945-1973**

Source: 1978-74 Tran81t Fact Book—American public Transit Association.

throughout the urban area, the attractiveness of fixed route multipassenger public transportation is not likely to increase. Scattering of origins and destinations militates against large vehicle mass transportation service on fixed routes. This inadequacy in serving diverse origin and destinations is particularly apparent in off-peak hours.

Rail rapid transit systems provide the highest capacities and are useful in high-density corridors linking common origins and destinations. They are also the least flexible in their coverage. Besides high capacity, rapid rail systems have other indirect advantages over automobiles: less pollution, lower petroleum fuel consumption per passenger, and less diversion of land to transportation-related use. Unfortunately, the number of metropolitan areas with sufficient concentration of trip origins and destinations is limited. The high capital cost for new rapid rail systems now under construction, or being planned, indicates that their direct cost per passenger may be higher than the comparable costs of highway construction. Thus, rail rapid transit systems are a limited alternative to automobiles.

Buses operating on exclusive or reserved rights-of-way have been successful. Bus riding is not considered an attractive alternative to automobiles when sharing highways with other traffic. They suffer from auto-induced traffic congestion, loading and unloading delays, route inflexibility, infrequency of service, and slow speed. Even total trip times on express buses tend to be longer than for automobiles.

Two other urban transportation services in general use—taxicabs and demand-responsive, Dial-a-Ride systems—have limitations other than the quality of service they provide. Taxicabs are expensive for single riders. Also, institutional problems and regulations protecting other interests prevent altering taxi service to meet public transportation needs in most cities. Dial-a-Ride systems provide service of a quality somewhere between scheduled buses and taxicabs, but initial experimenting with such programs indicates they require large public subsidies to attract and keep riders.

## Alternative Approaches To Meeting Urban Transportation Needs

In the previous section, it has been indicated that the transportation needs of urban communities are not being met in a satisfactory manner by private automobiles or by existing public transportation modes. This has prompted a search for new approaches into two directions. The first is reducing or redistributing the urban transportation demand. The second is trying to meet current and projected levels of urban transportation needs with new forms of transportation.

Approaches to reducing or redistributing urban transportation demand include:

- Changes in land use patterns so that employment and activity centers are located near residences so as to reduce travel.
- Staggered work hours to reduce peak hour demands on existing transport facilities.
- Clustering of activities, such as shopping, recreation, living and education, to encourage walking and to provide ready access to public transit.
- Creative use of transport facilities to guide urban development, including the acquisition of contiguous real property to integrate the design and development of stations and surrounding neighborhoods.
- Parking restrictions and toll charges which discourage auto loadings of one person per vehicle and the unnecessary use of large family-sized automobiles with their excessive need for space.

This list is not exhaustive. However, it does suggest the kind of changes that could reduce or redistribute the demand for transportation. In addition to what can be done to reduce or redistribute transportation demand, technology may be used to produce innovative solutions to transportation problems. While there are a variety of approaches, one approach which has received considerable attention in recent years is the use of small vehicle fixed guideway systems which require no human operator, that is AGT. Such systems could be used alone or combined with conventional line-haul modes such as rapid rail or fixed route buses.

Impetus for development of AGT systems in the United States 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."

Since passage of the Reuss-Tydings Amendments, many studies have been undertaken of the potential for AGT systems, in meeting transportation needs and a number of research, development and demonstration programs.

Although this assessment is concerned with a particular approach to urban transportation problems, it should be noted that there is probably no single solution. Some combination of approaches involving ways to reduce demand and utilization of new technology will probably be necessary.

## Characteristics and Current Applications of AGT Systems

Automated guideway transit systems have two distinguishing features:

- Vehicles are *automated*, that is, they can carry passengers without an operator on board.
- They have their own roadways, which are usually called *exclusive guideways*. These may be on elevated structures, at ground level, or underground.

AGT systems vary greatly. Any classification scheme is somewhat arbitrary, but three categories have been defined in the course of this study:

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

The three categories differ in degree of technical sophistication, service attributes, vehicle operations, and readiness for use. These differences are summarized in the accompanying table.

*Characteristics of AGT Systems*

| | SLT | GRT | PRT |
|---|---|---|---|
| Technical sophistication | Simple. Needs some refinement. | Intermediate, Problems in application. | Complex. Partially demonstrated. |
| Service attributes | En route delays and transfers are necessary. | Waiting time for proper vehicle. In group travel, transfers may be necessary. | Travel alone or with people by choice. Minimum en route delays, no transfers. |
| Vehicle operations | Vehicles follow unvarying paths. | Vehicles follow multiple paths. Switches required. | Vehicle follows path tailored to needs of traveler. |
| Readiness | Available. Many systems in specialized service, none in urban centers. | Emerging. 1 revenue system exists and 1 is in construction. | Conceptual. No system in use or construction. Testing abroad. |

SLT SYSTEMS

*(Characteristics.*—Shuttle-loo transit systems have **a** single essential characteristic. The vehicles fol**l**ow unvarying paths and make little or no use of switches. Vehicles may be of any size and may be used alone or coupled together in trains. Headways are 60 seconds or more. Capacities vary depending on vehicle size. Speeds range from 8 to 30 { .

I n a shuttle system, the vehicles move back and forth on a simple guidewa , without front or rear orientation. Shuttles have stations at oth en s of the run and may also have intermediate stations.

In a Zoo system, the veh]cles move continuously around a closed path which may contain any number of stations. Stations are on the main line. Possible variations of SLT include double guideway lines with switches at the end and single guideway lines with multiple **cars** and a by-pass near the midpoint of the line.

Combinations of shuttles and loops can be constructed.

*U.S. SLT Application.*—In the U. S., 15 SLT systems have been built or are under construction. Nine are in service.

The nine systems in revenue operation are at:

1. Tampa International Airort, Florida.
2. Houston Intercontinental Airport, Texas.
3. Seattle-Tacoma International Airport, Washington.
4. Love Field, Dallas, Texas (inactive at present).
5. California Exposition and State Fair, Sacramento.
6. Hershey Amusement Park, Hershey, Pennsylvania.
7. Magic Mountain, Valencia, California.
8. Carowinds, Charlotte, North Carolina.
9. Kings Island, Kin s Mill, Ohio.

Six SLT s ystems now under construction are at:

10. Kings Dominion, Ashland, Virgnia.
11. Pearl Ridge, Honolulu, Hawaii.
12. Bradley Field, Hartford, Connecticut.
13. Fairlane Town Center, Dearborn, Michigan.
14. Miami International Airport, Florida.
15. Busch Gardens, Williamsburg, Virginia.

Characteristics of these systems vary greatly. Examples of a shuttle, **a** 100 , and a shuttle-loop combination are briefly described to illustrate the characteristics. For additional information, see the Panel Report on Current Developments in the United States.

An example of a shuttle system is the SLT at the Tampa Airport where there are two shuttles on parallel guideways connectm each of four satellite or “Air-side” terminal buildings with the h Main or “Land-side” terminal. The longest run is 1,000 feet. Vehicle capacity is 100 passengers. The maximum speed is 30-35 mph. The capacity is 5,000 passenger per hour in each direction—the same capacity as two freeway lanes for automobile traffic.

A loop s stem has been installed at the Houston Intercontinental Airport. This eight-station system has 6,200 feet of guideway. At resent, up to six trains, each three cars lon , can run with an average headway of three minutes. Maximum speed is 8 mph with a capaclty of 720 passengers hour in each direction. The fleet can be enlarged to 18 trains. At headways of 60 seconds, capacity will reach 2,160 passengers per hour in each direction.

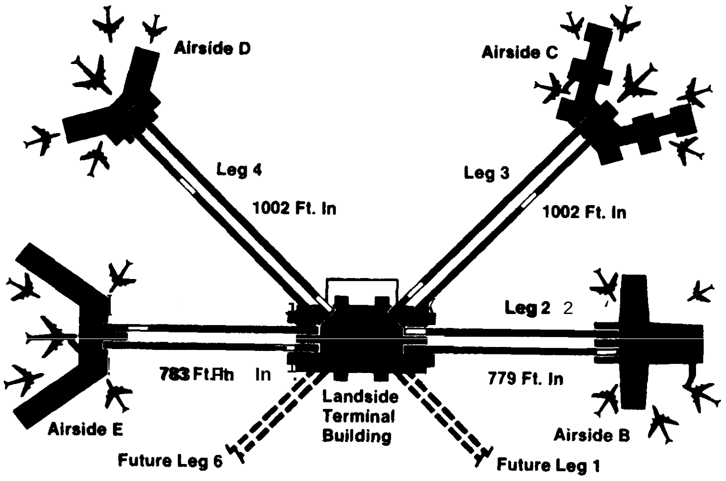



**Figure 2.—Passenger Shuttle System Layout**
**Tampa Airport**

The Seattle-Tacoma Air ort has a shuttle-loop combination. Referred to as the Satellite Transit System, it includes two loops and a shuttle which provide transportation between the main terminal

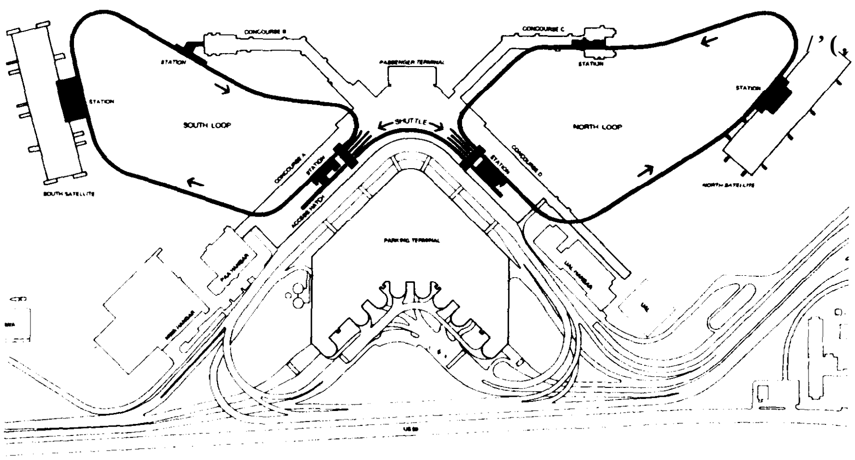



**Figure 3.-Satellite Transit System Layout (Note: two loops and a shuttle.)**
**Seattle-Tacoma International AirporL**

and two satellites. Nine vehicles are in service and three more are on order. Maximum loop capacities are 14,400 passengers per hour. Maximum speed is 27 mph.

*Foreign SLT Application~.*—There are only two AGT installations in actual revenue service outside the United States. Both are SLT s stems. One is a simple loop system which has been built at the Y atsu Amusement Park in Chiba Prefecture near Tokyo, Jap an. Two 30 passenger VONA vehicles operate on a 1300-foot track at two minute headways. The other installation is the VEC system which connects a department store in Paris with a remote parking garage about 1,000 feet distant.

*Potential SLT Applications.*—To date, SLT systems have been installed to accomplish three kinds of specific trip purposes: travel between two major activity centers, travel within a single defined activity center such as a park or recreation area, or travel from parking areas to a specified destination such as an air terminal. There are a number of additional applications for SLT which could be tested. These would provide data on the utility of the systems outside the rather specialized and/or novelty situations in which they have been used. Thus, SLT systems may have high potential for use in conjunction with conventional rail rapid transit as a collector or distributor at stations located near major activity centers, Another potential application is the use of elevated SLT systems to provide circulation in central business districts and other places where surface congestion impedes movement.

GRT SYSTEMS

*Characteristtis.*—Group rapid transit systems are designed with branching routes and serve groups traveling with similar origins and destinations. GRT vehicles may e of various sizes, thou h 10 to 50 passenger vehicles are likely to be most common. Vehicl es may be coupled together in trains.

GRT systems are likely to have stations located off the main line, allowing vehicles to pass a station while other vehicles are stopped there.

Switching capability allows the GRT s stem to provide service on a variety of routes much like bus service,but without the delays from traffic congestion. The traveler using a GRT system, must be careful to board the correct car. Also, GRT passengers making relatively long trips in metropolitan-scale systems may find it necessary to make one or more transfers. Thus, there may be significant waiting time involved.

GRT systems maybe designed too crate at headway s ranging from 60 seconds. to as low as three seconds or very advance versions. Since line capaclty is a direct function of vehicle capacity and headway, a GRT line with average headways of 30 seconds and average vehicle loads of 20 people would carry 2,400 people per direction—about the same as a freeway lane. Line capacity can be readily increased by coupling vehicles together into trains or reducing headways. However the system complexity increases significant as headways are reduced.

*U.S. GRT* Applications.-Because GRT is more complex, fewer systems have been built than SLT systems. Of the two United States systems, one is AIRTRANS which is located at Dallas/Ft. Worth Airport and the other is the system at Morgantown, West Virginia. Only AIRTRANS is operational. AIRTRANS includes 13 miles of guideway linking 55 stations. There are 51 passenger vehicles and 17 utility vehicles. Maximum speed is 17 mph. The guideway network permits 17 different service routes with a system capacity (over all routes combined) of **9,000** passengers, 6,000 pieces of luggage and 70,000 pounds of mail per hour. (No single part of the system would carry this total.)

*Foreign GRT Applications.—No* GRT systems are operational in other countries. *i* owever, three systems are under construction in Japan and one in Canada.

AIRTRANS SYSTEM AT THE DALLAS/FT. WORTH AIRPORT

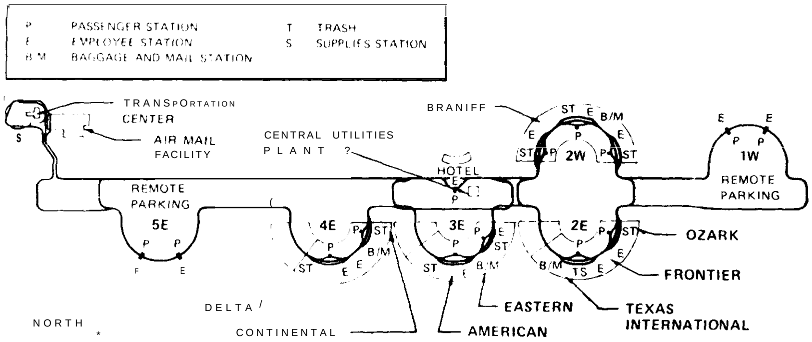
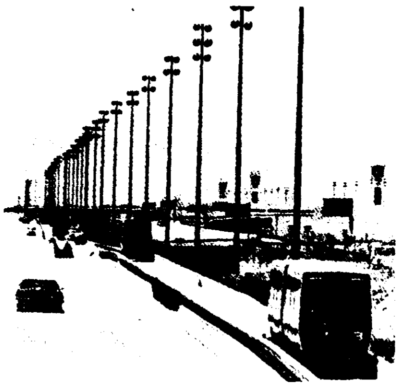
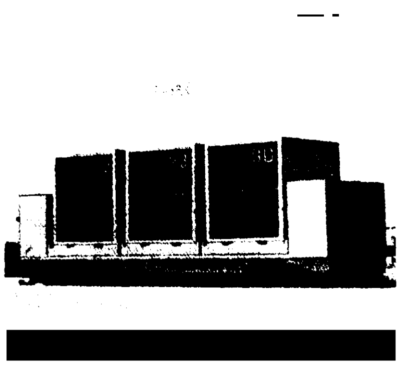



Figure 4.—Schematjc System Layout

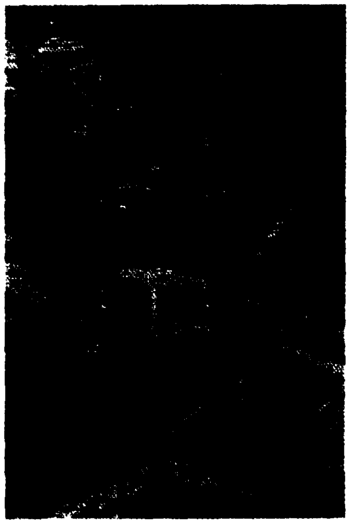




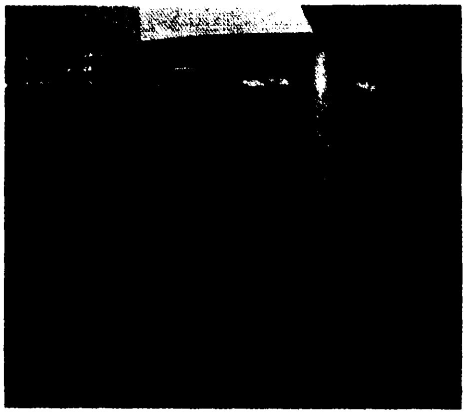
**Some of the** 51 Passenger Vehicles One of **the 17 Utility Vehicles**

*Potential (GRT .4pplicatiow.-GRT* systems could provide a broad range of services in major activity centers such as central business districts. These services include a variety of schedules for peak period use and on-demand service a times of low activity. With automatic coupling of vehicles, a technique which is currently being perfected, vary-ing route densities can be accommodated by selective coupling of vehicles as they converge onto heavily traveled corridors from outlying areas. This technique would permit a downtown loop to be fed by several radials connecting the CBD to suburban areas. As vehicles enter the central loop they could be automatic coupled together into two- to four-car trains, depending on the volume of traffic. When :eady to depart the downtown area, the: could be uncoupled, preferable- in a station, to help passengers board the correct vehicle for the outbound trip.

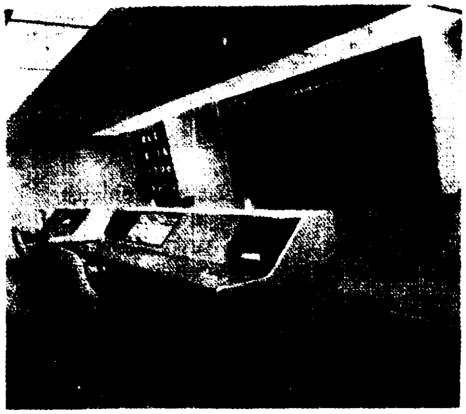
An important consideration is the potential of GRT to evolve in both capacity and versatility. A relatively simple sytem, or segment system, could be installed and later expanded. With proper planning, off-line stations could be added and headways reduce , without major alterations to the basic guideway network.



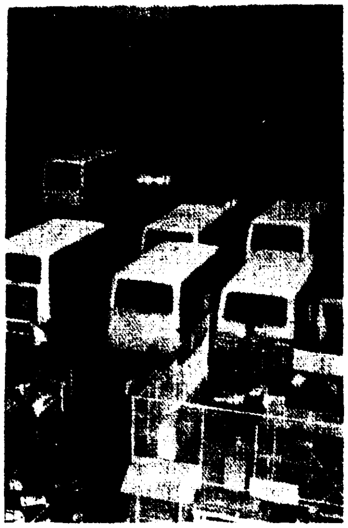
Vehicle Operating in Downtown Morgantown



Vehicle at Engineering Station



Central Control Console



Assembly of Vehicles at Boeing Aerospace Company Plant

PRT SYSTEMS

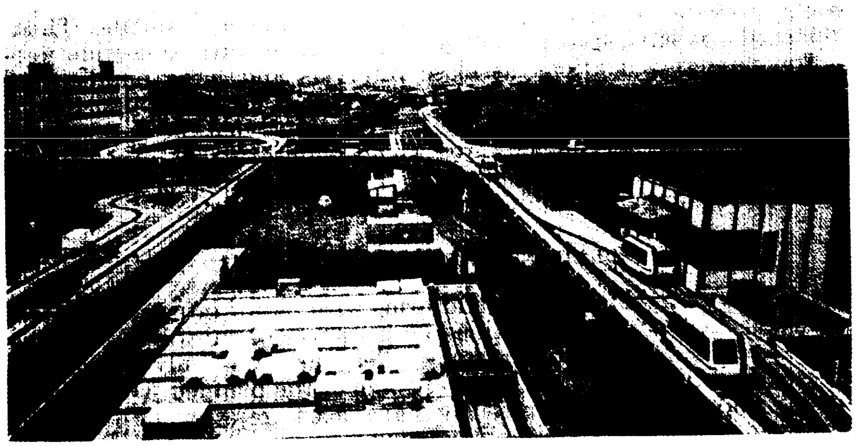
Characteristics.-The basic features of the personal rapid transit concept are small vehicles (up to six passengers) designed to carry one person, or a small group of people traveling together, non-stop from origin to destination over an extensive network of guideways connecting many stations. To provide convenient access ?or a maximum number of people, guideway grids have been proposed with spacings close enough to limit walking distances to mile or less.

The salient feature of PR& is provision of maximum convenience and flexibility. The result would be a level of service that is truly competitive with the private automobile. Thus, vehicles would move to any location throughout an extensive guideway network without enroute delays or transfers. Strangers could elect to ride together in a PRT vehicle if the happened to get on at the same time and were going to the same estimation.

Because of the lower vehicle capacity in PRT s stems, achieving the same line ca acities possible mth the less compex GRT systems requires that PhT vehicles operate at very short headways. For example, to move 2,500 people per hour at the average occupancy level of the private auto (1.4 people per vehicle) would require 1,800 vehicles per hour, or one every two seconds. Intersections would be equipped with switches enabling vehicles to make turns or continue in the original direction of travel much like automobiles at street intersections.

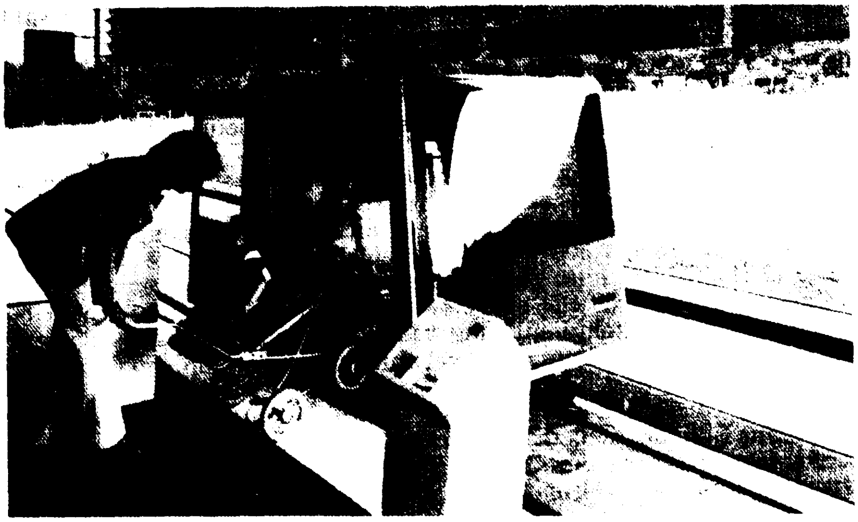
*United States Preapplications.*—There are no PRT developments or planned applications in the United States.

F*oreign PFT Applications.*—Prototype systems have been constructed in Japan, Germany and France. The Japanese CVS system is installed near Tokyo and includes a 4.8 km. test track, a sophisticated control system and 60 vehicles. These have operated at headways of six seconds and speeds of 30–40 km/h. A key objective of the test program is achieving safe operation at one-second headways..



**CVS Project Experimental Center, Higashimurayama Tokyo, Japan**

The German system, Cabinentaxi, includes five, three-passenger vehicles operating on a 1136 meter test track. Headways of .5 second have been achieved in the laboratory, and passenger carrying demonstrations under manual supervision have been conducted at one-second headways. The ARAMIS system in France which merges individual vehicles into groups has been tested on a one-km. test track with three vehicles operating at headways of 0.2 seconds between Yehicles and 60 seconds between grou s. This test track is no longer m existence, but a new one will be buiYt soon.



Cabinentaxi—Hagen, West Germany

*Potential PRT* Applicatioms.—The PRT concept was stimulated partly b," the desire to develop a public transportation s~"stcm which would provide an attractive alternative to the automobile. Thus, application is envisaged in well populated areas with area-wide networks, numerous stations at close intervals and large numbers of vehicles. The Aerospace Corporation estimates that some 10,000 square miles of urban area in the United States may be approriate for PRT service. Serving this area would require 30,000 miles or one-way guideway and three million PRT vehicles. In this same area, PRT would compete with other transportation systems,

## AGT Installations Studied in the United States

A survey of public agencies and firms with major interest in installations of AGT systems identified 36 instances of substantial studies completed for future AGT systems. The survey is only suggestive and Is not intended to be complete. Some of the planned AGT' installations may be, or may recently have been, rejected or deferred. However, because of the sizeable planning work and expense involved in each case, they are included to indicate the level of interest and activity in AGT development.

These planned systems have not been grouped by system class (SLT, GRT or PRT) because more than one class has been proposed for some locations. (For example, all three types of AGT technology have been studied for potential application m Minneapolis.) Instead, this listing is organized by the type of location for which the system has been proposed.

**METROPOLITAN NETWORKS AND CORRIDORS (6)**

Denver Region, Colorado.
Twin Cities Area, Minnesota.
San Diego Region, California.
Santa Clara County, California.
Pittsburgh, Pennsylvania.
El Paso, Texas—Juarez, Chi., Mexico.

**AIRPORTS (9)**

Atlanta, Georgia.
Boston, Massachusetts.
Chicago, Illinois (O'Hare).
Detro]t, Michigan (Metropolitan).
Los Angeles, California (International).
Oakland, California.
San Francisco, California.
New York, New York (J. F. Kennedy).
Newark, New Jersey (International).

**CBD/CENTRAL CITY (9)**

Ann Arbor, Michigan.
Detroit, Michigan.
Las Vegas, Nevada.
Long Beach, California.
Minneapolis, Minnesota.
Mid Manhattan, New York, New York.
Lower hlanhattan, New York, New York.
Norfolk, Virginia.
San Diego, California.

**MULTIPLE PURPOSE DEVELOPMENTS (8)**

Crown City, Kansas.
Echelon, New Jersey.
Cameron, Alexandria, Virginia.
Plaza del Ore, Houston, Texas.
Post Oak, Houston, Texas.
Southfield, Michi an.
Interama, Dade 8ounty, Florida.
Crystal City, Arlington, Virginia.

**31 EDIC!,4 I, CENTERS (4)**

Detroit Medical Center Corp., Detroit, Nlichigan.
Duke Universit~' Medical Center, Durham, North Carolina.
The Universit Health Center of Pittsburgh, Pittsburgh, Pa.
Texas Medicd Center Inc., Houston, Texas.

14- . .. . !

As can be seen from the above, planning studies ,of AGT cover a variety of applications. The proposed plans for medical centers, provision of transportation in central city areas, and provision of metropolitan network and corridor transportation are new applications.

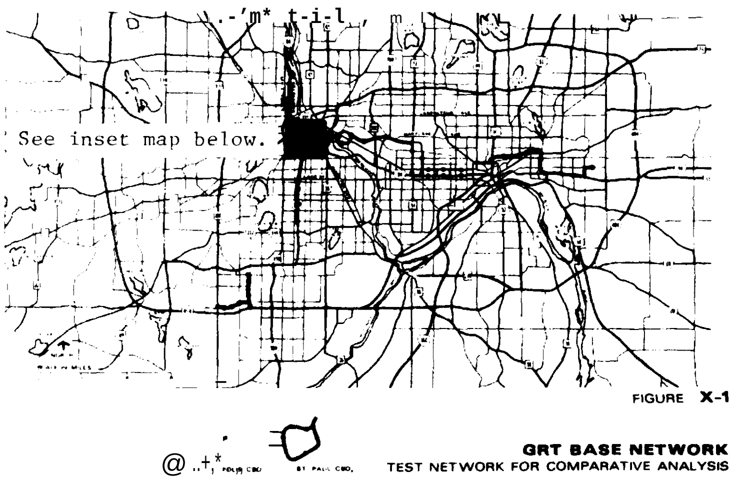
Some of the plans under evaluation are ambitious. For examplet there are four studies in metropolitan areas involving SLT or G T networks. A total of about 380 miles of dual guideways and almost the same number of stati~ns are being considered. T[ese would be built in stages at a total estimated cost of $6.7 billion. For comparison, there are now about 500 miles of rail rapid transit routes in the United States and the Washington METRO system will add about 100 miles at a cost of about $4.5 5million.

To illustrate some of the reposed applications, a system plan under consideration in each o the three AGT classes is summarized below.

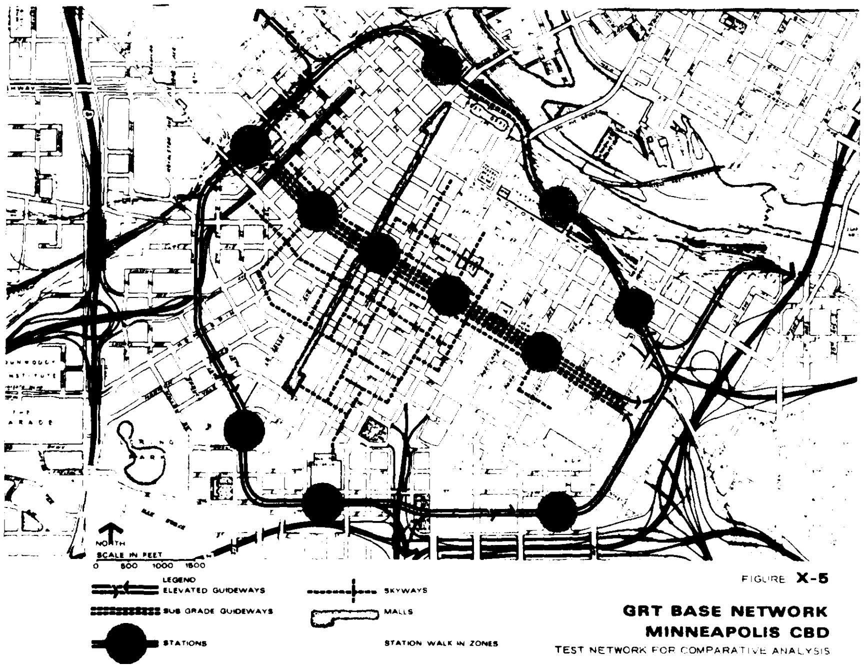
SLT

A "people mover" system to serve the C oastal City complex in Arlington, Va. is the subject of a current U TA-fianced technical study. A simple loop system with several on-line stations has been ro osed to provide convenient transportation to and from the E i $TRO station (under construction), to facilitate access to remote parking and for internal circulation within this office-cornmercial-residential development.

PROPOSED MINNEAPOLIS-ST. PAUL GRT SYSTEM




**Metropolitan Area Network (Dots indicate station location.)**




**Details of Network for Downtown Minneapolis**

Source: ***Automated 8mall Vehfcle Fiaed (Wdeway 8@em8 8tudg*, Technical Re ort IWO. 75-03, by De Leuw, Cather, Co., Inc., Bather, Ringnose, Wolsfeld, Inc., Honeywe I, Inc. ; hfarcb, 1975.**

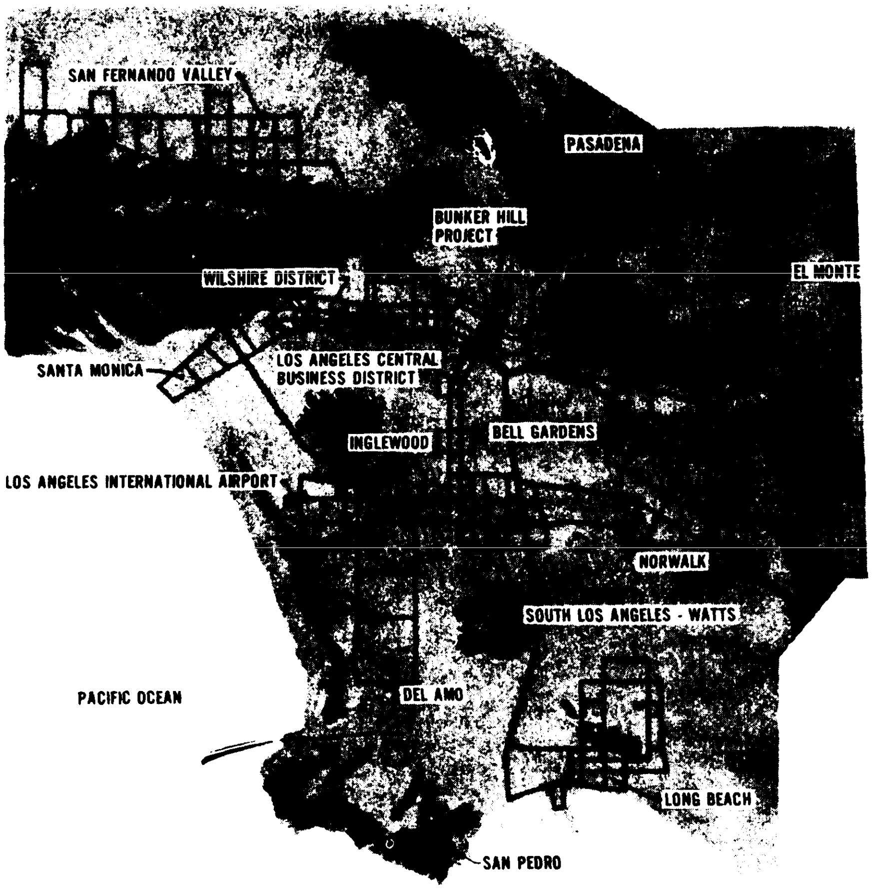
**GRT**

The Twin Cities Area Metropolitan Transit Commission, based upon detailed studies by a team of consultants led by Do Leuw Cather and Company, Inc. has determined that a GRT system would provide a satisfactory solution to transportation needs in the Minnea polis-St. Paul region. One plan which has been recommended proposes Euilding circulation systems in the two metro centers. Later extensions would provide lines into fully developed suburbs as indicated by the map on the preceding page.

A final decision on the system to be built awaits further detailed engineering studies in which GRT concepts will be compared with alternatives such as light rail.

PRT

The Aerospace Corporation, one of the strongest advocates of the PRT concept in the United States, in a study of the Los Angeles area, reposed *638* one-way miles of guideway, 1084 stations and 64,000 vehic les, as shown below.




Proposed PRT Grid for Los **Angeles**

The Aerosp ace Corporation compared its proposal to a conventional rail and excl usive busway system recommended by another group to the Southern Califorma Rapid Transit District, That system is reported to include 116 miles of rail, 24 miles of elevated busways and 62 stations. The Aerospace Corporation contends the PRT system could be built at about half the cost and provide better service.

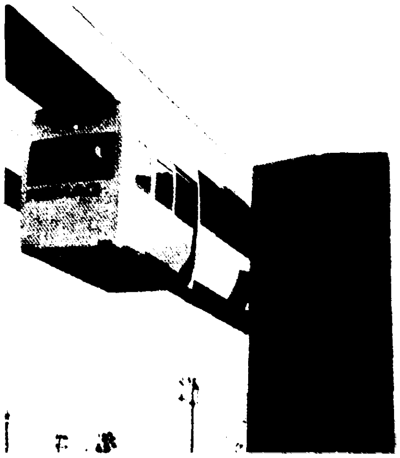
Further descriptive information about some of the applications proposed are contained in the Report of the Panel on Current Developments in the United States.

## SUPPLIERS OF AGT SYSTEMS

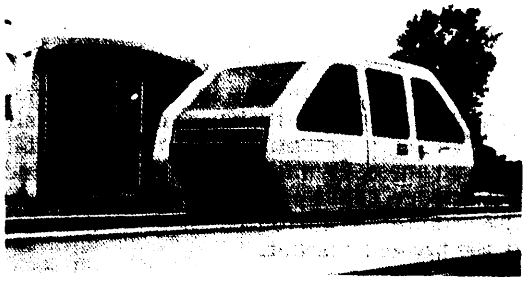
The number of existing systems and even greater number of plans for new ones indicates the high level of interest which AGT development has generated. Six different firms have installed the existing systems. Nine others have invested their own resources in develop-

SELECTED VEHICLE SYSTEMS WHICH HAVE FOUND NO MARKET
(Post-Transpo 72)

Astroglide
PRT Systems Corporation



R.omag
**Monocab,** Inc.
Rohr Industries



**Palomino**
**Aerial Transit**
**Pullman,** Inc.

ment efforts but have not received a contract for a revenue installation. Clearly, many firms have believed in a market potential for AGT.

The 17 AGT systems 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 reject, Braniff International's Jet-rail system for Love Field, Dallas, Texas. The firms are:

| | *Number of installations* |
| --- | --- |
| • Westinghouse Electric Corporation, Pittsburgh, Pa_. ----------- | 4 |
| Universal Mobility , Inc. Salt Lake City, Utah ---------------- -- | 6 |
| • Rohr Industries, (Monotrain) Chula Vista, Calif - ----------- | 2 |
| . Ford Motor Company, Dearborn, .Mich - -------------------- --- | 2 |
| . LTV Aerospace Corporation, Dallas, Tex- -------------------- -- | 1 |
| . Boeing Aerospace Company, Seattle, Wash- -------------------- | 1 |

Firms which have spent considerable time, effort and money on the development of full-scale test tracks and vehicles, prototype systems or temporary demonstration projects, such as Trans o 72, but have not yet sold a revenue passenger system in the United States include:

- Otis Elevator Company, Inc., Transportation Technology Division, Denver, Colorado.
- Rohr Industries, Inc. (Monocab), Chula Vista, California.
- General Motors Corporation, Transportation Systems Division, Warren, Michigan.
- pRT Sys,ems Corporation (associated with Braniff), Chicago, Illinois.
- Mobilit~ Systems and Equipment Company, Los Angeles, California.
- Alden Self-Transit Systems Corporation, Bedford, Massachusetts.
- Bendix Corporation (Dashaveyor), Ann Arbor, Michigan.
- Pullman, Inc. (Aerial Transit), Las Vegas, Nevada.
- Uniflo Systems Company, Minneapolis, Minnesota.

It is estimated that privately financed AGT development costs incurred by the 15 companies listed above total about $100 million. Lack of sales and unfavorable market conditions have caused some firms to curtail their programs or withdraw entirely. Others are considering abandonin their AGT programs. Certainly the number of suppliers exceeds% current market. One reason is that UMTA actively promoted AGT development in the late 1960's and early 1970's. Firms without prior transit experience, especially aerospace fires, perceived AGT as a potential new market to fill the gap of declining aerospace business. It was hoped by UMTA and these firms that aerospace knowledge could enable significant advances in AGT development. These factors contributed to the large number of suppliers relative to the present market.

## Chapter 3: Major Problems in Automated Guideway Transit

Them are many significant issues in the development and implementation of AGT systems. These are discussed under four broad headings: Institutional, Technical, Economic, and Social.

### INSTITUTIONAL

Compared with many other areas of entrepreneurial endeavor, the environment for innovation in transportation should be favorable. Urban transportation needs are extensive. Production of transportation hardware is dominated by relatively large and well en owed companies with much experience in the research and development process. Given these conditions, one would expect the state of the art of urban transportation technology to be highly advanced. The actual situation, however, is quite the opposite.

Urban transportation technology has advanced at such **a** slow pace that prevailing systems are almost indistinguishable from their counterparts of four to six decades ago (aside from some relatively minor cosmetic changes). However, the lack of progress is not a result of failure to advance technology. Much advanced transportation technology exists. Rather, it is a failure to devise effective ways to introduce the technology into urban transportation.

This failure stems from a lack of understanding by UMTA of the capabilities of the private sector and local transportation authorities and UMTA'S underestimation of the difficulties inherent in developing and implementing reliable and cost effective new systems. In retrospect, the new systems efforts have served not to stimulate interest in new technology but to discourage already reluctant local transit operators from considering it. The lessons of BART, Morgantown and AIRTRANS have not been lost on UMTA'S capital grants office which is now, understandably, reluctant to consider forms of AGT for capital grants funding. In addition to this limitation of the market, certain practices of the Federal government further discourage initiative within the supply industry

There are two areas in which the federal government could move to eliminate existing barriers to AGT innovation: contractual practices and capital grant procedures. Additionally, some of the institutional arrangements for system development adopted abroad are worthy of serious consideration in this country.

#### CONTRACTUAL PRACTICES

Many accepted Federal government research and development practices impose negative incentives on manufacturers and reduce Benefits from UMTA contracts:

*Patent Rights (TMe).—Whenever* any invention, improvement or discovery is made or conceived, or for the first time is actually reduced to practice, the contractor must notify the government Contracting Officer. The Secretary of DOT has the sole and exclusive power to determine whether patent applications shall be filed and whether the government shall acquire the patent rights. The contractor may be given a free license to such patents, but if not used during three years, the license may be withdrawn.

*Background Patents (License).*—After a determination that the product is required by the public in the interest of public health, safety or welfare, the Secretary can require the contractor to license others on reasonable terms to produce items under any background patent necessary for the production, sale or use of the end product.

*Rights in Datu (Title.*—All recorded information first produced in performance of the contract becomes the sole property of the government. Furthermore, the contractor must grant the government a royalty-free, nonexclusive and irrevocable license to pulish or otherwise use any and all data, not first produced or composed in the performance of the contract, but which is incorporated in work furnished under the contract.

—Current Office of Management and Budget (OMB) guidelines require up to 50 percent cost sharing in developmental contracts where there is a substantial commercial market.

*Fixed Ceiling Limitations.*—While written as cost reimbursable contracts (with or without fees), fixed ceiling limitations on R & D contracts make them fixed rice contracts, with an almost open-ended scope of work. For examp le, the four system suppliers who participated in the AGT demonstration at Transpo 72 were offered cost-reimbursable contracts with a ceiling of $1.5 million each. However, each contractor exceeded this ceiling b amounts reported to be from $1 million to, more than $2 million. E ach of the three contractors participatmg m the first phase of the Dual-Mode Program had cost-reimbursable contracts with a ceiling of $500,000. Actual expenditures were reported from $600,000 to more than $2 million. This project was cancelled at the end of phase I.

*Recovery of Developmental Costs.*—Depending on what is negotiated as a fair, reasonable and equitable amount, the contractor is required to pay the government up to five percent of sales or leases of any roduct substantially the same as that developed under the contract. b e is also required to pay up to 33 percent of finds received from technical agreements enabling others to sell, lease or use the product. Sales or leases of the product to the government, or its agencies, must be at a price reduce by the equivalent of the recoverable costs. The costs recovered under this provision are limited to the amounts paid by the government to the contractor for the development.

The implications of the foregoing practices may be summarized as follows.

- There is no incentive to make patentable discoveries because rights to resulting patents are acquired by the government. The contractor must assume the burden of protecting the discoveries and applying for the patents.
- The contractor risks disclosure and licensing of background patents to competitors.
- Proprietary data, even though originally prepared at company expense, may be released to competitors, lf reported m accordmce with contract requirements.

- Cost sharing is an invitation to spend corporate funds in the expectation of future returns on the investment. However, where programs are canceled, as in the case of the Dual-mode project, or where UMTA'S practice is to discourage capital assistance for deployment of systems, there is no opportunity for a return on the non-reimbursed costs.
- In return for a private investment which may exceed the federal share of the project cost, a company is obliged to relinquish nearly all proprietary rights,

CAPITAL GRANT **PROCEDURES**

With support from a coalition of major cities, organized labor, the transit industry, commuter railroads and equipment manufacturers, the Urban Mass Transportation Act of 1964 provided funds for capital improvements. This act made possible the preservation of bankrupt existing systems and gave aid to public agencies and, indirectly, to private operators for modernization and replacement of facilities and equipment. The 1966 amendments authorized the expenditure of funds for technical studies to plan, engineer, design and evaluate mass transit projects. These projects would be included in a unified or officially coordinated urban transportation system as a part of the comprehensively planned development of the urban area.

The implementation of the capital improvement and planning programs has not facilitated the application of new systems to urban needs. In particular, UMTA has failed to link its ambitious R & D programs to the capital grant program. In the absence of a carefully planned staged development of new systems from R & D, throug~ demonstration to deployment, new systems get little support for capital grant funding because they are considered untried and unproven concepts. It ias been the position of the UMTA staff that capital grant support is appropriate only for the purchase of proven hardware or ful y operational systems suitable for revenue service. There have been only two exceptions to this practice of discouraging capital grants for advanced systems (AIRTRANS and the Pittsburgh Transit Expressway Revenue Line) but neither has resulted in an urban insta lation.

UMTA'S philosophy is that R & D is necessary to develop advanced systems but that improvements to existing systems and urban deployment of simple AGT systems should be handled throu h the rivate marketplace and the capital grants process. However M T A [ a s been reluctant to establish equipment standards or criteria that would qualify advanced systems for procurement throug h the capital grant program. Without such standards there is no clear-cut method for communities to seek capital assistance for AGT systems, and there is little incentive for industry to continue to invest in systems that cannot be deployed.

There is a critical need for UMTA to develop a sound approach to the management of new systems technology from concept through deployment,. The half measures in force today do not provide any guarantees that the taxpayers' dollars are well spent on R & D. The purpose of the program should not be to develop test track hardware, but to solve urban transportation problems.

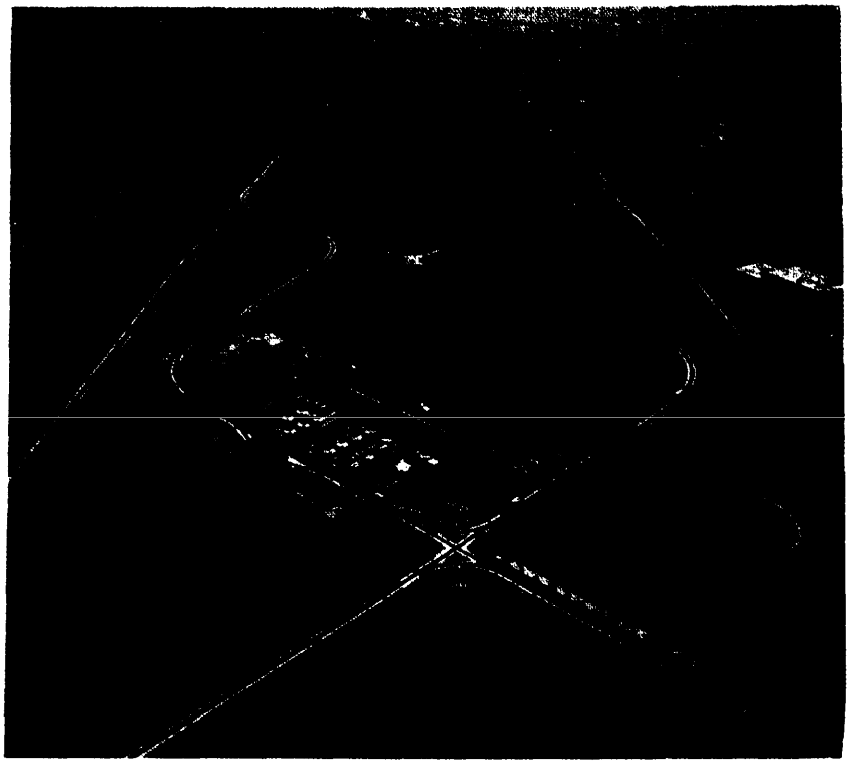
A new UXITA requirement calls for an analysis of alternative transportation solutions to substantiate selection of a particular system for Federal capital assistance. Cost-benefitt analyses tend to be unfavorable to new systems because they will have higher fist costs for production engineering, tooling and federal-share development repayments than do systems which have been deployed. Careful evaluation of service benefits and clear UMTA criteria for qualification of new systems for capital grants will be necessary to insure consideration of AGT and other new systems.

### FOREIGN INSTITUTIONAL ARRANGEMENTS

In a number of foreign countries novel arrangements between central and local governments and industry have been established to foster the development and ultimate deployment of AGT systems. Certain of these are worthy of consideration.

*R&D Organization.*—In Germany and Japan, research and technical development of AGT systems usually is not handled by the agencies having responsibilit for construction and operation of revenue functions. This division of function is advantageous in that it tends to

PRT RESEARCH AND DEVELOPMENT IN JAPAN



**Aerial View of CVS Test Track-Higashimurayama Tokyo, Japan**

insure longer-term continuity of development by avoiding competition for resources to solve immediate transportation problems. A disadvantage, however, is that system development tends to be isolated from the realities of urban deployment.

*Gvernrnent-hdwstry* Cooperation.—Consortia of several industries are sometimes fostered by national governments (e.g. Germany and Japan) to develop a particular concept. For example, in Japan a consortium of eight private industries, a trade association, the University of Tokyo and the Ministry of International Trade and Industry are cooperating on the development and the test facilities for the Com- uter-controlled Vehicle System (CVS). (See illustration, page 44.) L private capital may sponsor research and development through the concept stage. If the concept is found attractive, the government can offer many incentives for prototype development and testing, including cost sharing with a 50~0 cash advance, and company retention of proprietary rights for commercialization with payment of modest royalties.

Government financial support for a local development and demonstration project virtually insures the company against losses for investments in production facilities and engineering. This insurance ]s a strong incentive for a system developer to exploit his system commercially. Successful commercialization is an advantage to the Government since royalties are paid to the government until the initial cash advances, with interest, are fully repaid. Thus, the government is motivated to encourage adoption of new systems to secure a return of the investment in the initial development.

*Cooperation between systetem manufacturers and local vernmenti.*— In both Germany and Japan, the system developers have been involved in planning the actual installation and operation of the system. In France, AGT development has generally been initiated by local governments in conjunction with a hardware supplier. This arr~e- ment leads to early decisions as to the type of system to be incorporated in the local transportation im rovement program. If the planned development is deemed to be o national interest, financial assistance can be made available from various ministries having co "Zance **of** land use, regional development, transportation and pu Yic **works.** Representatives of local and regional planning and th~ operat@~ agencies, in addition to representatives from these ministmes, participate in management of the project.

An advant~e of this arrangement is that lanning tends to h more pragmatic with early, more intense invoYvement of a specific system supplier. Another advantage is that market uncertainties tend to be reduced throu h commitments to a su plier so that his system if any, will be instalfed. Once the hardware fecision is made, wastefui com etition is eliminated.

T~e French procedure also has some disadvantages. System selection may be based mostly on entrepreneurial prowess or influence. Absence of price competition may result in more costly installations. It is too early to judge whether this French management procedure offers a better solutlon to technical or implementation problems associated with AGT systems.

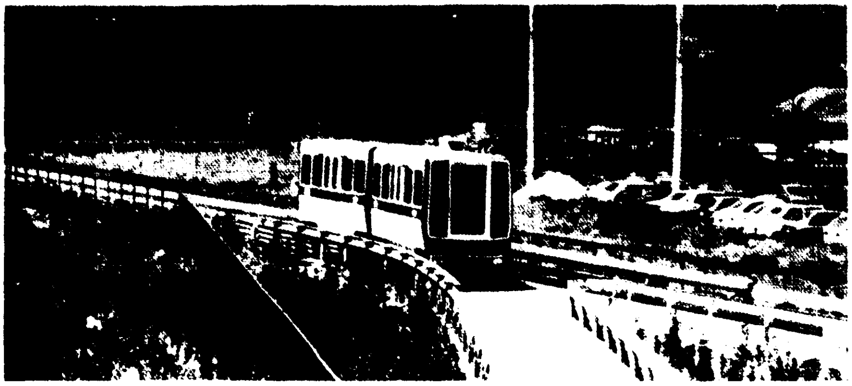
*Government Cor oration.*—The Ontario rovincial government has established an 6 rban Transportation b envelopment Cor ration (UTDC). The Canadiin Federal government, as well as otr er provincial governments, are expected to participate in the development programs.

Establishment of the UTDC required the government to appropriate u $6-million working fund and to delegate authority to enter into specific kinds of contracts. Once established, the UTDC is expected to proceed with developing and marketing of systems such as AGT, depending upon the cash flow from these operations to preclude the need for extensive additional government aid. This independence provides continuity JO development programs since they are not subject to fluctuations m annual appropriations.

*Contractual Advantages.*—Foreign develo ers enjoy certain advantages that are not availablo to United tates systems suppliers. Procedures differ slightly among countries, but common provisions are summarized below.

- Proprietary rights to the system are retained by the developer.
- The government must wait 12 months before releasing data to third parties, and longer if the data are company-confidential.
- Prototype hardware and software belong to the company, but may revert to the government if the company fails to achieve commercial success.
- Development contracts are cost-shared, based on an estimate of the total project cost. The government share may range from 50 to 80 percent, with cash advances made at predetermined rates.
- These cash ad~'ances are later refunded to the government, with interest, in the form of royalties from commercial sales. The government m:ty reduce the royalty rate, if a reduction would help the company win m export sale in competition.
- To stimulate company investments in production facilities, conmlercialization and marketing acti~.ities, the government insures ag:]imt 1o sscs. The de~'eloper is guaranteed a minimum financial return sufficient to cover the differences between the company's actual sales and its lxenk-even costs.

EXAMPLES OF U.S. TECHNOLOGY U'SED IN JAPAN



**Test** Track built by LTV **Licensees, Niigata Engineering Co. and Sumitomo Shoji Kaisha, Ltd.**

Kobe Rapid Transit (KRT) System for Expo '75 on Okinawa
Built by Kobe Steel, Ltd. **in cooperation with Boeing Aerospace Co.**

**3IULTINATIONAL LICENSING AGREEMENT**

Interest in AGT systems has produced several international licensing arrangements. Three United States companies have licensing and cooperative agreements with Japanese organizations: LTV Aerospace Corporation, the Boeing Compan~' and the Bendix Aerospace Corporation. The otis Transportation Technology Division has an understanding with SOCEA, an engineering and construction subsidiary of Saint Govain-Pent ~ Mousson to collaborate on planning an AGT system in hTancy, France, However, political and financial obstacles have caused uncertainties about the future of this ~roject.

Krauss-Maffei of Munich, Germany, still has a hcensing agreement with the UTDC in Toronto, Canada, despite cancellation of the project to build R magnetically levitated demonstration system on the Canadian National Exposition ground. This contract was terminated when the German Government withdraw support from the Krauss Maffei system.

Whether the AGT market will materialize sufficiently to make these licenses profitable is not yet known. These multi-national agreements among suppliers of AGT systems and hardware refute to some extent arguments that continued United States government support of AGT development would help protect the United States balance of payments. Under a typical hcensing agreement orIly a small amount of the money spent to build a project would fmd its way overseas to the organization which licensed the technology. Most of the materials and labor required to build a given project would normally be obtained domestically.

TECHNICAL

### COMMON DEVELOPMENT REQUIREMENTS

There are tichnical problems to be resolved for all three classes of AGT systems. These problems become more severe as system complexity increases.

The **major remaining development requirements common to all** AGTs terns are discussed below.

Control System Automation Development of computer programs for fully automating control functions! aa received considerable attention, although only for theoretical operating conditions. (In resent s stems, automation of central control functions is limited. Advance GRT and PRT systems will require such automation.) The most advanced work of this kind of the United States has been done by the Aeros ace Corporation, the A plied Physics Laboratory, and in Japan by VS. Development of reaY-time communications, com u-tation and display hardware for vehicle and traffic managementEas received little attention. The biggest difficult is that commercial available technology allows rates of failures in t ese components whic{ are much too high for transit systems. Military and space hardware that could achieve the required reliability is available, but at much higher costs. Development is needed to ievise real-time vehicle and traffic management systems which tolerate individual component faults and also can maintain some operations while the fault is being corrected.

*Headway Coni!rol.*—If the full projected potential of AGT s stems is to be realized, means must be found to reduce the relative{y conservative headways between vehicles now used by the mass transit industry. Further development is necessary to:

- Im rove the quality of emergency braking s stems so that hig[ er deceleration rates can be reliably and sa?ely provided.
- Develop emergency braking systems which rovide constant deceleration rates with variable forces, de~en8ing upon vehicle weight and loads, grades, windage and guldeway conditions.
- Develop vehicle separation sensing systems of higher resolution than are currently available to permit vehicles to operate at separations closer to the actual braking distance.

flystem reZidMty.—"System reliability" to the desi n en ineer becomes "system dependability" for the transit patron. T e protability of a system failure increases with the number of operating components in a vehicle and in the system. It also increases with the number of vehicles on the track between the traveler and his destination.

To improve reliability for AGT systems, the following must receive more attention.

- Procedures need to be developed for analyzing the potential failures in extensive networks with large numbers oi vehicles.
- Additional research is required on the levgl of dependability acceptable to the riding public.
- Development is required to achieve a satisfactory level of service dependability, including identification of critical components, establishing allowable failure and restoration rates, and monitoring test results.

Mathematical modeling alone will not improve system reliability. Models can identify critical areas which must \e given special analysis, but a combination of design procedures, modeling, production quality control, and testing is necessary to gain increased system reliability in actual public service.

*Guideway cost.*—Guideway costs represent 50 to 70 percent of the total cost of an AGT system installation. The cost of tunneling such systems could be three or more times the cost of an elevated guideway.

Areas where development work is required are itemized below:

- Standardization of design and uniform loading criteria could promote greater use of assembly line production techniques, with resulting cost savings.
- Studies are necessary to define an acceptable level of ride comfort and to establish trade-offs between guideway roughness and vehicle suspension systems.
- Development is required to minimize the disruption and hazards caused by snow and ice on guideways.
- There are applications where an AGT system would be inappropriate ground. An underground installation would require expensive tunneling and station construction. More work needs to be done on improving the efficiency of underground construction and on the trade-offs between aerial and underground guideways.

System *integration.* —System integration is necessary to insure that careful control is exercised over system design in order for performance requirements and design objectives to be met. This integration can be accomplished least expensively by first simulating system performance with computer assistance. After correcting errors in design, system integration can be effected through ext(mslve testing of components, subsystems, and finally the whole system. Work is needed in developing the computer simulations and preparing the related test programs for an AGT system with an extensive network and large number of vehicles.

*Test jacility.*—Because the problems described above are common to all AGT s sterns, private industry research and development to solve them would likely be redundant and hence wasteful of resources. A properly managed federal research program could address these common problems while clarifying the issues concerning ultimate urban de loyment of AGT systems. Part of such a rogram would be an A(!T system test facility. Such a facility could \e available for:

- Testing critical aspects of system designs.
- Establishing design and operational standards.
- Testing alternative desi n approaches and components for comparison with standarf s.
- Identifying and defining engineering trade-offs.
- Limited '(check-out" of systems prior to urban deployment.

The "HPPRT" Pro~ram reposed by UMTA provides the essential elements of such a facdity, ! ut only for a sin le manufacturer's concept. With some additional expenditure, the% PPRT" facility could satisfy the requirements outlined above for several systems.

### SHUTTLE-LOOP TRANSIT SYSTEMS (SLT)

The greatest remaining technical and cost challenges involve product improvements necessary to reduce capital, operating and maintenance costs. Product improvements are also necessary to increase operational reliability, including:

- Door operating mechanisms.[1]
- Communications systems.
- Automated control systems.
- Improved passenger information systems.

### GROUP RAPID TRANSIT SYSTEM (GRT)

Technological improvements required for GRT systems are described in two categories: those currently developed (headways greater than 15 seconds) and the advanced GRT systems still being developed (headways less than 15 seconds).

Though two GRT systems have been deployed in the United States (Morgantown and AIRTRANS), they can be regarded as still in engineering development. The basic technology has been proven and components have been assembled in a workable system; but additional engineering is required to improve performance and reliability, to reduce costs and to prepare the systems for larger scale production.

Further specific engineering developments required are:

- Achievement of a level of system reliability exceeding that of current transit systems at an economical cost.
- Reduction in weight of vehicles and guideways.
- Development of automatic vehicle coupling for assembling trains in stations.
- Development of techniques for detecting obstacles that may affect passenger safety or cause damage to a vehicle.
- Development of computer software for managing the vehicle fleet and for accommodating system failures.

*Advanced GRT systems*.-These systems are characterized by headways from about three to 15 seconds. The technical development requirements are similar to those for the current GRT systems. The shorter headways, however, require more attention to the following:

- Improvements in the responsiveness and accuracy of the longitudinal control system, including detection of separated vehicles and wayside communication.
- Development of an emergency braking system providing constant deceleration independent of vehicle loading, grades, windage and guideway condition while meeting established safety and reliability criteria.
- Careful integration of system hardware and software in order to meet development objectives.

Current planning for the "HPPRT" project includes most of this work.

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[1] Note that foreign practice requires transit patrons to activate the opening or closing of doors. Rear doors on United States transit buses are similarly opened by riders. Life cycles could be extended by patron-operated doors because these doors are operated only when needed, rather than repeatedly at all stops.

## PERSONAL RAPID TRANSIT SYSTEMS (PRT)

PRT systems are now in the exploratory development stage. Two critical issues that are the most challenging and require the greatest attention are:

- Sustaining high levels of service dependability with shorter headways and more vehicles than GRT systems have, and
- Developing computer software to manage a fleet of thousands of small vehicles safely and efficiently.

Other PRT development areas which must be addressed are:

- Basic PRT system requirements to conform to changes in regional topography" and meet urban travel needs, defined in terms of patronage, service, operations, network geometry, and facilities.
- Demonstration of the feasibility of longitudinal control systems for very short operational headways (0.5 to 2,0 seconds),
- Development of a constant deceleration emergency braking system (in contrast to fixed brakes currently used).
- Determining requirements imposed on the vehicle and other parts of the system in case of collisions,
- Vehicle crash-worthiness studies.

Progress toward resolving some of these issues could be made through development of the SLT and GRT systems. Nevertheless, a decision to initiate development and implementation of a PRT system must recognize that deployment would be perhaps 1O–15 ~rears away. The problems of management, financing, and risk would exceed those of any other development program undertaken by the Urban Mass Transportation Administration. Careful long-range planning and a long-term commitment to such a program are essential If a PRT system is to be put into service.

## ECONOMIC

### BETTER COST DATA NEEDED

One of the major problems facing those attempting to analyze the merits of AGT in relation to alternative transit modes is the ]aucity of meaningful data, Further, the limited information avaIlble is interpreted differently by consultants, public agencies and manufacturers. As a result, many conflicting estimates have been made and there is general confusion on the validity of the resulting cost-benefit analyses.

SLT.-There are enough SLT systems in operation and under construction to warrant a concerted effort to accumulate and interpret information on operation and maintenance costs as well as initial capital costs, This should, of course, be a continuing process as new data is taken into consideration. The tabulation on the following page summarizes the pertinent data which are currently available on the six SLT systems which involve relatively large vehicles.

As shown, there is a wide variation in the cost of construction. Some of this must be attributed to different guideway requirements (i.e., at grade, elevated, or tunnel). In general it should be noted that capital costs per mile for SLT systems are not large in comparison with other

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systems using exclusive guideway s. Operation and maintenance, exelusive of capital costs per vehicle mile vary from 72 cents to $2.08. This would compare to $1.45 for the Lindenwold Rail Rapid Transit Line (1974 figures), $1.75 for the Washington, D.C. Metrobus operation, and $1.70 for the bus fleet operated by the Chicago Transit Authority. Because SLT systems provide a lower capacity service than rail rapid transit, the per-passenger costs seem high and indicate a need for technical research and development to reduce them.

RZ'.-The only two GRT systems, at the Dallas/Ft. Worth Airport and at Morgantown, have both experienced major capital cost overruns. It is difficult to derive any useful conclusions from experience to date because neither system has been in operation long enough to establish a sound basis for projectin operation and maintenance costs. For example, after 16 months o operation, LTV was using about 120 maintenance employees to keep the AIRTRANS system operating—almost two per vehicle. Also, 36 station attendants, not contemplated in the original project plan, have proved necessary to compensate for the poor quality of information available to passengers in the system.

As more experience is gained and equipment reliability is further improved, LTV hopes to reduce the maintenance force towards the originally projected goal of 90. Moreover, with improvements in passenger information, systems design and station facilities, the need for station attendants can be eliminated or drastically reduced.

*Cost* **Data** *for SLT Systems* Involving Large *Vehicles*

| | R ; % | Sea Tac Airport | Miami Airport | Busch Gardens | Fai+~#: Center | Bradley Airport |
|---|---|---|---|---|---|---|
| Length of single lane guideway—in feet. . . . . | 7,100 | 9,050 | 2,800 | 7,000 | 3,400 | 4,400 |
| Number of stations. . . . . | 8 | 6 | 2 | 2 | 2 | 3 |
| Number of vehicles. . . . . | 1 8 | | 14 | 12 | 22 | |
| Capital cost—millions... | $8.25 | $;.,: | S $6.7 | $4.0 | 3 $4.5 | $;.: |
| Year completed. . . . . | 1971 | | 1976 | 1975 | 1976 | 1975 |
| Annual O. & M. costr4 thousands . . . . . . . . . . . . | $275 | $540 | 3$300 | NA | 3$250 | 3$250 |
| Passengers per year, millions . . . . . . . . . . . . . . | 12.5 | 5,7 | 35.1 | NA | 33.0 | 3 1.0 |
| Vehicle-miles per year, thousands .,...... . . . . . | 380 | 430 | NA | NA | 3 120 | S 230 |
| Capital cost per lane-foot . . . . . . . . . . . . . . . . . . | $1,150 | $1,550 | $2,400 | $600 | $1,300 | $1,000 |
| 0. &M. cost per passenger......, . . . . . . . . . . . . . | $0.02 | $0.09 | 3$0.06 | NA | 3$0.08 | S $0.25 |
| O.& M. cost per vehicle-mile, . . . . . . . . . . . . . . . . . | $0.72 | $1.26 | NA | NA | S $2.08 | 3$1.09 |

I Westinghouse Electric vehicles—90 to 100-passenger capacity.
Z Ford Motor Co. vehicles—24- to 30-passenger capacity.
$ Pro"ected.
t Exc(usive of capital cost.

In general, operating and maintenance costs of GRT will be highly sensitive to the number of maintenance personnel and the presence or absence of station attendants.

The Morgantown system is not yet in operation and consequently there are no actual operating data available. Boeing estimated that 42 people will be required to operate the system and maintain the equipment. Judging from LTV's experience at Dallas/Ft. Worth, where initial operations required three times as many staff people as originally estimated, it can be expected that during the break-in period appreciably more people will be needed.

Both AIRTRANS an Morgantown offer excellent opportunities to develop very useful information about the operating and maintenance costs of GRT systems. It is important that they be monitored carefully and that data be collected in a comprehensive and coordinated fashion.

PRT-There are not enough data available on these more complex systems to form the basis for reliable estimates of capital and O & M costs. Automobiles cost in the order of $1 to $2 per pound. Aerospace system hardware costs much more—for example, the 747 averages about $65 per pound. PRT vehicles can be expected to cost somewhere in between, probably in the range of $10 to $20 per pound, depending upon quantities produced and other factors.

Estimating the probable costs of PRT systems is a particularly perplexing problem. For example, the Aerospace Corporation has prepared a study which indicates that a PRT installation in the Los Angeles area would be cost-effective. They recommend 64,000 very small vehicles and conclude they can be produced in volume at a cost of $10,000 each. Manufacturers contacted by De Leuw Cather and Company, in connection with a detailed study of small vehicle systems for the Twin Cities Area Metropolitan Transit Commission, indicated that the on-board control equipment, alone, would cost well in excess of this amount.

Such differences in opinion on probable costs are not surprising because no PRT systems have been built, aside from overseas test tracks. Research is needed to assemble the best information available and, after thorough analysis, to make data available to those who are interested. The extensive test track installations in Germany and Japan could provide the basis for mutually beneficial international information exchanges.

