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SUMMARY DATA FOR SELECTED NEW URBAN TRANSPORTATION SYSTEMS

OST-72-35

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FINAL REPORT

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16. Abstract

In this report a selected set of information is presented for the most advanced of the new, unconventional or innovative urban transportation systems. Capsulized are system and vehicle physical characteristics, performance capabilities, costs and availabilities. A functional classification was developed and each system was categorized according to type of service provided. A method for using this data in the development of transportation plans for metropolitan areas is outlined.

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PREFACE

The information contained in this report was collected by the Transportation Systems Center at the request of the Assistant Secretary for Policy and International Affairs, Office of Systems Analysis and Information. The project plan is documented in a detailed task plan PPA OS217, dated September 15, 1971, and revised October 5, 1971. This task has since been reassigned to PPA OP201. This report provides some visibility to the capabilities and characteristics of new forms of transportation systems so that planning bodies which are evaluating transportation improvements can give these new systems adequate consideration.

The prime sources of information for the urban transportation systems were the system manufacturers. The Transportation Systems Center also received the cooperation and assistance of the Twin Cities Metropolitan Transit Commission and their consultant Daniel, Mann, Johnson and Mendenhall and the Urban Mass Transportation Administration, Office of Research, Development and Demonstration and their contractor, the Applied Physics Laboratory of Johns Hopkins University.

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1. INTRODUCTION

1.1 BACKGROUND

This study was undertaken by the Transportation Systems Center (TSC) to support the 1974 National Transportation Study at the request of the Assistant Secretary for Policy and International Affairs, Office of Systems Analysis and Information.

The study goal was the development of this document which summarizes physical and performance characteristics, costs, and availability of new transportation systems. Additionally, it suggests methodologies for incorporating new technology systems into transportation planning.

The data contained in this report is as of May 1972. In view of the rapid changes in the new transportation system field it is recognized that some of the information presented in this document may no longer be current at the time of publication.

1.2 PURPOSE

This report gives visibility to several new transportation systems and provides information concerning the new systems characteristics, capabilities, costs and availability. Also in cluded are suggested methods of using the information to select systems or system characteristics for urban area transportation planning studies.

This document is designed for use by state and metropolitan planning bodies as part of a technical assistance package to be included with the 1974 National Transportation Study.

1.3 SCOPE

There are hundreds of new or unconventional systems which have been described in the literature. However, most are paper concepts that have little chance of ever being constructed. This document concentrates on systems that have either great appeal or which could be ready for implementation within five years. It contains physical characteristics, performance characteristics, cost and current state of development of these new unconventional or innovative intra-urban transportation systems. The selection was made from among those systems which offer a substantial departure from existing transit service, employ vehicles carrying approximately 50 or less passengers, or use new methods of suspension and propulsion.*

This report was restricted by the adequacy of the information available or supplied by the system proponent or manufacturer. This resulted in the exclusion of some systems which would otherwise have been included. Systems developed outside the United States were not covered unless they had a U.S. representative from whom information could be obtained.

No proprietary information is included in this document nor is any system listed whose manufacturer wished it to be excluded. Also excluded from discussion are automated conventional rail rapid transit systems such as the Lindenwold Line in Philadelphia and the Bay Area Rapid Transit (BART) System in San Francisco although some of the vehicle characteristics of these two systems are listed in Appendix B along with those of the two largest non-automated rail rapid transit systems.

1.4 SOURCES OF INFORMATION

The most important information source was the system proponent or manufacturer. Secondary sources of information were the Applied Physics Laboratory of Johns Hopkins University, the contractors technical proposals for the United States International Transportation Exposition (TRANSPO 72) demonstrations at Dulles Airport, and the questionnaires compiled by the consulting firm of Daniel, Mann, Johnson and Mendenhall in their work for the Twin Cities Area Metropolitan Transit Commission. A bibliography is given in Section 8.

*Table 1-I (in rear pocket) contains the detailed characteristics of the selected systems.

2. NEW SYSTEM FUNCTIONAL CATEGORIZATION

2.1 FUNCTIONAL DESCRIPTION

For ease of comparison among the new systems it is useful to classify them according to function. A brief description of the transportation service characteristics and the service area of each system class is as follows:

Personal Rapid Transit Systems - complete network in central cities, possibly extending into the suburbs; off-line stations 1/4 to 1/2 mile apart; on-demand, origin to destination, single vehicle service; small vehicles; low line capacity; headways less than 5 seconds; for population densities up to 15,000 persons per square mile.

Circulation Systems - loops, shuttles, or very small networks; on-line stations less than 2000 feet apart; very short trips; scheduled service; small vehicles usually operated in trains; low capacities; headways over a minute; for high density areas or small activity centers.

Collection and Distribution Systems - limited network up to a few miles in length; on or off-line stations 1/4 to 1/2 mile apart; short trips; scheduled service; medium sized vehicles; train operation sometimes utilized; moderate capacities; headways less than 30 seconds; for high density urban areas, large activity centers, or low density suburban areas.

Line Haul Systems - linear or radial routes of several miles in length; on-line stations 1/2 to 3 miles apart; scheduled service; train operation frequently utilized; highest capacities per vehicle and per line; headways over a minute; for population densities above 5,000 persons per square mile.

All of the collection and distribution systems listed have the potential to operate in an on-demand origin to destination mode. Only single vehicles would be utilized in this service. This type of operation would be feasible under low levels of passenger demand such as off-peak travel periods. Stations must be off-line so that they may be bypassed if not selected as a destination by persons in the vehicle. Since sharing of vehicles by persons with different destinations would be likely, this service is more appropriately termed Semi-Personal Rapid Transit even though it is commonly labelled Personal Rapid Transit. The Urban Mass Transportation Administration's Morgantown Demonstration System is an example of semi-personal transit service.

The prime difference between semi-personal and personal transit service is the level of sophistication of control strategy, control hardware and vehicle management. Even though semi-personal transit systems are considered to be the technological predecessor to fully personalized transit systems, their characteristics are more closely related to the collection and distribution systems. Consequently, Semi-Personal Rapid Transit Systems are included in the collection and distribution classification and are not discussed separately in this report.

To date, most new systems have been installed in amusement parks, fairs, zoos, or other tourist attractions. They are now being considered for intra-airport circulation and airport access. Numerous cities are also seriously considering installation of these new systems as a solution to urban transportation problems.

2.2 SYSTEM CLASSIFICATION

Most of the systems listed in Table 1-1 fall quite clearly into one of the functional classes. Some systems, while having the capability to provide more than one type of service, usually do so at a reduced level of efficiency. The functions, both primary and secondary, which each system is capable of performing are listed in Table 2-1. Secondary functions which may require system modifications are also indicated.

TABLE 2-1 SYSTEM FUNCTIONS

SYSTEM \ FUNCTION	Personal Rapid Transit	Circulation	Collection & Distribution	Line Haul
Ford ACT	S*		P	
Aerial Transit System				P
Aerospace	P			
Aerotrain				P
Airtrans			P	
Alden-PRT	P		S*	
Alden-Dual Mode	P			
Carveyor		P		
Dashaveyor			P	
Minirail		P		
Monocab	P			
Morgantown			P	
Transit Express-way			S	P
TransMobile - Monorail "II"	S*		P	
TransMobile - Mini-Bus "III"	S*		P	
Transportation Technology Inc.	P		S*	
Uniflo	P		S*	
Unimobil II		P	S	
Urba 30	S*		S	P
Vehicle Distri-bution System			P	
WABCO "M"			S	P
WABCO "P"		P	S	

P = Primary function

S = Secondary function

S*= Secondary function requiring different vehicle size

3. SYSTEM AND VEHICLE CHARACTERISTICS

3.1 SIZE

Vehicle lengths and capacities are shown by functional category for each system in Table 3-1.

The personal rapid transit (PRT) and the circulation system vehicles, which accommodate 4 to 6 passengers, are generally 9 to 15 feet long. The systems categorized as PRT do not accommodate standees. Most of the circulation systems employ small vehicles coupled into trains. Some allow standees, others do not. Collection and distribution system vehicles which accommodate 6 to 16 seated passengers plus standees are generally 15 to 26 feet long. Line haul system vehicles are over 26 feet in length with a normal capacity of approximately 50 passengers.

3.2 WEIGHT

The loaded weights of vehicles are also shown in Table 3-1. Individual PRT or circulation system vehicles weigh 2000 to 7500 pounds. Collection and distribution system vehicles generally weigh 10,000 to 20,000 pounds. Vehicles serving the line haul service function weigh over 25,000 pounds except for the URBA 30 which has a loaded weight of about 10,000 pounds.

3.3 SUPPORT/SUSPENSION

3.3.1 Primary

Primary support/suspension methods are those which provide the direct contact or lift between the vehicle and the guideway enclosure. Unlike size and weight characteristics, primary support/suspension methods are not alike by functional category. Figure 3-1 shows the basic support/suspension concepts utilized in the systems. An overwhelming majority of the systems listed (17 out of 22) utilize rubber tires for primary support/suspension; three utilize air cushions; one is suspended by air suction; and one is supported by belts and rollers.

TABLE 3-1. SYSTEM PHYSICAL CHARACTERISTICS

	PERSONAL RAPID TRANSIT SYSTEMS						CIRCULATION SYSTEMS			
		Alden								
	Aerospace	PRT	Dual Mode	Monocab	Trans. Tech-nology Inc.	Uniflo	Carveyor	Minirail	Unimobil II	WABCO Series "P"
Vehicle Length	120"	168"	204"	115"	120"	192"	120"	144"	114"	150"
Passenger Capacity										
Seats	6	6	6	6	6	8	6	4-6	6	6
Standees	-	-	-	-	-	-	6	-	10	4
								8-16 veh trains	2 or more vehicle trains	multiple vehicle trains
Loaded Weight	2,400#	5,000#	5,000#	4,000#	7,600#	3,200#	4,400#	2,400# per veh	5000# per veh	5325# per veh

	COLLECTION AND DISTRIBUTION SYSTEMS							LINE HAUL SYSTEMS				
					TransMobile							
	Ford ACT	Airtrans	Dash-aveyor	Morgan-town	Mono-rail "II"	Mini-Bus "III"	Vehicle Distri-bution System	Aerial Transit System	Aerotrain	Transit Express-way	URBA 30	WABCO Series "M"
Vehicle Length	310"	255"	276"	186"	120"	192"	250"	780"	565"	366"	314"	348"
Passenger Capacity												
Seats	12	16	12	8	6	6	16	50	44	28	30	12
Standees	12	24	19	7	9	14	16	--	--	26	--	38
Loaded Weight	18,800#	18,600#	17,500#	10,150#	8500#	10000#	17,500#	29,800#	26,500#	28,700#	10,000#	24,700#

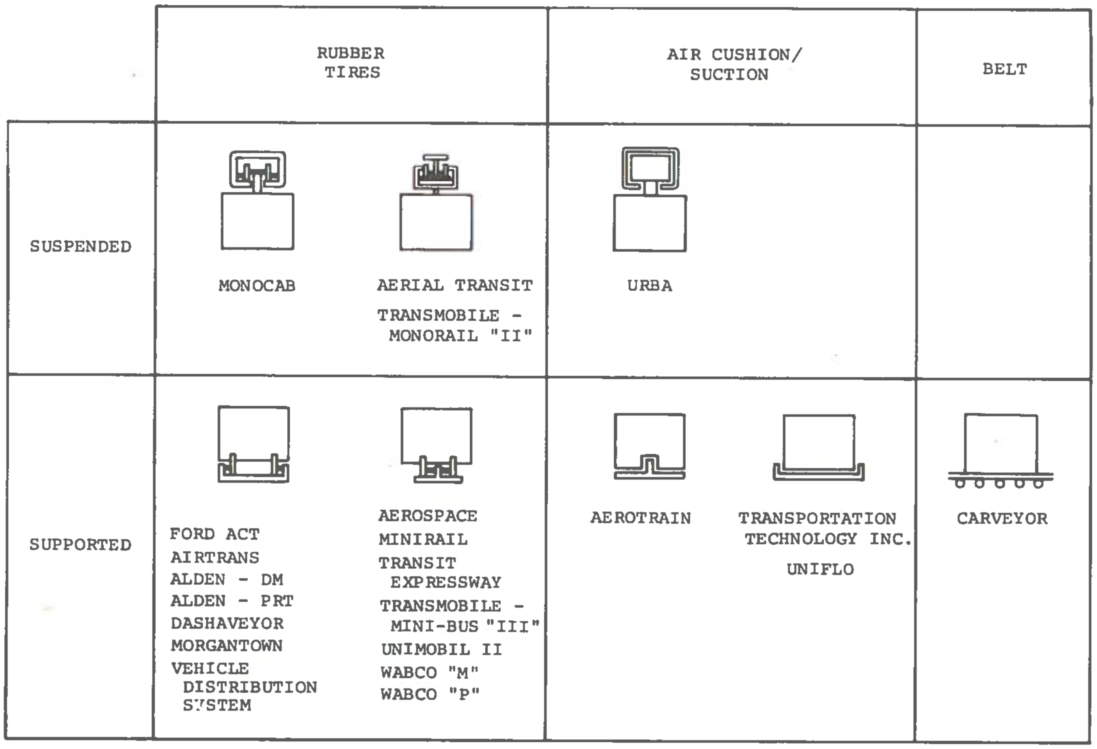


Figure 3-1. Primary Support/Suspension Methods

Of the seventeen rubber tired systems, three are suspended monorails and seven are supported monorails. The remaining seven use automotive type support systems. All three air cushions are supportive but one of the systems (Uniflo) delivers the air from the guideway. The most radical approach is the air suction suspension (URBA) proposed by Companie d'Energetique Lineaire of France. Several manufacturers are proposing the testing of magnetically suspended vehicle systems. These systems would appear to have equal potential for implementation as some systems listed but too few details were available for inclusion in this document.

3.3.2 Secondary

Secondary suspension devices are those auxiliary mechanical connections employed to provide a more comfortable ride than that offered by the primary support/suspension techniques. Methods range from none at all to a combination of several of the following devices: air springs, coil springs, shock absorbers, hydraulic dampers, torque arms, antisway bars, and load leveling valves. Eight of the manufacturers do not advertise a secondary suspension system although they may utilize one.

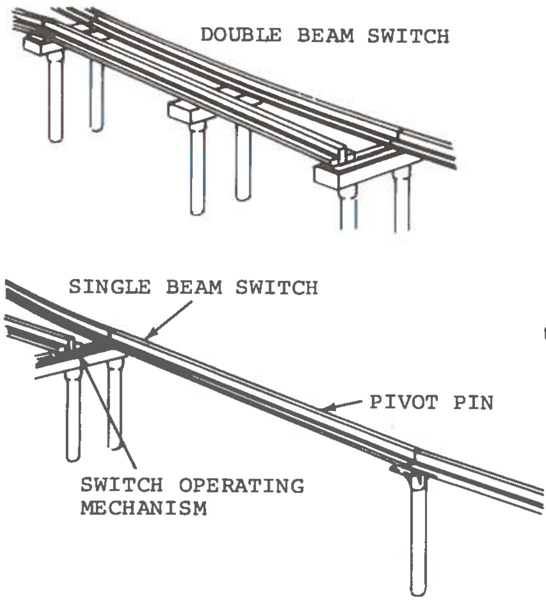
3.4 PROPULSION

Twelve of the systems utilize dc traction motors for propulsion. (See Table 1-1). The remaining propulsion motors are divided between ac linear (3), ac induction (3), ac synchronous (1), dc linear (1), linear air turbine (1), and internal combustion (1).

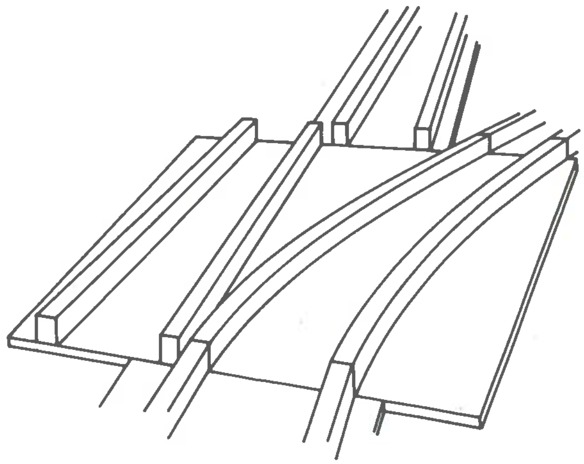
3.5 SWITCHING

All of the circulation systems which permit switching perform the switch maneuver by means of moving the track or a portion of the track from one position to another. (Figures 3-2a and 3-2b.) Since minimum headways for circulation systems are in the range of 30 to 60 seconds there is ample time to move the track and verify its position. Most of the line haul systems with minimum headway of 60 to 90 seconds also employ this method of switching. PRT systems which allow headways of less than 10 seconds all rely on some type of non-moveable guidebeam switch due to the short time available for accomplishment and verification. The collection and distribution systems which claim short headway potential also employ this type of switching mechanism while those with longer headways generally employ moveable guidebeam switches (See Table 1-1).

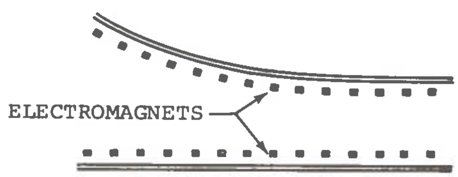
The principal methods of non-moveable guidebeam switching used by the manufacturers include energizing electromagnets in the guideway as the vehicle approaches (Figure 3-2c), engaging a track rail with vehicle based guidewheels (Figure 3-2d), arms or skids (Figure 3-2e), or biasing the steering mechanism in the desired direction of travel.



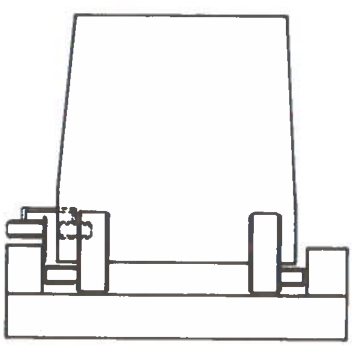
a. PIVOTING GUIDEBEAM SWITCH



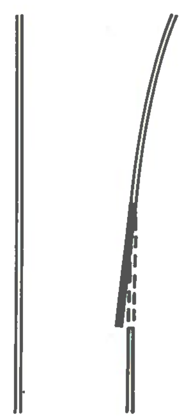
b. TRANSFER TABLE SWITCH



c. ELECTROMAGNETIC SWITCH



d. GUIDEWHEEL - GUIDERAIL SWITCH



e. GUIDEWHEEL - SWITCHBLADE SWITCH

Figure 3-2. Switching Methods

4. PERFORMANCE CHARACTERISTICS

4.1 SPEED

The operating speeds for the vehicle systems are shown in Table 4-1. The circulation systems have the lowest speeds of the new systems, 10 to 15 mph. This is quite adequate because of their short trip and frequent stop service function. The slightly higher speeds, 15 to 30 mph, of the collection and distribution systems reflect their somewhat longer trip lengths and less frequent station stop requirements. For PRT systems where operation will often range from the central business district to the suburbs and where stations will usually be off line, higher speeds of 30 to 60 mph are quoted by the manufacturers. All of the line haul systems quote speeds of 50 mph or more which is responsive to the high volume, fairly frequent station stop function of these systems.

4.2 POWER

The horsepower required for propelling these vehicles is closely related to their maximum speed. For 10 to 15 mph circulation systems, manufacturers quote propulsion systems of 10 to 20 hp per vehicle. Speeds of the 15 to 30 mph collection and distribution systems are provided by a total of 30 to 100 hp per vehicle. The line haul systems utilize 100 hp or more per vehicle. Propulsion for PRT systems is in the 40 to 60 hp range for rotary motors. Insufficient data was available on the three linear motors to establish a range. One significant departure from the other propulsion systems was the 160 hp internal combustion engine utilized by the Alden dual mode vehicle.

