JACKSONVILLE DPM

TECHNICAL REPORT 4

DPM SYSTEM TECHNOLOGY

JACKSONVILLE DOWNTOWN PEOPLE MOVER
FEASIBILITY AND IMPACT STUDIES

PREPARED FOR
JACKSONVILLE TRANSPORTATION AUTHORITY
AUGUST 1978

PARSONS BRINCKERHOFF/FLOOD & ASSOCIATES
A JOINT VENTURE

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N.D. LEA & ASSOCIATES, INC.
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1.0 INTRODUCTION

In order to evaluate the characteristics and capabilities of automated guideway transit equipment which may become serious candidates for the Downtown People Mover system, N. D. Lea & Associates made numerous contacts with manufacturers as well as operators of existing systems or prospective operators of systems in the process of construction. This has been necessary because few of the manufacturers propose to use equipment identical to that which is currently in passenger service. A notable exception is the Westinghouse Electric Corporation which has standardized on its "Eagle I" family of vehicles and with minor modifications, proposes to offer these for use in the DPM cities. However, even Westinghouse is working on a new vehicle design in the mid-size range, but details of this design have not been disclosed by the company.

In addition to the American manufacturers who have demonstrated AGT hardware, there are at least four foreign systems which must be considered as DPM candidates. As discussed in this report, the Boeing Company has entered into discussions with Swiss, French and Japanese firms with a view to serving as system manager to ensure proper integration of the hardware with the site to be served. Depending upon individual requirements at DPM cities, Boeing is thus in a position to offer large, medium or small vehicles. In addition, the West German consortium DEMAG/MBB has indicated keen interest in the DPM program and may offer one or more of the vehicle systems which they have demonstrated at their test track in Hagen, West Germany.

Three American system suppliers, Vought Corporation, Universal Mobility, Inc., and CTS/Disney, plan to offer modified versions of their existing hardware. Vought has been funded by UMTA for an extensive urbanization program aimed at augmenting the capabilities of the present AIRTRANS equipment to better satisfy transportation requirements in cities. Disney is conducting ongoing development work on a larger version of the WEDway system currently in operation at Disney World in Florida, and UMI proposes to demonstrate an improved and larger version of their Tourister II at the new installation at the Minnesota Zoo.

In order to provide a comprehensive basis for evaluation of the broad range of AGT alternatives, which are likely to become serious candidates for the Jacksonville Downtown People Mover, N. D. Lea has assembled a considerable amount of data on these new AGT designs. Such information as was pertinent was compiled from reports of past and ongoing assessment programs. These basic data were supplemented by numerous conversations, meetings and correspondence with prospective system suppliers. Additionally, contacts were made with personnel of other consulting organizations currently working on AGT technology programs.

Table 1.1 is a summary of the characteristics and capabilities of the principal AGT systems which are candidates for the DPM Program. More detailed information on individual systems is presented under appropriate headings in the report.

Among the problems which must be resolved before a specific AGT system is selected for any DPM application, is the extent to which product improvements will be permitted above and beyond the capabilities of equipment which has already been demonstrated, either in passenger service or in connection with a comprehensive prototype testing program. Most of the manufacturers propose to augment demonstrated capabilities by offering higher speeds, ability to climb steeper grades, enhanced switching capabilities and increased passenger carrying capacity. To achieve certain of these improvements may require substantial modifications to some manufacturers' hardware.

The Downtown People Mover program had its origins in certain recommendations made by a task force organized by the Congressional Office of Technology Assessment to the Senate Appropriations Committee

TABLE 1.1 SUMMARY OF AGT SYSTEM CHARACTERISTICS

Manufacturer/ System	Vehicle Capacity	Train- ability	Line Capacity One-way (Pass/hour)	Maximum Cruise Speed (mph)	Gross Weight (lbs.)	Minimum Turn Radius (ft.)	Maximum Grade (%)
LARGE VEHICLES							
Westinghouse (Eagle 1)	84-92	4 cars	11,448 - 12,744	45 (d)	50,300	90	10
Boeing/VAL	75-83	4 cars	10-800 - 11,952	35 (n)	51,000	100	7
MEDIUM VEHICLES							
Vought (Urban Airtrans)	53-59	4 cars	10,680 - 11,760	30 (t)	23,200	70	10
Boeing/Kawasaki	52-56	4 cars	12,240 - 13,440	44 (m)	38,622	82	10
Boeing/Habegger II		8 cars	8,160 - 9,120	20 (n)	31,500	66	10
Univ. Mobility (DPM)	38-42	4 cars	9,120 - 10,080	20 (n)	22,700	50	10
Otis (DPM)	39-43	2 cars	2,400 - 2,640	30 (m)	N/A	60	10
SMALL VEHICLES							
Otis (Duke)	20-22	2 cars	1,200 - 1,320	30 (m)	15,470	60	10
Boeing Morgantown	23-25	1 car	1,380 - 1,500	30 (d)	14,900	30	10
DEMAG/MBB (MK 18S)	20-22	2 cars	1,200 - 1,320	22 (m)	11,422	100	5
CTS/Disney DPM (5-car train)	45-50	1	540 - 600	30 (m)	22,000	20	5

(m) Manufacturer's claim
(t) Demonstrated on test track
(d) Demonstrated in passenger service
(n) N. D. Lea judgment

in 1975. As a result of OTA's report, Automated Guideway Transit, An Assessment of PRT and Other New Systems, and testimony by members of the AGT assessment team to the Senate appropriations Sub-Committee on Transportation, UMTA embarked on a program to deploy one or more of the proven shuttle-loop transit systems in an urban application. The then UMTA Administrator, Robert E. Patricelli, decided to call this program the Downtown People Mover Program in the belief that such a name would be readily understood by a broad segment of those interested and affected. Generally, the program which has been implemented today adheres quite closely to the original Congressional mandate.