## THE INFLUENCE OF AUTOMATION

AGT transit systems which involve relatively small vehicles must be automated in order to be economically viable. Experience in recent years with urban bus operations indicates that the cost of providing drivers for individual vehicles the size of a city bus or smaller has nearly reached the limit of support from the fare box. The strong thrusts in the past 10 to 15 years to develop systems that are less labor intensive recognize this factor. The successful introduction of automatic elevators is often cited as evidence that automation can provide better service at substantial savings.

Experience to date with Automated Guideway Transit systems, however, indicates that dramatic economies, through the substitution of computers and electronic equipment for operating personnel, are unlikely in the foreseeable future. To provide frequency, comfortable, reliable, and safe service without human operators requires much complex electronic and mechanical equipment that must be monitored and maintained by skilled technicians.. As the complexity of such systems increases, opportunities for equipment malfunction increase correspondingly, necessitating additional specialized personnel. For example, at the Tampa International Ai.rport the eight Westinghouse shutt'e vehicles are maintained by a crew of four full-time and two art-time employees, fewer than one per vehicle. At the Dallas/Ft. h Worth Airport, however, where a much more complex system is in operation, about 120 maintenance employees are currently required to kee 68 vehicles in operation.

The tabulation below illustrates how various levels of automation are related to manpower requirements. As noted in the table, even after the AIRTRANS system shakes down and a number

*Manpower Requirements for Alternative Transit Modes*

| | Conventional bus Metrobus Washington, DC | Semi-Automated PATCO Lindenwold, NJ | Fully automated GRT AIRTRANS Dallas/Fort Worth |
|---|---|---|---|
| Number of vehicles | 2,175 | 75 | 68 |
| **Number of personnel:** | | | |
| Administrative | 117 | 28 | 3 |
| Operating | 3,311 | [2] 117 | [4] 58 |
| Maintenance | [1] 793 | [3] 131 | 120 |
| Total | 4,221 | 276 | [5] 181 |
| Number of employees per vehicle [6] | 1.9 | 3.7 | 2.6 |

[1] Bus maintenance only, 726 people.
[2] Includes a plice force of 20 people.
[3] Includes 76 people in rail shops and 55 for way, power, and facilities.
[4] Includes 36 passenger service employees required to assist passengers in finding their way around the airport.
[5] The maintenance manpower should decrease to 100 *or less* as more experience is gained. Also the need for passenger service employees should diminish once better graphics are installed. Thus, a total manning level of about 125 people for both operations and maintenance may be anticipated, which would amount to about 1.8 employees per vehicle, or about the same as a bus fleet.
[6] The ratio of employees per vehicle is only one of several bases for comparing different systems and modes. AIRTRANS is a very complex system. At the other extreme, the Tampa Airport Shuttle System requires only .75 employees per vehicle.

of improvements and refinements have been completed, the number of people per vehicle required to maintain and operate It will be only slightly less than for a typical bus system. Thus, GRT must offer a significantly higher level of service and comfort if it is to operate as a cost-effective mode because capital costs will prove far greater than for buses on a highway.

A major unknown in the potential deployment of PRT systems, which have much more sophisticated controrand vehicle equipment, is the amount of manpower required to keep such systems working safel~~ and satisfactorily. Budt-in redundancy and other means can improve PRT reliability and reduce manpower requirements. It is unclear however, whether this reliability can be achieved at reasonable cost, and whether maintenance requirements can truly be reduced.

## THE RELATIONSHIP OF AGT TO OTHER TRANSPORTATION MODES

Not only must AGT systems compete with all other transit modes for scarce capital, operating and maintenance funds, they must vie for trips which are now being made in private automobiles. Conventional rail and bus systems have been steadily losing ground. At the least, innovative applications are needed to reverse this trend.

AGT systems are a. most ambitious new alternative for public transportation but at the same time involve great risks. These systems will compete with the private automobile, for which drivers are 'ifree" and many other true costs are well subsidized. Among these costs are traffic policemen; land consumed for roads, parking lots and service stations; pollution; excessive travel time due to congestion; inefficient use of energy; and urban s rawl.

Although SLT and GR?are otentially more attractive than other transit modes, they will probabry gain ridership in response to measures to discourage use of the private automobile. However, their potential for influencing the modals lit should be carefully evaluated. I?RT, if realizable, would undoubtelly have many attractive features that place it in a different class from conventional transit modes. In an~. serious consideration of PRT, which represents the most ambitious concept yet proposed for urban mobility, three fundamental questions arise.

- Is PRT technically feasible to build and operate at acceptable levels of service and reliability?
- Will the public find PRT socially acceptable and will people use it for a significant percentage of trips?
- Can the substantial capital and O & M costs be economically justified in relation to the resulting benefits, many of which are not readily quantified?

This last question is probably the most difficult because little hard datti me available. Some contend that the best way to develop meaningful cost estimates is to invest heavily in test track and demonstration facilities. Certainly, this approach would provide much better information than is currently available, and it would help answer the first two questions. However, a test track program would cost a great deal—probably well in excess of $50 million. Before making such a substantial investment, comprehensive research is needed to develop pertinent data. Analyses should be made with sufficient detail to provide firm answers to two basic questions:

- Would the potential use and benefit of PRT systems in the United States warrant the cost of development, testing and demonstration?
- Can a PRT system be built and operated at costs which riders can afford or which local and federal agencies are willing to subsidize?

Until more research has been completed on the social and economic problems involved in PRT, expenditures for hardware development should be limited to those necessary to support the findings of these analyses.

SOCIAL

Current studies of AGT systems indicate that planning and decision-making at the local level on the use of automated systems is an exceptionally difficult process. Achieving an acceptable plan involving massive capital investment, uncertain operating costs, educated guesses about impacts on transportation, the environment, and urban form, and serious risks of technological feasibility is a formidable task. The process must involve not only a complete analysis of realistic alternative approaches to transit, it must also be responsive to a broad range of community interest groups.

Major social issues are present. They are briefly summarized below.

*Lund* Use.—Urban transit systems affect land use, property values and the character of neighborhoods they serve. The full impacts are not well known, though the effect of urban highways are considerable. By coupling transit and land use plannin , many of the harmful effects could be lessened. Applying this princip e to planning AGT installations could enhance the nature of the areas served.

In general, the land use impacts of transportation are poorly handled in our society. Laws do not allow the optimum use of potential transit benefits. For example, the rise in property values adjacent to transit stations is allowed to accrue to private speculators or developers. This can inflate housing prices and deny both housing and transit service to the lower and middle income roups it was intended to accommodate. The increase in values, as we1l as the increased property tax revenues, could be recaptured for public pur oses such as paying the costs transit construction and operation. AG systems may have the potential to ameliorate many such land use problems, but this potential cannot be realized without supportive legislation and intelligent urban planning that recognizes the possibilities.

~ervice.-AGT systems demonstrate superior potential service attributes. Automated vehicles can be scheduled more frequently to provide much higher levels of service than manned bus or rail rapid transit. Demand service vehicles would add a further dimension, and direct origin-to-destination service would be even more convenient.

At the same time, the benefits of service must be distributed among the various populations that comprise an urban area. If maintaining service in high crime areas is a problem, it would be difficult to distribute GRT or PRT system benefits evenly among all groups; thus, the benefits might accrue primarily to the affluent surburban commuters. Such concerns are often voiced on rail rapid transit systems developed in the traditional hub and spoke fashion. Service characteristics deserve careful study for capital intensive transit systems.

Safety.-+LT systems have been operatin with good safety records which seem well established. AIRTEANS as likewise fared well in this regard. Thus, AGT systems can compare favorably with conventional transit in the safety area. However, emergency procedures and evacuation methods must be further developed.

PRT safety requires detailed investigation.for fractional second headways to be implemented, the "brick wall" criterion for transit safety must be replaced, That is, under certain situations, it may not be possible for a vehicle to be operated in such a manner as to allow it to stop before it hits the car in front of it. Passenger safety in controlled collisions between crashworthy vehicles could be high, or it could be significantly lower than conventional transit.

security.—Vehicle operators, conductors and station attendants all contribute to a feeling of security among the passengers. In high crime areas special transit police forces are employed to enhance system security. AGT systems, to be economically competitive, must reduce labor costs substantially over conventional modes to justify hi her capital costs. Current SLT and GRT deployments in nonuri an settings do not reveal much about security aspects.

Authorities have indicated that security functions can be automated to some degree. Closed circuit T.V. and two-way voice communications can provide a great measure of personal security when coupled with a quick-response police force and a system enforcement plan. However, problems of security increase with increasing numbers of stations. Mforeover, technological fixes to problems of security can raise costs.

Automated systems must be carefully designed to reduce vandalism and malicious mischief that will be difficuf t to handle without an on-board operator. The early warning of intrusion on the guideway provided b~" operators will be missing. If vandals discover that system disruption can be caused with ease and with little chance of detection, they will be tempted to harass the system, causing inconvenience and danger to patrons and increasing the cost of operation.

*System Design.*—AGT systems must concentrate design efforts on the passenger-system interface. Automated systems lack flexibility. The variety of information a station attendant or driver can provide will be missing. ***k system*** Complexity increases, the need for better information increases because travel becomes more complicated. While such human factors design is achievable, it should receive priority particularly in light of the failure in this regard at AIRTRANS.

*Elevated Guideways and Stations.-SLT* and GRT systems rely on relatively large and heavy vehicles which impose significant strength requirements on the guideways. Guideway width varies from 8 to 10 feet with significant depth, The guideways must be elevated to provide exclusivity without incurring the cost penalties of underground construction. These guideways and their associated stations will produce a major visual impact. However, they are unlikely to be located in resiiential areas where the most serious objections might be expected.

PRT systems will require much smaller guideways since the vehicles themselves are much smaller and lighter than other AGT systems. However, the advantage of PRT is direct origin to destination service which will require a proliferation of guideways over an urban area. While they may be less intrusive visually than the guideways of the larger AGT classes, their extensiveness may cause similar objections on aesthetic grounds, particularly in residential areas.

These guideways do not have to be obtrusive however. Sound urban design which addresses all facets of the area being served by a new transit system can help improve the environment. Guideways and stations can be incorporated into the cityscape in ways that could help make the area attractive. Reducing dependence on automobiles can eliminate many of their unsightly consequences—street congestion, parking lots, gasoline stations, and air pollution—thus making possible urban life styles with more amenities.

*Pollution and Energy.*—AGT systems are non-polluting in that the vehicles are electrically powered. However; the electricity generating plants will pollute at the source. The pollutlon problems may be accentuated if coal is used as the fuel.

AGT systems are presumed more energy efficient than automobiles and competitive with conventional transit. The use of coal or nuclear power would save scarce petroleum.

To the extent that higher service levels involve increased energy consumption (i.e., fewer patrons per mile or more empty shuttle traffic), savings will be decreased. System construction will also involve energy and pollution costs which have seldom been taken into account in transit or highway construction.

*AGT in Non-passenger Roles.*—AGT systems could be used to move goods and to provide urban services such as trash hauling under some conditions. Whether this is feasible or not should be studied because multipurpose service should be incorporated in earlys stem planning. Experience at AIRTRANS indicates that it may be di cult to achieve muYtipurpose service, and urban environments would seem less suited to AGT systems than special purpose environments like airports.

The above summary 1s by no means complete, but it does indicate the range of important questions of social acceptance for automated systems which must be answered before these systems can be considered market-ready. The breadth of these questions indicates the serious need for research in these areas as well as hardware. Urban demonstration of systems beyond the test track stage is an extremely logical approach to answering these questions.

Finally, an important but frequently overlooked art of urban demonstration and pFarming for transit is the need to develop more community involvement in plaming and to provide for a multi-disciplinary approach to design and im act assessment. Transportation is not an isolated element, the excrusive realm of technical experts, but a basic art of the urban fabric and community life. More efforts are needed to involve local communities in helping to set priorities for research and investment decisions, particularly when so many unknown effects on the total community are involved.

## Chapter 4: Assessment of AGT Research and Development

### THE FEDERAL PROGRAM

The HUD new systems study of urban transportation, submitted to the Congress by the President in 1968, stated that the Federal role should be to address the broad problems of social welfare raised by urban transportation—equal access to service, reduction in urban lad areas consumed, elimination of noise and air pollution, and improved urban mobility. While application of some available technology could help address these problems in urban areas, more intensive, longer-range efforts were considered necessary to develop technology capable of meeting future demands for urban transportation.

1t was apparent that no local public agencies at the time, had the interest, capability or resources to sponsor and manage the research and development pro rams required to bring new transportation systems into being. or did private enterprise have the incentive or the experience to grapple with the complex issues of transit user needs and social costs. Without clearly identifiable market opportunities, large scale private investment in transit research could not be expected. Hence, it was concluded that the Federal Government should assume the role of a "catalyst)' both in stimulating research and development activities and in encouraging implementation of the results of such R & D by state and local governments. This philosophy has formed the basis for the research, development and demonstration programs undertaken by UMTA during the past seven years.

### THE FEDERAL ROLE

In the area of urban mass transportation, the Federal Government is not the final consumer of hardware produced as a result of federally funded R & D programs, as is the case for defense and space hardware. On the contrary, the ultimate recipients of transit equipment are the local public agencies and private organizations providing transportation services, complicating the problems of deciding what R & D programs will contribute the most toward achieving long term transportation goals.

It has been UMTA'S olicy in the past several years to concentrate its R & D effort on hig{ risk areas, on the assumption that private industry will make the required investments for product improvement and pre-production engineering. Thus in the new systems area, which includes Automated Guideway Transit, the emphasis has been placed on the development of increasingly sophisticated systems such as hlorgantown and its successor the "HPPRT" project. Basic problems such as how to design cost effective unobtrusive guideways, how to insure continuous operation in ice and snow, and how to improve the reliability of mechanisms have received little attention. Institutional problems, such as how to implement AGT in the urban environment, have also been neglected.

**FUNDING**

As indicated by the following tabulation, amounts allocated for research and development constitute a small percentage of UMTA'S budget.

[Amounts in millions; fiscal years]

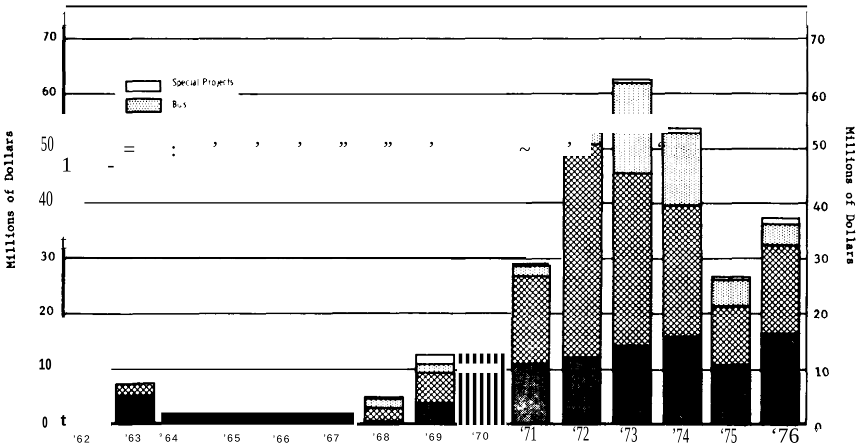
| Research and development | 1974 actual | 1975 estimated | 1976 estimated |
|---|---|---|---|
| Bus transit technology | $13,0 | $4.8 | $3.6 |
| Rail transit | 16.0 | 13.0 | 16.4 |
| New systems and automation,., | 23.4 | 7.9 | 16.0 |
| Special projects | .6 | .8 | 1.0 |
| Total R & D.... | 53.0 | 26.5 | 37.0 |
| Total UMTA funding. | 984.6 | 1,445.5 | 1,724.2 |
| R & D as a percentage of total funding | 5.4 | 1.8 | 2.1 |

By contrast, 10.6 percent of the Department of Defense budget for FY 76 is for R & D activity. Of the total Federal budget, R & D activity comprises 5.7 percent. Thus, in com arisen with other national programs, the current R & D funding leveYin the area of urban mass transportation is modest.

From fiscal year 1962 through fiscal year 1975, nearly $128.5 million has been allocated by UMTA to new systems development, phased over the years as indicated in the figure below.

UMTA R&D FUNDING BY PR06RAM AREA

1962-1976




Source: OM2A Fiscal 1976 Budget Estimates

Of this, a total of $95 million (including $64 million for Morgantown) has been spent on AGT systems development. To put this amount in perspective, $113 million was spent closing out the Supersonic Transport Program in the four years since its cancellation by the Congress.

### INDUSTRY

Of the nine Shuttle-Loop Transit Systems currently serving the public in airports and recreational facihties, only two have benefited from any significant investment of research and development funds from the federal government.

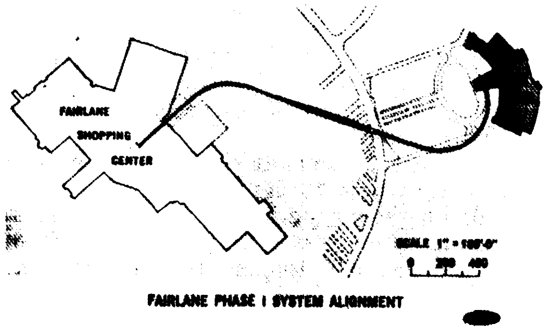
The two Westinghouse systems at the Tampa and Seattle-Tacoma airports can be directly traced to significant government involvement. Westinghouse built on their experience with the Transit Expressway development program which was initiated in 1963 with a two-thirds R & D grant from the Urban Transportation Administration of HUD, the forerunner of UMTA. Westinghouse reports that in the past twelve years they have s ent about $35 million of company funds on the follow-on Transit Expressway development. In addition, the Federal Government and local public agencies in the Pittsburgh area have spent about $7.5 million on this program.

The only GRT system thus far in revenue service is the AIRTRANS system at the Dallas/Fort Worth Airport. The system supplier, LTV Aerospace, entered the AGT field in 1971 after test tracks, funded in part by UMTA, had been built by VARO, Monocab and Dashaveyor. Thus, to all practical purposes, the AIRTRANS system, which was selected on the basis of competitive biddin , did not benefit from any Federal involvement. The system which exists at the airport is essentially the result of industry efforts.

### TRANSPO STIMULATED ACTION BY INDUSTRY

Of the six SLT systems which are now under construction, the two being built by the Ford Motor Company at Fairlane in Dearborn, Michigan, (see illustration, next page) and at Bradley Airport, Hartford, Connecticut, are direct outqowths of the demonstration facility built at Dunes International Awport for Transpo 72. UMTA awarded four contracts to selected system suppliers m amounts of $1.5 million each. Ford and the other manufacturers—Bendix-Dashave or, Rohr-Monocab and Otis-Transportation Technology-contributed substantial com any funds to supplement the federal R & D investment. Thereafter, ! ord built its own test track at Cherry Hill, west of Dearborn, to test and evaluate follow-on designs.

FAIRLANE TOWN CENTER PROJECT, DEARBORN, MICHIGAN

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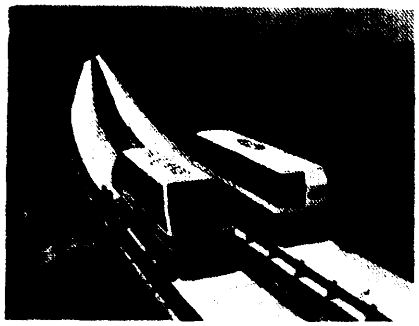


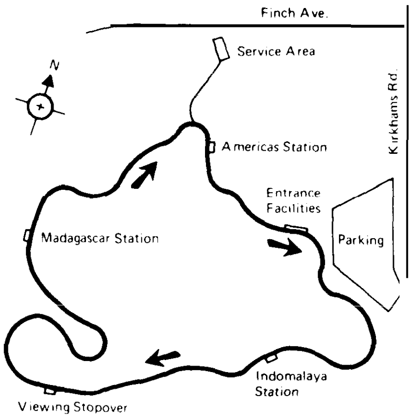
Fairlane and Transpo '72 Prototype
Vehicles on Cherry Hill Test Track

Two of the three other manufacturers that participated in Transpo-72 have also built test tracks near their plant facilities and continued an aggressive development program. Rohr-Monocab has developed a magnetically levitated version (ROMAG) of their suspended monorail system and Otis-Transportation Technology Division is actively advancing its technological capabilities, including evaluation of alternatives to air cushion suspension. Only Bendix-Dashaveyor has decided to withdraw from active competition for the AGT systems market. Before this decision was reached, however, Bendix devoted much effort and in-house funding to improving the hardware system which was demonstrated at Transpo-72. They are currently completing

## TORONTO ZOO ANIMAL DOMAIN RIDE

### Bendix-Dashaveyor

Forty-Passenger Vehicle
Operates on Test Track
at Ann Arbor, Michigan




Three-mile Guideway Layout
Conforms to the Terrain
Within 700-acre Zoological Park

Prototype Vehicle
is Assembled
at Ann Arbor, Michigan

24 vehicles for transport service at the Toronto **Zoo. (See** illustration, page 63.) A guide rides each vehicle to describe the activities of the animals along the way. Because he also doubles as an operator, full automation is not necessary in this system.

## MARKET UNCERTAINTY INHIBITS INITIATIVE

Most of the manufacturers contacted during the course of this assessment reported uncertainty about the market for AGT systems. Whereas there are a number of airports, recreational facilities and commercial centers where SLT systems are being given serious consideration, current prospects for urban application are at best uncertain. There are several reasons for this situation.

- UMTA has thus far given little encouragement to communities interested in applying for capital grants for AGT systems.
- The requirement that the transit mode selected be demonstrated to be the most cost-effective places AGT alternatives at a disadvantage. This is because significant development costs incurred by manufacturers must be spread over the first few rejects.
- Unfavorable publicity on a few conspicuous projects involving automation, notably BART, Morgantown and AIRTRAh~S, has prompted a wait-and-see attitude on the part of potential buyers of Automated Guideway Transit systems.
- R;alistic cost estimates are difficult to make in lixht of the major cost overruns experienced on several project~ Furthermore, no generally accepted formula has been developed to quantify such benefits as lower pollution, less congestion, better service, etc.

The manufacturers which have been active in the development of AGT systems report that they have spent company funds totalling ap~roximately $100 million on R & D thus far, Although muck of this private R & D investment can be attributed to UhITA's spending 'fseed money," most of these companies have indicated a reluctance to invest additional funds on development until the present uncertainties about the potential market are resolved.

### COMMENTARY

Unfortunately, the Federal AGT R & D program to date has not produced the chrect results which could reasonably be expected from an ex enditure of $95 million. One measure of the effectiveness of this 2 & D effort is the number of AGT revenue systems that have ant assistance. On this basis, results have been : : j : : l . c ? i a l he Fransit Expressway Revenue Line has received capital ant fundin for right of way acquisition and engineering design. B owever, enteavors to implement this project in Pittsburgh with federal capital assistance have met with considerable local opposition and the final outcome of these discussions is uncertain.

The Dallas/Ft. Worth Airport also received capital assistance of about $7.5 million for construction of the AIRTRANS system. This installation is having difficulty satisfying airline requirements. In short, despite seven years of effort and the expenditure of $95 million in Federal R & D funds, supplemented by $100 million from private industry, there is at present not one AGT system in revenue service in an urban setting.

To identify some of the factors which have contributed to this lack, it is perhaps advisable to begin by distinguishing basic and applied research. Basic research exists for its own sake, mostly unfettered by considerations of need or application. Applied research is closel~" coupled to development and real-world applications. Although all organizations which do research generally do some of each of these types, an agency can be characterized as primarily supporting basic or primarily supporting applied research. Because UMTA is organized to deal with mass transportation problems, its orientation must necessarily' be to applied research. In developing new urban mass transportation systems and technology, the systems must be evaluated in the urban environment. If they prove effective solutions, some means for fostering their implementation should be found. Thus an important step in the evolution of innovative transit hardware is operational evaluation through real-life demonstrations. It is not enough to build a sophisticated system at a test facility and run the hardware under controlled conditions. Before volume production or large-scale urban deployment are undertaken, an operational demonstration under typical urban conditions is essential, Such a demonstration should evaluate the overall public acceptance of the system and provide for the identification and correction of its faults and shortcomings, It also would serve to reassure city officials and transit operators that the full system will perform as planned.

Besides the lack of attention to urban application, another characteristic of the UMTA program is its orientation toward high technology, new sy'stems. Thus, many socio-economic issues remain unresolved, as do many immediate hardware problems.

It is clear from the above that a number of questions remain to be resolved.

- How much support should UMTA give to urban demonstration of new systems and what should be the source of funds for any support provided (the New Systems R & D Program, Service and Methods Demonstrations, or the capital Facilities and Formula Grants Pro ares)?
- Within the UMTA &# D program, what is the proper mix of (1) high technology, long-range, hardware-oriented work, (2) solution of immediate hardware problems and (3) conduct of studies in such soft areas as public acceptance and cost-benefit analysis?
- What is the relationship between AGT and other solutions to urban transit problem?

To assist in the resolution of these issues, the im lications of some courses of action and some alternatives are indicatef in the remainder of this chapter.

## SCENARIOS FOR DEVELOPING MARKET-READY SYSTEMS

As indicated, there is resently no generally accepted procedure for converting the results o R& D tomarket-ready systems. If it were decided that a major commitment to develop market-ready systems should be made, a number of steps would be required. To illustrate these steps, the time frame and approximate cost, three scenarios are set forth, one for each of the three classes of AGT discussed in this report.

### SCENARIO FOR DEPLOYING SLT SYSTEMS IN URBAN ACTIVITY CENTERS

As has been pointed out, five manufacturers have built SLT systems at 15 locations in the United States. None are in service in urban communities and no clear procedure exists for achieving urban deployment of cost-effective systems. To correct this problem, while at the same time accomplishing product improvement, reduced system costs, and a sufficient number of competitive suppliers, the following steps might be considered.

- In consultation with SLT system owners, manufacturers, urban communities and consultants, UMTA initiates a program of near-term development and product improvement to reduce costs and improve reliability. This development can be accomplished in conjunction with a demonstration installation in an urban activity center.
- Criteria are developed and standards are set by UMTA, possibly supported by APTA, which qualify SLT systems for capital grant funding. These standards would include the extent of operational testing of actual hardware necessary to insure that erformance specifications can be met.
- k conomies in production are achieved through standardization of performance criteria, vehicle sizes (possibly two or three sizes to. suit different applications) and guideway shape.
- Guidehnes are issued covering cost-effectiveness analyses and other procedures which public agencies must follow in justif ying a ca~ltal grant project covering an SLT system.
- Apphcations for capital grants are submitted, processed, and, if found acceptable, approved. Contracts would be awarded, based on competitive bidding, for procurement and installation of SLT systems.

It is estimated that this scenario would require from two to four years and would cost about $10 million. The costs of product engineering, product improvement and tooling would be shared by private industry.

### SCENARIO FOR DEVELOPING AND DEPLOYING GRT SYSTEMS IN METROPOLITAN AREAS

This scenario begins with the technology available from Morgantown and AIRTRANS, and extends the state of the art of GRT systems. For purposes of this example, the UMTA "HPPRT" program is the point of departure.

- Test vehicles, a control system, guideway and supporting facilities are build on a government site as proposed in the "HPPRT" program. A case can be made for continuing more than one candidate system through the prototype testing phase, but this scenario assumes that only one hardware concept will emerge from the proving-ground phase. Parallel urban deployment studies define the control system logic and methodology necessary for simulating an urban installation.
- To determine public acceptance and assess how well GRT meets urban transportation needs. UMTA arranges a demonstration project in a willing city. The site should be one in which planmng suggests a full revenue system could eventually be worthwhile.
- A 100 vehicle demonstration system with 10 to 15 miles of one-way guideway is built with costs shared among participants. The design of the guideway and other fixed facilities would overlap the final phase of prototype testing. Construction would be b~: competitive bidding. The previously selected vehicle suppher would incorporate all changes and improvements resulting from prototype testing in the vehicles supplied. He would serve as demonstration system manager and would be required to use competitive procurement to the maximum extent feasible for all subsystems.
- The demonstration system would be operated for three years with meticulous records kept on all aspects of performance, safety, reliability, maintainability, and costs as well as social consequences. Transit operators, planners, city administrators, legislators, and the general public would be afforded an opportunity to use the s}:stem with thorough records kept of their attitudes towards possible use of the system in their communities.
- At the end of the demonstration, under UMTA'S supervision the system manager incorporates all design changes and improvements into a comprehensive set of performance and system specifications which competent suppliers could respond to. The local public agency could apply to extend the demonstrated s~'stem under provisions of the capital grant program.
- Thereafter, local public agencies could decide whether to apply to install the demonstrated system in their communities under provisions of the UMTA capital grant program.

This scenario will take eight to 10 years to accomplish and is estimated to cost about $150 million to complete. These costs include a two-phase prototype design and test program, an urban demonstration, and preproduction engineering, tooling and product improvement for a revenue installation. Private industry could be expected to share the cost of this work.

### SCENARIO FOR DEVELOPING AND DEPLOYING PRT SYSTEMS IN METROPOLITAN AREAS

This scenario assumes a long-range commitment to PRT with intermediate check points such that development can be stopped if progress slips, costs are drastically overrun, analyses indicate there are no apreciable benefits, or if development does not prove technically feasitle. Based on these assumptions, several scenarios are possible but one approach is outlined below.

. Establish an in-house project team or select a s ~tem development contractor from among the non-hardware, L gh technology organizations to manage the project.

. Conduct two iterative analyses:

Systems analyses to formulate representative networks, estimate performance characteristics, establish ran es of modal sphts, estimate patronage and fare levels, ah conduct sensitivity analysls on hypothetical systems.

Market analyses to estimate potential applications, estimate cost effectiveness, verify usefulness of performance characteristics identified in the systems analysis, and test the hypothetical systems.

- If the prior analyses warrant, proceed with preliminary design studies. These studies would include: alternative methods of suspension, guidance, control and propulsion; evaluation of available components or improvements needed; development of necessary components; synthesis of the best design elements; and preparation of a preliminary systems design.
- Design and develop a prototype system including the vehicles, guideway, stations, controls, and other supporting features;
- On government test facilities, construct a test track with vehicles and su porting features to permit the test, evaluation, redesign, retrozt, and stabilization of the system design;
- Deplo a small demonstration system in an urban area. The proce Jures are comparable to those discussed above for demonstrating a GRT system.

. Estabhsh uidelines and criteria governing both the standardization of PRT system performance and the conditions under which federal financial assistance would be available for revenue installations.

. Process planning and capital grants which meet the guidelines and. are qtherwise eligible. Execute grant contracts for planning, engmeermg and procuring PRT systems.

This scenario could take from 10 to 15 years to complete and is estimated to cost about $250 million.

## ALTERNATIVE INSTITUTIONAL ARRANGEMENTS

The limited accomplishments of government, industry and transit operators since 1968 in devising effective ways to develop and deploy new urban transportation systems su gest that current roles and responsibilities should be reexamined. A ether a government bureaucracy is an appropriate mechanism for achieving improvements in urban mass transportation through innovation is open to question. As has been pointed out, funding for R & D programs has not kept pace with. the growth of UMTA'S resources for capital, operating, and planmng assistance funds. However, even if funding levels for R & D are increased to a level commensurate with the need to develop better solutions, the results will not contribute significantly to urban mobility unless a corresponding effort is made to devise effective means of applying the results of the R &D.

It appears appropriate at this time to reassess the federal role in urban transportation, particularly as regards the development and deployment of AGT systems, To this end, three possible alternative institutional arrangements are proposed for consideration.

## GOVERNMENT CORPORATION

There are at least two relevant examples of government corporations established for conducting R & D and managing the application of results.

In the United States, the Communications Satellite Act of 1962 created a corporation for profit, not an agency of the United States Government, to develop and Implement a commercial communications satellite system. The corporation is authorized to:

- **Plan, initiate, construct, own, manage and operate by itself or in conjunction with foreign governments or business entities a commercial communications satellite system.**
- **Furnish, for hire, channels of communication to United States communications common carriers and to other authorized entities, foreign and domestic.**
- **Own and operate satellite terminal stations when licensed.**
- **Conduct or contract for research and development related to its mission.**
- **Acquire the physical facilities, equipment and devices necessary to its operations? including communications satellites and associated equipment and facilities, whether by construction, purchase, or gift.**
- **Purchase satellite launch and related services from the United States Government.**
- **Contract with authorized users, including the United States Government, for the services of the communications satellite system.**
- **Develop plans for the technical specifications of all elements of the com-**municat~i&s satellite system.

In Canada, the Province of Ontario established the Urban Transportation Development Corporation in 1973. Other provinces and the Canadian federal government are expected to become share holders in this corporation.

The objectives of the Corporation are to:

- Acquire, develop, adapt, use and license patents, inventions, designs and systems for all or any part of transit systems related to pubhc transportation and rights and interests therein or thereto.
- Encourage and assist in the creation, development and diversification of Canadian businesses, resources, properties and research facilities related to public transportation.
- Undertake the design, development, construction, testing, operation, manufacture and sale of all or any part of transit systems related to public transportation.
- Test or operate and provide services and facilities for all or any part of transit systems related to public transportation and in connection therewith build, establish, maintain and operate, in Ontario or elsewhere, alone or in conjunction with others, either on its own behalf or as agent for others, all services and facilities expedient or useful for such purposes, using and adapting any improvement or invention for any means of **public** transportation.
- Manufacture vehicles and control, propulsion and guideway systems and their appurtenances and other instruments and plant used in connection with transit systems related to public transportation as the Corporation may consider advisable and acquire, purchase, sell, license or lease the same and rights relating thereto, and build, establish, construct, acquire, lease, maintain, operate, sell or let all or any part of transit systems related to public transportation in Ontario or elsewhere.
- Carry on any other trade or business that, in the opinion of the Board, can be carried on advantageously by the Corporation in connection with *or* as ancillary to the carrying out of the objectives of the Corporation set out above.

Both of these examples suggest means by which innovative transportation development and deployment could be achieved in the United States. Congressional action could establish a private, for profit corporation to undertake the development and installation of AGT systems.

### TRANSIT DEVELOPMENT CORPORATION

One frequently heard complaint is that the operators, collectively, have had little to say about what research and development is conducted to meet their needs., When originally conceived, the UMTA demonstration program was intend~d to help transit operators experiment with their own ideas of service and equipment improvements. Over the years, demonstrations have largely become structured and directed by the Federal Government.

The Transit Development Corporation (TDC) was established in October, 1972 by the major transit operating agencies of the United States and Canada. TDC is registered as a non-profit, scientific and educational organization whose purpose is to pursue and foster research and development projec.ts relatlve to urban mass transportation systems and the commumtles they serve. TDC'S purpose is also to make its findings and information available to the ~ublic, governmental bodies, and the industry. Specifically, TDC is intended to:

- Focus on the research needs of the industry today to improve reliability and performance of public transport.
- Sponsor research and development of use to the transit operators for public benefit.
- Mobilize the talent in the industry to help conduct and supervise such research and development.
- Develop industry-wide support of such research and development, both directly through financial contributions and indirectly through the furnishing of materials, plant and personnel for research and experimentation.
- Channel and coordinate demands made upon individual pro erties and groups of properties for agency personnel and agency services for research and development activities.
- Insure the dissemination of research and experimental findings and operational experiences among the transit operators, governmental agencies and the public.

The transit operators participating in this corporation are having difficulty financing TDC'S major activities. A recent administrative ruling b-y DOT makes TDC ineligible for sole-source, R & D grant contracts. Reconsideration of this ruling, or identification of other sources of financing, could enable this representative of the transit industry to help develop and implement AGT systems. Procedures used in funding the National Cooperative Highway Research Program or independent research and development under defense and NASA contracts could be considered.

### GOVERNMENT-INDUSTRY CONSORTIUM

While unprecedented in the United States, government-industry consortia are widely used throughout Europe and Japan as a means to accomplish research and development and to penetrate the commercial market. The arrangement has several advantages.

- The best talent of industry specialties can be concentrated on a particular development project.

- Scarce resources, including personnel, capital and facilities, can be conserved by avoiding competition between participants.
- Government expenditures are reduced through cost sharing with inclustry.
- Because the government is a participant, there is mutual interest in commercialization of the product. Both the government and industry stand to get a return on the initial investment.
- To strengthen the price advantage of the consortium in an initial foreign competition, the government can waive the recovery of cost provisions for the industry participants.

These advantages, available to foreign AGT system developers, have placed United States manufacturers at a competitive disadvantage.

The above alternfitive institutional arrangements offer opportunities to improve the efficiency of transit R & D and to accelerate the rate of transit innovation and improvement.

## OTHER TRANSPORTATION ALTERNATIVES

There are other transportation options which are worthy of attention in addition to Automated Guideway Transit but which do not truly fall within the scope of this study. Some of the possible options for solving the variety of problems confronting urban communities, including pollution, congestion, mobility for the disadvantaged and energy conservation, are briefly described below.

### BATTERY POWERED VEHICLES

Several versions of small automobiles powered by rechargeable batteries have been developed in the U.S. and abroad. In Washington, D. C,, the CitiCar is being marketed at a cost of approximately $3,000 for a 2-passenger vehicle which can travel about 4o miles at speeds of 35 miles per hour before requiring a recharge. The cost of electricity for recharging batteries is estimated at less than 1 per mile.

In Monchengladbach, Germany, the transit system uses battery-powered buses. Operating costs are reported comparable to those for diesel engines.

Battery powered vehicles offer several attractive advantages. They do not pollute the atmosphere, they do not consume petroleum fuels, though they would require more nuclear, coal or hydroelectric power sources if used in large numbers. Because of their restricted range and speeds, they are special purpose vehicles, limited to such uses as commuting and short neigborhood trips. This should not present a problem in urban areas where 90% of all trips are less than 10 miles long. However most of them have one serious drawback—the time required to recharge their batteries.

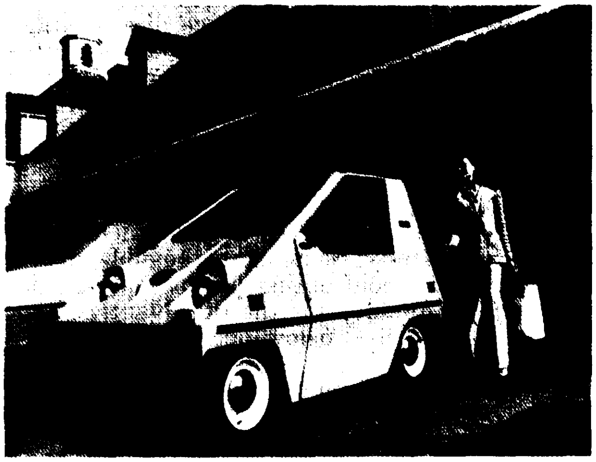
### VEHICLES ADAPTED TO DENSE URBAN AREAS

In addition to energy and pollution, the size of the average automobile causes serious problems both in the form of congestion on the streets and the space required for parking when not in use. Encouraging the use of small vehicles in cities and towns and for commutmg to built up areas from suburbia has been recommended by planners and consultants. The value of land in most urban areas is such that the

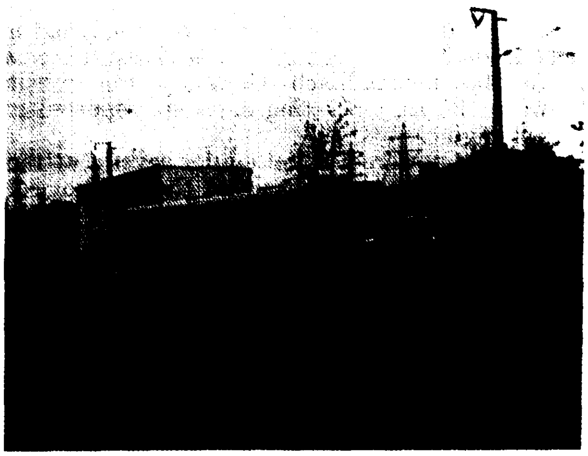
**cost of** structural and underground parking is about $3,5oo and $5,ooo respectively for a standard automobile parking space. Thus, there are significant economic advantages in reducing t e size of vehicles by a factor of 2 or 3. Conversely, the occupants of small vehicles are not as safe as those riding in big cars. Statistics indicate that, in mixed traffic, the risk and seriousness of injury increases as the weight of the vehicle decreases.

For most urban uses, low performance vehicles would be entirely satisfactory. They could use batteries or other low-power propulsion systems.

BATTERY POWERED VEHICLES



**CitiCar Manufactured by Sebring Vanguard, Inc. Sebring, Florida**



**Electric Bus Monchengladbach, Germany**

**(Note the trailer for battery and the recharging station, in background.)**

These vehicles will not fill the role of a family car on long trips. Such a car could be rented, or other forms of transportation used on such occasions. Neither will these small urban cars provide transportation for those who cannot afford or do not care to buy one, or who are unable to drive.

### SPECIAL RENTAL VEHICLES

To obtain better utilization and to minimize storage problems, the rental of special small vehicles has been proposed. A variety of options are available, but essentially the vehicles would be rented by individuals from a private company or public agency for single trips or extended periods of time. Such an arrangement is in operation in Amsterdam, where one may rent at 4¢ per minute, small,! battery-powered vehicles not unlike golf carts, for transportation to various places within the city. Special parking places are set aside for these vehicles at recharging stations near major attractions. By the end of 1975, it is planned to have 15 stations and 125 cars in service.

A similar operation can be visualized as a demonstration in Washington, D. C., for transportation between the many tourist attractions along the Mall and elsewhere in the heart of the city. Remote parking for full-sized family cars could be provided at locations such as RF Stadium and the Pentagon (on weekends). Small vehicle rental and storage facilities available at these locations, selected metro stations, and the Visitor's Center at Union Station could provide a personal transportation service.

### OTHER TRANSIT SERVICE POSSIBILITIES

Among other applications which offer interesting possibilities is the Company Van-Poo!, organized and operated by t! e 3M Corporation in Minneapolis, Minnesota. The company purchased 67 twelve-passenger vans and made them availabre to volunteer employees who drive them to and from work, stopping along the way for door-to-door service for fellow employees. A modest fare is charged, with an incentive arrangement for the driver which permits him to make money if he gets more than eight passengers.

After two years of operation the 3M program is reported to be very successful, averaging about 11 passengers per van. The average round trip is about **50 miles.** Other companies m the Twin Cities area are considering instituting similar service. Among the benefits resulting from such programs are:

- Less congestion on the roads.
- Less gasoline used and less pollution.
- Less employee parking space required.
- Less cost to employees for home to work transportation.
- N. government involvement, but privately financed **transportation with** cost shared by company and employees.

Shared use of taxi cabs also warrants consideration as an alternative for home to work transportation. Because of the cost of downtown parking and the cost of operating private cars, pooled taxi service is becoming increasinly popular, with groups of three or four people arranging to be ic ed up at their homes each morning by the same cab driver. In suburban San Diego, shared rides are subsidized by the cit .

The foregoing is but a partial listing of transportation o options which deserve continuing attention along with Automated Guideway Transit. While this list suggests alternatives to the large, family-owned automobile, it does not adequately address the needs of the transportation disadvantaged. Some modes, notably the private automobile, have created serious problems which command urgent attention.

Better urban mobility is likely only to be achieved through the judicious blending of a broad range of techniques. Conventional modes of transportation no longer adequately satisfy the growing requirements in some commumties. The Federal Government, through a balanced program of R & D and financial assistance, can provide the leadership and the incentive? for innovation needed for improving urban moblhty without adding to the problems created by past solutions.

# Chapter 5: The Fiscal Year 1976 Program—Alternative Courses of Action

The major issues raised in the last chapter provide a frame of reference within which UMTA's FY 1976 budget request for Automated Guideway Transit research and development should be considered. Many of these issues have far reaching implications and are deserving of careful study by the Congress.

This chapter presents four possible alternative courses of action on the FY 76 budget for research and development of Automated Guideway Transit. For each of these alternatives, the points in favor and arguments against are summarized under the headings 'Pro" and "Con". Consequences of each action are also discussed.

## ALTERNATIVE A

Approve the AGT R & D program as submitted. Provide $10 million for the 'High Performance Personal Rapid Transit (HPPRT)" Program and $4 million for the "Automated Guideway Transit Technology" program, which will also receive $4.4 million in reprogrammed or carry-over funds.

### PRO

- The Automated Guideway Transit Technology program will contribute to AGT systems at all three levels o technology: shuttle and loop transit, group transit and personal rapid transit. This program will accomplish needed work on theory; research, development and testing of components and subsystems; and preparation of standards and criteria for system acceptance.
- The "HPPRT" program will push forward the frontiers of technology in AGT. It will continue UMTA's thrust toward the development of automated guideway transit systems at the high-technology end of the spectrum—well beyond the capability of AIRTRANS and Morgantown.
- "HPPRT" will result in a test facility which can be used for further testing and evaluation.
- "HPPRT", through its Urban Deployability Studies, will develop simulations and generate data that, with the actual hardware, will be of assistance to urban communities which are considering or planning advanced GRT systems.
- A modest beginning on PaT concept evaluation will be made.

### CON

- SLT systems receive minimal attention. No actions which would lead to a demonstration of this technology in an urban activity center are indicated.

- It may be too soon to embark on another GRT system development. The results of Morgantown and Dallas-1 Fort Worth are not yet in. Once these results have been thoroughly assessed, a new program could be better structured.
- The three system concepts selected for initial appraisal in Phase I of the “HPPRT” project are very different. It will be most difficult to determine which approach is worthy of full development before actual hardware is built and tested. Also, selection of a single supplier may inhibit multiple source competition for full-scale production if a significant market
- The “HPPRT” project does not address a known requirement for such systems. No urban communities have made plans for highly sophisticated GRT s stems involving 12-passenger ve “c es moving at 3 second i eadways with a 7 to 10 year development lead time.
- The program does not provide for R & D effort in the social and economic areas.
- The AGT program as currently structured does not place sufficient emphasis on such problems common to all systems, such as guideway improvements, passenger safety and security, and door mechanisms.

### CONSEQUENCES

Approval of the program as submitted:

- **Continues the policy of funding R & D for systems of increasing complexity, with emphasis on high technology.**
- **Leaves to private enterprise most of the task of product improvement for short-term and mid-term applications.**
- **Requires continuing appropriations in three subsequent years to complete the “HPPRT” test program and 3 to 6 years thereafter to achieve market-ready status with multiple suppliers.**
- **Leaves unresolved most of the important social and economic considerations bearing on the potential role of PRT.**

### ALTERNATIVE B

**Provide no funds for Automated Guideway Transit Research and** Development. Use carry-over funds for data gathering and analysis.

#### PRO

- Delay in funding R & D starts will allow time to assimilate information on installations already made at Morgantown and Dallas-Fort Worth. Also, more time will be available to review the need for GRT and PRT, including factors affecting social acceptability and economics.
- Industry will not look to UMTA for leadership in R & D and will thus be more inclined to undertake proprietary developments more responsive to the needs of the market place.
- Rejection by t e Congress of proposals to proceed with the development of sophisticated systems will focus the interests of urban communities on conventional transit modes supplemented by shuttle and loop systems which are more nearly available.

CON

- Disapproval of further R & D funding will halt further regress in the United States toward the development and deployment of new urban transportation systems because industry has little incentive to spend its own resources on systems the Federal Government has rejected. State and local governments are not likely to expend resources without Federal participation in such programs.
- The possibility of perfecting a broader range of market-ready SLT systems from experience accumulated to date is diminished.
- Foreign exploitation of any potential United States market is invited with possible effects on balance of payments and United States dependence on foreign technology.

CONSEQUENCES

If no funds are provided, the following results can be expected:

- **The United States will become increasingly dependent on foreign sources for high technology improvements to urban mobility.**
- **Companies which have developed R & D capabilities for AGT systems may abandon this line of business, thus reducing the number of available suppliers and dissipating the expertise they have acquired.**
- **The primary transportation options available to urban communities will remain limited to bus and rail, supplemented by SLT systems.**
- **It will be possible to acquire useful data on the performance of the systems installed at Morjzantown and Dallas. Ft. Worth, if carry over funds are sufficient and are-applied to this purpose.**

ALTERNATIVE C

Approve the level of funding requested by UMTA for AGT, but restructure the program to provide:

| | *A?nount8* |
|---|---|
| "HPPRT": | |
| Continue detailed engineering work by the 3 selected manufacturers | **$3.0** |
| A & E and initial construction on test facility infrastructure and support facilities | **3.0** |
| AGT technology: | |
| Common development requirements, i.e., guideways, doors, brakes, etc | **3.4** |
| SLT—refinements and product improvements to facilitate an urban demonstration | **2.0** |
| GRT—analysis and operation of Morgantown system and surveillance of Airtrans operation | **3.0** |
| PRT—feasibility studies and simulations | *2.0* |
| AGT social and economic studies and analysis | **2.0** |
| Total, including $4.4 million of carryover funds | 18.4 |

PRO

- This restructured program provides improved balance in urban transit research between short-term improvements in capabilities and long range development of innovative new alternatives. It permits a start on the next logical stage in the development of advanced AGT systems, the "HPPRT" project. It recognizes the need for intensive work on social and economic issues which have heretofore been neglected.

- The program provides for follow-on detailed engineering by the three manufacturers selected for the ~'HPPR ' " project. This avoids the necessity to select a sin le concept for further development on the basis of paper stu "es only.
- Allocation of R & D funds to perfecting and monitoring SLT systems will facilitate the deployment of such systems by documenting unproved performance and costs. It. will also encourage supphers stay in business, thus preserving opportunities for competition and more options for urban consideration. Successful initial efforts could lead to a federally funded demonstration project in an urban area.
- Industry should be stimulated to fund product improvement work.
- The benefits of earlier GRT programs are maximized, while the forward momentum of the program is maintained.

**CON**

- The time required to design, build, test and evaluate advanced technology s stems would be stretched out.
- UMTA would r be in the business of financing development and engineering , a responsibility previously allocated to industry.
- SignificantYy increasing the number o[ subjects to be addressed in the AGT R & D program may cause administration and coordination problems.

**CONSEQUENCES**

Redirecting the emphasis to near-term solutions:

- Shifts the balance of new systems R ~ D from exploring distance Possibilities toward exploiting existing technology.
- Involves government in the process of product development which has been considered by UMTA to be the function of industry.
- Delays the possibility of *installing* the more advanced AGT systems in United States cities. In some cases, stretching out the development period may prompt local agencies to abandon such programs.
- *Recognizes the* potential of simpler SLT Systems as useful supplements to conventional transit modes which are currently available.
- Acknowledges that the long range potential of PRT warrants a modest investment of R & D funds for economic studies, market analyses, social acceptability studies and limited operational simulations.

**ALTERNATIVE D**

Increase the scope and funding for AGT R & D as follows:

| | *Amounts in millions* |
|---|---|
| "HPPRT": Detailed engineering and hardware work by the 3 selected manufacturers, plus a start on construction of the test facility | $15.0 |
| AGT technology: | |
| Common development requirements | 5.4 |
| SLT—refinements and product improvements and support of urban demonstration project | 3.0 |
| GRT—analysis and improvement of Morgantown and Airtrans systems | |
| PRT—feasibility and urban deployability studies and simulations | :: : |
| AGT social and economic studies and analysis | 3.0 |
| Total, including $4.4 million of carryover funds | 34+ 4 |

PRO

- Increasing the AGT funding level to $34.4 million, by roviding $30.0 million in new fiiscal Year 1976 funds, wi bring UMTA'S R & D budget to a level more in keeping with other government programs.
- The probabi ity of making a good decision on the selection of a preferred "HPPRT" concept will be improved if it is based on the evaluation of operational hardware rather than paper design concepts, as is currently planned. The three manufacturers selected for Phase I are designing three very different approaches: a suspended monorail with magnetic levitation, an air cushion suspension and linear motor propulsion, and rubber tires with conventional traction motors. Final selection of the concept to be demonstrated in urban use will be difficult even after extensive test track operations.

The increased cost of carrying three hardware concepts through the prototype testing stage can be minimized by the use of common facilities, such as:

A multi- purpose guideway, wayside power supply "and control cabring system to serve the two bottom-supported systems; and

Central control computer, shop and support facilities to serve all three test programs.

- A significant increase in funding for R & D of components and common development requirements, as well as a stepped-u~ effort to learn from the Morgantown and AIRTRANS experiences, will maximize the possibility that AGT systems will become cost-effective alternatives for urban transit.
- Such action will demonstrate interest by the government in finding better ways to provide urban mobility through technological innovation.
- It will stimulate innovation by manufacturers, particularly in the area of product improvements, and will allow industry to plan on a continuing Federal commitment.
- With more money available, it will be appropriate to make a significant start toward determining the technical, operational, and economic feasibility for PRT systems.

**CON**

- Any large increase in funding for AGT systems is inapproriate until the need for such systems has been more clearly established and the national potential market has been assessed.
- Additional time and funds will be required to meet the "HPPRT" program goals through testing three prototype systems. Even with maximum use of common facilities, a total program cost on the order of $5o million (in lieu of UMTA'S estimate of $34.5 million for the current proposal) should be anticipated.
- Management of the "HPPRT" program will be complicated by testing three prototype systems concurrently through the use of common support services.

- **UMTA** may not have the management capacity and organizational structure to handle an expanded R & D program so as to insure that the funds are spent where they will do the most good.
- There **is no point in stepping up** R & D efforts until better procedures are developed to prepare for delivery of the results of R & D to the marketplace.

CONSEQUENCES

**A** significant increase in funds implies the following:

- **There will be a need to continue the significant increase in R & D funding over a period of several years.**
- **A substantial increase in UMTA's R & D program will require a corresponding expansion and improvement of R & D management capability.**
- **An expanded R & D program will increase employment in this business sector and will sustain employment in at least two companies which are likely otherwise to be forced to curtail or abandon this line of business.**
- **Emphasis on SLT and GRT concepts in this program will generate requests for Federal funds to plan and install such systems in urban areas.**
- **Actual installation of systems will be dependent not only on success of R & D but also on linking R & D to capital grant programs.**

# APPENDIX A

# ORGANIZATION AND PROCEDURE FOR CONDUCTING THE ASSESSMENT

# APPENDIX A

## ORGANIZATION AND PROCEDURE FOR CONDUCTING THE ASSESSMENT

### APPROACH

This assessment was conducted by the Office of Technology Assessment (OTA) Transportation Assessments Group. The OTA staff was augmented by two consultants who served as project principals. Mr. Frederick A. F. Cooke was the Program Director and Mr. H, William Merritt was Deputy Program Director. Both have had broad experience with PRT and other forms of Automated Guideway Transit. They were assisted in framing the assessment and directing the Service by Dr. Leon M. Cole of the Library of Congress, Congressional Research

At the outset of the study, the subjects to be examined were grouped in five general categories:

Current Developments in the United States.
Economics.
Social Acceptability.
Operations and Technology.
International Developments.

Detailed topics within each of these categories are listed at the end of this appendix.

Five study panels were organized, one for each of the general areas. Panels were drawn from public transportation agencies, nonprofit organizations and associations, manufacturers, transit planning organizations, educational and research institutions, consulting firms and citizen organizations. A special effort was made to have a variety of points of view represented on each panel, i.e., enthusiasts and skeptics alike. (Brief biographies of panel members are provided at the end of this appendix.)

The work of each panel was organized and directed by its Chairman with the support and assistance of the Program Director. The panels met in Washington several times to discuss findings, issues and conclusions. Each panel chairman submitted a report. Abstracts of the five panel reports are attached as Appendix B.

During the course of this assessment, most of the Federal and local government officials concerned with the planning and implementation of Automated Guideway Transit projects were contacted by members of the study team, as were a majority of the significant s stem suppliers. About 20 members of the team were briefed in detail by UMTA Administrator, Frank C. Herringer and members of his staff. In addition, there have been many separate meetings with UMTA and DOT personnel. Special briefings were made by Dr. J. Edward Anderson, of the University of Minnesota, and Messrs Harry Bernstein and C. L. Olson of the Aerospace Corporation. Members of the team visited the Morgantown project in January and April and the AIRTRANS project at Dallas/Ft. Worth in February.

### DATA BASE

During the course of this assessment, the Program Director, Deputy Program Director, and the Panel Chairmen reviewed numerous reports, studies, professional papers and general material on the subject of Automated Guideway Transit. Additionally, the views of many people of diverse backgrounds were solicited. This material forms the data base for this assessment report. It is maintained on file for ready reference in OTA'S Transportation Assessments Group. The bibliography which is attached as Appendix C lists material of general interest. Eaoh panel report also includes a listing of reference material which is available on file.



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## ACKNOWLEDGEMENTS

This assessment was made possible by the capable and enthusiastic support of the panel members, a majority of whom were made available to OTA at no cost by their parent organizations. In addition to the panel members, many other individuals participated in this effort by attending panel meetings and by preparing thoughtful responses to detailed questions. Specific acknowledgements are contained in the reports prepared by the Panel Chairman.


## TOPICS ASSIGNED TO STUDY PANELS

The following pages outline in greater detail the topics assigned for investigation by each of the five panels:

### 1. CuRRENT DEVELOPMENTS IN THE UNITED STATES

- Identification of strong points as well as deficiencies.
- Levels of reliability which have been achieved.
- Safety record and analysis of causes of major accidents.
- Extent of public acceptance.
- Capital as well as operating and maintenance cost. Effect of varying degrees of system sophistication on such costs.
- How can experience to date be applied to new systems being planned?

### II. ECONOMICS

Cost-benefit analysis of AGT in relation to other transportation modes:

- As an alternative to buses as feeders to conventional rail transit system.
- As a means of linking remote automobile parking facilities with activity centers.
- As circulation systems in congested downtown areas, airports, commercial developments, universities and other major activity centers.
- As a reasonable alternative to the private automobile in urban areas.

Economic aspects of short headway systems, ranging from three seconds to the fractional second headways required to achieve high capacity with very small vehicles:

- Effect of large volume production on vehicle costs,
- Projected guideway network and station costs.
- Effect on capital as well as O & M costs of increasing levels of control sophistication.
- Measures required to achieve required levels of reliability and cost implications.
- Projection of extent to which personalized service can be expected to increase ridership.

### 111. SOCIAL Acceptability

#### Safety and Security

Passenger safety:

- identification of major hazards.
- Evaluation of risks and determination of acceptable probability levels for accidents and injuries.
- Revriew of safety criteria being used as a basis of current designs for adequacy and uniformity.
- Emergency escape and rescue capabilities.

Safety of the general public:

- Review of measures being used to keep people off the guide ways.
- Evaluation of alternatice means of preventing injuries or damage to property resulting from vehicles running off or falling from guideways unto city streets.
- 1s further federal action required to insure that adequate safety measures are uniformly observed?

Passenger security:

- Risks to passengers—especially women traveling alone at night on station platforms and in unattended vehicles.
- Evaluation of alternative techniques to insure security, such as TV n~onitors, emergency communication, roving patrols, etc.
- How can public be convinced that adequate security is being provided?

System security:

- Measures required to minimize opportunities for vandalism rind/or sabotage.
- Equipment design to reduce cost of repair. what further action is indicated?

### Environmental Impacts and Aesthetics

- maximum allowable noise levels both inside and outside vehicles.
- Visual impact of elevated guidewny systems and station structures.
- measures required to insure architectural compatibility with existing surroundings. How can public acceptance be assured?
- Effect on adjacent land values of overhead systems.
- Arc current revulations governing environmental impact studies effective? **Do PRTs** warrant special treatment?

### ~Social Implications

Offsetting economic costs, how can AGT enhance the overall quality of urban life by:

- Reducing air pollution and noise levels?
- Easing traffic congestion and reducing travel and commuting time?
- Providing increased mobility for the disadvantaged, the elderly and the handicapped?

How can these benefits be evaluated or quantified?

To what extent can the social benefits of AGT bc expected to foster public acceptance, i.e. :

- Willingness to approve bond issues to pay for first costs and to cover possible operating~-deficits?
- Reducing reliance on the private automobile?

Under what circumstances can a case be made for providing free PRT service as is universally. accepted in the case of elevators in buildings?

## IV. OPERATIONS AND TECHNOLOGY

### Lev.el of Service

What is the optimum level of service which must be provided if **PRT** is to become a viable alternativ'e to the private automobile?

- How far arc people willing to walk under varying circumstances?
- How long arc they willing to wait?
- How important is travel time in relation to comfort?
- What is the minimum acceptable interval between stops?

Can meaningful conclusions be drawn from actual experience with existing automated \-chicle systems and other transportation modes?

- Are current planning criteria based on fact or theory?

How important is it to provide point-to-point, non-stop service?

- Will ridership fall off as intermediate stops are made and to what extent?

Under what circumstances are people willing to transfer from one vehicle to another enroute?

- To what extent will transfer affect ridership?

### Ride Quality and Comfort

W'hat criteria are being used for acceleration,/deceleration rates, jerk rates, sound levels, smoothness of ride, air conditioning and heating, etc?

- Is there a need to establish uniform criteria for specific types of service?
- To w'hat extent have design objectives been met in existlng systems?
- Can any meaningful conclusions be drawn as to public acceptance of varying level~ of comfort? How rough a ride is acceptable?

How long arc people willing to ride standing versus seated?

- what has been the basis for determining number of seats versus space for standees?
- How much crowding is acceptable and safe?

To achieve an acceptable Ievel of comfort should emphasis be placed on building guideways to precise smoothness and tolerances or on \.chicle suspension systems?

- What conclusion can be drawn from experience to date?
- What further study is indicated?

### Energy Considerations

Energy consumption for varying levels of **service, vehicle** sizes, means of propulsion.

Comparison with amounts of energy consumed by conventional rail systems, buses and automobiles.

Effect on ridership of continuing gasoline price escalation or shortage of supplies.

### Reliability

What reliability criteria have been used to date and what results have been achieved?

- Are uniform criteria being established for similar systems?
- Are criteria consistent with experience with other transportation modes and other industries?

What cost-benefit studies have been made in determining:

Extent to which hi h reliability components are used?

- Use of redundancyf
- providing rapid diagnostic and repair cabilities?

How does reliability affect public acceptance

- What level of occasional breakdown will the public accept willingly?

To what extent does the current state of the art it the degree of complexity and sophistication which can reasonably be incorporated into PRT systems?

What further work needs to be done?

## V. INTERNATIONAL DEVELOPMENTS

Appraisal of PRT developments abroad:

- To what extent has foreign technology advanced beyond ours?
- How are foreign governments stimulating development and fostering export of technology and hardware to the United States and the world at large?
- How successful have foreign companies been in penetrating the United States' market for PRTs? What licensing agreements have been made with United States industry? and
- What can we learn from PRT developments and actual experiences abroad in the areas of technology and public acceptance?

What is the extent of the international market for PRTs?

- What is the competitive posture of the United States engineering and industrial community? and
- What steps are being taken by the United States Government to insure a fair share of foreign projects for United States intereats?

### Future Directions

Does the promise of PRT as a cost effective new mode of transportation warrant a continuing investment of substantial government funds for research development and demonstration, and if so:

- In what areas?
- At what financial levels? and
- On what time schedule?

All Panels considered these questions.

## PROJECT TEAM

The team assembled to conduct this assessment, under the overall direction of Dr. Gretchen S, Kolsrud and V. Rodger Digilio of the Transportation Projects staff of OTA, was composed of the following people:

### ASSEMENT PROGRAM DIRECTION

Frederick A. F. Cooke, Program Director
Consulting Engineer
On Contract with OTA

Since 1968 Mr. Cooke has been active in planning and implementing AGT systems. Earlier he directed highway and semi-metro designs in Europe. As Vice President of the Dashaveyor Company, which became a Bendix subsidiary, he conducted numerous studies of potential applications for innovative systems. He supervised the construction, installation and testing of the Bendix-Dashaveyor TRASPO-72 demonstration at Dulles Airport.

H. Wm. Merritt, Deputy Program Director
Transportation Consultant
On contract with OTA

H. Wm. Merritt directed the Study of New Systems of Urban Transportation for HUD in 1967–1968. Until 1973 he was the Associate Administrator for Research and the Director, Special Projects, in UMTA. Since 1973, he has consulted on urban transportation planning, engineering, and energy conservation. Mr. Merritt chairs a task force of the National Academy of Sciences which publishes a Newsletter on New Concepts of Urban Transportation.

Dr. Leon M. Cole
Congressional Research Service
The Library of Congress
Consultant to OTA

Active in teaching, research and consulting in urban transportation and lanning *for* fifteen years, Dr. Cole was co-author and editor of *Tomorrow's ramporiation: New systern.s for the Urban Future,* published in 1968. As a former commissioner of the Texas Urban Development Commission and chairman of the City of Austin Board of Natural Resources and Environmental Quality, he has helped develop state and local governmental policies in transportation matters as well as Federal legislation. Dr. Cole also serves as a group council member of Transportation Research Board, National Academy of Sciences—National Research Council.

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 Systems* prepared for the Federal government in 1968. He has conducted studies for local and regional transit agencies and for suppliers 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 studies 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 guldeway 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 1971–1972 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

Since 1965, Mr. Lobosco has been responsible for a program directed toward installation and operation of an AGT system serving Newark International Airport and connecting the terminal with a proposed PATH extension. He has super~'ised internal planning and the work of consultants and has negotiated with four potential suppliers regarding all technical and operational features of their proposed systems.

Panel on Economics

Dr. Lyle C. Fitch, Chairman
President, Institute of Public Administration
Washington, D.C.

Lyle C. Fitch is president of the Institute of Public Administration, the nation's oldest nonprofit govrnmental research and consulting organization, He has held numerous municipal, state and federal offices, including City Administrator of New' York City. He holds a Ph.D. in economics from Columbia University and has taught at Columbia, City University of New York, Wesleym Univcrsit}", and clse~~'here. In 1961 he directed a study of federal urban transportation policy, commissioned by HHFA and the Bureau of Public Roads, which provided important inputs to the first federal urban mass transportation act.

Dr. J. Edward Anderson
Regional Transportation District
Denver, Colorado

J. Edward Anderson, PhD, P. E., is a professor of Mechanical Engineering, CTni~.ersit3. of ~~innC?S0t:l, on lea~'c a+ consultant to Regional Transportation I)istric\, I)en\'er, Colorado. IIis ncad('mic expcri('nces includes BSIIE, Iowa State L nit.ersity, 1949; hISNIE, Uni\'crsit~" of Jlinnwotil, **1955; and Phl~, hlassn-chusctts Institute of Technology, 1962. IIc is (3encr:il Chairman of the international Conference on Personal Rapid Transit and Editor,** *Personal Rapid Transit. Personal Rapid Transit II.*

Thomas B. Deen
Vice President
Alan M. Voorhees and Associates, Inc.
McLean, Virginia

Mr. Thomas B. I)eel~ has ser~red as principal-in-charge of comprehensi~'e transit and Urban Transportation Studies in many principle cities of the world including \\':lshington, D. C., Atlanta, Baltimore, Caracas, 1 Ionolulu, and Rio Paulo. He formerly was director of planning for the federal agency which developed plans for the \\'ashington Metro now under construction. His writings ha~'e been published in most of the professional journals in the urban transportation field.