4.3 ACCELERATION/DECELERATION

Acceleration and deceleration characteristics of the vehicles do not lend themselves to categorization nor do they vary significantly among the systems. Most of the systems list normal acceleration and braking rates between 3.2 and 4.4 fps^2, which is well within the comfort range for standing passengers.

TABLE 4-1. SYSTEM PERFORMANCE CHARACTERISTICS

	PERSONAL RAPID TRANSIT SYSTEMS						CIRCULATION SYSTEMS			
		Alden								
	Aerospace	PRT	Dual Mode	Monocab	Trans. Tech-nology Inc.	Uniflo	Carveyor	Minirail	Unimobil II	WABCO Series "P"
Speed	20-60mph	30mph	30mph (45mph off guide-way)	28-70mph	30-60mph	20-50mph	15mph	8-15mph	15mph	12mph
Power	1000v motor	60hp motor	160hp engine	40hp motor				7 1/2hp motor	18hp motor	3-7 1/2hp motors
Acceler-ation	up to 8.05fps^2	3.85 fps^2	3.85 fps^2	3.75 fps^2	3.2fps^2 to 6.4fps^2	4.7fps^2 to 6.4fps^2	3.0fps^2	3.2fps^2	3.2fps^2	4.4fps^2

	COLLECTION AND DISTRIBUTION SYSTEMS							LINE HAUL SYSTEMS				
					Transmobile							
	Ford ACT	Airtrans	Dash-aveyor	Morgan-town	Mono-rail "II"	Mini-Bus "III"	Vehicle Distri-bution System	Aerial Transit System	Aerotrain	Transit Express-way	URBA 30	WABCO Series "M"
Speed	30mph	17mph	up to 45 mph	30mph	6-20 mph	15-45 mph	30mph	125mph	112mph	55mph	50mph	50mph
Power	100hp motor	75hp motor	2-25hp motors	60hp motor	max. 2-15 hp motors	up to 80hp	60hp motor	4-150hp motors	400kw motor	2-60hp motors	80kw motor	2-50hp motors
Acceler-ation	4.4fps^2	3.4fps^2	3.75 fps^2	4.0 fps^2	up to 5fps^2	up to 5fps^2	3.7 fps^2	4.2fps^2	3.2fps^2	3.2fps^2	4.3fps^2	4.4 fps^2

5. COSTS

A special effort was made to obtain cost information which is a major missing element of new system data. The cost data supplied by the manufacturers were prepared in a number of forms and are difficult to compare directly.

System costs quoted are generally optimistic and do not include such things as tunneling, right-of-way, preparation of the roadbed in difficult terrain or any other special difficulty that might be encountered. Furthermore, costs are so dependent upon the application and location that total installation might run several times the estimated per mile system costs listed here. In addition, many of the manufacturers have not advanced to the stage where precise cost estimates have been developed. Nevertheless, all costs furnished are included with the system data. Unless otherwise noted all costs are in 1970 dollars.

It was not intended for this project to assess the validity of the estimates supplied. Consequently, the Transportation Systems Center cannot vouch for the accuracy of the cost data listed.

5.1 VEHICLE

Vehicle cost estimates vary from $4,000 by Aerospace Corporation for a 6 passenger vehicle to $325,000 for the 50 passenger Aerial Transit vehicle (See Table 5-1). This translates to a cost per passenger space of $670 for the former and $6500 for the latter. These two data points would indicate that the cost per passenger space increases with the size of the vehicle. This does hold generally true as can be seen in Figure 5-1, but there are exceptions.

The very limited data makes generalization risky, but it appears that circulation and PRT vehicles will likely cost between $600 and $1,000 per passenger space. Unimobil II and Transportation Technology Inc. are exceptions with costs of $2,360 and $3,700 respectively. Collection and distribution and line haul

TABLE 5-1. VEHICLE COSTS

SYSTEM	MANUFACTURER'S ESTIMATED VEHICLE COST ($)	NORMAL MAXIMUM PASSENGER CAPACITY*	COST PER PASSENGER SPACE ($)
Personal Rapid Transit			
Aerospace	4,000	6	670
Transportation Technology Inc.	22,200	6	3,700
Uniflo	5,000	8	625
Circulation			
Carveyor	4,000-8,000	4-12	670-1,000
Unimobil II	300,000	128	2,340
WABCO "P"			700-1,000
Collection and Distribution			
Dashaveyor	75,000-125,000	31	2,420-4,000
Morgantown	130,000	15	8,700
TransMobile Monorail "II"	25,000-45,000	15	1,670-3,000
TransMobile Mini-Bus "III"	30,000-55,000	20	1,500-2,750
Vehicle Distribution System	44,000	32	1,375
Line Haul			
Aerial Transit System	325,000	50	6,500
Aerotrain	160,000	50	3,200**
Transit Expressway	112,000	54	2,080***
URBA 30	20,000	30	670
WABCO "M"		50	1,500-2,000

*Excluding Crush Loaded Conditions

**1968 Cost Estimate

***1969 Cost Estimate

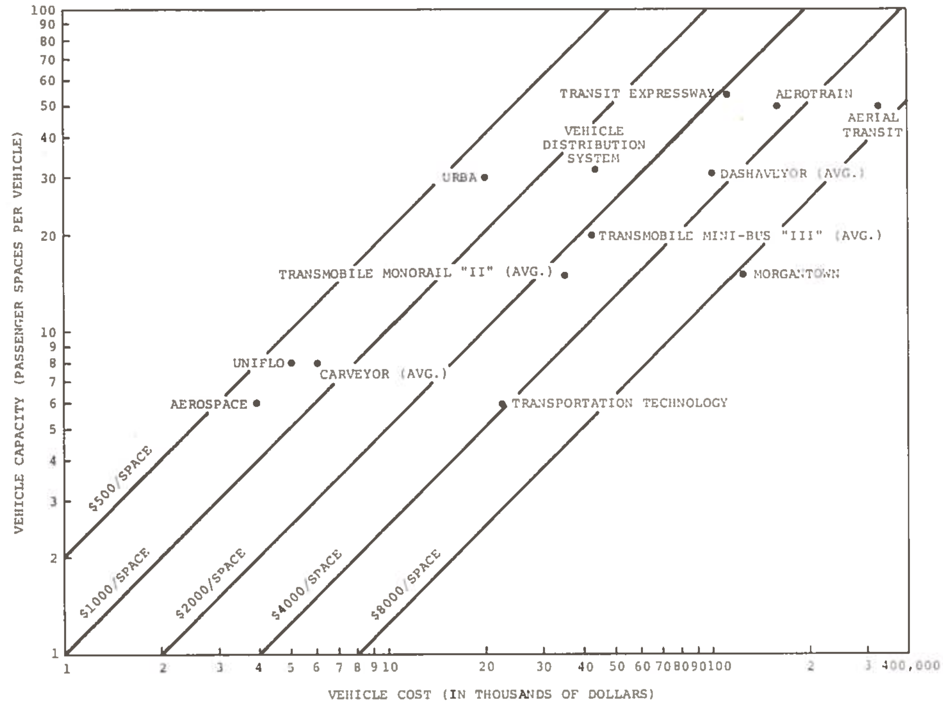


Figure 5-1. Vehicle Cost vs. Vehicle Capacity

vehicles appear to run between $1,500 and $3,000 per passenger space. Exceptions are Aerial Transit at $6,500, Morgantown at $8,700 and URBA at $670.

Of the sixteen systems listed, all but four of the manufacturers claim to be able to supply vehicles for less than $2,500 per passenger space. The lower limit appears to be approximately $600.

5.2 TERMINAL

The estimated terminal costs provided by the system proponents were difficult to compare. Some manufacturers quoted a price per square foot; one quoted a price per lineal foot of platform; and a few quoted typical station costs. Terminal cost estimates, excluding parking and landscaping, ranged from a minimum of $30,000 for a small suburban at grade station to over a million dollars for a large urban station. Per square foot station cost estimates ranged from $5 to $60.

5.3 GUIDEWAY

With three exceptions, cost estimates for guideways are $3 million dollars or less per mile. This would include a double elevated track, power, electrification, signalling, communications and installation. Guideway cost estimates did not lend themselves to a functional grouping. The cost estimates submitted by the manufacturers varied from $200,000 per mile for a single track, at grade system without installation (WABCO Series "P") to $7,900,000 per mile for a completely installed guideway (Morgantown).

Table 5-2 lists the per mile cost estimates for at grade, elevated, single and double track guideways. Figure 5-2 is a graphical representation of this table. No clear pattern is evident from the data. Dividing the claimed guideway cost by the guideway capacity produces a cost per mile per unit of maximum passenger capacity (Table 5-3). In all cases except Morgantown, this figure was less than $500. It should be noted that the capacities quoted are often the limit of the technology employed in the system and cannot be scaled upward at the same cost per passenger rate. Some systems do, however, permit training of vehicles even though this feature was not used for the capacities in Table 5-3. These systems would, of course, be able to provide the additional capacity at a much lower rate per passenger mile, but training of vehicles could change the service function of the system.

5.4 COMMUNICATIONS AND CONTROL

Manufacturers estimates for communication and control varied from $28,000 to $684,000 per mile. Since the method and complexity of the control system is perhaps the most significant difference between the systems, it is not surprising that there are such extremes in the cost of this element. Nevertheless, the majority of the estimates were in the $250,000-$350,000 per mile range.

5.5 OPERATING COST

Manufacturer's operating cost estimates were submitted in

TABLE 5-2. GUIDEWAY COSTS (MANUFACTURER'S ESTIMATES)

SYSTEM	AT GRADE		ELEVATED	
	Single Track ($Million/mile)	Double Track ($Million/mile)	Single Track ($Million/mile)	Double Track ($Million/mile)
Personal Rapid Transit				
Aerospace			1.0	
Transportation Technology Inc.		1.35		
Uniflo				5.2
Circulation				
Carveyor		2.0-3.0		
Unimobil II	1.25			
WABCO "P"	0.2*			
Collection and Distribution				
Morgantown				7.92
TransMobile Monorail "II"			0.24-0.48	
TransMobile Mini-Bus "III"			0.18-0.70	
Vehicle Distribution System		0.48*		
Line Haul				
Aerial Transit System				1.373
Transit Expressway		2.50**		4.9**
URBA 30				1.75
WABCO "M"	0.3*			

*Does not include installation costs.
**1969 Cost Estimate

TABLE 5-3. GUIDEWAY COSTS PER MILE PER UNIT OF MAXIMUM CAPACITY

SYSTEM (CLAIMED DIRECTIONAL CAPACITY-PASSENGER SPACES PER HOUR)	AT GRADE		ELEVATED	
	Single Track	Double Track (per direction)	Single Track	Double Track (per direction)
Personal Rapid Transit				
Aerospace (42,600)			$24	
Transportation Technology Inc. (1440)		$469		
Uniflo (5800)				$450
Circulation				
Carveyor (9600)		$104-$156		
Unimobil II (15,300)	$82			
WABCO "P" (1800)	$111*			
Collection and Distribution				
Morgantown (3600)				$1100
TransMobile Monorail "II" (5400)			$45-$88	
TransMobile Mini-Bus "III" (4800)			$36-$145	
Vehicle Distribution System (1150)		$210		
Line Haul				
Aerial Transit System (2400)				$286
Transit Expressway (8400)				$330**
URBA 30 (8100)				$208
WABCO "M" (12,000)	$25*			

*Does not include installation costs.
**1969 Cost Estimate

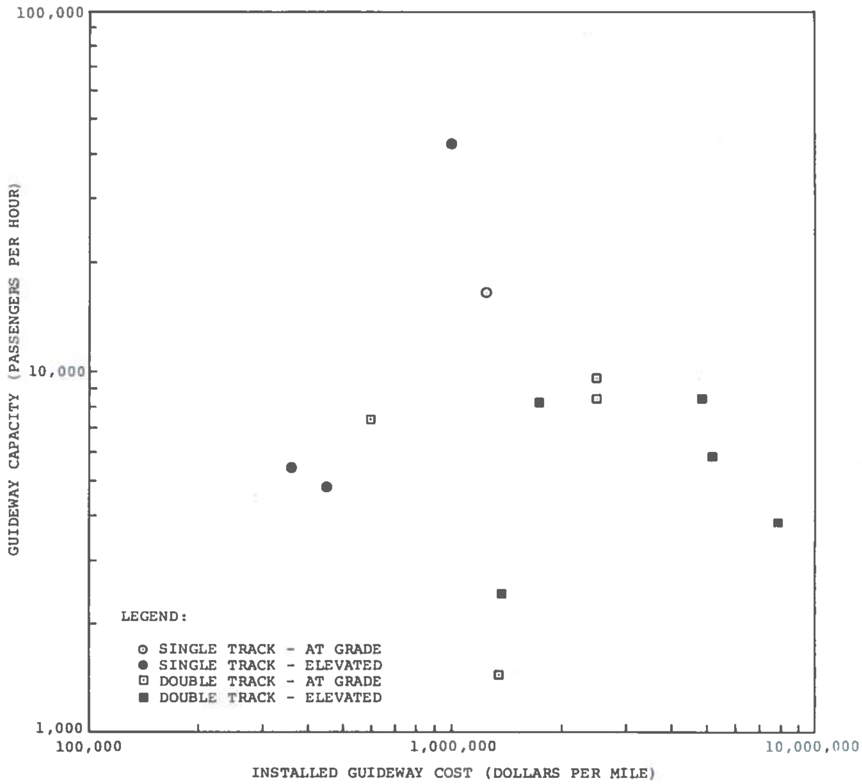


Figure 5-2. Guideway Cost vs. Guideway Capacity

several different forms. Some basic assumptions concerning average operating speeds and hours of service were utilized in order to translate this data into equitable comparisons. Two clusters of operating costs appeared; one around 10 cents per vehicle mile and the other around 30 cents per vehicle mile. The lower operating costs were for the PRT and circulation systems and the higher operating costs were for the collection-distribution and line haul systems. Adequate operating cost data was submitted for only one line haul system, however. On the basis of that single sample it would be erroneous to conclude that 30 cents per vehicle mile would be the upper limit.

5.6 MAINTENANCE COST

The manufacturers estimates of annual maintenance costs were quite uniformly between 1% and 2% of the system capital cost exclusive of right-of-way. The Airtrans system was an exception but it is much more than a passenger carrying system and could be expected to have a higher maintenance cost.

5.7 TOTAL SYSTEM COST

Several manufacturers have estimated a total system cost of $1 1/2 to $2 1/2 million dollars per mile as can be seen in Table 5-4. These estimates include the cost of vehicles, terminals, guideways, communications and control, maintenance shops, and storage yards but do not include right-of-way acquisition, site clearing, difficult construction problems, or operating costs.

A general indication of the percentage of total system cost which is represented by each of the elements is shown in Figure 5-3. The percentages shown represent the average of all the systems which provided sufficient cost information. However, Table 5-5 shows that there is a wide range in the percentage of total system cost associated with each element of the various systems. This is due principally to the different methods of suspension and propulsion employed.

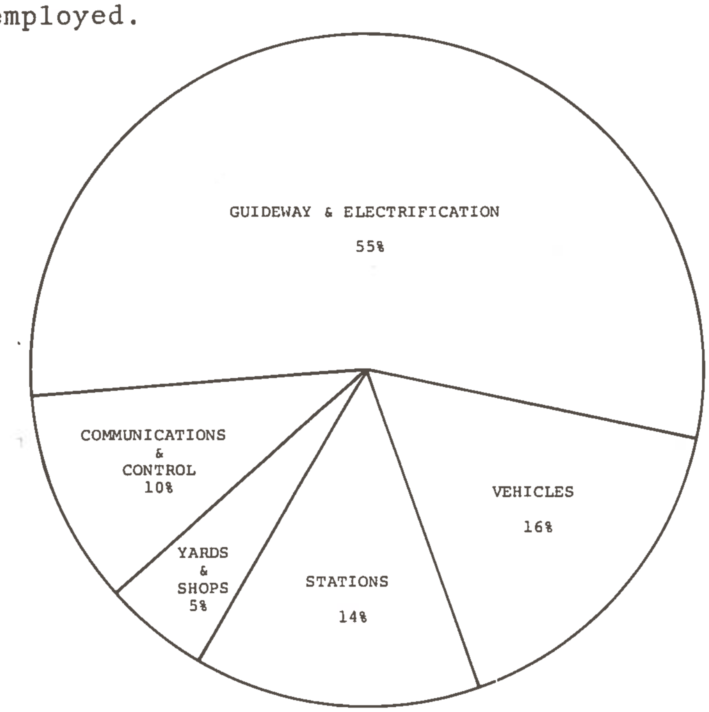


Figure 5-3. Average System Cost Breakdown

TABLE 5-4. TOTAL SYSTEM COSTS

SYSTEM	SYSTEM COST ($Million/Mile)	BASIS OF COST ESTIMATE
Personal Rapid Transit		
Aerospace	1.51	Hypothetical 54.3 mile, 57 station, 1617 vehicle system for Tucson, Ariz.
Monocab (a)	3.3	Hypothetical 1 mile, 3 station, 6 vehicle system.
(b)	2.24	Hypothetical 20 mile, 20 station, 150 vehicle system.
Transportation Technology Inc.	1.73	Hypothetical 2 1/2 mile, 2 station, 23 vehicle system.
Uniflo	6.57	Hypothetical 1 mile, 2 station, 20 vehicle system.
Circulation		
Carveyor (a)	5.7	Quoted price for 1 mile Seattle, Washington application.
(b)	6.7	Quoted price for 1.38 mile Tampa International Airport installation.
Unimobil II	1.75	2500 passenger per hour capacity.
Collection and Distribution		
Airtrans	2.58	System being constructed at Dallas/Ft. Worth Regional Airport.
Dashaveyor	1.5-3.5	Unspecified.
Morgantown	16.7*	2.1 mile, 3 station, 45 vehicle system.
TransMobile Monorail "II"	1.12	Hypothetical 1 1/4 mile, 3 station, 10 vehicle system.
Line Haul		
Aerial Transit	2.09	1975 cost estimate for hypothetical 30 mile, 2 station, 24 vehicle airport a access system.
Transit Expressway	10.85	1969 cost estimate for 10.6 mile South Hills-Pittsburg transit line.
URBA 30 (a)	3.1	1971 cost estimate for 4.7 mile, 10 station, 62 vehicle system for Rouen, France.
(b)	5.9	Estimate for 16.1 mile system for Manchester, England.

*Estimated Research and Development costs have been removed.

Some estimates have been made for actual system applications. For example, the South Hills Transit Expressway Revenue Line in Pittsburg would cost almost $11 million per mile. The Airtrans-Dallas/Fort Worth Airport system is expected to cost nearly $31 million for the 12-mile one-way guideway system. The Morgantown, West Virginia system is estimated to cost approximately $35 million (excluding research and development) for 2.1 miles of dual guideway operation. These estimates are not directly comparable, however. The Transit Expressway estimate, for example, encompassed all costs while the Airtrans and Morgantown estimates excluded acquisition of right-of-way and the Airtrans installation called for only a small amount of site preparation.

There was a large spread between the lowest system cost estimate of $1.12 million per mile and the highest of $16.7 million per mile. The fact that the system with the highest cost is the only one which is currently being implemented in an existing urban environment is worthy of note. It suggests that the cost of an installation may be several times the cost of the basic system equipment due to costly construction (as in the Morgantown case) or expensive right-of-way acquisition.

TABLE 5-5. VARIATION IN COST OF SYSTEM ELEMENTS

System Element	Percent of Total System Cost
Guideway & Electrification	33-78
Vehicles	1-39
Stations	3-28
Yards & Shops	4-7
Communications & Control	2-26

6. SYSTEM AVAILABILITY

6.1 CURRENT INSTALLATIONS

There are several circulation systems of the non-automated monorail type in operation at amusement parks, fairs and zoos throughout the country. Of the circulation systems described in this document, only Minirail has actually been used in passenger carrying service. This system is still operating at the site of EXPO 67 in Montreal, Canada. However, the other three systems appear ready for immediate implementation subject to site engineering requirements.