The shuttle-loop transit classification, as originally envisaged by the OTA assessment team, includes in addition to simple shuttles and loops, as simplified by the Tampa and SEA-TAC systems, pinched loops which involve operational switching, such as was demonstrated at Transpo 72 by Bendix-Dashaveyor. The Atlanta Airport System, which is currently under construction, involves this type of arrangement.

The line of demarcation between Shuttle-Loop Transit (SLT) and Group Rapid Transit (GRT), as defined by OTA, is not entirely sharp or precise, and some overlap between these classes is to be expected. One major feature which distinguishes the GRT class from the simpler SLT is branching and merging. Systems which employ off-line stations, such as AIRTRANS and Morgantown, involve vehicles departing from stations to merge into the stream of traffic moving along the main line. Similarly, systems involving branching onto alternative routes involve a significantly higher level of control sophistication. Such capabilities were not originally contemplated for the DPM program, nor is N. D. Lea aware of any disposition on the part of UMTA to include such capabilities at this time.

2.0 REPRESENTATIVE AGT SYSTEMS CURRENTLY IN REVENUE SERVICE

2.1 AIRTRANS SYSTEM (Vought)

The AIRTRANS system at the Dallas/Forth Worth Regional Airport is a fully automated AGT system providing ground transportation for passengers, personnel, baggage, mail, supplies, and refuse between four airline terminals, one hotel, two remote parking facilities, and a maintenance facility.

A single lane network serves a total of 53 stations over 67,697 ft. of guideway. Service is provided on a fixed schedule by 13 overlapping routes - 5 passenger routes for 14 passenger stations, 4 employee routes for 14 employee stations, 2 trash and 2 supply routes for 25 utility stations. Routes are unidirectional loops through the guideway network.

Passenger stations are equipped with coordinated doors on two loading and unloading berths to accommodate two-car trains. Passenger admission is controlled by turnstiles operated by coin insertion. Directions in stations are given by active graphics, in vehicles by public address system. Guideways are all concrete structures, 80 percent at-grade, and 20 percent elevated. All utility stations and most of the passenger and employee stations are off-line, only 8 stations are on-line.

The vehicle fleet consists of 51 passenger vehicles and 17 utility vehicles.

TABLE 2.1.1 VEHICLE DESCRIPTION

Operating Configuration	Single Unit or 2-car train
Uni- or Bidirectional	Unidirectional
Vehicle Capacity	16 seated, 24 standing
Length, overall	21.0 ft.
Width, overall	7.0 ft.
Height, overall	10.0 ft.
Empty Weight	14,000 lbs.
Gross Weight*	21,940 lbs.
Door Width	54 inches
Door Height	76 inches
Number of Doors	1
Number of Propulsion Motors	1 per vehicle
Type of Motor	60 hp compound-wound DC

---

*Lea Transit Compendium.

TABLE 2.1.2 SYSTEM OPERATIONAL CHARACTERISTICS

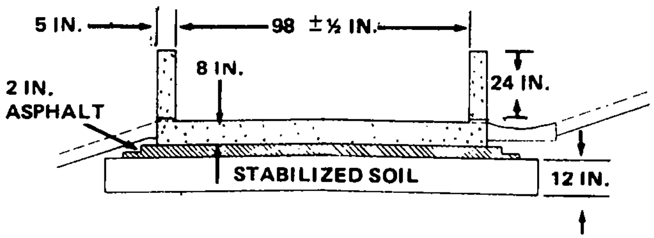
Single Direction Line Capacity	10,667 psgr/hr*
Boarding/Deboarding Capacity of Station	4,000 psgr/hr
Maximum Waiting Time	2 min.
In-Station Dwell Time	18 sec.
Minimum Headway	18 sec.
Maximum Velocity	19 mph
Cruise Velocity	17 mph
Estimated Average Speed	10 mph
Operating Modes	fixed route-fixed schedule
Service Acceleration/Deceleration	0.12 g
Maximum Jerk	0.08 g/sec.
Emergency Deceleration, Full vehicle	0.22 g
Stopping Precision in Stations	± 12 inches
Number of Switches, diverges and converges	71
Maximum Grade	7.8%
Minimum Turning Radius	150 ft.

---

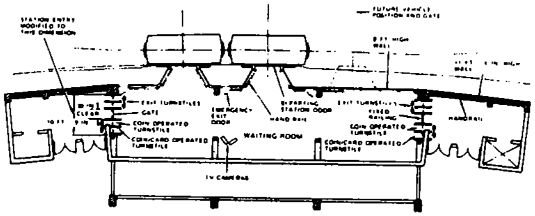
*The line capacity is determined by using the minimum headway, the capacity and an adjustment factor to allow for merging vehicles. It is calculated on a per hour basis.

$$\text{Line Capacity} = \frac{(3600 \text{ sec/hr}) \times (80 \text{ psgr/train})}{18 \text{ sec headway}} \times (2/3)$$