Dr. Paul K. Dygert
Senior Consultant
Peat, IJlarwick, Mitchell & Company
J\rashington, 1). C.

Dr. D?rgert has cngngcd in **teaching, rcse:lrch, and Cons[llting in** transportation economics and financing for a number of J-cars. I{ecentl~' he undertook a financial feasibility anal~"sis for a proposed personal ru])id transit system, and conducted ~ *Study Of L'rban .Vass Transportation Needs and Financing* which the Secretar~' of Transportation transmitted to the Congress in July, 1974. He has also undertaken transportation studies for international, state, and local agencies.

Dr. Aaron J. Gellman
President
Gelhman Research Associates, Inc.
Jenkintown, Pennsylvania

Dr. Gellman, since 1972, has been president of his own research consulting firm and is concurrently an adjunct professor in the Transportation and Regional Science Division of the Wharton School of Business, University of Pennsylvania. Before forming the consulting firm, Dr. Gellman was vice president for planning at the Budd Company, Philadelphia, where he was responsible for all economic planning activties of the company. His formal education took place at the University of Virginia (B.A.- Economics), the University of Chicago (M.B.A.-Transportation) and M.I.T. (Ph. D.-Economics).

Charles Hickox
Director of Ground Transportation Marketing
LTV Aerospace Corporation
Dallas, Texas

Mr. Hickox has been responsible for market planning and development for ground transportation since the inception of his company's commitment to this field of business. He has been closely associated with the development of the AIRTRAN'S system at the Dallas/Ft. Worth Airport and the licensing of this technology in both Japan and France. He has lectured extensively on automated transit.

Douglas B. Lee
Office of Comprehensive Planning
Fairfax County
Fairfax, Virginia

Dr. Lee recently left the University of California, Berkeley, where he was teaching in city planning and conducting research in the comparative costs of urban transportation modes. After spending a year working in Fairfax County's land use planning program, he will join the faculty at the University of Iowa.

Sumner Myers
Director Urban System Studies
Institute of Public Administration
Washington, D.C.

Sumner Myrers, a graduate of M.I.T., is a director of Urban Systems Studies for the Institute of Public Administration in Washington, D.C. and the author of numerous publications on technological innovation and transportation. He was a participant in H.U.D.'s study of transportation technology and an editorial advisor for its final report, *Tomorrow's Transportation: New Systems for the Urban Future.*

Panel on Social Acceptability

Jacquelyn A. Ingersoll, Chairman
Citizen Advisor on Urban and Transportation Planning
St. Louis Park, Minnesota

Mrs. Ingersoll has been very active in civic planning and transportation matters in the Twin Cities for several years. She is past chairman of the St. Louis Park Planning Commission which serves a community of 50,000 people. She also serves as a membcr of the Citizens Advisory. Committee on Transit of the Twin Cities Metropolitan Transit Commission.

Ralph Jackson
Director of Planning
Regional Transportation District
Den\'er, Colorado

Mr. Jackson returned to his home town of Denver in September, 1970 to accept the position as director of planning for the Regional Transportation District (RTD). Previously, he was a senior associate engineer with Barton-Aschman Associates, Inc. of Chicago, where he participated in transit planning and traffic engineering studies in over 20 cities. Prior to his employment at Barton-Aschman Associates, hr. Jackson was a research associate with the Departmemt of Urban Studies, University of Illinois at Chicago.

Alain L. Kornhauser
Assistant Professor of Civil and Geological Engineering
Princeton University
Princeton, N.J.

Professor Kornhauser has taught courses and conducted research on transportation for the past five years, specializing in automated forms of mass transportation. He is co-editor of *Personal Rapid Transit* I and author of journal publications on design of automatic control systems, network design and analysis methodologies, energy impacts and attitudinal considerations in predicting the demand for new technologies.

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Dr. Lay has conducted and supervised the evaluation of a broad range of ground transportation systems as a member of MITRE's consultant systems engineering staff supporting the USDOT Urban Mass Transportation and Federal Rail R,D & Programs. He has directed a recent technology review and an assessment of the state of the art of personal rapid and dual mode transit systems.

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Mr. Schnell has served in this position with APTA for five years and specializes in all of the technical maintenance and operation aspects of urban mass transportation and automobile transportation with the Institute of Traffic Engineers and the Keystone Automobile Club. He has been a county engineer and a township engineer.

Reed H. Winslow
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Mr. Winslow's experience includes twenty years of progressive development in transportation management, planning, and engineering. Under a contract with the Urban Mass Transportation Administration, Mr. Winslow has been involved in research and development projects for demand responsive transportation, bus propulsion systems, methods for granting priority to transit buses in traffic, automatic vehicle location and monitoring systems, urban transportation planning, and software and advanced technology for rapid transit systems.

George V. Wickstrom
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Mr. Wickstrom has been actively engaged in the practice of urban transportation planning for over 20 years. He has served as director of several large-scale urban transportation studies in Philadelphia, Delaware and Washington, D.C. A registered professional engineer, he is also active in transportation research, and has authorized over 20 published articles on land use and traffic planning.

Panel on Operations and Technology

Robert A. Makofski, Chairman
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Mr. Makofski has been involved in the research and development of automated transit systems since 1968. This work has covered a broad spectrum of technology in automated systems with emphasis on the command and control aspects of these systems. He is also a Senior Research Associate of the Center for Metropolitan Planning and Research of the Johns Hopkins University.

Richard H. Donlon
Director of Operations
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Mr. Donlon has 24 years of experience in a wide range of advanced technologies with emphasis on technical program management, engineering and research. He has devoted the last seven years to the development of advanced automated vehicle transit systems. Mr. Donlon was a founder of Transportation Technology, Inc.

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Mr. Jones has been involved in the planning and design of transportation facilities for over 25 years. He serves on the Board of Directors of Northeast Utilities, the State National Bank of Connecticut and the Stamford Area Commerce and Industry Association. He was Chairman of the Committee on New Towns and Urban Development for the Consulting Engineers Council,

Thomas McGean
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Mr. McGean provides technology and system engineering support on a nationwide basis—most recently in studies of transit alternatives for the Twin Cities, Denver and Santa Clara. Prior to joining De Leuw, Cather he was involved in numerous major Federal transportation programs including tracked air cushion vehicle research, the TRANSPO '72 People Movers, Dual-Mode, the Rapid Rail Research Program and the HPPRT program.

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Mr. Phelps is responsible for the management of funded programs and offers technical direction in providing work scope for proposed programs. He was previously with GE where he was Manager of Development Engineering and Systems Engineering. He was responsible for advanced preliminary design and proposal activity on transit and commuter rail car design. He received a BSEE with honors from Lehigh University and is a registered professional engineer.

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Mr. Spinwebber has served as Supervisor of the Ground Transportation Projects Section since 1972. He has a BS Degree from Pennsylvania State University, MS Degree from Stevens Institute of Technology, and is a licensed Professional Engineer and Planner. He is responsible for planning, developing, and implementation of all ground transportation projects for Kennedy and La Guardia Airports, including rail access, bus programs, and automated passenger and baggage handling systems.

Dr. Vukan Vuchic
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Dr. Vuchic holds a diploma from the University of Belgrade, Master's and Ph.D. degrees from the University of California (Berkeley). In addition to his academic work he has been consultant to many firms and to the U.S. Department of Transportation. He has lectured at a number of universities, professional and public forums and published over 30 professional papers here and in Europe. His specialties are urban transportation systems; public transportation; urban and national transportation policy.

Panel on International Developments

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Robert A. 13urco specializes in urban transportation system evaluation, institutional aspects of planning and public policy and technology assessment. In 1971–1972 he assessed innovations in urban transit in Europe, North America, and Japan for OECD. Mr. Burco authored the 1968 SRI report on impacts of future urban transportation systems. He is a member of the OTA Urban Mass Transit Advisory Panel and the NAS Transportation Research Board.

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Mr. Floyd is currently involved in the transfer of European technology and industrial innovations to the United States, specializing in ground transportation. Prior to his association with DGA International in 1969, Mr. Floyd was the director of research project management in the Urban Mass Transportation Administration. In this capacity, he was responsible for the planning and management of research, development and demonstration programs.

Howard R. Ross
Transportation Consultant
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Mr. Ross has worked in the urban transportation field for over ten years, and has specialized in problems of advanced technology systems. Since 1971, he has headed a consulting firm dealing with system design and analysis, technology forecasting, transportation planning, financial studies and economic analyses for urban transit systems. Mr. Ross was a founder of Transportation Technology Incorporated in 1968, and prior to that was at Stanford Research Institute.

# APPENDIX B

# ABSTRACTS OF PANEL REPORTS

## APPENDIX B

# ABSTRACTS OF PANEL REPORTS

### ABSTRACT OF THE REPORT OF THE PANEL ON CURRENT DEVELOPMENTS IN THE UNITED STATES

This report describes the development and current status of Automated Guideway Transit (AGT) systems in the U.S. It is based on information from a wide variety of sources, including the major suppliers of equipment for the 17 AGT systems now being built or in operation in this country and public agencies which are considering future systems.

The anel examined seven questiom+ as follows:

(1) #hy *AGT?* This section is a recitation of the arguments which proponents of AGT systems put forward.

(2) *What distinguishes three AGT system types from one another?* Shuttle-Loop Transit (SLT), Group Rapid Transit (GRT), and Personal Rapid Transit (PRT), are described in terms of their use and particular attributes.

(3) *Who owns AGT?* The 17 existing systems are described in detail. Fifteen of them are SLT systems, representing private investment of $75 million. The other two are GRT systems, representing private investment of about $46 million and federal investment of about $72 million. Of the 17 systems, 10 are in service, one is idle, and six are in advanced stages of construction.

The systems, in general, have operated very safely. There has been one injurious accident in about 150 million passenger trips. The ability of these systems to provide continuous service varies a great deal, depending on the reliability of component hardware and on system layout and vulnerability to complete shut down as a consequence of a single failure.

(4) *Who warks AGT?* This section examines data from studies of possible AGT application in 36 localities. The studies represent perhaps one-third to one-half the planning that has been done on potential deployment of AGT. Four of the studies are for metropolitan networks at a cost of $6.7 billion. Two are for corridor systems in urban areas at a cost of about $250 million. The remaining 30 plans are for business districts, airports, and other major activity centers at costs totaling about $1 billion.

Most of the studies are on simple SLT systems but some include low technology GRT features. Several studies for large, metropolitan systems have considered high technology GRT or PRT systems and then rejected them because of uncertainty about whether certain technical features are sufficiently developed for everyday use, Prospective buyers appear to be more interested in proven systems which could be quickly installed rather than in more sophisticated systems which may require R & D. Thus, prospective buyers seem to have little interest in systems more sophisticated than the low technology GRT level.

(5) *Who supplzes AGTand what are their probknzs?* Six firms in the AGT business have supplied all but one of the 17 AGT systems. A larger number of companies are prepared to sell systems if they can find a market. Reliable estimates su gest that these firms have invested $100 million corporate funds in develo ing GT capability. However, the market has become increasingly uncertain. Jome firms have already discontinued their AGT programs and others are considering similar action.

(6) *What has UMZ'A done?* Federal agencies, mainly the Urban Mass Transportation Administration, have spent more than $100 million on AGT installations and development programs. The two GRT systems—AIRTRANS at the Dallas/Ft. Worth Airport and the Morgantown project—received about 70Y0 of the federal funds. All other A GT efforts, including $10 million spent on demonstration of four systems at Transpo '72, absorbed the remaining 30Y0.

(7) *What actions would encourage greater exploitation of AGT?* The panel sought the views of suppliers on this question and found their responses varied. Recommendations ranged from minimal government involvement to extensive government involvement both in financial support and product control.

The suppliers agreed that UMTA must clarify the level of funding which will be available for capital grants for AGT and the conditions that a supplier must meet to qualify his product for capital funds.

Suppliers also said a clearer definition of the part the federal government intends to play in research and development is needed.

Finally, they asked that the federal government specify what financial aid or assurance of markets it can provide industry in order to encourage investments which, the suppliers say, me necessary to get technically advanced systems into production.

From the information before it, the panel on current developments in the U.S. concludes that UMTA has the authority to establish conditions for the qualification of new products for capital grants and needs only to act, if it chooses to do so. Likewise, the role of UMTA in developing and selecting hardware-systems, subsystems and components—could be redefined by administrative action, backed by the necessary appropriation of funds.

## ABSTRACT OF THE REPORT OF THE PANEL ON INTERNATIONAL DEVELOPMENTS

This report discusses recent international developments in Automated Guideway Transit systems. The research and development efforts underway in Germany, France and Japan on PRT and the institutional arrangements for developing and deploying new systems are highlighted.

The stimulus for automated systems in foreign cities is that these cities adapt poorly to large numbers of automobiles. Some older urban areas have suffered physical, environmental and aesthetic damage from excessive automobile use. As a result, many foreign governments are taking steps to arrest further automobile intrusions.

The remedies include preservation and improvement of traditional transit service including tram and bus lines. In addition, the cities are considering AGT systems where transit service is insufficient or nonexistent. In some cities, these remedies are coupled with the creation of auto-free zones. Only walking and transit are permitted in these zones. Sheffield, England, and Grenoble, France serve as examples.

Lower technology AGT systems have not proliferated in Europe and Japan as fast as they have in the United States. One SLT system is in operation in Paris and one in Japan. Also in Japan, three GRT systems are under construction.

Despite lower levels of application than in the U. S., foreign technical research and development is more ambitious. PRT systems are in prototype testing in Japan, Germany and France. If present plans are followed, they will have surpassed United States technological developments in this field in two to four years.

If PRT systems are of interest to United States cities, this country has three options:

- To begin a catch-up program of research and development.
- To attempt to negotiate cooperative development and licensing agreements with foreign governments or companies.
- To import the technology when it becomes available.

Foreign AGT system development, in general, is proceeding relatively faster than it is domestically, in part, because of official attitudes. In the first place, the purpose of AGT installations overseas is primarily to solve urban transportation problems; not to perform limited, special tasks, as it is in the U.S. In addition, uncertainty about the economics of a system (particularly the high technology systems) is not considered serious enough to halt research and development.

With these attitudes have come institutional advantages to the developers of foreign systems that are not available to U.S. manufacturers:

*France.—A* supplier is selected early in the planning process, He details his design and engineering work for the specific installation, instead of universalizing the product for general sale. He concentrates his efforts, with the cost of competition eliminated. Developers are also advanced "front-end" funds which are paid back from the resulting commercial installations; thus the government also has an incentivre in seeing that the eventual revenue operation is successful.

Germany.-Suppliers arc funded up to 80% of project costs by the Ministry of Research and Technology. The Ministry finances only those projects which industry considers most viable. The 20% industry share is an inducement to build a profitable system, The developer may retain all patents, rights to data and rights for commercial exploitation.

*Japan.—As* in other areas, Japanese transportation development involves cooperative government-industry cartels. Development of the CVS has involved eight industries, partially funded through the Japan Society for the Promotion of

Machine Industry. CVS is managed by a team from the Ministry of International Trade and Industry and the University of Tokyo. The Japanese Dual-Mode Bus Program involves a consortium of 17 industrial parties.

One particular interesting institutional arrangement is the Urban Transportation Development Corporation in Ontario, Canada. The corporation encourages the participation of other provinces and the federal government in its research and development efforts, thereby aggregating a large enough market to undertake large-scale development, license imported technology, and market the various systems. Sales royalties are used to offset costs of the operation.

In conclusion, a review of foreign programs suggests that there are many institutional arrangements which the U.S. might consider in developing and deploying AGT systems. Foreign installations are not as extensive as those in the U. S., but development programs are more ambitious. The status of technology is comparable, at present, but if present plans are successfully completed overseas, foreign technology will surpass that in the U.S. in two to four years.

## ABSTRACT OF THE REPORT OF THE PANEL ON ECONOMICS

This panel examines the reasons for the scanty AGT market that now exists' briefly discusses the probable economics of AGT compared with other transit modes, and recommends an accelerated UMTA research and development program to assess the utility of AGT systems in urban environments.

Properly timed research and development of AGT systems can be expected to yield two results: improved hardware systems and an understanding of the potential of AGT for competing with auto transportation in cities. To the extent that the need for urban arterial highways is reduced, there will be a direct return on the research and development investment. A savings in energy cost over rapid rail will occur if AGT system technology can produce a reduction m the weight of vehicles per passenger. At present AGT hardware is not an improvement over rapid rail with respect to energy cost.

One indication of the size of potential economies of AGT systems lies in the fact that AGT capital costs are projected by UMTA at half the cost of rail transit systems, if both are constructed above ground. More research is needed to test whether the potential AGT cost can be achieved in practice. Research is also needed on the technical and social implications of deploying AGT in already developed areas.

No form of existing transit meets the random access needs of the millions of suburban residents as efficiently as the personal automobile. Once the consumer owns an automobile, use of that auto versus use of mass transit is determined by perceived cost, even though the social costs of urban auto use are undoubtedly much higher.

Therefore, a shift to mass transit could best be achieved by raising the cost of driving a car in congestion-prone areas. Several reputable studies indicate that raising the out-of-pocket costs of auto trips is a more effective method than doing the reverse, that is, lowering transit fares. Political and public opposition, however, have so far made raising auto costs impractical.

The remaining option is to subsidize competing transit modes as heavily as the automobile is being subsidized.

Because of their economic situations, states and localities will not be inclined in the near future to make heavy, additional expenditures for new transit services. If a community or metropolitan area perceives the level of federal transit assistance to be low, the demand for building or improving mass transit will also be slight; the more federal money available, the greater will be the public demand for transit.

The panel finds that the potential benefits nationwide of AGT technology are great enough to justify the high risk investment which AGT research and development will require.

The panel recommends that Federal research and develoment should remain at least as high as five percent of the mass transit budget. In the decade 1963–73, R & D was about seven percent of the total UMTA program; in 1974 the level was about five percent, and in 1975 and 1976 it dropped to about two percent.

R & D programs should include demonstrations of systems in actual USC. Such systems should be built in incremental stages, beginning with small applications of promising technologies and, if these are successful, continuing with progressively larger applications,

The panel recommends that research and development of AGT systems be accclerated so that it does not fall behind in the general UMTA mass transit program and so that the technology can be applied during the period of urban growth expected to end circa 1995.

A critical question is the manpower savings that can be achieved by automation. Depending on the levels of wages and interest rates, the amount that can be economically spent on automation may range up from $100,000 per job saved. However automated systems have yet to demonstrate significant manpower savings in practice. Any savings in operating personnel are largely offset by increased maintenance manpower requirements.

The current UMTA program lacks long-term objectives for AGT. It also lacks hardware specifications and criteria for evaluating AGT systems.

The panel has four major concerns on the current federal AGT research and development program:

- **With regard to the "HPPRT" project, selection of one of three quite different technologies before each is demonstrated could result in selection of a less than optimal technology and prevent development of alternatives.**
- **With regard to the "HPPRT" project, selection of a single company to build the prototype AGT project could reduce future competition** in the transit supply field, because of the enormous competitive advantage of the chosen firm.
- Conduct of research and development without application tends to make R & D a dead-end exercise.
- Use of research and development projects for corporate or government public relations purposes tends to destroy much that could be learned from the projects.

## ABSTRACT OF THE REPORT OF THE PANEL ON SOCIAL ACCEPTABILITY

This report examines potential attitudes of a spectrum of interest groups regarding whether or not to introduce an AGT system in a metropolitan community.

The panel found five areas of significant public concern, summarized as follows:

Quality of service.—The acceptability of transit service is clearly dependent on quality. The level of availability, area coverage, safety and dependability that are proposed for public AGT systems determine, to a large extent, the social acceptability of the systems.

*Relationship to Automobile* Use.—Whether AGT is Derceived as an alternative form of transportation for specialized trips, or perceived as a general transportation system will influence acceptability. The manner in which the relationship between AGT and automobile use either evolves naturally, or is regulated, is of public concern.

Cost.—Present knowledge of cost is inadequate. Construction, operation and maintenance costs for AGT are often generalized and Preliminary. First system **implementation costs and capital and 'operational financing arraangements have received little analysis, though financing will directly affect public acceptance.**

*Aesthetic and Land Value Impact.* The total physical impact of AGT systems, both the appearance and the effect on land values m both business and residential districts, is poorly understood.

Effect on *Development Patterns.* Undoubtedly fixed transit guideways and the travel patterns they create will influence development patterns. However, the extent of influence and the benefits and liabilities which might accompany poorly defined patterns are even less well understood than the four effects already discussed.

The panel makes four recommendations about federal R & D activities:

- Re-evaluate the concept of deriving system performance criteria for PRT directly from the automobile. The current presumption that automated transit must copy the good features of the automobile in order to attract people from their cars may be mistaken. This presumption requires that AGT research and development progress toward pure PRT forms. Instead, the federal government should develop national goals for AGT that match its service characteristics with services not being adequately performed by automobiles. Commuting in critical corridors and access to and circulation within major activity centers are examples.
- initiate a major research effort into the social, political, financial and operational effects of installing AGT systems which are matched with specific, existing transportation needs.
- Establish measures of the benefits and liabilities of AGT to a community so that the value of the system can be weighed by the public during planning stages.

- Develop guidelines for superimposing fixed guideway systems on urban master plans, just as guidelines are developed for adopting major thoroughfare plans or urban development plans and superimposing them on the master plan.

The panel concluded that the general public will support improved transit, particularly as the cost of private transportation rises. The majority of non-transit users, however, are not likely to 'convert to transit without special incentives. If installation of automated transit is accompanied by economic penalties or disincentives to drivers of automobiles, the rising costs could cause this tax-paying majority to balk at transit expenditures, particularly if transit is viewed as "welfare" program. A national commitment to mass transit, the panel concludes, must be accompanied by guarantees of federal financial aid sufficiently large to reassure the local taxpayer that the commitment will be met. Otherwise the taxpayer, who pays added sales tax or whose home is being assessed for the local share of transit projects, will object to the increased taxation.

In conclusion, the panel urges that Federal R & d policy include a program to put several SLT and less sophisticated GRT systems into operation in cities. The panel rejects the contention that SLT and medium- to large-vehicle GRT is ready for use whereVer needed. It is the opinion of the panel that UMTA's present approach neglects the near term need of local communities, and that concentrating solely on the small vehicle GRT type commonly called "HPPRT' will unnecessarily delay putting automated systems into use.

## ABSTRACT OF THE REPORT OF THE PANEL ON OPERATIONS AND TECHNOLOGY

This report describes the technological advances necessary to improve upon present installations or to develop more sophisticated types of Automated Guideway Transit systems. The panel began by identifying potential system applications and then developed technological requirements.

The four unanimous findings of the Panel were as follows:

- The moderate headway Group Rapid Transit concept (headways of 15 seconds or more and \'chicle capacities of 15 passengers or more) can provide a technologically feasible and useful transit service at a capacity between that provided by buses and rail rapid transit. GRT line-haul and collection/distribution services combined with other modes are feasible. The present need is to develop the concept to a fully automated operational status, to improve reliability and performance, and to reduce cost and weight of the vehicles and guideway. A small scale urban installation of an improved system is essential to establish design and performance standards, cost data, and the size of the potential market.
- The development of a technological baseline for the Group Rapid Transit concept should be pursued along with the initial staging of a federally owned test facility. The baseline can be used to: 1) provide data on performance, cost, reliability, and safety; 2) formulate specifications for deployable systems; 3) examine performance and cost trade-offs; and 4) examine options in operational mode. The proposed UMTA "HPPRT" program, with reorientation, could provide this development to support and permit expansion of initial simple deployments of group rapid transit technology. The "HPPRT" test facility can also be employed for continued development and testing of various automated transit systems and their components.
- The case for or against the Personal Rapid Transit system concept has not been adequately established. The panel is skeptical regarding the eventual deployment of these systems because of the long-term development requirements, possible lack of economic viability, and the intrusive nature of the fine-grid network of guideways. How-ever, limited funding is justified to clarify the advantages and disadvantages of the PRT concept.
- Because the requirements for development of new technology are dependent on the application, the federal government should interact more strongly with transit authorities in urban areas to consolidate and to define the public transit needs of these areas and the relationship of automated vehicle transit systems to those needs. This interaction is necessary to identify which AGT systems combined with which other modes will most economically meet transportation needs.

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The panel concluded that certain development requirements are common to all Automated Guideway Transit systems, regardless of type. These include:

*Automation.*— Improvements to performance and reliability of certain critical subsystems such as wayside and vehicle control systems and wayside-to-vehicle communications; development of software techniques to manage vehicle fleets; and development of methods to accommodate failures.

Short headway operation will require improvement in vehicle detection, faster responding equipment, increased accuracy in speed and position control, and development of controlled deceleration profile emergency braking.

*Reliability.*— Improved definition of reliability goals, improvement in reliability of critical subsystems and components, and development of techniques to minimize the time to restore service in the event of failure. Establishment of a reliability data bank is recommended.

*Guideway Cost and* lntrusion.-Guideways represent about one-half the system capital cost which warrants effort to develop procedures, designs, and erection techniques to reduce cost. Improved ride quality standards are also required,

System Integration.—Integration of subsystems is necessary to insure that design objectives are achieved. This process requires computer simulation of systems and testing of subsystems and components.

The panel concluded that certain technological development requirements are specific to the different classes of automated systems, as follows:

Shuttle-Loop Transit.—The technology for this class is essentially developed and available for limited operation in urban areas. Systems still require product improvement and production engineering, especially in reliability.

*Moderate-Headway Group Rapid Transit* (greater than 15 seconds) .—The feasibility of this concept has been demonstrated. Improvement is required in reliability, software development for system management, cost and weight reduction of vehicles and guideway. Vehicle suspension technology trade-offs need to be examined to determine effects on guideway size, cost, foul weather operation, and lateral guidance and switching.

*Short-Headway Group Rapid Transit* (three to 15 seconds).—This class requires a test facility for integrated system prototype testing with specific attention to improving the responsiveness and accuracy of longitudinal control systems and to the development of a controlled deceleration profile emergency braking system. The potential application of this concept including safety and economic features, needs to be clarified.

*Personal Rapid* Transit.—Development requirements for PRT include such initial steps as establishing the basic system goals: performance, cost, reliability, service level and development objectives.

# APPENDIX C

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# APPENDIX C

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# PANEL REPORTS
# ON
# AUTOMATED GUIDEWAY TRANSIT

**IN SUPPORT OF**

~lN ASSESSMENT OF PRT AND
OTHER NEW SYSTEMS

**I.** CURRENT DEVELOPMENTS IN THE UNITED STATES

**11.** INTERNATIONAL D E VLOPMENTS

**III.** ECONOMICS

**IV.** SOCIAL ACCEPTABILITY

V. OPERATIOXS AND TECHNOLOGY

**PREP. ~REI) FOR THE**

**OFFICE OF TECHNOLOGY ASSESSMENT**
**“U.S. CONGRESS**

**,1[’A’E 197.7**

The reports contained in this volume are the work of five panels assembled to compile background material in suport of *Automated Guideeway Transit, An Assessmentt of PRT a* ***Other New*** **Sywstems, prepared by the Office of Technology Assessment.**

**The views presented in the Panel Reports are those of the** panel members, as interpreted by the respective panel chairmen, and do not, **necessarily, reflect the views of the Office of Technology Assessment.**

# REPORT OF THE PANEL ON CURRENT DEVELOPMENTS IN THE UNITED STATES

## Prepared for the Office of Technology Assessment


**PANEL MEMBERS**

Clark Henderson, Chairman

John K. Howell
John R. Jamieson
Thomas A. Lancaster
Roy LobOScO

# 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; elimination of barriers; installation of mechanical aids such as elevators, escalators and conveyors; and the elimination of competition between pedestrians and vehicular traffic. However, 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

[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 c1aimed 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 1GT 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

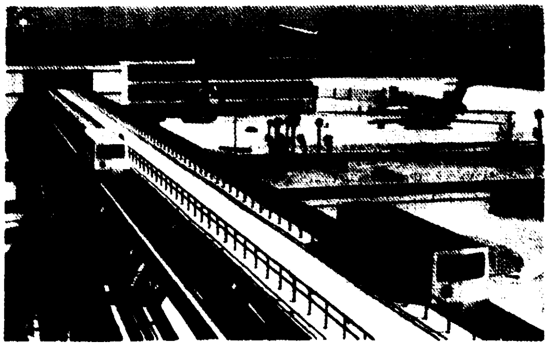
AGT systems can differ from one another in ~ great many ways and any scheme of sub-classification is necessarily somewhat arbitrary.

~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.

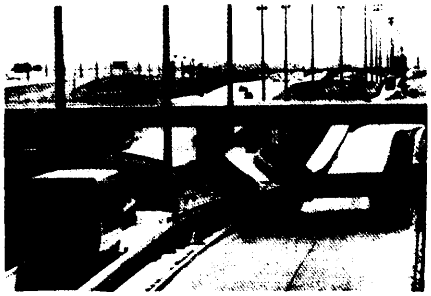
## CLASSESOF \UTOMATED GUIDEWAY TRANSIT

**Shuttle-Loop Transit**

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



Passenger Shuttle-Tampa International Airport



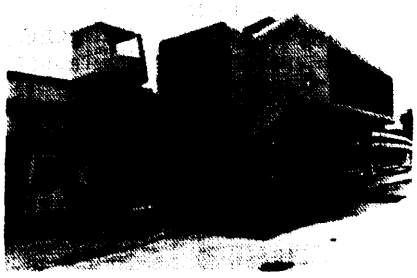
AIRTRANS-Dallas/Fort Worth Airport

**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 we]]. (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 S1.'1' 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[T]. 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.

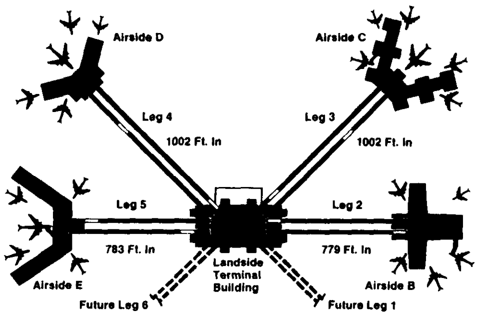
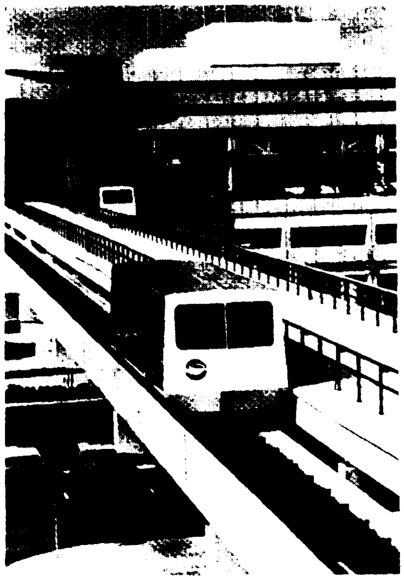



Figure I.—Shuttle System Layout

(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.

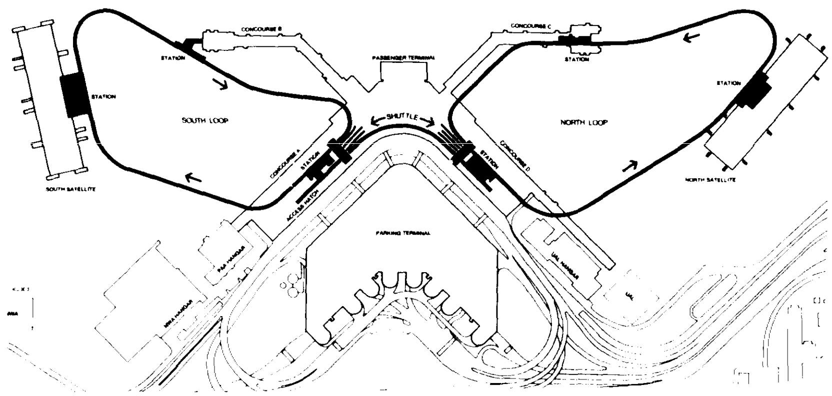



Figure 2.—Sea-Tac Satellite Transit System Layout

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.

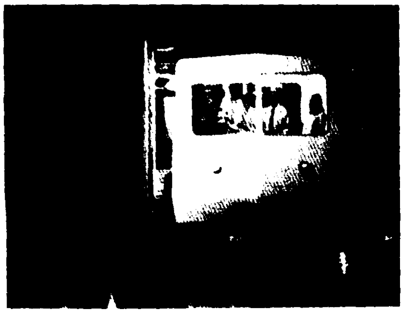
No fare is collected. Patronage has been estimated to be about 6,000,000 riders per ~'ear.

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.

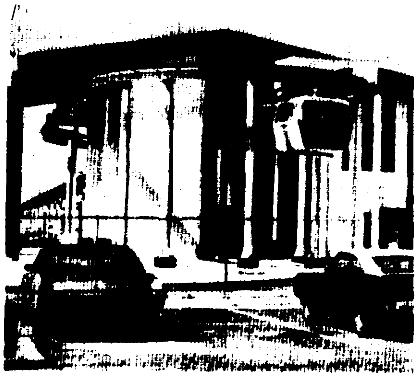
It is estimated that each vehicle will average 47,000 miles of travel per year.



**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.

## hlIAlll 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.

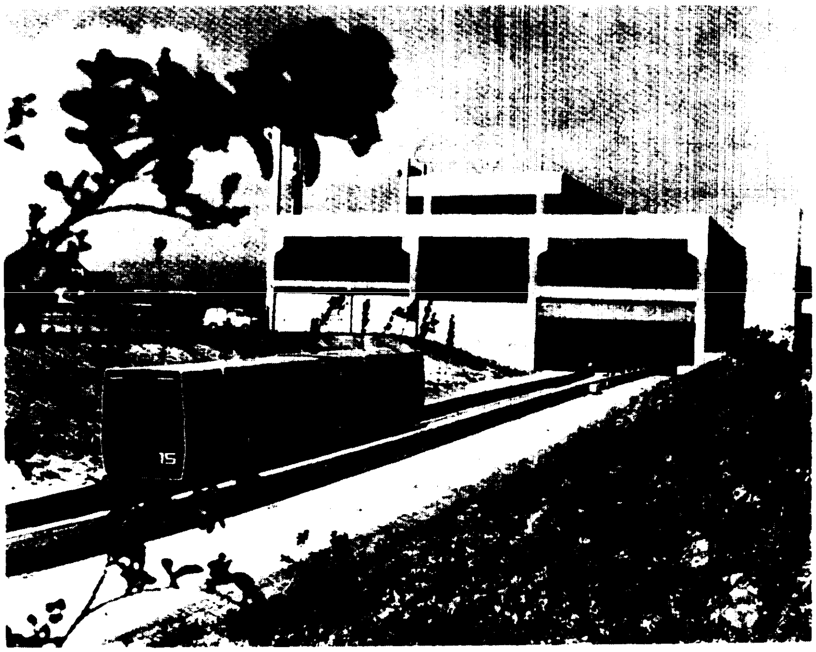
68 vehicles:
- 51 passenger.
- 17 utility.

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

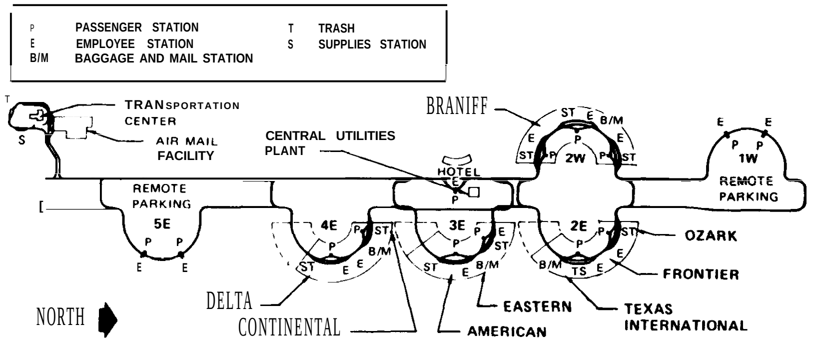
AIRTRANS SYSTEM DALLAS/FT. WORTH AIRPORT

(LTV Aerospace Corporation)

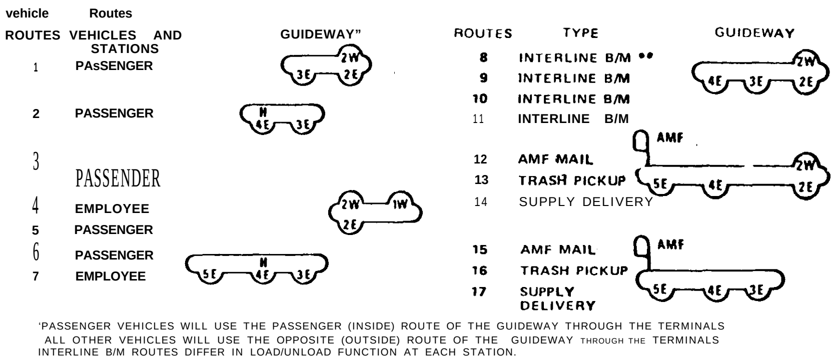



Vehicle Train on Passenger Service Route destination without transfers, in almost all cases, and with few station delays. These technical and operating features make Airtrans outstanding in size and complexity in comparison with all systems discussed above.

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. m 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- |
| 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, til e 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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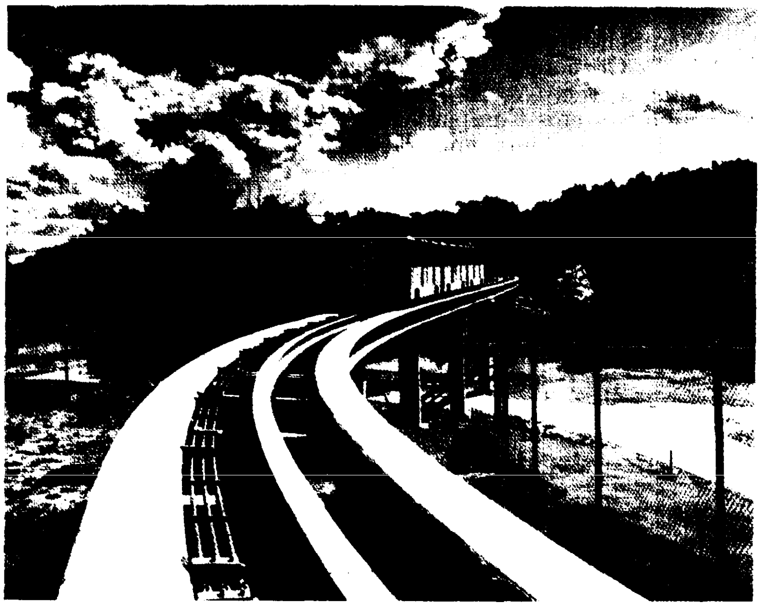
Transit Expressway system at South Park in Allegheny County. That demonstration opened successfully in 1965 and remains intact and operable.

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 online 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.

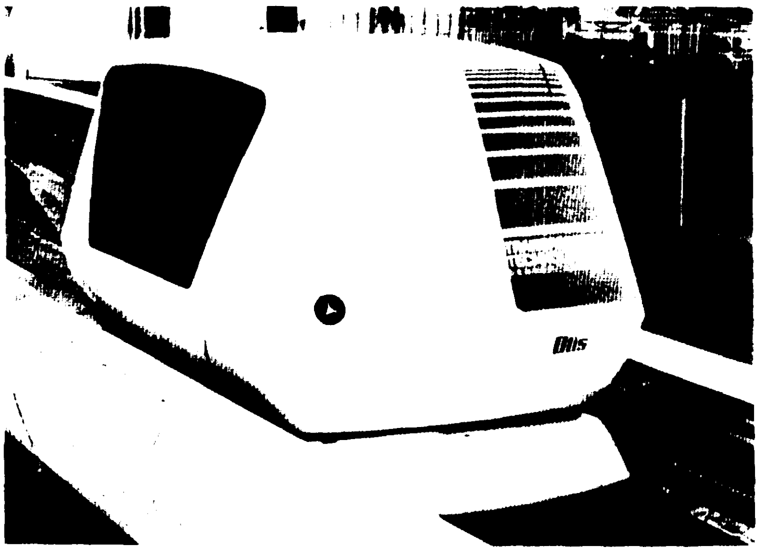
Boeing spokesmen indicate that the firm does not have a clear picture of where the market is going. There is no national policy —no long-term plan or direction. UMTA has confused industry about opportunities. Boeing, like other firms, is always prepared to do work on a cost-plus-fixed-fee basis but does 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 funding 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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# REPORT OF THE PANEL ON INTERNATIONAL DEVELOPMENTS

Prepared for the Office of Technology Assessment


PANEL MEMBERS

H.William Merrit, Chairman

Robert A. Burco
Thomas H. Floyd, Jr.
Howard R. Ross

# CONTENTS

## Introduction

This assessment of international developments in automated guideway transit has been accomplished by:

- First, a panel whose members have visited and studied foreign developments, then discussed and reported on their findings. Biographic sketches of the panel members are included in Appendix A.
- Second, the willing cooperation of officials in foreign governments and industries who have shared their knowledge with the panel. The invaluable contributions from these individuals are acknowledged in Appendix B.

The panel also appreciates the assistance of many others who have contributed to this effort. particularly:

- Mlyron B. Kratzer, Counselor for Scientific and Technological Affairs, U.S. Embassy; Tokyo, Japan.
- Akira Yamashita, CVS International; Boston, Massachusetts.
- R. M. Du Bois, Consultant, LTV Aerospace Corporation; Washington, D.C.
- Donald G. Agger, President, DGA International; Washington, D.C.
- J. Edward Anderson, University of Minnesota; Minneapolis, Minnesota.
- K. P. Fletcher, Transit 70's; St. Paul, Minnesota.
- Steven A. Barsony and Duncan MacKinnon, UMTA-DOT; Washington, D.C.
- Richard F. Daly, Raytheon Company; Lexington, Massachusetts.
- Dr. John Harding and Matthew Guarino, Jr., FRA–DOT; Washington, D.C.
- Niels de Terra, Office of International Affairs, DOT; Washington, D.C.
- Dr. Geurt Hupkes, Vice President, Center for Transportation Planning; Utrecht, The Netherlands.
- Namiki Oka, Chief Transportation Editor, Asahi Shimbun, Tokyo, Japan.

## Chapter 1: History of Foreign Interests

Much of the impeus for foreign development of Automated Guideway Transit (AGT) stems from a study of new transportation systems initiated by the United States Congress in 1966. The resulting report, *Tomorrow's Transportation, New Systems for the Urban Future,* was submitted by. the President, to the Congress in May, 1968. It has been translated into French, German, and Japanese. This report, and the related back-up studies, are generally credited with providing the incentive for developing new transportation systems in those three countries.

Foreign research on the technology that was to become a part of these systems began much earlier. For instance, the Krauss-Maffei work on magnetic attractive levitation began in the early 1960's and was based on research by Professor H. Kemper initiated in 1935. A French engineer, Emile Bachelet, built a small demonstration transport system using magnetic levitation and propulsion in 1912. Serious work on electric linear induction motors for transportation use began with the publication of E. R. Laithwaites' book, *Induction Machines for Special Purposes,* in 1966 at the Imperial College, London.

The combination of technologies into new transportation concepts commenced in earnest in 1968. Tokyo University began planning for the Japanese Computer-controllecl Vehicle System (CVS) in that year. The computer control logic, using a "traffic game", was demonstrated at the World Exposition in Osaka from March to September of 1970. The French government began assisting several private developers in 197. German industry commenced research and development of AGT systems in 197o. The Federal Ministry of Research and Technology has shared in the cost of this development since 1972.

Development of an AGT system in Great Britain preceded the U.S. New Systems Study. Such a system, "Cabtrack," was conceptualized by L. R. Blake of the Brush Electrical Company in 1966. This work was inspired by a trip to the United States where Blake became acquainted with pioneering efforts with the staRRcar, Urbmobile and Teletrans.

Interest in Great Britain was also crystallized with the publication in 1.966 of Brian Richard's book: New *Movements in Cities.*

# Chapter 2: Requirements and Opportunities

The incentive for foreign development of AGT' systems originated from several sources. Cities in Europe and ,Japan have not adapted well to the private automobile. Street congestion has reduced the efficiency and use of trams and buses. The high cost of building and operating heavy rail rapid transit systems has hindered plans for future installations of this mode. These problems, coupled with advantages perceived for AGT systems, have prompted the development of 18 foreign systems and commensurate planning for their installation.

## DEFICIENCIES IN PRESENT TRANSPORTATION SYSTEMS

Most major cities throughout the world are faced with the same general problems: rush-hour street congestion, mass transit overcrowding in peak periods and underutilization during off-peak hours, deteriorating bus service, increasing traffic accidents, noise and air pollution, and continually rising transit costs. The ubiquitous automobile has been at the center of the cause and effect of most these problems.

### PRIVATE .4 ATOMOB1LES

The foreign popularity of private automobiles as preferred personal transportation did not emerge until the 1950's. While owners were were quick to take advantage of new-found mobility, city officials were slow in anticipating the long-range consequences of increased motor vehicle use. The urban form, pattern and size of city- streets in Europe and ,Japan were established long before the advent of motor vehicles. Provision of roads and parking has not kept pace with motorization. In Western Europe, for example, the number of cars per 1,000 persons increased from 68 in 1960 to 174 in 1970. During the same period in Japan, car ownership in increased from five to 85 per 1,000 persons. Adaptation to such increases has been difficult. find in the process has eroded much of what was once described as old world charm".

Ancient buildings have been damaged by passing motor trucks and automobiles-m have been destroyed to make way-for roads and parking structures. The automobile population in Paris covers more area than till her road surface, thus, the tree-lined medians and sidewalks become parking lots at night. The din of automobile horns in Paris has been quieted in recent years by- strictly enforced codes. The high level of traffic accidents are universally cited as a major urban problem to be addressed by new transit systems. Injury accidents per 100-million vehicle-kilometers in 1970 were 126 in France, 139 in West Germany and 390 in Japan in 1969. Automobile air pollution is regarded as the cause of extensive illness among school children in Tokyo. Chronic traffic jams and limited parking spaces have reduced the usefulness of private automobiles for transportation in major Japanese cities. Recent advertising campaigns by automobile agencies in Japan stress the comfort, air conditioning and entertainment within the private space of an automobile, but not the convenience of trip taking. These problems and the related environmental deterioration have caused serious social and political problems.

on the other hand, motor vehicles have provided a range of independent mobility and service unknown previously'. In England, the limited degree of private car ownership now (3.6 persons per car) and in the future is a major reason for the need of public transport. Yet, the present level of car ownership is the major cause of traffic congestion and reduced efficiency oF public transport, The increasing dependence on automobile transportation in Germany is shown by the following:

. In 1950, travel amounted to a little more than one trip per person per day and 70 percent of this travel was by public transit.
. By 1970, travel doubled to nearly two trips per person per day, with 75 percent by private automobile and only 25 percent by public transit.

Freight movement also depends heavily upon motor carriers. For example, in Japan in 1973, 93.6 percent of all freight was moved by motor vehicles. In Japanese urban areas, 50 percent of all traffic is truck movement. Delivery trucks and service vehicles are a major source of street congestion, but functions performed by these vehicles are not performed by public transportation systems.

Greater reliance on motor vehicles for private transportation has affected public transportation in two ways. First, the increased amount of urban travel performed in private automobiles has diverted transit patrons. Private automobiles enabled large sections of the population to move to the fringes of cities where thinl~' populated areas could not be served by mass transit. As a consequence, public transport has suffered a proportionate and absolute decline in usage. The following German experience illustrates the loss of attractiveness in spite of reliable service and good networks:

Transit supply capcity increased from 9.5 million passenger-km per day ii 1960 to nearly 15 million passenger-km per day in 1970.
. During this same period, the load factor dropped from 32 to 17 percent.

,Second, street congestion has reduced running speeds and has made accurate scheduling for surface transit impossible. For example, in West Germany 80 percent of urban public transportation is provided by buses and trams which operate in the same space as private automobiles and motor trucks. Typical traffic speeds averge 28 km/hr (17 mph). The average speed of a Paris bus declined from 15 km/hr (9 mph) in 1959 to 9.5 km/hr (5.7 mph) in 1968. The decline in use and usefulness of public transit has forced operators to curtail services and raise fares (or obtain larger subsidies).

In addition to the impact of the private automobile discussed above, other deficiencies in present transportation systems have prompted the development of automated guideway systems. Some of these other deficiencies are discussed below.

## BUSES

Except for taxicabs, buses are the most labor intensive form of public transportation. Between 70 and 80 percent of bus system operating costs are for labor. Escalating personnel expenses result in higher fares or larger subsidies and add to the general inflation. In recent years, transit operators have had difficulty recruiting and retaining staff. For example, in recent years as much as 20 to 30 percent of London Transport equipment has been out of service during peak hours due to the lack of operating personnel. This situation is being corrected through an aggressive job enhancement program, a wage increase and the depressed state of other employment opportunities. Nevertheless, there is less willingness to work the awkward times necessary to keep a public service operating 18 hours a day.

Buses operating on exclusive rights of way or on priority lanes have been successful in attracting and increasing ridership. Dial-a-Bus systems have also filled a gap in public transportation services. However, initial experiments with these systems have found that the~ are expensive to operate. A demonstration project in North Toronto was discontinued after six months, even though one-third of the patrons were automobile users who previously. did not use transit. More research and experimentation is needed on exclusive and demand responsive bus services in order to successfully tailor their use to specific community. needs.

## LIGHT RAIL TRANSIT

Of the conventional public transportation modes, light rail transit (LRT) offers the service characteristics which most closely approximate SLT and GRT systems. Nevertheless, LRT also has deficiencies which justify a search for improved alternatives.

LRT, or trams, running on city streets are subjected to delays from traffic congestion, as discussed above. Left turns at busy intersections contribute to the congestion. Patrons crossing streets to and from loading points are subjected to traffic hazards. Dedicated rights of ways can avoid some of these problems, can be made attractive, and are thus more acceptable to the neighborhoods they traverse.

LRT is labor intensive, though not as much so as bus transit. A typical 4-axle tram can seat 32 and has a total capacity of 110 with standees. For a 6-axle LRT, these capacities become 43 and 158 respectively. Thus, the passenger-driver ratio is about twice that of a bus. New articulated, three-car vehicles can provide 94 seats and a total capacity of 254. The addition of an unmanned, non-powered trailer (as used in Hong Kong) can add 150 to the capacity. At 400 passengers per operator, the tram becomes one-fifth as labor intensive as a bus.

LRT is also subject to the same labor problems as other conventional modes. Split shifts, double shifts or overtime are necessary to cover the morning and evening peaks. LRT does have the advantage of being able to add equipment, without necessarily adding operators, to meet peak-hour demands.

Other objections to LRT include the obtrusive overhead catenaries for power. A third rail on dedicated rights of way can remove this objection, but a trough for power collection on city streets (once used in Washington, D. C.) presents formidable maintenance problems. Noise and limited ability to climb grades are also cited as disadvantages.

The deficiencies discussed above are generally regarded as the reasons for shifting to other forms of public transportation. All but three tramways have been abandoned in France. There is a resurgence of interest throughout the world in LRT, particularly where tramways or other rights of way exist. On a trip to four European countries m January, one panel correspondent visited 32 cities where light rail or pre-metro systems are being upgraded or extended. Even where totally new systems are contemplated, LRT is being evaluated as one alternative to new forms of automated guideway transit.

Proponents of LRT contend that research and development on this form of transit could bring significant advances in performance. It has been suggested that LRT could be fully automated for segregated routes. Vehicles could be made smaller for higher frequency routes when automation becomes operational. R & D could help reduce the costs of construction and operation. Reductions in vehicle weight would lower energy consumption, noise and vehicle costs. The result of this R & D would be a public transit system comparable to the SLT and GRT systems being assessed by this report. Only a semantic difference would remain.

## RAIL RAPID TRANSIT

Heavy rail rapid transit systems, such as the London Underground, do not provide the fine mesh transport offered by bus systems. Access time to the system is relatively long. Underground stations are costly to build and are widely spaced. Such systems are appropriate for long trips where the volume of travel along the corridor warrants the investment.

Service attributes of rail rapid transit systems, while tolerated, are not considered ideal. Use requires time-table dependent waiting or rushing. Entry and exit to and from stations and vehicles may be uncomfortable or impossible for many. Long intervals between runs, especially during off-peak hours and standing in crowded vehicles during peak hours discourages use. Tokyo's railroad and subway net.-work is one of the most extensive and modern in the world. Seventeen railroad companies operate 35 passenger lines with a total length of 832 km (520 miles) in the greater Metropolitan Tokyo region, and seven lines of subway with a total length of 155 km (97 miles). Railroads and subways account for 20.4 million passenger trips each day, or over 59 percent of all passenger trips made within 50 km (23.5 miles) of the city center.

Despite the extensiveness of the network, it lacks the capacity to handle rush hour demands. on almost all the lines during the morning rush hours, trains are overcrowded to 2.5 times normal capacity. Passengers are so tightly squeezed together that injuries are not uncommon. Railroads hire college students as '(pushers') and "pullers" to get people on or off the trains.

Efforts to meet the growing demand include such measures as: increasing the length of the trains, combining different suburban railroad lines to and from downtown points, adding additional tracks to existing lines, and improving old and adding new subway lines downtown. Three measures are hampered by the cost of underground construction and by the lack of space for extending station platforms or building new subways.

The high construction and operating costs, the space constraints and undesirable service features of heavy rail rapid transit systems are cited as justification for pursuing an automated guideway transit alternative.

## DESIRED AUTOMATED GUIDEWAY TRANSIT CHARACTERISTICS

To overcome the deficiencies cited above, and to improve the supply of public transportation serves, government agencies and private sYstem (developers nave postulated the characteristics desired in an AGT system. These features constitute the goals on which system developments are focused. They are also the basis for planning future installations.

**The** characteristics summarized below represent a cross-section of the expectation expressed in correspondence from officials in government agencies and industrial firms in Canada, Great Britain, France, West Germany, and Japan.

### FLEXIBILITY

Service which is more responsive to the needs of the traveler is envisaged. Departure from limited routes and fixed schedules is the aim. Sufficient capacity to meet peak-hour demands, perhaps with scheduled operations, but on-call service during off-peak hours would best accommodate travel needs. Automation would permit vehicles to be coupled into trains to vary capacity for peak demands without a one-to-one increase in operating personnel, Automation would also enable service to be extended at nights, on holidays and weekends at times when manned service is infeasible. Flexibility in choice of times for departure and arrival should compare favorably with a private automobile. Flexibility also implies the capability to build the system in useful increments so that it can be extended and upgraded without, major changes in the basic technology.

### CONVENIENCE

Finer networks of lines with stations spaced closer than rail rapid transit systems would shorten walking distances. off-line stations would permit station spacing from 100 to 350 km (300 to 1,000 ft) without reducing on-line speeds. A network of lines would reduce the need for transfers, reduce the capacity required on individual links and enhance the capability to provide “door-to-door” service.

Such convenience requires exclusive guideways, segregated from other traffic. Guideways must be unobtrusive and with tight turn radii (1 O meters, 33 feet) in order to follow existing street patterns.

Stations should be designed to facilitate transfers. If designed well as part of an urban complex, stations could make transfers an enjoyable part of the trip.

Convenience implies individual usage, or a choice of riding with a roup having the same origin and destination. Direct travel is the aim, But economies and site-specific situations may require transfers or intermediate stops enroute. Convenience also implies minimum overall travel time by providing:

- Short access time by means of convenient stations.
- Short waiting time with frequent service.
- Direct service with few intermediate stops, operating flexibility, and combined services which are responsive to variations in demand.
- Short transfer times where required through frequent service and integration with other modes.
- A high level of service 24 hours a day.

To make travel times comparable to average street traffic, vehicle speeds should be a minimum of 28 km/h (17 mph). To minimize travel times on long trips, top speeds of 60 to 80 km/h (36 to 48 mph) are contemplated.

## CAPACITY

AGT systems are needed to fill the gap in capacity between typical bus or tram operations and rail rapid transit services. Intermediate capacities in the range of 2,000, to 30,000 passengers per hour per direction are required. These capacities can be provided by a combination of vehicle sizes and headways. These factors could range from vehicles with 100 passengers and one-minute or more headways, six to 50 passengers and three to 50-seconds headways, down to two or three- passenger cars traveling at headways less than three seconds. The o jectives of greater flexibility and convenience are better satisfied with smaller vehicles and shorter headways. Capacity implies the capability to satisfy peak demands while adapting to daily fluctuations in requirements.

## RELIABILITY

Technical components and system integration should achieve a high degree of reliability with operating and maintenance procedures requiring only normal skills. Reliability to the patron means service dependability which would be achieved by adherence to schedules or quick response to on-demand calls. The patron must have confidence in the systems' ability to provide a vehicle that will take him to his destination within reasonable travel times. The system must continue to function, insofar as possible, while observing safety criteria, in the event of breakdowns in the lines, vehicles, automation components, or from congestion in the system.

## ENVIRONMENTAL

To minimize the neighborhood impacts, an AGT system should function at the least possible levels of noise and vibration. Direct and indirect air pollution should be minimized. Conflicts with surface movements of vehicles and pedestrians should be avoided in order to improve safety and traffic flow. Land taking should be minimal. Guideways and stations should not intrude or create community barriers. Rather, they should contribute to good urban design by providing relatively low-cost opportunities for physical integration into the architecture of major centers of activity. AGT systems should complement other transport systems and services and should be in accord with related urban functions,

### IMPLEMENTATION

Capital investments should be acceptable in terms of the service, direct and indirect benefits expected. Advantage should be taken of small, lighter vehicles and guideways in determining capital costs. Running costs for personnel, energy and operating materials as well as the interest and depreciation on investment over the life of the system should compare favorable with alternative systems. Expectations are that fully automatic operations and lower maintenance costs will make AGT systems more economically attractive than comparable investments in conventional systems.

### OTHER

The desired characteristics described above are expected to be achieved with a comfortable ride and no compromise in safety. Furthermore, investment in the infrastructure for an AGT system warmths consideration of its use for goods movement in appropriate settings.

### PERCEIVED ADVANTAGES AND OPPORTUNITIES

Achievement of the characteristics described above offer many opportunities for alternative solutions to urban problems. Public transportation is recognized for its key role in urban development and the opportunities it holds for arresting some of the problems created by private automobiles. AGT systems are perceived as advantageous by enhancing the role of public transportation in improving the environment, reducing air pollution, easing traffic congestion, and filling a gap in the demand for urban mobility with a more rational use of petroleum fuels.

Sponsors perceived that AGT sy:stems allow additional intermediate transit capacity to be introduced into existing cities with a minimum of disruption. Smaller ph~'sical dimensions present opportunities for lower capital costs and easier insertion into urban space. Line capacities could be increased in a small cross-sectional area in congested urban situations. Segregated tracks, above ground or tunneled, should be less expensive than rail rapid transit tracks.

Automation is perceived as an opportunity to provide more frequentl, responsive service. Achieving full automation introduces the opportunity to curb rising costs entirely controlled by escalating labor costs. By the same token, AGT offers a public transport solution which avoids the necessity for working large numbers of people at unsocial hours. Dependability' is enhanced by eliminating potential labor conflicts. Thus, there is an opportunity to provide public transport in an acceptable form, under particular circumstances, at all hours of the dav or night. In such a situation, traffic restraints on private automobiles could become more accetable.

AGT is expected to achieve t e same transport effectiveness at 50 percent of the cost of highway technology. At intermediate capacities, AGT systems have the opportunity to provide transit service in average cities where demands do not warrant heavy rail rapid transit installations. In this regard, AGT is perceived as an agent for renewin interest in public mass transportation.

P lanning for AGT system installations in Europe and Japan is primarily concerned with the following opportunities:

- In heavily traveled corridors, AGT systems would augment existing modes—subways, streetcars, buses—to relieve the ressures and improve services.
- Fn less dense areas, AGT networks would be complemented by bus service.
- In new towns and limited small areas. AGT svstems would provide general service and feeders to ‘and from subway and railroad stations.

Transportation technology, represented by the new AGT systems can be active or passive, it can be used or not. Only if developed and deployed will there be an opportunity to assess the usefulness of these concepts in overcoming the deficiencies in present transportation systems and achieving the expected advantages.

## Chapter 3: Status of Foreign Systems

Foreign development of AGT systems commenced later than U.S. development. This lag, a more deliberate planning pace and the smaller economic base available in other countries, have resulted in fewer foreign installations. This chapter presents the status of implementing AGT systems. First, the systems in operation are described, then those under construction. Planning for one system progressed to the point that construction bids were invited, but never awarded. Finally, the status of planned installations is discussed. A more detailed technical discussion of the systems is provided in Chapter 4. Enough description is included here to depict the complexity of the installations.

### OPERATIONAL SYSTEMS

Only two operational systems of any significance have been installed—one in Japan and one in France.

#### YATSU AMUSEMENT PARK, CHIBA PREFECTURE, JAPAN

This installation is a prototype for the system described as the "Vehicle of a New Age" (VONA). A single loop, 400m (1312 ft.) long, with two, 30-passenger, vehicles and one terminal station platform comprise the installation. The vehicles operate automatically, on two-minute headways, without an attendant on the vehicle. Vehicles are designed to travel at a maximum speed of 60 km/hr (36 mph). They do not stop at the station but slow down to 2 km/hr (1.2 mph). The outer ring of the station datform rotates at 2 km/hr to effect loading and unloading.

VONA

The VONA system was developed by Mitsui Trading Company and Nippon Sharo Seizo Kaisha, Ltd. The installation at Yatsu was purchased by the Keisei Electric Company, Ltd. in 1973. No other reformation is available on costs or operations.

## PARIS, FRANCE

A prototype installation of a VEC system has been in operation since June, 1974. The installation, 300 meters long, connects a large Paris department store, F. N.A.C., to its remote parking garage in the Montparnasse area. Technical problems have temporarily halted operations.

The system uses two-p assenger vehicles with seats facing outboard. Vehicles normally travel at 1o–2o mph on steel wheels supported by tubular rails. A conveyor belt, propelled by linear induction motors, drives the vehicles. In stations, the vehicles are slowed to about 1 ft/sec or stopped for loading and unloading.

## SYSTEMS UNDER CONSTRUCTION

Five AGT systems are under construction—two in Okinawa, one in Nagoya, Ja an, one in Kita-Kyushu, Japan, and one in Toronto, Canada. The Canadian installation has experienced a set-back which is discussed below.

## OKINAWA

Two AGT systems are under construction as part of the International Ocean exposition to be held in Okinawa starting in July, 1975. One is a GRT system, as defined elsewhere in this study. The other combines the features of a GRT and a personal dual-mode vehicle system.

Kobe *Rapid Transit* (KRT).—This system uses essential the Boeing Morgantown vehicle under licensing agreements with ~obe Steel, Ltd., and the Nisho Iwai Trading Company. Boeing is su~pl ing the control system; all other subsystems are being fabricated mi apan.

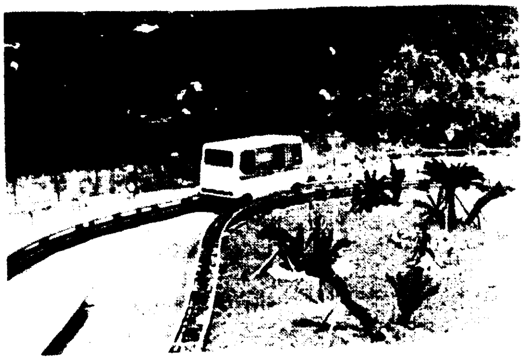
Construction of the KRT system began in November 1974 and is to be complete by July 1975. The overall length of the guideway is 2.8 km (1.75 miles) with three stations. The system will use 16 vehicles, with a capacity for ei ht sitting and 13 standing. The vehicles will travel at top speeds of 30 mph at 15 second headways. The system will include three stations—two on-line terminals and one off-line station. Switching will be demonstrated at the off-line station.

*Duul-Mode Vehicle System*.—This system, also called CVS, is based on the conce ts being developed at the MITI test track at Higashimurayama. ?)f the original consortium only Mitsubishi Heavy Industmes and Nippon Steel Corporation are Involved in the Okinawa installation.

The system will use 15 PRT-type vehicles and three dual-mode vehicles. The latter will be capable of automated operation on the guideway and manual operation when driven off the guideway. The guideway length is about 1.2 miles with a figure-of-eight configuration at one end. Vehicle speeds will average **20** km/hr (12 mph) at headways of about 13 seconds. Operations will be scheduled rather than on-demand. Five off-line stations will be included in the facilities. As with CVS, the Okinawa vehicles will seat four persons. Other features are quite different: the control system has been simplified to a single computer, the guideway and station designs are less complex, speeds and headways are slower.

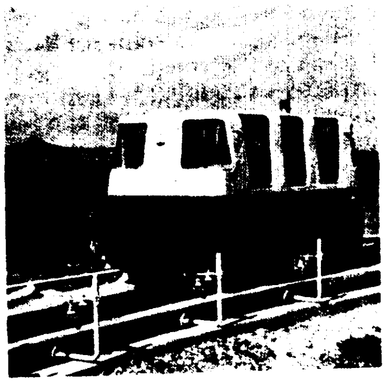
INTERNATIONAL OCEAN EXPOSITION OKINAWA

Kobe Rapid Transit (KRT)
Built by Kobe Steel, Ltd.
in cooperation with
Boeing Aerospace Co.



CVS Dual-mode Vehicle
Is Driven Manually
on the Road . . .


. . . or Controlled
Automatically on the Guideway



## KOMAKI, NAGOYA PREFECTURE, JAPAN

In 1974 construction started on a GRT system connecting a newly developed residential town to a neighboring interurban railway station. This system will be 7.7 km (4.6 miles) long and is expected to cost $44.6-million. The system is planned to carry 40,500 passengers per day by 1985. Most of the trips are for work and school.

## KITA-KYUSHU, JAPAN

This system, also started in 1974, uses a monorail guide beam. The system, 8.8 km (5.3 miles) long, connects the central business district with a suburban residential area. The installation is expected to cost $87-million. It will be in operation in 1978 and is planned to carry 107,000 passengers per day. Most passengers will be workers or students.

## GO-URBAN TRANSIT DEMONSTRATION SYSTEM, TORONTO, ONTARIO, CANADA

In May 1973 Krauss-Maffei AG of Munich, Germany, signed a contract with the Ontario Provincial Government for $16-milTion to build an AGT system at the Canadian National Exhibition Park in Toronto, Ontario. The system was to become operational in August 1975 and available for testing and public passenger-carrying throuh September 1975 followed by a one-year proving test program. The installation was planned with a one-way guidewa loop about 2.5 miles long and an additional mile of station tracts and a storage loop. Four off-line stations were planned, though econom measures reduced these to three stations, one on-line and two on-line. The system design called for full automation, with a hierarchical, trile computer, relatively centralized control s stem. Fifteen vehic Yes capable of operation singly or in trains of ti ree vehicles were to be tested. Vehicle specifications required 12 seated and 8 to 15 standing passengers. Speeds would normally be 45 mph with a maximum operating speed of 50 mph. Headways would be 10 seconds at 30 mph and 15 seconds at 45 mph. For testing, without public passengers, headways of 6 seconds at 30 mph would be used.