The pure personal rapid transit systems will take the longest time for implementation because of the complex control and stringent reliability requirements. Very likely early versions will be instituted in the semi-personal rapid transit form or in situations where high capacity and very short headway operation are not necessary. Two of these systems (Monocab and the Transportation Technology) in limited form were demonstrated at the United States International Transportation Exposition (TRANSPO 72) held at Dulles International Airport in May 1972. These systems were among four new systems that were installed on 100 by 750 foot sites. Two vehicles were operated by each manufacturer. Only Monocab had a complete loop installation.

The only system in actual passenger service which exhibits some of the attributes of PRT operation is an early version of the TransMobile System (Jetrail) at Love Field in Dallas (See Figure 6-1). This installation is an 8,460 foot loop with six switches, three passenger loading areas and ten vehicles. The system can operate in a static, continuous or demand mode.

Several collection and distribution systems will be implemented or demonstrated in the near future. The two most extensive systems under construction are the Vought Aeronautics' Airtrans system for the Dallas/Fort Worth Regional Airport and the Boeing system for the University of West Virginia at Morgantown.

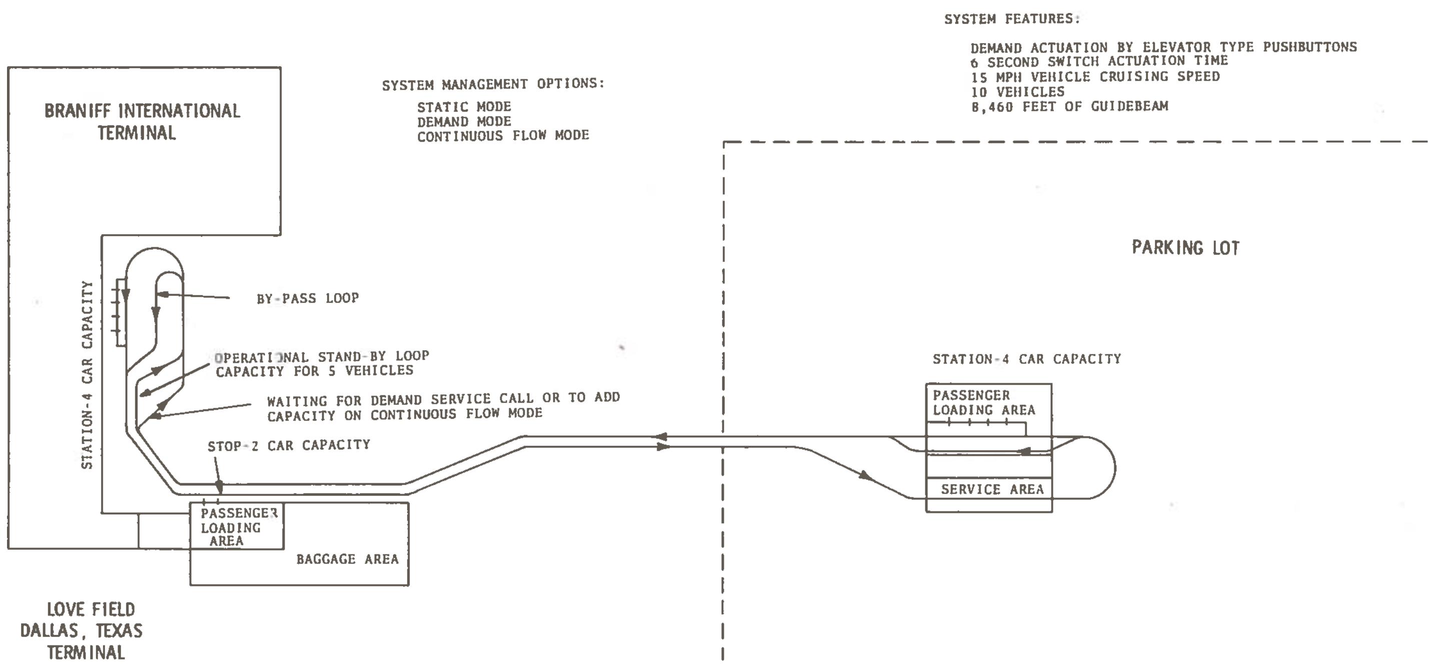


Figure 6-1. JETRAIL Installation (Courtesy: Mobility Systems and Equipment Co.)

The Airtrans system (Figure 6-2) will provide service between four terminals, two remote parking areas, mail facilities and a maintenance area - a total distance of over twelve miles, 20 percent of which will be elevated. The system will operate with about 75 vehicles over five passenger routes, two employee routes, six interline baggage and mail routes and two airport mail routes. System capacities will be 9,000 passengers, 6,000 bags and 70,000 pounds of mail per hour. The system cost is $30.9 million which is being privately financed. This system cost does not include site preparation or station construction. Vought planned to have operational vehicles undergoing tests at the airport by mid-1972. The full system is expected to be operating by mid-1973.

The first phase of the Morgantown, West Virginia project (Figure 6-3) will initially consist of three stations, 5 vehicles and 2.1 miles of track, 70 percent of which will be elevated. The three stations will be located in the Morgantown Business district, the University's downtown campus and the Engineering Campus. The original agreement was for UMTA to provide up to $28 million for a prototype operation which would then qualify for a capital grant to turn the system into an operational entity. A capital grant would provide two-thirds of the funding. If the system is expanded to its maximum size, three more stations, 1 1/4 route miles of track and 70 or more vehicles would be added. The first phase is scheduled to be in operation by the fall of 1972. The system is not scheduled for passenger service until the fall of 1974.

The other major new system project involving collection and distribution systems was the TRANSPO 72 demonstration mentioned previously. The Ford ACT and the Dashaveyor systems were demonstrated using two vehicles each on short sections of straight track with on-line stations.

Only one of the line haul systems has been demonstrated in the form listed in this report. The Westinghouse Transit Expressway has been operating on a 1,360 foot single loop test track near Pittsburg since 1967 and is being considered for a 10-mile revenue line serving suburban Pittsburg. A 6 kilometer line in Rouen, France will be the first commercial service installation for URBA

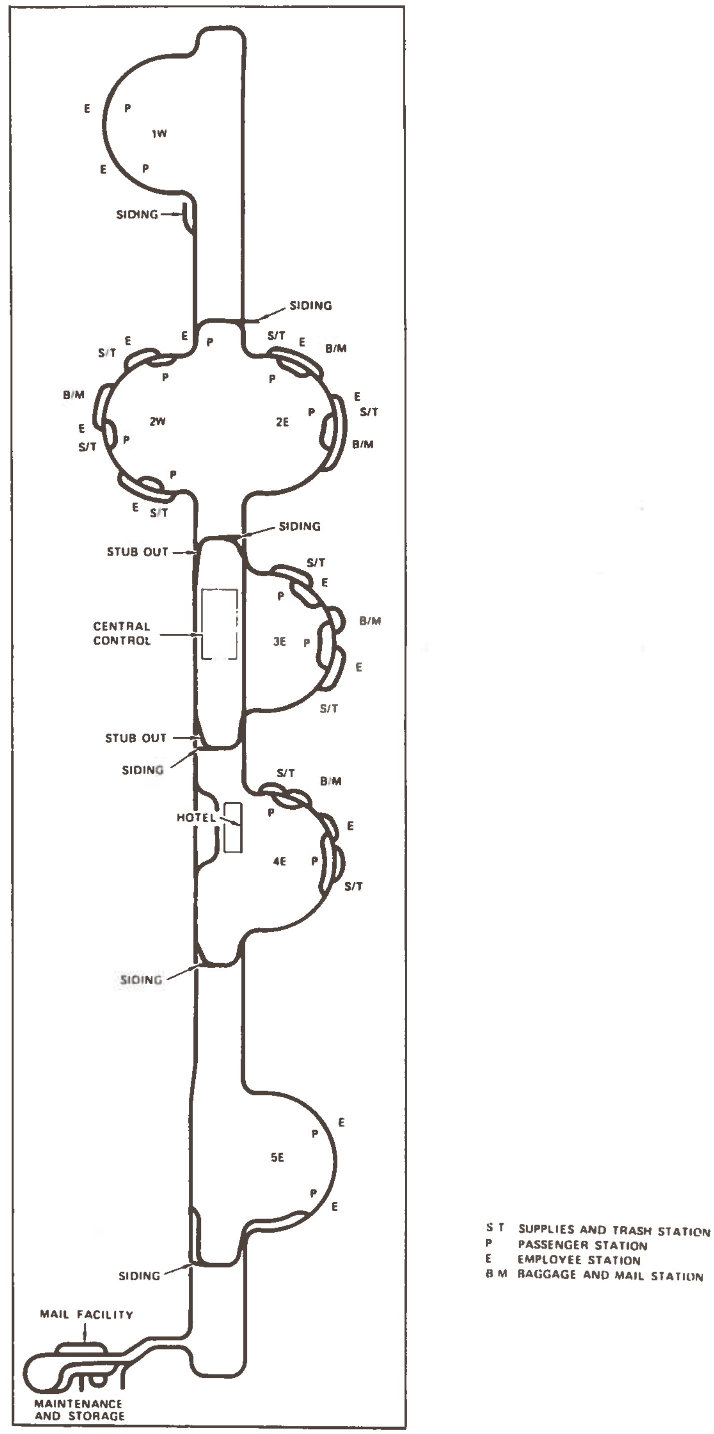


Figure 6-2. Dallas/Fort Worth Regional Airport Guideway Configuration (Courtesy: Vought Aeronautics Co.)

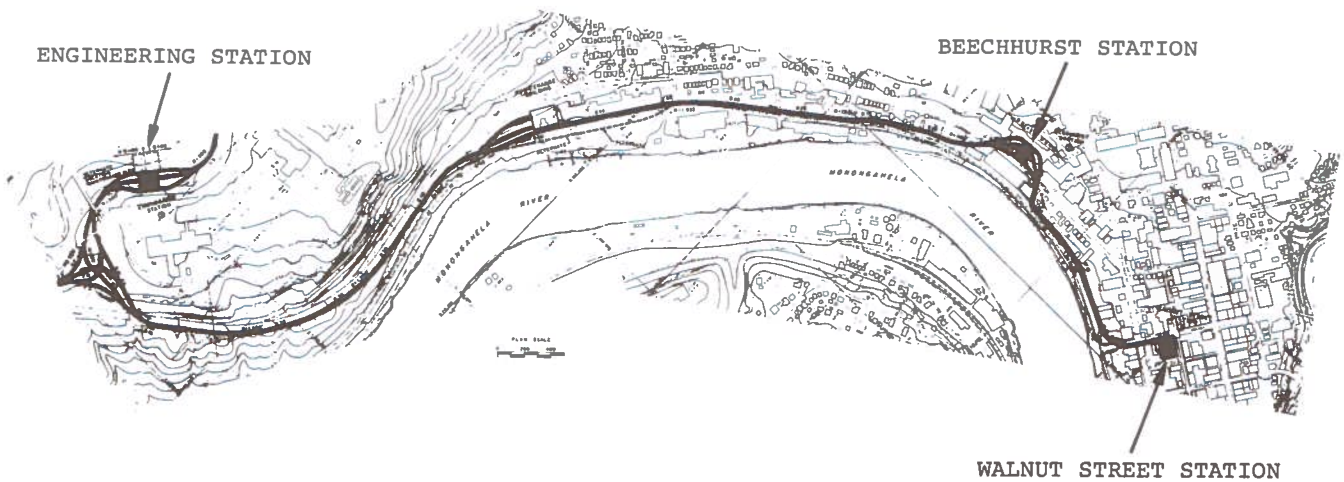


Figure 6-3. Morgantown Demonstration Project (Courtesy: Jet Propulsion Laboratory)

but it will employ small 8 passenger vehicles instead of 30 passenger vehicles. The other listed systems are much further from implementation.

6.2 POTENTIAL SITES

The Urban Mass Transportation Administration is currently screening applications for a second demonstration of an automated, small vehicle system in an urban environment. A decision on the demonstration location is expected in the Fall of 1972.

North American cities which have applied for the UMTA demonstration or which are considereing some form of new urban transportation system include Atlanta, Georgia; Boston, Massachusetts; Dallas, Texas; Dearborn, Michigan; Denver, Colorado; Houston, Texas; Inglewood, California; Las Vegas, Nevada; Los Angeles, California; Minneapolis-St. Paul, Minnesota; Nashville, Tennessee; New York, New York; Newark, New Jersey; Omaha, Nebraska; Pittsburg, Pennsylvania; Salt Lake City, Utah; San Jose, California; Seattle, Washington; Spokane, Washington; Toronto, Ontario; Trenton, New Jersey; Tuscon, Arizona; Vancouver, British Columbia; Washington, D.C.; and Westwood, California. In addition, new transportation systems are being considered for several new towns including Columbia, Maryland; Hosana, Virginia; Jonathan, Minnesota; and Riverton, New York. The systems proposed for Dearborn (industrial area), Houston (Post Oak Shopping Center), Las Vegas (23 mile PRT system serving the airport, downtown and the hotels) and Toronto (initial phase will be one mile long with four stations) appear to have the highest probability of implementation.

Other cities considering new systems include Freiburg, Germany; Gothenburg, Sweden; Hong Kong; Paris, France; Tel Aviv, Isreal; and Tokyo, Japan. Those with the highest probability of implementation seem to be Paris and Tokyo.

6.3 RESEARCH AND DEVELOPMENT REQUIREMENTS

The amount of research and development required varies with each of the systems listed. The principal element necessitating additional research and development is the automated control system.

There is generally little or no research and development required for control of the circulation and line haul systems listed. Existing techniques and hardware are adequate for control of these systems since headways between individual vehicles or trains are normally greater than one minute. The limited number of installations is principally due to lack of component reliability sufficient for cost effective operation.

The collection and distribution and the personal rapid transit systems may require extensive research and development depending upon the control complexity and headway requirements. It is difficult to predict the number of years required to produce significant reductions in headways between vehicles. Some signal equipment manufacturers claim that the technology is presently available to build a system that will allow a five to six second headway between vehicles.

To reduce the headway to 2 seconds, to 1/2 second, or to virtually bumper to bumper operation will require tremendous research and development investment at each step. However, it is not yet certain that 1/2 second or less headways are necessary or desirable when travel demand, type of service and station requirements are considered. Therefore, the availability of the control systems will be dependent upon the pressure exerted for each significant reduction in headway and the amount of money made available for accomplishment of the objective. Nevertheless, it is likely that a minimum of two years would be required to reduce the vehicle separation to the 2 second level if a concerted effort was made to accomplish this goal.

7. SUGGESTED METHODOLOGIES FOR EVALUATING NEW SYSTEM APPLICABILITY

The comparison and evaluation of alternative transportation systems is an integral part of the overall planning process which normally includes the following planning steps:

a. Definition of Goals and Objectives/Problem Definition

b. Establishment of Needs

c. Alternative Transportation Concepts Survey

d. Alternative Concept Performance Evaluation

e. Social and Environmental Impact Analysis

f. Economic Analysis

g. Concept Selection

h. System Design and Performance Specification

Two methods of assessing the applicability of new systems as solutions to a given transportation problem are offered in this section. The first is a very rough screening tool to select the class of system that might be appropriate. The planning agency should be able to narrow the range of systems to be extensively investigated based on the following three considerations:

a. The crude travel requirements established during the first planning step,

b. The descriptions of the functions performed by the various systems which were described in Section 2 of this report, and

c. The summary in Table 7-1 of the more significant system characteristics.

However, Table 7-1 is only a general guideline. A specific system may have characteristics which do not fall within the general range listed. For example, Unimobil (circulation) and Ford ACT (collection and distribution) systems claim capacities of 15,000 to 16,000-passengers per hour. Aerospace Corporation

TABLE 7-1 SYSTEM CHARACTERISTICS BY PRIMARY FUNCTION

	Line Capacities (passengers/ hour)	Speeds (miles/ hour)	Line Headway (seconds)	Vehicle Capacity (passengers)
Personal Rapid Transit	1,000-5,000	30-60	less than 5	4-6
Circulation	1,000-5000*	10-15	over 60	4-15
Collection & Distribution	5,000-10,000	15-30	5-30	15-30
Line Haul	over 10,000*	over 50	over 60	30-50

*Multiple vehicle trains

(personal rapid transit) claims a 42,600-passenger per hour capability. Quoted capacities lower than the functional range include the Vehicle Distribution System (collection and distribution) with 1150 passengers per hour and Aerial Transit (line haul) with 2400 passengers per hour. Systems claiming higher capacities than the functional range reach the higher values by employing shorter headways. The deviation of other specific system characteristics from the ranges listed are not particularly significant.

Once the general class of system has been selected for further investigation, the detailed second method of new system applicability assessment begins; i.e., the transportation systems analysis phase.

At the stage in the planning process where alternative transportation systems begin to be considered, the following material has usually been developed:

- The basic highway and transit networks.
- Estimates of population, employment and other socio-economic variables found to be causative agents for tripmaking.
- A model which distributes the variable activities to specific locations (Land Use Allocation Model).
- A procedure to estimate travel by mode.

With this material in hand, the next step is to establish systems and networks to test. The approach to developing alternative transportation networks varies with the size of the area to be covered. The approach would be relatively simple in a small activity center since the number of system and network alternatives are limited. The complexity becomes formidable when an entire urban area is considered. For each new system to be evaluated, it is reasonable to compare its use to that of standard bus service.

A rough estimate of the additional transportation service requirements over present levels is normally established early in the planning process. This can be accomplished by methods varying from intuitive judgement to a complete future travel assignment to the existing or existing plus irrevocably committed transportation networks. In specific instances such as major activity centers, the demand may even be predetermined. Based upon the crude additional transportation service estimate, alternative transportation solutions are selected for evaluation. Using each new transportation system alternative as an input, the planning process models are exercised, if appropriate, to determine more precisely the travel demand and the service level each alternative provides. The results of each of the alternative proposals are measured against the transportation criteria established in the goals and objectives. Several iterations of this evaluation cycle may be necessary before acceptable or "optimum" transportation solutions are found.

The performance evaluation just described is not the end of the evaluation procedure, however. Financial viability and the degree of success in meeting the overall social and environmental goals and objectives are important dimensions in the decision making process which must be thoroughly studied and assessed before any transportation system is selected for implementation.