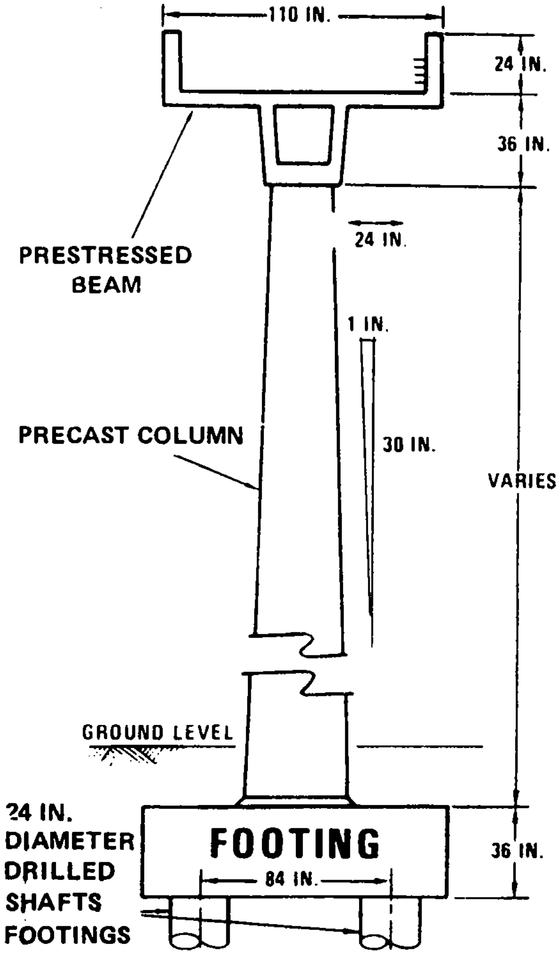
NOTE: Every third slot of the 18 second headway has to be employed to allow merging of vehicles from off-line stations.



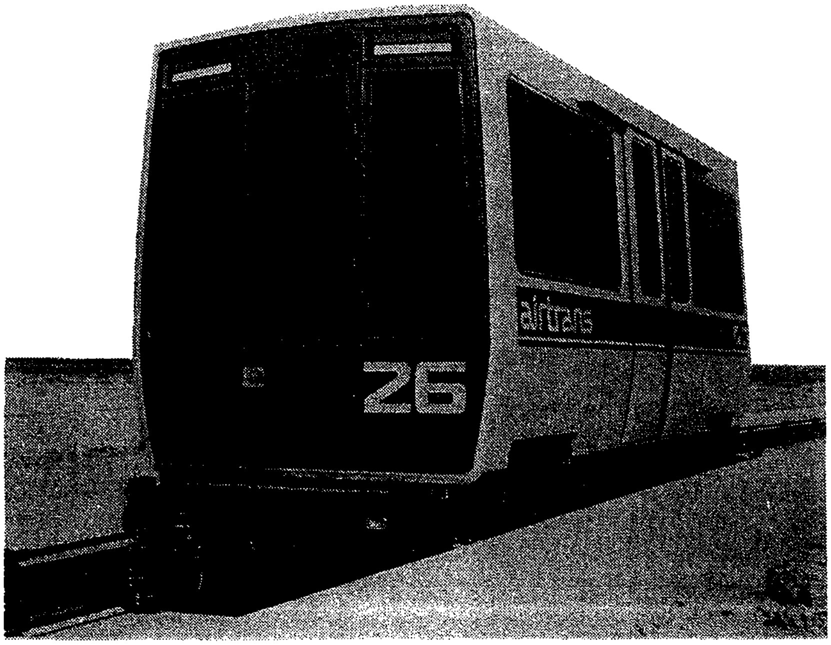
AT-GRADE GUIDEWAY CROSS SECTION



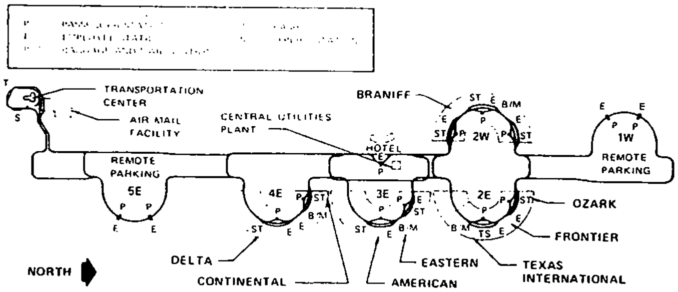
STATION LAYOUT



ELEVATED GUIDEWAY CROSS SECTION



AIRTRANS PRODUCTION VEHICLE



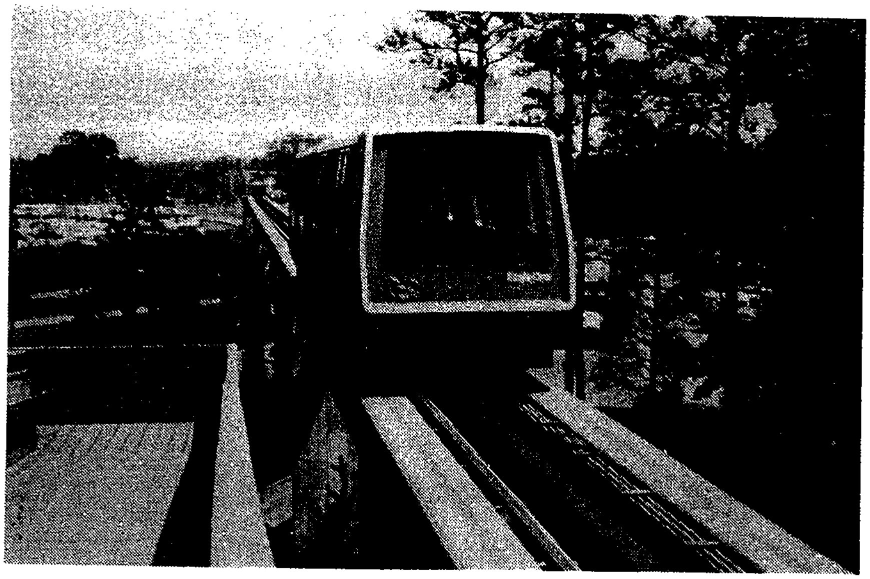
GUIDEWAY CONFIGURATION OF DALLAS-FORT WORTH AIRPORT

2.2 BUSCH GARDENS SYSTEM (Westinghouse)

The system at Busch Gardens, near Williamsburg, Virginia, transports visitors between the theme park and the brewery hospitality house. A single-lane closed loop connects the two stations. The park station is open to the environment and is a simple wood-steel structure. The hospitality center station is incorporated into the building. Since the building is air conditioned, guideway entrances are sealed by air curtains. No coordinated doors are used.