The vehicles were to be magnetically levitated and guided, Electromagnets on the vehicles attracted to armature rails on the guideway would suspend the vehicles. Current to the magnets would be regulated to maintain a constant air gap. No seconday suspension was contemplated. Propulsion was to be supplied by a linear induction motor, controlled by an inverter and fed from a 600-volt D.C.power distribution system.

Switching was to be accomplished magnetically from the vehicle. There were to be no moving parts on the track. An on-board mechanical switch arm deployed from the vehicle would serve as a safety back-u .

By November 1974, most of the 482 guideway caissons had been placed. Existing underground utilities had been relocated. Bids received for the guideway and stations were rejected as excessively costly. These facilities were redesigned to make them more spartan. A 1200-meter engineering test track with full-scale switches was completed in Munich. Two rubber-tired vehicles were built to test the automatic command and control system. The third prototype of the magnetically levitated vehicle had undergone static tests preparatory to the start of drive tests.

At this point, technical difficulties appeared. Weight of the three electromagnetic systems (suspension, propulsion and switching) and electronic controls to regulate them exceeded initial estimates. This added weight, and the vehicle dynamics involved, required heavier, and more costly, guideway beams than had been originally designed. A technical evaluation by the Ontario Urban Transportation Development Corporation (UTDC) found that these problems could be corrected with more time and at additional cost.

From a review of this situation, the German Ministry of Research and Technology concluded that magnetic levitation for transport vehicles was more suitable for high-speed, high-passenger capacity systems. The component weights, electronic complexity and costs could be economically distributed on systems with potentially higher productivity than the small urban vehicles proposed for Toronto.

This review resulted in a decision on 14 November 1974 by the Ministry to withdraw further financial support from the Krauss-kfaffei urban system program. This decision had several consequences.

- Without Ministry financial support Krauss-Maffei was unable to uphold its contract with Ontario. By mutual agreement the contract to complete the Transit Demonstration System has been terminated.
- The Ministry has consolidated magnetic levitation development in a new program to develop a 400 km/hr (240 mph) train. This program reaffirrns confidence in the performance, environmental advantages, and freedom from obsolescence afforded by mag-lev technology. The program combines the talents of both Krauss-Maffei and Messerschmitt-Bolkow-Blohm in a new consortium funded by the Ministry.
- Krauss-Maffei is continuing the development of an automated ~rban transportation vehicle system. This development will retain the best features of the linear induction propulsion system and control system previously developed.

UTDC is now seeking other vehicle and system suppliers to complete the Transit Demonstration System. Available choices are under consideration and a decision is expected to be made in time for a revised system to be in operation for the 1977 Canadian National Exposition. Under terms of the licensing arrangements with Krauss-Maffei, UTDC will retain the right to use Krauss-31affei technology, to use the test facilities, and to exchange engineering information on system developments.

## SYSTEMS PLANNED TO THE BID STAGE

In 1972 French officials awarded four $100,000 study contracts for an SLT s~-stein to be constructed in conjunction with the new Charles de Gaulle Airport near Paris. The four participants were Jeurnont Schneider (with Westinghouse), MATRA, Regie Renault and the LTV Aerospace Corporation in conjunction with COMSIP Enterprises. The studies were to cover proposals to build a 3.6 km, two-direction, loop from Aerogard No. 1 and the central unit; designs for a second 2.8 km loop from the central unit to Air France at Aerogard No. 2; and Plans for a future extension 4.4 km long to serve other airport faciltiies.

Bids were requested in April 1974 from three firms: LTV/COMSIP, based on AIRTRANS; MTE, a joint venture with Schneider and Creusot Loire, an industrial and 'railroad heavy equipment manufacturer; and Engins MATRA, using the ARAMIS system. In June, 1974 it was decided to delay the project for several years; no contract awards were made.

## SYSTEMS APPLICATION PLANNING

A summary of the status of planned installations is given below:

### ENGLAND

#### Sheffield

Under a study sponsored by the Transport and Road Research Laboratory (TRRL), preliminary design of a GRT system (Minitram) has been completed for Sheffield. Sheffield is in Yorkshire, in the heart of England's industrial area, about 380 km north of London. The population is 570,000 with nearly one million persons in the metropolitan area.

The planning for Sheffield has envisioned use of system concepts advanced by Hawker-Siddeley Dynamics, Ltd. (HSD) or the EAS-AMS Ltd. (a GEC subsidiary). Both concepts have been under feasibility study financed by the Department of the Environment. The Department has also funded British Rail to investigate magnetic levitation for the Minitram route in Sheffield.

The guideway route starts with a turning loop at the British Rail station and follows the axis of the shopping spine. The route serves bus stations, automobile parking lots, commercial areas, the Town Hall and a pedestrian shopping center. The other terminal serves a redevelopment area. The proposed GRT route makes additional pedestrian shopping areas possible that could not be served as well with existing modes of transport.

A schematic drawing of the route is shown in Figure 1 on the next page.

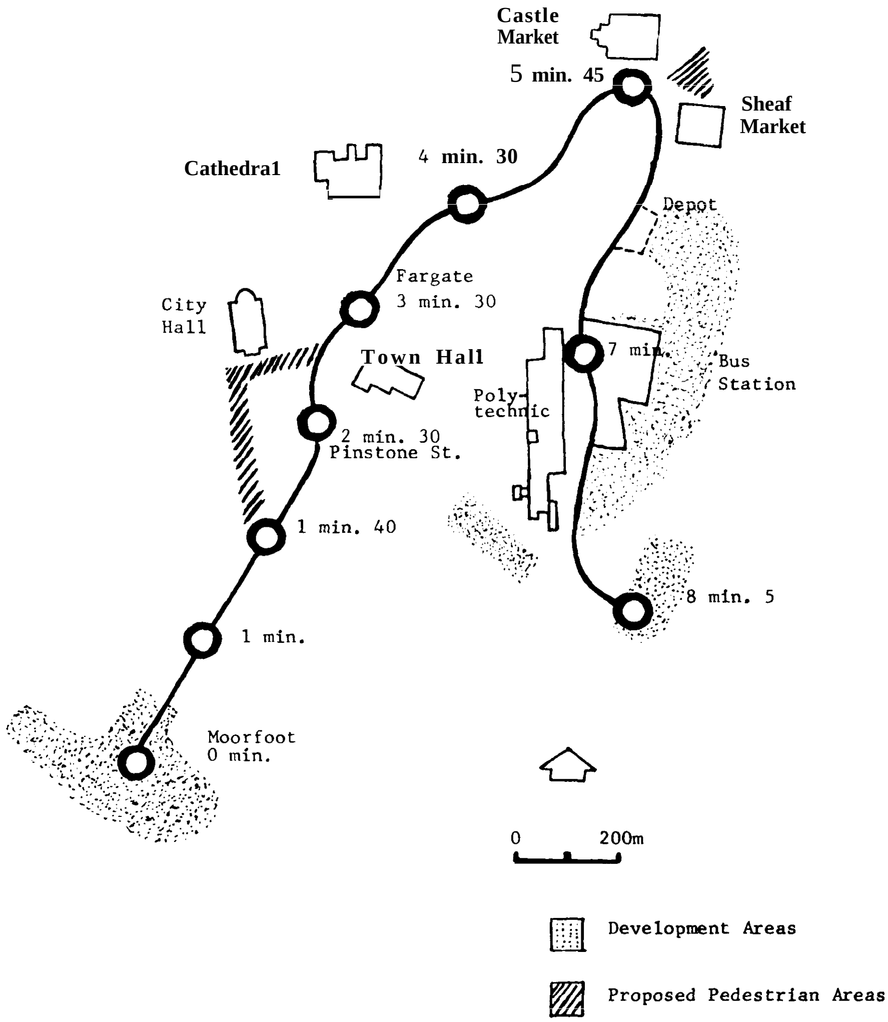



**Figure 1.—Route Map—MINTRAM in Sheffield**

Planning and preliminary engineering and operations studies were completed in 1974 by Robert Matthew Johnson-Marshall and Partners. The following summarizes the planning for Sheffield:

| | |
|---|---|
| Guideway.. --------- _ - _ ------ _ | 2.4 km of double track.<br>5.0 km total length with loops.<br>Elevated clearance: 5.1 m at traffic cros-simzs. 3.5 m elsewhere. |
| Stations- -- _ _ ---- _ ------------- | 9 s~ations with average spacings of 300 m.<br>1 or 2 off line.<br>Dwell time: 15 sec. |
| Vehicles_ - _ -------------------- | 25 with 6 seated, 6 to 18 standing. |
| Speed- - _ -- _ --- ___ ------------- | 15–20 km/hr terminal to terminal.<br>60 km/hr cruise speed. |
| Headways - ----------------- ___ | Peak hour: 30 sec.<br>Off peak: 90–120 sec. |
| Operations____ _ _ _ _ - _ ----------- | Single vehicles off peak: 180 seats/hour.<br>3-car trains, peak hour 5,400 passengers per hour. |

On May 22, 1975 the Minister for Transport advised leaders of the Sheffield Metropolitan District Council, and the South Yorkshire County Council, that he would not proceed with the proposal for a public demonstration in Sheffield of the Minitram automated public transit system. The two main reasons given for the decision were the public expenditures required and the need for more development work before the system could enter public use. The decision is a final one for a public demonstration at this particular site. This avoids leaving any uncertainty in Sheffield which might affect other proposals for the development of the city. Research plans are being revised and an experimental test track program for Minitram is being reconsidered.

### Brighton

An SLT system has been proposed for Brighton, East Sussex. Brighton is a seaside resort, 50 km (30 miles) from London, with a population of 400,000. The system runs a distance of 2.8 km (1.75 miles) between Aquarium and Black Rock along the seafront. The SLT system would replace the Volk Railway which is an existing narrow gauge railroad built in 1883. This railroad is now considered antiquated with limited capacity and poor service amenities.

The SLTProject is sponsored by the Brighton Corporation, Proposals have been received from Otis International for a small vehicle system, and from Sussex University for a magnetically levitated system. Since most government funds available for AGT development are focused on the Minitram project and a possible demonstration elsewhere, the Brighton proposal has a highlly doubtful near-term future.

*Summary.—Princi* al government planning efforts are focussed on the project in SReffiefd. The government has sponsored a competition between two potential suppliers—EASAMS Ltd. and Hawker Siddeley Dynamics Ltd.—and is evaluating a magnetically levitated alternative system. Since the risks are considered too great for commercialization at this time, the Department of the Environment is financing 100 percent of the development and planning costs. Cancellation of the reject in Sheffield would likely have a serious effect on the future or AGT development in England.

## FRANCE

Initiatives in France for planning AGT systems appear to originate local 'y. The central government has encouraged local innovation with the result that several projects are well along in the planning phase. The projects are focussed on solving urban transportation problems, not merely the application of new technologies in special settings.

Along with the local initiative there is an early marriage between hardware suppliers and local planners. This arrangement, which is quite different from U.S. practices, is claimed to%ave several advantages:

- Wasteful competition is eliminated at a time in the life of a project when hard decisions are needed.
- Early involvement of a system supplier makes his designs more responsive to public needs, and makes project planning more reaYistic in terms of the technologies that can be !urnished.

- An early commitment to a system supplier reduces anxiety about the market and eases the financial burden in preparing preliminary engineering and cost data.

This arrangement in France is evidenced by the presumption that Societe POMA has a clear field in Grenoble; that Otis/SOCEA will build the system in Nancy; and that MATRA is favored in Line and Nice. These, and other plans under consideration in France, are discussed below.

### Grenoble

The city of Grenoble has a population of 340,000, with 420,000 in the region. It is now experiencing one of the most rapid growths of any French city, with a population of 510,0OO expected for the region by 1985. Current public transport needs are met by trolleys (3 lines, 30 vehicles and 25 km of routes), and by buses (15 lines, 100 vehicles and 135 km of routes). Use of public transportation is declining, which the Agence d'Urbanisme de la Region Grenoblois (AURG) attributes to its service characteristics, Buses, for example, average less than 8 km/hr (5 mph) in the city. To reverse this trend AURG has adopted a planning policy which concentrates on:

- Improving the existing trolley and bus systems.
- Creating a completely new system on an exclusive right-of-way.

The system on which planning is based is the POMA 2000. This system was developed in Grenoble by Pomagalski (a ski lift manufacturer) and Creusot Loire. The planned installation for Grenoble envisages three lines requiring passenger, rather than vehicle, transfers between the lines. A total system with 40 km (25 miles) of two-way lines is contemplated. The system would be built in four stages, with an initial 1 km demonstration line.

The demonstration line, which would become part of the 15 km revenue line, would connect the new town of Echirolles to downtown Grenoble. A l-million FFr study has been undertaken for the preliminary design of this line. Results are expected in the spring of 1977. Cars with 15 seated and 15 standees have been considered, but no decision has been made and, hence, no data are available on the number of cars or capacity of the system. Stations would be on line, though a switching capability is being developed for situations where a double track and limited express service is deemed desirable. The system concept is limited to scheduled service, since the operating mode precludes demand responsiveness.

The major planning difficulties center on whether or not parts of the line must be put underground. Societe PO.MA 2000 and AURG originally envisaged an aerial structure throughout. However, the central area of Grenoble, where the three lines would cross, contains clustered old buildings on narrow streets. There are legal questions as to whether an elevated guideway could be permitted to obscure two historic plazas. Many local officials consider that an elevated structure in the central area would be destructive. Thus, there has been considerable pressure on the local planners to place the lines underground in the center area. Underground construction would quadruple the cost of an elevated system.

Construction of the elevated demonstration line has been estimated to cost about $6-million, No decision has been made to proceed with the demonstration sy~stem. Thus, no schedule for planning and constructing the system 1s available.

## Nancy

The city of Nancy is growing almost as rapidly as Grenoble. Only 17 percent of CBD trips are made on public transport, and a decline in usage is attributed to increasing affluence in the area. As a result, the narrow city streets are greatly congested; pollution and motor vehicle accidents are considered serious problems. Near term improvements focus on the bus s)'stem, while longer term solutions involve an automated guideway transit system.

(he of the largest manufacturing firms in France is the Saint Gobain-l?ont a' Mousson group, located in Nancy. The group's subsidiary)', SOCEA (an engineering and construction firm), teamed as the prime contractor, with Otis-TTD in 1973. A project plan was submitted to the District Urbain de Nancy in December 1974. This plan is summarized below:

| | |
|---|---|
| Guideway. ------- | 23.1 km (13.9 mi) of one-way guideways and sidings.<br>Elevated—13.8 km (8.3 mi).<br>Underground—9.3 km (5.6 mi.) |
| Stations- -- _ --- _ -- | Total—28.<br>Elevated—18.<br>Underground—lO.<br>Dwell Times—15 sec.<br>Initialiy on-line, but with provisions for later conversion to off-line operations. |
| Vehicles- - _ _ _ --- _ _ | Suspension —air cushion.<br>Propulsion—linear induction motor.<br>Capacity—12–16 seated, 20–16 standing, 32 total capacity.<br>Vehicles per train—3 (individual or 2-car trains in off-peak hours).<br>Total number—106 (10 spares).<br>37—Train Lead Cars.<br>69—Train Cars (1$'ithout Vehicle Control System). |
| Speed- --- _ _ -- _ _ -- | Maximum—50 km/hr 30 mph).<br>Civil Limits on Curves-40 km/hr (24 mph), 23 km/hr (14 mph) and 18 km/hr (11 mph). |
| 1leadways _ _ _ _ _ --- | West Loop—43 sec.<br>East Loop—90 sec.<br>West Loop Turnback—84 sec.<br>East Loop Turnback—90 sec. |
| Operations ---- - _. - | Inbound plus outbound service—Initially: 14,300 passenger trips/hr.<br>Growth: 3.9 percent per year for 10 yrs.<br>19 hr scheduled operations per day. |

Several alternative plans have been considered. The favored option at present would start operations with three-car trains in a line-stop mode of operation. Provision would be made for convwsion to off-line operations and individual vehicle operations within the second half of the first decade of operations to accommodate the projected traffic increase. This conversion would substantiate further capital investment. This changeover would be accomplished without interruption of service. The District of Nancy has not formally responded to the proposed plan. As a result of elections held in the fall of 1974, the district is reorganizing with appointment of a new transit director and staff. While there is still interest in the Otis-TTD system, a certain amount of redirection is anticipated. The project, which may take from 4 to 5 years to complete, is expected to be delayed at least a year.

## Line

The city of Line has a population of 800,000 and is expected to grow to one million by 1985. It is part of an urban complex of 1,470,000 comprising Lille, Roubaix and Tourcoing. This three-city conurbation embracm 87 separate municipalities.

At present, Line is served by three transportation systems:

- Buses provide some local service throughout the mea.
- The national railways (SNCF) have a terminal station in Line with main line and suburban services to nearby towns in seven directions.
- The Societe Nouvelle L'Electrique Lille' Roubaix-Tourcoing **(ELRT)** operates **23** km of meter-gauge electric tramway, 86 percent of it on reserved track. This tramway links Line with the cities of Roubais and Tourcoing near the Belgian frontier. Although the fleet of 28 cars is over 20 years old, these are being progresively modernized and much of the track has been renewed and upgraded. Commercial speed of the cars at present is 22 km/hr (13 mph).

Transport planning in the region has considered several possibilities:

- Proposals exist for a metro system which would connect Lille with Nord-pas de Calais, Tourcoing and Arras. Other metro lines would serve Ronchin, Lomme, La Madeleine, Roubaix/ Tourcoing and Velleneuve d'Aeq (Lille-Est). A new metro line through the center of Line to the Regional Hospital center would require mini-metro cars to save costs in tunnel construction.
- An automated guideway transit system (1'AL) has also been proposed to connect Lille with the new town, as well as to provide service to the hospital center, Tourcoing and Roubaix.

Engins MATRA, in conjunction with EPALE (the public authority formed to direct. development of the new town) have undertaken planning the VAL system to Lille-Est and the university there.

T'here has been considerable controversy about the system recently, mainly of a political **nature** but to some extent flavored with technical concerns. One of the three remaining streetcar lines in France is in the city of Lille and this has resulted m a huge contrivers}: between the advocates of VAL and those who prefer light rail transit technology?'. The issues are well summarized in an October 1973 article in *Railway* Gazette *International* by Professor Vuchic of the University of Pennsylvania. To resolve the controversy, the city of Lille has requested financial assistance from the government to undertake a two-phase further analysis lasting a total of about 9 months. The government has not yet provided any funding for this study, but the French Chamber of Deputies in late 1974 authorized the government to decide whether to provide more funds. A decision is expected in about **2** to **3** months.

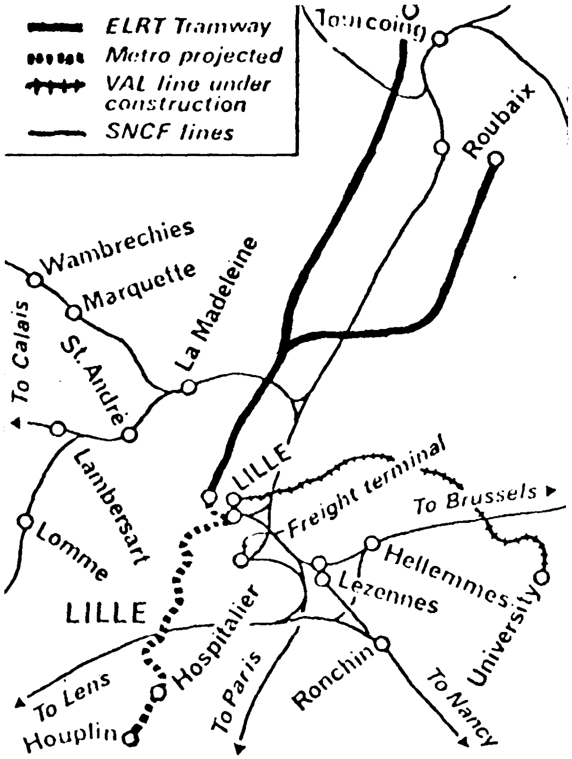



**Figure 2.—Route Ma~VAL in Line**

The selection of VAL is one of the few examples in France of the use of the American technique of inviting proposals through a request for proposals (RFP). Engins MATRA was the winner of the competition. The Paris metro system (RATP) is a consultant to EPALE for the decision on the system.

Though VAL is an elementary SLT system, use of a fully automated vehicle is seen by the participating agencies m Line as a major innovation and departure from tradition.

## Paris

The Regie Autonome des Transports Parisiens (RATP), the regional transport authority for Paris, is involved in three aspects of PRT development and planning.

. RATP is managing, on behalf of the French ~overnment, a develo ment program to establish the reliabihty, safety, costs, tra&c management, and ultimate qualification of the ARAMIS PRT system. This program is based on the results of earlier experiments carried out on a l-km test track with 3 vehicles near Orly Airport. This 12-month study began in September 1974 and includes a parallel assessment of bus transit. Two comparisons of the costs and benefits are being made. One compares the performance of both systems in meeting the same total demand. The other optimizes the two systems and compares performance for the resulting demand, Preliminary Rndings suggest that the bus service is 2 to 3 times as expensive as ARAMIS.

- A new test track with 3 km of guideway, 3 stations and 10 to 15 six-passen er vehicles is bein planned in the vicinity of Creteil and 6 hoisy-le Roi near $ aris. (Consideration is also being given to the use of 12-passenger vehicles for this demonstration. ) Tests will not involve passengers, but will focus on maintainability and automatic test eqmpment. The aim is to have the system certified for urban use in 1977 or 1978.
- Concepts are bein developed for a revenue system to link suburban terminals of rail commuter lines. The eventual plan is to provide a rather complete network linking the commuter lines on the outskirts of Paris in an arc about 70 km in length. An extension of 20 km would be made by 1982 and the remaining connections would be completed by 1990. Since these plans are to provide case studies to guide realistic development of ARAMIS, there are no commitments to their implementation. A demonstration line, comprising a useful increment of a commercial system is contemplated. This line would be 6–10 km long, include 6-8 stations and would involve 200-300 vehicles, Capacity would handle 2000 people per hour in one direction. Building and testing would require 26 months plier to the start of passenger operations.

## Nice

With a population of 300,000 no corridor in Nice is ever expected to generate more than 10,000 passengers per hour. Since difficult subterranean conditions exist, the municipal authorities decided to examine an advanced transportation system in lieu of a subway. In 1974 a study was commissioned to consider an ARAMIS PRT system.

The system being studied would be largely elevated, use 4 to 12 passenger vehicles, would be demand activated, and would operate at speeds of about 50 km/hr (30 mph), Although no route plans have been published, a north-south alignment from St. Sylvestre to Massena and an east-west corridor from St. Augustin to the port of ISice are being examined, Long-range plans call for a network of 35-4o km of double tracks, 50–55 stations and approximately 2000 vehicles. The system would carry 8000 peak-hour passengers in one direction, Near term lans, to be completed by the end of 1975, call for an increment 6–10 km long with 10–15 stations. Though this reference line is to be self supporting, no data was available on potential patronage or numbers of vehicles anticipated.

S'unwnary.-France: Planning in France which contemplates AGT technology is focussed on urban transportation problems. Service is planned to complement existing systems, to relieve street traffic or to provicie new service where either marginal or no service exists. The major planning difficulties occur with the problems of inserting a new elevated guidewa~' s~wtem into an older historic community. The costs of tunneling an~' transit system are almost prohibitive. Where serious planning for AGT systems is occurring, there has been an early selection of system hardware. Principal systems being considered me POMA 2000, Otis-TTD, ARAMIS and VAIJ.

## SWEDEN

Gothenburg is the second largest city in Sweden, with a population of 458,000 and 690,000 in the region. The total regional population is expected to go to about 850,000 by 1985. As headquarters for Volvo, it is one of Sweden's most important industrial cities.

At present Gothenburg has 10 tram lines 96 km in length (60 miles) with 268 trams in service. Though tram and bus ridership have shown a steady clecline over the past 20 years, Gothenburg is planning some extensions to the existing tramlines. One factor contributing to the decline of ridershi is the high standard of living which is expected to increase automobiŸe ownership from 0.33 per capita to 0.55 by 1985.

In 1970a study of a large PRT system was i~itiated b,? the Goteborg Sparvager (municipal transport operators) under the direction of Mr. Sixten Camp. This study concluded by recommending a PRT system using five-passenger vehicles and having 250 km (153 miles) of double track and 360 stations. The stations were intencled to be within 800-1000 meters from homes in low density areas and 500 meters in high density areas. This system would require 18,000 vehicles. The report recommended that a test track be constructed for demonstration purposes, and that the entire network be built in stages over a 20–25 ~"ear period. The table below suggests the staging plan and related change in control technology toward shorter headways for the initial increment of the total network.

Table I.–Staged plan for Gothenburg, Sweden, PRT system

| Part | D:;abJ: miles | Stations | Vehicles | I n operation | Cost mill ion crowns | Headway (seconds) |
|---|---|---|---|---|---|---|
| 1 . . . | *3* | *6* | 100 | *1976* | | *8,0* |
| *2*. . . . . . . . . . . | | | *800* | *1980* | l % | 4.0 |
| 3. ..., . . . . . . . . . . . . . . ,,. | : : | ; : | 1,100 | 1985 | 150 | 2.0 |
| 4, . . . . . . . . . . . . . . . . . . . . . | 3 | 9 . . . . . . . . . . | | 1985 | 200 | 1,5 |

The network proposed would be expected to attract 38 percent of the trips made in the year 2000, compared with 13 percent for the conventional bus and train systems.

In 1972 a second study was made, the Gothenburg Public Transport Study, and all alternatives including PRT were reexamined. This study concluded that all of the modes were feasible, and that the PRT system with small vehicles would be preferred. It recommended against use of the subway s~"stem originall~. planned for C~othenburg. However it also concluded that there were technical and economic uncertainties with the new sj~stem, and that satkfactorj" public transport could be provided for the next few years by conventional means.

The recommendations from the study were:

. Improve the existing system.

. Reconsider the use of an advanced system in 5 years (before 1980) .

. Reserve space for an advanced system with a fairly dense network of the PRT type,

## WEST GERNfANY

Planning for AGT systems in West German?-, as in France, depends on an early close association of hardware supplier and local agencies, Three systems under development and their" planning sites include:

Cabinentaxi: DEMag and MBB (Messerschmitt-Bolkow-Blohm GmbH)—Hagen, Westphalia.
Trasurban: Krauss-Maffei-Heidelberg.
H-Bahn: Duwag and Siemens—Erlangen.

The status of each of these planning endeavors is summarized below:

### Hagen, Westphalia

In late 1971 the Hagener Strassenbahn AG (street railway system) contracted with the DEhlag-MBB consortium to stud)- the application of a PRT s.~-stem in the greater Hagen area. This area includes peripheral cities of Wetter, Gebelsberg, Herdecke and Berchum Hohenlirnburg, Population in the area is expected to reach 400,000 b~' the ~'ear 2000. These studies were completed in 1972 and have been published in several reports.

While the analysis for Hagen was extensive, some U.S. visitors to Hagener Strassenbahn contend that the effort was no more than a plan to help define operational characteristics for the Cabinentaxi s~stem.

The network for Hagen has been 1aid out in stages. The first stage includes 33 km (20 miles) of guidewa~' and 42 stations. Subsequent stages bring the total s)-stem to 138 km (86 miles) of aerial track and 182 stations.

Traffic projections for the year 2000 suggest a total of 572,000 passenger trips per day (24 hours) with 158,000 for business trips and 414,000 for occasional trips. The volume of morning peak hour travel was estimated at 56,000. With the closely meshed network, station loading was estimated as averaging about 170 alighting and entering passengers per peak hour over both directions of travel. Only in exceptional instances would station loading exceed 300 passengers per peak hour.

At a pessimistic occllpanc~" value of one passenger per car, for about 96 percent of the line length, a capacity less than 4,000 cars per hour is required. The following table summarizes the number of cars with a three-seat capacit~- required for various degrees of occupancy.

Table 2.—Occupancy rates projected for Hagen-area PRT system

| | | | | | | |
|---|---|---|---|---|---|---|
| Occupancy. . . . . . . . . . . | | | | | | |
| Occupied runs.. . . . . . . | 34,3;: | 28,5;; | 24,5;: | 21,4:: | 19,0k: | 17,1% |
| Empty runs. . . . . . . . . . | 18,000 | 15,000 | 12,860 | 11,250 | 10,000 | 9,000 |
| Number of cars. . . . . . . . | 8,900 | 7,400 | 6,400 | 5,600 | 5,000 | 4,500 |

>. $-37(1 f ) - ', j . 1(,

The computation is based on a peak hour demand of 34,300 passengers on a mean distance for one useful run of 6.07 km. The modal-split models for predicting patronage used total trip time as the principal parameter.[5] These analyses predicted use by Cabinentaxi of 60 percent of the overall peak hour travel, 60 percent of the business trips, 40 percent of the occasional trips. While 50 percent of the overall daily trip average was projected for Cabinentaxi, only 20 percent of the overall average for short-distance travel was forecast for the conventional bus and tram systems. 1

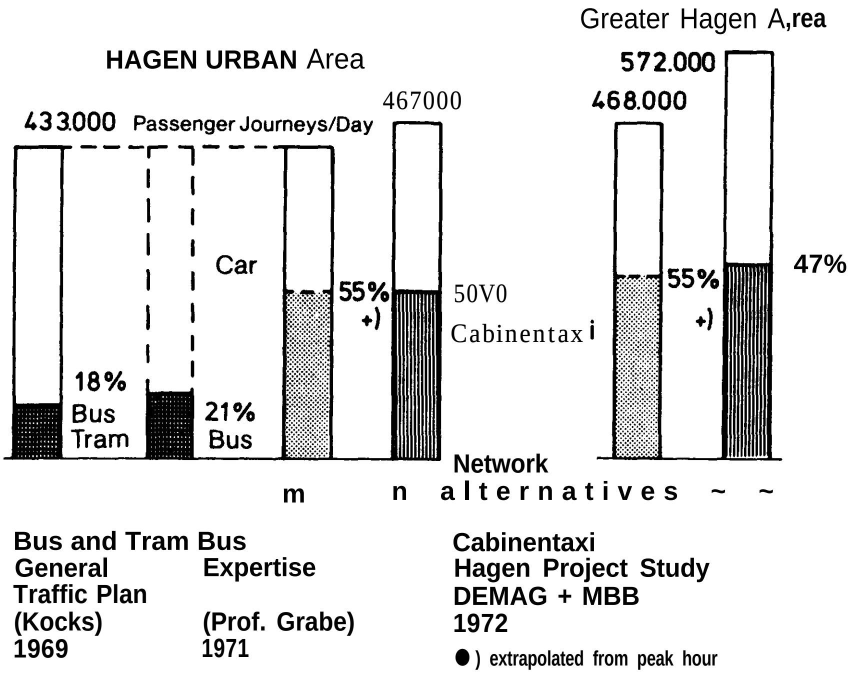



**Figure 3.—Comparison of Forecasts for the Year** 2000
Source: DEMag-MBB, Hagen, West Germany.

The Cabinentaxi, developed as a PRT system, would operate at one-second headways, traveling at speeds of 36 km/hr (22 mph). These headways and speeds have been demonstrated at the Hagen test facility.

A reduction in the FY 1975 budget for the Ministry of Transport eliminated a proposed urban demonstration of Cabinentaxi in Hagen.

## Comparative Analysis of Hagen

An independent analysis of transit network plans for Hagen, West Germany, has been made by Dr. Guert Hupkes, Vice President, Center for Transportation Planning, Utrecht,[1] The Netherlands. This analysis compared Cabinentaxi, Transurban, an upgraded bus/tram system using reserved rights of way, and an actual bus~tram system having no exclusive right-of-way. The study used basic data derived from the original Hagen study and from the system suppliers, but modified as deemed necessary for purposes of comparison. Costs were prepared for the years 1975–2000, using 1972 guilders which have been converted below at the rate of $0.30/guilder, exclusive of inflation. The study assumed a 4 percent yearly growth for wages and 6 percent for energy. The following table summarizes the results of this analysis.

Results of comparative analysis

| | Cabinen-taxi | Trans. urban | Bus/tram right of way | Bus tram no rfght of way |
|---|---|---|---|---|
| System date: | | | | |
| Inhabitants | 400,000 | 400,000 | 400,000 | 300,000 |
| Network (kilometers)/(miles) | l~8~~&J | 83fW& | 1 19/;;; | 145{:: |
| Vehicles | | | | |
| Commercial sDeed (kilometers Der hour) /(miles per hour) | 304& | 33/19 | 25/15 | 15/9 |
| Person net | | 350 | 978 | 790 |
| Passengers/year (millions) | 60 | 60 | 60 | 30 |
| Passenger kilometers/year (mile lions) | 300/180 | 300/180 | 300/180 | 120/72 |
| Cost (million dollars): | | | | |
| Investment in infrastructure | 249 | 206 | 120 | 0 |
| Investment per vehicle (dollars) | 4,500 | 60,000 | | |
| 1975 cost 1 | | 21 | 16.2 | 9.6 |
| 2000 cost 1 | 3 % | 34.8 | ; . ; | 22 |
| 1975-2000 cost totaled 1 | 712 | 654 | | 354 |
| Disbenefits per year: ~ | | | | |
| Energy used (billion kilo calories) | 279 | 240 | 75 | 119 |
| Land use (hectares)/(acres) | 35/;; | 42/1~() | 114/2;$ | 146/361 |
| Noise index (db (A)) | | | | 100 |
| Air pollution (tonnes)/(tons) | 559/616 | 477/;2; | 485/;3; | 1,643/1,811 |
| Safety (fatalities) | 0.4 | | 0 | 8,5 |
| Visual intrusion (kilometers/miles viaduct) | 69/41 | 83/5; | 50/30 | 0 |
| Criminality (index) | 3 | | 1 | 1 |
| Benefits per year: | | | | |
| Travel time won (million hours) | 3.35 | 3,85 | -0.25 | |
| Number of iobs | 581 | 549 | 1,230 | 1,28: |

1 Costs include operations plus 50 percent of investment in infrastructure; the other 50 percent government grant disregarded.
230,000,000 passenger trips per automobile included.

Under the conditions assumed, this study concluded:

- The capital and operating costs of the automated uideway systems investigated over the 25 year period wouldie higher than the costs of the upgraded bus and tram system;
- The disbenefits of the actual bus/tram system are attributed largely to 30 million trips which would be made by automobiles but which would be diverted to the other three innovative concepts; and
- There are benefits in travel times associated with the automated systems as well as reductions in direct and related labor.

Several factors highlighted by the study warrant consideration:

. The ratio of personnel per vehicle for the Cabinentaxi system is low in comparison with United States experience on AGT systems to date.
. This consideration would delay by several years, at current labor inflation rates, any benefits attributed to the labor reduction on the automated systems.
. Cabinentaxi vehicle costs are considered low, even though based on a volume production run of 6–9,000 vehicles.
. The diversion of 30 million automobile trips to any of the three innovative systems would likely require coercive government action.

## Other Plans fol Cabinentaxi

Reports persist of Ianning activity involving Cabinentaxi at other locations in West &ermany. The following summarizes the best current information available:

Perlach: A system would serve a surburban community of 80,000 with 30,000 jobs.

Freiburg: A suburban community would be linked to the city center as the first increment of a potential overall network.

Ziegenhain: The hospital, near Kassel, would be equipped with a special version of Cabinentaxi to transport patients, hospital staff, food, supplies and other materials between the different buildings of the medical center. Plans call for the system to be in operation during 1977.

Hamburg and Marl: Applications have been made for a reference installation. Studies would be initiated in 1975. After completion, and if a project is approved, one city would be selected for the installation. Both small and large cabs would be tested for public acceptance and serviceability. Construction would begin m 1977 and the system would be operational in 1979.

## Heidelberg

An extensive preliminary design, urban compatibility, patronage and economic feasibility study was done by the Krauss-Maffei consortium in collaboration with the planning authorities of Heidelberg. This study contemplated a Transurban system as developed and tested by Krauss-Maffei at their facilities in Munich. The system involved 3.6 km (2.2 miles) of guideway and 10 stations f~r the central part of the city. Consideration was given to placing the system underground to preselve the historic bmldings in the city center. lt was expected that a small vehicle system could be tunneled at less cost and with less danger to building foundations. Withdrawal of funding support by the Ministry of Research and Technology for Transurban development has not cancelled further planning in Heidelberg. The city is evaluating other bottom-supported GRT systems that could meet planned requirements. Krauss-Maffei is continuing with the development of a GRT system but without magnetic levitation for vehicle suspension, and hopes to team with another supplier.

### Erlangen

As the headquarters for Siemens, Erlangen is a natural choice for simulating deployment of the H-Bahn system. A fine-grained network has been planned, with all stations within walking distance. The simulation uses a 45 km network, 60 off-line stations and 260 vehicles. The vehicles seat 8, on two, four-abreast seats facing each other. There is space for an additional 8 standees in the middle. Vehicle speed is planned at 36 km/hr (22 mph) at 8 second headways. Thus, vehicle flow rates are 450 per hour or 3600 seats per hour. Dwell times for a three-berth station are 20 seconds. hTo additional information on the status of plans for deployment of H-Bahn is available.

## JAPAN

There is considerable activity throughout Japan concerned with planning the deployment of AGT systems. There is evidence of some intense competition between cities to be the first to install a new system in ,Japan. In addition to the (NS development, eight system suppliers are vying for the market. Two significant planning efforts for deployments in Tokyo, as well as those planned in other parts of Japan, are discussed below.

### Ikebukuro, Tokyo

The most ambitious lans for deployment of CVS involve the northwestern part of To[yo, Ikebukuro. These plans would connect central Tokyo with Ikebukuro by means of 8.5 km (5.3 miles) of guideway. The four-lane track would be all elevated with two lanes northbound and two southbound. The system would be designed to carry both passengers and goods. However, the 36 to 50 stations along the route would be designated to handle either people or cargo, but not both. Stations would be simple in design with a single channel, off-line ~latform, space for a few vehicle berths, fare collection gates, destination selection equipment and a small shelter. Vehicles would operate at one-second headways during peak hours. Since land is extremely expensive in Tokyo, every effort has been made to minimize the space requirements. The study is being financed largely by private industrial groups with very few data released. Representatives of .Mitsubishi report that planning was about 90 percent complete at the end of 1974. The plan is expected to be presented to the Ministry of Construction early in 1975. If approved, it would be submitted to the Ministry of Finance and then to the Diet for appropriations, hopefully during 1975.

### Tsukiji, Tokyo

The Tsukiji District of Tokyo is in the eastern part of the city near Tokyo Bay on land reclaimed from the sea. Tsukiji is growing rapidly, and would be an attractive commerical area, if it were served adequately with a transit system.

Funding was approved in 1974 in the amount of $1.7 million for preparation of plans to be submitted to the .Ministry of Construction in mid-1975. Unlike plans for Ikebukuro, the system for Tsukiji would be selected by competition.

## Other Planned installations

There are eight industrial firms in Japan either independently developing or marketing their versions of U.S.-licensed automated guideway transit systems. The following is a list of these systems:

| Firm | System |
|---|---|
| Mitsubishi | MAT (Mitsubishi Automated Transit). |
| Mitiui/Seizo Sharyo | VONA (Vehicle of a New Age). |
| Kawasaki | KCV (Kawasaki Computer-Controlled Vehicle System). |
| Hitachi | PARATRANS. |
| Kobe Steel | KRT[1] (Kobe Rapid Transit). |
| Niigata Tekko, Sumitomo | NTS[2] (New Transportation System). |
| Toshiba | Minimonorail. |
| Nichimen, Fuji Car | Dashaveyor.[3] |

1 Adaptation of Boeing/Morgantown.
2 Adaptation of LTV Airtrans.
3 Adaptation of Bendix/Dashaveyor.

These systems exhibit the performance characteristics of SLT or GRT systems. Their technical characteristics vary slightly, but generally conform to specifications for an on-line medium-capacity and medium-speed system. All of the systems listed use rubber tires. All but KRT have track switching systems; all have automatic coupling capabilities. The nominal headway is 90 seconds. These specifications a pear to be tailored for small-scale installations at Osaka and Kobe. Planning for deployments in these cities is discussed below.

*Nanko Project, Osaka.*—The Nanko Area Project (south Port Area of Osaka) is on reclaimed land in the Osaka harbor, which will have 900 hectares (about 2300 acres) when completed. The permanent population of 40,000 will reside on 110 hectares of land; about 5000 of this population already resides there. Originally intended as primarily industrial, Nanko has been expanded to include a large residential area.

A new GRT system is planned to connect Nanko with the No. 3 subway line terminal. The length of the new system is to be 7.2 km (4.5 males); it would all be aerial, and there would be 9 on-line stations. Extensions within the Nanko area and beyond the No. 3 terminal are planned for the future. The cost of the system is projected at 22 billion yen, or about $70 million ($15 million/mile). A decision on type of system is expected in mid-1975.

Kobe.—A system with many similar features is planned for Kobe, a city with three quarters of a million people. Plans exist for a subway in Kobe (14 km by 1978; 22 km by 1985). The new system, described by representatives of the Traffic and Transportation Bureau of Kobe, would be about 4 km in length, linking Sannomiya station of the Japanese National Railways (JNR) with a "port island" new town. The new town, built on land fill in Kobe arbor, has a projected population of 14,000 people. A completion date of about 4 years was indicated.

*Proposed Installations.-One* of the companies that is contending for the Osaka and Kobe installations is Mitsui/Seizo Sharyo, M/SS reports that it has submitted the following proposals for installations:

Interurban

Toso New Town in Chiba Prefecture: 3,350 m (10,928 ft) Guideway, 42 Vehicles, 3 Stations, 2.5 min Headway, and 5,640 Passengers/hr Capacity.

Kaihin New Town in Chiba Prefecture: 14,300 m (46,904 ft) Guideway, 178 Vehicles, 8 Stations, 1.5 min Headway, and 20,000 Passengers/hr Capacity.

Tokadai New Town in Aidi Prefecture: 17,500 m (57,400 ft) Guideway, 183 Vehicles, 20 Stations, 1.5 min Headway, and 18,720 Passengers/hr Capacity.

Fujisawa Seibu New Town in Kanagawa Prefecture: 12,000 m (39,360 ft) Guideway, 55 Vehicles, 7 Stations, 2.5 min Headway, and 5,500 Passengers/hr Capacity.

Airport Distributor

Shin Tokyo International Airport in Chiba Prefecture: 600 m (1,968 ft) Guideway, 24 Vehicles, 2 Stations, and 1.5 min Headway.

Cargo Distributor

Grocery Distribution Center in Chiba Prefecture: 7,000 m (22,960 ft) Guideway, 39 Vehicles, and 6 Stations.

No decisions have been made on any of the above proposals.

*Summary-Japan.—AGT* system planning in Japan is proceeding at a pace commensurate with the status of development. One PRT system, CVS, is being planned for the Ikebukuro District of Tokyo. Since CVS testing will not be completed before the summer of 1978, deployment could not begin earlier. Other installations are being planned for competitive proposals from among eight prospective system suppliers. Several of the planned installations address the transportation problem created by the historic development of many Japanese coastal cities in which the port activities were separated by many miles from the commercial and residential centers of the city. There are numerous other proposals for AGT installations serving new towns, the new Tokyo airport and a food distribution center.

# Chapter 4: Description of Foreign Suppliers

Industry support for AGT system development starting in the late 1960's and early 1970's occurred for many reasons. Some companies were already involved in supplying the transportation industry and this new form of transit was a logical extension of their manufacturing and marketing capabilities. The aerospace and military hardware suppliers looked upon AGT development as technically challenging and an opportunity to diversify into a civilian market. The apparent U.S. interest in AGT systems, as evidenced by the N'ew Systems Study, undoubtedly suggested an opportunity for foreign exports. Though energy was not a major concern, problems of the environment, air pollution and automobile congestion provided an incentive for alternative ancl attractive transit s,ystems. The rapidly expanding population and interest in new residential areas—even new towns-invited consideration of complementary new transit systems.

A combination of these factors led many industries to believe that a potential market for such systems was developing that could bring a reasonable return on corporate investments. This belief was reinforced b~ government's willingness to share or totally compensate for the cost of developing this new urbtin transit system.

As a result, hundreds of concepts evolved, many were developed, some have progressed to operational testing and deployment. The following section describes the status of the significant developments which have survived. hTo attempt has been made to exhaust the subject. The purpose is to show that foreign development of AGT systems is seriolw and proceeding on a technically sound basis.

## ENGLAND

A PRT network-t 'pe system was first conceived in Great Britain in 1965. Leslie R. dlake of the Brush Electrical Company, a subsidia~~ of Hawker Siddele~", formulated his concepts for such a s~-stem after visiting staRR car and Te]etrans developments in the U.S. Studies of the Auto-Taxi were sponsored by the National Research and Development Corporation (N RDC) in 1967. These studies continued through 1971 under the name of Cabtrack b~- the Transport Research Assessment Group (TRAG), a working group attached to the Joint Ministries of Transport and Technology. A number of components and subsystems of Cabtrack were developed to the stage of full-scale experimental technology at the Ro~'al Aircraft Establishment at Farnborough. During this periocl., a number of crucial aspects of the original concept were altered, but m basic outline, it remained a PRT-t~-]m of s~-stem. The system being developed was to be a 4-seat, automatlcall~ controlled, electrically' propelled vehicle. It was to travel at 35–40 mph on an exclusive guldew~~-. Passengers could travel between stations of their choice without intermediate stops. These features conforni to the Personal Ral)id Transit conce])t as presentl~- defined. An environmental stud}- of Cabtrack undertaken in 1971 endeavored to show the architectural iml)act on the West End of London. The attempt was to assess the visu~il accel)tance of such a s~wtenl in an existing cit~". 'llc Tlrest End was selected because considerable traffic data were available, but the study highlighted the difficulties of adding aerial structures to a well-known, densely developed and cherished section of London. Critical press reports m May, 1971 resulted in a reevaluation of the project.

In 1971 a change in administration of the Department of the Environment and the ensuing reevaluation of Cabtrack resulted in redirection of efforts to a technically less ambitious system. The m'inciDal reasons for dropping Cabtrack were:

- .' Technical goals appeared too ambitious relative to the develom ment funs available and to the benefits to be realized. 'A one-second headway for cars was not regarded as a realistic objective at that time. Better benefit/cost values could be achieved, it was believed, with larger capacity vehicles operating at reater headways.
- Fail-safe features were neither well-enough analyzed nor shown to be feasible at reasonable cost. Risks to passengers had been too readily dismissed in earlier studies,
- The addition of aerial structures within compact, older areas of London (and similar cities) could have serious adverse environmental impacts, far greater than originally envisioned. Tunneling became the only sensible approach, which would be excessively extensive.

The result of the redirection of activity was a decision to study a new concept which became known as "Minitram."

This concept uses a larer vehicle than Cabtrack. It would have mostly on-line stations, afthough the system is being conceived to allow incremental future evolution into a system having PRT attributes, such as: off-line station capabilities, fully automatic control, and some degree of demand responsiveness.

The Department of the Environment, through the Transport and Road Research Laboratory, has competitive feasibility studies with EASAMS Ltd. (a GEC subsidiary) and Hawker Siddeley Dynamics Ltd. Probable characteristics of the eventual system, depending upon final design, are:

| | |
|---|---|
| Capacity- _. ... --- | 12–15 seated, 10–15 standees. |
| S eed_----------- | 30-45 mph. |
| $ eadways - ------- | 10 seconds. |
| Operations---- ---- | Individual and 3-car trains. |
| Grades -_ - _- --- --- | 10-percent maximum. |

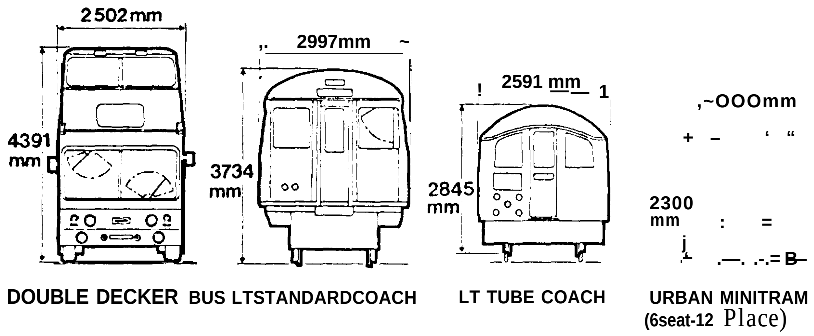



**Figure 4.—Cross Section Dimensions of Various Urban Vehicles**

**Source : Dr. M. H. 1., Waters,** *Minitram-The TRRL Programme,* **Transport and Road Research Laboratory, Crowthorne, Berkshire, 1973.**

There are differences in the two system designs:

. The Hawker Siddeley system uses rubber tires on a concrete guideway, A center slot below the running surface provides guidance, power collection and vehicle retention. The vehicle steering mechanism is controlled by guide wheels in the slot. Guideway side walls provide emergency guidance and reduce any noise or splashing.

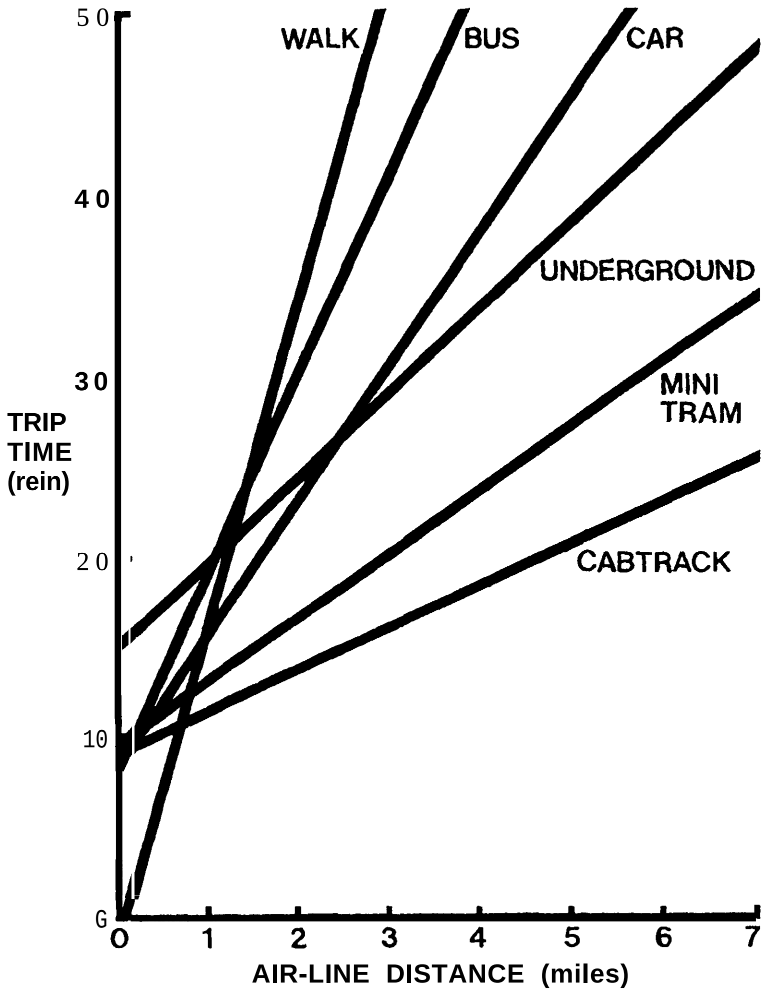



**Figure 5.—Performance Curves of Various Urban Vehicles**

**Source : Dr. J. W. Fitchie, iNew** *Tran8port @8tf2m8 for (?it{e8,* **Transport and Road Research Laboratory, Crowthorne, Berkshire ; 1973.**

. **The ESSAMS** system also uses concrete as a supportin structure, but the vehicle uses steel wheels on steel rails. Ti e steel rails are mounted on resilient isolators to reduce noise and vibration. The steel wheels are also fabricated with resilient materials to minimize noise and vibration transmissions. Use of steel wheels and rails eliminates the need for additional uide wheels, but imposes a requirement for steering to avoid fan.ge contact and the resulting noise on tight curves. Concrete side curbs contain the power rails and provide positive vehicle retention.

In addition to the EASAMS and HSD designs, the Department of the Environment is investigating a magnetically levitated alternative. This study is based on the contention that maintenance costs could be lowered through reductions in rotating equipment and less guideway wear. British Rail is doing the magnetic levitation work. Data developed thus far raises more questions than are answered. The possibility of lower reliabilities f?r the magnetic levitation and higher operating costs for linear induction propulsion may offset an}. other advantages.

## FRANCE

Three AGT systems are under active development in France. A fourth, VEC, has been installed commercially. Each is discussed below.

A2?AlZ~S'.-The ARAMIS systeIn k being developed by Engins MATRA from patents of Gerard Bardet. This system is the most likely of all French developments to achieve PRT performance. The following is a summary of ARAMIS technical characteristics.

| | |
|---|---|
| Guideway.. --- _ -- | Concrete running surface with lateral guidance curbs. |
| Stations- --------- | Sized for volume of traffic.<br>Control the adjacent line operations.<br>Load/unloading areas may be superimposed vertically. |
| Vehicles_ --------- | 4–10 seats.<br>Run on 4 pneumatic tires.<br>Guided by 4 rubber wheels.<br>Traction: 2 variable reluctance motors, 1 for each rear wheel. |
| Speed --- _ ________ | 50 km/hr (30 mph). |
| Headway s- ------- | Vehicles are electronically coupled 0.3m apart.<br>Spacing: 0.2 seconds between vehicles, 60 seconds between platoons. |
| Operations ---- _ _ _ - | **25 electronically trained vehicles with 10 seats in a platoon could provide a capacity of 15,000 seats.**<br>**Electronic coupling permits high-speed switching for adding or removing cars.**<br>**Iligh traffic capacities are possible with off-line stations and high-speed switching.** |

Development of ARAMIS was started in 1970 with design studies, site feasibility studies in the Paris suburbs and prototype development. A one-km test track with three prototype vehicles has been constructed near Orly Airport. Tests with the prototype vehicles are essentiall~' complete. The cost of the program through this prototype testing phase is about 13.9 million FFr. Total French government assistance since 1970 has been approximately 7.1 million FFr. The second phase of the program started in 1974. The system manager for this phase is the Regie Autonorne des Transports Parisiens (RATP), the regional transport authorit~- for Paris. RATP is funding 70 percent of a 40–50 million FFr program of 30 months duration. This phase will include the following three parts:

I?art I—Design Review, September 1974 to September 1975:

. Analyses of equipment, costs, reliability, safety and traffic management,

. Technical qualification of critical components.

. Redesign of the ARAMIS system incorporating features proven from RATP experience with the Paris Metro and from the design review.

Part II—Qualification Tests, September 1975 to March 1977:

. Construct a *new* test track, 3 km long with 3 stations, crossing switches, underground and elevated sections and 10 to 15 vehicles.

. Conduct qualification tests on the maintainability and automatic diagnostic equipment.

. Public use of the system during these tests is not planned.

Part III—Experimental system, March 1976 to May 1978: 1n parallel with Parts I and 11, case studies will be made of possible ARAMIS installations in the Val de Marne district near Paris. Plans for a possible demonstration installation are discussed in Chapter 3 of this report.

**ARAMIS Test Facility, Orly AirporQ Pari% France**

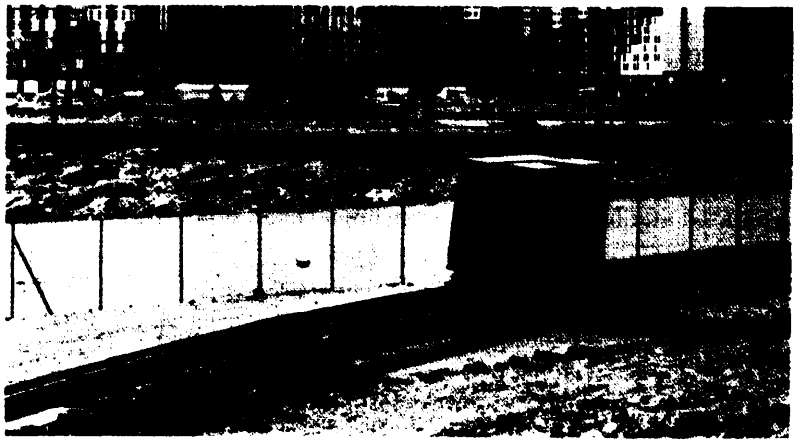
*VAL* The VAL system is also being developed by Engins MATRA of Velizy, an industrial park near Paris, in conjunction with EPALE, the Public Authority for the Planning of Lille-Est. French government assistance began in 1970. Total expenditures thus far on the system amount to 30 million FFr, of which the government's contribution has totaled about 24 million FFr, the VAL system is fully automated and has the following technical characteristics:

| | |
|---|---|
| Gujdeway. ------ | Concrete running surfaces. |
| Stations---- ----- | On line. |
| Vehicles_ -- _ -- _ -- | Capacity: 36 seated, 17 to 26 standees. |
| | Rubber tired. |
| speed - ---- ------ | 40 km/hr avg, 30 km/hr max (25-50 mph). |
| Headways - ------ | 1 min. |
| Acceleration- ---- | 1.3 m/sz (2.8 m/hr/see). |
| Operations ---- --- | Single- or 2-car trains. |
| | Capacity: 2,000-15,000 persons per hour per direction. |

Test facilities were constructed in 1972 and consist of a 2 km test track with two switching sections, a station, a central control post and two prototype vehicles. Tests have been underway since 1973. Engins MATRA plans to expand these facilities to provide 8 km of test track and 8 stations in 1975.

**VAL Test Vehicle at Line, France**

POik2A 2000.-The POMA 2000 was develo ed by a Grenoble firm, Pomagalski (a ski lift manufacturer) and 8reusot Loire Enterprises. A joint venture subsidiary, Societk POMA 2000, has been formed to develop and market the system. POMA 2000 uses a passive vehicle with cable propulsion—a modern version of the San Francisco cable car. However, rubber tires are used foI support and guidance, and the vehicle is automatically latched to the cable and released. In 1971 a prototype vehicle and a test track were constructed at Montmelian. In 1972 two rototy e vehicles and a 565 meter test 100 were constructed at the Pomaga Yski facilities in Grenoble. Tests witt the three vehicles since 1972 have resulted in claims that the passive vehicle and simplification of the control system offer major advantages. The ride, at 33 km/hr (20 mph) on the test track is con-



**POMA 2000 Test Facility, Grenoble, France**

sidered quiet and of high quality. Headways as low as 10 seconds appear to be feasible. This system is fully automated for on-line operations. The vehicles seat 36 with 17 to 27 standees and would operate in married pairs.

The next step in the test program will be to double track the test loop, to add a second station and to build three additional vehicles. These facilities are expected to cost about 8.5 million FFr and will be available early in 1976. Total expenditures thus far on the system are aproximately 4 million FFr. The French government has been assisting with development since 1971. Of the total expenditure, the company is allowed to provide one half, either in cash or in equivalent facihties and services. The General Commission for Scientific and Technical Research provides a loan for the other half. Repayment of this loan with a low interest rate is required only if a return is realized on future commercial sales.

VEC.-The VEC system uses passive vehicles propelled by a conveyor belt. Present vehicles seat two passengers in an open cab, but designs are available for a 4–6 seat enclosed cab with space for six standees. Technical characteristics are summarized below:

| | |
|---|---|
| Guideway... ---- | Concrete with a tubular steel rail for 1 side of the vehicle, the conveyor belt supports the other side. |
| Stations --- ------ | Station lengths determined by traffic. On-line or off-line.<br>May use a moving belt loading platform.<br>Vehicles are slowed to 1 ft/sec or stopped for loading and unloading. |
| Vehicles -- - -_ -- _ - | Propulsion is pa9sive.<br>For 2-seat vehicle passengers face outboard.<br>For an enclosed vehicle, passengers face fore and aft. |
| Propulsion ---- --- | In stations, vehicles are moved by slow conveyor belts and accelerated or decelerated by a friction wheel.<br>In line operations, vehicles are moved by a continuous conveyor belt propelled by linear induction motors. |
| **Speed** ---- -_ _ - | 10–20 mph. |
| Headways ------- | Separation is maintained by contact with conveyor belt.<br>Vehicles are allowed to bump at low relative speeds in stations.<br>2 to 6 second headways are achievable. |
| Operations ------- | Capacities: 1,800 to 21,600 passengers/hour.<br>Shuttles, loops or grids are possible. |

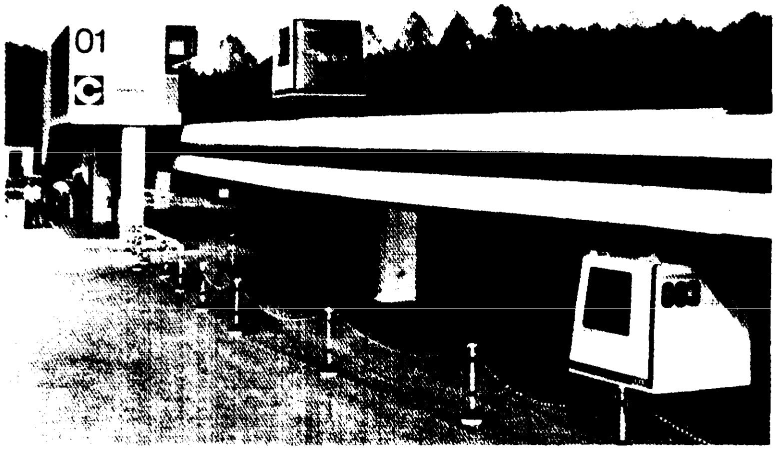

**VEC Installation in Montparnasse, Paris, France**

The system was developed with French technology by the SAVEC Company. This technology was acquired by Cytec Development, Inc. of Minneapolis, Minn.; a licensing agreement with SAVEC provides for further development with SAVE facilities and for marketing the system in France and elsewhere. Development of the system commenced in 1972. Approximately 1.4 million FFr have been expended to date, of which governmental assistance has totaled about 0.8 million FFr. The French government considers the system ready for commercial applications. It has recently issued a letter of commitment to provide financial assistance in the form of working capital up to about 1 million FFr. This letter was provided through the Ministry of Industry, Commerce and Small Business. In addition, the government is continuing with non-financial support by providing the company a place for demonstrating the system at the planned Transport Expo in 1975.

### WEST GERMANY

Development of AGT systems in West Germany began in 1970. The initiative for this development came from private industry. Participation by the Federal industry for Research and Technology commenced in 1972. The development was not ordered, rather an incentive was offered in the form of payments up to 80 percent of the cost. The remaining 20 percent was borne by private industry. Cost sharing was considered advantageous to. the governent in that only those projects would be sponsored which private industry felt could be successful, but which otherwise were too costly, or risky, to be undertaken by industry alone.

Four systems under development in West Germany are discussed below.




**Cabinentaxi Test Facility, Hagen, West Germany**

*Cabinentaxi.*— Development of Cabinentaxi was started with design studies in 1970 by DEMag-MBB (Messerschmitt-Bolkow-Blohm). Federal participation commenced in January, 1972. The objectives of this development were to provide an urban transportation system with the following characteristics:

- Small, comfortable vehicles with seats, available at stations and ready for use on demand.
- Origin-to-destination operation with no changes or intermediate stops by virtue of separate stopping tracks at the stations (no obstruction of through traffic).
- Traveling speed of at least 30 km/hr (18 mph).
- Separation of the track from road traffic, most efficiently achieved by elevated guideway structures. The flexibility of the system should permit underground installation, if required.
- Fully automatic operation of the entire system.
- Linear induction motor drive to guarantee low noise levels and no exhaust fumes.

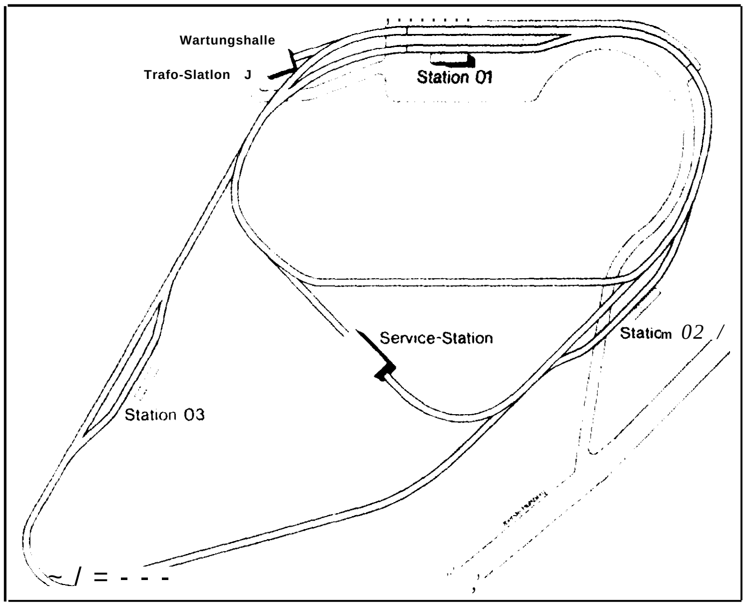



**Figure 6.—Cabinentaxi Test Track Configuration, Hagen, West Germany**
Source : DEMag-MBB, Hagen, West Germany.

System definition and laboratory experimentation on components commenced in 1972. The control system was developed and tested on a 13m diameter, rotary, test fixture during 16 months, commencing in October, 1972. The first stage of a test faclhty was completed near Hagen in August, 1973, and test operations commenced the next month. Facilities included 150 meters of double guideway (for both supported and suspended vehicles), a merge point, a passenger station and three vehicles. By October, 1974 the track had been extended to a closed 100 with two by-passes, 1136 meters long. Five vehicles, three above an two below the track, have since been undergoing operational tests. In 1975 the track will have two passenger stations, a service building, a check-out position and nine fully automatic vehicles. In October 1975 a 12-seat vehicle is planned to be introduced onto the guideway for testing. In 1976, the test facilities will be completed to form a small operating network with 1.9 km of guideway, three stations and 24 vehicles. Testing will continue through 1977, after which work will begin on a reference installation for public transport in a city. The system is expected to be put into service in 1979.

Technical characteristics for Cabinentaxi are summarized below:

| | |
|---|---|
| Guideway.. - _ --- | Box girder provides guidance and support for vehicles both under and over the girder. |
| Stations ---------- | Off-line stations spaced 0.3 to 0.8 km apart. Capacity: 1,000 vehicles/hour. |
| Vehicles_ -- _ _ ---- | 3 seated, no standees. |
| Propulsion --- ---- | 2 double-comb linear electric motors, mounted horizontally inside the box girder. |
| s eed- --- -_ ---- - | 36 km/hr (22 mph). |
| # eadways - --- --. | 0.5–1.0 seconds. |
| Operations ---- --- | For guideway 20 percent full: 5,000 veh/hr or 15,000 seat/hr. For guideway 100 percent full: 7,200 veh/hr or 21,600 seat/hr. |

Headway control is based on three factors: the vehicle's own speed, distance to the preceding vehicle and speed of the preceding vehicle. The headway is a fully asynchronous operation, monotonously increasing with speed. During tests, Cabinentaxi has achieved headways down to 0.5 seconds in the speed range of O–36 km/hr (o–22 mph).[1] Passengers have been carried at l-second headways., but only under manual control. Close-headway operational tests with all vehicles will be performed by the end of 1975.