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APPENDIX A

SOME SYSTEM PHOTOGRAPHS, SKETCHES AND COST DETAILS*

*Cost details presented if provided by manufacturer

APPENDIX A-1

THE AUTOMATICALLY CONTROLLED TRANSPORTATION (ACT) SYSTEM OF THE FORD MOTOR COMPANY

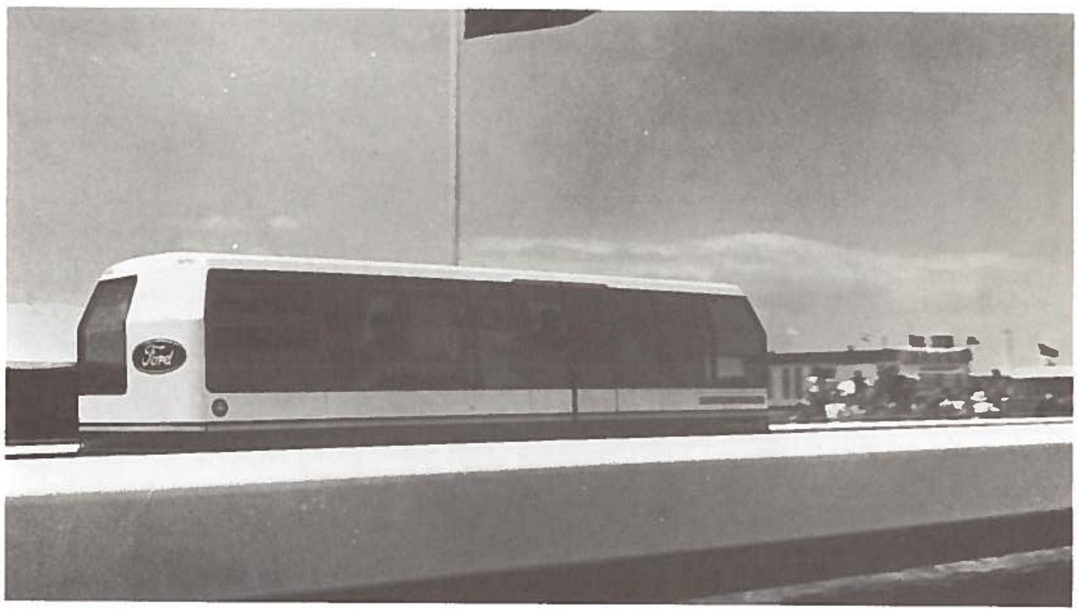


Figure A-1. Photograph of Ford's ACT Vehicle and Guideway at TRANSPO 72

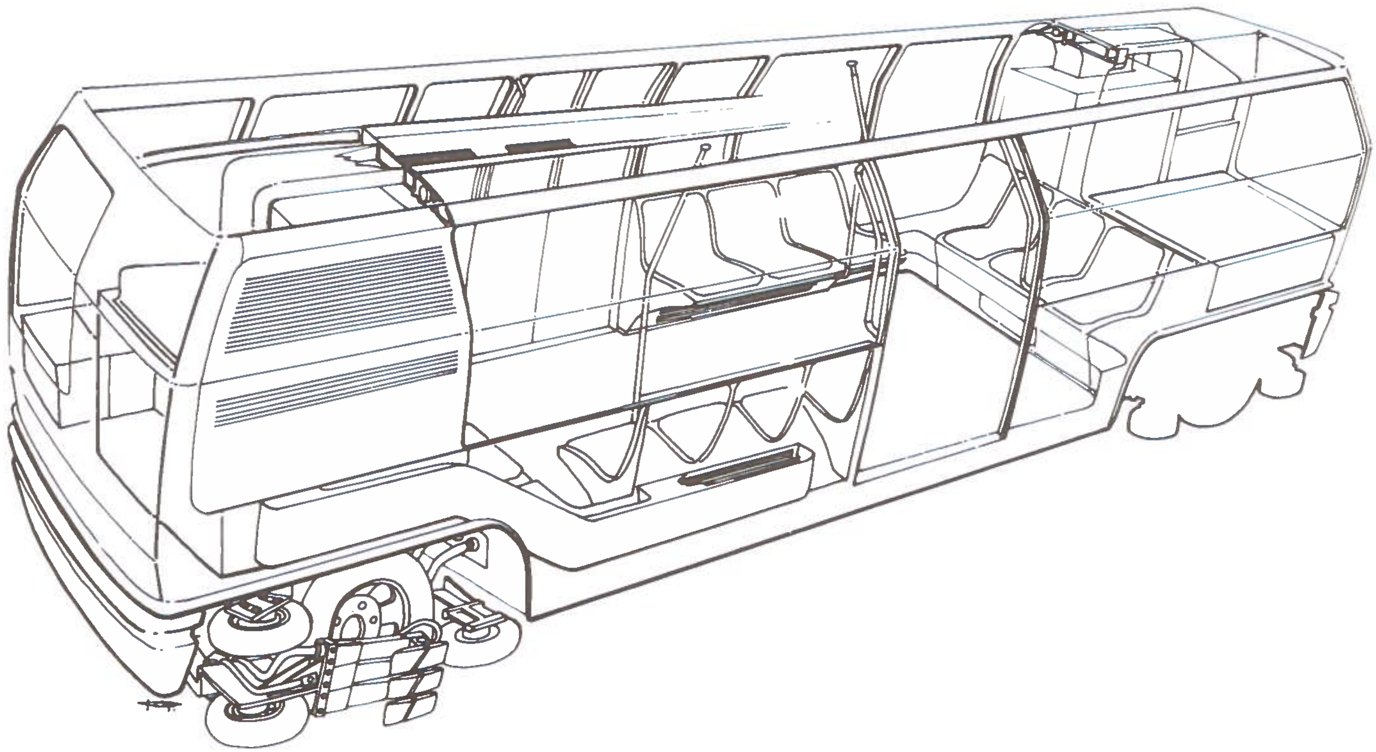


Figure A-2. ACT Vehicle Interior Sketch (Courtesy: Ford Motor Co.)

APPENDIX A-2

AERIAL TRANSIT SYSTEM
BY AERIAL TRANSIT SYSTEM, INC.

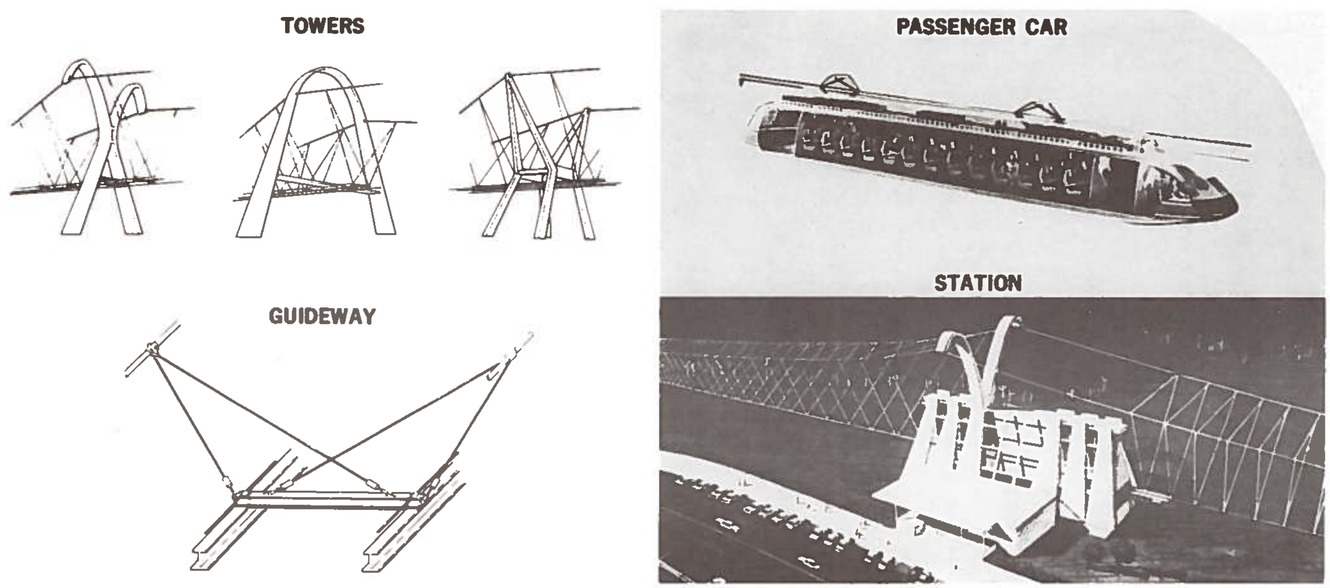


Figure A-3. Aerial Transit System Components (Courtesy: Aerial Transit Systems, Inc.)

AERIAL TRANSIT SYSTEM

Aerial Transit Systems, Inc.
Torrance, California

TYPICAL SYSTEM COSTS

30 Mile Airport Access System (Right-of-Way Provided)

Downtown Terminal Shared Terminal Building	$1,040,000
Airport Terminal Use Aircraft Terminals	N/C
One Intermediate Station Suburban	$ 144,000
24 Passenger Cars $325,000 ea.	$7,800,000
Tower and Guideway (30 miles) ($450,560+$921,923)30	$41,174,490
Total	$50,158,490
Allowing 25% for (Escalation-Contigency-Profit)	12,539,622
Total System Cost 1975	$62,698,112
or	$ 2,090,000 per mile

GUIDEWAY

	Dollars
Concrete foundation (Caissons with reinforced cap)	7,700.00
Precast tower segments	45,800.00
Erection	29,900.00
Miscellaneous material, transportation labor, etc.	19,000.00
Tower total	102,400.00
$\$102,400 \times \frac{5280}{1200} =$	$450,560.00 per mile

GUIDEWAY (CONTINUED)

	Dollars
Main cables 8 each=9600 ft. at $6.51 ft.	62,496.00
Hanger cables 4400 ft. at $.53 ft.	2,332.00
Track rails 2400 ft. at $32.00 ft.	76,800.00
Struts, Connectors Tower expansion joints, misc.	10,900.00
Electrification 1 ϕ, 60 Hz 20,000 volt AC cable, Hangers and insulators	10,000.00
Erection and installation	47,000.00
Guideway Total	209,528.00
$\$209,528 \times \frac{5280}{1200} =$	$921,923.00 per mile

TYPICAL CAR COSTS

Aerial Transit System car (traction powered)	300,000.00 to 325,000.00

STATIONS

Sharing occupancy in terminal building 40,000 sq. ft. at $26.00 sq. ft	1,040,000.00 Terminal
Suburban station 8,000 sq. ft. at $18.00 sq. ft	144,000.00 Station

APPENDIX A-3

ADVANCED PERSONAL RAPID TRANSIT (PRT) SYSTEM
BY THE AEROSPACE CORPORATION

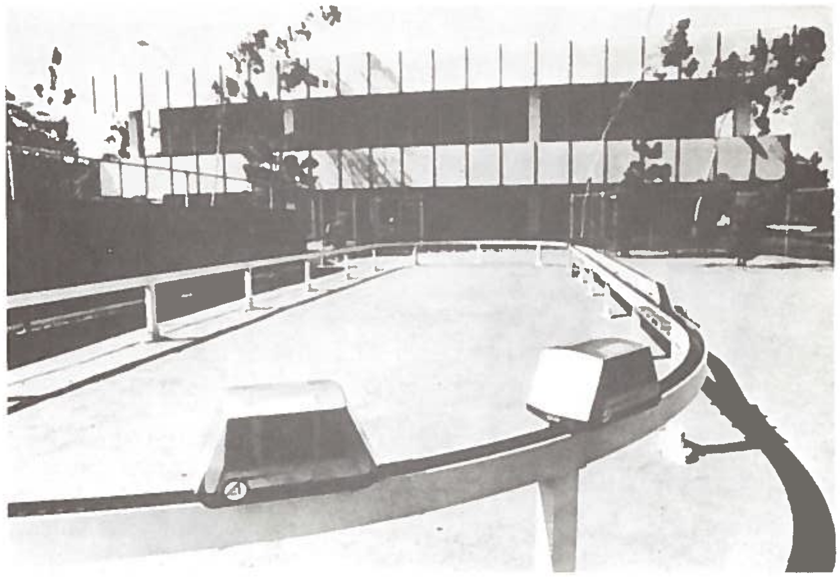


Figure A-4. PRT Scaled Model Facility (Courtesy: The Aerospace Corporation)

Figure A-5. Montage of High-Capacity PRT Installation in Downtown Los Angeles (Courtesy: The Aerospace Corporation)

AEROSPACE

Aerospace Corporation
El Segundo, California

The city of Tucson, Arizona, was chosen as a study city by Aerospace as being a typical candidate for the application of a limited system PRT network. The network includes high-speed 60-mph lines and low-speed 25-mph lines. There are 65 stations of the taxi or moving belt varieties, and 54.3 miles of track. The taxi stations would generally be used for low patronage areas, while one or more moving belts would serve the higher capacity stations. To minimize the cost of the network trackage, the high-speed lines were assumed to allow slowing of the cars to 25 mph at intersections.

Network Parameters

54.3 miles of guideway (15 low speed, 39.3 high speed)
57 stations (40 taxi, 17 belt and multibelt)
15 PRT parking lots (13 paid, 2 free)
1617 cars

Patronage and Operating Statistics

6444 peak-hour trips
64,440 daily trips
19.3 million vehicle trips/year
8 cent/mile fare charge
25 cent/car parking charge
106 million vehicle miles/year

Annual Cost Data	Cost (Millions of $)	
Total capital investment		82.16
Guideway	44.44	
Stations	22.94	
Cars	8.41	
Facilities	4.50	
Parking lots	1.87	
Operating Cost		4.852/ year

CANDIDATE NETWORK

PRT COST ASSUMPTIONS FOR THE LARGE URBAN NETWORK

System costs are divided into operating and capital costs. Operating costs can further be divided into a variable cost which varies as a function of vehicle use and includes the cost of providing power to the vehicles and vehicle maintenance; and fixed operating costs which includes power for stations, facilities, maintenance, and salaries for station cleaning crews. Studies indicate that variable operating costs are 1.9 cents per occupied car mile while fixed operating costs are approximately 2.5% of the facility capital costs per year. The variable operating cost estimate assumes that one-third of the vehicles in use are empty and are enroute to pick up passengers.

Capital Cost Assumptions

A unit cost of $4,000 per vehicle was assumed, plus $1,200 per vehicle for garaging, giving an effective cost of $5,200 per vehicle. The station costs include computer costs for car control and station operations, station structure costs, and trackage required for merge, demerge, acceleration, deceleration, and the station itself ($146 per foot). Other capital costs include a central computer cost of $2.5 million, and a central facilities cost of $2 million. The assumed parking lot costs were $400 per car space, plus 320 square feet required per space at a land cost of 23 cents per square foot ($10,000 per acre), giving a total of $474 per car space.

Operating and Labor Cost Assumptions

Costs for car operations were estimated at 1.9 cents per occupied vehicle mile. Station and guideway operating costs included a guideway cost of 2%, and an electronics maintenance cost of 10%. The cost of operations for parking lots at stations was assumed to be $30 per space plus 7% of the parking revenue. Control was assumed to be automatic, and thus not require attendants at gates. Labor costs at stations were based on the assumption that one man can clean four stations in a single shift at a salary of $8,000 per man-year, and that station attendants would only be required at belt-type stations for two shifts per day at a salary of $10,000 per man-year. On all operating costs except parking, a figure of 15% was assumed for overhead. This was added to account for items such as insurance, billing expenses, security, etc.

APPENDIX A-4

THE AEROTRAIN SYSTEM

BY THE ROHR CORPORATION

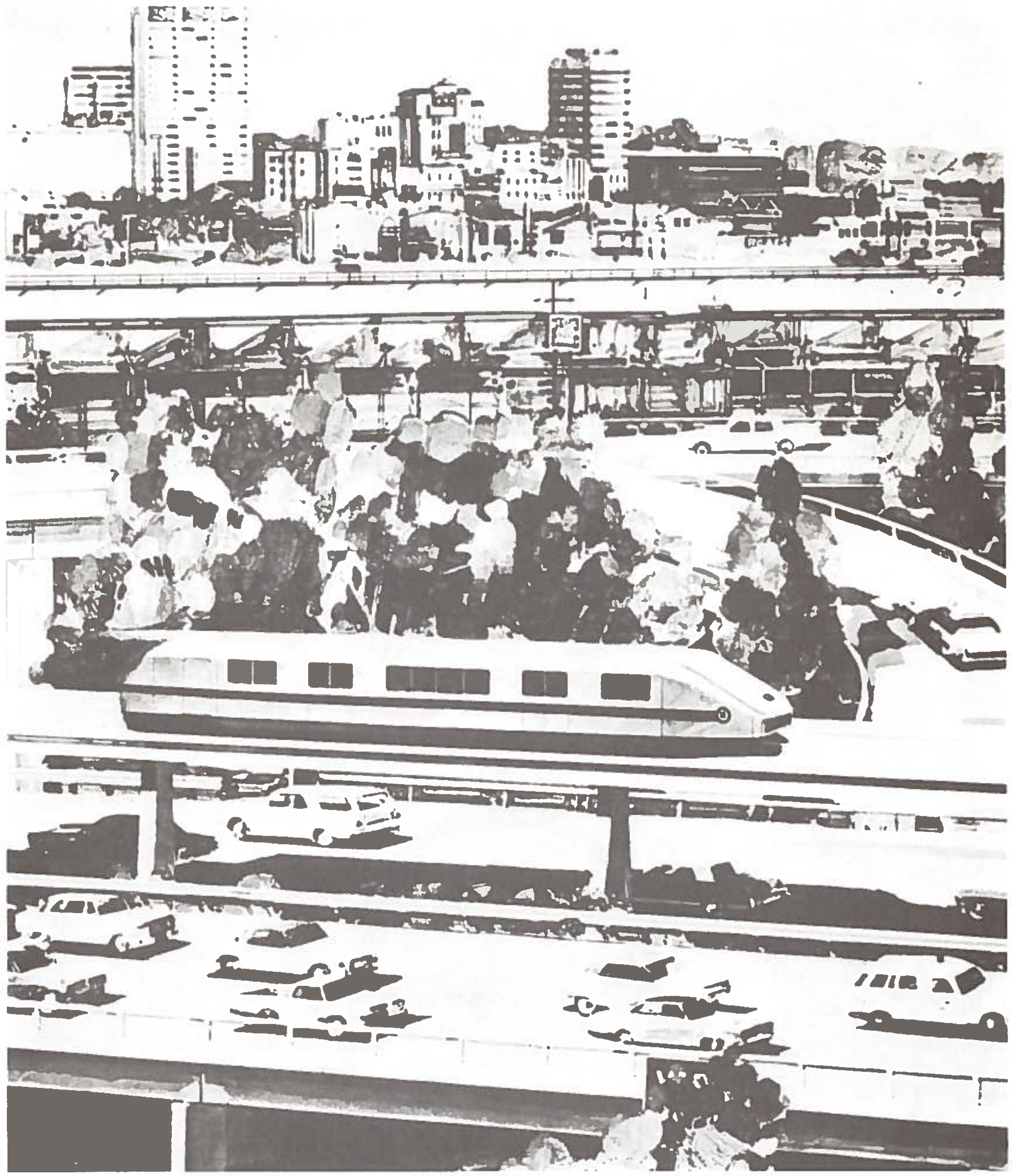


Figure A-6. Artist's View of Aerotrain in Median Strip of Freeway (Courtesy: Aerotrain Systems, Inc., A Subsidiary of Rohr Corp.)

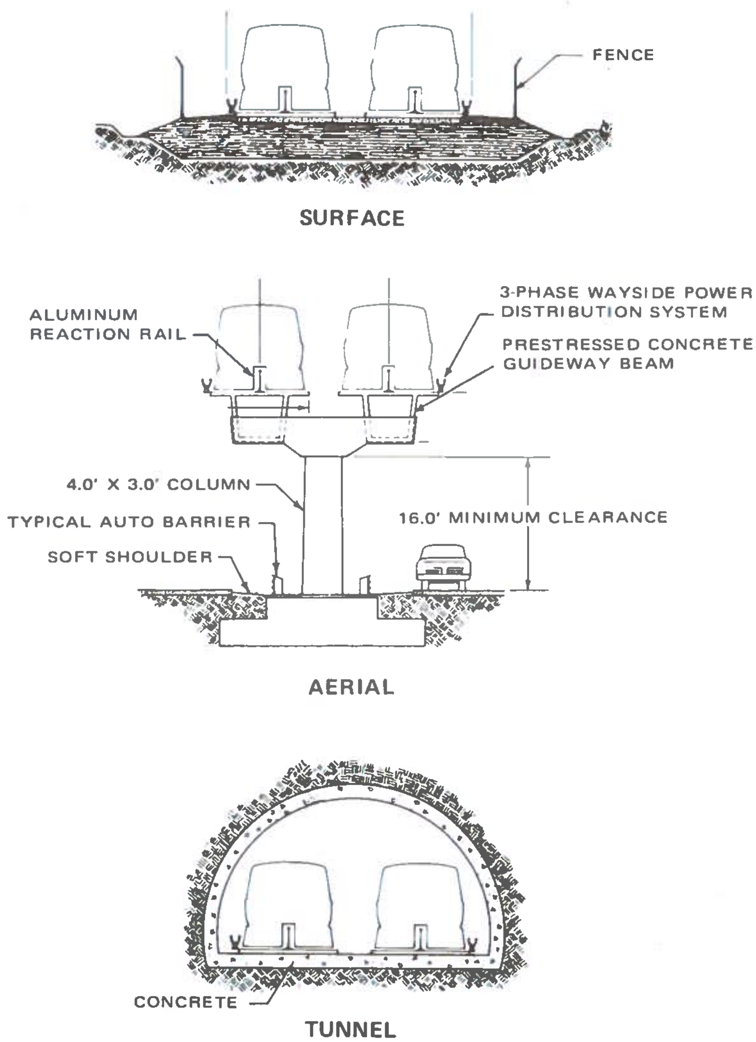


Figure A-7. Typical Guideway Configurations (Courtesy: Aerotrain Systems, Inc., A Subsidiary of Rohr Corp.)

