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 has been the position of the UMTA staff that capital grant support is appropriate only for the purchase of proven hardware or fully 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 installation.

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.

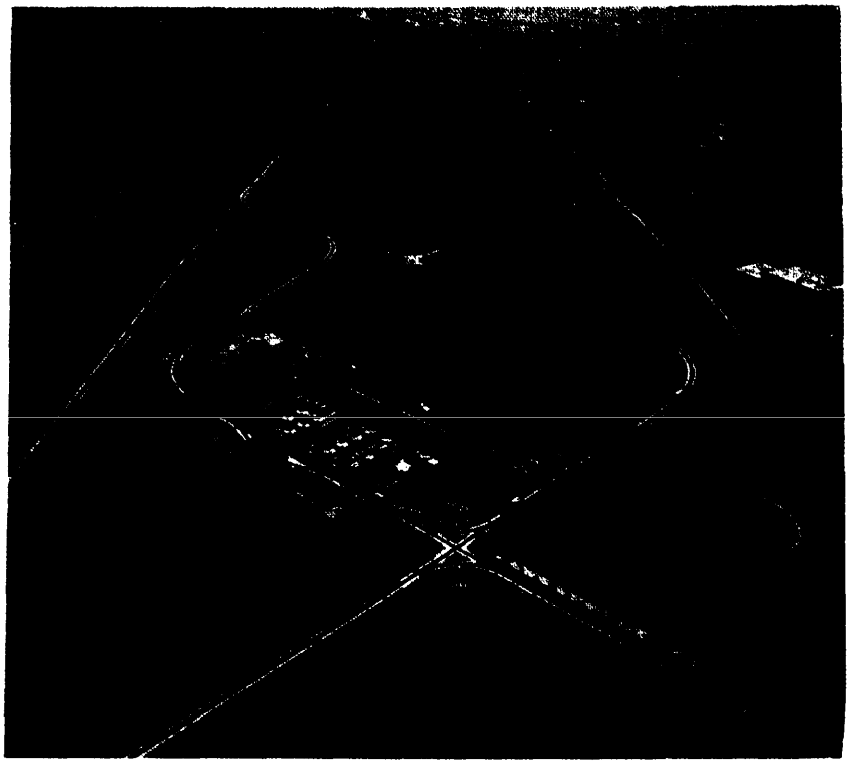
A new UXITA requirement calls for an analysis of alternative transportation solutions to substantiate selection of a particular system for Federal capital assistance. Cost-benefitt analyses tend to be unfavorable to new systems because they will have higher fist costs for production engineering, tooling 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.

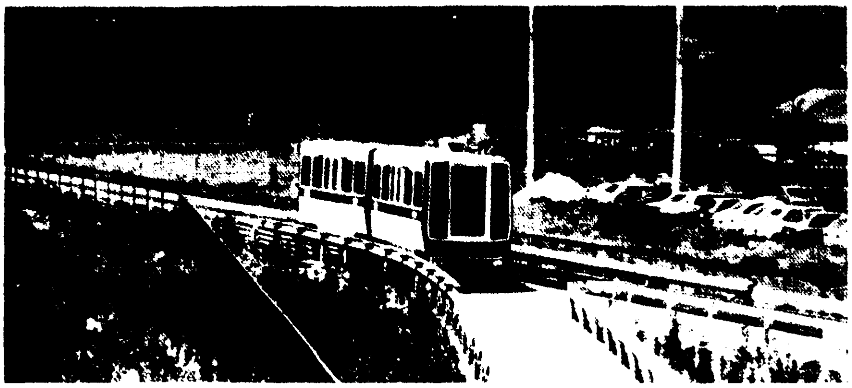
Government Cor oration.—The Ontario rovincial government has established an 6 rban Transportation b envelopment Cor ration (UTDC). The Canadiin Federal government, as well as otr er provincial governments, are expected to participate in the development programs.

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 wou1'd 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 avalble 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	[3]3.0	[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 shuttľe 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 control and 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 undoubteIly 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 we71 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.