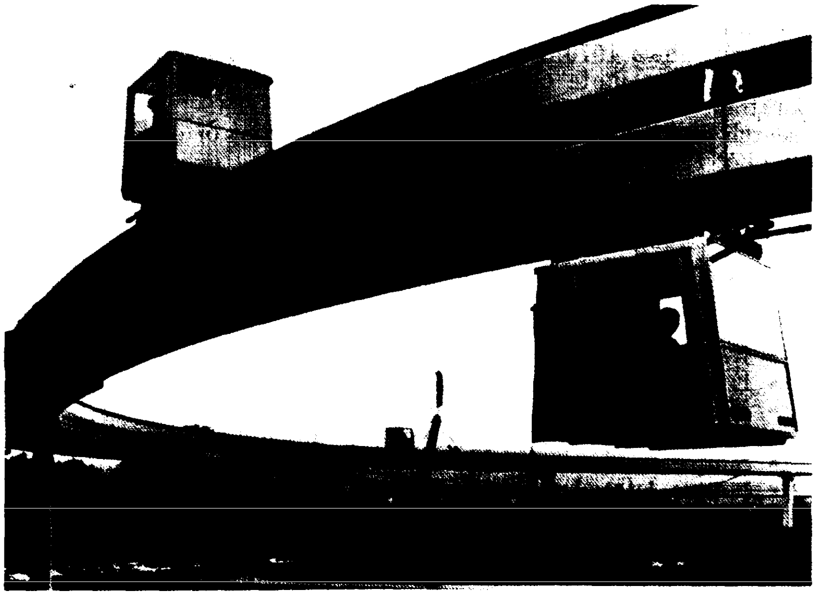
The vehicle has three independent braking systems: a linear eddy current brake, a hydraulically operated wheel brake and a mechanically operated wheel brake for standstill. Braking is at a constant deceleration. An emergency braking distance of 7 meters (23 feet) has been experimentally demonstrated.

Though Cabinentaxi operates at headways larger than the emergency braking distance, several safety measures have been taken.

- The vehicle structure will resist a brick-wall crash at full speed without loosening essential parts.
- The front side of the passenger cabin is equipped with a crash pad.
- An air bag system is under test—particularly to protect standing children.

Cabinentaxi is the most significant PRT development in West Germany. Tests of a 12-passenger vehicle indicate that GRT a plications are also being considered. The Ministry of Research and Technology has participated in the cost of development since 1 January 1972. Funds allocated by the Ministry through 1975 are estimated at about 37.3-million DM ($13.3-million).

[1] **The 0.5 second headway was attained on the 13m rotary, test fixture in Munich.**



**Cabinentaxi: Suspended and Supported Vehicles**

**Cabinentaxi: Guideway and Supporting Structures**

*Transurban.*—This system has been under development by Krauss-Maffei AG since 1970. Standard Elektrik Lorenz AG has developed the electronic remote control and surveillance system. Design and laboratory testing was sufficiently promising that the Ministry of Research and Technology began sharing the cost of development on 1 October 1971.

Magnetic attraction suspension was demonstrated with a prototype vehicle in 1972. Trade-off studles conducted by Kraus~-Maffei suggested that magnetic attractlon suspension would require less than half the power per unit weight of? repulslon system. Other advantages claimed for the magnetic suspension and guidance system were:

- No contact with the underlying surface (no wear).
- No noise or vibration emission.
- Extremely low drag resistance.
- Minimal vehicle cross section.
- No secondary suspension required (no moving parts).
- Simple track construction with wide techmcal tolerances.
- Simple infrastructure due to better load-distribution and absence of overload problems.

By displacing the armature rails with respect to the magnets for support and guidance, the system was "self centering" and required no additional guidance system. Figure 7 shows the position of linear motors, magnetic suspension and guidance units relative to the reaction and armature rails.

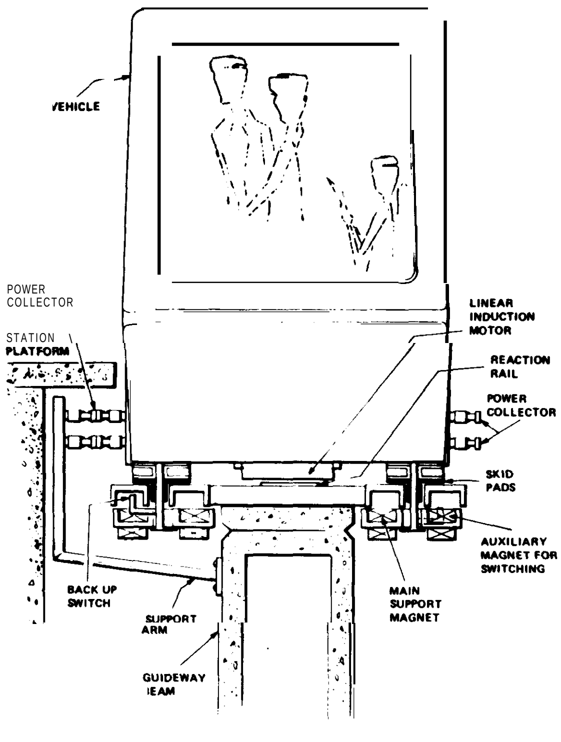


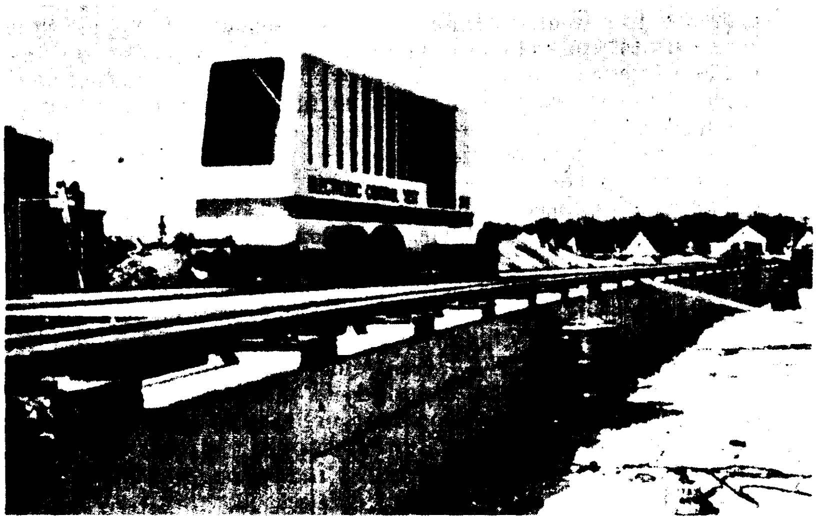

**Figure 7.-Cross Section of Transurban Vehicle**

Source : "Intermediate Capacity Transit—Ontario's Program," Ontario Ministry of Transportation and Communications ; February, 1974.

Additional characteristics of Transurban are summarized as follows:

| | |
|---|---|
| Guideway.. ----- | Reinforced concrete post and beam construction surmounted by the reaction and armature rails.<br>Radius of curvature at 12mph:30m (98ft).<br>Maximum slope: +8 percent, –15 percent.<br>Clearance for double track: Width:4.40m (14.4 ft). Height: 3.85n~ (12.6 ft).<br>Clearance for tunnels: Width: 5.00m (16.4 ft). Height: 3.85m (12.6 ft). |
| Stations- ----- _ -- | On-line or off-line. |
| Vehicle ---------- | 12 seated, 6–8standees. |
| Propulsion ------- | Single-sided linear induction motor.<br>600 v D.C, 50 kwat50 mph. |
| Speed ------------ | Nominal:45mph.<br>Maximum:50-75mph. |
| Headways ------- | At 48 km/hr (30 mph); 10 seconds.<br>At 72 km/hr (45 mph); 15 seconds. |
| Operations ______ | Vehicles would operate singly or in 5-car trains.<br>Coupling and uncoupling would be automatic.<br>Economic operations were projected at capacities of 100 to 2,000 passengers per hour per direction per vehicle. |

A ],200-meter (3,636 -foot) test track loop was completed in 1973. This track has been used primarily to test the automatic control system with two rubber-tired vehicles.



**Electronic Control Test Car and Track**

Another 600-foot test track is available for testing the prototype magnetically levitated vehicle, This track also includes a prototype of the passive switch design.

**Prototype Transurban MagLev Vehicle**

Visitors to the Krauss-Maffei test facilities who have heard and ridden the prototype vehicle have generally had two observations:

. The system is noisier than expected. Vibration of the reaction plate due to excitation from the linear induction motor produced an objectionable 50-cycle hum. This noise source could be corrected by a heavier plate or by anchoring it more securely to the supports.

. The ride has been described as "hard. " There is no secondary suspension on the vehicle. Rigid maintenance of an air gap between 10 and 25 mm (0.4-1.0 inches) gives a ride t at emphasizes any imperfections in guideway smoothness.

The German Ministry for Research and Technology allocated 31.7-million DM ($11.3-million) for Transurban development from 1 October 1971 through 1976. The project was terminated on 14 November 1974 for the reasons descrnbed in Chapter 3. Krauss-Maffei remains active in AGT development endeavors and is seeking to establish a joint venture with another supplier so that their earlier work on automated controls and linear induction propulsion can be utilized.

H-Bahn,-This system, designed with the track above the vehicle, is being developed by Siemens and DuWag with financial assistance from the Ministry for Research and Technology.

System design and component tests began m 1973. A 180-meter (590-foot) full scale switch section and tract with a prototype car have been built at the DuWag plant in Dusseldorf. Tests started in October 1974. Plans are to build a 1.5 km (4920 ft.) test track with ten vehicles at the Siemen facility in Erlangen. A one to two-year test program would start early in 1976.

Technical characteristics of H-Bahn are as follows:

| | |
|---|---|
| Guideway. _. _ - _. | Hollow steel box beam, l meter(39.4 in) deep. Slot on the bottom through which the vehicle is suspended. |
| Stations- - _ - _ ---- | On and off-line. 20-second delay for a 3-berth station. |
| Vehicles. - _ - _ - _ -- | 16-passenger maximum capacity. Two 4-abreast seats facing 8 standees in the middle. |
| Suspension ------- | Steel wheels with composite facings run on the inside bottom surface of the box beam. Lateral guidance is provided by rubber wheels which press on the vertical upper inside surface of the box beam. |
| Propulsion ------- | Two l-sided linear synchronous electric motors. Used asynchronously during acceleration and braking. |
| Controls --------- | Speed and position control determined by spacing of iron cores in the track. |
| Speed----------- | 35 km/hr (21 mph). |
| Headways ------- | 80 meters (260 feet). Based on a braking distance of 50 meters and a 7.5 meter fixed block sensing system using inductive loops in the track. |
| Operations -------- | Vehicle flow-4,50/hr. Seats—3,600/hr. |

H-Bahn is conceived as a GRT s~~stem offering demand-type service over a coarse network of lines.

The Nlinistry of Research and Technology has allocated 8.5-million DN1 ($3-million) for H-Bahn development over the period from 1 ,Januarry 1973 through 30 April 1975.

1 Kom~akfbahn.—G1onceptllnlizati{)n and design of an intermediate capacitj" AGT system by Krupp Industries and Stahlbau began in Jully 1974. Fom vehicle sizes under study are described below:

| Vehicle type | Capacity, Seated | Capacity, standing | Total | Vehicle height Meters | Vehicle height Feet | Track width Meters | Track width Feet |
|---|---|---|---|---|---|---|---|
| **AO.** | ***32*** | ***28*** | ***60*** | ***2.0*** | ***6.6*** | ***2.2*** | ***7.2*** |
| **Al, ...** | | 20 | | 2.0 | | | |
| A2. ... ... , ,, | x | | i% | 1.5 | ::: | : : : | H |
| A3. | | | 18 | | 18 1.5 | 4.9 1.3 | 4.3 |

All vehicles are 8 meters (26.2 feet) long with a minimum turn radius of 9 meters (29.5 feet), Operations me on line with vehicles run singly or in trains. Guideway's are reinforced concrete channels to guide the rubber-tired vehicles. No other technical det ails me available.

The Ministry for Research and Technology has allocated 3.4-million DM ($1 .2-million) to the project for the period 1 ,JulJ' 1974 to 30 June 1975. Plans are to condurt tests on a 1,000-meter (3,280-foot) closed loop test track at the I{rupp works, Proposecl test facilities include a switrh, passenger loading station and a varie~~- of guideway materials. Tests would begin in 1976 and be completed m 1977.

## JAPAN

The greatest interest in AGT development has been shown by the Japanese. They have imported systems from Boeing Morgantown), LTV Aerospace (AI RTRAA[T]S) and Bendix Dashave}ror). Five other SLT or GRT systems are under development by Japanese industry.

The Ministry of International Trade and Industry has sponsored development of the world's most sophisticated PRT system—CVS (Computer-controlled Vehicle System). In addition, a small dual-mode vehicle system, also called CVS, will be demonstrated at the International Ocean Exposition on Okinawa in July 1975.

The CVS developrnent is described below. Characteristics of the other systems are summarized at the end of this section.

CViS.-This PRT system has been under development in Japan since 1968. At that time preparations were made for a "traffic game" to be demonstrated at the Osaka World Exposition, which was held from March to September 1970. The demonstration in the Automobile Industries Pavilion consisted. of more than ten specially designed electric vehicles operating indlvldually under computer control on a checkerboard-like guideway network with intersections every five meters (16.4 feet). The two-seat vehicles communicated with the central computer through an underground communication channel.

Though primarily designe() as an exhibition facility, this demonstration accomplished several things, includmg:

- Development of elementary computer logic for controlling a small fleet of vehicles.
- Development of techniques for managing vehicle grade crossings on a highly integrated network of intersections.
- Assessment of public attitudes toward the use of small, tiutomated vehicles.

The basic concept for CVS was formulated in July 1970. In the autumn of 1970 work on the basic design of the system began with support of the Ministry of International Trade and Industry (MITI). Miniature models of vehicles and a glideway were constructed. A total system with 1,000 vehicles was simulated on a. large computer as the basis for preparing fundamental techmcal specflcations.

Based **on** this research, a reduced-scale experiment was preptired from April to October 1971. Cars for a network representing the central 300-meter" square area (984 feet) of the Ginza District in Tokyo. CVS cars at 1 :20 scale were operated under computer control for the public at the 18th Tokyo Motor show from 28 October to 21 November 1971. Though the velllcles and guldeway were one-twentieth scale, the computer-control system was full scale. Thus, the experiment provided an opportumt)' to exercise both the computer hardware and software for an extensive automated network system.

At the conclusion of the Tokyo Motor Show in November 1971, full-scale development of CVS began. hlITI financed construction of test facilities on the site of Japan's first automobile test track at Higashimurayarna, about 30 ,km (18 milep) wept of Tokyo. The test-track configuration is shown m the follo\\-mg diagram. An aerial view of the CVS test facilities are shown on the next page.

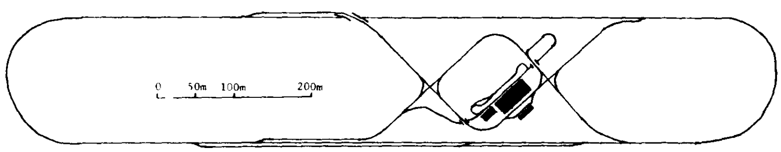
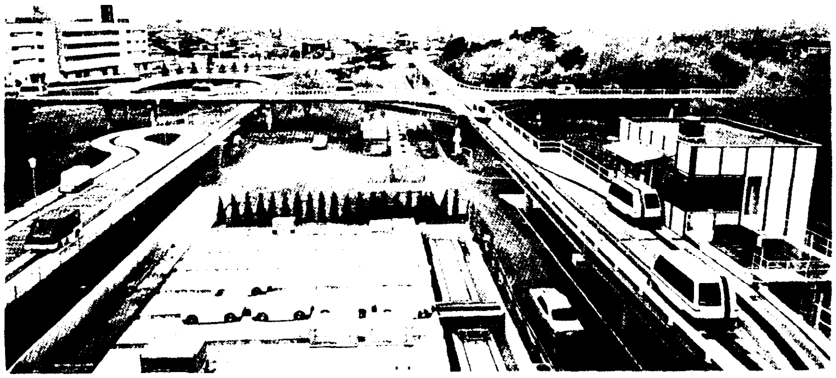



**Figure 8.—CVS Test Track Configuration, Higashimurayama Tokyo, Japan. (The maintenance area and an off-line station are shown within the 100-meter grid in the middle of the test loop.)**

The total length of the guideway is 4.8 km (2.9 miles). At the top of the diagram, 2 km of straight track permit high speed operations at 60–80 km/hr (36–48 mph). Two parallel traffic lanes at the bottom of the diagram permit, high-speed lane changing experiments. The diamond-shaped portion in the center represents the grid in a low-speed network. One side of the grid is 100 meters (328 feet) long, which is technicall~: the minimum distance betw'een stations. The test track is designed with two at-grade crossings to check performance of the vehicle control system at these intersections. The telephone-shaped track inside the grid has a circular guideway with a radius of 5 meters (16.4 feet) at both ends and is used as a maintenance mea. The control center, vehicle storage yard and passenger cargo station are below the maintenance truck. A second passenger/cargo station is located at midpoint on the upper high-speed track.



**CVS Project Experimental Center—Higashimurayama, Tokyo, Japan. (Vehicle storage in the foreground, off-line station at the right and at grade intersection at the right rear.)**

## Control System

The CVS system is controlled by a synchronous moving block system using three separate computer systems. The first one is the Hitachi computer system, which controls the vehicles high speed operation, i.e., the outer-ring (speed betw-een 40-60 knl/hr) ; the second is the Toshiba computer system controlling the low speed operation, i.e., the inner-ring (speeds below 40 km/hr) and moving blocks on the guidway; the third one is the Fujitsu computer system which functions as the supervisory computer, controlling overall SJ stem operation, and monitors the other two computer systems.

## Vehicles

While originally planned for a 100-vehicle test operation, inflation has reduced the scope to 60 vehicles, as follows:

| | Phase 1 | Phase 2 |
|---|---|---|
| **"All up" vehicles:** | | |
| Passenger | 0 | 13 |
| Cargo | o | 6 |
| **"Testbed" chassis:** | | |
| Passenger | 16 | 27 |
| Cargo | 8 | 14 |
| Total | 24 | 60 |

All vehicles have been delivered tothe site, but test operations will be scheduled over two phases discussed in a following section.

A variety of vehicle configurations are available for testing. The "all-up" versions are complete prototypes, whereas the ‘itest-bed" chassis contain only the essential propulsion, control and braking systems. Passenger vehicles generally have four seats—facing backwards for safety purposes. Standing is not permitted on automated transit s stems in Japan. Other passenger-carrying versions have forward facing seats; two of the seats can be folded to provide space for a baby carriage or hand baggage. The following photograph shows **a** CVS passenger vehicle manufactured by the Toyo Kogyo CovLtd.

The cargo vehicles are designed witha capacity of300to 400kg (660-880 pounds), and since the vehicleshaveno springs, they remain level with the cargo platform. Three versions have been observed: a flat-bed type with two conveyor belts built into the floor, a panel truck type and apostal truck type.

**CVS Passenger Vehicle**

## System Characteristics

The following is a summary of the main CVS characteristics:

| | |
|---|---|
| Guideway. _ --.-. | Steel "I" -beams for the running surface.<br>Steel sections for the guide groove containing controls and power rails.<br>Dimensions: 2m (6.6 ft) wide, 0.8m (2.6 ft) deep.<br>Span: 20-30m (66-98 ft).<br>Maximum Grade: 10 percent.<br>Minimum Radius: 5m (16.4 ft). |
| Stations- -------- | Passenger or cargo,<br>Off-line.<br>Minimum spacing: IOOm (328 ft). |
| Vehicles- -------- | 4 passengers (all seated).<br>Pneumatic rubber tires.<br>Propulsion: 200v AC motor. |
| Speed- ---------- | Normal: 40 km/hr (24 mph).<br>High Speed: 60 km/hr (36 mph).<br>~%~;i~;m: 80 km/hr (48 mph). |
| Headways.. ------ | |
| Braking --------- | Electric regenerative for high speeds—O.2 G.<br>Friction for low speeds—O.2 G and 0.5 G.<br>Emergency, explosive activated—2.O G. |
| Operations ------- | Per lane: 3,600 veh/hr 14,400 seats/hr.<br>Entrained operations are contemplated with 20 to 30 passengers/train. |

## Program Schedule

The Higashimurayama project begain in 1971 and its basic design was completed by the middle of 1972. In the autumn of the same year the maintenance guideway and the first experimental vehicle were completed. Basic driving tests under manual control commenced shortly thereafter. In the spring of 1973 basic experiments with computer control began. The full length of guideway was constructed in the autumn of 1973. At this time the second stage of experiments began, including: computer control of several vehicles, operations for passenger service at stations, control of automatic loading and unloading of freight containers, lane changing experiments and overtaking of vehicles at high speed.

Phase I of the Higashimurayama project will extend through the spring of 1976. The objective during this phase is to accumulate itemized basic experimental data. Condensed experiments will be conducted to maximize the capability of vehicles to follow the guide target. The system reliability including the reliability of mobile communications between the vehicle and the wayside computer. Phase I is intended to prove the technical practicability of CVS through item tests of components and subsystems.

Speed tests have been conducted at 60 km/hr (36 mph) and headways of five seconds have been consistently achieved at 20 to 30 km/hr (12 to 18 mph). No attempt has been made to test operations at headways close to one second. To reduce risks to equipment and vehicles, the short-headway tests will not be attempted until they can be carried out safely, sometime during Phase II.

The second phase will last several years, starting in the spring of 1976. The urpose of Phase II is to conduct a total trial of the system, with 60 veFicles operating on the test track under complete computer control. This phase will be primarily concerned with cargo operations, and will not emphasize passenger transport. Reliable and consistent one-second headways will be attempted with those vehicles designed for such operations. Phase II will also incorporate mechanisms for collision avoidance, obstacle detection/avoidance, and a 0.5 G emergency braking system.

### Observations

Those who have had an opportunity to visit Higashimurayama generally have the following observations:

- The test facilities and scope of the experimental operations are impressive.
- The three-tiered computer control system seems unnecessarily complex. The Japanese claim it was no more difficult to design the computer interfaces than a single computer system to do all the necessary functions.
- Use of an explosive-actuated emergency brake to avoid a catastrophic collision would produce a 2.0 G deceleration force. While passengers face backwards on high-backed seats to minimize the effect of such an instantaneous stop, there is concern that injuries may still occur.

### Project Management

The CVS Project is under the general direction of MITI and is sponsored by the Japan Society for the Promotion of Machine Industry (JSPMI). The Ministry has spent approximately $10 million to date on the project, mostly for the test track and related facilities. JSPMI channels funds derived from other industry associations to help fund the project.

A consortium of eight private industrial firms share in the cost and provide technical resources. These firms are:

Toyo Kog~o
Mitsubishi Jukogyo
Tokyo Shibaura Denki
Hitachi Seisakusho
Fugi~su
Sumltomo Denki Kogyo
Nippon Denki
Shm-Nihon Seitetsu

The CVS Project is managed by a team from Tokyo University and MITI.

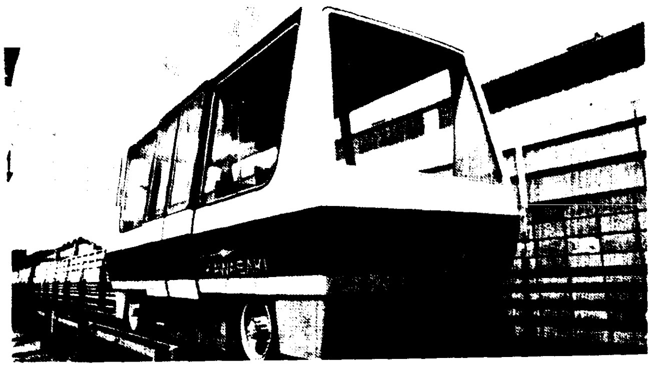
*Other Japanese A(7T Systems.*—Of the eight SLT or GRT systems under development, three are based on United States Technology. Two of these three systems—KRT (Boeing) and NTS (LTV)—are pictured on the next pa e. Vehicles for the third system, Dashaveyor (Bendix), have been sol% but not shipped to Japan. The main features of all eight systems are summarized in Table 3.

Another transit system known as “Beltica” has been developed by the Fuchu Worfis of Toshiba Electric Co. Ltd. A prototype system with 400 meters (1,312 feet) of track and one vehicle has been built and operated at the Toshiba plant. Vehicle capacity is 20 with five seated and 15 standees. The vehicle is propelled by a continuously moving rubber belt within vertical concrete guide rails. Both the car and a belt on the passenger platform move at 1.5 mph for loading and unloading. After leaving the station, the vehicle is accelerated to 15 mph by powered wheels in the guideway. Though no operator is on board the vehicle, the moving-way technology employed as well as the short distances (0.5 to 4 km, 0.3 to 2.4 mi) and high capacities (40,000 passengers per hour) preclude further assessment as an AGT system.

**JAPANESE SLT/GRT VEHICLES**

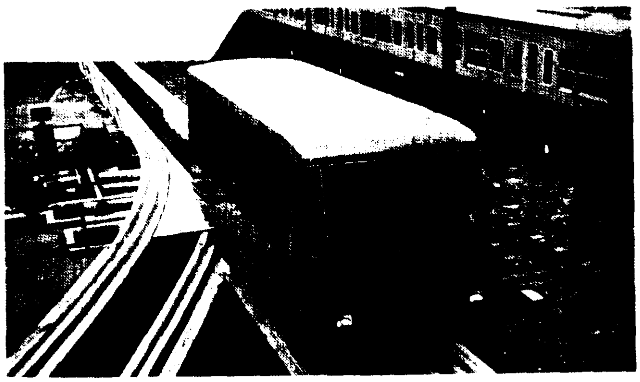

**MAT**

**Mitsubishi Heavy Industry, Ltd., 32-Passenger Vehicle**



**KCV**

**Kawasaki Heavy Industry, Ltd., 30 to 50-Passenger Vehicle**



**ParaTran**

**Hitachi 40-Passenger Vehicle**

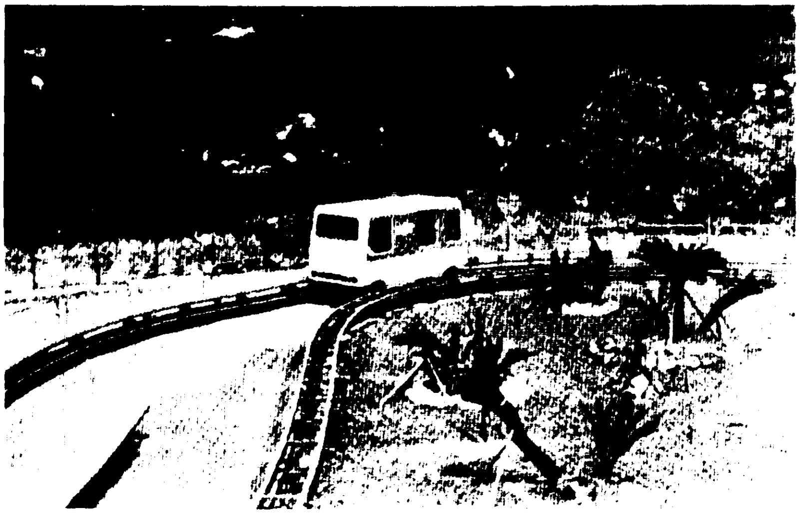
Table 3: FEATURES OF EACH SYSTEM

| | Item | KGV | NAT | Mini Monorail | NTS | Paratran | KRT | VONA | Dashaveyor |
|---|---|---|---|---|---|---|---|---|---|
| | Developer | Kawasaki Heavy Fuji Electric | Mitsubishi Industry* | Heavy Toshiba, Anzen Sakudo | Niigata Sumitomo | Tekko, Hitachi Tokyo Ele Sharyo | Kobe Steel, Nisho Iwai | Nihon Tradi Mitsui Trading | Bendix/ Dashaveyor |
| | Guideway Type | Guiding at sides | Guiding in Middle | Mounting type, Small monorail | Guiding at sides | Guiding inside or rails | Guiding at sides | Guiding in middle | Guiding at sides |
| | Development Stage | Test Track | Test Track | Design | Test track (licensing by LTV) | Test track | Licensing by Boeing | Test track (Yazu Park Oper.) | Test track Transpo 72 |
| Vehicle | Standard Capacity | (1) 50<br>(2) 30 | 32 | (3) 22<br>(4) 25<br>(5) 25 | 50 (seats 20) | 40 | 25~70 | 30 | (8) 36 (seats 12)<br>(9) 4~6 (all seated) |
| | L x W x H (m) | (1) 9.1 x 2.35 x 3.15<br>(2) 6.35 x 2.35 x 3.15 | 5.15 x 2.2 x 2.9 | (3) 7.15x2.0x2.4<br>(4) 4.5 x2.0x2.4<br>(5) 5.475x2.0x2.4 | 7.5x2.3x3.4 | 7.0x2.2x3,15 | 4.7x2.0x2.7 | (6) 5.8x20.6x3.08<br>(7) 5.3x2.06x3.06 | (8) 7.2x2.2x3.2<br>(9) 3.4x1.6x.17 |
| | Empty Height (ton) | (1) 8.5<br>(2) 4.5 | 4.5~5.0 | (3) 6.8<br>(4) 3.8<br>(5) 4.5 | 6.4 | 5.5 | 3.9 | (6) 5.5 or less<br>(7) 5.0 or less | (8) 6.5<br>(9) 1.1 |
| | Tires | 4 Rubber Tires | 4 Rubber Tires | 4 Rubber Tires | 4 rubber tires | 8 rubber tires | 4 robber tires | 4 rubber tires | 4 rubber tires |
| Power | Voltage | 3∅ AC 440/400V | 3∅ 550V | 3∅ A C 440/400V | 3∅ A C 440/400V | 3∅ 440/400V | AC 600V | DC 600V | (8) AC 3.09<br>(9) DC 480V |
| | Traction Motors | (1) 50~65kw x<br>(2) 50~65kw x 1 | 265 kw | 45 kw | 50~70 KW | 55 KW | 75PS | 55 KW | (8) 30 Ps x 2<br>(9) 15 PS x 2 |
| Perform | Max. Speed (kmph) | 75/45 | 60/36 | 60/36 | 60/36 | 60/36 | 64/38 | 60/36 | (8) 65139<br>(9) 48129 |
| | Max. Grade (X) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| | Min. Turning (m/ft) | (1) 20/66<br>(2) 12/39 | 10/33 | 15/49 | 25182 | 30/98 | 9/30 | 20/66 | (8) 23/75<br>(9) 6/20 |
| Guideway | Beam Material | Steel or Concrete | I Steel | Box Steel | Concrete | Concrete | Steel or concrete | I - steel | Concrete or Steel |
| | Standard Span (m/ft) | 15/49 | 15/49 | 20/66 | 20/66 | 15/49 | 15149 | 10-17/33-56 | (8) 15/49<br>(9) 251S2 |
| | Post Material | Steel pipe or concrete | Steel pipe or concrete | Steel | Concrete | Steel pipe or concrete | Steel | Steel pipe | Steel or concrete |
| | Stitching | Vertical | Rotating (180") | Horizontal | Switching blade | Block type | On Board Type | Horizontal Swing | (8) Vertical<br>(9) Horizontal |
| | Switching Time (sec) | | 6 | 8 | 3 | 4 | 1.2 | 5 | (8) 4<br>(9) 1 |
| Operation | Control | central, automatic & Floating | Central, automatic & Floating | Central, automatic & Floating | central, automatic & floating | central, automatic & floating | Central, automatic & | central, auto-floating | Central, automatic & floating |
| | Min. Headway (see) | | 90 | 120 | 20 | 90 | 10 | 90 | (8) 15, (9) 5-8 |
| | Max. capacity (Psn/hr) | (1) 28&2<br>(2) 17,000 | 20,000 | 12,000 | 20,000 | 19,000 | 16,000 | 19,000 | (8) 21,000<br>(9) 5,000 |
| | Notes: | (1): KCV-12<br>(2): KCV-13 | *Mitsubishi Electric Mitsubishi Trading | (1): front car<br>(2): middle car<br>(3): rear car | *Toyo Electric Sumitomo Trading | | | (6): front car<br>(7): following car | (8): GRT<br>(9): PRT |

Source: Handling Tomorrow's Transportation Today: The New Transportation System; Japan Transportation Planning Association.

**EXAMPLES OF U.S. TECHNOLOGY USED IN JAPAN**

**Test Track built by LTV Licensees, Niigata Engineering Co. and Sumitomo Shoji Kaisha, Ltd.**



**Kobe Rapid Transit (KRT) System for Expo '75 on Okinawa. Built by Kobe Steel, Ltd. in cooperation with Boeing Aerospace Co.**

## Chapter 5: -Acquisition Procedures

The development and deployment of new transportation systems, such as A GT, depend upon the institutional and financial procedures available in the sponsorin$_g$ countries. The days are long gone when a priviate inventor or entrepreneur could muster enough cspital and political license to build an innovative transportation system in the expectation that fares would realize a profit on the scheme. The success of transportation innovation depends on government involvement, industry incentives and institutional-political considerations which establish the climate for innovation.

### GOVERNMENT INVOLVEMENT

Policies and procedures adopted by federal and local governments have a msjor effect on the realization of new system concepts. Policies on sponsoring and funding, proprietary rights, contracting procedures for both development and construction, and continuity of support influence the outcome of such efforts. Government involvement can set the pace for innovation or can interfere with attempts to do so.

### SPONSORING AND FUNDING

#### Research and Development

The derision to sponsor and fund R & D for AGT systems development recognizes the need for transportation alternatives beyond the capability of local governments or any one industrial compsny. Federal goverm\nment financial involvement absorbs some or all of the risks and provides an incentive for development of AGT alternatives. The opportunities for exporting systems has also figured in decisions to sponsor and fund AGT system development. CVS development in Japan is under the general direction of the Ministry of International Trade and Industry (MITT), not by the Ministries of Transportation and Construction who would normally have responsibilities for installations of such a system. In England, the Programmes Analysis Unit, a joint unit of the Department of Industry and United Kingdom Atomic Energy Authority, completed a study, in 1974 of the likely export market for systems developed in the United Kingdom. Recent endeavors to establish licensing agreements reinforce the idea that foreign decisions to sponsor and fund AGT system development recognize the potential world-wide export market.

In England, AGT hardware development has been 100 percent funded by the Department of the Environment. The work has been accomplished through the government research establishments in the belief this procedure produces the most robust results. Functional specifications for hardware performance have been drawn up by external consultants under contract to either local or national government bodies. Propositions from the small companies can be presented to the government and to the National Research and Development Corporation for funding. No recent transit proposals have been worthy of support by these means.

The French government uses a variety of techniques, many similar to those employed in the United States, to stimulate industry and university laboratories to engage in the research, development and commercialization of new systems. Some techniques act directly. Examples are loans, grants and reimbursable advances. Others have an indirect effect, with examples being tax policies and measures to stimulate the creation of private venture capital.

The following techniques are worthy of particular note because they tire not presently practiced at all or to the same degree in the United States.

*Reimbursable* Advances.—In the development stage of new systems, when the developer must invest in expensive prototype hardware and software, the government and the company enter into a shared-cost contract based upon the estimated total cost for the project. Typically, the government agrees to provide a 50 percent cash advance, payable periodically at pre-determined dates. The company agrees to generate the balance during the term of the project in my form accountable on the company's books. The government allows the company to possess the proprietary rights to the system and to commercialize it; however, the company must agree to the following:

- To pay a royalty (typically about 2 percent) on the value, less taxes, of each commercial sale of the system.
- To pay a royalty (typically as much as 30 percent) of royalties received from third parties who sell the system under lcenses from the company.
- To continue to pay royalties to the government until the government's cash advance, plus interest (at a rate established in the contract), has been fully repaid,

If the first phase has gone well, and If the system prototype is in good running order, the government will increase the share of financing for subsequent phases.

*Assistance to Inventors.—A* special agency of the French government, the National Office for Dissemination of Research (ANVAR), was established in July 1968 to stimulate invention. It provides several kinds of assistance. It can make, for example, small financial advances that me reimbursable in amounts and according to a schedule which is a function of revenues from future sales. It can also establish a special entity to assist the inventor in bringing the invention to the status of commercial exploitation. In addition, it can make available up to a maximum of 20 percent of the capital of an existing company to help strengthen its capability to adopt the invention.

In contrast to practices in other countries, the Federal German Ministry for Research and Technology has not ordered AGT developments, but pays 80 percent of the development costs. The remaining 20 percent must be borne by the developing companies. This cost-sharing is to the advantage of the government in that only those projects are furthered which are liable to succeed but which are too expensive for industry alone.

The sponsored development is carefully controlled by:

- Critical discussions in annual status seminaries, during which the development team has to present their results and further Planning in the presence of their competitors.
- independent experts.
- A project monitor, who controls critical cost, time and work schedules.

The Ministry for Research and Technology, however, leaves the entire power of decision and complete responsibility for the direction of development to the developing industry. The Ministry neither directly nor indirectly participates in the development and does not give technical directions. In this way, the expenses of governmental administration are minimized and the developing industry can react very flexibly to altered circumstances.

## Construction

Procedures for financing the construction of AGT systems also vary among foreign countries. In Jap)an, the government (princi])all~' the Ministry of Construction) could finance up to 50 percent of the cost. This share would cover the fixed facilities considered part of the road and street network. The source of these funds would be gasoline tax relenues. The remaining costs would be divided between the local government or municipality, and the operating agency. The operating agency would collect revenues, meet operating? financing and depreciation costs, and retain any profits. The Ministry of Construction appears to favor ownership and operation by a governmental agency. The Ministry of Transportation seems to favor private owner operations and is considering procedures whereby a private operator could be loaned funds for system development and installation. After acceptance test approval, the Ministry of Transportation would no longer be involved in system operations.

Procedures are similar in West Germany, except that federal and state (lander) governments would finance up to 80 percent of the fixed facilities. The federal share would be 60 percent and the state would provide 20 percent. The municipality would cover the remaining 20 percent of the fixed instillation and 100 percent of the vehicle costs.

In France, the government can provide up to 50 percent of the capital costs for public transport. Most important, it will finance up to 70 percent if new technology systems are being introduced. A law introtuced in July 1973 permits the local share to be derived from a salary' tax imposed on emplo~-ers of more than nine people in an urban area. with a population of more than **300,000.** In special cases, even smaller towns qllalify.

In the Unite(l King(lom, allocation of funds for the requisition of a transit s~wtem is made through the Transportation Polic~- and Programme proced~we. Each ~"ear each county (state) prepares a document, the "TPP", which states its policy intentions to allocate its transport funds over the next five ~'ears. A district counci] and county council would have to agree to i~corporate an AGT system for the town in the TPP. The Secretary of State for the En~Tironment, on the basis of the total set of TTPs submitted, and the amount of money avadable, allocutes funds to the local governments through a Transport Supplementary Grant.

## PROPRIETARY RIGHTS

Foreign governments differ with the United States government in their treatment of data and patents considered proprietary by system developers. Though foreign government funds are used to reduce concepts to operating prototypes and to develop and test new systems, the proprietary rights remain with the foreign private developer. In France, even the prototype hardware and software belongs to the company, except that if the company fails to achieve a commercial success with the system, the prototypes may revert to the government. Furthermore, the government must wait at least 12 months before releasing data or other information about the system to any third parties and may be limited beyond 12 months from releasing information considered to be company-confidential. In ,Japan, patent rights stemming from CVS development are jointly owned by the Japan Society for the Promotion of Machine Industry and the eight participating enterprises.

In the United States, R & D accomplished with Federal funds generally requires the relinquishment of proprietary rights. While the specific requirements vary with contract negotiations, the general implication is that United States developers are at a disadvantage in terms of exploiting new developments. (This subject is discussed in greater detail in Chapter 3, Volume 1).

## CONTRACTING PROCEDURES

### Research and Development

Foreign R & D depends to a greater degree on private initiatives than it does in the United States. As mentioned above, initiatives for AGT development in Germany originate with private industry. In France, development occurs in collaboration with both a system supplier and another transport agency or government body. Sole-source contracts are used extensively, but there are exceptions. The development of VAL, in conjunction with the new French town of Lille-Est, responded to a competition based on a request for proposals initiated by EPALE, the local public planning authority.

Sole-source development contracts arc considered advantageous in that the costs of preparing competing proposals are eliminated. There is believed to be a greater commitment to achieve company motivated performance than to satisfy system specifications drawn up by others. The disadvantages to sole-source contracts are that costs may not be the lowest for comparable effort and potential sources may be excluded from the development. Nevertheless, officials in England, France and Germany consider that their present R & D programs embrace the systems worthy of development.

AGT development procedures in England most nearly match those in the United States. The Department of the Environment, which has responsibility for transportation planning, construction and operations in the United Kingdom, initiated development of the Minitram system through a field agency, the Transport and Road Research Laboratory, Competitive feasibility studies for hardware concepts htive been undertaken. In addition, the laborator~~ has commissioned detailed planning, engineering and operating feasibility studies for a demonstration system in Sheffield. The resulting report, *Minitram in Shefield*, was published in October ]974. The Department of the Environment must be satisfied with the technical feasibility of the project. The Sheffield metropolitan District Council must decide whether to participate in the demonstration project.

The practice of planning demonstration installations in parallel with technical development is used in most foreign countries. This procedure has not been commonly used in the United States. The main advantages in the practice are that hardware development is conditioned by the realities of feasible deployment and planning is kept pragmatic by the realities of achievable system designs. The disadvantagc is that technical development could be curtailed if city officials disapprove a demonstration installation.

## Construction

Actual construction of operating AGT systems abroad has not been sufficient to assess differences in constructlon contracting procedures. However, various procedures have been considered and the Panel on International Developments considered it important to include a discussion of the significant procedures in this report.

*Public works contracts.-~lost* public agencies prefer, or are required by law, to acquire facilities through typical public works contracting procedures. Under these procedures, plans and specifications are prepared for various elements of a transit system, competitively advertised and awarded to the lowest price, responsible, and responsive bidder.

Tile public agency administers and inspects the construction and installation as lt progresses.

### ADVANTAGES

- The procedure is well-known; contract administration would be straightforward.
- Maximum competition could be achieved with some opportunities for small local contracting firms.

### DISADVANTAGES

- There is no standardization of AGT technology. Standardization would prematurely preclude competition among s~'stem suppliers. The lack of standardization makes difficult the engineering design and construction of fixed facilities through public w'orks contracting procedures.
- The guideways represent 50 to 70 percent of the cost of an AGT installation. Separation of this clement and other fixed facilities may ]eavc a vehicle supplier with 10 to 20 percent of the project funds, but with most of the exposure for success or failure of the system.
- Public agencies have little capability or experience in the integration management of such a system. This service can be performed by a consultant organization, hilt the illtimate responsibility for the performance and satisfactory operation of the system rests with the vehic]e supplier. however, uncler

typical public works contracting procedures the vehicle supplier has virtually no authority over features that would interface with the vehicle, such as: guideway configuration, power rails, automatic control system.

*Systems Integration Management.*—Under this procedure the public agency retains a non-hardware, consulting engineering organization, to plan, design, and prepare bidding documents for the AGT installation. The consultant would be responsible for managing the integration of all elements of the system, reviewing the technical adequacy and prices of proposals, and would supervise the installation. The public agency would control funds, advertise and award contracts.

**ADVANTAGES**

- A qualified organization can provide special competence not normally available in the public agency.
- Interface problems are minimized and can readily be resolved when they occur.
- Maximum competition is preserved.
- The technique has been successfully used in space, defense and rail rapid transit programs.

DISADVANTAGES

- The total project cost may be increased, but this cost is likely to be far less than the overruns resulting from the lack of integration management.
- There are few non-hardware firms with extensive experience in managing the installation of AGT systems.

*Turn-Key* Contracts. -Under these procedures, the public agency would complete all preliminary engineering, including foundation analyses, site surveying, locating underground utilities, right-of-way acquisition, and make this data available m the bid-reformation package. A system supplier is selected from competitive proposals responsive to a performance specification, and would be responsible for the final engineering, system integration management, construction, vehicle fabrication and pre-acceptance system testing. The system supplier is responsible and has authority for the scope of the work—he is held accountable to a public agency for performance of the system within agreed upon costs and time schedules.

**ADVANTAGES**

- The vehicle supplier, with the greatest technical knowledge of his system, has responsibility for satisfactory performance.
- Competition among system suppliers is preserved, avoiding a premature rejection of alternatives.
- The vehicle supplier can make the most cost-effective tradeoffs on such features as ride comfort involving guideway roughness and vehicle suspension.

DISADVANTAGES

- While there is competition among suppliers, and subcontracts for certain features (guideways) could be competitively awarded, other elements would be proprietary to the system and may not be bid.

- This procedure can be the most costly since the vehicle supplier is performing the integration management and would base his profits and overhead on the total project cost.
- Most system suppliers have had only limited experience in managing construction contracts.

## CONTINUITY OF SUPPORT

A long-range commitment to a development project is necessary if there is to be a reasonable chance for success. Appropriate check points should be included in a development plan to review progress and to determine whether to proceed or terminate, but these check points may not coincide with the start-stop cycle of fiscal year appropriations. Continuity of support for development programs abroad depends on the way some foreign governments are organized.

In Germany and Japan, technical development of AGT systems tends to be separated from agencies having responsibility for construction and operation of revenue systems. The German Ministry for Research and Technology undertakes development through test operations of prototype systems The Ministry of Transportation budgets funds for urban demonstration and revenue installations. The Japanese Ministry of International Trade and Industry manages the long-range development of CVS while the Ministries of Construction and Transportation share responsibilities for installation and operation of available AGT systems. Such separations have the advantage in that competition for resources to solve immediate transportation problems is avoided, at least within one ministry. The arrangement has two major disadvantages. Organizations responsible for the eventual installation and operation of the new systems are not involved in their development. Planning considerations may not be adequately addressed, unless parallel studies are undertaken, as described above.

The continuity of support is provided by other means. In Germany, the Ministry for Research and Technology has established a program through 1978 with a budget of 350-million DM ($125-million). Development of AGT systems is a major part of this program. In France, the government's current five year plan makes a commitment to commercial experiments with AGT systems in medium-sized towns. Grants are available for R & D. This form of government planning and commitment has encouraged the early marriage of a system supplier and local municipality described in Chapter 3.

## INDUSTRY INCENTIVES

Most foreign AGT system development has been initiated by private industry. For many of the developers this endeavor was regarded as a logical expansion of traditional transit supply activities or diversification from military and aerospace production. While governments have encouraged AGT development, private firms were expected to independently develop a potential product before government support was made available.

For those industries which have taken the initiative in supporting initial development and are willing to share costs up to system commercialization, a variety of incentives are available.

*Costg sharing.—As* discussed above, governments may reimburse from 50 to 80 percent, or even 100 percent, of the development costs. As the Krauss-Maffei experience with Transurban indicated, government support is not interminable. However, foreign developers can expect consistent government cost sharing throughout the life of the project. This practice contrasts with typica] United States procedures which establish ceilings on the amount of financial support with no relief from full contractual obligations.

*Recouery of costs.*—As is the practice with R & D procurement contracts in the United States, foreign development also requires the payment of royalties to recover the government share of costs. However, these royalties may be reduced if a lower rate would help the company win an export sale in a competition. Furthermore, the recovery of cost provisions are regarded as an incentive for commercialization. Government agencies in France, Germany. and Japan actively participate in endeavors to achieve the commercial success of systems at home and abroad.

*Insurance against loss.*—A technique used by France in other areas of transportation which may be applied in the AGT market is a government guarantee against loss in the marketplace. This protection is made available to stimulate a company to invest in production facilities and marketing activities when the product is socially desirable but is risky to commercialize, In effect, the government guarantees the company a minimum financial return sufficient to cover the company break-even costs. The measure is the difference between actual sales and the company's break-even point if the actual sales generate a lower value.

## INSTITUTIONAL AND POLITICAL CONSIDERATIONS

There are differences in foreign institutional and political arrangements for sponsoring the acquisition of AGT systems which offer both advantages and disadvantages in comparison with procedures in the United States. Since there are no AGT installations abroad which compare with those made in the United States it is too early to judge the effectiveness of the foreign institutional and political arrangements. However, to the extent that United States practices are found wanting, foreign procedures are worth~" of consideration.

### COOPERATION BETWEEN SYSTEM MANUFACTURERS AN-D LOCAL GOVERNMENTS

Concurrent system development and planning is fostered through the close cooperation of manufacturers and local governments. System developers in Germany and Japan have been involved in detailed planning studies for the installation and operation of their systems. This cooperation has aided the developer in defining development requirements. It has also helped the public agency in evaluating alternative solutions to local transportation problems. So far as is known, this cooperation has not resulted in commitments for engineering design. or construction of an AGT installation in Germany.

In France, local governments are encouraged to initiate innovative transit solutions. Contractual arrangements with a system supplier define the scope of activities relatlve to planning and pricing the installation. Negotiations lead to early decisions concerning the type of system to be installed, the scope and staging of the project. Projects which have national interest and are consistent with the government's five-year plan become eligible for financing from various ministries having cognizance of land use, regional development, transportation and public works. The project is managed by representatives from these ministries in addition to officials from the local and regional planning agencies and transit operating authority.

The main advantage to early cooperation between supplier and local government is that planning tends to be more pragmatic. The system manufacturer becomes aware of performance requirements which must be achieved through his development programs. Local planners can incorporate specific system characteristics rather than leave them unresolved until a final system choice is made. Early involvement of a system supplier has other advantages. The cost of preparing and evaluating competitive proposals is avoided. The developer is encouraged to proceed with confidence that if there is to be a commercial installation, it will be his, thus assuring a return on his development investments. Government participation in the project will underwrite the supplier's development costs. One successful installation will enable a system supplier to write off costs for preproduction engineering and tooling.

There are disadvantages to such a cooperative arrangement. System selection may be based on entrepreneurial influence without an objective evalutaon of potentially- more competent systems. Without price competition, obtaining the least costly installation becomes much more difficult. If parallel development IS not successful, some planning efforts could be wasted and installation would be delayed.

## GOVERXIIENT-INDUSTRY COOPERATION

While llnprecedented in the United States, government-industr~' ronsortia nre w-idel~" used thmughollt Europe and Japan as a means to accomplish research nnd development an(l to penetrate the commercial market. In German?'j L'abinentaxi development is being accomplished throllgh a joint ventllre involving DE31ACI Forclertechnik and 31essers{:hrnitt-Bf) lko\~~-BlohIll GInbH. in Japan a consortitlm of eight Pril'ate inC{11strie5, ~ tra(]e associ ll tion, tl~e ~~niversit~' of '1'ok~'o and the hl inistr~- of Int erntit ional Trade and Industrj- me cooperating on the development, find the test facilities for tl~e Compllter-controlled l'chicle S~wtem (L'J'TS). The ~~inistr~ of Construction in Japan has organized an ~lll tolna teC l (]lla l-nloc~e blls developtnent group involving 17 private enterprises. The total cost of this latter pro~oect is estimated at nbout $5.5 -nlillion; abotlt one-fourth of the cost WI1l be subsidized by the l[inistr~' of (.'onstr~lction.

While a consortium is cliffiiclllt to manage, the arrangement has several advantages:

- The best talent of industr~ specialties can be concentrated on a particular development project.
- ,Scarce resources, inc]uding personnel, capital and facilities, can be conscr~'ed b~- aloiding competition between participants.
- Go ~"ernnlent expend it ures are reduced through cost sharing with industrl.

. Because the government is a participant, there is mutual interest in commercialization of the product. Both the government and industry stand to get a return on the initial investments.
. To strengthen the price advantage of the consortium in an initial foreign competition, the government can waive the recovery of cost provisions for the industry participants.

These advantages, available to foreign AGT system developers, have placed United States manufacturers at a competitive disadvantage.

GOVERNIIENT CORPORATION

Government corporations have been established for conducting R & D and for managing the commercialization of results. In the United Kingdom, the National Research and Development Corporation was set up by the government to invest in new technological development with a responsibility for breakin even in its operation "taking one year with another". In July 1973, tie Province of Ontario, Canada, established an Urban Transportation Development Corporation (UTDC). Other provinces and the Canadian Federal government are expected to become share-holders in this corporation.

The objectives of the Corporation are to:

. Acquire, develop, adapt, use and license patents, inventions, desi ns and systems for all or any part of transit systems relatei to public transportation and rights and interests therein or thereto.
. Encourage and assist in the creation, development and diversification of Canadian businesses, resources, properties and research facilities related to public transportation.
. Undertake the design, development, construction, testing, operation, manufacture and sale of all or any part of transit systems related to public transportation.
. Test or operate and provide services and facilities for all or any part of transit systems related to public transportation and in connection therewith build, establish, maintain and operate, in Ontario or elsewhere, alone or in conjunction with others, either on its own behalf or as agent for others, all services and facilities expedient or useful for such purposes, using and adapting any improvement or invention for any means of public transortation.
. .Ganufacture vehicles and control, propulsion and guideway systems and their appurtenances and other instruments and plant used in connection with transit systems related to public transportation as the Corporation may consider advisable and acquire, purchase, sell, license or lease the same and rights relating thereto, and build, establish, construct, acquire, lease, maintain, operate, sell or let all or any part of transit systems related to public transportation in Ontario or elsewhere.
. Carry on any other trade or business that, in the opinion of the Board, can be carried on advantageously by the corporation in connection with or as ancillary to the carrying out of the objectives of the Corporation set out above.

The goal of UTDC is to improve the quality of urban life through innovations in transit. The company operates as a private, for-profit, corporation with a management team and a board of directors representing a broad cross-section of private and public interests. Technical and management staff within the corporation are directly engaged in immediate and long-range development of transit concepts, products and systems. In addition UTDC retains the assistance of consultants from Canadian universities and industry.

In addition to the development and demonstration of an AGT system, UTDC has inaugurated development of a small bus and a light rail vehicle. Originally designed for dial-a-bus service, the small bus is being configured to accommodate handicapped persons in wheel chairs. The light rail vehicle will incorporate the most modern technology available for Canadian operating requirements.

Establishment of the UTDC required the government to appropriate a $6 million working fund and to delegate authority to enter mto specific kinds of contracts. Once estabhshed, the UTDC is expected to proceed with developing and marketing new transportation systems, depending upon the cash flow from these operations to preclude the need for extensive additional government aid. This independence provides continuity. to development programs since they are not subject to fluctuations m annual appropriations.

## Chapter 6: Findings and Summary

Significant finding: from this assessment of foreign AGT develop--merit are summarized as follows:

- Foreign technical developments are more ambitious than those in the United States. Actual technical accomplishments are comparable at present but foreign developments will surpass those in the United States by 1979 if all present programs are carried out as planned.
- No nation has an ideal organizational arrangement for the development and deployment of AGT systems. France appears to use one of the best procedures but the lack of any actual revenue installations makes judgment difficult at this time. All other countries, including the United States, have a serious gap between programs to develop and test AGT systems and programs to install and operate AGT systems in revenue service.
- Foreign developments are focused on the solution of urban transportation problems. There are no foreign deployments comparable to those in the United States, but those being planned will provide transit in urban areas in contrast to the highly specialized areas served by United States systems.
- Foreign development procedures offer potential system suppliers many advantages not available to United States developers.
- Other institutional arrangements for the development and deployment of AGT systems are worthy of consideration. Alternatives such as a national development corporation or a consortium of cities and industries merit serious consideration.
- Licensing arrangements which export and import foreign technology are Proliferating. Whether market expansion will make these agreements 'worthwhile-remains to be seen.

International developments of AGT systems are earnest. They are focused on meeting anticipated deficiencies in existing transit systems and providing alternatives to increasing dependence on the automobile with its attendant problems of congestion and use of petroleum fuel. Foreign developments also have an eye on a potential United States market and within four years will be able to offer AGT systems more attractive than an~' under development in the United States at present.

### SUMMARY

An assessment of foreign development can be summarized as follows:

. Technical development is comparable to that which has been achieved in the United States. There are differences in specific accomplishments:

The United States lags by about four years in the acquisition of test facilities comparable to those of the Japanese for CVS or the Germans for Cabinentaxi. However, no foreign deployments of AGT systems have been made which are comparable to the airport installations in Tampa, Sea~tle.-Tacoma, and Dallas/Ft. Worth, or to Morgantown, West Vwgnua.

Development goals for the foreign systems are generally more ambitious than those in the United States. For example:

| | Foreign | United States |
|---|---|---|
| Headways | 1.0 second and less. | 3.0 seconds. |
| l-way line capacities (seats per hour). | 16,000 (maximum). | 14,400 (maximum). |
| Velocities (miles per hour): | | |
| Maximum | 22.4 to 50. | 40 to 55. |
| Cruise. | 22.4 to 37. | 16 to 40. |

The state-of-the-art in braking, propulsion and control technology is approximately the same for both United States and foreign developments. Thus, there are less risks in achieving the 6nited States goals than there are for the foreign programs.

- Differences in the way foreign governments are organized to sponsor AGT system development offer both advantages and disadvantages in comparison with United States procedures:

In Germany and Japan, technical development of AGT systems tends to be separated from agencies having responsibility for construction and operation of revenue systems. This separation has an advantage in that it tends to insure continuity of development by avoiding competition for resources to solve immediate transportation problems. Such separation has a disadvantage in that system development tends to be aloof from the problems of deployment. In both Germany and Japan, the system developers have been involved in planning large urban AGT networks. However, this planning has been more concerned ~vith defining development efforts than with planning the actual installatlon and operation of a system.

In France, AGT development has generally been initiated by local governments in conjunction with a hardware supplier. This arrangement leads to early decisions as to the type of system to be incorporated in the local transportation improvement program. If the planned development is of national interest, financial assistance can be made available from various ministries having cognizance of land use, regional development, transportation and public works. Representatives of local and regional planning and operating agencies, in addition to representatives from these ministries, participate in management of the project. One advantage to this arrangement is that planning tends to be more pragmatic with early heavy involvement of a specific system supplier. Another advantage is that market uncertainties are reduced through commitments to a supplier that his system, if any, will be installed. Once the hardware decision is made, wasteful competition is eliminated. This arrangement has disadvantages. System selection may be based on entrepreneurial prowess. Absence of price competition may not produce the least costly installation. It is too early to judge whether this management procedure offers the best solutions to both the technical and implementation problems of an AGT system.

AGT development procedures in England most nearly match those in the United States. The one ministry having cognizance of transportation planning, construction and operations is sponsoring AGT development through a field laboratory. The laboratory- has sponsored detailed planning studies for a demonstration installation, but—as in the United States—the city selected will have the final say as to whether it will host the project. This procedure has the advantage of keeping a focus on the realities of eventual deployment. The disadvantage is that technical development may be truncated if a city demonstration is not forthcoming.

- Deployments of AGT systems in the United States have been in hlghll- specialized areas-parks, airports, commercial developments and a university campus. NO comparable instillations have been built overseas. As mentioned above, foreign planning for large-scale networks has been associate(l wltb definition of harware requirements. Planning for actual deplo~ment is limited to SLT or GRT systems of modest scope. m le significant difference is that concrete planning for foreign installations is predominantly for urban, rather than special uses. Though installations at airports ancl medical centers are contempltitecl, principal applications are as follows:

  ~ew towns or residential complexes near existing cities would be served with SLT or GRT s~-stems to provide some internal service and to connect these towns to existing rail lines in the adjacent cit,~-.

  ,Sorne existing older t owms have experienced population growth tind increased automobile usage. ll~here the resulting traffic congestion and decline in transit usage is not readil~~ correctable b~" conventional means, national governments have encour~gecl innovation with AGT systems. Either SLT or GRT s]:stems would augment existing transit service and open up possibilities for auto-free, pedestrian malls served b~- the new transit s~-stem.

- Foreign ;}-stem developers frequently have an advantage over their Umted States counterparts. Preelection through noncompetitive procedures is common (France). Consortia of several industries are fostered b~" the national governments to develop ~~ particular concept (Germtin~' and Japan). Private capital ma~- sponsor research and development through the concept stage. If the concept is found attractive, the government can offer nltin~" incentives for protot)pe development and testing, including:

  Cost sharing with a 50 percent cash advance.

  Compan~' retention of proprietary rights for commercialization with payment of modest royalties.

  Companyt retention of hardware, software and data rights. Government financial support for a local development and demonstration project virtuall~~ insures the company against losses for investments in production facilities and engmeerin~. This insurance is a strong incentive for a developer to explolt his system commercially. Successful commercialization is an advantage to the government since royalties are paid to the government until the initial cash advances, with interest, are fully repaid. Thus, the government is motivated to encourage adoption of new systems to secure a return of the investment in the initial development.

. Other institutional arrangements for developing AGT systems are worth noting.

The Ontario government in Canada has established an Urban Transportation Development Corporation (UTDC). The Canadian government, as well as other provincial governments, me expected to participate in the development programs. The role of this corporation is to:

Coordinate and promote the development of advanced technology of all types relating to public transit and to integrate this development with the design and production of conventional transit facilities.

Fund research in transit innovations in intermediate capacity systems and others.

Market systems through the private sector in Ontario and Canada.

Under the Government of Ontario, the UTDC has authority to:

Acquire and hold license rights for Canadian and foreign developments pursuant to contracts for present and future related technology.

Retain patents and industrial property for system applications in Canada.

Develop an export market from which it would receive a percentage of royalty income.

Sublicense companies in Canada for the manufacture and sale of complete transit systems, subsystems, and components.

Establishment of the UTDC required the government to appropriate a $6-million working fund and to delegate authority to enter into specific kinds of contracts. Once established, the UTDC is expected to proceed with developing and marketing systems, such as AGT, depending upon the cash flow from these operations to preclude the need for extensive additional government aid. This independence provides continuity to development programs since they are not subject to fluctuations in annual appropriations. There are precedents in the United States for similar institutional arrangements in the establishment of the Communications Satellite Corporation and passage of the Solar Heating and Cooling Demonstration Act of 1974.

Institutional arrangements used in Japan for development of CVS are somewhat more complex. The project is under the general direction of the Ministry of International Trade and Industry (MITI), which provided the test facilities at Japan's first automobile proving grounds in Higashimuryama, Tokyo. Sponsorship is provided by the Japan Society for the Promotion of Machine Industry. This society channels funds derived from other industry associations to finance the development project. A consortium of eight industries share in the cost and provide technical resources. A team from Tokyo University and MITI comprise the management of the CVS project. This approach, using management by committees, has produced some significant results:

In six years, the most ambitious PRT development program in the world has progressed from conceptual planning to a sophisticated test program involving 60 vehicles and 4.8 km of test track.

Government expenditures *on* the development have been less than $10 million to date. However, arrangements between three responsible Ministries (International Tracie and Industry, Construction, and Transportation) have yet to be devised which will make a revenue installation possible.

. World-wide interest in AGT systems has produced several international licensing arrangements.

Three United States companies have licensing agreements with Japanese organizations. (LTV) Aerospace corporation, the Boeing Company, find the Bendix Aerospace Corporation.)

The otis Transportation Technology Division has an understanding with SOCEA, an engineering and construction subsidiary of Saint Gobain-Pent a' Mousson to plan and build an AGT system in Nancy, France.

Kralws-hIaffei of Munich, Germany, has a licensing agreement with the Urban Transportation Development Corporation, Toronto, Ontario, Canada.

LTV)' and their French licensee, C0MSIP Enterprise, jointly bid a variation of the AIRTRANS system for the new Charles de Gaulle Airport.

Several United States companies are pursuing licensing agreements with European developers. Both European and Japanese developers are actively seeking United States licensees. W'hether the AGT market will materialize in a way that could make these licenses profitable remains to be seen.

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# APPENDIX A

## BIOGRAPHIES

### Members of the Panel on International Developments

**H. Wm. Merritt, Chairman**
**Transportation Consultant**
**Arlington, Virginia**

H. Wm. Merritt directed the Study of New Systems of Urban Transportation for HUD in 1967–1968. Until 1973 he was the Associate Administrator for Research and the Director, Special Projects, in UMTA. Since 1973, he has consulted on urban transportation plannin , engineering, and energy conservation. Mr. Merritt chairs a task force of the# ational Academy of Sciences which publishes a Newsletter on New Concepts of Urban Transportation.

**Robert A. Burco, President**
**Public Policy Research Associates**
**Berkeley, California**

Robert A. Burco specializes in urban transportation system evaluation, institutional aspects of planning and public policy and technology assessment. In 1971–1972 he assessed innovations in urban transit in Europe, North America and Japan for OECD. Mr. Burco authorized the 1968 SRI report on impacts of future urban transportation systems. He is a member of the OTA Urban Mass Transit Advisory Panel and the NAS Transportation Research Board.

**Thomas H. Floyd, Jr.**
**Vice President DGA International**
**}1'ashington, D,C.**

Mr. Floyd is currently involved in the transfer of European technology and industrial innovations to the United States, specializing in ground transportation. Prior to his association with I)GA International in 1969, Mr. Floyd was the director of research project management in the Urban Mass Transportation Administration. In this capacity, he was responsible for the planning and management of research, development and demonstration programs.

**Howard R. Ross**
**Transportation Consultant**
**Menlo Park, California**

Mr. Ross has worked in the urban transportation field for over ten years, and h specialized in problems of advanced technology systems. since lgi'1, he has headed a consulting firm dealing with system design and analysis, technolog~" forecasting, transportation planning, financial studies and economic analyses for urban transit systems. Mr. Ross was a founder of Transportation Technology Incorporated in 1968, and prior to that was at Stanford Research Institute.

# APPENDIX B

## INTERNATIONAL CONTRIBUTIONS

The panel gratefully acknowledges information on international developments provided by the following individuals:

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Mr. Michel Frybourg, Director, Transportation Research Institute.

### WEST GERMANY

Dr.-Eng. Herman Zemlin, Federal Ministry for Research and Technology.

Dipl-Kfm G. von Lieres u. Wilkau, Manager External Relations, Messerschrnitt - Bolkow-Blohm.

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# REPORT OF THE PANEL ON ECONOMICS

Prepared for the Office of Technology Assessment

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## CONTENTS

## Introduction

A high level of dissatisfaction with urban transportation is indicated by the growing interest in maintaining, improving and expanding systems, despite the precipitous decline in transit [1] usage over the past two decades. That interest is demonstrated by the increasing number of communities which are subsidizing transit out of general tax funds, and the number which are giving serious consideration to installing fixed .guideway systems or otherwise expanding transit to something more than buses traveling in mixed traffic.

The dissatisfaction stems from both the disadvantages of present private automobiles and the deficiencies of existing transit.

Auto disadvantages include high capital and operating costs, the large amounts of space required for movement and parking,[2] contribution to the nation's air pollution (50 percent or more of the total), and (of recent special concern) high energy requirements, accounting for about 50 percent of the nation's petroleum consumption. Typically, congestion in urban places increases as automobiles use increases, but attempts to relieve congestion by building more roadways, at progressively higher costs, only promote still more auto travel and a new round of congestion.[3] The other main complaint against private automobile transportation is its failure to serve those who cannot afford automobiles or who, for reason of age or physical condition, cannot drive.