APPENDIX A-5

THE AIRTRANS SYSTEM
BY LTV AEROSPACE DIVISION
OF LTV CORPORATION

Figure A-8. Artist's View of Airtrans Vehicle and Guideway
(Courtesy: Vought Aeronautics Co.)

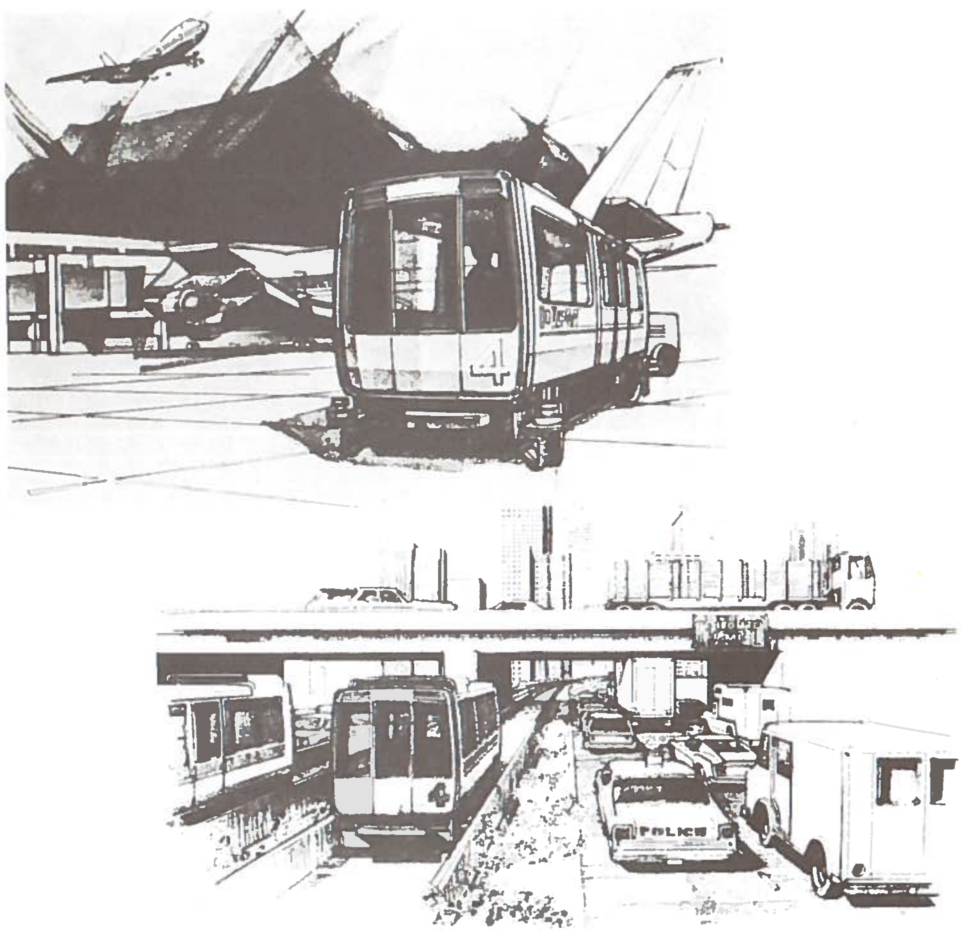


Figure A-9. Potential Airtrans Applications (Courtesy: Vought Aeronautics Co.)

AIRTRANS

Vought Aeronautics Company
Dallas, Texas

The initial routing of Airtrans will provide service between specially-designed stations at four terminals, two remote parking areas, mail facilities and a maintenance area-- a total distance of over twelve miles. Depending on system demand, the system will operate with about 75 vehicles.

There will be 15 discretely-scheduled routes -- five for passengers, two for employees, six for interline baggage and mail, and two for airport mail. System capacity with these routes will be 9,000 passengers, 6,000 bags and 70,000 pounds of mail per hour.

Total system cost is $30.9 million which converts to a little over $2.5 million per mile.

APPENDIX A-6

A PRT SYSTEM VEHICLE AND A DUAL-MODE SYSTEM VEHICLE
BY THE ALDEN SELF-TRANSIT SYSTEMS CORPORATION

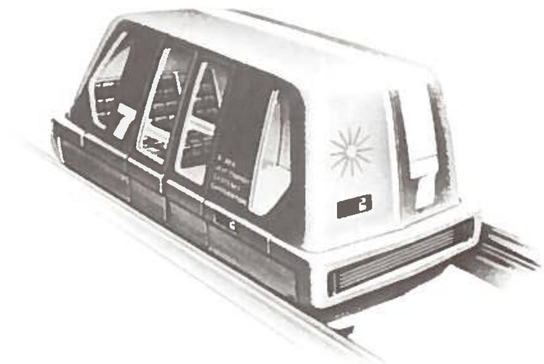


Figure A-10. PRT Vehicle (Courtesy: Alden Self-Transit Systems Corp.)

Figure A-11. Dual-Mode Vehicle (Courtesy: Alden Self-Transit Systems Corp.)

APPENDIX A-7

THE CARVEYOR SYSTEM
BY THE GOODYEAR TIRE AND RUBBER COMPANY

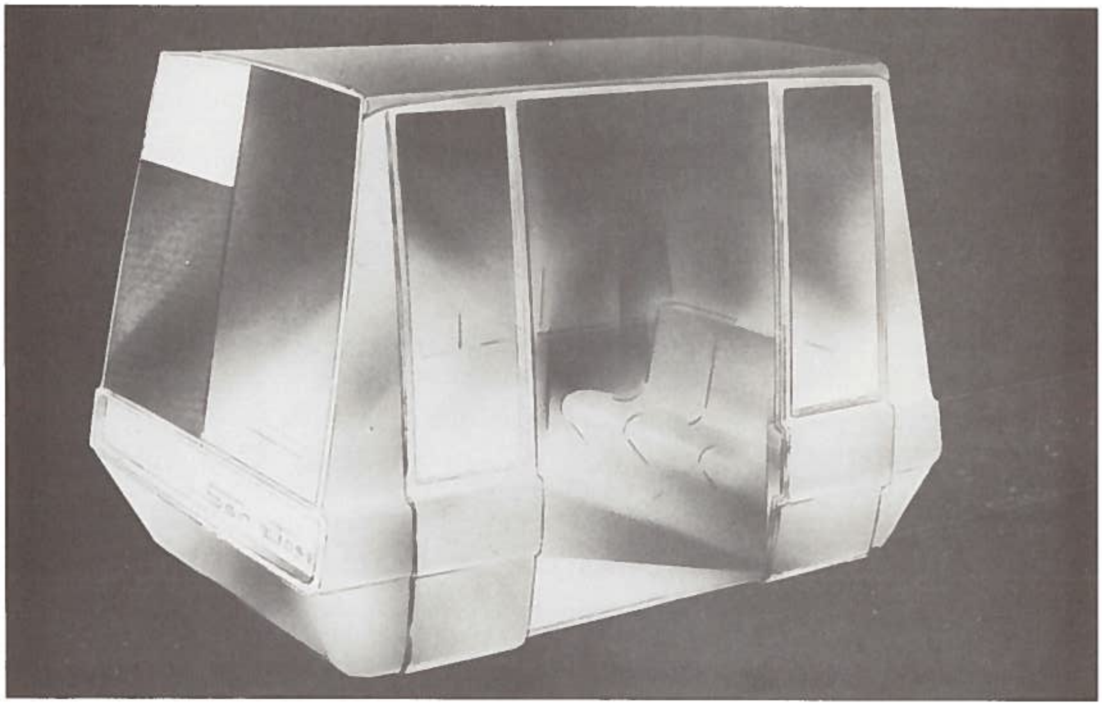


Figure A-12. Artist's Sketch of Carveyor Vehicle (Courtesy: The Goodyear Tire and Rubber Company)

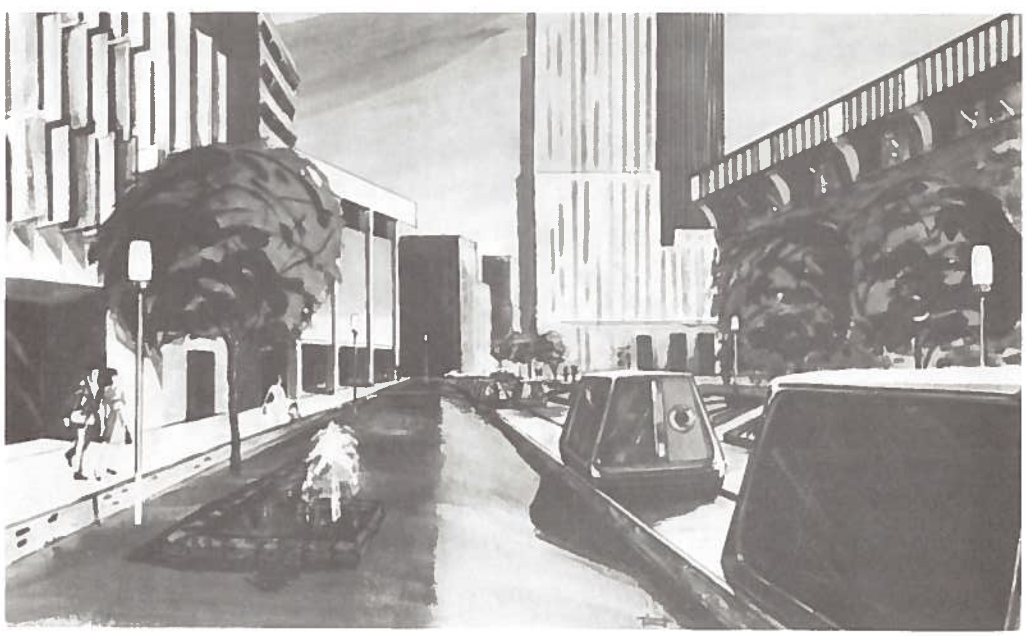


Figure A-13. Artist's View of Carveyor in Urban Setting (Courtesy: The Goodyear Tire and Rubber Company)

CARVEYOR

Transport Systems Department
The Goodyear Tire & Rubber Company
Akron, Ohio 44316

Costs:

Vehicle:	$4,000-8000 depending upon size and optional equipment
Terminals:	Approx. $250,000/station
Guideway:	Elevated double guideway $2-3 million per mile
Control & Communication:	Information not available
Operating Cost:	$6-8 per hour power cost plus two operating personnel per shift.
Maintenance Cost:	Not over 1% of capital cost per year, including labor.
Total System Cost:	$5-8 million per mile

The costs vary depending on station spacing, car appointment (e.g., air conditioning), and line capacity.

A 1-mile Seattle installation was quoted at $5.1 million plus $500,000 for foundations, accessways to stations, and local bidding and construction regulations. On the Tampa Airport installation, comprising 7,280 feet of system and 7 loops, a cost of $9.3 million or $1,275 per linear foot was quoted. These costs are taken from firm quotations.

APPENDIX A-8

A COLLECTION AND DISTRIBUTION SYSTEM BY DASHAVEYOR/BENDIX

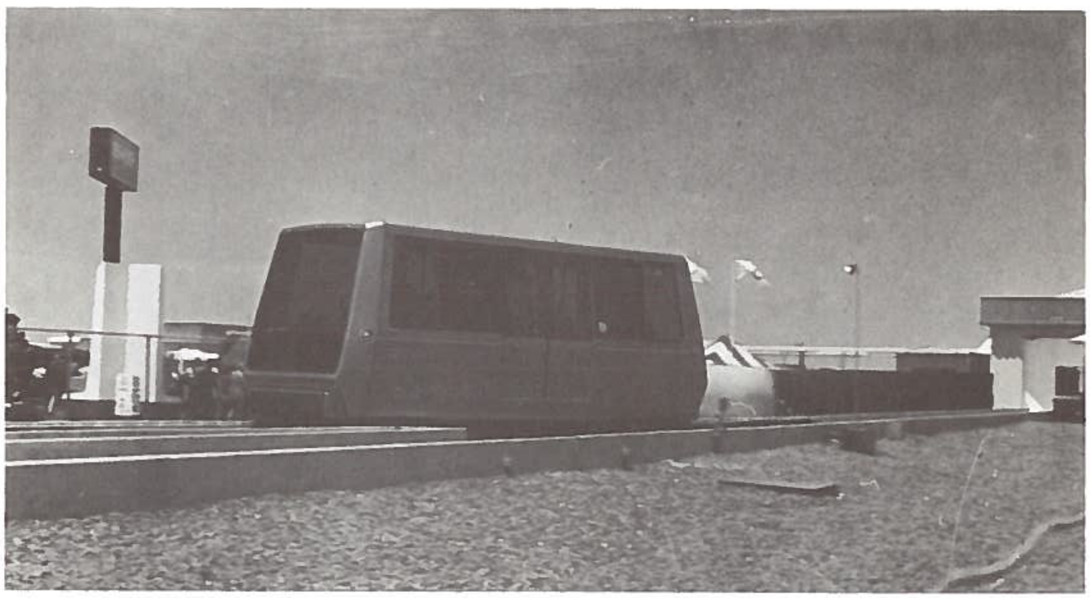


Figure A-14. Photograph of Dashaveyor Vehicle at TRANSPO 72 (Courtesy: The Dashaveyor Co.)

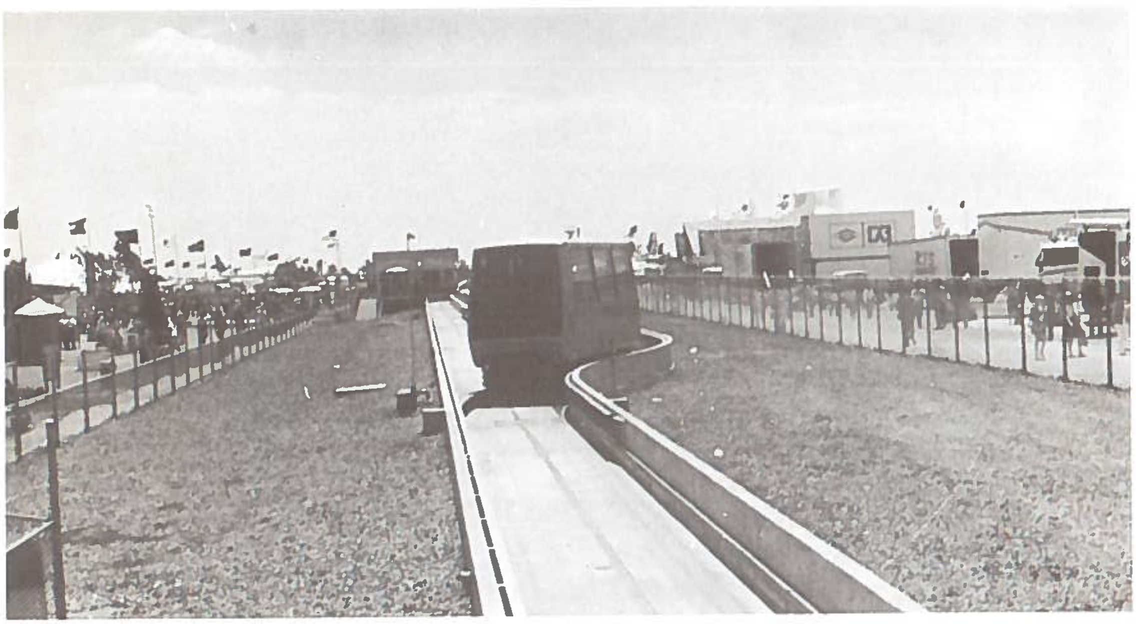


Figure A-15. Photograph of Dashaveyor Guideway and Vehicle at TRANSPO 72

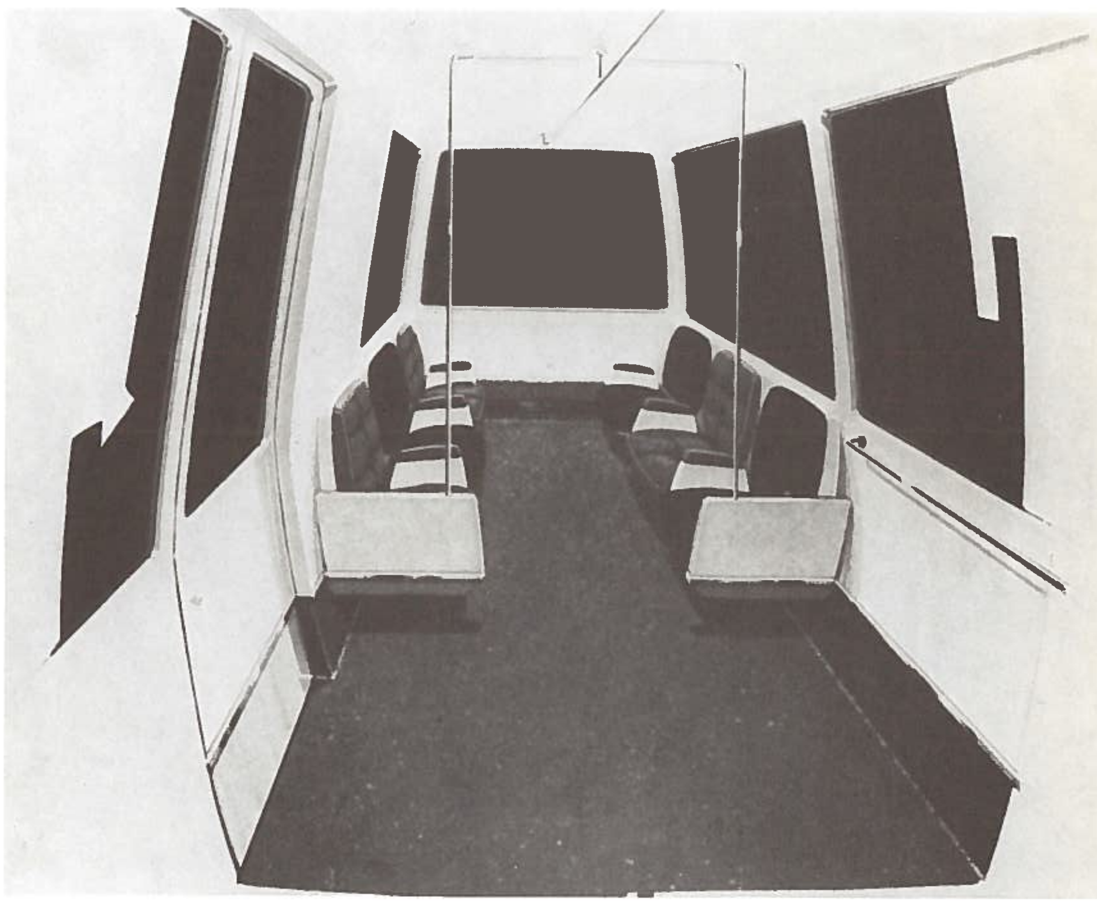


Figure A-16. Dashaveyor Module Interior

APPENDIX A-9

THE MONOCAB SYSTEM
BY THE ROHR CORPORATION

Figure A-17. Photograph of Monocab Vehicle, Station and Guideway at TRANSPO 72

MONOCAB

January 7, 1972

Monocab, Inc.
Garland, Texas

The following is submitted as Budgetary Pricing information:

System Definition	Small	Medium	Large
Guideway (miles)	1/2 to 2	2 to 6	6 & up
Vehicles	1 to 10	10 to 50	50 & up
Stations	1 to 5	5 & up	5 & up
Typical System			
Guideway (miles)	1	4	20
Vehicles	6	30	150
Stations	3	10	20
Total Price	$3,331,000	$10,158,000	$42,455,000
Price/Mile	3.3 million	2.54 million	2.24 million

APPENDIX A-10

THE MORGANTOWN SYSTEM
BY THE BOEING CO.