The guideway is of concrete-steel construction. Vehicle steering is accomplished through a center mounted I-shaped steel beam. Of the 7,011 ft. guideway loop, 4,141 ft. are at-grade and 2,870 ft. are elevated.

A two-vehicle train operates fully automated on a fixed schedule during the operating season of the park from April through October with fully automated control. The system can accommodate two more two-car trains without modifications.



BUSCH GARDENS SYSTEM

TABLE 2.2.1 VEHICLE DESCRIPTION

Operating Configuration	Single unit or 2-car train
Uni- or Bidirectional	Bidirectional
Vehicle Capacity	8 seated, 92 standing*
Length, overall	36.33 ft.
Width, overall	9.33 ft.
Height, overall	11.00 ft.
Empty Weight	26,500 lbs.
Gross Weight**	46,800 lbs.
Door Width	7.00 ft.
Door Height	6.67 ft.
Number of Doors	4 - two on each side
Number of Propulsion Motors	2 per vehicle
Type of Motor	100 hp series-wound DC

---

*Owner limits capacity to 8 seated and 82 standing passengers per vehicle.

**N.D.Lea estimate, based on crush capacity of 8 seated passengers at 4.5 ft^2 seating area per passenger and 119 standing passengers at 1.8 ft^2 per passenger, at 160 lbs. per passenger.

TABLE 2.2.2 SYSTEM OPERATIONAL CHARACTERISTICS

System Capacity	7,200 psgr/hr*
One Train Operational Capacity	2,000 psgr/hr**
In-Station Dwell Time	35 sec.
Minimum Headway	100 sec.
Operational Headway	6 min.***
Maximum Velocity	30 mph
Cruise Velocity	30 mph
Estimated Average Speed	17 mph
Operating Modes	fixed schedule, not rigid
Service Acceleration/Deceleration	0.11 g
Maximum Jerk	0.10 g/sec.
Emergency Deceleration, full vehicle	0.23 g
Stopping Precision in Stations	± 12 inches
Number of Switches	none
Maximum Grade	10%
Minimum Turning Radius	150 ft.

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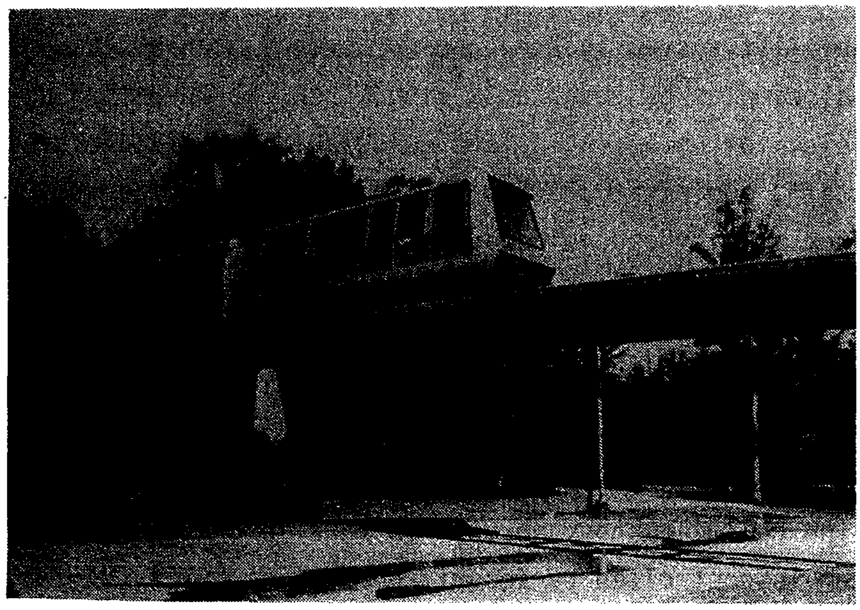
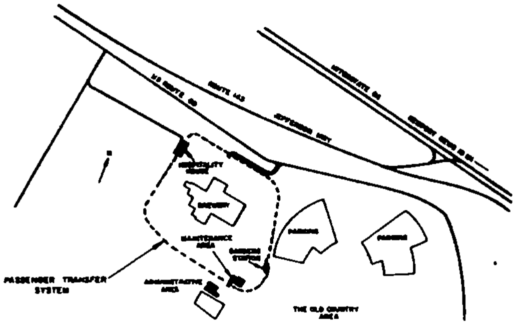
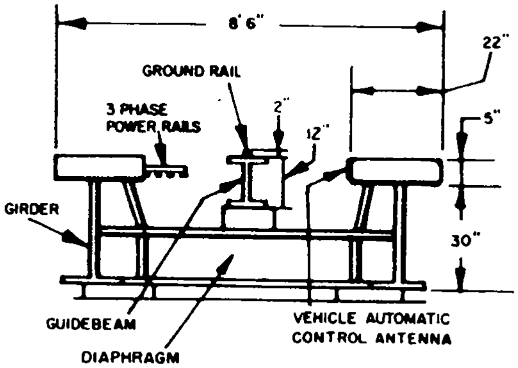
* Based on minimum headway and a capacity of 100 psgr/car.
** Based on operational headway and a capacity of 100 psgr/car.
*** Based on present operation with one two-car train.