Meanwhile, it becomes increasingly apparent that existing transit forms are not suitable for the emergmg requirements of many urban areas. The two principal proven technologies available are heavy, large-volume rail transit and buses operating either in mixed traffic or on exclusive rights-of -what~. In addition there is "light rail transit, " the trolley car, or adaptations thereof, which is still being used in several American cities and in many European cities.

Heavy rail hardware still leaves someth!ng to be desired, as is shown by the long record of problems with the BART system in the San Francisco Bay Area. Even more serious, recent cost estimates of the new systems indicate that their full average long-run costs per passenger mile may be higher than the comparable costs of private automobile transportation. If this is so, there are two implications. First, the main rationale for building a heavy rail transit system must rest on any indirect cost advantages it, may have over private automobiles, such as lower pollution, lower fuel consumption per passenger, and less diversion of land from other purposes. Second, there is a great need for lower cost, more adaptable, fixed guideway technology.

An even more basic problem lies in the fact that large rail systems-six now existing, one under construction (Washington, D.C, area), and two which have recently broken ground (Atlanta and Baltimore),

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1 Transit here means *public transit*—mass transportation facilities available to the general public. Transit rides per year declined from approximately 17.2 billion in 1950 to 9.4 billion in 1965 to 6.7 billion in 1973. The annual rate of decline *in* 1950-1973 was about 4 percent in both periods. Between 1960 and 1970, the proportion of the labor force going to work by automobile rose from 64 percent to 78 percent. The proportion using rail transit fell from 3.8 percent to 3 percent, and bus, 8 percent to 5.5 percent (American Transit Association, reported in the United States Statistical Abstract, 1974, Table 949).

2 Depnding on assumptions concerning the average number of passengers per vehicle, the average journey-to-workat about 20 mph requires by automobile roughly six to 45 times as much road space per personas by transit bus, and 10 to 90 times as much road space as travel by multiple-unit rail car. The differentials are even greater at higher speeds. Lyle C. Fitch and Associates, *Urban Transportation* and *Public Policy* (Chandler Publishing Company, 1964, p. 14).

3 Part of the difficulty lies in the fact that street networks and access roadways of already built-up communities cannot be readily enlarged to handle the increasing volumes of traffic generated by arterials.

have been designed primarily to carry passengers from residential suburbs to concentrated central business districts. Population and employment in most of the larger central cities have been declining recently, so that this function promises to be decreasingly important. Also rapid rail transit does not meet the needs of central city residents who commute, or might commute, to dispersed places of employment either in or outside central cities.

Buses have also suffered from design deficiencies, though desi n improvements are appearing. Buses in mixed traffic are slowedEy traffic congestion, and by loading-unloading delays. Exclusive rights-of-way enable faster service, but right-of-way requirements for buses are greater than for automatically guided vehicles of the same width. The necessity of a driver for each vehicle is a major cost.

For suburban transportation needs, nothing has appeared which meets the need for random access as well as the private motor vehicle, although special services have developed to meet special needs: school buses, commuter buses and trains for channelized, mostly journey-to-work, movement.

Light rail systems (LRV) still remain in a few American cities, operating essentially as streetcars, competing with buses and auto traffic on the same roadways. UMTA'S Standard Light Rail Vehicle (SLRV) program will provide modern versions of the time-honored streetcar for San Francisco, Boston and other cities considering such equipment. It is possible some of the innovations being introduced in European cities by LRV systems may be employed in various ways as means of bridging the gap between rapid rail and buses and automobiles, following innovations already induced in several European cities.

Suburban taxi service tends to be erratic and expensive. Fares and regulations are usually designed to further the monopolistic positions of the politically potent taxi interests rather than to promote competition in the interests of the riding public. An exception is the D.C. taxi system, which is one of the cheapest in the country and indicates some of the possibilities of competitive taxi service.

Dial-a-ride systems are proving moderately successful in some communities, providing a service with fares somewhere between taxis and buses, but usually requiring substantial public subsidies. Jitneys, which still might perform a useful function, have long since been driven out of existence in most areas by a combination of taxi and transit interests.[4]

The need in urban transportation, therfore, is not only for new and improved technologies per se but also for concepts of systems which can serve unmet needs of the kinds described above, which can fit into already developed areas and into new urban communities, and which are financially and administratively feasible.

Personal rapid transit, its advocates claim, can meet such criteria. If so, it holds out great promise for improving intra-urban transportation, the convenience of urban living, and the quality of the urban environment.[5]

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[4] Regulatory commissions, which purpose to regulate the various modes, have little concern with quality of service or with encouraging technological innovation or with adapting existing services, such as bus routes, to changing needs and demands.

[5] *Definition of PRT.* PRT here refers to a system of small automated vehicles which travel on exclusive guideways and are designed to carry one person, or a small group of people traveling together by choice, from origin to destination without intermediate stops.

PRT is essentially a metropolitan-scale concept in that it would link all parts of a metropolitan area instead of linking only central cities to suburbs—the essential function of presentday rail and express bus intra-urban transit systems. PRT service thus would approach more closely the level of automobile service than do present transit services.

## Chapter 1: Changing Transportation Needs

### POPULATION SHIFTS IN URBAN AREAS

In the postwar period, central cities have been losing much of the manufacturing and other goods-handling activities which historically concentrated in cities. The reasons stem largely from the development of private motor vehicle transportation; these activities have gravitated to the periphery where land is cheaper, congestion less, and taxes lower. Older central cities which attained the status of national or regional capitals have continued, until recently, to provide a congenial climate for certain specialized manufacturing, cultural, recreational, and educational functions and, most notably, corporate and management functions and their attendant services. Office industries became the predominant economic activity of the large central cities. Central cities which were not management centers have tended to decline throughout the postwar period.

Middle-class white collar workers who man the office industries have been leaving central cities for residences in the suburbs. This exodus has reached flood tide. Table 1 reveals what has been happening in the 1960s and 1970s.

In brief, in the 1960s central cities of all United States metropolitan areas gained 3.3 million blacks and 19,000 whites; suburbs gained 14.7 million whites and 0.8 million blacks; the numbers of blacks and whites locating in metropolitan areas were respectively 109 percent of the total black population increase [1] and 78 percent of the white population increase.

In the period 1970-1973, central cities lost 2.2 million whites and 121,000 blacks; 139 percent of the black population increase, but only 3 percent of the white population increase, located in metropolitan areas.

One of the most striking developments is the fact that in 1970–1973 the increase in the number of white residents of the country's metropolitan areas dwindled to near zero, in contrast to the 1960's when 78 percent of the white increase located in metropolitan areas. A large proportion of the white increase apparently has located in rural areas; [2] some of it is probably in exurban counties outside the existing SMAS and ma~' be commuting to work in the SNIAS.

In the 1960s there was no net central city-to-suburban white shift for all metropolitan areas, though the central cities of the 24 largest metropolitan areas lost approximately 2 million whites who were replaced by an equivalent number of blacks.

1 The fact that the numher of blacks locating in metropolitan areas was 9 percent greater than the total population increase is explained by the migration from non-metropolitan areas to metropolitan areas.

2 U.S. Bureau of the Census, Mobility *of the Population of the United States, March 1970–March 1974*, Current Population Reports, Series P-25, No. 273.



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'1'ABLE *I.—Location of Black-white Population Increases, 1960-70 and* 1970-73

| | 19s0-70 | | 1970-73 | |
|---|---|---|---|---|
| | Number (thousands) | Percent of total increase | Number (thousands) | Percent of total increase |
| **Black population increase:** | | | | |
| United States | 3, 708 | 100.0 | 609 | 100.0 |
| Metropolitan areas | 4, 031 | 108.7 | 849 | 139.4 |
| Central cities | 3, 267 | 88.1 | 728 | 119.5 |
| Suburbs | 764 | 20.6 | 121 | 19.9 |
| Nonmetropolitan areas | –323 | –8. 7 | –240 | –39. 4 |
| U.S. annual rate of increase, percent | | 1.8 | | . 9 |
| **White population increase:** | | | | |
| United States | 18, 917 | 100.0 | 1, 825 | 100.0 |
| Metropolitan areas | 14, 755 | 78.0 | | |
| Central cities | | | –2, 2;; | – 12? : |
| Suburbs | 14, 7;: | 77 : | 2, 276 | 124.8 |
| Nonmetropolitan areas | 4, 162 | 22.0 | 1, 774 | 97.2 |
| U.S. annual rate of increase, percent | | 1.3 | | . 4 |
| **Total opulation increase:** | | | | |
| Tnited States | 22, 625 | 100.0 | 2, 434 | 100.0 |
| Metropolitan areas | 18, 786 | 83.0 | 900 | 37.0 |
| Central cities | 3, 286 | 14.5 | –1, 497 | –61. 5 |
| Suburbs | 15, 500 | 68.5 | 2, 397 | 98.5 |
| Nonmetropolitan areas | 3, 839 | 17, 0 | 1, 534 | 63.0 |
| U.S. annual rate of increase, percent | | 1.2 | | .4 |

Source: U.S. Bureau of the Census, Currant Population Reports: Special Studies, Series P-23, No, 48, "The Social and Economic Status of the Black Population in the United States, 1!)73," July 1974; and series P-25, No. 537 ,"Population Estimates and Projections, " Estimates of the Population of Metropolitan areas, 1972 and 1973, and Components of Change Since 1970.

Also significant was the rise, in 1970–1973, of black migration into metropolitan areas, and the greater degree of concentration in central cities.

These and other data also indicate:

- Significant shifts of economic activity from metropolitan to non-metropolitan areas;
- Shifts in the functions of metropolitan areas and their central" cities;
- Shifts in the location of political power, with blacks gaining in central cities and whites strengthening their numerical position elsewhere, which in turn affects the politics of mass transportation systems; and
- Decreasing concentration of population and lower land-use densities in urban areas.

The implications of these data for intra-urban travel patterns are not yet clear. The substantial shift of white populations from central cities to suburbs may increase journey-to-work travel from suburbs to central cities, in the historic commutation pattern, but there is as yet little indication of such a development.

Much depends on what will happen to employment in central cities. Employment declined in a number of the larger central cities in the early 1970s, when even white collar employment began slipping. New York City, for example, lost in the 1970 recession all the employment it had gained during the 1960s, and the decline has continued and accelerated during the 1974–1975 recession. There are indications that the boom in office industries, which has recently sustained large-city economies, may be over as (1) corporations and governments prune their managerial and white collar staffs; (2) corporations shift white collar functions out of central cities into suburbs, following the flight from central cities of middle-class whites; (3) computers replace clerical workers; and (4) electronic communications replace vis-~-vis conferences.

With all the recent metropolitan growth in employment and population locating in the suburbs, increases in intra-urban travel demand likewise are concentrated in the suburbs, but suburban development has been predicated almost entirely upon automobile transportation. The decentralized pattern of suburban settlement, with no systematic planning, has tended to scatter activity centers. Accordingly, urban residents require a "random access" form of transportation capable of carrying different members of a suburban family in different directions to different activities at different times. Of the available modes,. the automobile can best meet such requirements, though it has great disadvantages for those who cannot drive, and only the fact that suburban housewives serve as family chauffeurs enables many suburban families to carry on their multiple activities.

As Anthony Downs and others have shown,[3] urban sprawl magnifies the length and the number of vehicle trips needed to serve the urban population, in addition to being costly in other respects. Urban designers hold that more systematic planning can improve both the efficiency and the aesthetic qualit~' of urban development;[4] for example, the Regional Plan Association of New York has suggested a plan of polynucleated settlement in the New l"ork region, with more concentrated activity centers. One objective is reduction in overall transportation requirements (particularly length of trip), and arrangements whereby a larger proportion of person trips can be served by mass transportation. Other planners argue that the travel reduction made possible by even highly structured land-use development may not exceed 10 percent.[5] In any case, such patterns have gained little support from either consumers or developers thus far.

Fifteen years ago it was still thought, and hoped, that transportation planning in itself could rationalize urban settlement patterns, at least to the extent of allowing choices among different patterns predicated upon different transportation systems (combinations of modes). This belief turned out to be unrealistic for several reasons. First, attempts to formulate models which would show the relationship between transportation systems and land-use development proved

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3 Real Estate Research Corporation, *The Costs of Sprawl*, Vol. 2, prepared for the Council on Environmental Quality and other federal government agencies (U SGPO. 1974).

4 Wilfred Owens, The Accessible City, (The Brookings Institution, 1972).

5 The Year 2000 Plan for the Washington Metropolitan Area, drawn up by the National Capital Planning Commission in the late 1950's is a case-in point.

abortive. Second, several broad-scale regional plans which were formulated for New York, Washington, and other areas, and which rested heavily on specific transportation systems for their realization, failed to attract general support.[5] One reason lies in the fractionated local governments characteristic of American metropolitan areas, which make development of a consensus about regional land-use policy almost impossible, since some jurisdictions in an area are likely to be disadvantaged compared to others when such regional schemes are imposed. Third, planning and development dynamics in this country make It difficult to use transportation for purposes of implementing large-scale land-use plans; the tendency is for transportation to respond to development, rather than to be used as a force for guiding it. The one thing on which there is general agreement is that every residence, place of business and other activity center must be accessible by motor

Whiie the growth in transportation demand is heavily concentrated in the suburbs, many of the central cities still suffer from transportation deficiencies and are seeking to improve both internal transportation and links to suburban areas. The main objective is to save and expand central cities, most of which are declining in both residential population and jobs."

The new heavy rail transportation systems under construction or in planning (such as the San Francisco Bay Area,' Washington, D. C., an: Atlanta systems) have been designed primarily to ferry white collar suburbanites to central city jobs, and thus to save and expand central cities. Thus, the Bay Area system was sold by a group of downtown San Francisco businessmen anxious to preserve the dominance of the central city in the Bay Area.[8]

In view of the sharp decline of traffic on the five older heavy rail systems (New York, Chicago, Philadelphia, Cleveland and Boston) and the failure of those systems to prevent recent central city decline (though they doubtless delayed it), many critics think the new systems may turn out to be quixotic rear-guard efforts. Only time will tell.

The new transit systems have not been designed for the reverse commute—hauling central city workers to suburban jobs. It has been claimed that lack of transportation facilities in the past has prevented large numbers of urban dwellers, predominantly unskilled, from reaching available jobs in suburban factories and other employment centers, [8] but the notion that more adequate transportation would have promoted higher employment of central-city slum dwellers has never been verified.l"

There are numerous kinds of needs for special services, such as hauling people from large parking facilities and rapid transit stations to work places in central business districts, circulation in central

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6 Some cities, particularly cities of the south and southwest, are still growing. Although a majority of the 25 largest central cities declined in population in the period 1970-1973, several increased, including Houston, Miami and San Diego (large increases), and Dallas, Buffalo, Seattle, Milwaukee and Newark (small increases).

7 The Bay Area system is in operation but several facilities are still under construction and extensions, such as to the Oakland and San Francisco airports, are still under study.

8 Stephen Zwerling, *Mass Transit and the Politics of Technology, a Study of BAR T and the San Francisco Bay Area (New* York: Praeger, 1974).

9 John F. Kain and John R. Meyer, "Transportation and Poverty," *The Public Interest,* Winter 1970.

10 There is considerable evidence that the journey to suburban jobs of non-whites is considerably longer, on the average, than that of whites. But this is a problem of housing location, not of transportation per *se*.

business districts, university campuses, and new towns and new business centers, and intra-airport transportation, which need improved transportation technologies. And finally there are the special needs of the aged, the poor, and others who do not drive. The aged and the poor, particularly, are concentrated in the central cities.

### DEMAND FOR TRANSIT BY INDIVIDUALS

The choice of a potential traveler between transit and auto depends on a number of factors having to do with (1) the circumstances of the individual and his household, and (2) the comparative advantages which he perceives between the transit ride and the automobile ride. The main factors are summarized in the following expression in which:

Subscripts ~ and *a* refer to transit and automobile, respectively,
DE= The decision respecting a particular trip,
1= Household income,
C= Number of cars owned by household members,
H= Number of drivers in household,
2'7'= Time required for trip, including walking at both ends,
V!l'=Variation in times required for individual trips
CE= Convenience, as measured by accessibility and average waiting time,
CO= Comfort,
*SA*= Safety, referring both to vehicular safety and personal security,
*OF*= Other factors,
P= hloney cost to the would-be traveler of a trip or series of trips.

$$DE=f(I,C,H),\left(\frac{TT_a}{TT_t}\frac{VT_a}{VT_t}\frac{CE_a}{CE_t}\frac{CO_a}{CO_t}\frac{SA_a}{SA_t}\frac{OF_a}{OF_t}\frac{P_a}{P_t}\right)$$

This expression assumes that the individual's choice is between auto and transit for making a particular trip. He may have other options, such as not making the trip at all, or utilizing still other means of transportation, including walking.

In comparison with auto, most transit is slower, less convenient, and less comfortable. Long-run costs and the larger social advantages of one mode over another, such as pollution, environmental damage, and so on, will not ordinarily influence modal choice save for individuals with a strong personal commitment to environmental or other social values.

Rising family income levels are also an important factor in the transit decision. Although the evidence is not conclusive! a number of studies indicate that, above a certain level, income increases will reduce the demand for transit, i.e., the income elasticity is negative.11

Although the out-of-pocket cost of making a transit trip is only one factor in the transit choice, it is nonetheless true that if transit is to attract riders who have a choice, the price of transit rides must be sufficiently lower than auto-trip costs to offset transit's relati~Te disadvantages.

As long as transit systems were forced to pay their own way, they were subjected to a competitive disadvantage against heavilj- subsidized automobiles, which contributed to their rapid decline in patronage over the ~-ears.l[z]

11 See George W. Hilton, *Federal Transit Subsidies: The Urban Mass Transit* Assistance *Program*, (American Enterprise Institute for Policy Research, 1974), p. 119.

19 See Fitch, *op.cit.*, especially chapter 4; T.E. Kuhn, Public *Enterprise Economics and Transport Problems* (University of California Press, 1962); John R. Meyer et al, *The Urban Transportation Problem* (Harvard University Press, 1965); Martin Wohl, *Transportation Investment Planning* (D. C. Heath & Company, 1972), especially chapter 3.

The familiar vicious cycle of increasing costs + rising fares + reduced patronage + falling revenues was dramatic evidence that transit patronage is sensitive to fare levels. The old rule of thumb is that a given increase of x percent in fares will reduce patronage by $ percent. But it is also well known that peak-hour travel, which typically is dominated by the journey-to-work, is less sensitive to fare changes than off-peak travel, when recreational, social and other trip purposes are more important. This has led to proposals for multi-fare systems, with higher fares in peak hours and lower fares in off-peak. Until recently, this idea has been resisted by transit operators, but an increasing number of systems are reducing fares for off-peak and/or Sunday and holiday travel, with encouraging results.

Recognizing these facts, the National Mass Transportation Assistance Act of 1974 states that continued increases in the cost of transit to the user, particularly low-income persons, are undesirable and that therefore it is a goal to hold down transit fares. The Act also in effect provides that, as a condition for federal financial assistance, operators must reduce fares by at least 50 percent to elderly and handicapped persons during off-peak hours.

The effect of sharply reducing fares was dramatically demonstrated in Atlanta when, in 1972, bus fares were reduced from 40 cents to 15 cents. In the following 12 months, ridership increased 30.2 percent. An estimated 63.7 percent of the increase represented diversions from automobiles.[13] Since that time, ridership has continued growing, and there were sharp increases during the energy shortage in the first quarter of 1974.

One principal reason for the transit price disadvantage concerns the perceived price of automobile transportation in households which own automobiles. Once a car is purchased, a user contemplating a particular trip presumably will take into account only the out-of-pocket costs, mainly gasoline, tolls and parking charges. Costs which accrue over a longer run, such as repair costs and depreciation, will get less consideration; and those which are largely a function of time, such as insurance and garage costs, will not be considered at all. Presumably, the only time when such costs are taken into account is when the decision is made to acquire a car for a specific purpose that could otherwise be provided by transit—usually the journey to work.

The automobile enjoys a number of other price-cost advantages, in that its cost to users does not fully reflect its cost to the public. First, it is well established that the cost of providing road space in congested urban areas usually exceeds the user charges paid by motorists m the form of taxes and tolls. In addition, many of the costs of controlling traffic and otherwise serving automobiles, including costs of protection against theft, are typically met from general taxation rather than from specific automobile charges. Motorists using road space and traffic and other services are in effect subsidized from other sources. Second, automobiles impose a number of indirect costs not paid by the motorist, which are borne by the public at large or by other motorists. These typically include air and noise pollution and congestion costs.

[13] Metropolitan Atlanta Rapid Transit Authority, *Analysis of Transit Passenger Data*, October 1973.

Such costs are not communicated by the system of pricing for automobile travel in congested centers. The main user charges, aside from tolls and parking charges, are gasoline taxes. But, considered as a charge for the use of roads, the gasoline tax is a highly inefficient instrument in that the charge is the same under all conditions—for high-cost roads and low-cost roads, for peak-hour travel when the supply of road space is scarce and at slack periods when it is plentiful. Parking fees aside, it does not cost the motorist any more to drive in downtown traffic on high-valued land than on empty suburban streets or on lower-valued land. (Flat-rate transit fares are subject to the same limitations.) In crowded urban centers automobile use is held in check by congestion and the competition for parking space.

In summary, the private-car owner seldom keeps any true accounts, ordinarily pal's nothing extra for more expensive rights-of-way, does the driving himself, and thinks that his heavy bills for depreciation and insurance have no connection with the individual decision to take the car because his payment for these items is annual and not related to each trip. Neither does he take into account as a cost for the trip the cost to the community of road and parking space, policing and maintenance. He thus makes his decision on what for him may be a rational basis but which is for the total economy a fallacious comparison.[14]

Given that automobile use in congested urban places is heavily subsidized, the economic remedy is to raise the cost of driving an automobile in congestion-prone areas, and at congestion-prone times, to the point where congestion will be eliminated.[15] The revenues from such charges would in some measure meet the costs which previously have been subsidized. The main rationale of "anti-congestion pricing," however, is not to raise revenue. It is rather to tailor the demand for road space to the supply thereof, so that vehicles can move freely in the urban network.

The extent to which raising auto-user charges would shift patronage to transit has never been thoroughl~- tested; there is a need for more research and field experimentation m this area. Some shifts have been observed recently, as the cost of automobiles and motor fuel and other auto operating costs have risen. Several studies indicate that, raising the out-of-pocket costs of automobile trips is more effective in shifting travel from auto to transit than is lowering transit fares.[16]

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[14] Fitch, *op. cit.*, pp. 22-3.

[15] A number of technical means of imposing such charges have been suggested. Some employ electric vehicle identification technology. Setting parking charges at levels which discourage driving into congestion-prone areas is the only measure much used to date. Although parking charges are a rather crude instrument of control, properly used they are much better than nothing. (See Transportation Research Record, Number 494, *Problems in Implementing Roadway Pricing*.)

[16] *A* Rand Corporation report argues *that*, for diversions of automobiles exceeding 5 percent, disincentives to auto driving are about three times as effective as transit subsidies. B. F. Goeller et al, *San Diego Clean Air Project Summary Report*, Report R-1362-SD, Rand Corporation, 1973. Cited in Hilton, *op* cit., p. 110.

Computations by Moses and Williamson with Chicago data of the late 1%50s indicated that increase of direct user charges of 48 cents would divert some 40 percent of commuting motorists 10 other modes of travel. See Leon N. Moses and Harold F. Williamson, Jr., "Value of Time, Choice of Mode, and the Subsidy Issue in Urban Transportation," *Journal of Political Economy*, June 1963. Owing to limitations in the data and analytical technique, the findings are only suggestive, not conclusive; in any cm?, the ante has gone up considerably in the ensuing 15 years.

But while anti-congestion pricing has the support of a band of economists and transportation planners, it is anathema to politicians and the motoring public. The public has accepted the principle of special tolls and charges only as a means of paying for something visible, such as bridges and turnpikes, and staunchly resists paying for something which historically has been free, especially since they cannot see what they are paying for.

In the face of pubic opposition to raising auto-user charges to levels more nearly approximating full economic and social costs of auto driving, the only recourse, if transit is to be economically competitive, is to subsidize transit. Subsidies may take the form of **improved service,** or lower fares, or both. The level at which subsidies should be set to get the best economic results is an unsettled issue.

In principle, the subsidy per trip should be reasonably uniform for all competing transportation modes. In other words, if for historical reasons (good or bad) one mode of transportation is being subsidized by a certain amount per passenger trip, competing modes should be subsidized by at least roughly corresponding amounts per trip.[17]

The difficulty of applying this principle is that the amounts of subsidy for automobile trips vary according to a number of factors, including the time at whicE the trip is taken. Second, the automobile subsidy includes a variety of indirect costs, some of which are not quantitatively measurable. The notion of matching subsidies therefore cannot be applied with and de ree of precision, though it is a useful principle to keep in mind.[18]

The principle most widely accepted, until recently, is that capital costs of transit should be met by public subsidies, leaving only operating expenses for the fare box. There is no particular economic reason for distinguishing between capital and operating costs, so far as subsidies are concerned, and the distinction does have the disadvantage of encouraging investments in capital intensive improvements, such as automated controls, not necessarily because they reduce the total cost of trips but only because they hold down operating costs and hence fares. (The computation of tradeoffs between capital and labor is discussed in a following section.)

The principal *ration d'i%v* for basing fares on operating expenses is not so much economic as political—the hope that public resistance to fare increases will dampen wage demands of transit labor. The hope has proved futile, and the resistance to operating subsidies is crumbling.

A number of jurisdictions are makin funds available to cover transit operating deficits. The Federal 8 rban Mass Transportation Assistance Act of *1974* for the first time provided federal funds for transit operating subsidies.

Unless the conditions for such grants are spelled out very carefully, they may be dissipated by labor demands and wasteful management practices. Such difficulties are always encountered by subsidies for

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[17] Fitch, op. *cit.*, pp. 156ff.

[18] A formula sometimes suggested calls for transit subsidies sufficient to make transit fares equal to the out-of-pocket costs of automobile operation. The formula is faulty on two counts. First, out-of-pocket auto operating costs per passenger vary widely depending on the number of passengers, the amounts of tolls and parking charges paid by the particular vehicle, and other variable factors. Second, the amount cf the transit subsidy under this formula has no necessary relation to the amount of automobile subsidy; the transit subsidy might be much higher or much lower, depending on circumstances.

operating expenses,. though the difficulties maybe minimized by having flat grants for major service units, rather than simply picking up the bill for operating deficits.[19]

Some communities have been experimenting with zero fares (Seattle, for instance, and, as above noted, Atlanta's system has used revenues from a special sales tax to reduce fares to 15 **cents,** thereby stimulating patronage. The main objection to very low transit fares is that they. encourage the use of facilities whose marginal costs (costs of hauling additional passengers) are likely to be relatively high in peak hours, though they may be relatively low in off-peak hours.

Once an expensive transit system, particularly one using exclusive rights-of-way is in place, fares should be set low enough to insure its full utilization, even though subsidies for operating costs, as well as capital costs, may be required. The economist's rule that fares should not go below incremental (or marginal) costs may be breached if (1) the social benefits of additional travel, made possible by low fares, are thought to justify the additional subsidies required, or if (2) the alternative is greater automobile use and resulting financial and social costs which would exceed the amounts of transit subsidies.

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[19] This suggests as a starting point, a simple flat grant per transit passenger trip. Such a grant would at once avoid incentives to wasteful management and would encourage service improvements and ether efforts to increase patronage, thereby increasing the amounts of grants.

## Chapter 2: Demand for Transit Service of State and Local Jurisdictions

### ABILITY AND WILLINGNESS TO FINANCE TRANSIT INNOVATION AND DEVELOPMENT

From the standpoint of the community at large, there are a number of reasons for subsidizing transit service:

- To balance the subsidies, direct and indirect, already extended to automobile driving in congested urban centers, as discussed in the preceding section.
- To reduce the high social-environmental costs of and the large amounts of space required by automobile transportation.
- To avoid the necessity of building even more expensive highways.
- To provide such service for those physically or financially unable to drive automobiles.
- To stimulate the growth, or arrest the decline, of central cities or other built-up areas.
- To stimulate patterns of urban growth more efficient than the ‘(sprawl” patterns of development associated with the primary reliance on the automobile.

If transit is to be subsidized, why should not the subsidies be paid by governments of the states and localities where transit is used rather than by the federal government?

One reason is that the federal government is already heavily subsidizing highway construction and transit subsidies are needed to redress the balance.

Second, a premise of American federalism, by now generally accepted, is that the federal government is superior as a revenue collector to the state and local governments, and that it should use this power to assist lower levels of government to meet their responsibilities. This is the premise underlying the increasing grants-m-aid to state and local governments, and the recently instituted concept of revenue sharing.

Third, governments responsible for urban areas are already pressed by a multitude of competing demands and are hurting financially. Many are already subsidizing existing transit services.

State and local governments account for over 80 percent of domestic government purchases of goods and services in the United States. Total expenditures went from $49.6 billion in 1960 to $206 billion in 1974, an annual increase of 9.9 percent compounded. By comparison, the annual increase rate of the Gross National Product was 7.6 percent. State-local expenditures were 9.8 percent of the GNP in 1960 and 14.7 percent in 1974. An increasing proportion of state-local expenditures has been financed by federal grants-in-aid: 13 percent in 1960 and 21 percent in 1974.

In general, state-local government as measured by employment, grew more rapidly than any other major economic sector in the period 1960-74, and the rate of inflation was greater in the state-local government sector than in any other economic sector. (The high inflation rate was due in large part to the extraordinary increase of employee compensation rates.)

Tough state and local governments, as a class, were not pinched for revenues during the 1960s and early 1970s, the recent rapid increase of state-local taxes has stiffened taxpayer resistance to further tax, and hence expenditure, increases. Suc resistance, coupled with revenue declines resulting from the economic recession, have forced many state-local governments to retrench and to begin reducing personnel. Capital improvements are one of the first casualties.

Governments of large cities, where major transit deficiencies lie, are another matter. Their revenues have been constrained, and their costs increased., by the fact that they have become concentration centers for minority and poverty-prone groups while losing large numbers of middle-class, predominantly white, residents. In recent ears, most large cities have lost population and jobs, and most have high rates of unemployment.

Saddled with the burfens of providing special assistance and services for poverty-prone populations, they were forced to retrench earlier than other governments. After an upward surge in the early 1960s, their expenditure increases began leveling off.[1] Most large cities have been financially strapped for years. New York City, for example, faces a budget deficit of some $650 million in the current fiscal year and a larger gap in the coming fiscal year. Cleveland and Detroit were, and most other large cities recently have been, forced to follow suit.

## STATE AND LOCAL GOVERNMENT TRANSIT SUPPORT

Although a few state governments (including New York, New Jersey, Connecticut, Massachusetts) are contributing to mass transit support, political forces in various states can be expected to severely limit state financial support, for the simple reason that people in areas not directly served by transit see little reason for helping finance transit. Only in areas where suburbs make common cause with central cities can there be hope of getting substantial state funds. This throws the financial burdens back on the metropolitan areas themselves. Both states and municipalities, as noted above, will be strapped for funds in the foreseeable future, with little likelihood that they will make heavy additional expenditures for new transit systems.

A survey by the American Transit Association put total state-local subsidies in 1972 at $454 million. Among communities already subsidizing transit, New York City contributes several hundred million dollars a year, including funds for operating subsidies. The state of New York is contributing some $100 million to help preserve the 35 cent transit fare. The communities served by the Boston MBTA have long shared MBTA deficits; recently the state of Massachusetts has undertaken to meet half the MBTA deficit. A number of jurisdic-

1 New York City was an exception: its expenditures accelerated in the latter 1960s owing partly to an exuberant administration, partly to the strength of the municipal unions in collective bargaining.

tions impose special property, sales or payroll taxes specifically for transit. Thus the Twin Cities XITA is empowered to impose a special property tax (replacing an earlier tax on automobiles). Atlanta imposes a special sales tax.

8 Only one area, the San Francisco Bay Area, undertook to raise funds from its own sources for a large new transit system. BART District voters in 1962 approved a bond issue of $792 million thereby obligating themselves to pay debt service from property taxes.[2] As time went on and cost escalated, residents accepted a .5 percent sales tax earmarked for BART. Still later state gasoline tax revenues were diverted to transit purposes, including support of BART.[3]

### DEMAND FOR FEDERAL FINANCIAL ASSISTANCE

In the late 1950s, the American Municipal Association launched a campaign for federal grants for transit expansion and improvement. The campaign was impelled by—

- Increasing congestion in central cities, brought about in part by the new arterials constructed to bring vehicles into cities.
- The high cost of providing road space in cities, and the greater space economies of mass transportation, which can handle several times as many passengers per lane [4] as can private autos.
- The large amounts of funds supplied bv federal and state governments for highway construction and maintenance, in particular the resources of the Federal Highway Trust Fund established by the Highway Act of 1956. Municipal officials and transit proponents claimed! with considerable justification, that federal subsidies runmng up to 90 percent of costs inevitably distorted state-local decisions, skewing them toward highways instead of exclusive right-of-way transit.

After considerable pulling and hauling, the first federal legislation to provide significant capital assistance was passed in 1964. A trickle of funds has steadily increased, and the federal government now provides financing for a large proportion of expenditures for transit equipment, mainly buses, in the country today. The annual grants, by year, for the period 1965–73, are as follows:

| Fiscal year: | UMTA capital (?%(%8) |
|---|---|
| 1965 | $52 |
| 1966 | 106 |
| 1967 | 121 |
| 1968 | 122 |
| 1969 | 148 |
| 1970 | 133 |
| 1971 | 284 |
| 1972 | 491 |
| 1973 | 871 |

With funds authorized by the Urban Mass Transportation Assistance Act of 1974, the total authorization for assistance over the next six years stands at $11.8 billion.

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Z At the time it was hoped that farw would cover a substantial part of the debt service.

$ BART received support from still other sources. The tunnel under the bay was financed by revenues from Bay Bridge motor vehicle tolls. The federal government has also contributed to various elements of the system.

t An arterial highway lane can handle about 1,803 cars per hour—2,400 people assuming a load factor of 1.33; buses can move 6,000-7,000 people per lane per hour; and rail transit UP to 40,~ Per how.

## MAGNITUDE OF POTENTIAL TRANSIT NEEDS

The concept of transit "needs" is ambiguous because of the difficulty of defining seeds. " "Needs" is a relative concept, which depends on the communit 's income level and the priority accorded transportation compare to other community "needs". From the community level, the amount of federal or state financing available is also an important factor in the community's perception of its own 'heeds."

In this discussion, the term "mass transportation needs" refers, first, to mass transportation facilities and services which, if instituted, are projected to yield benefits exceeding their costs. Since this condition might be met by several different transportation systems, or combinations of modes, in a particular community, a second condition is required—that the transportation facility chosen is the most cost-effective, which is to say the most economical, means of meeting that particular travel demand. The choice of a rail transit facility over alternative modes, for example, is taken to mean a comparative analysis has been made of all means of satisfying the articular set of travel demands, and that rail transit is considered to Ee economically referable, all things considered.

In practice, thorough projections of benefits and costs are not often undertaken. In any case, they are subject to wide margins of error, and so are projections of needs. To take one instance, the projections underlying the San Francisco Bay Area urban rail system (BART) were controversial from the beginning; many transportation experts doubted that the volume of travel and other benefits projected for the system would actually materialize. Costs escalated over the planning and construction period, and finally turned out to be about double the amount projected at the time the voters approved the project. Similarly the Washington, D.C. system is costing several times as much as had been projected when decisions to proceed with it were taken. It is likely that neither system would have been undertaken if accurate cost projections had been available for making decisions. The planned Atlanta rail system is a "need," as defined by local advocates who have convinced the community to proceed with the project, whose costs are estimated at $1.4 billion but will doubtless go much higher if they follow the precedents of the BART and WMATA systems. Again the decision may well have been taken out of a failure to foresee ultimate costs.

Given the lack of adequate cost-benefit data and other information for sound decisions, estimates of transit "needs" must rest mainly on what community officials and planners say they plan to spend for transit, if stipulated amounts of outside assistance are forthcoming. All large new systems now under serious consideration are predicated on the assumption that the federal government will put up a large share of the capital costs; present legislation now provides for up to 80 percent. The lower the level of federal assistance expected, the less will be the serious demand for a transit system and equipment. The BART system was remarkable in being financed largely by local funds.

Recent surveys by the Institute of Public Administration for the Department of Transportation indicate that the perceived need for transit facilities, on the part of state-local transportation planners, is in the magnitude of $33 billion over the next ten-year period. By comparison, the congressional fund authorization now stands at $11.8 billion, which on an 80-20 sharing basis would fund approximately $14.6 billion expenditures, less than half the indicated "need." The discrepancuy- is greater than these figures show because of the certainty that costs will continue rising. Assume they rise at the rate of 10 percent per year; the minimum amount necessary" to carry out the "needs" program is at least $53 billion. In summary, the relative data are—

| | *Billion* |
|---|---|
| Estimated transit "needs" over next 10 yrs. (1975 dollars) | $33.0 |
| Minimum current dollar costs of meeting "needs," assuming annual cost inflation of 10 percent | 53.0 |
| Outstanding Federal authorization | 11.8 |
| Amount of funding supportable by Federal authorization (80 percent matching) | 14.6 |

## COMPARATIVE COSTS OF TRANSIT MODES

Central to policy choices in the field of urban transportation are the comparative costs of various levels of service and various transportation modes. Yet, in this field, there is little solid information on which to base judgment. Different transit systems now operating show substantial variations in operating and maintenance costs, and great differences in capital costs. New systems such as the BART and WMATA have grossly overrun original projected costs, owing partly to inflation and partly to unanticipated developments. NTew demonstration systems, notably Morgantown, have had even more difficulty with cost overruns.[5]

The situation is further complicated by the fact that, whereas art of the costs involved in a transit choice are measurable by standard statistical and accounting procedures, part of them—in particular many of the all-important social and environmental costs—are not amenable to quantitative measurement in dollar terms.

Cost comparisons are relevant, moreover, only if they involve alternative means of accomplishing approximately the same objective. While transportation systems featuring different modes (auto, express bus, rail transit, automated guideway group rapid transit, or personal rapid transit) may serve community travel needs, such diflerent systems in fact ordinarily perform somewhat different tasks and cause their service areas to develop in somewhat different ways.

Given the public apathy toward transit generally (as evidenced by the secular decline in transit patronage), transit development can be justified only if it promises to be substantially cheaper in out-of-pocket costs, or has the clear advantage of providing superior service.

Preceding studies have established, however, that the advantage of existing transit over auto is in the line haul, where large numbers of people can be carried along a corridor. Here, transit's potential advantages can be realized, including economies as to right-of-way, space required for vehicles, capital costs of vehicles, operating and maintenance costs, and fuel consumption. On the other hand, transit has a number of disadvantages, such as the fact that economies

[5] The Morgantown Automated Guideway Demonstration Project, first projected by West Virginia University to cost $18 million, has thus far cost $64 million for little more than half the system originally planned.

depend on a relatively high load factor, and the need for paid drivers or for costly automatic guidance and control systems. A subtle competitive disadvantage is in the previously discussed peculiarities of the automobile pricing system which hide a substantial part of automobile transportation costs.

The Economic Panel is therefore unable to present a systematic picture of costs, particularly operating and maintenance costs of the newer guideway systems. More information on this subject is one of the greatest needs for future policy decisions. Some light on general parameters may be shed, and perhaps some illusions dispelled, by the following data and conjectures.

The most recent comparative estimates that came to the attention of the Economics Panerwere from a study now being completed by Douglas B. Lee, a member of the panel. Lee's comparative cost data are based on the Washington metropolitan area. The first set of figures indicate the following "average long run" cost per passenger mile of three modes, assuming that each mode is utilized to 20 percent of capacity.

*Average estimated long-run costs per passenger mile-auto, rail, and bus*

| Mode: | *Ce?lt8* **per mile** |
|---|---|
| **Rail rapid, half in subway.** | |
| **Rail rapid, all above surface-** | **: :** |
| **Automobile (1.2 riders)** | |
| **Bus, in mixed traffic** | **; :** |

The picture changes, however, if we assume that the respective s stems are built for, and charged against, peak-hour travel, which in tt e Washington area is dominated by the journey-to-work. Transit vehicles are assumed to be loaded to full seated capacity.

*Estimated cost* of *peak hour travel on exclusive rights of way, auto, rail, and bus per passenger mile*

| **Mode:** | *c e n t a per* **mile** |
|---|---|
| **Rail rapid, surface** | **29** |
| **Bus, on exclusive right-of-way** | |
| **Automobile (1.2 riders)** | **%** |
| **Automobiles (3 riders)** | **35** |

The broad relations shown by the above figures are believed to be generally valid though absolute figures for different systems will, of course, vary.[6] The following observations are of particular interest. "

. Where average loading is 20 percent of capacity, rail rapid costs per mile are by far the highest cost mode. But when facilities are provided exclusively for peak-hour travel, the auto is by far the most costly *unless* the average number of passengers can be substantially increased.

**6 The relation between auto and heavy rail transit costs for eak-hour travel corresponds with computations made from cost estimates prepared for the $ ashington Mass Transportation Study in 1958 of the costs for handling peak-hour trafic by three modes—with automobiles and rail rapid transit each requiring new roadways, and express buses requiring reserved lanes and other special facilities. The per-passenger-mile figures were :**

| | *Cent8 per mile* |
|---|---|
| **Automobile (1.5 riders)** | **1:.:** |
| **Rapid rail** | |
| **Express bus** | **318** |

**(Fitch and Associates,** *op. cit.,* **p. 266. ) The substantial differences between these figures and Lee's figures reflect both the extraordinary inflation between 195S and 1973, and the fact that the 1958 figures omit some elements included by Lee, notably environmental costs.**

- Bus costs are relatively low when buses utilize existing roadways, where they are impeded by competing traf%c. Improving bus service by exclusive rights-of-way increases costs.
- Bus and rapid rail operating costs per mile are approximately equal. Where buses operate on exclusive rights-of-way, total costs per mile are approximately equal to those of rail on surface.
- About 60 percent of bus costs are in labor, and about 40 percent (two-thirds of the labor costs) are in bus drivers. (Some systems report substantially higher proportions.)
- Rapid rail is fastest, but is disadvantaged by the time and effort required to get to the relatively few stations.
- Buses destined downtown. and rapid rail. are disadvantaged by difficulties of distributing passengers to'destinations.

### RANGE OF TRADEOFFS BETWEEN AUTOMATION AND LABOR

A subject of great interest among transit engineers and operators has to do with automation as a means of reducing transit labor requirements. Bus operators in particular, plagued by high ratios of operator costs to total operating and maintenance costs, collective bargaining and rising wage rates, and the always-present threat of strikes, find the idea of automation appealing. The automatic elevator is often cited as evidence that automation can produce substantial savings by replacing operating personnel.

Ignoring for the moment the politica and labor relations problems of substituting automatic controls for union labor, however, the economics of automation involve a tradeoff between labor required for a less automated system (all transit involves some degree of automation) and the amount of capital *and labor* required for a more automated system. Automation requires high-skilled labor for maintenance which at least partially offsets the greater labor requirements of less automated systems. The central question concerns the amount which can be economically invested in automation for the purpose of reducing personnel requirements.

Assume: (a) drivers compensation beginning at $15,000 a year, increasing at the rate of 7% a year; (b) a 15-year life for automated equipment; and (c) a discount rate of 7%. Under these assumptions, the present value of the driver's compensation, for 15 years, is approximately $136,000, which is the limit of an investment in automation to replace one driver (or equivalent employee). Various assumptions as to the rate of wage inflation and the level of discount (interest) rates yield the following results.

*Initial wage--$l5,000 a year*

| Annual rate of wage increase | Discount rate (percent) | Break+ men point for labor-saving investment in automation |
|---|---|---|
| 5 percent | 7 | $117,274 |
| 7 percent | | 136, 700 |
| 10 percent | ; | 172, 700 |
| 7 percent | 10 | 90,200 |
| 10 percent | 10 | 114, 000 |

The break-even point varies directly with the level of wages and fringe benefits and the rate at which they increase, and inversely with the levels of interest rates: high interest rates raise the cost of capital equipment.

With these data we can make some illustrative conjectures respecting the benefits and costs of complete automation. We begin with an actual bus transit operation in a major city, with 2,OOO buses. It employs—

3,300 operating personnel.
700 maintenance personnel.

The number of personnel required is thus two per bus, 1.65 for operations, and .35 for maintenance.

An engineering group with recent experience in automated guideway construction estimates that the cost of complete automation, including equipment for both guideways and vehicles, is approximately equal to that if unequipped vehicles. The cost of a present-day 50-passenger bus (weighmg 15,000 pounds) is a about $60,000. Assuming that automation costs another $60,000 we have a benchmark for evaluating the possibilities of tradeoff, using the data presented in the preceding table of breakeven points.

An automated system itself requires extensive maintenance, both because of the complexities of the control technology and the very high performance standards required to keep the system in continuous safe operation. Referring back to the personnel requirements of the above-cited bus system, assume that automation could reduce the number of operating personnel required by two-thirds, but that an additional .5 man per vehicle would be required for maintenance. These assumptions would reduce the labor force to 2,800 for a saving of 1,200 or .6 employees per vehicle. Reference to the above table shows a positive payoff for an investment of $60,000 to eliminate one position. For example, assume for the eliminated position:

Starting compensation of $15,000, increasing at an average rate of 5 percent per year;
A discount rate of 7 percent; and
A 15-year life for equipment.

The discounted cost of .6 of a position is approximately (.6X $117,272) $70,400; the benefit-cost ratio is ($70,400-$60,000) l.17—not a large margin in view of the many uncertainties.

If it were possible to bring the operating and maintenance staff down to one per vehicle, the benefit-cost ratio under these assumptions would be 1.9. But observation of present systems, and consideration of union pressures and other factors, make it appear unlikely that any such figures can be achieved. The semi-automated Lindenwold line, with 75 cars, employs a maintenance force of 76 for vehicles and 55 for right-of-way, power, signals, communications, and stations—a total of 1.75 per vehicle. Another 117 (1.56 per vehicle) are employed in operations—police, passenger agents, operators, revenue collectors. The total is 3.31 per vehicle, 1.31 more than that of the bus system referred to.

The above statements, to reiterate, are only conjectural. But they do argue against blind faith that complete automation can signficantly reduce transit labor costs. Automation must depend on otYer rationales such as greater safety in operation, increased comfort (as through controlled acceleration and deceleration), and lower headways (making it possible to increase the flow of vehicles on a guideway).

Finally, a high degree of automation is required for personal rapid transit, if this is to be an ultimate objective of transit R&D.

### COSTS OF AUTOMATED GUIDEWAY AND PRT SYSTEMS

At the time of this report, only two automated guideway systems more complex than simple loops or shuttles had been installed—Airtrans at the Dallas/Fort Worth Airport and the Morgantown demonstration system at Morgantown, West Virginia. The Airtrans system had not yet s%haken down, " so that no data were available on the number of operating and maintenance personnel which would be required after the shake-down period.

The Morgantown system was not yet in operation. Engineers of The Boeing Company, main contractors for the system estimated roughly that the capital costs would break down approximately as follows: right-of-way, 50 percent; vehicles, 25 percent; automatic control system, 25 percent.

Vehicles cost about $113,000 apiece, or roughly $13 a pound for an 8800-pound vehicle with a capacity of 20 (8 seated, 12 standing). Boeing engineers expressed the opinion that production in modest volume might reduce costs to roughly $10 per pound, or $85,000-$90,000 per vehicle (1974 dollars).

The fact that the development costs of the Morgantown system were greatly over original projections ($64 million has been spent on little more than half a system originally projected to cost $18 million) indicates the hazards of projecting development costs of new technologies, let alone ultimate capital and operating costs of actual systems deriving therefrom.

The point is demonstrated also in the great differences in the projected costs of constructing, equipping and operating a PRT system. The following table gives comparative data from three recent analyses: one by the Aerospace Corporation of a system projected for Los Angeles; [7] one done for the U.S. Department of Transportation of a hypothetical town (Plastictown); [8] and one by a consortium of firms headed by DeLeuw, Cather and Company, for a system projected for the Twin Cities area.[8]

The data for the last study concern a so-called "high performance personal rapid transit", elsewhere referred to as "group rapid transit", which is between the present generation of SLT systems and true PRT. The vehicles are 8-passenger instead of 4 to 6–passenger.

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[7] Results summarized in Economics and Science Planting, Inc, *Public Transportation* Service *Quality—Some program .4 lternatives*, a report prepared for the Urban Mass Transportation Administration, Department of Transportation, March 1975.

[8] *Ibid.*

[9] *Automated Small Vehicle Fixed Guideway Systems Study*, Twin Cities Metropolitan Area Transit Commission Study, March 1975. Page VII-18.

TABLE 2.—*Comparison of HCPRT Co Es ima*

| | Los Angeles | | Plastictown (hypothetical 1990 city) | Twin Cities |
|---|---|---|---|---|
| Analyst | (1) | | (2) | (3) |
| System length (miles) | 638 | | 825 | |
| Number of stations | 1,084 | | 1,600 | |
| Per station cost (thousands)[4] | $17[illegible]–$225 | | $600 | [5] $120–$2,200 |
| Guideway width (feet) | 2½ | | 10 | |
| Guideway costs (millions per mile elevated) | 1.1 | | 1.1 | 2.3–3.7 |
| Vehicle weight (pounds) | 1,800 | | 3,000 | |
| Per vehicle cost (thousands) | $9.8 | | $10 | $100– |
| Modal split (percent) | 10 | 20 | 14 | |
| Patronage (passengers per day thousands) | [illegible] | 2,000 | 700 | |
| Average trip length (miles) | 10 | 10 | 6 | |
| Cost per passenger-trip | .04 | [6] $0.78 | [6] $2.60 | |
| Cost per occupied car mile | 156 | .117 | .65 | |
| Cost per passenger-trip mile | .104 | .078 | .43 | |

[1] Aerospace.
[2] DOT-TSC.
[3] De Leuw Cather.
[4] Costs of first 2 columns are in 1973 dollars; last column, January 1975 dollars.
[5] Depending on type and location of station.
[6] All costs are based on full recovery of investment as well as operating expenses.

Sources: "Public Transportation Service Quality—Some Program Alternatives," a report prepared for the Urban Mass Transportation Administration; March 1975, by Economics and Science Planning, Inc. and "Automated Small Vehicle Fixed Guideway Systems Study," Twin Cities Metropolitan Area Transit Commission Study, March 1975.

Even allowing for the fact that the cost data are on somewhat different bases, the respective projections differ greatly; vehicle cost estimates, for example, are an order of magnitude apart. It may be pointed out, however, that the $10,000 per vehicle cost estimates for PRT systems are in the cost range of high-performance automobiles, although the performance reliability for PRT vehicles would need to be much higher than for private automobiles, in addition to which PRT systems would require highly complex control systems.

The Twin Cities study vehicle cost projection is in the range of the actual cost of the considerably larger Morgantown vehicles. There is no apparent reason for the great difference between the vehicle cost estimates; if anything, the more complex pure PRT vehicles should be more costly.

There are no comparable estimates of operating costs, but data published by Aerospace engineers appear unrealistically low. One Aerospace-sponsored study cites a vehicle operating cost figure of 1.9¢ per occupied vehicle mile.[10] Average occupied mileage per vehicle is estimated at 20,000; annual vehicle operating costs thus would be $380 (1971 dollars). But if one assumes one maintenance man for five vehicles (probably a conservative estimate in view of the experience of present systems), at $10,000, the annual labor cost for maintenance alone would be $2,0OO per vehicle, or 10¢ per occupied vehicle mile for maintenance alone. Another $1,000 for fuel and operating labor costs, which seems not unreasonable, would bring total operating costs to 15¢ per mile.

Assume (a) a more realistic, but still conservative, vehicle capital cost of $25,000, (b) a 20-year life for vehicles, and (c) an interest rate of .08 percent per annum. The annual amortization charge per vehicle is $2,546, or 12.74¢ per mile. This brings the total figure for vehicle operating and capital costs to 27.7¢ per occupied mile, compared with the Aerospace projection of 15.6¢ for *total* costs, including operating and capital amortization costs of guideways and stations, shown in Table 2.

These projections and conjectures are cited only to demonstrate the unsatisfactory state of PRT cost data at the present time.

## Other Questions About PRT

Assuming that PRT systems are technically possible, a number of other critical questions respecting them arise which cannot be answered with information now available. More extensive engineering and economic studies may narrow the range of cost projections, utilization projections, etc., but no amount of paper analysis can take the place of actual hardware development and testing, and experimentation on a substantial scale.

Critical questions include the following:

- Can PRT systems provide cheaper transportation than private automobiles? It would seem that the more nearly PRT approximates the kind of random access capability afforded by the private automobile, the more likely it is to exceed automobile-

10 Leon R. Bush, *The Economics of High-Capacity PRT Systems*, a paper presented at the National Conference on Personal Rapid Transit, November 1971.

level costs. The proper comparison is not with the present generation of automobiles but with the future generation which will be on hand by the time PRT systems can be developed and installed, and which (if present trends continue) will be lighter and more economical. There appears to be no reason why automobiles designed for urban use should be bigger or heavier than PRT vehicles, and accordingly there is no a parent reason why they should require more energy [11] PRT as the major disadvantage of requiring higher performance vehicles and complex control systems, both of which would be costly and woufd require a high level of maintenance.

. How many automobiles could be replaced by PRT vehicles? For peak-hour work trips, the number of PRT vehicles required will be some fraction of the number of automobiles, which is approximately the reciprocal of the number of rush-hour work trips they can make. Presumptively the average is between one and two, meaning that each PRT vehicle can replace no more than one to two automobiles. In off-peak hours some PRT vehicles can be employed for off-peak travel, replacing still other automobiles. t he ones replaced, however, WOU1 presumptively be only those whose use is limited to the urban area served by PRT. There would seem to be an outside limit on the number of automobiles that could be replaced per PRT vehicle.

. What is the tradeoff between storing automobiles in parking lots or garages near work places, and the alternate of storing PRT vehicles in other areas where land maybe cheaper? Back-and-forth movement of empty PRT vehicles would offset part of the presumptively more expensive storage of automobiles near activity centers.

. How much social cost would PRT impose on neighborhoods in the form of noise, unsightly guideways, disruption of on-going activities, alteration of buildings, etc. ? Despite claims to the contrary, the structure for an elevated guideway in high density areas would have to carry at least as much weig t as a single-lane guideway designed for automobiles, since it would have to support moderately heavy vehicles running at short headways.

. How much road space could PRT eliminate? What with continuing urban decentralization and lower, but more homogeneous, land use densities, there will be less need for transit lines or freeways to provide access to areas of high concentration. Roadways will still be needed for motor vehicle access, goods movement, and other purposes, so that the possibilities for tradeoffs appear to be limited.

. How good a substitute is PRT for the private automobile, particularly in less densely populated areas? A PRT rid with ines spaced one-half mile apart, for example, WOU1d require trips of up to one-half mile to reach a PRT station.[12]

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11 Probably PRT vehicles would utilize a different form of energy, for example, electricity instead Of gasoline.

12 A person located in the center of a square of a grid ½ mile on aside is [2(.25)3] .6, or.% mile, as the crow flies, from the intersections of the grid, where PRT stations would be located. If he has totravel along streets laid out parallel angles to the grid, he would have to travel ½ mile to reach an intersection.

. What are the tradeoffs between PRT and various substitute transportation systems and modes? Three possible alternatives, as yet little utilized, are the following:

Uncoupled grid systems with transit vehicles running back and forth on the rows and columns of the grid, so that a traveler starting from any intersection on the grid could reach any other intersection, with only one change of vehicle. One of the advantages is that different types of vehicles might be used on the various lines of the grid, depending on travel densities, local physical conditions, and already existing facilities.

Utilization of small rental automobiles, perhaps electrically powered, which could be procured expeditiously for trips between points in the service area. (Amsterdam is reported to be experimenting with such a system, which would have the advantage of (1) utilizing existing roadways and (2) avoiding the need for high-cost guidance and control systems.)

Para-transit modes, for example, dial-a-bus systems.

## Chapter 3: Justification for Transit Research and Development

What criteria can be used to decide upon the amounts of research and development funds which the Congress should appropriate to further transit expansion and improvement? As with many such questions, there are no formulae which give definite answers, partly because the benefits of R&D expenditures may not be immediately discernible, may take a different form than those originally anticipated, and may accrue to society at large instead of a particular corporation or government agency in a form which can be measured.

There are no data with which cost-benefit analyses can be constructed. The cost of obtaining specified results in this field cannot be computed in advance within wide limits. Estimates of the cost of developing PRT technology, for example, run up to $250 million; its benefits, at the present stage, are, in the view of most of the members of this committee, unpredictable.

R&D expenditures in this field, therefore, are essentially an exercise in decision-making under conditions of uncertainty. In such situations, however, there are rules for promoting desirable outcomes and reducing the probability and impact of bad decisions.[1]

The following considerations and suggestions set forth in a concluding section aim at these objectives.

### R&D Expenditures in the United States

Estimated research and development outlays in the United States were $13.7 billion in 1960 and $32.1 billion in 1974. Defense and space expenditures, however, accounted for 55 percent of total R&D *in* 1960 and 38 percent in 1974. The federal government supplied 64 percent of R&D funds in 1960, and 53 percent in 1974. Industry funds supplied 32 percent in 1960 and 40 percent in 1974.

In the defense area, R&D expenditures were 16 percent of U.S. defense expenditures in 1960, and 12 percent in 1974. Industr~-supplied R&D funds amounted to 6 percent of U.S. private domestic investment in both 1960 and 1974,[2]

### Considerations Bearing on Transit R & D

The following considerations bear upon the needed R&D effort in transit, and particularly for the automated guideway program:

. Industry interest in the field of transit has been greater than in many other fields, because of the hopes in the 1960s that a market would develop for new transit forms which would be lighter and more flexible than traditional heavy rail systems and avoid the disadvantages of buses operating on highways

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[1] See Ruth P. Mack, *Planning on Uncertainty; Decision-Making in Business and Government Administration*. New York: John Wiley & Sons, 1971.

[2] Source of data: U.S. National Science Foundation, reported in *Statistical Abstract of the United States, 1974*, pp. 530-2.

and streets. Several variations of automated guideway transit systems were developed and exhibited in prototype form at DOT's 1972 transportation exposition. (Transpo-72). But the market never materialized. Outside of several airports and amusement parks, there were no commercial applications of light-weight AGT systems in the United States. Industry is losing interest in the field.

. Technological development in the field of transit is similar to that of government technological applications generally. It is difficult to stimulate demand for products which have not yet been developed; private industry, uncertain as to the needs and potentia for technological applications in a field dominated by government, hesitates to undertake large R&D expenditures.

. Expenditures for transit R&D were of the ma f cent of total Federal capital rants between PY 1966 and FY 1973, but for FY 1974 andfY 1975, R&D has amounted to somewhat less than 5% of capital grants.

. As indicated earlier, the Federal government is already committed to spend nearly $12 billion in transit improvement over the next half dozen years. Total transit needs over the nexit decade are projected at $33 billion; and as much as $60 billion over the next two decades. (These projections are in 1975 dollars.) The Economics Panel's opinion is that expenditures of as much as 5 percent of the amount of projected grants for mass transit improvement would be a modest investment in improved transit technology to realize the greatest possible benefits from transit development expenditures. The amount would be equivalent to some $600 million R&D, as a corollary to the present congressional authorization of $11.8 billion. The panel points out also that it is imperative that, for the huge transit development program to benefit from technological advance, the advance must be made early in the program. The panel therefore recommends accelerating the R&D program for automated guideway transit systems, and undertaking the exploration of several technologies. We emphasize that if the results of such research are not forthcoming early, their potential benefits will almost certainly be greatly reduced since a large share of the nation's future urban growth will occur in the next two decades.

Having indicated the *amount* that may be justified, however, the panel wishes to add that productive expenditure of transit R&D funds will require much better management of UMTA'S R&D program than has characterized the program in the past. Some speci!c suggestions and recommendations toward this end are made in the final section.

- A s reviously mentioned, the two chief technologies now avaif'able are rail systems (with some distinction between "light" and "heavy") and bus. A number of communities, including the Twin Cities and Denver are interested in automated guideway (GRT) systems with lower capital and operating costs and greater flexibility than the heavy rail systems which have dominated transit development recently. While GRT capacities are less than those of heavy rail systems, the capacity specified by UMTA—15,000 per lane per hour—is adequate for nearly every corridor **in** United States urban areas today **not** already served by **mass** transit.

- The magnitude of the potential benefit of R&D is suggested by the following comparisons. The **costs** of the Washington **mass** transit system will **come** between $45 and $50 million per mile for **a** two-track system, with the **cost** of the above-grade por**tion** of the METRO system trackage estimated **at** $11.7 million **a** mile. The target figure for UMTA'S GRT project is $3.0 million for above-grade, single lane guideway, **or** $6.0 million per mile for **a** two-track guideway, and $8.0 million **a mile** for the complete system.

Recognizing that these **two sets** of figures **are not** strictly **com**parable (the WMATA guideway figure includes land **costs,** for **exam**ple), the UMTA target **is a cost** figure of **no more than half, perhaps less, of the cost of present heavy rail systems. however it should be emphasized that such savings apply only to systems which can be constructed above ground. Once It becomes necessary to put** AGT underground, guideway **costs** may approach those of **conventional rail systems. More research is needed respecting the problems of deploying GRT in already built-up areas.**

**Another question lies in the area of operating costs. While the weight of the so-called light transit vehicles may be less than that of conventional buses and rail cars, the weight per passenger of systems developed thus far approaches that of conventional systems. Without a reduction of per passenger weight it will not be possible to reduce energy costs of operation. Table 3, below, shows the comparative weights of various transit vehicles.**

TABLE 3.—*Comparative weights of various transit uehicles*

| | Lm~ty | Area (Sq. feet) | Empty weight (pounds) | Weight per sq. foot | Maximum passenger load 1 | Loaded weight per passenger z |
|---|---|---|---|---|---|---|
| BART. | 75.0 | 787.5 | 59, 000 | 75 | 240 | 395 |
| Lindenwold | 67.5 | 675.0 | 72, 000 | 108 | 169 | 600 |
| Washin ton Metro | 75.0 | 765.0 | 72, 000 | 94 | 221 | 475 |
| Ford 8A T | 24.7 | 165.5 | 12, 500 | 75 | 48 | 410 |
| Mor antown | 15.5 | 103.8 | 8, 600 | 83 | 21 | 565 |
| AIR?I'RANS (Dallas/ Fort Worth Airport) | 21.0 | 147.0 | 14, 000 | 95 | 60 | 403 |
| Westinghouse (Seattle-Tacoma Airport) | 30.5 | 265.4 | 20, 500 | 77 | 120 | 340 |

1 Based on maximum possible loading.
z Ratio equals loaded weight divided by the number of passengers.

. Another **measure of potential return on transit** R&D lies **in the possibility of reducing the needs for urban arterial highways for peak-hour transit. The cost of a six-lane highway, in an area with an average population density of 6,000 per square mile, is of the rnagnitucle of $25–$30 million per mile, of which $14–$16 million is for construction. The capacity of such a freeway assuming average loading of 1.2 persons per auto, is less than** the target capacity specified by UMTA for the automatic guideway project.. If UMTA'S cost targets of $4 million per one-way system mile could be achieved, a saving from reducing highway construction by one mile would pay for four miles of two-lane transit line, of somewhat greater capacity. Land costs for GRT would also be lower.

- The hoped-for payoffs of R&D are two. First is a much deeper knowledge of the nature of transportation needs in present and developing urban communities and the technologies by which needs may be most effectively served. Second are improved technologies which can meet future as well as present transit needs in many urban areas. At the least, there is bright hope for improvement of propulsion systems, braking systems and other hardware which will improve the serviceability and comfort of the next generation or transit vehicles. Further in the future is the potential of a true personal rapid transit technology, which should go far toward overcoming the disadvantages of and inadequacies which characterize today's urban transportation systems.
- The panel warns that transit R&D is a high-risk investment. It is not yet certain that quantum advances are possible. In the panel's estimation, however, the potential payoffs of a well-managed R&D program justify the risk.

## GENERAL RAD POLICY

The Economics Panel concurs with R&D expenditures of up to 5 percent of federal appropriations for transit, providing that program objectives are more clearly defined and more emphasis is given to the purposes to be served by different transit modes, the environment in which they must operate, and the kinds of new technological developments most needed.

The Economics Panel is concerned with the lack of knowled e respecting specific transit needs in American cities, how new technologies might be adapted to already built-up areas without incurring the enormous costs of going underground, and how they most effectively serve new developing areas. One panel member expresses his concern as follows:

> Deployment studies should be the main focus of PRT research because it is not certain that present hardware development objectives, even if they achieve fractional headways, would be useful for major metropolitan systems in the United States. Extensive research and development in improving the suspension, propulsion, and control hardware on PRT systems wou Yd seem to be premature until it is clear that they would be useful when perfected,
>
> Application studies should be conducted across a wide range of cit)' sizes, densities and configurations. In each case, actual PRT systems should be laid out and planned on the assumption that technological im movements can be made available. Simulation studies should be conducted to the extent necessary to determine best control of system strategies, vehicle deplo~'ment strategies, best highwa~' planning strategies, etc. The results would provide better insights into such matters as:
>
> 1. The headway required for transit vehicles to be effective under different situations; (Perhaps fractional second headways are not needed after all.)
> 2. The number of stations required under different conditions;
> 3. The number of tracks needed and the dimensions of stations in central business districts, outlying residential areas, and other major commercial areas;
> 4. The line spacings appropriate under different city sizes, densities, and configurations;
> 5. Research on public acceptability of new hardware in various areas in actual cities.

Another panel member believes that great emphasis in UMTA'S overall program should be on rationalizing urban transportation policy in such a way as to create a climate that is conducive to the success and growth of transit alternatives.

For example, full cost pricing-especially during peak periods—of existing transportation would have much more impact on urban transit than the most exotic, attractive and functional new technology. Anything less would leave UMTA with an increasingly expensive sector to subsidize, less flexibility in responding to urban transit needs, and little opportunity to introduce new technology into a friendly environment.

Another panel member also questions the priority of more hardware R&D at this stage. He says:

The main (research) issue is whether there exists a set of transit performance characteristics that, at any non-negative price, and at existing or expected automobile trip prices, wil 1 lead significant numbers of persons to choose transit rather than automobiles for urban trip s during congested portions of the day.

It would seem, then, that the requisite research would divide rather naturally into the following parts:

1. The first part would be some sort of a parametric simulation to determine if any vector of transit characteristics, including price, exists which might have some chance of attracting large volumes of riders, with or without changing the price structure for automobile trips.

2. If such a vector is found, the second step would be to undertake the hardware and system research required to determine whether a system with the desired characteristics can be produced and operated at costs which would make it consistent with acceptable fares and subsidies.