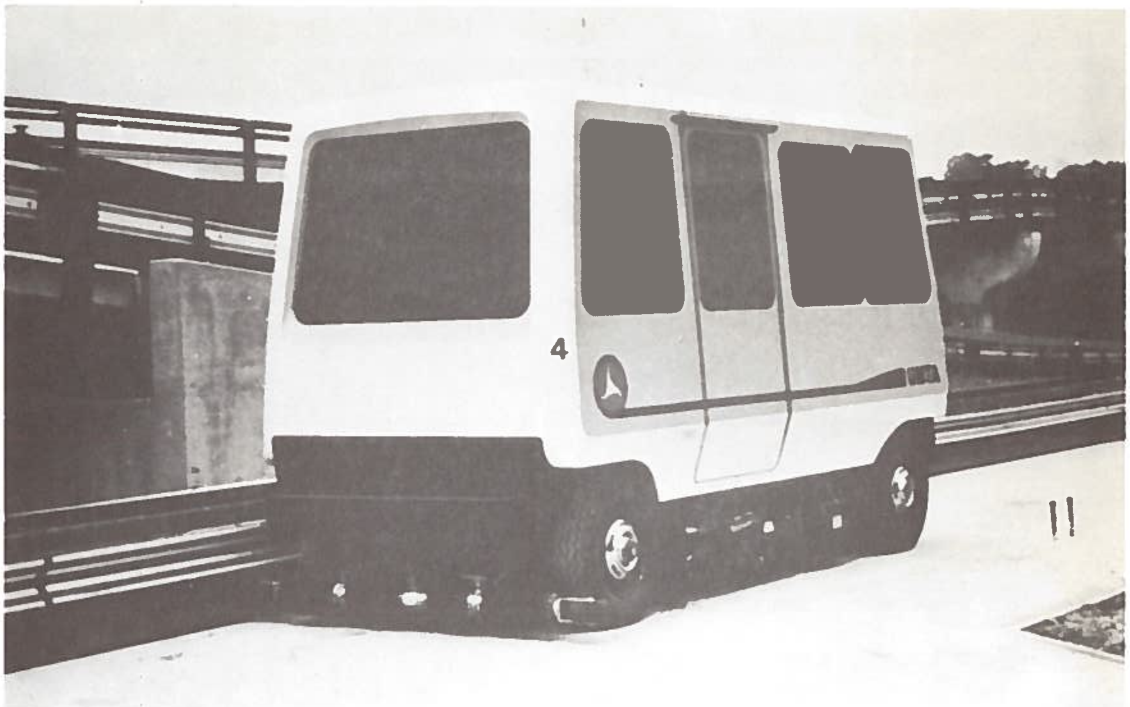


Figure A-18. Photograph of Morgantown Vehicle

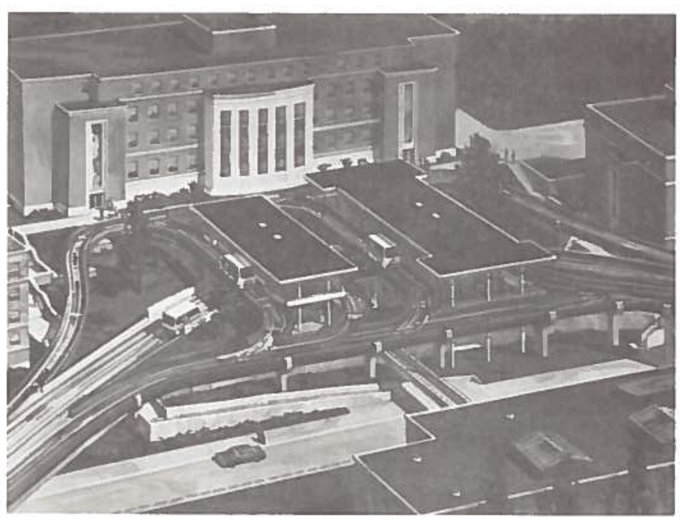


Figure A-19. Artist's View of Beechurst Station (Courtesy: The Boeing Co.)

APPENDIX A-11

THE TRANSIT EXPRESSWAY SYSTEM
BY WESTINGHOUSE ELECTRIC CO.

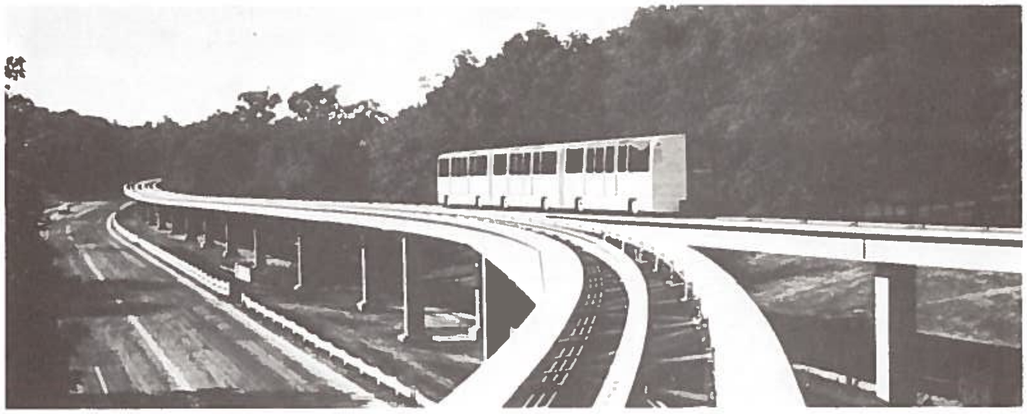


Figure A-20. Transit Expressway Vehicles in a Train Configuration (Courtesy: MPC Corp.)

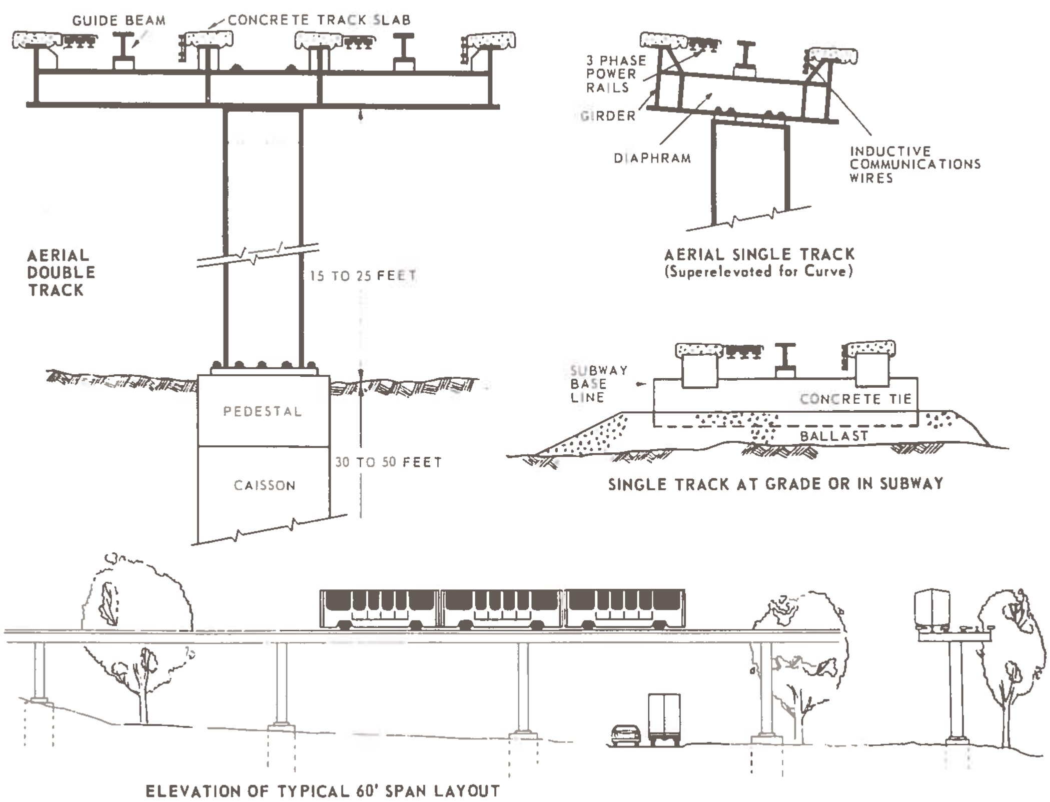


Figure A-21. Roadway Structure-Cross Sections (Courtesy: MPC Corp.)

TRANSIT EXPRESSWAY

Westinghouse Electric Corporation
Transportation Division
Pittsburg, Pennsylvania

Estimated Capital Costs by Major Categories
for the Transit Expressway Revenue Line
(1969 Prices)

Right-of-way	$ 14,000,000
Structures and roadway	41,375,000
Passenger stations	17,829,000
Electrification	10,638,000
Automatic train operation and communications	7,245,000
Maintenance shops, storage yards, and consist change yard	6,634,000
Vehicles	16,238,000
Engineering	8,800,000
General and administrative	1,140,000
Construction management	4,592,000
Systems start-up and shakedown and operations training	434,000
Total (Before contingencies and escalation)	$128,925,000

Essentially the table describes an 11-station, 10.6-mile system which will initially have 145 vehicles, each with 26 seats and a total capacity of 66 riders. Initial two-minute headways are planned for 16 hours a day, 365 days a year, with no more than 15-minute headways for the remaining, off hours.

APPENDIX A-12

TRANSMOBILE VEHICLES
BY MOBILITY SYSTEMS AND EQUIPMENT CO.

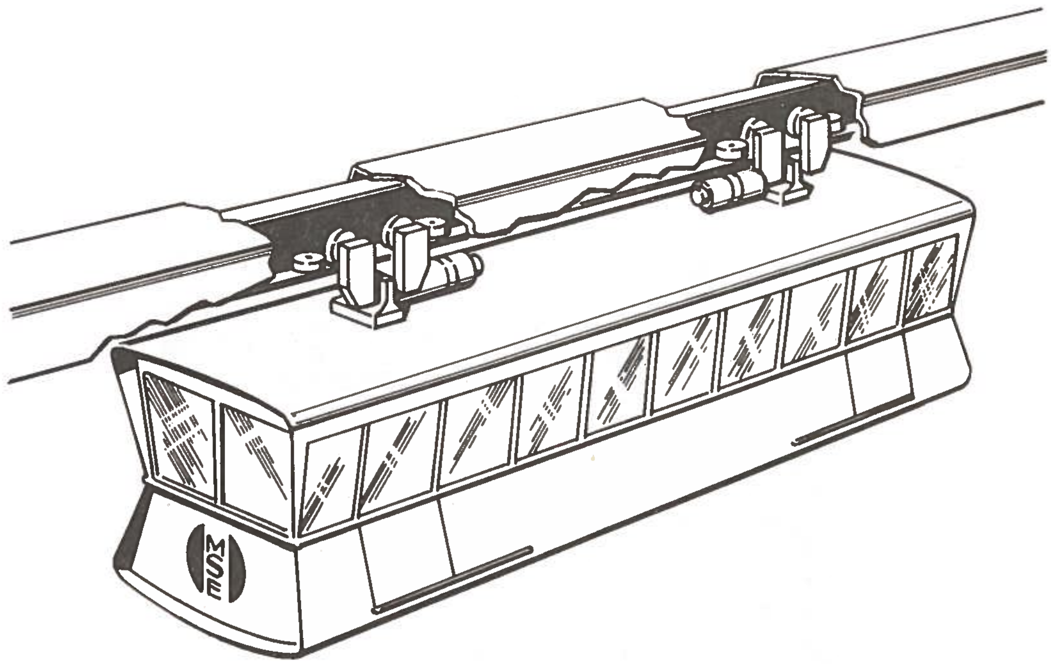


Figure A-22. TransMobile Vehicle-Monorail Type III Configuration
(Courtesy: Mobility Systems and Equipment Co.)

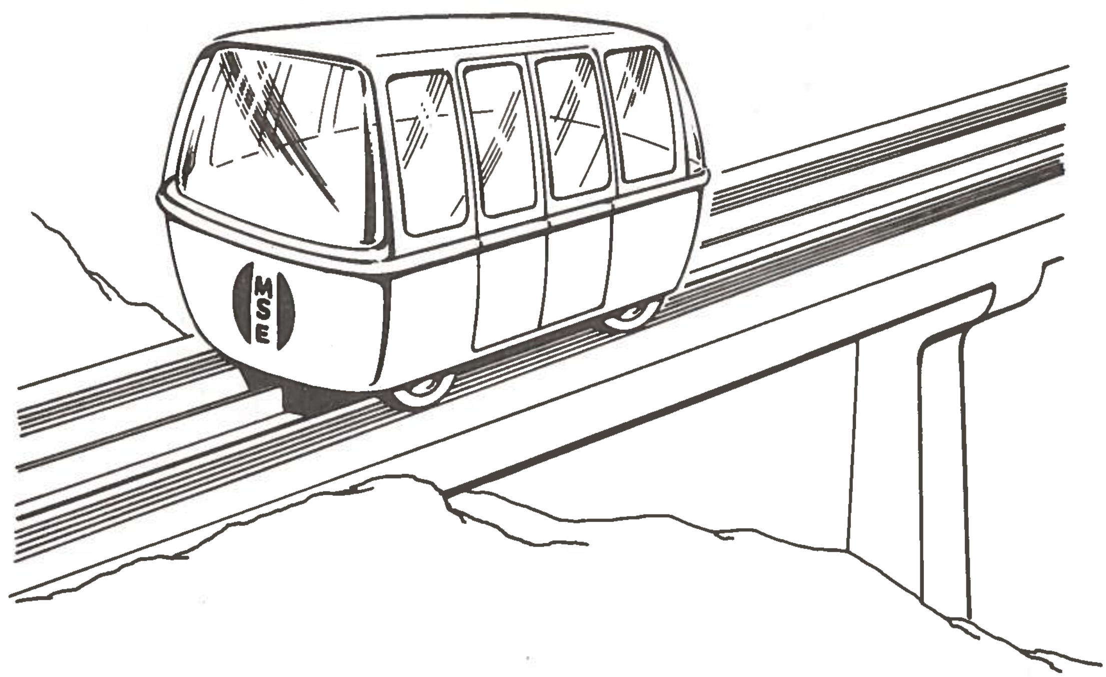


Figure A-23. TransMobile Vehicle-Mini-Bus Type I Configuration
(Courtesy: Mobility Systems and Equipment Co.)

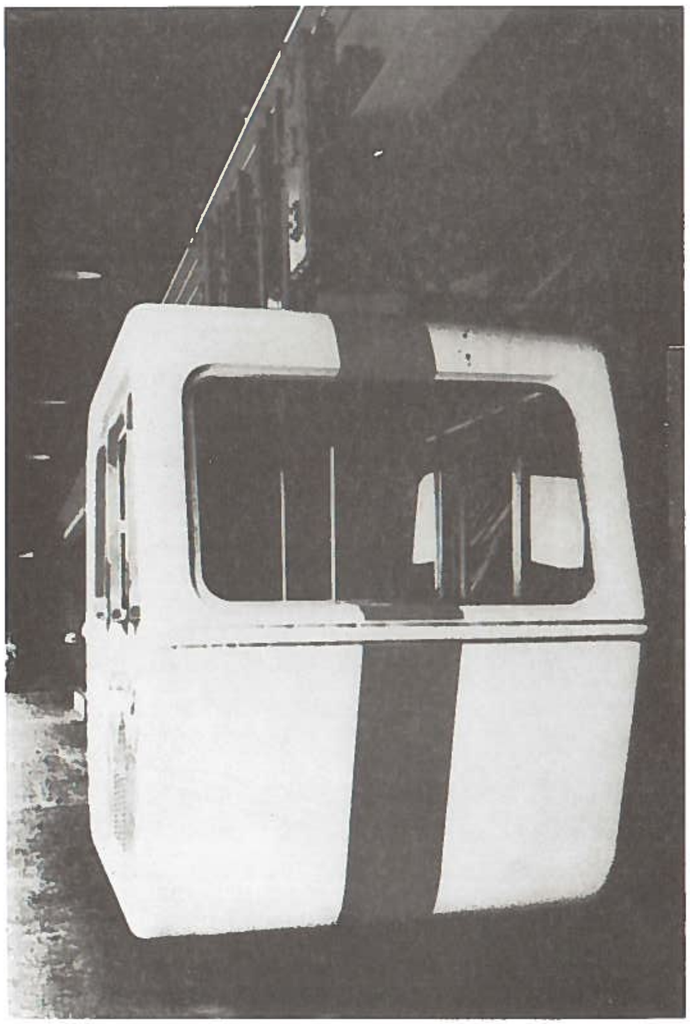


Figure A-24. Photograph of JETRAIL Vehicle at Love Field Dallas Texas (Courtesy: Mobility Systems and Equipment Co.)

TRANSMOBILE MONORAIL "II"

Mobility Systems and Equipment Company
Santa Monica, California

TOTAL SYSTEM COST - SUMMARY

Based on Type II, Monorail configuration - two stations, one stop, two dispatching patterns, 6 doors, station selection, 10 vehicles - urban area - free right of way - 1 1/4 miles.

10 vehicles @ $35,000.00		$350,000.00
Terminals (2) and one (1) stop		
6 doors - $3,000.00/or		18,000.00
Term. 2 x 3,000 $ft.^2$ @ $25.00		150,000.00
top 1 x 500 $ft.^2$ @ $20.00		10,000.00
Foundations-1 1/4 miles @ $40,000.00		50,000.00
Guideway-1 1/4 miles @ $200,000.00/mile		250,000.00
Switches - 2 - @ $15,000.00/or		30,000.00
Control and Communications		
(Wayside speed and safety subsystem)		
1 1/4 miles @ $240,000.00/mile		300,000.00
Electrification		
$80,000.00/mile plus 10% (4) =		140,000.00
Vehicle Communications		
Per Terminal	Stations (2) $1,500.00	3,000.00
	Vehicles - 10 x $375.00	3,750.00
Dispatching Logic and Control -		
Station $20,000.00 x 2 plus 10%		44,000.00
Stop $ 5,000.00 x 1 plus 10%		5,500.00
		$1,354,250.00
	Total	$1,400,000.00

Operating Cost

	Basic	$60,000.00
Plus 4 vehicles @ $2,000.00		8,000.00
Plus 50% for Type II		34,000.00
	Total	$102,000.00/per year

APPENDIX A-13

A PRT SYSTEM
BY TRANSPORTATION TECHNOLOGY INC./OTIS ELEVATOR CO.