BUSCH GARDENS TRAIN



SYSTEM LAYOUT

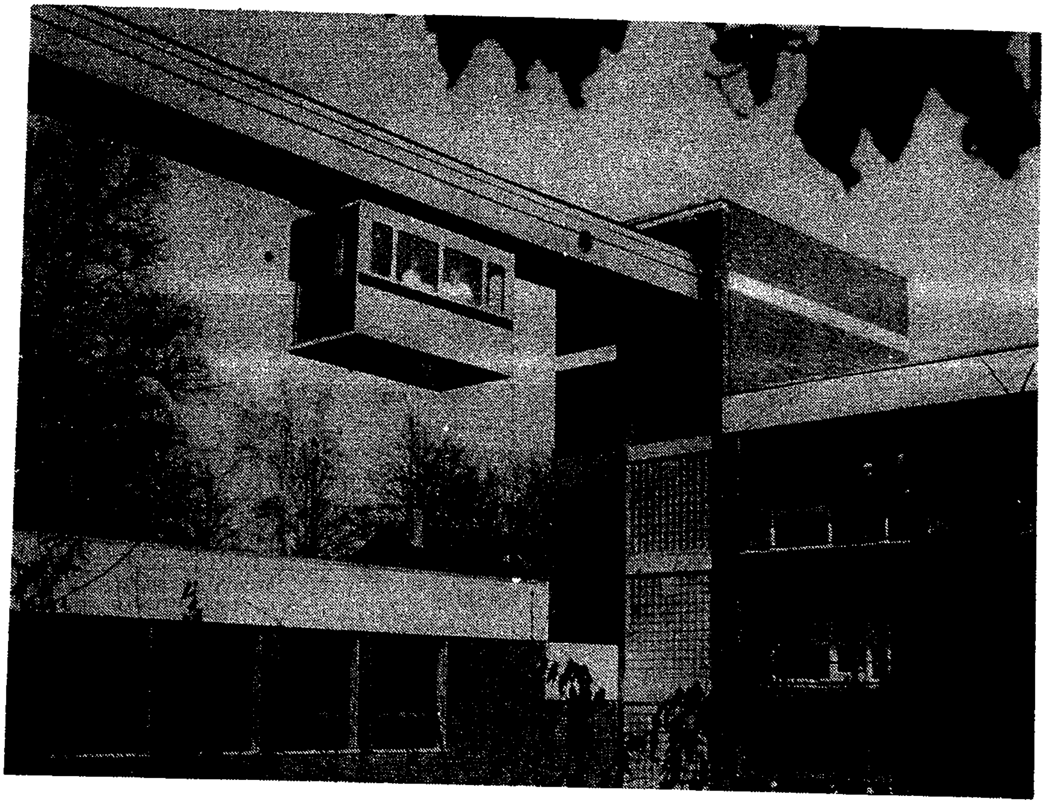


TYPICAL GUIDEWAY CROSS-SECTION

2.3 CABINLIFT (Demag/MBB)

The Cabinlift system in Ziegenhain, Germany, connects two buildings of a hospital complex by means of a single vehicle operating as a horizontal elevator on a single-lane guideway. The shuttle transports patients, staff, equipment and food fully automated. The vehicle is suspended from an overhead guideway which also carries utility lines. The distance between the two stations is 1,897 feet.

The system operates on demand. Departure is initiated by the passenger. Access to the vehicle is through doors at each end of the cabin. The guideway is of concrete construction. Stations are incorporated in the buildings they serve. No fare is charged, but the use of the system is controlled by security cards.



ZIEGENHAIN SYSTEM

TABLE 2.3.1 VEHICLE DESCRIPTION

Operating Configuration	Single unit
Uni- or Bidirectional	Bidirectional
Vehicle Capacity	3 seated, 9 standing
Length, overall	12.4 ft.
Width, overall	6.4 ft.
Height, overall	7.7 ft.
Empty Weight	4,850 lbs.
Gross Weight*	7,040 lbs.
Door Width	46.1 inches
Door Height	78.7 inches
Number of Doors	2 - one on each end
Number of Motors	2 per vehicle
Type of Motor	Linear induction motor

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*TSC-SNV, Development/Deployment Investigation of Cabintaxi/Cabinlift System, Report No. UMTA-MA-06-0067-77-02, December 1977.

TABLE 2.3.2 SYSTEM OPERATIONAL CHARACTERISTICS

Single Direction Line Capacity	90 psgr/hr*
Maximum Waiting Time	7.3 min.
In-Station Dwell Time	On demand only
Operational Headway, average	7.3 min.
Maximum Velocity	13.5 mph
Cruise Velocity	13.5 mph
Estimated Average Speed	7.2 mph
Operating Modes	demand
Service Acceleration/Deceleration	0.031 g
Maximum Jerk	0.034 g/sec.
Emergency Deceleration, Full vehicle	0.1 g
Stopping Precision in Stations	± 0.4 inches
Number of Switches	none
Maximum Grade	3.4%
Minimum Turning Radius	130 ft.