3. If a system appears technically feasible, the third stage of research would be to desi n and deploy that system in an environment in which both the technical anJdemand characteristics of the system could be tested. The purpose of this step would be to validate both the market simulation and the technical research. If the system proved effective, further deployments could be executed.

The major difficulty with the research program outlined by the panel report is the inadequate emphasis on demand and the excessive emphasis on the hardware and system side. There is little point in designing new hardware or systems unless there is some indication that the system would attract riders at some economically reasonable price.

## SUGGESTIONS FOR TRANSIT RESEARCH MANAGEMENT

Various members of the Economics Panel sumgested that the UMTA R&D program in the past has lacked focus and direction and that more attention should be given to improving research management and to strategies for encouraging the development and adoption of new transit technologies. The panel lacked time to formulate a comrehensive set of suggestions, but contributed a number of suggestions For improving research management.

*Broader Views of Transit Functions.—As* to UMTA'S proposed research on automated guideway transit, the Economics Panel has expressed four main concerns.

- It was generally felt that the proposed GRT development program, which will select one of three quite different technologies for actual development and demonstration, will incur the risk of freezing GRT technology before the principal alternatives have been sufficiently explored.

- **There is some danger in the proposal that the firm selected to build the prototype system in Phase 2 of the GRT project will gain a monopolistic position in the transit supply field. Such a development, it is felt, would be prejudicial to the interest of both potential future transit suppliers and the urban areas which are the potential customers for new transit technologies.**
- **The proposed technique of selecting firms for R&D does not afford sufficient incentive for firms to develop products in the hope of marketing them thereafter. Partly because of disillusionment over the failure to develop a market for new technologies, firms tend to regard R&D projects as ends in themselves, from which to extract as much profit as possible. Such an attitude is not conducive to the innovative, yet practical, product development at which American industry presumably excels.**
- **The Economics Panel wishes particularly to emphasize demonstration projects should not be exploited for political purposes of the incumbent administration, nor for public relations purposes of the supplier or of UMTA. Both the Morgantown demonstration project and the BART system have suffered as a result of pressure to rush them along and to open them prematurely.**

*Specific Long-Term* Objectives.—The present "HPPRT" program, is felt to be lacking in specific long-term objectives. A principal objective mentioned by UMTA is the ultimate development of PRT technologies, It is not clear how the proposed project would contribute to this long-term objective, or what the next steps would be. Also, there is no plan for utilizing the results of R&D thus far, nor the results of the proposed project, The most pressing present needs, on the other hand, are ones to which light-weight GRT systems may be applicable.

*Increasing Incentive for Suppliers.—UMTA* should examine the possibility of aggregating markets for transit systems and transit hardware as a means of increasing incentive for suppliers to undertake R&D on their own and enable realization of economies of large-scale production. Market aggregation could be achieved in several ways. One way is to induce several communities with similar needs to contract with a supplier or suppliers for specific items, which may range from whole systems to specific hardware. Such a buyer consortium would presumably use mutually agreed-upon specifications in soliciting bids from suppliers. (The following recommendation has to do with the development of specifications for such purposes.) UMTA'S position as a major source of funds for transit development places it in a strategic position to encourage such consortiums.

*Specifications.—One* of **the objectives of the research program should be the development of specifications for automated transit systems and components thereof. It was noted that many elements of transit technology are still in the experimental stage. (Even the rail systems which have recently begun operating, notably Lindenwold and BART, have experienced much trouble with design and performance of various hardware components.)**

- Primary attention should be given to developing specifications for requirements of transit systems overall, environmental aspects (for example, designs which can be adapted to already built-up areas), and hardware components.
- Also needed are better evaluation criteria for determining whether performance specifications have been met.

*Deployment Dernomtrationx.*—Once a new technology has been developed, UMTA should take the responsibility for seeing that it is adequately tested and demonstrated in real-use situations. This involves projects which will put the technology to actual use. For example, the next round of development in GRT systems might be utilized to meet some such common need as connecting a large parking area to a central business district. University campuses offer a good testin ground for transit development. The unfortunate experience with Morgantowm should not preclude deployment demonstrations on other campuses.

*Incremental* Building. -Such deployment demonstrations may serve as building blocks for testing larger systems. For example, a technology which has proved successful on, say, a university campus might be employed next in a small urban community as a second development stage, and in a still larger community as a third stage. Or transit systems may be built incrementally, perhaps in $100-million units rather than billion-dollar units. In this connection, the experience of Toronto, which started with a four-mile line along Yonge Street, is instructive, Baltimore and Buffalo are using such a strategy at the Present time.[1]

*Continue and Expand Present* Systems.-UMTA should make sure that the utmost benefit is derived from projects already mounted. This means learning all Possible from the Morgantown. Dallas-Fort Worth, BART, and other new systems. In particular, a' system such as Morgantown should not be written off as an unfortunate mistake but should be continued and, if possible, expanded to the point of making the project useful for learning purposes as well as for practical **DurDoses.**

*Personal Ravid Transit.*—Finallv, it should be recorded that one member of the' Economics Panel, ~. 'Edward Anderson, feels strongly that personal rapid transit is so promising, and the need for it so imperative, that a significant portion of federal transit R&D should concentrate on bringing the technology and planning methodology to fruition within the shortest practical time consistent with good management practice. He believes that the concept is feasible technologically. Other members of the panel are skeptical about the possibility of developing dependable, economically feasible PRT within the foreseeable future.

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**[1] One panel member objects that "the deployment demonstrations suggested simply do not contemplate the kind of environment necessary to make the necessary market tests."**

## APPENDIX

### COMPOSITION OF THE PANEL ON ECONOMICS

**Dr. Lyle C. Fitch, Chairman**
**President, Institute of Public Administration**
**Washington, D.C.**

**Lyle C. Fitch is president of the Institute of Public Administration, the nation's oldest nonprofit governmental research and consulting organization. He has held numerous municipal, state and federal offices, including City Administrator of New York City. He holds a Ph.D. in economics from Columbia University and has taught at Columbia, City University of New York, Wesleyan University, and elsewhere, In 1961 he directed a study of federal urban transportation policy, commissioned by HHFA and the Bureau of Public Roads, which provided important inputs to the first federal urban mass transportation act.**

**Dr. J. Edward Anderson**
**Regional Transportation District**
**Denver, Colorado**

**J. Edward Anderson, Ph. D., P. E., Professor of Mechanical Engineering, University of Minnesota, on leave as consultant to Regional Transportation District, Denver, Colorado. BSME, Iowa State University, 1949; MSME, ~Tniversitlr of ~~i_nne s_o t_a, 195,5; Ph. D.,** Massachusetts **Institute of Technology, 1962. General Chairman, International Conference on Personal Rapid Transit. Editor,** *Personal Rapid Transit. Personal Rapid Transit II.*

Thomas B. Deen
Vice President
Alan M. Voorhees and Associates, Inc.
hlcLean, Virginia

hlr. Deen has served as principal-in-charge of comprehensive transit and urban transportation studies in many large cities of the world including Washington, D. C., Atlanta, Baltimore, Caracas, Honolulu, and Sao Paulo. He formerly was director of planning for the federal agency which developed plans for the l$rashington Nfetro now under construction. His writings have been published in most of the professional journals in the urban transportation field.

Dr. Paul K. Dygert
Senior Consultant
Peat, Marwick, Mitchell & Co.
Washington, D.C.

Dr. Dygert has engaged in teaching, research, and consulting in transportation economics and financing. Recently he undertook a financial feasibility analysis for a proposed personal rapid transit system, and conducted a study for urban mass transportation needs and financing which the Secretary of Transportation transmitted to the Congress in July 1974. He has also undertaken transportation studies for international, state, and local agencies.

Dr. Aaron J. Gellman
Gellman Research Associates
Jenkintown, Pennsylvania

Dr. Gellman, since 1972, has headed his own research consulting firm and has servdd as adjunct professor in the Transportation and Regional Science Division of the Wharton School of Business, L"niversity of Pennsylvania. Formerly, he was vice president for planning at The Budd Company, Philadelphia. B.A,—Economics, L'niversity of Virginia, i$lBA-Transportation, I_~niversity of Chicago and Ph.D.—Economics, M.1.T.



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Charles Hickox
Director of Ground Transportation Marketing
~~mAe+~;p;ce Corporation

Mr. Hicko~ has been responsible for market lanning and development for ound transportation since the inception of L{V's commitment to this area. Ee has been closely associated with the development of the AIRTRANS system at the Dallas/Fort Worth Airport and the licensing of this technology in both Japan and France. He has lectured extensively on automated transit.

Dr. Douglas B. Lee
Office of Comprehensive Planning
Fairfax County
Fairfax, Virginia

Dr. Lee was formerly at the University of California, Berkeley, where he taught City Planning and conducted research in the comparative costs of urban transportation modes. After a year's work on Fairfax County's land-use planning program, he will join the faculty of the University of Iowa.

Sumner Myers
Director Urban System Studies
Institute of Public Administration
Washington, D.C.

Sumner Myers, a graduate of M. I. T., is a director of Urban Systems Studies for the Institute of Public Administration in Washington, D.C. and the author of numerous publications on technological innovation and transportation. He was a participant in HUD's study of transportation technology and editorial advisor for the final report, *TomorrotL$s Transportation.*

# REPORT OF THE PANEL ON SOCIAL ACCEPTABILITY

Prepared for
the Office of Technology Assessment


**PANEL MEMBERS**

**Jacquelyn A, Ingersoll, Chairman**
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# CONTENTS

## Introduction

Any assessment of the social acceptability of automated transit can only be speculative at this time. The Social Acceptability Panel offers the following comments and opinions to illustrate issues that need further research and consideration rather than to attempt a definitive or authoritative review of the subject. Indeed, the most significant conclusion this panel can offer is that there is at least as much research work to be done on the potential social and environmental impact in urban areas of automated guideway transit as there is on the technological developments.

The evidence of recent and current local studies on automated transit indicates that planning and decision-making at the local level on the use of automated systems is an exceptionally difficult process in automobile-dependent communities.[1] Achieving an "acceptable" plan involving massive capital investment, uncertain operating cost, and educated guesses about the resultin impact on trans ortation, the environment, and urban form is a formldable task.khe process must not only involve a complete analysis of all possible alternative approaches to transit—automated, non-automated, and mixed—but must also be responsive to a broad range of community interest groups. It must be strongly related to comprehensive regional land use planning. If the reserach efforts of the Federal government are to result in actual urban use of automated systems, it must be recognized that communities need a great deal more than test track technological developments with which to judge the merits of these automated systems. They must have better answers about human engineering issues, costs, eflects on land use and environmental impact. At this time, it may be appropriate to apply existing automated technology to urban and specialized settings to get some of those answers be ore committing the bulk of available research funds to more advanced technology ies. It must be remembered that local decision-makers are more lif ely to be politicians than technical experts. The negative consequences of their last venture into major transportation 'improvement" (i.e., urban freeways) has made them very wary.

This panel agreed that raising the level of confidence concerning the social acceptability of automated transit will require:

- R&D programs directed at the process of predicting, interpreting, and communicating the social consequences of transportation improvements.
- clear indication of long-term Federal financial commitment to automated transit.

[1] "Development of Performance Specifications for the Regional Fixed Guideway System," Simpson & Curtin/Midwest Planning, Inc. for Twin Cities Area Metropolitan Transit Commission. Reports 74-1 & 2, January 1974.
"Automated Small Vehicle Fixed Guideway Systems Study," prepared by DeLeuw-Cather for Twin Cities Area Metropolitan Transit Planning Commission, #75-03 (Preliminary Draft), January 1975.
"The Transit Issue," Thomas Todd, presented to the House Local and Urban Affairs Committee, Minnesota Legislature, January 22, 1975.

The and members gratefull acknowledge numerous contributions from their colleagues and the generous response of specialists, particularly:

- Earl Putnam, General Counsel, Amalgamated Transit Union.
- Frank Caiatl, GM Transportation Systems Division.
- Larry Dallam, Director of Transportation Planning, Twin Cities Metropolitan Council.

The appendix summarizes the professional experience of the members of this panel, Social Acceptability of Automated Guideway Transit in the United States.

## Chapter 1: A Context of Need

**The question of the overall social acceptability of automated guideway transit must be viewed within the context of the comprehensive transportation challenge facing many emerging metropolitan communities today. Until fairly recently, the combination of cheap land, cheap energy, strong economic growth, and lack of concern about pollution and urban decay, coupled with relatively high personal income and widespread auto ownership , led inevitably to the wide dispersion of homes, jobs, stores and urt an activities. In most cases, the only link now joining these elements is an extensive network of highways and streets. Public transit systems, coomposed mainly of buses, carry only a tmy fraction of travelers even m communities which are pursuing aggresslve upgrading of service.**

**8lowly people began to notice that the resulting urban form with its accompanying auto congestion was causing roblems both in the suburbs and central cities. Public awareness or the plight of those with no access to the auto developed. The first step taken to combat the ills was localized opposition IO new urban freeways. Renewed interest in improving public transit marked the beginning of a new era. Environmental concerns, shortage of oil, inflation and the threat of economic slowdown boosted the cause and elevated transportation issues into general public consciousness. Current man-on-the-street interest in public transit may be shifting from an attitude of "We must have better public transit so that I can drive without hindrance and my neighborhood can be protected from excessive through traffic" to a new focus best expressed as "Can I get to work on time if I have to give up my second car, or, will my family have to face isolation at home during the day?"**

**This shift in public attitude has major potential for those who must find solutions. The task may no longer be to lure the consumer from his auto by duplicating the characteristics of that auto in the form of regionally deployed true PRT, as was once thought. It now seems more probably e that the challenge of the next thirty years lies in increasing the productivity of** *aU* **elements of the** *existing* **investment in road systems. This period will probably be characterized by a reduction in family auto ownership, emphasis on more efficient autos, car pooling, more efficient use of roads, attempts to check urban sprawl, and reduction of total transportation demand through clustered development. The public transit systems will be expected to increase ridership significantly, particularly in peak hours for work trips, and to provide access to transportation for the disadvantaged. In the interest of labor, equipment and energy efficiency, some transit operators can be expected to make a relatively modest, but none the less costly, shift to electrification and automation to boost the productivity of buses. Regional land use planners will be interested in using automated systems as a tool to direct new developments toward more economic patterns of land use.**

The 2lst century seems likely to bring a period of major shift from an oil based urban transportation system to one dependent again on electricity. There could, but not necessarily would, be a shift of equal magnitude in modal split between private and public transit. Urban form could change drastically. Life styles, the mechanics of earning a living and personal value systems could undergo changes as radical as were expemenced in the last century's shift from horse and electricity to oil. It is futile to speculate on the exact nature of such changes, but automated transit systems may well become primary elements of urban transportation. Beyond that assertion, one can only see that the nature of such systems will be geared to the unpredictable human needs and urban form of that time. Current resumptions that such systems must inevitably be of the pure PRT type are based on a debatable determination that this is the ideal response to the needs, values and urban form of today, which is not a very reliable guide for the future.

It maybe well to heed the lessons of natural evolution which indicate that creatures with. the generalized capacity to adapt to a wide range of unpredictable circumstances tend to survive over those not so gifted. Applied to transit technology, it would seem wiser to assume at this time that all possible automated systems types have potentially valid urban application on their own merits and are not simpIy steps to PRT. This is an issue of overall importance to the social accept-ability of automated guideway transit to da as well as its utility in the future. So long as t e "all roads lead to P T" psychology prevails, there will be extreme reluctance to make major capital investment in near-term available automated transit that may shortly be "out-dated." This concern, coupled with the doubtful public acceptability of fine-gnd aerial PRT guideway networks in residential areas may cause local commumties to drop consideration of automation alto-gether. This would be unfortunate, because simpler automated systems could play an important role in meeting the needs of those communities in the next few years.

Public and "expert" percetion of the problem must be turned from the oversold long-term need or an alternative to the automobile to the more prosaic but urgent need to make existing bus and rail systems, as well as the auto, more productive. Discussion and utilization of auto-mated guideway transit can then proceed on a more realistic basis to meet the needs of today and provide sufficient experience to guide the planning for using automation in the future.

Public acceptance is seldom clearly traceable to calm reasoning. Opinions about the influence of major transportation improvements on the quality of life are not necessarily formed from orderly inter~reta-tion of fact. Broad community education and involvement is re-quired before the oinions of incident groups will include an under-standing, for exampYe, of economic costs and benefits.

Acceptability in the short term is a function of clearly perceived immediate advantages to the individual. The public consensus, such as may evolve, will be an integration of many narrow viewpoints; the ad-vanta es to the broader society of environmental protections sought by specia interest groups, for example, are generally only recognized with hindsight.

One source of information on public acceptance of new systems is the continuing Bay Area Rapid Transit (BART) Impact Study.

Early evaluations were reported at the annual Transportation Research Board conference in January 1975.[1] Apparent from the study is a time lag between building the system and feeling its effects: very few clear impacts are yet traceable to BART, probably because of the size of the region involved. Certainly, many people ride the system and alternative modes of public transportation have in some cases lost patronage. Effects other than those on the total transportation systems' modal split, however, are less obvious at this early date. Impacts that were predicted, both positive and negative, have not yet materialized. This may be due partly to community accommodations, partly to imprecise techniques for stating and measuring probable Impacts, both by planners and lay citizens.

National interests center on issues of federal involvement in research, development and demonstration of new systems and probable heavy Federal funding of local systems. AGT systems are of national interest because of their potential for contributing to a better balanced urban transportation system and increasing the productivity of money and energy used in transportation. National interests in environmental improvement and improved transit for the disadvantaged are also important considerations. Further, there is national interest in the economic consequences of developing a new AGT industry. The potential of both domestic and foreign markets for U.S. AGT systems and competition for U.S. markets from foreign suppliers is a significant matter of national policy.

Hence, the questions of encouraging or discouraging automated transit technology touch both immediate, individual interests and national interests. Both ends of the spectrum deserve much more careful thought on the part of those who make transit decisions. In particular, ways and means have to be found to ready existing institutions to make the chosen transportation improvements work.

Finally, the panel noted the considerable (if not overriding) influence state and local government wields over transportation decisions. State governments have major transportation responsibilities. They can be expected to be concerned about costs. The rise in the cost of urban road building and maintenance creates interest at the state level in automated urban systems; so does the lack of public acceptance of new highways. The states usually have a responsibility for environmental improvement as well as a concern for the economic health of the state as a whole. The movement of goods is heavily regulated at the state level as is traffic and public safety.

State governments are the ultimate source of the powers delegated to local governments. Structuring metropolitan agencies to make them capable of handling regional problems in a coordinated fashion is a tremendous challenge, particularly in the field of transportation where jurisdictions are typically fragmented and in competition for ever scarcer transportation funds. Extensive reliance on automated transit to meet a significant portion of urban trips would likely require much greater coordination and more centralized authority than is now typical . creating and funding effective, accountable, and responsive metropolitan agencies to handle transportation and land use problems is the most serious challenge facing state governments, and one that is critical to the future of automated transit.

[1] "A Review of Some Anticipated and Observed Impacts of the Bay Area Rapid Transit System," R. Ellis (PMM&Co.), TRB Annual Meeting Conference Session, January 13, 1975.

## Chapter 2: Interest Groups and Their Concerns

Assessment of the social acceptability of automated guideway transit systems must proceed from an understanding of the needs and concerns of groups of people, all of whom have a role to play in the local decision making process. The panel selected a short list representing the incident society, whose concerns will govern the "acceptability" of AGT plans and subsequent implementation. The following brief summary of these stakeholders and their interests highlights some of the most important considerations.

### TRANSIT USERS

As a group, users can be expected to be concerned mainly about reliability, safety, total trip time, comfort, noise, convenience and accessibility, availability and frequency of service, personal security, out-of-pocket cost, and ease of transfer to and from other modes of travel. Users have a large stake in the question of how soon transit can be significantly improved and how extensive systems will be.

#### PERSONAL TRANSPORTATION COSTS

Many users and potential users, particularly commuters, have a serious and urgent interest in reducing personal overall transportation costs by reducing the need for a second car.

#### PASSEN(3ER INFORMATION

An important and frequently overlooked concern of the user and would-be user is the need for information about how to use the transit system. Ready access to complete and specific information about the system poses a challenge to managers in all forms of transit. Not only must information be available in stations and bus shelters, it must be available in the home where most decisions on mode are made. Public awareness campaigns comparable to existing driver education programs are needed.

#### THE ECONOMICALLY DISADVANTA(3ED

The stake in the potential of automated guideway transit is perhaps greatest for those disadvantaged by lack of access to private autos, especially in communities that are today essentially auto-dependent. These groups comprise the bulk of present transit users and their ranks will grow as more and more famdies are unable to afford private transportation for all family members for all trips. Daily existence, for this group, is tied to the adequacy of the public transit system. Increasing the range of choice of jobs, housing, health care, educational opportunity, shopping, recreational and cultural opportunities for this group can be expected to be an important goal of regional transportation planning. f t is possible that a great number of latent transit users could be found among the disadvantaged. They could easily be overlooked in making patronage estimates, particularly for off-peak travel; though they should be counted.

### THE PHYSICALLY DISADVANTA(3ED

If automated systems are to be useful to the elderly, the very young and the handicapped, design features that enable them to use the system easily and safely are of paramount importance. Attendants in stations may be necessary. These factors may add significantly to operating and capital costs of automated systems.

### PERSONAL SECURITY

Personal security is of critical concern to users. Transit crime is a reality in non-automated systems; it poses even greater problems in automated ones. Concern for security must be an Important aspect of design for all types of automated systems. Adequate remote surveillance, good communication and prompt response to incidents may add significantly to labor costs of automated systems. And labor costs may increase proportionately as the size of vehicles is reduced and the number of vehicles and stations increases.[1] Efforts to enhance security must recognize that dangers perceived by the user may not correspond with actual danger. The user must not only be secure, but feel secure. The security problem may be especially acute for small vehicles featuring shared rides where there is neither the safety in numbers characteristic of medium and large vehicles of the group rapid transit and shuttle types, or the privacy of true PRT.

### RELIABILITY

Reliability is another critical measure of user acceptability. Reliability of an automated system should be based upon a standard, relevant to the consumer, such as: the passenger should not have to experience a significant delay (30 minutes or more) more often than once in 100 trips.

### PEDESTRIAN SUPPORT

In general, users can currently be expected to walk about 1/4 of a mile.[2] This, of course, presumes adequately constructed and maintained pedestrian access—a cost factor frequently overlooked because it falls outside the jurisdiction of transit operating agencies. 1t is possible that if auto usage becomes severely curtailed, longer walking distances will be more acceptable.

### TRANSFERS AND INTERMEDIATE STOPS

A major continuing theoretical discussion, relative to acceptability by the user, centers on the events of transfers and interxnediate stops vs. origin-destination service. Transfers have a bad name. This is

[1] Preliminary Draft Study Report of the Twin Cities SVS, DeLeuw-Cather and Co., Inc. et al, Report No. 75-03, January 1975.

[2] This, and other characteristics of Transit Users as a class. have been extensively reported and reviewed, e.g.,

"User Determined Attributes of Ideal Transportation Systems," Department of Business Administration, University of Maryland, June 1966.

"Technology Assessment o/ Personal Rapid Transit Systems," The MITRE Corporation, MTR 6664, January 1975, quite understandable since transfers on the present bus service frequently involve long waits unexposed locations. One response to this problem is to attempt to develop a transit system which carries a passenger from origin to destination on a single vehicle, preferably on a personal basis without intermediate stops. Such an attempt may well exceed public need or expectation and, since it is technically difficult and very expensive to achieve, deserves some re-examination. Studies in Denver indicate that the negative environmental impact of guideway interchanges significantly outweighs the marginal patronage advantage achieved by eliminating transfers.[3]

Investigation may show that what is really important to those currently depending on autos and pressed by increasing auto costs is safe, reliable, frequent service to multiple destination in a reasonable period of time. Transfers that can be accomplished quickly in a climate controlled, secure location may be quite acceptable. If transfer points are laced with opportunities to turn single-purpose trips into multipurpose ones, so much the better.

Using the station clustering concept—carrying groups of passengers from a cluster of origin stations to a cluster of common estimation stations—the few intermediate stops involved may not add significantly to total trip time. It is possible that this will suffice for "personalizing" service as far as passengers are concerned.

Adoption of these points of view has considerable implication for the near-term utilization of AGT systems. Currently available technology for loop and shuttle systems and medium and large vehicle GRT could probably do an acceptable job in many urban applications. It would no longer be necessary to choose a single vehicle for a system. A regional transit system could be composed of a mixture of AGT systems, each geared to the needs of the area or function it serves. Those beleaguered citizens seeking to replace a planned freeway or reduce its scale with an AGT suitable for coridor service could be satisfied as could those needing a smaller vehicle system to serve a university community with a different set of problems.

Attempting to provide no-transfer non-stop service for an entire region puts all generic types of AGT under severe technological and economic stress. As suggested above, it may not be all that important to the user. Certainly further consideration of true public need and preference is desirable. Such consideration should be based on some real urban experience with AGT.

Regional pr arming agencies, committed to development strategies which encourage living, working and shopping within a single compact subregion, will probably place a premium on short trip transit service. Provision of transfer-free region-wide service would work against short trips.

## STANDEES VERSUS SEATED PASSEN(3ERS

Recent improvements to the interior design, and the resultant comfort levels, of bus and rail transit vehicles are assumed for AGT. One particular aspect of AGT vehicle design with broad acceptability and system design implications is the question of standing passengers. A great many technical problems hang on the issue of whether standees should be allowed.

[3] "Alternatives Analysis Report," Denver Alternative Analyais Study, Denver RTD, April 1975.

Seated, and preferably restrained, passengers would vastly improve safety and comfort features of small vehicles operating at very short headways. Such a requirement has two serious drawbacks. One: requiring passengers to be seated reduces operating flexibility in coping with unanticipated increases in demand on a localized basis and could result in a significant increase in waiting time. Two: a policy requiring seated passengers could be very difficult to enforce. Even low ceilings are not a complete answer because they would not affect young children, Controlling the exact number of passengers entering a vehicle is complicated and expensive for group-ride vehicles. Interlock systems for passenger restraints could cause serious delays in stations. On the other hand, public cooperation may prove easier to achieve with an entirely new mode than has been the case with the auto.

The standing vs. seated question has relevance to acceptability beyond the technological aspects of achieving safety and comfort. If it is presumed that people will not shift from autos to transit unless guaranteed a seat, that presumption should be retested. Studies done a few years ago in an era of higher auto availability and cheap gasoline are apt to be misleading for today in trying to answer this question, and others, Such evidence as exists from current transit usage indicates that standing for short trips or short portions of long trips at peak hours is quite acceptable. An exception would be the elderly, but most travel by the elderly is probably during off-peak periods when seating is not a problem.

If the shift from auto to transit is based on an attempt to reduce personal transportation costs, being seated is not likely to be nearly so important as trip time, reliability, and frequency of service. Auto owners' recent willingness to relinquish automobile comfort and safety features in favor of better mileage and lower capital cost has important implications for this and other operational characteristics of AGT.

## OPERATING AGENCIES

Operators originally developed an interest in automated transit in the hope of increasing the productivity of labor. Now, in the face of community demand for an expanded role and level of service for transit, the concern for reducing marginal cost is even greater.

Rehability of automated systems is perhaps the most important issue to operators. Automated systems that require an army of highly skilled maintenance workers for both preventive maintenance and restoration of breakdowns represent a risk that few operators are likely to be willing to take. At the present time, it appears that the risk of high expense for maintenance increases as vehicles get smaller and more numerous, and headways become shorter.

Safety is an important issue to operators. Today's safety standards dictate that there be sufficient headway between vehicles to allow for safe stopping distance without collision. Operators have to be concerned that any change in that policy to allow "soft" crashes (as may well be necessary to achieve adequate system capacity on the smaller vehicle systems) poses serious questions of public acceptability and potentially high insurance costs. The popular solution is to require that all passengers be seated and restrained. As stated previously, this could reduce flexibility in system capacity and add additional costs for

**passenger management. The panel noted that a major reason airline cabin personnel are required is to insure passengers are buckled in seats and trays are upright during take-off and landing. Another area of potentia!l~r high labor cost with automated systems is that of personal security~~, Responding promptly to emergencies is an important key to security. It is probable that the cost of that response is tied directly to the number of vehicles and stations.**

**It has been assllmed that the development of automated fare collection systems and superior methods for informing and managing passengers would eliminate the need for attendants in stations. It is possible, however, that the interaction of patrons and the system is more complex than realized. At this time, operators will probably have to assume that stations must be manned, especially in high crime are~s, until it is proven unnecessar~-. This represents another potential cost to operators, one that is directly related to the number of stations involved and the number of hours of daily operation.**

**The panel was asked to examine the impact of providing free transit on automated s~-stems. A few examples of no-fare transit systems have been in continuous operation for a number of years. These include the service at Colonial Williamsburg, which operates in a continuous one-way loop from the visitor center, and the M&O subway in Fort Worth, Texas which although primarily intended to serve shoppers, has developed a significant commuter load. These systems, however, are relativel~" limited in size and scope.**

**No-fare systems also operate on a number of college campuses and into the surrounding areas. One such system, at Kent State University (Kent, Ohio), has all the characteristics of a conventional bus system, with a number of routes, and seven day per week operation. Ridership is limited to students, faculty, and employees of the university, and is financed through a levy on riders,**

**Fare boxes, particularly the registering type, have proved to be a persistent maintenance problem on buses, and a common source of road calls. By definition, a no-fare system eliminates the need for a transit company to handle cash, and no monitoring of assengers is required b~" the operator, except where ridership is rimited to a specific group of users.**

**The impact of a no-fare system on ridership is difficult to estimate. It is possible that ridership will not increase significantly at peak times, since there is evidence that peak-period riders tend to select their transportation on the basis of convenience rather than cost. I.arger increases in ridership are to be expected at off-peak times, when cost is a more critical factor than convenience. This minimal experience (in addition to the example of elevators in buildings and the majority of operating automated systems in airports) points to a no-fare policy being acceptable when: (1) The system serves special interest groups or enhances a commercial enterprise, (2) there is no reasonable alternative mode, (s) the typical trip is short, frequent, and many-to-many, (4) handling money, operating and maintaining fare box equipment, and the associated security problems outweigh the value of the revenue, and (5) the operators' expenses are offset by other economic advantages, which is not likely to be the case with urban systems.**

Beyond the questions of labor costs, reliability and safety, operators have to consider capacity, patronage, revenues and energy requirements. Effectively coordinating automated transit service with other public systems and private transportation is important. Operating flexibility and the ability of the system to expand are of serious concern. Operators must consider staging strategy for capital investment. They must also consider development costs, a significant item even for so-called '(existing" technology. The are anxious to reduce technological and acceptance risks and 100 to the federal government for help in this area as well as capital funding, especially those considering "first" applications of new technology.[4]

For the long run, operators have to consider how systems they might install in the near future can gracefully adapt to new technological developments. They have to consider the possibility that public transit will one day be the most dominant element in urban trans ortation and perhaps the only element along with walking, within seYected urban settings.

### THE COMMUNITY AND THE GENERAL PUBLIC

At the community level, the interests of all the stakeholder groups come together in the local decision-making process. The lack of sohd information about the technological feasibihty, capital and operating cost, social and environmental impact and public acceptance of automated systems makes that process very difficult. It must be emphasized that balancing all of the interests involved would be a difficult political task, even if good information existed. Communities are considering a major shift in travel behavior when they examine transit options. Depending on the option chosen transportation costs could shift from the private to the public sector, as education costs did decades a o. Certainly, this would be the case with extensive deployment of automated systems. The complex impact of such shifts cannot be overestimated and it should not be surprising if communities are hesitant to make quick decisions. People want assurance that automated systems will solve more problems than they create.

The following is simply a sample of community concerns about the possible consequences of automated transit. These must not only be Identified, but also weighed against one another in any assessment of AGT.

- Impact on achieving compliance with air quality and noise level standards.
- Impact on regional energy consumption and conservation.
- Impact on present land use and property values.
- Impact on the pattern and extent of future development.
- Impact on existin and future road systems.
- Impact on regiona7 economic growth.
- Impact on personal m!bility and op ortunity.
- Impact on citizen artlcipation in urt an planning.
- Impact on regionar bonded indebtedness.[6]
- Impact on local and state taxes.

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4 uestions Of Multi-modality and Incremental planning were central to the item of a Nent UMTA/TR% workshop: see "O ning Remarks by C. Kenneth Omki, before the Conference on Evaluation of Urban Transportation A lternatives Airlie House, Warrenton, Virginia, February 24, 1975".

t ~~The Au~mated Small VeMcle 'Fixed ~ufdeway Study," (P. *). A Report to the 1975 bisktue 'f the Stab of Minnesota, Metropolitan council of the T~n ci~le.s Area, April 1975, Individuals who choose not to use automated transit will nevertheless face higher transportation costs in the form of increased taxation to pay for the system since it cannot be assumed at this time that either capital or operating costs will be met by revenues. It is possible that if installation of automated transit is accompanied by economic penalties or disincentives for auto usage, costs for this group will climb even higher. Resentment and opposition from this majority group could be a serious acceptability problem, particularly if transit is viewed as a ‘(welfare” program.

The unserved public can be expected to pressure for expansion of service, just as is now the case with bus service. Such expansion maybe uneconomic or out of phase with system implamentation strategy and severe political and economic problems cou ld result.

The general public can expect to share in any general community benefits such as lessened auto congestion and environmental enhancement. Residents of the central city and those in the suburbs do not necessarily agree on just what are the transit "problems". The confirmed automobile driver has been characterized as looking to public transportation to bring about a return to the uncontested roads of an earlier privileged era. This attitude (if it ever reflected a significant percentage of auto drivers) is no doubt losing ground as the perceived cost of driving a private car increases. An operating agency, however, can hardly expect support in financing large capital costs solely on the expectation of long term community benefits.

$ Proposals for major capital investment in automated transit, whatever its virtues, must compete with other capital needs in the community. The Metro Council in the Twin Cities[ as indicated its support for low capital transit alternatives, basing its case heavily on protection of the regional credit rating.

## LABOR

Labor groups can be expected to view the prospect of automated guideway transit in terms of jobs. In general, automation will be viewed as a positive step if it both increases the productivity of labor and enhances job opportunity. Labor groups can be expected to take a strong political role both locally and nationally in transit decision making and the thrust of their efforts will be related to how much consideration is given their interests in the local planning process.

Transit operatmg unions are interested in the potentid of automation for increasing the role of public transit in urban areas and therefore expandin job opportunities. These unions prefer that institutional controY of re~onal transit be unified. They also feel that more imaginative approaches to management and labor relations are needed to cope with the complexity automation will bring. They are especially interested in the safety, reliability and personal securit aspects of AGT as well as improved fare collection systems for a 1l elements of transit. These groups have an interest in promotion of equality of mobility for all, and m seeing transit become a completely tax-supported public service available to all without charge, a position which may or may not be altruistically motivated.

Others unions can be expected to have an interest in the potential of automated systems to provide new job o opportunities in the construction and fabrication fields. Unions wiR a major stake in the auto industry may consider the boost AGT could give to public transit as both an opportunity and a threat,

### LANDOWNERS AND DESTINATION GROUPS

The possible impact of automated s stems on patterns of urban development and re-development is t 1e principal concern of real estate interests. Its potential effect on the abatement of sprawl and on the clustering of development around stations and in major activity centers will be acceptable or unacceptable to landowners depending on whether they stand to lose or gain. The timing and extent of deployment and its impact on road building will be of concern to this group as will be the manner of assessing costs. The impact on parking needs is important. It could be expected that "downtown" interests might be in continuous conflict with those in more dispersed locations on the question of the extent and type of deployment of automated systems.

Employers, retailers, and purveyors of professional services have a large stake in transit improvement as have recreational, cultural and educational institutions. They be can expected to take a strong interest m levels of service, extent of networks, location of stutions, comparability with other modes and the timing of deployment. Some in this classification are heavy community taxpayers and will be very concerned about costs. The extent of concentration or dispersion of the facilities these groups control within the urban area wdl greatly influence the type of automated system chosen, if any.

Predicting, interpreting and communicating the impact that AGT systems will have on the environment and neighborhood is a major challenge. Jerome Lutin put this aspect of AGT development into context as follows: ~

"Research in urban planning and physical design for PRT systems has lagged far behind that of a more purely technological nature. This is indeed unfortunate, for architects and urban planners have a unique opportunity to predict and plan for long-term urban growth by utilizing an innovative form of transportation as a determinant for the placement of activities. Although many of the technical problems of PRT have yet to be resolved, the physical and performance parameters are known. By relating these parameters to the attainment of goals for structuring future urban society, it may be possible to achieve an orderly progression to future forms of urban development. Present conflicts between transportation systems and urban form may be eliminated, and future conflicts prevented. Clearly, there is a need to involve the planning and design professions more closely in the development of PRT. Such an involvement should not merely be that of mediating the effects of systems which constitute an imposition on urban life, nor should it be one of applying superficial cosmetics. The inquiry of the design professions should be addressed to a much more fundamental issue, that of fitting the system to the needs and aspirations of society, and bringing together all the elements in a unified physical form. "

Recent studies in the Twin Cities and Denver indicate that well designed aerial guideways are probably acceptable in major transportation corridors (highway or rail), along purely commercial arterials, and in areas subject to redevelopment where an opportumty exists to truly integrate guideways with new land uses. Aetual guideways in the metropolitan centers (downtowns) of the Twin Cities are unacceptable for aesthetic reasons, but there the opportunity exists to use cut and cover techniques under pedestrian malls, in an economical way.

In Denver, downtown aerial guideways are preferred to the disruptions inherent in underground installation.[2] Acceptability in residential areas, particularly the low-density, and suburban ones, is a questionable proposition. The problem is deeper than aesthetics and visual intrusion, important as those two factors are. Preservation of personal privacy in the home and yard in the face of a stream of prying eyes at second-story level is a serious matter. Concern for the protection of the trees which canopy the streets, is another. Perhaps the most important concern is for the stability of property values and land use in the guideway path and the vicinity of stations. This worry is closely followed by a well-founded concern that stations could bring on an increase in auto traffic in affected neighborhoods, especially if provision is made for park-and-ride.

[1] "A Methodology for Integrating p RT Networks into the Urban Environment," Jerome M. Lutin, *PRT II*, University of Minnesota, 1974.

[2] "Environmental Overview Report," Denver Alternatives Analysis Study, Denver RTD, April 1975.

All of these concerns are potentially as important as the similar set that leads impacted neighborhoods to oppose freeways. It is important to remember that in the Twin Cities (and probably elsewhere) the life style inherent in this kind of housing which emphasizes privacy and tranquility is prized above all other considerations including transportation. It is possible that the positive features developed by the urban design study team such as inear parks along guideways, that themselves are confined to side streets, and integration of stations into neighborhood shopping facilities, could improve acceptability, but no one is taking any bets. Experiences in t\ e Twin Cities and Denver bring into question whether fine grid networks can be im le-men ted and raise some doubt about the eventual regional deployabiYity of the smaller vehicle types of AGT that require such networks. It ap ears that deplo ment will have to be limited to major corridors, rufing out small vei icle systems in residential areas.

According to most proponents of personal rapid transit, the popular concept of small vehicle automated systems is that they will function best in a uniform gridded network. In such systems, particularly those using one-way guideways, one finds a configuration which seeks to provide a uruformly high level of accessibility to all sections of the urban area. Many PRT advocates feel that ubi uitous service and coverage is the most important attribute of the%RT conce t; that only by providing service to the majority of dispersed trip enzs in the urban area can PRT be an effective transit competitor to the auto.

In many respects, PRT and auto networks share similar attributes. Each expects small vehicles with low vehicle occupancy. Each functions best on a guideway system with relatively even spacing. Neither favors on-line stations, and both seem to have low tolerances for congestion. The similarity between PRT and the auto is a conscious effort to emulate the most “successful” transport mode history has ever seen. Yet how far should this similarity go? By replacing autos with a transit system so similar in operating characteristics we run the risk of propagating many of the adverse impacts of the system we seek to dis lace, including the low load factor typical of autos.

8y attempting to create a uniform level of accessibility throughout the urban area, the PRT planner allows, and in fact encourages, activities to be dispersed throughout the urban area. At the same time, the guideway system like the auto will encourage a uniform distribution of po ulation and activity density throughout the area. In both auto and $RT systems, this is the logical consequence of networks which attempt to minimize congestion by adding links, and thus, as a consequence, foster urban sprawl.

Before one advocates a transit network whose form guarantees the continuation of the present urban form, one must examme the factors which underly the creation of that form. Contemporary low-density cities may not be the reflection of consumer preference as to house type and location, neighborhood references, and travel desires. A more diverse range of choice may {e in order. Even if cities were the exact sum of all appropriate consumer preferences, can we assume that these preferences are an adequate statement of human desires? The main point of this argument is that one should not begin planning

PRT systems with assumptions about gridded networks or uniform population densities, at least, not without careful testing of those assumptions.[3]

Demonstration and deployment of the larger GRT systems should shed some light on guideway acceptance. P T advocates insist that the less bulky guideways of small GRT and PRT systems will solve the problem, but as indicated above, aesthetics is not the only issue, and perhaps not the most important. The panel sees evidence that neighborhoods will accept loss of personal convenience in driving and even lowered response time for fire and police service in order to keep traffic volumes down. They will go to court over even imagined threats to land-use and property values. The potential for aerial guideways to be accepted in residential neighborhoods is very low, judging from reactions to similar intrusion.

It is important to note that unless neighborhood groups are included in the regional transit planning process, the full dimensions of opposition to and support of AGT systems in residential areas is not likely to surface until the environmental impact statement stage, It would be well not to repeat this mistake, too frequently made in freeway planning, The procedure tends to coalesce the opposition and leave the support disorganized, regardless of the merits of the project.

The challenge of integrating an AGT guideway into the environment has been the subject of numerous papers. Among the more significant is a study by Jerome Lutin[4] and a review by H. Riley of several additional studies.[5]

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[3] The four paragraphs above are the rationale behind and stimulus for an architectural design workshop held at Princeton University reported in "Using PRT to Shape Suburban Growth", Transportation Program, Princeton University, 1974.

4 "A Methodology for Integrating PRT Networks into the Urban Environment," Jerome M. Lutin, *PRT II*, University of Minnesota, 1974.

6 "The Assessment of Visual Intrusion," H. Riley, Warwick University/Manchester Polytechnic, Urban Transportation Research Group, Working Paper No. 17, August 1973.

# Chapter 4: Conclusions of the Social Acceptability Panel

**The Social Acceptability Panel reached the following conclusions in its discussion about the direction of federal research, development and demonstration programs in the field of automated transit,**

**(1) We suggest that the first order of business is the establishment of specific sets of national and local goals on the role of transit in urban transportation and its desired impact on urban form. The focus, direction, and funding level of R, D&D should be based on those goals. In the interest of public and private economy, provision of mobility for the disadvantaged, oil conservation, environmental improvement, and liveable urban form, transit must be given an increased role, particularly in those metropolitan areas of moderate size which are now almost totally dependent on automobiles. The needs which arise out of national and local goals provide the basis for the necessary R, D&D programs.**

**(2) Recent survevs by regional planning authorities and by Congressman W. Frenzel (R.-Minn.) indicate that public interest in investing in transit improvement, as opposed to other public needs, is quite high. Public willingness to use existing transit, however, does not appear to be assured. Transit ridership is declining in many communities.**

**The major response to the gas shortage was a cut back in travel, not a shift to transit. Some panel members felt strongly that even the higher service levels possible with automated systems will not attract increased patronage without strong government regulation of auto use. Other members felt that the natural rise in auto costs alone will ultimately have a significant impact on transit usage, assuming high levels of service. In any case, the possibility that annual costs for automated systems could be lower than operating costs for bus systems justifies continued research and development at least until the cost issues are settled.**

**(3) The panel does not, at this time, see any likelihood of regional deployment of automated systems. There appears good reason, on the other hand, to believe that the most likely deployment of automated systems will be in downtown and major activity centers. Some corridor applications coulcl occur. Such applications, both downtown and corridor, will be for the purpose of increasing bus productivity}", allowing remote parking interception, improving air quality, promoting clustered, mixed use development, and overcoming deficiencies in highway and street capacity.**

**(4) Consideration of a national policy to increase transit usage a significant amount carries with it the implication of far greater investment of public funds to subsidize both operating and capital costs. It is not likely that fare revenues in a given region will cover**

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[6] A Mass Transit Survey by the Comprehensive Planning Organization for San Diego Region's Council of Governments, January 1975.

"1974 Attitude Survey," memorandum to the Technology Advisory Committee from the Transportation Staff of the Twin Cities Metropolitan Council, February 1975.

"Summary Report," Denver Alternatives Analysis Study, Denver RTD, April 1975.

system operating expenses, although some segments may more than pay their way. Low out-of-pocket cost to the user appears to be as essential as high level of service if transit is to attract new riders and meet the needs of the disadvantaged. Unless the commitment at all levels of government exists to provide the billions required to develo , construct, and operate both the automated and non-automated x elements of effective transit systems in a significant number of cities, there is little point in spending any money on research and technolo ical development of automated transit.

(5) The amount of money proposed by the Administration for research in automated technology 1s far too small if the intent is to provide new options for current problems.

(6) Time is of the essence. Automated transit cannot hope to be a significant factor in near-term national energy, transportation and environmental policy unless system de loyment in urban areas can begin within the next few }-ears. It must e remembered that planning, fabrication and construction of local systems is itself a lengthy process. That recess cannot even begin until technological feasibility and reliabr e cost estimates are clearly established. A significantly heavier investment than is now being made in development of low technology AGT systems over, say, the next five years, coupled with assurance of adequate capital and o crating funding concentrated in the next fifteen years, would give !oth private industry and local communities the kind of fiscal assurance necessary to undertake the massive job of alterin travel behavior. If this cannot be agreed, it should be stated clearY y that automation is not considered a viable option for meetin transit needs for the remainder of the Xlth century—that locaY communities will have to concentrate on other means.

(7) In addition to an increase in research and development funding and assurance of adequate ca ital and o crating funds based on a clear national policy for AG?, the SociaY Acceptability Panel feels that Congress needs to give more direction to research efforts it supports. To date, efforts have failed to yield market-ready systems, primarily because the research has not provided sufficient answers to establish the necessary levels of confidence about technological feasibility, reasonable and predictable costs, and social acceptabdity and impact for urban decision-makers. VVe reject uMTA's contention that the technology for Shuttle-Loop Transit and medium-to-lar e vehicle GRT is "here" today and that the bulk of currently availab! e research money should be spent at this time on the small vehicle GRT type commonly called HPPRT. It is our opinion that this approach is not based on an assessment of near term need by local communities and will unnecessarily delay implementation of automated systems. Current local studies imply that simpler and more nearly available systems can do an adequate and even su erior job with much less risk of acceptability. It would be very help F1 from a social acceptance viewpoint if policy direction clearly favored the regional im lamentation in this century in a number of urban areas of SLT and'GRT systems operating at headways which allow safe sto ping distance without collision and can achieve adequate capacity witt out deployment of fine grid aerial guideways. If such systems are supplemented with strong and innovative programs for feeder and express bus and all forms of para-transit, the transit needs of many communities can probably be met. under such a policy, research funds

should be primarily devoted to the list of AGT programs directed at improving reliability and safety proposed by UMTA and heavily supplemented by urban demonstration projects aimed at problems of social engineering, guideway acceptability and costs, proper integration with other transit modes, and land-use controls.

It is our belief that this approach for transit research is the most consistent with the broader goals of improving the productivity of existing transportation resources, meeting the established standards for air quality and noise levels, beginning the transition from oil as a transportation fuel, and providing adequate mobility for urban populations. We believe a new focus for AGT research is also a necessary step in determining the role and form of public transit for the 21st century. Specifically, it is necessary for determining the need, impact and acceptability of regional application of PRT.

(8) An understanding of the thinking of comprehensive regional planners about the urban form of the future is basic to determining regional transit needs in the future. One approach being suggested, most notably in the Twin Cities and Denver, is that, in the interest of public economy and reduction of the anxiety of urban life, more individuals should be enabled to live, work, shop and meet most daily needs within fairly small subregions.[7] Public transportation investments and housing policies should be directed at encouraging short trips, a broad mix of housing for all income groups, and clustered industrial, commercial and high density residential development. This approach is completely opposite from recent patterns which tend to encourage long trips and dispersed development. Whether such a shift on a significant scale is either possible or desirable will be the subject of lively debate. Exactly what its implications are for public transit, particularly automated transit, is not clear at this time. Certainly adoption of a transportation and development policy which encourages short trips would not be likely to lead to a transit system which provides single vehicle origin to destination service over an entire metropolitan area. Such a policy could favor that kind of service on a local basis and provide it in a number of ways, including both automated and non-automated modes, paratransit, and walking. Requiring transfers to make longer regional trips would be a positive strategy under such a policy. Traditional line-haul service would probably not receive priority for the most superior service. Express Euses would probably be used extensively for line-haul to major activity centers wherever freeways are available to accommodate them. Under this sort of planning, automated transit could play a useful role in circulation systems for activity centers and downtowns and in provldmg local service within subregions. It could also provide line-haul service, particularly in areas where freeways are not yet built or are seriously deficient in capacity.

It is the consensus of this panel that the concept of favoring the short trip and clustered development has merit, although there is doubt it can be successful if the constraints on regional travel are applied only to transit. We also feel the short trip concept drastically eases the strain on technological development of automated transit. Creating compact systems to serve a particular area or purpose

[7] "Metropolitan Transportation Development Guide Policy Plan," Metropolitan Council of the Twin Cities Area, as revised March 1975.
"Summary Report," Denver Alternatives Analysis Study, Denver RTD, April 1975.

without having to interconnect them physically would obviously make all phases of operation easier and probably much less expensive.

(9) We question the wisdom of anticipating extensive regional implementation of HPPRT or PRT. Local studies in Denver and the Twin Cities have shown that extensive deployment of aerial guideways and stations is probably unacceptable in most residential, and some downtown, areas. Requiring that all passengers be seated would be a drawback. Such systems may require high expenditures for labor for preventive maintenance, breakdown response and security forces, thereby negating one of the principal reasons for automation. 1t appears at this time that both the high order of reliability required and the extensive guideway needed will be very costly.

The personalized non-stop service provided by these systems can probably be handled adequately at lower cost in the near future by para-transit, innovative use of taxis, and specialized services. We do not feel that public transit is going to have to duplicate the level of service offered by the auto in order to be successful in the next thirty years. The rise in auto costs will in and of itself lower public demand for luxury service. The general rise in the cost of public services, which is outstripping the growth of public resources, will dictate economy. 1t does not seem reasonable that the ublic will be able to bear the cost of what amounts to a double set or roadways—one for PRT plus the existing one for conventional vehicles. The emphasis on encouraging short trips and clustered development could answer the need for PRT levels of service.

(10) We particularly question the utility of HPPRT from a social acceptability oint of view. It seems to offer the greatest likelihood of serious pro lems of personal security of all the automated types because of the high probability of forced shared rides with one or a few strangers.

Simulation in the Twin Cities and Denver studies indicated that small group service even to and from a cluster of stations involves significant longer waiting time than either scheduled GRT service or true PRk A number of studies have shown that waiting is the most irritating aspect of transit service to the user as well as the most dangerous in terms of transit crime. Further, the weight of the HPPRT eight to 12- passenger vehicle would seem to make the task of achieving reliable anx safe performance at very short headways much more difficult than it would be for true PRT with a smaller, auto size vehicle.

(11) Since the majority opinion of the Social Acceptability Panel finds neither sufficient need for, nor public acceptance of, hi~h technology, area-wide small vehicle systems at this time, we suggest that such systems receive less research priority unless funds are virtually unlimited, Should this class of AGT later become more viable, it will have done so in large degree from urban experience gained with simpler technology, and from any deficiencies found in experiments with systems favoring short tri s. The funding and program proposed for HPPRT is not unreasonable when viewed as long term preparatory research. To spend limited research funds on HPPRT instead of taking steps to meet real current needs with lower technology seems unreasonable.

(12) There are a number of reasons why urban demonstration of AGT system prototypes should be considered as much a part of a research program as test track technological developments:

- How well the system serves actual passengers must be explored for a wide range of operational problems.
- The full scale impact of stations needs to be assessed in a variety of settings.
- Land-use controls along the guideway and near stations need to be developed and effectively demonstrated.
- The opportunity to integrate stations and guideways properly into redevelopment projects and new development needs to be explored.
- The impact of AGT service on auto congestion and parking in activity: centers and near stations needs to be determined.
- The ability~ to move goods, of all kinds, needs to be developed for AGT systems and demonstrated in an urban setting.
- The extent to which the system can accommodate needs of the young, the elderly and the handicapped economically needs to be determined so that communities can judge what supplementary specialized services will be required.
- The true labor cost of AGT needs to be established for maintenance, security, station management, controls, and other functions.
- Work needs to be done on the coordination of AGT with other modes: buses, rail systems, para-transit, private autos, taxis and pedestrian systems.
- The nature of psychological resistance to automation *per se,* if any, on the part of potential passengers needs to be evaluated.
- The impact of AGT on housing choices of the poor needs to be assessed. It is possible that land values in AGT service areas could rise so high that pressures for redevelopment would push the poor out of. the area and defeat the basic goal of improving moblhty for this group.
- The securitv risk of AGT in high crime areas needs to be assessed as does the cost of vanda'i'ism.

This list is by no means complete, but its scope does indicate the nature of important unknowns for automated systems that simply cannot be handled on a test track or in simulation. Automated transit cannot be considered market ready until such work is done.

Every effort should be made to do as much evaluation as possible of social impacts of existing automated and near-automated systems. This work will have to be supplemented by more urban demonstration in the near future.

(13) A number of service features assumed for AGT systems could be tested using conventional transit and para-transit including:

- The effect of saturating an area with high qualit~- demand responsive service.
- The effect of transfer reduction and/or provision of climate controlled transfer points.
- The effect of improved passenger information programs.

(14) An important aspect of urban transit demonstration and planning for transit improvement in general, that is frequently overFooked, is involving the community in the planning and allowing for a multidisciplinary approach to design and impact assessment. Transportation is not an isolated element, the exclusive realm of technical experts, but a basic part of urban life. We urge that more effort be made to involve local communities in helping to set priorities for research.

# APPENDIX

## BIOGRAPHIC SUMMARY OF PANEL MEMBERS

Jacquelyn A. Ingersoll, Chairman
Citizen Advisor on Urban and Transportation Planning
St. Louis Park, Minnesota

Mrs. Ingersoll has been very active in civic planning and transportation matters in the Twin Cities for several years. She is past chairman of the St. Louis Park Planning Commission which serves a community of 50,000 people. She also serves as a member of the Citizens Advisory Committee on Transit of the Twin Cities Metropolitan Transit Commission.

Ralph Jackson
Director of Planning
Regional Transportation District
Denver, Colorado

Mr. Jackson returned to his home town of Denver in September, 1970, to accept the position as director of planning for the Regional Transportation District (R D). Previously, he was a senior associate engineer with Barton-Aschman Associates, Inc., of Chicago, where he participated in transit planning and traffic engineering studies in over 20 cities. Prior to his employment at Barton-Aschman Associates, Mr. Jackson was a research associate with the Department of Urban Stidies, University of Illinois at Chicago.

Alain L, Kornhauser
Assistant Professor of Civil and Geological Engineering
Princeton University
Princeton, N.J.

Professor Kornhauser has taught courses and conducted research on Transportation for the past five years, specializing in automated forms of mass transportation. He is co-editor of *Personal Rapid #ran.sit Z* and author of journal publications on design of automatic control systems, network design and analysis methodologies, energy impacts and attitudinal considerations in predicting the demand for new technologies.

Rodney K. Lay
Group Leader, Transportation Systems Planning
The Mitre Corporation
McLean, Va.

Dr. Lay has conducted and supervised the evaluation of a broad range of ground transportation systems as a member of MITRE's consultant systems engineering staff supporting the USDOT Urban Mass Transportation and Federal Rail R, D&L) Programs. He has directed a recent technology review and an assessment of the state of the art of Personal Rapid and Dual Mode Transit Systems.

John B. Schnell
Manager-Research
American Public Transit Association
Washington, D.C.

Mr. Schnell has served in this position with APTA for five years and specializes in all of the technical maintenance and operation aspects of urban mass transportation. He previously was involved in both mass transportation and automobile transportation with the Institute of Traffic Engineers, the Keystone Automobile Club and has been a County Engineer and a Township Engineer.

Reed H. Winslow
Department Head
Transportation Systems Planning
The MITRE Corporation

**Mr. Winslow's experience includes twenty years of progressive development** in transportation management, planning, and engineering. Under a contract with the Urban Mass Transportation Administration, Mr. Winslow has been involved in research and development projects for demand responsive transportation, bus propulsion systems, methods for granting priority to transit buses in traffic, automatic vehicle location and monitoring systems, urban transportation planning, and software and advanced technology for rapid transit systems.

George V, Wickstrom
Director, Office of Technical Studies
Metropolitan Washington
Council of Governments
Washington, D.C.

Mr. Wickstrom has been actively engaged in the practice of urban transportation planning for over 20 years. He has served as Director of several large-scale urban transportation studies in Philadelphia, Delaware and Washington, D.C. A registered professional engineer, he is also active in transportation research, and has authored over 20 published articles on land use and traffic planning.

# REPORT OF THE PANEL ON OPERATIONS AND TECHNOLOGY

Prepared for
the Office of Technology Assessment

PANEL MEMBERS

**Robert A. Makofski,** *Chairman*
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## Summary

The primary purpose of the Operations and Technology Panel is to determine the technological development requirements for the systems considered in the report-Shuttles and Loops, Group Rapid Transit Systems, and Personal Rapid Transit. The fulfilling of this purpose is relatively straightforward once the potential a placations and the operational service characteristics have been de tined. This is not to say that the solutions to these technological requirements will be easy or inexpensive to obtain but rather that the technology cannot be separated from the social and economic considerations that determine the applicability of these systems. The basic issues center about the need and applicability of some of the concepts.

### MAJOR FINDINGS

The panel arrived at several major findings that reflect the view of the entire panel.

*The Group Rapid Transit Concept.*—This concept is exemplified by the moderate headway (15 sec. or more), intermediate-sized vehicle (15 pass. or more) which can provide a technologically feasible and useful transit service in the capacity range between buses and rail rapid transit both in the line-haul mode of service and in the collection and distribution mode. Several of these group systems are in prototype operation and the basic needs are to bring the full automation to operational status and for product improvement in terms of reliability, performance, and cost and weight reduction of the vehicles and guideway. A small-scale urban installation of an improved system is absolutely necessary to establish design and performance standards, cost data, and the size of the potential market. Because of the uncertainty regarding the market and the substantial funding required for final development and demonstration, it will not be possible for a specific communit~- or organization to undertake such an effort without federal financial assistance. Rather, the urban installation and production engineering will require a mechanism by which the federal government can provide partial funding for these activities. The technical study and capital grant programs may be able to serve as a vehicle for such funding. Details regarding the develo~ment requirements for these systems are provided in the text of this report.

*The Development of a Technological Baseline.—The* Group Rapid Transit Concept needs such a baseline which should be pursued along with the initial staging of a federally owned test facility. Such a baseline can provide technical data on performance, cost, reliability, and safety characteristics which can be used to formulate specifications for deployable s wtems; can aid in identifying and examining the performance ancl cost trade-offs; and can permit the options in operational mode to be examined. The proposed UMTA HPPRT program can be reoriented to provide this development to support and ~ermit ex ansion of initial simple de loyments of Group Ra id Transit technof'ogy as advocated under#inding No. 1. The HP$RT program with proper orientation can also provide the test facility for continued development and testing of various automated transit systems and their components. System-level improvements, es ecially in automatic control performance and overall system rel'iability, are essential if initial installations are to expand to a meaningful role in urban transit.

In addition, a program should be pursued for the development of critical components and subsystems common to all systems. This activity can support the above effort and can be encompassed by the Automated Guidewa Technology program proposed by UMTA.

*The Personal RapJ' , Transit Conce t.—As* defined in this study, the concept a proximate most closely t Ee service provided by the automobile. l+'owever, the long-term development requirements, the economic viability, the intensive nature of a fine grid network, and the difficulty of introduction of such systems into an urban area resulted in skepticism on the part of the panel regarding the eventual development of these systems. However, the placing of major constraints upon automobile use in urban areas may provide an incentive for the development of these and other automated systems. The majority of the anel feels that the case for or against the Personal Rapid Transit ~ystems has not been adequately established and limited funding is justified to more fully clarify the advantages and disadvantages of this concept. One of the panel members feels that there are no conceivable conditions under which this conce t would find a significant role in transportation and recommends no k &D funding for this concept. Details are provided in the text.

*Interaction by the Federal Government.—The* Federal Government should interact more strongly with transit authorities in urban areas to consolidate and define the ublic transit needs of these areas in order to better determine the test methods of ap@ication for automated vehicle transit systems. This type of interaction is already present to some degree in the categories of rail and bus transit systems. It should be implemented even more vigorously with regard to automated vehicle systems so that an understanding can be obtained of the most economic spectrum of modes required to satisfy the real needs of our urban communities.

## COMMON DEVELOPMENT REQUIREMENTS

Regardless of the system considered, there are certain common roblems which differ only in the degree of development required?'hese include:

*Automation.-The* development of fully automated transit systems will require a substantial develo~ment effort directed toward improving the performance and reliabihty of certain critical subsystems and ~arameters. These include substantial improvements in the reliability of the wayside and vehicle control systems, in communications (especially between vehicle and wayside), and in the data processing equipment. The development of software techniques to manage the vehicle fleet are required and will probably be the pacing item in the introduction of systems employing demand-actuated operation. Insufficient attention has been devoted to the methods for managing system failures and of introducing methods to keep the system operational in the event of failure. Furthermore, the improvement of methods of detecting or removing foreign objects on the guideway which may affect safe operation is required.

As the headway$ are reduced, the complexity of the system and the need for components and subsystems with improved performance and accuracy is required, Specifically, a substantial reduction in headway below 15 seconds will require Improved vehicle detection techniques, faster responding equipment, increased accuracy in speed and position control, and, eventually, the de~~elopment of a controlled deceleration profile braking s~'stem.

l?eZiaWity.-The need to improve the reliability of automated guideway systems is beyond question. The development of better reliability will require improved definition of the s~'~tem reliability goals necessary for public acceptance of the system, Improvements to the critical subsystems and components to reduce failure rates, and the development of techniques to minimize the time to restore service in the event of a failure.

There exists a need to establish a data bank on the reliability of transit system components and to develop procedures and models that permit a common basis for obtaining reasonably accurate estimates of system reliability. Such procedures are necessary to permit the development of reasonable specifications and to identify the subsystems and components for which improvements in reliability are cost effective.

*Guideway Cost and Intrusion.-Since* guideways represent a substantial portion (5o~0 to 7o~c) of the investment costs for all of these automated systems and also a major obstacle to public acceptance, a successful effort to reduce the cost and intrusiveness of the guideway can have an immediate impact on the successful deployment of these systems. Such an effort would require work on the design, materials, fabrications, and methods for erection of such guideways, on the minimum design requirements to meet ride qllality standards, on the vehicle support and suspension technologies that produce the least expensive and minimum size guideway, and on the techniques for ice and snow removal and for passenger evacuation from a stranded vehicle.

*System Integration.*—The development of reliable high performance component or subs~wtem does not insure that this item will operate as designed in a transit system unless the entire system design is carefully controlled with specific design objectives and with an understanding of the interactions between the various subsystems. This process called system integration generally represents about 10˜o to 15~c of the system development and investment costs but is critical to obtaining satisfactory performance of the transit system. The system integration process requires that careful control be exercised over the system design to insure that design goals are being met and that the trade-offs in s~.stem performance are being examined. Such a process requires constructing and exercising computer simulations of the system and the extensive testing of the components and subsystems individually and then in the system as a whole.

*Test Facility.*—The well publicized failures of attempts to concurrently develop and implement a complex automated transit system are indicative of the risk of attempting to bypass the prototype develo - ment stage and of insufficient attention to carrying out a carefulry planned test program free of the demands of revenue operation. To minimize these roblems and to provide a common basis for the develo~rnent of t[ ese systems, a federally owned and operated test facihty is suggested; the facility being located at a permanent site to permit long-term development and testing. Such a facility would be available for:

- Testing critical aspects of system design.
- Estabhshing design and operational standards.
- Testing differing design approaches and components for comparison with standards.
- Testing verification of integrated automatic control systems, operational performance and reliability.
- Identifying and defining engineering trade-offs.
- Limited ~{check-out" of systems prior to urban deployment.

With proper reorientation, the HPPRT program can provide the initial stage of such a facility. It will be necessary to include as a design requirement for this facility the need to provide sufficient flexibility to permit the testing and development of alternative subsystems and components either separately or together.

The development requirements for the systems considered are given below:

1. tVLUttZe *and Loop* Systems,—Are essentially developed and available for limited operation in urban areas although the full potential of these systems has not been explored or exploited for urban transportation. The systems require product improvement and production engineering, especially in reliability, prior to urban deployment. However, the lower level of sophistication and previous experience with these systems suggest that these requirements do not pose a significant technical risk.

2. *Group Rapid Transit in the moderate headwuy* **jorm.-Can be** considered to be in the engineering development state, i.e., the feasibility of the concept has been demonstrated but significant effort is required to improve the product and to undertake production of the system. The major development requirements are given in Chapter 5 and include improvements in reliability especially of the automated control, computer software develo ment for managing the system, cost and weight reduction of vehicfes and guideways, and of methods for detecting or removing obstacles.

The initial requirements are related to the development of full automation of the systems which requires two basic characteristics: physical guidance of the vehicle and full control of the right-of-way. Neither of these requirements are related to any specific uideway or vehicle support technology. In fact, the support and gui%eway technologies require a closer examination of their impact on guideway s]ze, cost, and on the needs for lateral guidance and switching to define their applicability and potential.

3. *Group Rapid Transit in the short headway form.*—Currently under development in the UMTA HPPRT Pro ram. The concept 1s based upon the use of smaller vehicles and imp¥icitly smaller guldeways to

reduce the intrusive nature of the guideways and to make them more acceptable to the community. Operation at shorter headways should permit line capacity growth and more frequent service to the diverse destinations typical of urban travel and should result in increased system patronage; the smaller vehicle requirement being the result of increased frequency cf service and an increase in the number of destinations. At peak demand periods, the system could be operated in a scheduled manner with the smaller vehicles coupled into trains. There exists, however, a considerable body of opinion that feels that the economics of such systems may be unacceptable to the community and that the increased service may be more apparent than real, i.e., that comparison of passenger travel times, for instance, a~ provided by these systems or the longer headway Group Rapid Transit Systems would be about equal. This opinion group feels that further develo - ment of these systems requires clarification of "the potential app li-cations'' and an examination of the 'fsafety and economics. "

As already discussed in Finding Number 2 the panel suggests that the priorities of the HPPRT program be directed toward establishing of a technological baseline with emphasis upon reducing system capital and operating cost and upon increasing system reliability. A long-term goal can be that of determining the extent to which the state-of-the-art of Group Rapid Transit Systems can be advanced while still adhering to the conventional safety standards.