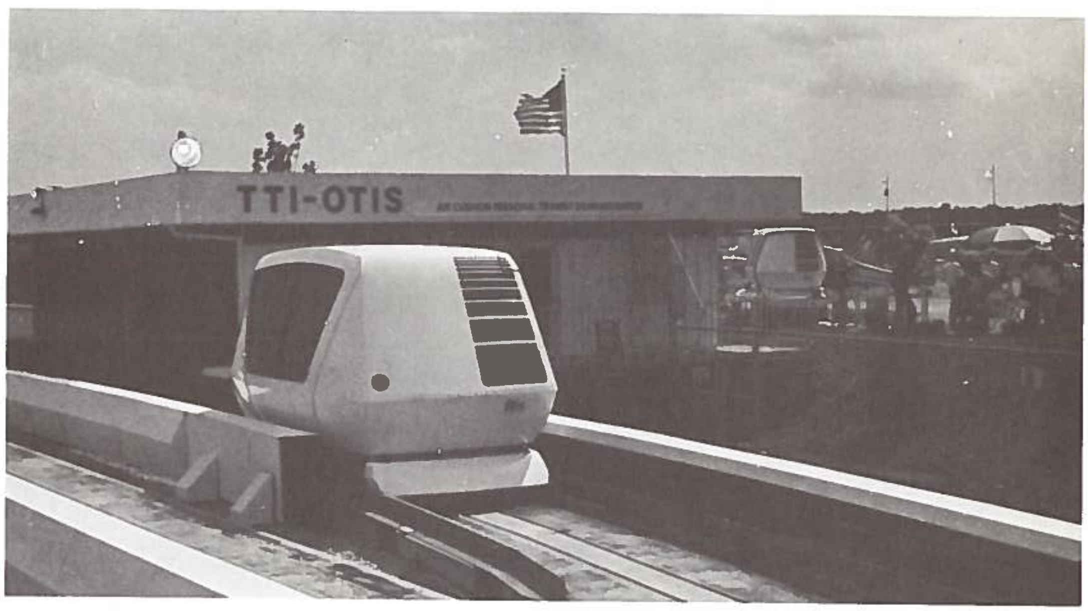


Figure A-25. Photograph of TTI Vehicle, Station and Guideway at TRANSPO 72

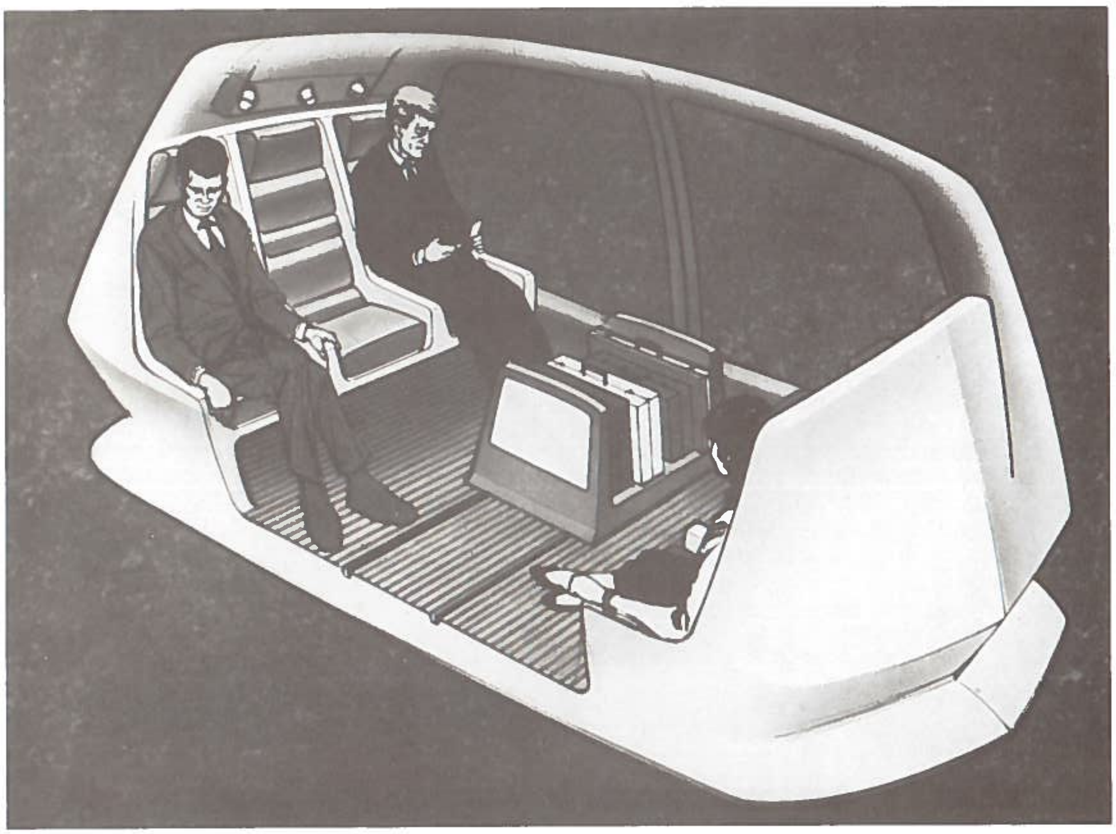


Figure A-26. Artist's View of TTI Vehicle Interior (Courtesy: Transportation Technology, Inc.)

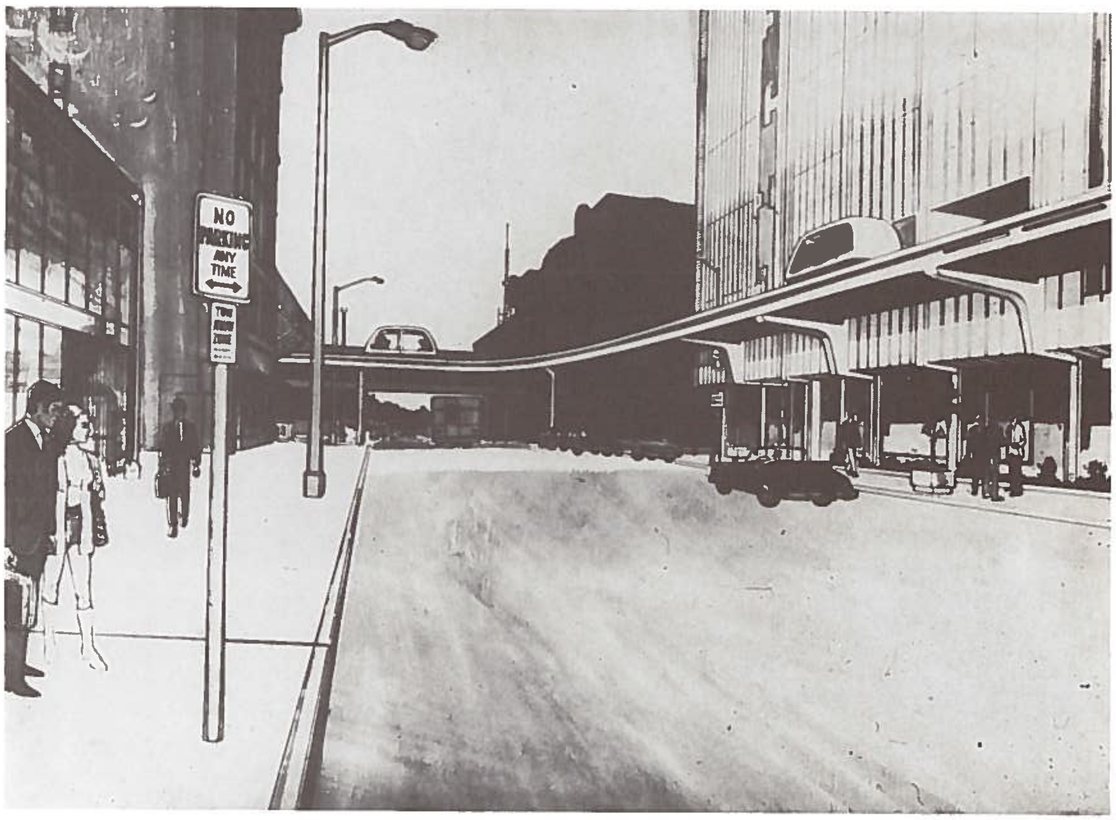


Figure A-27. Artist's Conception of TTI System in Central Business District (Courtesy: Transportation Technology, Inc.)

TRANSPORTATION TECHNOLOGY INCORPORATED

Transportation Technology, Inc.
Denver, Colorado

CAPITAL AND ENGINEERING COSTS

GUIDEWAY		
TWO-WAY DOUBLE "T" SPAN = 60.0 FEET	$ 1495000.00	
POWER DISTRIBUTION	$ 1318409.00	
POWER RAILS	499979.94	
		$ 3313388.00
STATION AREAS		
DOCKS INCLUDING CURB MAGNETS	$ 28750.00	
STORAGE	$ 75000.00	
MAINTENANCE AREA	$ 60000.00	
CLEANING + WASH AREA	$ 28750.00	
CONTROL ROOM	$ 25000.00	
		$ 217500.00
VEHICLES		
23 VEHICLES	$ 509999.81	
		$ 509999.81
CONTROL + COMMUNICATIONS		
TRACK HARDWARE	$ 68964.94	
		$ 68964.94
CONSTRUCTION + CONTRACT MANAGEMENT SERVICES	$ 439600.00	
		$ 439600.00
CONTINGENCY	$ 140000.00	
		$ 140000.00
SELLING PRICE	PRICE/MILE = $1.726 MILLION	$ 4249851.00

APPENDIX A-14

A PRT SYSTEM
BY UNIFLO SYSTEMS CO.

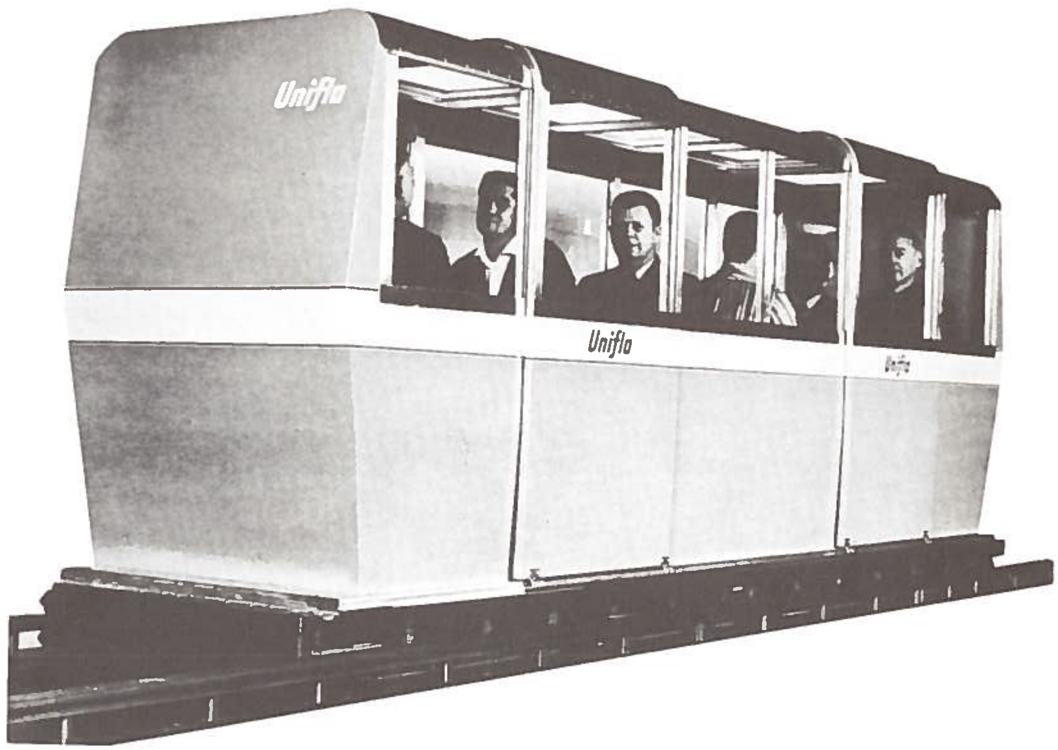


Figure A-28. Uniflo Vehicle Mock-up (Courtesy: Uniflo Systems Co., A Subsidiary of Rosemount Engineering Co.)

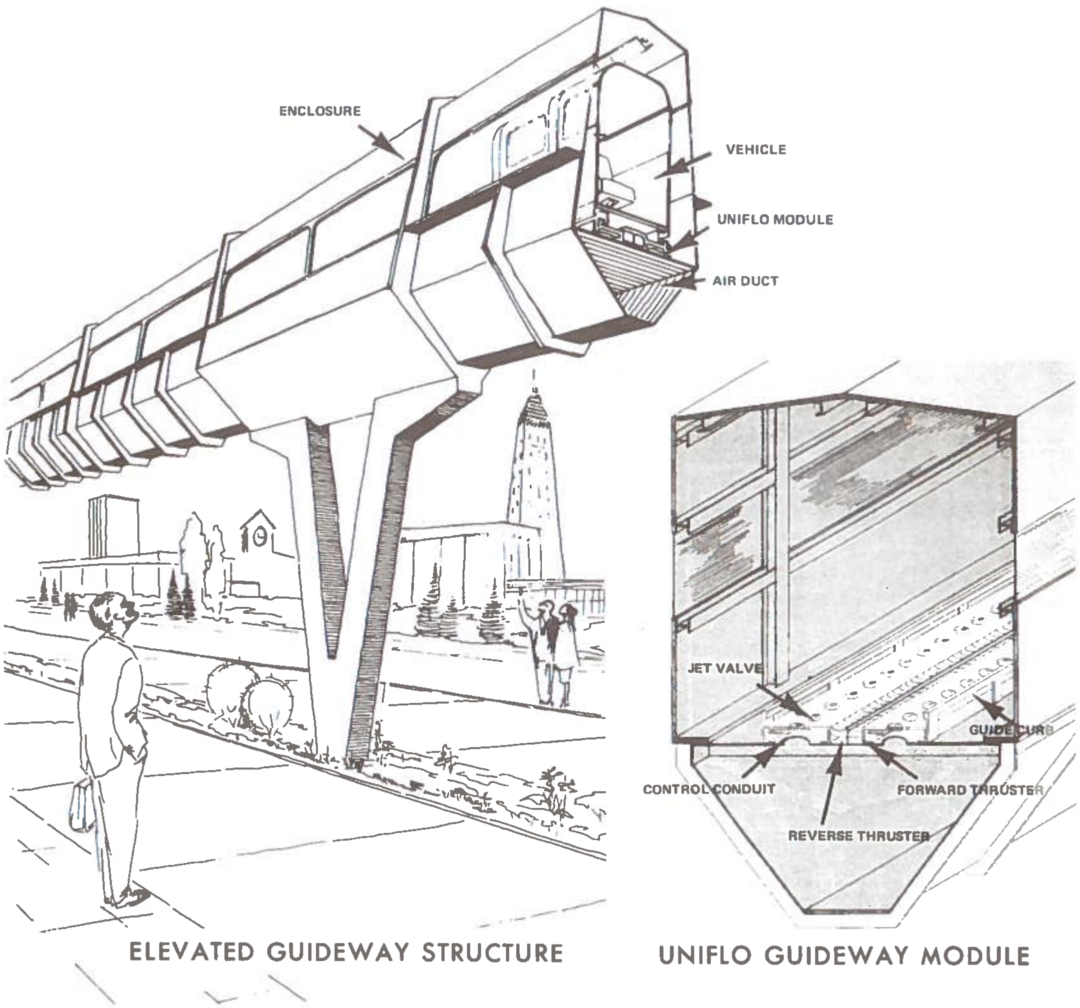


Figure A-29. Uniflo Guideway (Courtesy: Uniflo Systems Co., A Subsidiary of Rosemount Engineering Co.)

UNIFLO

Uniflo Systems Company
Minneapolis, Minnesota

Estimated System Cost Summary

Prices include installation, but do not include right-of-way acquisition. System conditions consist of a typical Central Business District Application (medium-to-high density), with two 4-berth stations per mile.

1. Guideway -

   Basic elevated, enclosed double guideway with 110' long spans........................$5,200,000/Mile

   Guideway Includes: Speed and spacing control, safety control, and switch control.

2. Station -

   4-berth capacity with 2,000 $ft.^2$ of building area............-.........................$430,000/Station

   Station Includes: Necessary acceleration and deceleration guideway, station berthing equipment with controls, and passenger flow control equipment.

3. Vehicles -

   8-passenger.................................$5,000/Vehicle

4. Supervisory Control -

   Added control to provide empty vehicle management, daily and weekly program variations, traffic demands of unusual events, and total system monitoring...........................$320,000/Mile

5. Blower Stations................................$90,000/Mile

6. Typical Maintenance Costs -

   Average annual cost..........................$126,000/Mile

7. Typical Operating Cost

   Average annual cost (excludes interest and depreciation)............................$110,000/Mile

8. Total System Capital Cost (exclusive of right-of-way)...........................$6,570,000/Mile

   Total System Includes: One mile of enclosed, double guideway, two passenger stations, twenty 8-passenger vehicles, one blower station, and one supervisory control.

January, 1972

APPENDIX A-15

THE UNIMOBIL II SYSTEM
BY UNIVERSAL MOBILITY INC.

Figure A-30. Photograph of Unimobil II Vehicles and Guideway
(Courtesy: Universal Mobility, Inc.)

APPENDIX A-16

THE URBA 30 SYSTEM
BY COMPAGNIE D'ENERGETIQUE LINEAIRE

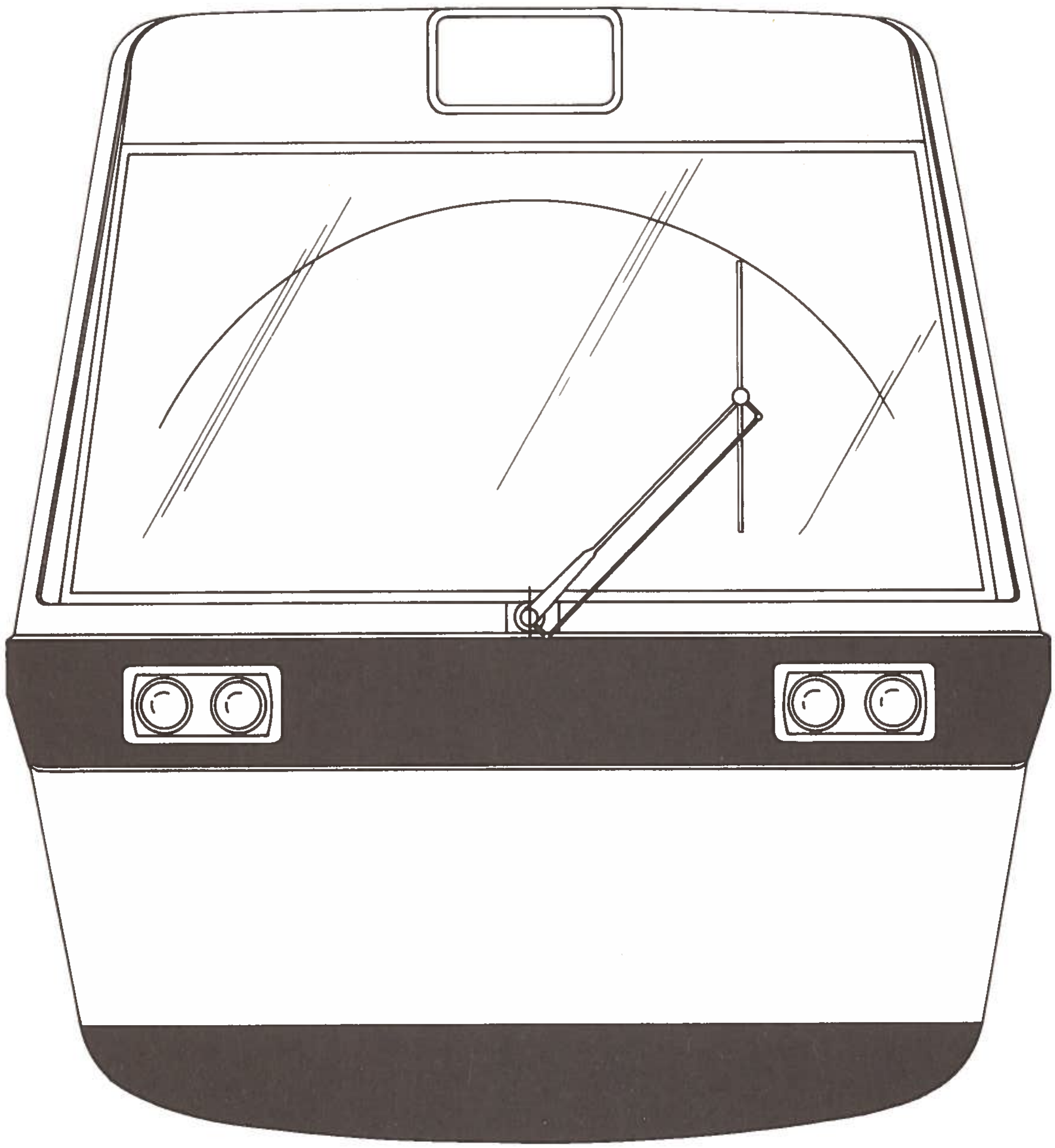


Figure A-31. Front View of URBA Vehicle (Courtesy: MGA Technology, Inc.)