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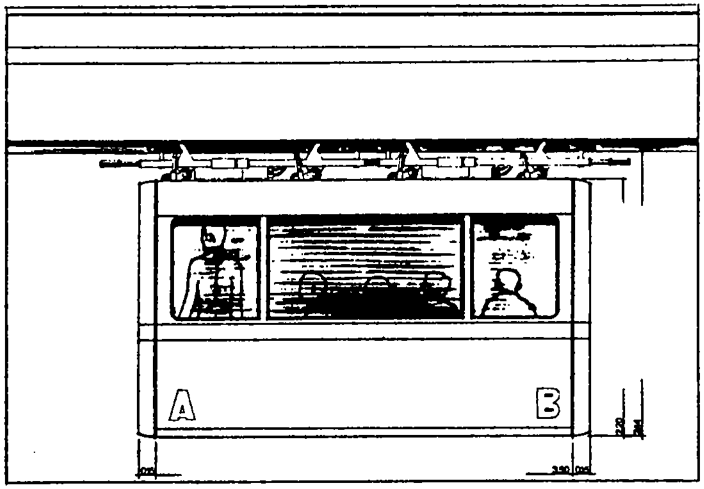
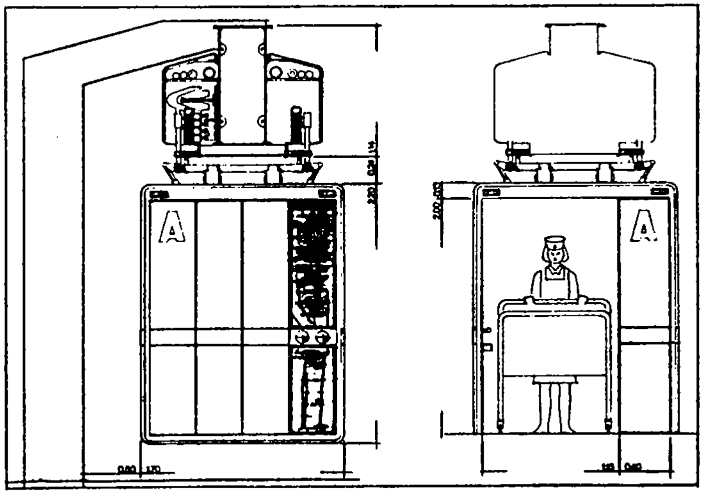
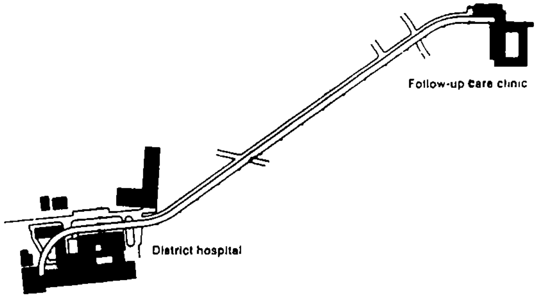
*Based on average operational headway since system operates on demand.



SKETCH OF VEHICLE



VEHICLE CROSS-SECTION



SYSTEM LAYOUT

2.4 KING'S DOMINION SYSTEM (UMI)

The Tourister AGT system at King's Dominion, near Richmond, Virginia, transports park visitors through the park and the wild animal enclosure "Lion Country."

The single loop guideway is 10,900 ft. long. With the exception of 550 ft. which is elevated, it is built at-grade. The primary structural material is limited-rust steel.

The vehicle fleet consists of six trains. Each train has a lead vehicle and eight passenger vehicles, permanently coupled, to make up the traveling unit.

Trains are dispatched by the station attendant at predetermined intervals. Train attendants explain and point out highlights during the trip, assure that the train does not collide with animals, and activate doors. Train operation is fully automated.

There is only one station in the system where passengers board and disembark; it can accommodate one train. No coordinated doors are employed. Fair collection is joined with park admission fee collection.

TABLE 2.4.1 VEHICLE DESCRIPTION

Operating Configuration	1 lead car and 8 passenger cars permanently coupled
Uni- or Bidirectional	Unidirectional in automatic mode Bidirectional in manual mode
Car Capacity	12 seated
Train Capacity	96 seated
Length, overall train	127.0 ft.
Length, passenger car	12.2 ft.
Width, overall	6.0 ft.
Height, overall	7.4 ft.
Empty Weight, passenger car	1,900 lbs.
Empty Weight, 8-car train, approximately	18,700 lbs.
Gross Weight, 8-car train, approximately*	34,220 lbs.
Door Width	19 inches
Door Height	72 inches
Number of Doors, per car	4 - two on each side
Number of Motors	8 per train
Type of Motor	7.5 hp series-wound DC

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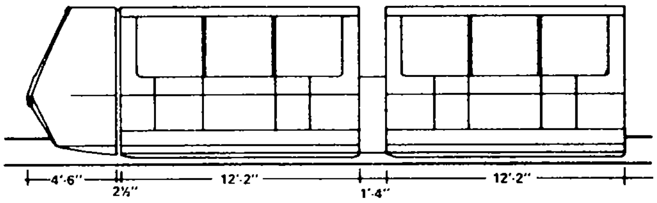
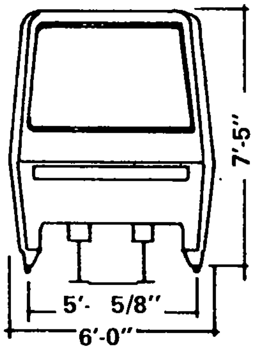
*N. D. Lea estimate, based on 3.820 lbs. gross weight per passenger vehicle plus 3,660 lbs. for lead car.

TABLE 2.4.2 SYSTEM OPERATIONAL CHARACTERISTICS

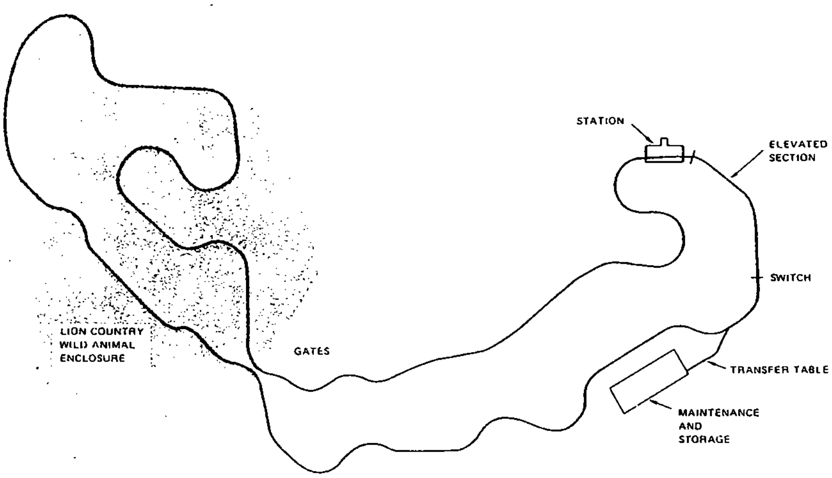
Single Direction Line Capacity	1,730 psgr/hr
Maximum Waiting Time	4.0 min.
In-Station Dwell Time, average	3.0 min.
Operational Headway	3.3 min.
Maximum Velocity	18.0 mph
Cruise Velocity	6.5 mph
Estimated Average Speed	6.2 mph
Operating Modes	Fixed schedule, not rigid
Service Acceleration/Deceleration	0.09 g
Maximum Jerk	0.09 g/sec.
Emergency Deceleration, full train	0.20 g
Stopping Precision in Station	± 3 inches
Number of Operational Switches	none
Maximum Grade	+6%, -8%
Minimum Turning Radius	100 ft.