Development of the advanced group concept will require a test facility for integrated system protot~"pe testing with specific attention to improving the responsiveness and accuracy of the longitudinal control s)-stem and to the development of a controlled deceleration braking system to replace the currently employed fixed force emergency braking.

4. *Personal Rapid Transit Systems.*—Have been discussed previously. The development requirements for these systems include establishing the basic system requirements in terms of performance, cost, reliability, service and development objectives. These requirements include demonstrating the essential feasibility of the lon itudinal control system for short headway operation and of the vehicle design to permit controlled collisions.

In conclusion, the panel wishes again to emphasize that the technological requirements of a system cannot be separated from the economic and social considerations and that the priorities in development must be established by need. However, needs and requirements are often based upon available technology and are known to change drastically with time. For these reasons, the priorities that are established by identifiable and immediate needs should not be so narrowly defined so as to preclude the capability to investigate alternative procedures which may be needed to satisfy future requirements.

# Chapter 1: Introduction

At the request of the Senate Appropriations Committee, the Office of Technology Assessment (OTA) is examining the potential urban transportation role 'of small-to-moderate size vehicles that operate under automatic control on exclusive guideways; these systems often being misnomered as "PRT's".[1] The purpose of this assessment is to determine if these systems can provide sufficiently improved service and life cycle costs compared to conventional transit systems to warrant continuing development, to identify the development and implementation requirements, and to establish the needs and priorities for development.

To aid in this assessment, OTA formed several panels to consider various aspects of these systems. One of these panels is concerned with operations and technology. This report covers the work of that panel.

The Operations and Technology (O & T) Panel in the conduct of this work considered:

- The potential urban applications of these systems as related to the level of service offered to the passengers and to the operational modes available.
- The capability of these systems to offer these services in comparison with current systems.
- The development requirements and specific issues concerning the development and implementation of these systems.
- The priorities for development of these systems based upon identifiable needs.

It is not possible to separate the technology requirements from the social and economic aspects of these systems. As a result, the panel was required to make judgments on the applicability of the systems based upon social and economic considerations and then to apply these judgments to the operational and technological requirements. This report reflects the views of the panel members regarding all of these considerations.

## Panel Membership and Procedures

The panel membership was chosen not only on the basis of technical knowledge of the systems but also to reflect the viewpoint of different interest groups—system suppliers, consultants, transit operating agencies, and academics. The panel membership, their affiliation, and a brief biographical note on each member are given in Appendix A.

The panel members performed this work for OTA over a period of 10 weeks while attending to their regular duties. The Chairman met with individual panel members on several occasions and also discussed specific points b~~ telephone. Four of the panel members attended the briefing by UMTA officials on January 31, 1975. The full panel met only once for a two-da~' session on February 18 and 19, 1975, to formulate and discuss the primary issues.

[1] The term "PRT" in this report is specifically reserved for the class of systems called Personal Rapid Transit as defined in Chapter 3.

The panel's initial efforts were devoted to classifying automated guideway transit systems and to formulating a questionnaire to solicit various viev~points regarding these systems. The classification scheme is described in Chapter 3.

The questionnaire (Appendix B) was concerned with the principal issue of whether the use of exclusive rights-of-way, automation, and small-to-moderate sized vehicle transit systems can provide sufficient)' improvecl service and life cycle costs compared to conventional transit to warrant their continued development. The questionnaire was sent to approximately' 50 individuals and organizations. The responses listed in Appenclix C are on file at the ()TA office in Washington, D.C, No attempt has been made to correlate the various responses; ratl~w, they were usec] by the individual panel members as an aid in assessing the various viewpoints regarding the development of these automated systems.

Further, various individuals with specific technical knowledge of these systems were invited to participate in the discussions during the February 18 meeting of the panel. These individuals and their affiliation are given in Appendix D. The panel wishes to acknowledge the contribution of these individuals to the work of the panel.

The meeting on February 19 was attended onl~'. by panel members. The purpose of this meeting was to define the prlmary issues and to formulate the views expressed in this report.

## SYSTEM CLASSIFICATION AND MODES OF OPERATION

The automated guideway svstems were classified according to the operational complexity' (and, implicitl)', technological complexity and according to the vehicle occupancy: characteristics, i.e., whether the vehicle is occupied by. multiple individuals or parties simultaneously (as in a bus) or by. a single individual or related party (as in an automobile). This classification scheme (Table 1) is identical to the scheme used by the other panels except that the technoloqy assessment required the system characteristics to be more explicty~' defined. Further the Group Rapid Transit concept was separated into two categories to reflect the differences in operational and technological cornplexit~- between the two categories of the Group Rapid Transit concept. system clescriptions are given in Table 1 ancl covered in more detail in Chapter 3. In general, as the vehicles considered for the various systems decrease in size, the service becomes more personalized and more complex to provide, especially in terms of the level of automation.

The classification scheme does assume certain operational and service characteristics and, implicitly, certain types of applications but it does not assume specific technologies. For example, any of the systems can use steel wheel-on-rail, rubber-tires, air-cushions, or magnetic levitation. This is not to say that such considerations are not important. The eventual capability of these system concepts to provide the service expected at minimum cost will be strongly dependent upon the technologies chosen for the various subsystems. It is incumbent upon the system designer to examine the subsystem technologies available and to choose these technologies to prowcle the best overall performance for the system.

operation of these systems can be either scheduled or demand-actuated. The schedule mode provides service over predetermined routes following a predeterrrlinecl timetable with the passenger expected to time his arrival inlrnediatelJ' prior to the vehicle arrival or with the frequencl- of service being sufficiently high so that the ]Jassenger waiting ~ime is short. Demand-actuated o~)eration, on the other hand, provides a space or vehicle to a passenger in response to a specific request for service with the passenger waiting time being (lepen(]ent llpon the availabilit~- of vehicles to that station. In the multiple partjr occllpancj' case, the waiting time is dependent upon the availabilit~' of a space aboard an approaching vehicle which can provide the necessar~- service.

The dependence of these operational mocles upon the various s~'stem configurations possible is discussed below:

~huft/e.-This tJ-pe of s~'stem serves moderate traffic density (several hundred passengers **per hour) operating between two points tvpica]l~' separated b~ a few hundred feet to a large fraction of a mile. A single vehicle or train is operated in both directions on the gui(lewa~-. .Sometimes pairs of guicleways and vehicles are used to increase capacit~- and reliability; a prime example being the Tampa Airport Shuttle system. Service can be scheduled or partially demand-act uated.**

*On-Line Stop.*—The stations in this configuration are located so that the vehicle stops on the main line. This configuration is best suited to 1arge vehicles (e.g., 40 to 100 passengers) or trains of vehicles. The vehicles generall~- operate in a scheduled mode and are typically programmed to stop at ever)- station on the line or to operate in a skip-stop mode (e.g., everl- other station or everj' third station, etc.). I.oading dwell times in combination with time allocations for acceleration, deceleration, and safe operating headw?~-s typically require the vehicles to operate at headwn~-s of one mmute or more. Demand actuation is not usuall?: appropriate. However, the number of trains or vehicles on line is a(i]ustecl to variations of demand up to a saturation level. Since onl~~ some lines are interconnected, transfers are usual!}- required. This configuration is emplo~"ed by most existing transit s~'stems. It would also appl~" to simple multi-stop shuttle and loop s~-stems ancl could be used at line-end stations for Group Rapid Transit systems.

*Of-1ine* Stops.—Passenger loading and unloading is done at stations located on sidinos connected to the main line. This configuration permits the vehic res to b~'pass intermediate stations and to operate from zone to zone or m express mode to meet trip time objectives with low to moderate line speeds. Schedules and operating modes would be adjusted to meet projected demands. Shorter headwa~'s are feasible thereby effecting potentiall~- much higher main line loadings than is the case with the on-line stop operation. Current headwal-s with off-line loading are limited to about 15 seconds minim(lm.

Off-line stations are t~'pical in proposed applications of Group Rapid Transit s~stems using medium sized vehicles. This allows serving of the collection, distribution, and line-haul functions of medium densit~' urban areas using interconnected lines and minimum transfers, The service would be primaril~" scheduled, however, demand-actuation may be appropriate in off-peak periods with the smaller Group Rapid Transit vehicles. Off-line loading is required in the Personal Rapid Transit class of systems.

In addition, a differentiation must be made between those systems which in general will require a passenger to transfer and those which provide direct origin-to-destination service. The latter service is designed to provide a passenger with a trip from a station near his origin to a station near his destination withcut transfer. This service is generally associated with demand-actuated operation and is primarily of interest to Personal Rapid Transit Systems but can be implemented to a limited degree in off-peak periods ~th the group transit concept. Even in these systems, a transfer wdl be required between the fixed guideway system and the flexible route portion (auto or bus). Transfers can also be an effective method of accommodating high demands while reducing, to some degree, capital cost requirements and simplifying control system requirements. Reasonable limits must be placed on the number of transfers any one passenger must make in order to maintain an acceptable level of service and to provide a hi h ridership incentive.

The current technologicalf state-of-the-art is also an input to anysuch examination of systems. The panel, in general, was well acquainted with the current status and this kno~~'ledge was enhanced by means of the questionnaire, by discussions with the people invited to attend the February 18 meeting, and by other contracts. No definition of the state-of-the-art will be provided in this report except as necessary to the discussion of specific problems. Rather, the reader is referred to the report of the Panel on Current System Developments.

## Chapter 2: Potential Role of Automated Systems

The purpose of this section is to identify the urban transportation problems that can be effectively addressed by the various types of automated guideway systems. The urban transportation problem has many facets including traffic congestion, lack of mobility for certain groups, land use, energy and environmental impacts, capital and operating cost of publicly supported systems, level of service, and safety. The role of automated transit may be brought into focus by comparing its capabilities and disadvantages with the merits and weaknesses of the automobile and present modes of public transportation.

### THE URBAN TRANSPORTATION PROBLEM

Congestion is obvious to anyone who must travel major arterial streets or freeways during commuter rush hours. This problem is probably what most people think of when they refer to the urban transportation problem. Less obvious to those with access to an automobile, but frustratingly real to the remainder of the population, is the lack of mobility in our auto-oriented cities if no car is available. Only half of the American population is licensed to drive. The remainder, comprising the young, the old, the poor and the handicapped must either rely upon a friend or family member with a license or make do with the present transit systems which are inadequate in many of our cities.

The energy and environmental impacts of transportation are also important. Transportation[1] accounts directly for approximately one-quarter of our annual energy consumption—in addition, approximately half again as much fuel is consumed indirectly for production and maintenance of vehicles, highways, fuels and facilities. The transportation segment of our energy consumption is especially significant because 96% of this segment requires petroleum-based fuels. Therefore, the development of transportation modes that are energy efficient and that are less petroleum dependent will be favorable to current efforts to conserve energy and to lessen the nation's dependence on foreign oil.

The adverse environmental impact of transportation is also well known. About seventy-five percent of our atmospheric pollutants are attributable to transportation. These emissions consist primarily of unburned hydrocarbons, carbon monoxide and oxides of nitrogen. Because pollution is concentrated in areas of high auto density, the diversion of auto use to public transit in some of these regions can be important in reducing emissions,

The cost of transportation, especially mass transportation, is high. Revenues from bus and rail systems are inadequate to cover replace-

1 Hirst, E., "Automobile Energy Requirements, " Transportation Engineering Journal of ASCE, Vol. 100, No. TE4, November 1974.

ment of capital equipment and are inadequate to meet operating costs. To halt the complete deterioration of our transit systems from a vicious cycle of increased fares, reduced patronage, less frequent schedules, further reduced patronage and further increased fares, capital grants and, more recenty-, operating subsidies have been provided. However, the economic condition can be most significantly improved by increasing labor productivity and by attracting more passengers—perhaps through increasing the level of service.

Level of service refers to the convenience, reliability, accessibility, frequency of service, speed and comfort offered by a transportation model. On this basis, most public transit compares poorly with the automobile. There are, however, two areas where the level of service of the automobile is rapidly declining, and these present natural opportunities for the application of public transportation. Congested commuter routes and the dowmtown areas of many of our cities are areas of opportunity for a public transit service that can provide lower trip times and reduce land use.

Finally, about one-third of the 50,000 automobile-related deaths in the U.S. occur in urban areas. Since the evidence now available indicates that public transportation is about 30 times safer on a per person-hour of exposure basis,[2] the potential saving in life and in money cannot be ignored in the cost-benefit equation for public transit.

## Role of Automated System

The development of new transportation technology has been to some degree a part of an attempt to refocus technical effort from aerospace to civilian markets in response to cuts in defense and space budgets and shifts in what are perceived to be national priorities. This involvement of the aerospace companies has been desirable in that it has helped spark a technical renaissance in the transportation industry. However, there has been some tendency to view the transportation problem in isolation from concomitant problems of economics, finance, modal compatibility, politics, legal issues and community acceptance. As a result, systems have been proposed having institutional obstacles of such magnitude as to appear insurmountable. To avoid this pitfall, realistic markets for these systems must be identified and examined. Three such markets are discussed below.

The first potential market is already' being exploited. This market involves the use of simple shuttle and loop concepts as horizontal elevators for airports, shopping centers, remote parking areas, hospitals, and similar applications. There is evidence that such applications may be financially viable without federal assistance because of the increased architectural freedom and improved land use made possible. A developer may be willing to spend several million dollars to connect two activity centers with an automated system if such a connection permits budding on a less expensive and more suitable site and reduces construction disruption in the existing areas. The technology for such applications is proven with installations at airports in Tampa, Miami, Houston, Seattle-Tacoma and Hartford which are either operational or presently under construction. In addition, the Airtrans system at Dallas-Forth Worth has gone beyond demonstrating feasibility for

[3] Starr, Chauncey, "Social Benefit versus Technological Risk," Science, Vol. 165, No. 3899, Sept. 19, 1969,

simple shuttle and loop applications by operating (albeit with well publicized problems) a simple network with off-line stations and switching.

The second use for which automated systems have promise is to circulate people in downtown areas and major activity centers. These automated systems can increase the feasibility of auto-free zones while reducing pollution, saving energy, and enhancing the mobility and quality of life in the downtown areas. Such concepts can also reduce the disproportionate amount of valuable urban real estate devoted to parking, streets and automotive support functions.

The third market for automated sytems is that of intermediate capacity line-haul systems. The use of automation permits smaller vehicles which can provide more frequent service, especially during the off-peak hours. Such line-haul concepts do not offer a replacement for the automobile and are not expected to attract more than about 10% of the total trips in an urban area. However, these systems when designed to complement the automobile offer a number of significant benefits to the community".

These benefits include provision of reliable and efficient transportation for the young, aged, disabled poor and others without access to an automobile. The system should permit orderly land use development and should reduce and control the urban sprawl induced by sole dependence on the automobile. It may prove to be the missing tool to permit a development alternative to the high density eastern city served by subways on one hand and the low density western city served solely by the automobile. The line-haul automated system, concentrated as it is on major corridors, can be expected to provide relief to the taxpayer's major complaint-rush hour traffic congestion—and will also offer benefits in reduced pollution and energy consumption. In the event of a petroleum shortage, the line-haul system can represent a nonpetroleum dependent transportation backbone to assure continued commercial viability of the community.

The major economic incentive for all of the automated transit concepts is that of increased labor productivity. Studies [3] suggest that fully automated transit systems may have operating and maintenance costs of about 60¢ per vehicle-mile, about half that of buses and a third that of manned rapid transit. These lower costs make it possible to offer more frequent service in non-peak hours-providing a frequency of service sufficient to significantly increase ridership and service to the community.

### COMPARISON WITH CURRENT CAPABILITIES

The decision on the implementation of an automated system must rest on a detailed comparison with current alternatives—automobile, bus, and rail transit—for the given application and site. Such an examination is beyond the scope of this panel. However, some general commentary on this comparison is appropriate and is given below.

### AUTOMATED SYSTEMS AND THE AUTOMOBILE

In most respects, the automobile as a transportation mode is without peer. It offers demand service, has low labor costs since it is self-driven, and has low capital costs associated with highly sophisti-

[3] De Leuw Cather, et al., "Automated Small Vehicle Fixed Guideway Systems Study." Draft report prepared for Twin Cities Area Metropolitan Transit Commission.

cated mass production of a thoroughly proven design. But the automobile is by no means capable of performing all transportation functions better than other modes. The primary function of transit, then, is to complement the auto mode by doing well those tasks which the auto does most poorly.

The deficiencies of the auto mode are most evident on major traffic arteries in our urban areas. Here, attempts to move large numbers of commuters by automobile have been notoriously unsuccessful. The result has been traffic congestion, pollution and excess energy consumption. Attempts to meet the need with additional freeways have met with citizen opposition to the unreasonable land requirements for multi-lane freeways and the undesirable impact upon the quality of life.

In downtown areas, the concentration of heavy auto traffic into a small area destroys the human vitality which is essential to a metropolitan area, interferes with commerce, and prevents effective human interaction. Excessive land use is devoted to parking and auto service functions. The prevalence of off-street parking prevents use of the auto for travel within the downtown area without heavy cost and time penalties. Such travel is also unattractive because of the heavy congestion on city streets, which cannot be relieved because of the high cost of land and the previous investment in valuable real estate development.

These tasks, line-haul, arterial traffic and downtown circulation, performed so poorly by the automobile, are ideal for the automated guideway transit system such as the Group Rapid Transit concept. Such systems can carry more than ten times the passengers of a freeway lane on a right-of-way that is several feet narrower. They remove noise and pollution from the congested downtown area and major line-haul arteries and offer attractive energy savings over use of the automobile, typically about a quarter as much energy per passenger mile.

## AUTOMATED TRANSIT AND THE BUS

The bus, because of its low capital cost, is often promoted as the panacea for transit. However, the poor labor productivity of bus operation has lead to high operating deficits which in turn have lead to reduced service frequency and coverage during off-peak hours. Typical bus systems have about one employee for every 120 to 160 daily passengers or every 14,000 vehicle-miles.[4] Several proven operating installations, such as Tampa and Seattle-Tacoma Airports, average one employee per more than 1000 daily passenger or more than 30,000 vehicle-miles. Admittedly the operating conditions and environment are substantially different between an airport and a city but the large difference in magnitude between these numbers suggest the advantages of automation.

The labor disadvantage of the bus is magnified on line-haul routes such as the Shirley Highway Expressway by the large amount of deadheading— or travel opposite to the prevailing direction of flow— required to circulate the equipment to where it is needed. This counterflow service generates very little revenue. An automated system, because it is unattended, can better afford to circulate vehicles to meet the demand. In a downtown circulation mode, the slow speed of the

4 **American Transit Association "Transit Operating Reports, "**

bus on congested streets reduces both its labor productivity and the attractiveness of its service to the public. In Washington, the bus takes longer to traverse a 12-block (about 1.6 mile) downtown route segment during rush hour than is spent on the entire trip segment on the longest Shirley Highway Express route (about 10.8 miles).

The advantage of automated systems compared with buses are more frequent service, shorter travel times downtown and lower operating costs and, possibly, lower life cycle costs. The disadvantages are in the considerably higher capital cost requirement and the lack of ubiquity compared with the bus. The automated system is constrained to its expensive right-of-way, while the bus is free to travel anywhere and can easily adapt to changes in demand patterns.

A final advantage of the automated system is its ability to affect land development. The high investment in guideway committed by urban authorities, inspires similar investments from the private sector which can be confident the transit system will be there to improve mobility and increase land values. Conversely, no such confidence can exist that bus routes will be maintained.

## AUTOMATED TRANSIT AND RAPID RAIL

**Since** both rapid rail and automated guided transit systems use fixed guideways, the distinction here can only be based on two criteria—vehicle/train size and degree of automation. Present practice in rapid rail transit operation requires that an attendant be present on each train regardless of its size and degree of automation. On the other hand, over four years and many millions of passenger miles on fully automated systems (Tampa, Sea-Tac, and **D/FW** Airports), has been accumulated without a single fatality, admittedly under better controlled conditions than exist for rail rapid transit. There is some evidence that the very conservative safety-first design approaches used for automated systems and the use of coordinated vehicle-station doors to prevent passenger access to the guideway, may lead to a new standard of transit safety. At any rate, the safety record during what is always the dangerous introductory phase seems to establish the high probability that completely driverless operation would be acceptable on regular transit systems. If this proves to be true, then automated transit will offer a potentially higher labor productivity than manned rapid rail. Further, this higher productivity will make possible smaller vehicles and **more frequent service—especially during off-peak hours.**[5] **Thus, the concept of fully automated fixed guideway systems, whether they be rail or some other support technology, offer a high potential for improving service and increasing the system productivity. Obviously, the benefits of full automation can be applied to existing systems, such as light rail, where applicable. In this case, the advantages of a proven support technology place less of a demand on the system development requirements.**

**such system characteristics may** make line haul fixed guideway systems economically viable for the large number of American cities which are too small to justify full rapid rail systems and which are too large to be adequately served only by bus transit.[6]

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[5] Vuchic V. R., "Rapid *Transit* Automation and the Last *Crew* Member, " Railway Gazette International, October 1973, pp. 382–385.

[6] Vuchi, V. R., and Stanger, R. M., "New Transit Technologies : An Objective Analysis is Overdue," Railway Gazette International, October 1974, pp. 384-387.

## SUMMARY

To conclude, the auto is here to stay and no transit mode will completely replace it in the foreseeable future. However, it is essential to complement the auto mode with transit for two reasons:

- The automobile is unable to function effectively on high density commuter routes or in crowded downtown areas. It causes congestion, pollution and high energy consumption.
- Mobility must be provided to those without access to an automobile.

For lightly traveled routes, the bus will remain the preferred mode because of its ability to operate on the existing street network. On major line-haul routes or in downtown areas, where existing street networks are overcrowded, it makes sense to consider fixed guideway transit, since a single lane can carry ten times the traffic of another highway lane. By automating the fixed guideway system, a doubling of productivity seems possible compared with bus systems. When peak-hour demand exceeds 20–30,000 passengers per hour, it seems clear that conventional rail rapid transit systems, possibly automated to reduce operating costs, will continue to be the mode of choice.

The role for fully automated, fixed guideway transit will be to provide line haul and downtown circulation functions, which are presently poorly met by the automobile and require operating subsidies when met by buses. These systems will also continue to play an expanding role as horizontal elevators connecting remote parking lots and buildings within major activity centers.

## Chapter 3: System Description and Development Requirements

**This section describes the systems given in Table 1, below, with emphasis on the technological development requirements. These parameters are summarized in Table 2.**

### SHUTTLE AND LOOP SYSTEMS

Shuttle and Loop Systems represent the most advanced of the systems being considered in terms of their engineering development being in operation at several airports and other locations. The report of the panel on current status describes these applications in more detail. The basic physical difference between these systems and the other automated guideway systems is that the Shuttle and Loops do not make extensive use of operational switching in passenger carrying operation. As a result, stations must be on-line and the time allocations for stations dwell time, acceleration, and deceleration require headways between vehicles of about one minute. The required vehicle size is set primarily by the anticipated peak demand.

Because of the limitations imposed on travel time by the mode of operation and guideway layout, such systems are generally limited in length and in the number of stations that can be accommodated on a single line. However, the potential in comparison with buses for improved service at lower operating cost and life cycle cost recommends these systems for use as short-haul transit and as feeders to other transportation modes. These advantages must, of course, be balanced against the higher capital investment and the need for exclusive rights-of-way.

The potential use of these systems in urban areas has not been sufficiently examined or exploited. A partial reason may be the desire on the part of interested communities in obtaining the greater capacity and flexibility promised by the Group Rapid Transit concept, It should be noted, however, that Shuttles and Loops do possess the evolutionary potential to be upgraded as necessary to the Group Transit concept. Incorporation of operational switching could be exploited initially to permit off-line stations and, as required, to interconnect lines.

For their current applications, the Shuttle and Loop Systems can be considered to be fully developed with site-specific engineering required and, of course, some product improvement. If the systems are to be deployed in substantial urban installations, further production engineering will be necessary with emphasis on increased system reliability.

### GROUP RAPID TRANSIT SYSTEMS

**Because of technological differences in the characteristics and state-of-the-art, these systems are discussed according to their operational headway. For convenience these categories are listed as moderate headway (greater than 15 seconds) and short headway (less than 15 seconds).**

## Group RAPID TRANSIT SYSTEMS (MODERATE HEADWAY)

The moderate headway Group Rapid Transit, as a generic classification, represents only a slight departure from those rail rapid transit modes presently in existence. Group Rapid Transit is typically deployed in network configurations involving switching for multiple routing and involves the operation of single or trained vehicles. The typical capacity of the vehicles in those systems allows the use of fixed block train separation systems readily available with state-of-the-art technology. In general, Group Rapid Transit Systems utilize vehicles noticeably smaller than those normally associated with conventional rapid transit, but this generic classification can be considered, at the high end, to merge with the overlay with light rail transit.

Table 1 summarizes typical examples of the moderate headway Group Rapid Transit systems and their generic characteristics. Table 2 lists some of the advantages and disadvantages of these systems compared to conventional rail transit. The systems are capable of operation as intermediate capacity line-haul systems and as regional networks. In addition, they have the potential to circulate people in major activity centers and to connect major centers. The required vehicle size is primarily a function of the peak demand and the type of operation employed. The panel believes that these systems represent a much needed mode which, if satisfactorily developed, will assume a major role in urban transportation between rail rapid transit and the bus and that the deployment of these systems should be encouraged.

Group Rapid Transit Systems operating at moderate headways have been deployed in special applications, e.g., "Airtrans" at the Dallas/Fort Worth Regional Airport. These deployments are in a benign environment compared to that expected in urban deployment. Therefore, a selected urban installation will be required to "prove" these systems in an urban environment. These systems are considered to be in engineering development, i.e., the basic technology has been proven and work is required on the system design to improve the product and to prepare the system for larger scale production, The required improvements and development include:

- Substantial improvements in system reliability, especially automated control and communications, switching equipment and automated vehicle doors.
- Extensive development of computer software for managing the vehicle fleet and for accommodating the system to failures.
- Reduction in cost and weight of guideways and vehicles,
- Improvement of techniques for detecting or removing obstacles that may affect passenger safety or cause damage to the vehicle.

The substantial funding required for the engineering development is beyond the means of a specific community or organization especially in view of the current economic climate and the uncertainty regarding the market and level of federal involvement in these systems. Deployment of these systems will require at least partial federal funding for the conduct of the engineering development.

The panel specifically cautions that this consideration of Group Rapid Transit is based upon the service concept and does not imply an endorsement of any of the existing hardware,

## GROUP RAPID TRANSIT SYSTEMS (SHORT HEADWAY)

The short headway Group Rapid Transit System is characterized by headways from about 3 to 15 seconds, smaller vehicles (8 to 20 seats passengers), operational switching, and off-line stations. Capacities range from 3,000 to 15,000 passengers per lane per hour. The potential application for such systems are as activity center circulation and connection and as urban network systems. These applications are based upon the premise that the smaller vehicles and, implicitly, smaller guideways would reduce the cost and the intrusive nature of the guideway and increase their acceptability to the community. in addition, the operation at shorter headways would permit line capticity growth and more frequent service to the diverse destinations typical of urban travel and would result in increased system patronage; the smaller vehicle requirement being the result of the increased service and an increase in the number of destinations. At peak demand periods, the system could be operated in a scheduled manner with the smaller vehicles coupled into trains. If the unit costs and the guideway intrusiveness are reduced, more guideways can be constructed for the same price. In turn, the added guideway will increase the system reliability as perceived by the passenger by providing multiple routing alternatives to by-pass failures.

However, the economic feasibility, the increased service potential, and the greater accept ability of the potentially lighter guideways have not been established and a considerable body of opinion exists that feels that the short headway group system will not be acceptable. This group feels that further development of these systems requires clarification of the potential applications for these small vehicle, short headway systems and an examination of their economics and safety.

This difference in viewpoint does exist within the panel especially with regard to the UMTA HPPRT Program. However, the panel does feel that the priorities of this program with proper reorientation can be directed toward establishing of a technological baseline with emphasis upon reducing system capital and operating costs and upon increasing system reliability. A long-term goal can be that of determining the extent to which the state-of-the-art of GRT Systems can be advanced while still adhering to conventional safety standards.

The decision to develop the short headway Group Rapid Transit System concept will require a test facility for integrated system prototype testing with specific attention devoted to:

- Improving the responsiveness and accuracy of the longitudinal control system including the vehicle separation detection and wayside communication,
- Development of an emergency braking system capable of providing a controlled deceleration profile independent of vehicle loading, grade, and winds while still meeting the safety and reliability goals, and
- careful intergation of the system hardware and software if the development goals are to by achieved.

## PERSONAL RAPID TRANSIT SYSTEMS

The Personal Rapid Transit (PRT) System, as defined in this report, is considered to provide non-stop service from an origin to a destination station for an individual or related group of passengers.

Demand-actuated service is provided using small (4-to-6 passenger) vehicles. To achieve adequate capacity, headways of one-half to two seconds are required. Since these headways are below the headways that can assure an emergency stopping distance without collision, the system must be designed to be highly reliable and the vehicles designed to accept only seated passengers and to be crashworthy in the event of a collision. The proponents of these systems see them as eventually providing area-wide coverage with a fine-grained network of guideways and stations.

The PRT concept is based upon the premise that the only means by which a significant fraction of the urban trips may be attracted from the automobile is to provide a service comparable to that of the automobile, that is a personal vehicle with accessibility to a major portion of the urban area with trip times, cost, and direct service competitive with that of the auto. To obtain this service level, the system would require spacings of guideway and stations of approximately one-half mile and fleet sizes of the order of 10,000 vehicles for a city of one million population. Supporters of this concept feel that a large market for these systems exists because of the need to suppress the automobile. As a result, the economics of mass production will reduce the capital and operating costs to a level comparable to that of the auto.

The opposing viewpoint questions whether the PRT even with its claimed service could attract a significant fraction of the urban automobile trips unless severe restrictions are placed upon the use of the auto. Impedances such as the walk to and from a station and the difficulty of handling and storing packages are often cited as constraints on the use of such a system. The primary questions, even for those who accept the service concept, focus upon the economic viability and community acceptance of a fine-structured elevated guideway network which would essentially duplicate the existing street system and the capital and operating costs of a large fleet of vehicles designed to accommodate single party occupancy. The arguments for the large reduction in capital costs by means of mass production are not generally accepted nor are the means to attain the market required for mass production adequately defined.

The panel, as a whole, is skeptical regarding the eventual development of PRT Systems because of the long-term development requirements, the economic viability of the system, the intrusive nature of the fine grid network, and the difficulty of introducing such systems into an urban area. The majority of the panel feel that the case for or against PRT's as defined in this report has not been adequately established and that limited funding is justified to more fully clarify the advantages and disadvantages of this concept by a group of knowledgeable persons other than the system proponents.

One of the panel members feels that the PRT concept is inherently self-contradictory combining small vehicles optimal for dispersed travel with expensive fixed facilities which are economically viable only in high density corridors. He also claims that it can be shown that the claimed performance of this mode in terms of fractional second headway with acceptable speeds and safety cannot be physically achieved. Further, the inefficiencies of small vehicles in terms of energy, costs, and complexity in control and operation place these systems outside the realm of reality. He feels that there are no conceivable conditions under which this system would play a significant role in transportation and that with current trends with respect to energy the chances for these systems are even less likely in the future. As a result, this panel member recommends no R&D funding for this concept.

Another panel member who also believes that the economics of the larger vehicle sytems are likely to prevail supports limited funding for the Personal Rapid Transit concept because the technological advances resulting from such research will be applicable to the broad spectrum of automated transit and because the evolution of technology has in the past provided viable concepts that were originally believed to be uneconomic.

A decision to pursue the development of the Personal Rapid Transit concept will require resolution of the problems described for the other systems and, to some extent, can be aided by these developments. However, in view of the exploratory nature of this concept, emphasis should be placed upon establishing the basic economic and technological feasibility of these systems prior to undertaking major development. Thus, attention should be devoted to:

Basic system recquirements to provide service.

- Performance-speed, headways, acceleration and deceleration requirements.
- **Service—capacity,** passenger waiting and travel times, accessibility, and availability.
- Development objectives-Safety and reliability goals, cost goals, guideway and vehicle envelopes, station throughputs and configurations.

Demonstrating feasibility of longitudinal control systems for short headways (0.5 to 2.0 sec.).

Determining the requirements to be imposed on the vehicle and on other parts of the system by permitting controlled collisions.

Examining the fleet management requirements for short headway operation.

The decision to initiate a development and implementation program for a Personal Rapid Transit System must recognize that the system deployment can be a decade or more away and that the management, financing, and risk exceed in magnitude any other development program ever undertaken by the Urban Mass Transportation Administration, The need for careful long-range planning and for a commitment on the part of the federal government to such a program, if initiated, cannot be overstated.

## Chapter 4: Discussion

This section discusses the systems covered in Section 5 with emphasis upon the technological development requirements common to all of the systems and upon a development plan for these systems.

### General Comments

All of the systems in this assessment operate automatically without attendants or drivers in the vehicles. The objectives of this automation are the reduction and stabilization of operating costs, the improvement of service to the passenger, and a reduction in life cycle costs compared to other modes using drivers such as buses and manually operated rail systems. No one class of these systems is clearly superior for the entire range of applications envisioned. Each system has a range of conditions for which it may be best suited and it is only natural to expect that an urban area will be best served by a multi-modal approach incorporating these systems and conventional transit.

The complexity of the systems considered increases as the size of the vehicle and the headways decrease and as the operation expands to demand-actuated and origin-to-destination service. The introduction of this complexity is an attempt to increase the attractiveness of the system to the potential passenger and to reduce the trip impedances normally associated with transit use. There is no doubt that increasing the system accessibility to the passenger and reducing the passenger's waiting time and trip time are desirable and necessary attributes of a system if the potential ridership is to be increased. However, even in this case quantitative measures of the impact of time saving on the modal split are arbitrary and in need of further study. Other attributes such as no-transfers and single party occupancy are even more difficult to assess. For example, the public apathy to transfers is probably based upon current systems where the transfer takes place at an unprotected location with long or at least uncertain waits for the arrival of the next vehicle. Transfers may not be considered odious if they occurred in a protected environment and were simple and quick as has been done with some subway systems. The use of transfers would, in general, reduce the cost and complexity of the transit system. In effect, the panel requests that more study be given to this subject so that the necessary system attributes can be separated from those that may be desirable but may have only a small effect on the service provided or on the level of ridership.

Although prototypes of these automated guideway systems do exist and some are in operation in limited and special purpose installations, none of the systems are operating in a true urban environment. Urban operation places severe requirements upon a system in comparison with operation at airports, universities, or other activity centers especially in terms of the maintenance and reliability requirements and for operation under varying climatic conditions. At the same time it must be noted that the well publicized problems of automated systems me not a reflection on the concept but rather a problem in management and hardware; problems inherent in the introduction of new equipment.

It is not sufficient for these new systems to be shown to be operationally and technically feasible prior to their introduction into urban transportation. In addition, their role in urban transportation will be determined by their capability}' to offer a service and cost "package" which is superior to or at least equal to such "packages" offered **by** existing modes. It is incumbent, therefore, upon the agency developing these new systems to conduct an objective analysis of the system for comparison with conventional modes; the analysis taking account of the experience of transit planners and operators.

### COMMON DEVELOPMENT REQUIREMENTS

The major technical problems that need to be resolved regardless of the system considered are the development of reliable automation for the control of the system, the increase in overall system reliability, the development of less intrusive and less expensive guideways, and the assurance that system integration has taken place in accord with the development objectives. These items arc **discussed** below.

### CONTROL SYSTEM AUTOMATION

Full automation implies automatic functioning of three distinct operational responsibilities. The first is system management of vehicle movements, schedules, fleet size, and operating strategies under normal and degraded conditions. The second is control of vehicle propulsion and braking, door operation, station stopping, and the like. The third is the prevention of vehicle collisions and the protection of system equipment, personnel, and passengers under emergency conditions.

Neer systems such as BART employ computer installations to automatically maintain or adjust schedules and fleet size. The second function is performed in existing systems with widely varyring levels of automation depending on site specific and system specific considerations. Extensive use is made of automated equipment to perform the third function in existing rail systems.

The automated systems considered in this report differ from automation in current systems mainly by complete removal of the vehicle operating crew. This full automation promises reduced operating costs and, perhaps, life cycle costs, increased service by providing the opportunity to run smaller vehicles or trains at greater frequency, and in compaison with manual operation, some possible benefits in energy consumption, ride comfort, capacity, and schedule maintenance. These advantages are purchased at the price of increased investment costs and complexity.

For the automated guideway systems, the major R&D problems for full automation are those associated with management of the vehicle fleet, especially in dermand-actuated operation, and with the control of individual vehicles in short, headway operation. These are discussed below :

**Vehicle Management**

The vehicle and traffic management function of automated guideway transit systems provides the overall opertitional control for the vehicles in the system and as such implements the real time decisions pertaining to the disposition of vehicles in the fleet, The major subfunctions which the vehicle and traffic management system must perform are:

Provision of a vehicle to serve a trip.

Regulation of traffic flow on the guideway network to prevent saturation.

Adaptation and reconfiguration of the system in response to anomalous conditions arising in the network.

Scheduling vehicles for periodic servicing such as cleaning, washing, and inspection.

Providing system status to supervisory personnel and implementing their decision.

The development of the vehicle and traffic management system for an urban installation requires work in three areas:

(a) Development of algorithms for performing the required automated functions.

Most of the attention in this area has been directed at demonstrating the feasibility of algorithms for nominal operational.[1,2,3] The work in deman-activated operation has developed algorithms for regulating the number of vehicles in use relative to the total trip request rate, for circulating vehicles to locate them near anticipated trip origins, and for regulating the flow of vehicles at merge junctions and stations. Algorithms for performing the automatic detection and evaluation of anamalous operating conditions and for implementing the required response remain to be developed. This development to some extent has been delayed by the dependence of the algorithm on the network configuration and hardware selection.

(b) Development of real-time communications, computation, and display hardware system.

The hardware components for such systems exist but the collection and integration of these equipments into a cost-effective system needs to be performed for a particular application. Better estimates are required of the storage and timing requirements of the various software algorithms. These estimates will help prevent the recurring problem of undersized computers.

(c) Development of real-time computer software for executing the control programs.

The development of the real time software has lagged behind the conceptual hardware design. This software which is dependent upon the selected hardware controls the implementation of the vehicle management algorithms, set priorities within the equipment on which algorithms are to be operated, and controls the input and output of data from the machine.

Headway Control

The safety standards for guided systems have historically required the headway be limited to the "brick-wall stop", i.e., the spacing between vehicles be constrained to a value exceeding that required

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**1 "Personal Rapid Transit, " edited by J. E. Anderson, et al.**
**2 "personal Rapid Transit I I ," edited by J. E. Anderson, et al.**
**3 "Command and Control Status Report, " edited by E S. Hinman. UMTA DOT Report available from NTIS PB–231 681/SET.**

for a vehicle to come to a full stop under emergency braking conditions. The braking distance [24] is a function of the vehicle speed, the braking rate and jerk (usually the guaranteed minimum rates), the detection and reaction delays necessary to recognize the existence of an emergency and to implement braking, and the state of the vehicle at the time of the emergency, e.g., whether the vehicle is accelerating or traveling at constants speed. Current systems employing fixed block detection techniques will have a minimum headway of 10 to 12 seconds at 40 feet per second. The development of high resolution separation detection devices in place of the fixed block scheme and the use of accelerometers to detect vehicle overspeed will decrease the headway to approximately 6 to 8 seconds. These developments together with the development of a braking system capable of providing a controlled deceleration profile independent of vehicle weight, grade, and winds should reduce the headway to about 3 seconds. Such emergency braking systems which would replace the constant force emergency brakes currently in use are being proposed for development in the HPPRT Program.

Further reduction in headways to those proposed (2 to ½ sec.) for the Personal Rapid Transit concept will require the "brick-wall stopping" criteria to be abandoned in favor of a criteria which emphasizes high reliability and which permits occasional collisions between vehicles in the event of a failure. The requirements for these systems are discussed in Section 5.

Further work is also needed on identifying and seeking solutions to the social and legal problems that may be encountered as full automation is introduced into an urban area.

### SYSTEM RELIABILITY

One of the most important aspects of the practicality of automated guideway transit is the degree to which travel may be made reliable. This is especially true for the automated systems which employ a large number of vehicles. Methods for expeditiously and economically handling failures in the system and for maintaining service to as high a degree as possible must be designed into both the traffic management system and the hardware subsystems.

The reliability of a system is dependent upon:

(a) System availability goals for public acceptance. The availability goals are often expressed as: On the average, a passenger should not be subjected to more than one 5-minute delay in 10 trips or no more than 1-hour delay in 1 year. Too often these values are set without a careful analysis of the passenger's acceptance criteria. Since low values may reduce the public acceptability of the system and high values will result in higher costs, the availability goals must be established on a firmer footing than current practice.

(b) Subsystem and component failure rates. Procedures and a data base with which to estimate the reliability of typical components used in automated systems are only beginning to be available; e.g., data to establish appropriate derating factors for the application of electronic components in a mass transit environment. Such information will allow the critical components with high failure rates to be

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[24] Hinman, E. J. and Pitts, G. L., "Practical Headway Limitations for Personalized Automated Transit Systems." Proceedings or TEI Conference on Control Aspects of New Forms of Guided Land Transport, London, England, August 1974.

identified and to be improved by controlling the environment in which the part operates, by derating the component, and by adding redundancy to the system for those subsystems and components where reducing the failure rate is of critical importance. In all such cases testing of the components and subsystems and of the total system are necessary to establish the failure levels of the system.

It has been shown [5] that the reliability dependent, subsystems of an automated transit system are a relatively small percentage (about 20%) of the total system costs. If this factor remains valid, additional funding to develop improved reliability of these subsystems can have a marked impact upon the overall system reliability without significantly increasing the system costs.

UMTA should consider the establishment of a data bank on transit system components with the information provided and used by the transit operating agencies and other transit-related organizations. The existence and organization of such information can of itself provide an incentive for manufacturers to improve component reliability.

(c) Time to restore service. Failures which require long periods to repair and restore service will affect proportionately higher numbers of passengers and reduce the public acceptance of the system. Efforts, then, to develop means of rapidly identifying failures and to take quick corrective actions are of prime importance to these automated systems and are in need of development. It should be noted that if for the same investment the smaller scale vehicles and guideways permit more dispersion of guideways than the larger scale systems, then the additional routes available can provide a means of quickly restoring service even with a blockage in the system.

There is a need for design procedures and methods to permit determination of the system availability especially for the smaller vehicle systems. Such analysis will ultimately require a computer simulation to evaluate the numerous design variations which affect system reliability. Such work must be performed during the planning and specification stage for any automated system.

It is necessary to remember however, that mathematical modeling will not make a system reliable. Rather, it is the combination of design procedures, modeling, production quality control, and testing which is required. Such programs are generally expensive but experience has taught that their successful application has been worth the price.

### GUIDEWAY COST AND INTRUSION

Two of the most critical factors facing the implementation of automated guideway systems are the cost of the elevated structure, which represents 50% to 70% of the total investment cost, and the community acceptance of the elevated structure. Significant attention to these items is required. This work should include:

- Introduction of realistic design standards for guideway design. This work should include design studies on innovative structures that can reduce guideway cost and size such as those being undertaken by various architectural and engineering firms for the moderate headway group systems.

[5] Smith, Frank C., "System Assurance ; Current and Future Guideway Transportation Systems," First International Conference on Dual Mode Transportation, Washington, D. C., May 1974,

- **Introduction of production and assembly techniques to reduce the cost of the guideway elements and to reduce the disruption associated with on-site construction. Pre-cast concrete is particularly adaptable to this requirement.**
- **Determination of realistic ride quality standards. Current standards appear to be overly stringent resulting in higher costs and larger guideway structures than are necessary.**
- Development of cost effective methods of minimizing the effect of ice and snow on system operation.
- Development of techniques or various elevated guideway configurations for providing for safe and rapid evacuation of passengers from a stranded vehicle.
- Examination of guideway configurations and vehicle support technologies to establish the trade-offs in terms of cost, guideway size, energy consumption, operational reliability and foul weather performance.

The final item includes the need for additional development of the basic lateral guidance and switching concepts as related to the support technology. To-date, most automated group system vehicles have employed rubber tires although alternative suspension concepts have been proposed using steel wheels and rail, air cushions, and magnetic levitation. Currently, the basic lateral guidance and switching capabilities of steel wheel technology still a pear to be superior to that of rubber-tired systems although the adhesion for fail-safe emergency braking may limit the headway capabilities of a system employing steel wheel technology. Further work is necessary to define the applicability of these various suspension concepts and the effect of the suspension on guideway size and cost and on the lateral guidance and switching.

## SYSTEM INTEGRATION

The development of a reliable high performance component or subsystem does not insure that this item will operate as designed in a transit system unless the entire system design IS carefully controlled with specific design goals and with an understanding of the interactions between the various subsystems. This process called system integration generally represents about 10% to 15% of the system development and investment costs but is critical to obtaining satisfactory performance of the transit system. The system integration process requires that careful control be exercised over the system design to insure that design goals are being met and that the tradeoffs in system performance are being examined. Such a process requires constructing and exercising computer simulations of the system and the extensive testing of the components and subsystems individually and then in the system as a whole.

It should be noted that the systems integration process has been informally applied to many transit projects. However, the increasing complexity of the automated systems and the interdependence between subsystems requires that this process be formalized and controlled. System integration does not insure absolute success of the system development program but neglect of the process almost positively insures that the design goals will not be achieved.

## TEST FACILITY

Many of the problems encountered in attempting to introduce automated systems are the result of attempting to undertake concurrent development and implementation of a system. Further, the pressure for implementing the system has tended to reduce the time available for system testing, check-out, and debugging. As a result, failures which could have been avoided by developing and testing of a prototype system occurred with embarrassing frequency in revenue operation,

To minimize these problems and to provide a common basis for the conduct of the above developments, a federally owned and operated test facility is suggested; the facility being located at a permanent site to permit long-term development and testing. Such a facility would be available for:

- Testing critical aspects of system design.
- Establishing design and operational standards.
- Testing differing design approaches and components for comarisen with standards.
- Testing and verification of integrated automatic control system operational performance and reliability.
- Identifying and defining engineering trade-offs.
- Limited "check-out" of systems prior to urban deployment.

With proper reorientation, the HPPRT program can provide the initial stage of such a facility. It will be necessary to include as a design requirement for this facility the need to provide sufficient flexibility to permit the testing and development of alternative subsystems and components either separately or together.

As noted by one of the panel members, there may be justification in certain cases for limited funding to specific vendor/manufacturers to construct a limited test facility for supplying specialized data.

## DEVELOPMENT PLAN AND RECOMMENDATIONS

In view of their development status, the Federal Government should be receptive to providing capital grant support for initial deployments of the systems now available which are shown to be the best alternatives for the proposed application. The deployments should be carefully planned to permit modest improvements in the performance and reliability of these systems with sufficient schedule allocation to permit these improvements to be accomplished with confidence. The initial deployments should be planned to permit incorporation of improvements in performance and expansion capability derived from parallel R&D programs to enable extension and upgrading of these systems while mimmizing the interruption to existing service.

In the R&D area, the development of a technological baseline for the Group Rapid Transit concept should be pursued along with the initial staging of a federally owned test facility. Such a baseline can provide technical data on performance, cost, and component characteristics that can be used to formulate specifications for deployable systems, can aid in identifying and examining the performance and cost trade-offs, and can permit the options in operational mode to be examined. The HPPRT Program can be re-oriented to provide this development and to be the initial stage of a test facility for continued development and testing of automated transit systems and their com- orients. Such improvements, especially in automatic control performance and overall system reliability are essential if initial installations are to expand to a meaningful role in urban transit.

In addition, a separate program to pursue the critical component and subsystem development common to all systems should be pursued. Further, the majority of the panel feels that the issues surrounding the Personal Rapid Transit concept warrant limited exploratory funding to determine if the economic and technological feasibility exists and if the systems can be acceptable to the community. This study should be carefully addressed to the feasibility issues and include proponents and opponents of these systems. The study should also be staged so that the need for further study can be determined and directed.

Finally, the Federal Government should interact more strongly with transit authorities in urban areas to consolidate and define the public transit needs of these areas in order to better determine the best methods of application for automated vehicle transit systems. This type of interaction is already present to some degree in the categories of rail and bus transit systems. It should be implemented even more vigorously with regard to automated vehicle systems so that an understanding can be developed of the most economic spectrum of modes require to satisfy the real needs of our urban communities.

TABLE 1.–AUTOMATED GUIDEWAY SYSTEM CLASSIFICATION AND DESCRIPTION

| System classification | System chaaracteristics | Examples | Vehicle occupancy | Pro service modes | Intermediate stops and transfers | Station location | Routing capability | Appilcations actual (A), proposed (P) |
|---|---|---|---|---|---|---|---|---|
| Shuttle and loop transit systems. | Large vehicles (30 to 00 plus passengers); headways equal 1 minute or greater; limited operational switching; capacity from 3,000 to 5,000 pass/lane-hour. | Tampa Airport, Seattle/Tacoma Airport, Houston Airport. | Multiple party. | Generally scheduled but may operate only in response to observed demand. | Yes------- | On-1ine---- | None ------------------ | Special purpose short-haul A); feeder to other transit modes (P). |
| Group rapid transit systems: | | | | | | | | |
| Moderate headway. | Moderate-to-large vehicles (15 to 40 plus passengers); headways equal 15 seconds or more; operational switching capacity from 3,000 to 15,000 pass/lane-hour. | Dallas/Fort Worth Airport "Airtrans," Morgantown, | ... -ado----- | Generally scheduled although demand responsive service possible. | Possible.. - | *On-* and ofl-line. | Limited alternative routing. | Intermediate capacity line-haul (P); *regional* network (P); circulation (A). |
| Short headway. | Moderate sized vehicles (8 to 20 seats); headways equal 3 to 15 seconds; operational switching; capacity from 3,000 to 15,000 pass/lane-hour. | HPPRT program (UMTA). | .--do---- | Scheduled and demand-actuated. Possible origin-to-destination service at low demand | -----do---- | Generally Off-line | Moderate alternative routing. | Regional network (P); activity center circulation and distribution (P). |
| Personal rapid transit systems. | Small vehicle (4 to 8 passengers) all seated; headway equal 0.5 to 3 seconds; rapid switching capability; from 1,000 to 10,000 pass/ lane-hour. | Aerospace concept (United States)–prototypes: Cabinentaxi (Germany), CVS (Japan). | Single party. | Origin-to-destination demand actuated Service. | No-------- | Off-line --- | Generally conceived as having many alternative routes, | Fine-grained regional network (P). |

TABLE 2.—SYSTEM COMPARISON AND DEVELOPMENT REQUIREMENTS

| System classification | Comparison with conventional transit: Advantages | Comparison with conventional transit: Disadvantages | Comparison with previous category: Advantages | Comparison with previous category: Disadvantages | Development Status | Development requirements | Development time | Risk of succesa- techno- development |
|---|---|---|---|---|---|---|---|---|
| Shuttle and loop transit system. | Lower operating cost per passenger possible lower life cycle cost; improve service and reduce travel time to passenger; potential reduction in energy consumption per passenger-mile. | Higher capital investment. Requires guideway. | ------------------- | ------------------- | Essentially developed (Site specific engineering required). | Product improvement especial reliability (for larger installations). | ----------------- | None. |
| Group rapid transit | | | | | | | | |
| Moderate headways. | Above, plus smaller vehicle t!l an rail rapid transit permit use of smaller guideways; shorter trip times than buses; may be able to combine intermediate line haul with limited circulation in activity centers. | Above plus; complexity with implied higher initial maintenance costs to obtain required reliability. | ------------------- | ------------------- | Engineering development revenue operation systems in existence). | Selected urban installation; product improvement especial reliability, cost and weight, reduction of guideways and vehicles; obstacle detection and removal; fleet management software. | Development, urban implementation, 3 to 5 years. | Very low. |
| Short headway-. | Above, plus provide higher performance than minibus or taxi; existence of system in activity center could generate demand; could provide means to encourage auto-free zones if travel times are sufficiently | Above ---------- | Higher service capability direct service and fewer transfers; routing options would exist and demand-actuated-Service possible; vehicles and guideways should be smaller. | More extensive guideway net- interchange required for land; increased complexity; higher energy consumption per unit passenger Space. | Advanced development; (prototype design) | Above plus: longitudinal vehicle control including vehicle separation de- t8&fmnwayaidecommu- ; braking System development; system integration. | Development, urban imple mentation; 3 to 6 years. | Moder- “ |
| Personal rapid transit systems. | Basically acts as an automobile alternative since it provides single party occupancy, origin-b destination: service over trip length highest level of transit service. | Change in current safety criteria; requires significant development. | Single party occupancy; direct origin-to-destination service. | Extensive guideway network; highest level of . plexity; requires significant advances in state-of-art. | Exploratory development. | Establish system requirements; determine feasibility of: longitudinal control; braking and propulsion; collision protection; vehicle fleet control. | Development, 3 to 5 years; urban implementation, 4 to 7 years. | High. |

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## APPENDIX A

## BIOGRAPHIES OF MEMBERS OF THE PANEL ON OPERATION AND TECHNOLOGY

**Robert A. Makofski**
**Manager, Urban Transportation Programs**
**Applied Physics Laboratory**
**The Johns Hopkins University**
**Silver Spring, Maryland**

**Mr. Makofski has been involved in the research and development of automated transit systems since 1963. This work has covered a broad spectrum of technology in automated systems with emphasis on the command and control aspects of these systems. He is also a Senior Research Associate of the Center for Metropolitan Planning and Research of the Johns Hopkins University.**

**Richard H. Donlon**
**Director of Operations**
**Transportation Technology Division**
**Otis Elevator Company**
**Denver, Colorado**

**Mr. Donlon has 24 years of experience in a wide range of advanced technologies with emphasis on technical program management, engineering, and research. He has devoted the last seven years to the development of advanced automated vehicle transit systems. Mr. Donlon was a founder of Transportation Technology, Inc.**

**Eugene Jones**
**Senior Vice President**
**Frederic R. Harris, inc.**
**Stanford, Connecticut**

**Mr. Jones has been involved in the planning and design of transportation facilities for over 25 years. He serves on the Board of Directors of Northeast Utilities, the State National Bank of Connecticut, and the Stanford Area Commerce and Industry Association. He was Chairman of the Committee on New Towns and Urban Development for the Consulting Engineers Council.**

**Thomas McGean**
**De Leuw Cather and Company**
**Washington, D.C.**

**Mr. McGean provides technology and system engineering support on a nationwide basis—most recently including studies of transit alternatives for the Twin Cities, Denver and Santa Clara. Prior to joining De Leuw Cather, he was involved in numerous major federal transportation programs including tracked air cushion vehicle research, the TRANSPO '72 People Movers, Dual Mode, the Rapid Rail Research Program and the HPPRT program.**

David R. Phelps
Director of Systems Technology
Transit Development Corporation, Inc.
Washington, D.C.

Mr. Phelps is responsible for the management of funded programs and offers technical direction in providing work scope for proposed programs. He was previously with GE where he was Manager of Development Engineering and Systems Engineering. He was responsible for advanced preliminary design and proposal activity on transit and commuter rail car design. He received a BSEE with honors from Lehigh University and is a registered Professional Engineer.

Stanley A. Spinwebber
The Port Authority of New York and New Jersey
ONE World Trade Center
New York, New York

Mr. Spinwebber has served as Supervisor of the Ground Transportation Projects Section since 1972. He has a BS Degree from Pennsylvania State University, MS Degree from Stevens Institute of Technology, and is a licensed Professional Engineer and Planner. He is responsible for planning, developing, and implementation of all ground transportation projects for Kennedy and La Guardia Airports, including rail access, bus programs, and automated passenger and baggage handling systems.

Dr. Vukan Vuchic
Department of Civil and Urban Engineering
University of Pennsylvania
Philadelphia, Pennsylvania

Dr. Vuchic holds a diploma from the University of Belgrade, master's and Ph. D degrees from the University of California (Berkeley). In addition to his academic work he has been consultant to many firms and to the U.S. Department of Transportation. He has lectured at a number of universities, professional and public forums and published over 30 professional papers here and in Europe. His specialties are urban transportation systems, public transportation, urban and national transportation policy.

# APPENDIX B

## OPERATION AND TECHNOLOGY PANEL QUESTIONNAIRE

Your response to the questions given below are solicited by the Operations and Technology Panel to aid in their deliberations. Due to the short time available to the panel, a response by February 10 would be appreciated.

To provide a basis for responding to the questions, the automated, fixed guideway transit systems under consideration have been classified as: Loops and Shuttles, Group Rapid Transit, and Personal Rapid Transit. A brief description of this classification is given in Attachment A. It should be noted that the emphasis of this classification has been placed upon driverless, self-propelled vehicle systems that employ exclusive rights-of-way.

In responding to these questions, please cite or, if possible, supply documentation that would assist the panel in its work.

### QUESTIONS

1. What do you foresee as the potential urban transportation role, if any, for the automated, fixed guideway systems described in Attachment A? What service attributes, operational modes, and life cycle cost advantages must these systems possess to fulfill that role? Life cycle costs are taken as being the total capital and operating costs over the useful life of the equipment including labor, material, energy, replacement parts and maintenance.

2. Can these service attributes be provided by modifying or upgrading current urban transportation systems? What advantages, disadvantages, and risks would accrue from such an approach?

3. Based upon cost considerations and upon the service attributes and operational modes described above what range of trip demand densities can these systems be expected to serve?

4. The Group Rapid Transit Concept is often considered to be a retreat imposed by technological considerations from the Personal Rapid Transit Concept. However, the Group Rapid Transit, concept does appear to have considerable flexibility in \'chicle size, in ability to train vehicles, in providing scheduled or passenger-actuated operation, and in possibly being able to provide Personal Rapid Transit capabilities in off-peak hours. How can the potential service capabilities of the Group Rapid Transit concept be exploited? Can the same service be provided by conventional means in a more "cost-effective" manner?

5. The automated systems currently being considered employ driverless, self-propelled vehicles operating on a fixed and exclusive guideway. Can lower capital cost systems (cost per route mile) using less complex technology be devised that will provide a level of service better than that of current transit? How would the operating cost and life cycle cost characteristics of such an approach compare with the automated guideway alternatives? Please provide details on how such an approach may be implemented and the level of service to be achieved.

6. In your view, what is the development status of systems described in Attachment A, particularly in the category of the Group Rapid Transit? What additional development should be performed to assure successful large scale urban deployment? It is appropriate to express such development requirements in terms of procedures, time. and cost to reach the stage at which prototype technology can be implemented at an acceptable risk to the community, assume an urban system consisting of 150 to 200 miles of one-way guideway, 60 to 70 stations, and 2,000 to 2,500 vehicles. An urban system of such scale would necessarily be implemented in an incremental fashion.

7. Given a limited level of R&D funding, should the priorities be placed upon continuing the development of systems currently undergoing prototype development and testing or on advancing the technology to improve the performance, service level, and cost characteristics of these systems.

8. For the classes of systems given in Attachment A, identify the R&D requirements that are critical to the eventual development of these systems and that will have a major impact on the capital and operating costs. Estimate the cost and time of developing a solution to each of these requirements.

9. What are the reliability requirements that must be imposed upon the systems described in Attachment A for these systems to provide a viable urban service? How can these requirements be attained and at what cost?

10. One of the long standing controversies regarding automated systems is the need and safety of short headway operation. From a technological point of view, what are the major development requirements, time, and costs to develop prototypes of systems capable of operating at headways of 20 sec., 10 sec., 6 sec., 3 sec., 1 sec., and 0.5 see?

11. What is your estimate of the current status of software development for the management of the fleet of vehicles? What are the critical development areas? How much of this development can be performed independent of site-specific applications?

12. Would the development of these systems be helped or hindered by establishing standard sets of specifications for these systems?

13. The systems described in Attachment A implicitly assume a large portion of elevated guideways in urban areas. Inevitably the question of guideway esthetics and intrusiveness and of public acceptance becomes of critical importance to the eventual development of these systems. Studies in cities such as Minneapolis suggest that guideway locations along freeways, railroads, and certain major thoroughfares may be acceptable but that locations in residential neighborhoods may not be acceptable. From both technological and environmental-architectural points of view, what can be done to improve the acceptability of the aerial structure to the community, particularly in residential and semi-residential neighborhoods? What impact will such changes have on cost? Will the need to locate guideways for public acceptance seriously hinder the operational modes and service capabilities of these systems?

14. There has been considerable discussion on how the development of these s stems should be funded and who should set the standards and specifications. The federal government presently controls the market by control of capital grant funding. What should be the role of the federal government? Should the federal government sponsor prototype development and depend on industry and the transit authorities to take the prototypes to production status? Should the federal government set standards for the different system applications?

15. Please supply additional information or statements that you believe would be of use to the panel.

## AUTOMATED GUIDEWAY SYSTEM DESCRIPTION

A brief description of the system classification employed in this questionnaire is given in the table below. It is recognized that the relation of the system description to the passenger service concepts are not based upon a 1: 1 correspondence. Rather, the classification is to be used as a basis for responding to the questions. Alternative classifications are welcomed.

The possible overlap in system classification and the wide variety of technological and service options are recognized but are not included for simplicity of presentation. Two GRT concepts are given to reflect differences in current and future technological developments.

Some of the terms employed in the table are given below:

| | |
|---|---|
| Single-party occupancy | Vehicle occupied by 1 or more passengers traveling as a grou from the same origin to the same destimation. |
| Multiple-party occupancy | Vehicle occupied by 2 or more unrelated parties. |
| Routing capability | Determines if network employed permits a choice of 1 or more routes from origin to destination under normal operating conditions. |
| Special purpose circulation | Limited network or guideway layout that may be employed for special purpose movement of people such as at airports, universities, amusement parks, etc. |
| Collection, circulation, and distribution | Implies a more extensive network application such as in CBD's, large airport complexes, major activity centers, etc. |

## ATTACHMENT TO APPENDIX B

### AUTOMATED GUIDEWAY SYSTEM CHARACTERISTICS

| System | Characteristics | Vehicle occupancy | Service mode | Intermediate stops | Transfers | Station location | Routing capability | Possible application | Example |
|---|---|---|---|---|---|---|---|---|---|
| **Loops and shuttles.** | Generally larger vehicles (site dependent); moderate headways (~1 min.+); switching not normally employed m passenger service. | Multiple parties. | Generally scheduled but may operate only in response to observed demand. | Yes- . . . . . . | Yes . . . . . . | On-line - -. | None ------ | Special purpose circulation; feeder; collection, circulation, and distribution; possible line-haul applications. - | Tampa Airport; Sea-Tac Air-Field; etc. |
| **Group rapid transit (I).** | Bus-sized vehicles (20 to 40 pass.); moderate headway (-15. sec. +). | . . do----- | Probably scheduled although demand responsive service possible. | Possible--- | Possible--- | Off-line and on-line. | Limited alternative routing. | .- ..do ---------------- | Dallas/Fort Worth **"Airtrans";** Morgantown. |
| **Group rapid transit (II).** | Somewhat smaller vehicles (~12 ass.); short headway (-7.5 sec. +); rapid switching capability at line speeds; requires advanced technology. | -.. do- | Both passenger-actuated origin-destination service and scheduled operation. | .--do ------ | -.-do ------ | Generally | ---**do**------ | Above; possible regional application. | HPPRT (UMTA). |
| Personal rapid transit. | Small auto-sized vehicles; short headways (<1 sec. +); requires advanced technology. | Single parties. | Origin-to-destination, passenger-service. | No-. . . . . . . | No-------- | Off-line --- | Alternative available. | Collection, circulation, distribution; regional application over extensive network. | |

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## APPENDIX C

## LIST OF QUESTIONNAIRE RESPONDENTS

Given below is a list of respondents to the questionnaire of Appendix B as of April 1, 1975. The panel wishes to thank these respondents for their aid and interest in this effort.

1. The Aerospace Corporation, Harry Bernstein, Los Angeles, California.
2. Alan M. Voorhees & Associates, Inc., Thomas B. Deen, McLean, Va.
3. Alden Self-Transit Systems Corporation, William L. Alden, Milford, Mass.
4. American Public Transit Association, John B. Schnell, Washington, D.C.
5. Applied Physics Laboratory, W. H. Avery, Silver Spring, Maryland.
6. Battelle Memorial Institute, Roger L. Merrill, Colombus, Ohio.
7. Bendix Aerospace S stems Division, T. T. Trexler, Ann Arbor, Michigan.
8. Boeing Aerospace Company, A. E. Hitsman, Seattle, Washington.
9. Department of Transportation, E. L. Tennyson, Harrisburg, Pa.
10. Department of Transportation, Charles E. Zen, Sacramento, California.
11. Dallas/Fort Worth Airport, Donald J. Ochsner, Dallas, Texas.
12. Ford Motor Company, Russell F. Thielman, Dearborn, Michigan.
13. General Railway Signal Company, Peter M. Kirk, Rochester, New York.
14. Honeywell Systems and Research Center, Nell C. Sher, Minneapolis, Minnesota.
15. IBM Corporation, J. F. Obendorfer, Gaithersburg, Maryland.
16. Kaiser industries Corporation, Farrel L. Schell, Oakland, California.
17. LTV Aerospace Corp., C. R. Hickox, Dallas, Texas.
18. The Mitre Corporation, Reed H. Winslow, McLean, Virginia.
19. Otis Elevator Company, E. K. Latvala, Denver, Colorado.
20, Princeton University, Alain K. Kornhauser, Princeton, New Jersey.
21. Frank C. Smith & Associates, Frank C. Smith, Dallas, Texas.
22. Southern California Rapid Transit District, Richard Gallagher, Los Angeles, California.
23. Transportation Research Board, Wm. Campbell Graeub, Washington, D.C.
24. Tri-State Regional Planning Commission, J. Douglas Carroll, Jr., New York, New York.
25. West Virginia University, Samy E. G. Elias, Morgantown, West Virginia.

## APPENDIX D

LIST OF NONPANEL MEMBERS ATTENDING FEBRUARY 18, 1975 MEETING OF THE PANEL ON OPERATIONS AND TECHNOLOGY

1. Dr. Harry Bernstein, Aerospace Corporation, El Segundo, Calif.
2. Mr. Charles Broxmeyer, Urban Mass Transportation Administration, Department of Transportation, Washington, D.C.
3. Mr. Eugene J. Hinman, Johns Hopkins Applied Physics Laboratory, Laurel,
4. Mr. Robert Macguire, Tampa Airport Authority, Tampa, Fla.
5. Mr. Robert C. Milner, Boeing Aerospace Corporation, Seattle, Wash.
6. Mr. George Pastor, Urban Mass Transportation Administration, Department of Transportation, Washington, D.C.
7. Mr. Frank C. Smith, Frank Smith and Associates, Dallas, Tex.



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