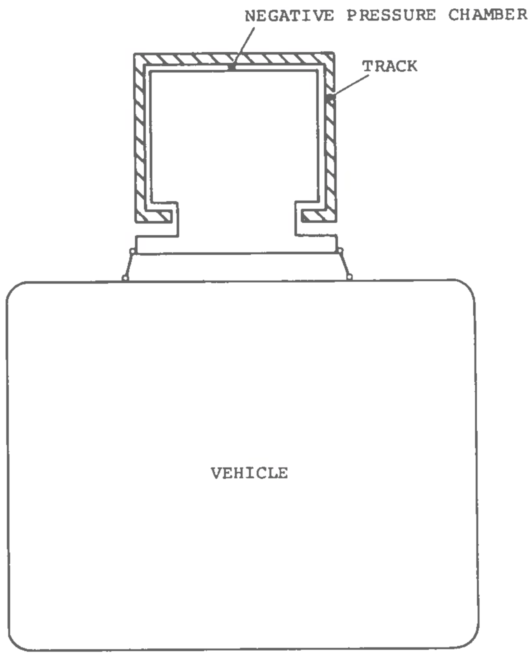
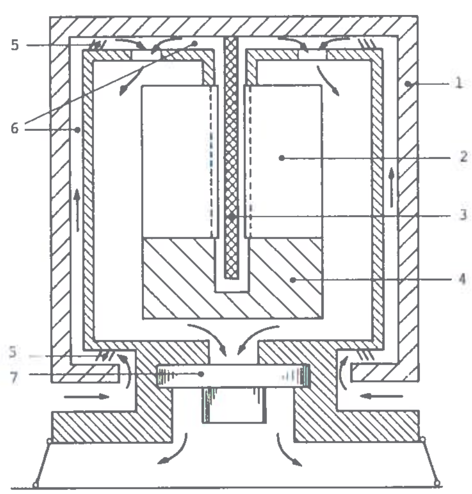


Figure A-32. Schematic of Vehicle and Track (Courtesy: MGA Technology, Inc.)



1. TRACK
2. PRIMARY OF THE LINEAR MOTOR
3. SECONDARY OF THE LINEAR MOTOR
4. LINEAR MOTOR CHASSIS
5. SEALING BAFFLES
6. NEGATIVE PRESSURE CHAMBER
7. THE FAN

Figure A-33. Detail of Suction Suspension Principle (Courtesy: MGA Technology, Inc.)

URBA

Companie d'Energetique Lineaire
Vanves, France

Material submitted by:

MGA Technology, Inc.
Chicago, Illinois

URBA Status
December 1971

COSTS

The figures presented are drawn from the plans and estimates for a double track, 7.5 km. installation authorized for Rouen.

Vehicle Elements	Francs,M*	$M	%Total
Cabin	100	20	32
Guideways & Suspension	19	4	6
Propulsion	51	10	16
Linear Electric Motor	96	19	32
Cables	10	2	3
Motor Aspirators	14	3	5
Elec. Equip.	18	4	6
	308M	62M	100

The basic structure per km. of double track can be seen from the following tables:

Element	Type Foundation	Suspended Pile	Double Post Piles	Double Post Footings	Central Post Piles	Central Post Footings
Concrete track	MMF/km.	1.33	1.125	1.125	1.125	1.125
Supports	MMF/km.	0.12	0.335	0.335	0.200	0.200
Foundations	MMF/kn.	0.70	1.855	0.540	1.060	0.305
Pylons	MMF/km.	0.32	-	-	-	-
Cables	MMF/km.	0.70	-	-	-	-
Total	MMF/km.	3.17	3.315	2.000	2.384	1.630

*M=thousand; MM=million throughout.

An overall view can be obtained from the estimates for Rouen's 7.5 km double track structure.

Designation	Cost, million francs	%Total
Track, including crossing the Seine; spans, supports and spurs	17.1	42
Electrical equipment and catenaries - lines	9.4	23
Control Signals	6.0	15
Electrical Equipment-ground	5.1	13
Shops & garage 2400 sq.	2.8	7
Total	40.4	100

Engineering studies and charges averaged some 11% and these added 10.4 million francs to the base structural cost. The additional cost of 62 URBA 30 x 2 vehicles is 24.8 million francs (400,000 francs or approximately $20,000 per car). This brings the total cost to:

Infrastructure	40,450	thousand	francs
Anticipated cost increases	750	"	"
Sub-total	41,200	"	"
Studies and estimates	9,570	"	"
Sub-total	50,770	"	"
124 URBA 30 vehicles	24,800	"	"

Total approximately 76 million francs

Comparatively this amounts to about 3.1 million dollars per mile.

Maintenance costs are expected to be of the following magnitude:

Stations	1% of capitalized value
Signals	2% of capitalized value
Structures	0.5% of capitalzied value
Spurs Tracks	2.0% of capitalized value

Vehicle maintenance cost estimates are based on the Rouen traffic studies. They have been estimated in terms of francs per vehicle kilometer per year, assuming 10 million km per vehicle (yearly)

Category	Unit Cost Francs/Vehicle km (Yr)
Routine inspection	0.0314
Cleaning	0.0376
Guideway Mechanical	0.0611
Cars-mechanical	0.0126
Electrical	0.0610

In Rouen electrical energy costs are about 0.1 franc per kwh. Consumption will be about 35 million kwh annually.

In summary the unsubsidized capital costs for amortization purposes at Rouen will be:

Structures	27 million francs
Equipment	13 million francs
Vehicles	25 million francs

The annual operating expenses will be:

Maintenance - Structures	0.28 million francs
- Vehicles	2.38
Electrical Energy	3.48
Conductors (drivers)	1.87
Supplies	0.80
	8.81 million francs

COMPARISON OF URBA AND DUO-RAIL COSTS ON THE BASIS OF THE MANCHESTER RAPID TRANSIT STUDY

Type of construction (unless otherwise stated)	Length in miles
Elevated	5.0
Cut-and-cover	5.7
Tunnel	1.6
Open cut	2.5
At ground level.	1.3
Total	16.1

£x1000	Duo-rail	URBA 30
Track and structure	21,320	10,280*
Services	1,100	1,100
Stations, yards and shops	9,010	7,850*
Power supply	590	810
Signals	1,890	1,900
Property	6,600	5,100
Rolling stock	2,000	2,300*
Contingencies (15%) and engineering (12%)	11,270	8,400*
Total	53,570	39,580

Notes:

1. All sums except those marked* are taken from the Manchester Rapid Transit Study.

2. The power supply costs used for URBA are those used for the highest of the four systems considered in the Manchester Study.

3. The Manchester Study estimated costs are one-fifth to one-tenth the cost of recently completed, or almost completed, duo-rail systems in London, Paris, Rotterdam, San Francisco and Mexico.

APPENDIX A-17

THE VEHICLE DISTRIBUTION SYSTEM
BY WESTINGHOUSE ELECTRIC CO.

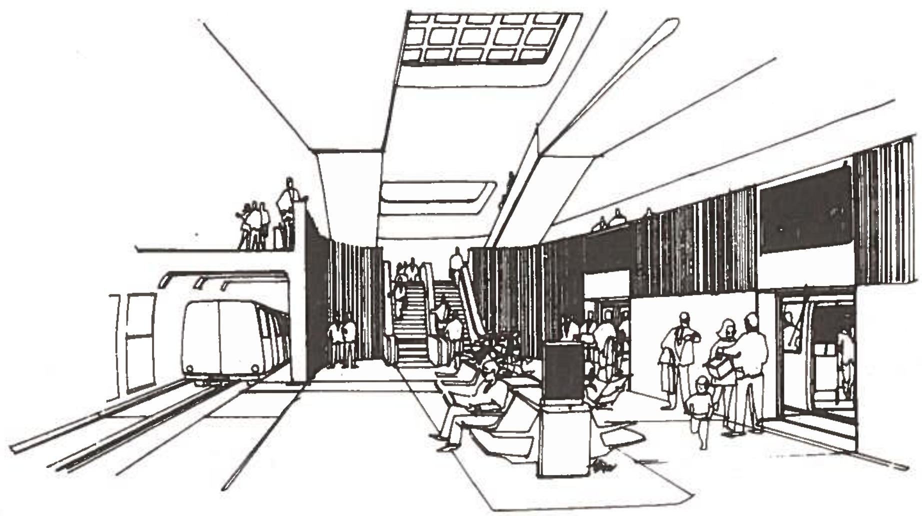


Figure A-34. Station (Courtesy: Westinghouse Electric Corp.)

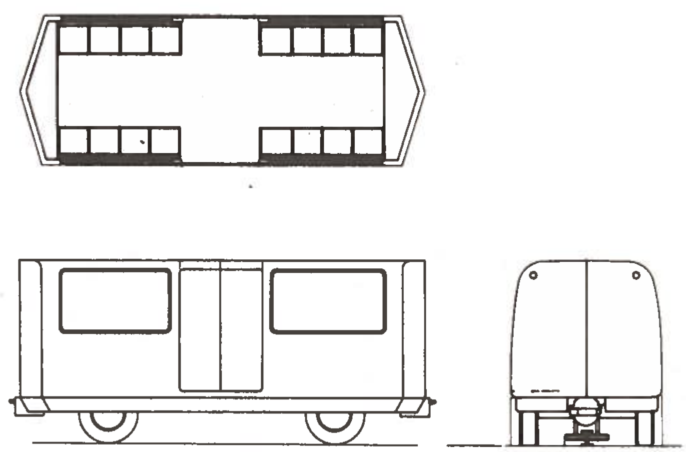


Figure A-35. Passenger Vehicle Outline (Courtesy: Westinghouse Electric Corp.)

VEHICLE DISTRIBUTION SYSTEM

Westinghouse Electric Corporation
Transportation Division
Pittsburg, Pennsylvania

Capital Costs

General

The capital costs presented in this section are based on a preliminary design study of the transportation system. The estimates are in terms of 1970 costs for labor and material.

The capital costs do not include the cost of the:

- civil guideway structure.
- stations.
- cargo terminal
- escalators, etc.
- direction indicators.

Preliminary Bill of Material

Guide beam (138270 ft.)	$ 7,770,000
Switch mechanism (199)	3,000,000
Maintenance equipment	266,000
Power distribution (138270 ft. contact rail; 4174 Kva substation capacity)	4,900,000
Automatic train control and voice and video communication	4,560,000
Vehicles (1970)	7,560,000
	$28,056,000

The cost estimate is for the application of a Westinghouse transit system to a regional airport. The system consists of passenger and cargo trains running on an exclusive right-of-way connecting the many elements of the airport. For complete flexibility, the guideway network will be double to provide two-way movement and will run at-grade, aerially and in tunnels. Guideway crossover and branching switches tie the network together.

Both passenger and cargo trains will be fully automatic and electrically powered with each vehicle supported by pneumatic rubber tired wheels.

The passenger vehicles operating singly or coupled into trains will stop at each station on fixed routes in providing comfortable, fast, frequent and efficient service. During off-peak periods, the system may be operated in an "on-call" manner.

Each 20 foot long air conditioned passenger vehicle will comfortably seat 16 passengers with room for 16 standees. The vehicles will reach a maximum speed of 30 mph.

The cargo trains, a powered tractor pulling up to five trailers, will operate over the same guideway as the passenger trains. In addition links will be provided to the U.S. Post Office, cargo city and the refuse disposal area. The cargo trains will haul mail, freight, refuse and interline transfer baggage. The trailers also 20 feet long will be able to carry the standard airplane containers, including a full sized 747 container, with provisions for mechanized handling and securing.

The passenger and cargo trains will be powered by a 480V, single phase a.c. contact rail system.

APPENDIX A-18

SERIES "M" VEHICLE & SERIES "P" VEHICLE
BY WESTINGHOUSE AIR BRAKE CO.

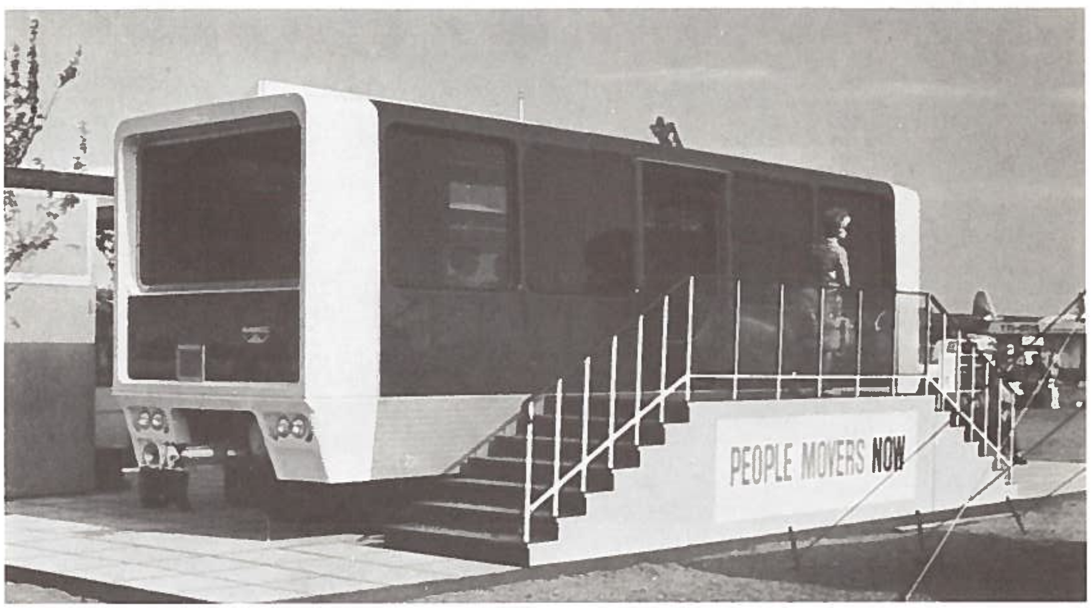


Figure A-36. Photograph of WABCO Series "M" Vehicle on Display at TRANSPO 72

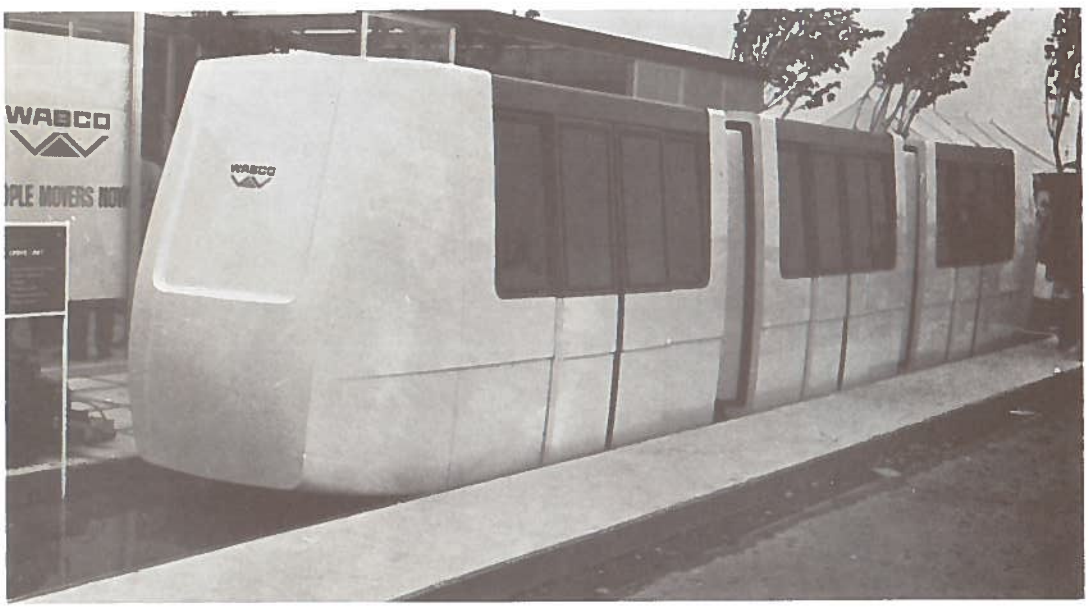


Figure A-37. Photograph of WABCO Series "P" Vehicles on Display at TRANSPO 72

WABCO ALL SERIES

WABCO
Westinghouse Air Brake Company
Monorail Division
Wildwood, New Jersey

The M/N line trains sell for $1,500 to $2,000 per passenger space, depending on performance and amenities, and this does not include the car-carried ATO* package.

Model P trains sell for $1,400 per rated passenger space not including car-carried ATO package. Guidebeam and contact rail can be furnished and installed for $175,000 per single track mile.

The M/N guide beam and contact rail sells for $300,000 per single track mile, exclusive of anchor bolts and installation but including contact rail.

Without installation, wayside signal and control apparatus sells for $100,000 per single track mile including modest but adequate central indication. Car-carried ATO is estimated at $15,000 per controlled unit.

Central Control, for a system requiring it, may be estimated at from $1/4 million up.

Power substations, cables, switchgear, etc. may be estimated at $60,000 per route mile.

*Automatic train operation

APPENDIX B

RAIL RAPID TRANSIT VEHICLE CHARACTERISTICS

TABLE B-1. RAIL RAPID TRANSIT VEHICLE CHARACTERISTICS

Rail Rapid Transit System	Size	Empty Weight	Passenger Capacity	Power	Normal Acceleration	Max. Speed	Max. Grade	Train Headway	Scheduled Line Capacity	Vehicle Cost
Bay Area Rapid Transit District (BARTD)	L = 75' W = 10'-6" H = 10'-6"	56,268 #	Seat = 72 Stand = 0 Stand (crush) = 72	624 Hp	3.2 fps^2	80 mph.	10%	177 sec.	46,080 pass. per hour with 10 car trains	$339,000
Port Authority Transit Corporation (PATCO) Lindenwold Line	L = 67'-6" W = 10'-0 H = 12'-4"	72,000 #	Seat = 72 Stand = 120 Stand (crush) = 220	500 Hp	4.4 fps^2	75 mph.	-	120 sec.	36,000 pass. per hour with 6 car trains	$191,000
Chicago Transit Authority (CTA)	L = 48'-3" W = 9'-4" H = 12'-0"	46,500 #	Seat = 47-51 Stand (crush) = 130	400 Hp	4.4 fps^2	55 mph.	10%	120 sec.	30,000 pass. per hour with 8 car trains	$126,000
New York City Transit Authority (NYCTA)	L = 75' W = 10'-10" H = 12'-2"	85,000 #	Seat = 84 Stand (crush) = 244	400 Hp	2.5 fps^2	50 mph.	6%	120 sec.	54,000 pass. per hour with 8 car trains	$210,000

APPENDIX C

GLOSSARY

Guideway - the surface or track, and the construction supporting it, on which vehicles run.

Headway - the time interval between successive vehicles, including vehicle length.

On-line station - a station in which the guideway on which vehicle stopping occurs is a part of the main line.

Off-line station - a station in which the guideway on which vehicle stopping occurs is not a part of the main line.

Line capacity - the hourly volume that could be carried if every vehicle operated at the minimum headway which the control system permits.

Vehicle capacity - the normal maximum number of passengers that the vehicle is designed to accommodate comfortably but which may be exceeded under crush loaded conditions.

On-demand service - the operation of a vehicle system in which a passenger entering a station summons a vehicle which transports him and his party non-stop to the destination station.

Scheduled service - the operation of a vehicle system in which a passenger entering a station boards any of the vehicles arriving at fixed intervals and travels to his destination station stopping at all intermediate stations and transfering to vehicles operating on different lines where necessary.

Activity center - a small geographic area with a large transient population and a high density of tripmaking (e.g., central business districts, airports, universities, shopping centers, sports arenas, and amusement parks.

Linear network - a single transit line or set of lines, basically straight, which form no particular pattern.

Radial network - a set of transit lines, basically straight, which evolve esentially uniformly around an activity center.

Loop network - a single closed transit line or set of lines, circular or oblong in form, with transfer stations at points of tangency between lines.