VEHICLE SIDE VIEW



VEHICLE END VIEW



GUIDEWAY LAYOUT AT KING'S DOMINION

2.5 MORGANTOWN SYSTEM (Boeing)

The Morgantown system in its initial Phase I configuration connects the Main Campus of West Virginia University with the Evansdale Campus and the Central Business District. The three stations are connected by a double-lane guideway totaling somewhat over two miles in length. The system provides fully automated, non-stop service between origin and destination in a scheduled or demand mode.

Stations are equipped with platforms designated for different destinations. Each platform has one loading berth and three unloading berths. Coordinated doors are not employed. Fare collection and passenger flow is controlled by turnstiles.

Guideways are of steel-concrete construction and are equipped with running surface heating systems for winter operation.

Unidirectional vehicles are designed for single car operation and cannot be trained. The Phase I fleet consists of 45 vehicles.

A major expansion of the system (Phase II) has recently been completed which adds two additional stations at the Towers Dormitory Complex and the Medical Center as well as 28 vehicles. Improvements to the existing system have also been implemented.

The end stations in the system are on-line stations, while the others are off-line stations with through traffic provisions.

TABLE 2.5.1 VEHICLE DESCRIPTION

Operating Configuration	Single unit
Uni- or Bidirectional	Unidirectional
Vehicle Capacity	8 seated, 13 standing
Length, overall	15.5 ft.
Width, overall	6.7 ft.
Height, overall	8.8 ft.
Empty Weight	8,600 lbs.
Gross Weight*	11,800 lbs.
Door Width	38 inches
Door Height	73 inches
Number of Doors	2 - one on each side
Number of Motors	1 per vehicle
Type of Motor	70 hp compound-wound DC

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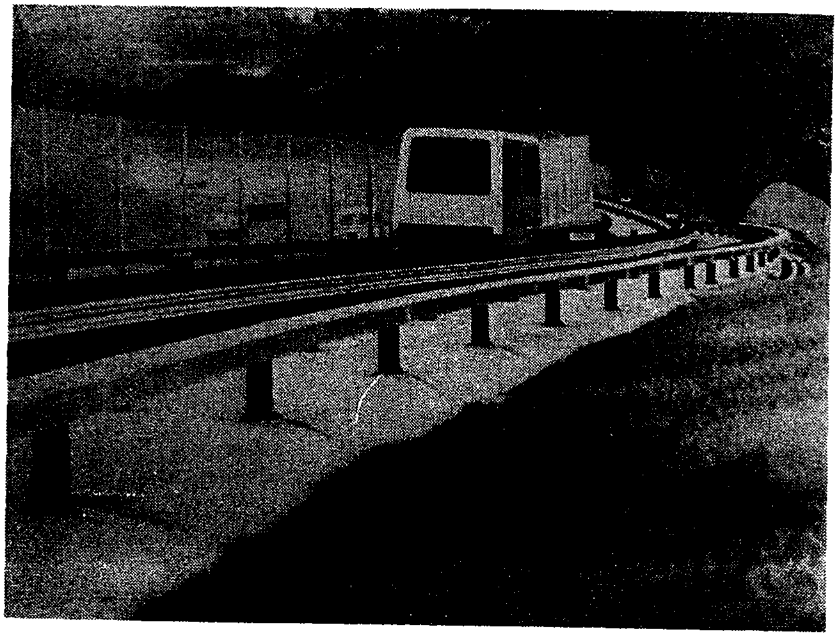
*Manufacturer's quote in Central Control Operators Manual.

TABLE 2.5.2 SYSTEM OPERATIONAL CHARACTERISTICS

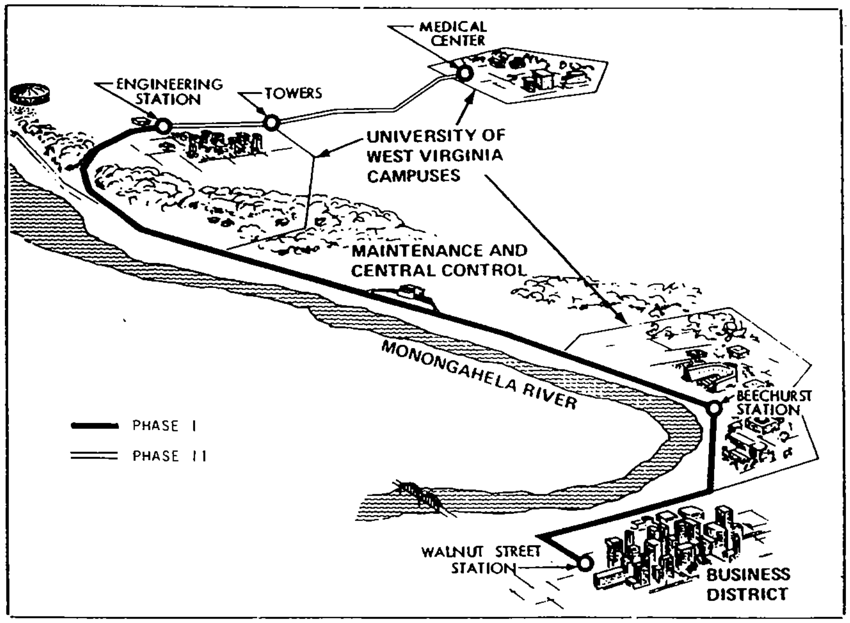
Single Direction Line Capacity	3,360 psgr/hr*
Maximum Waiting Time	5.0 min.
In-Station Dwell Time	2.9 min.
Minimum Headway	15 sec.
Maximum Velocity	30 mph
Cruise Velocity	30 mph
Estimated Average Speed	16.5 mph
Operating Modes	Scheduled and demand
Service Acceleration/Deceleration	0.0625 g
Maximum Jerk	0.3 g/sec.
Emergency Deceleration, full vehicle	0.35 g to 0.50 g
Stopping Precision in Stations	± 3 inches
Number of Switches, converges & diverges	27
Maximum Grade	10%
Minimum Turning Radius	30 ft.

$$\text{*Line Capacity} = (3600\ \text{sec/hr}) \times \frac{(21\ \text{psgr/veh.})}{(15\ \text{sec headway})} \times (2/3)$$

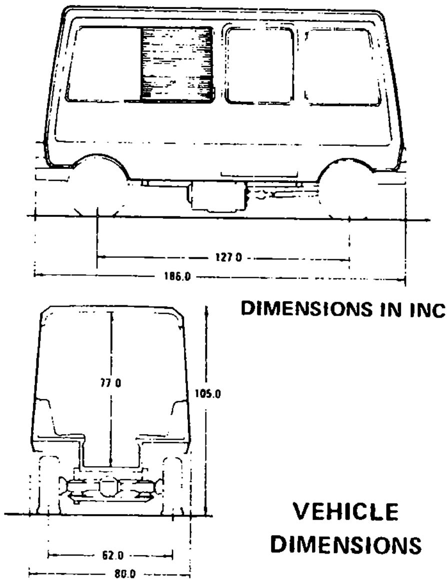
NOTE: Every third 15 sec. headway slot has to be empty to allow for merging vehicles from off-line stations.



MORGANTOWN VEHICLE

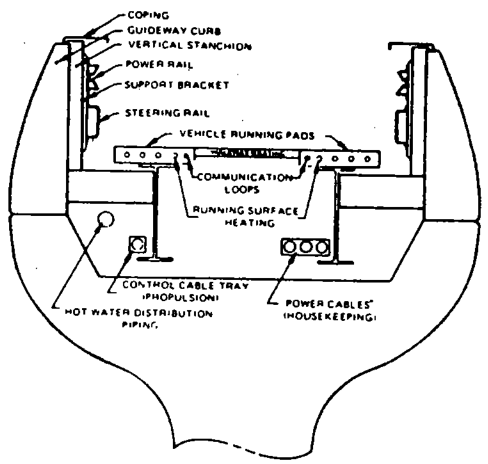


SYSTEM LAYOUT



DIMENSIONS IN INCHES

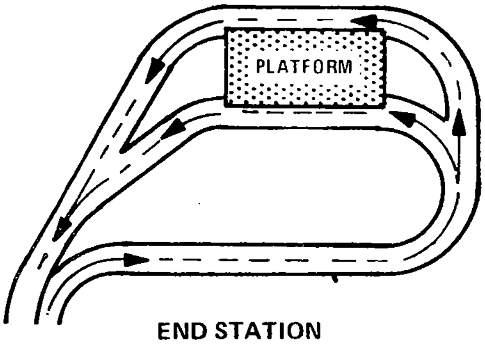
VEHICLE DIMENSIONS



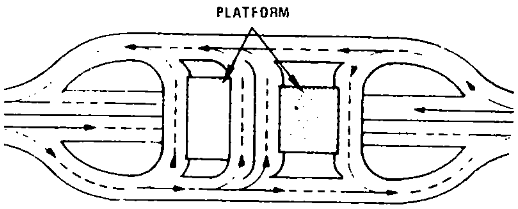
NOTE

THE CROSS SECTION SHOWN IS AT A TRANSITION POINT WHERE DUPLICATE POWER AND STEERING RAILS ARE PROVIDED (MERGE AND EMERGE POINTS)

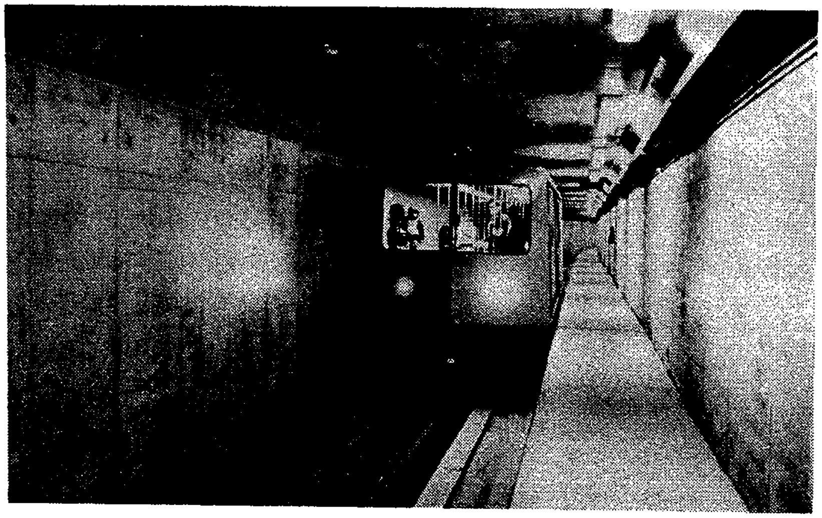
GUIDEWAY CROSS-SECTION



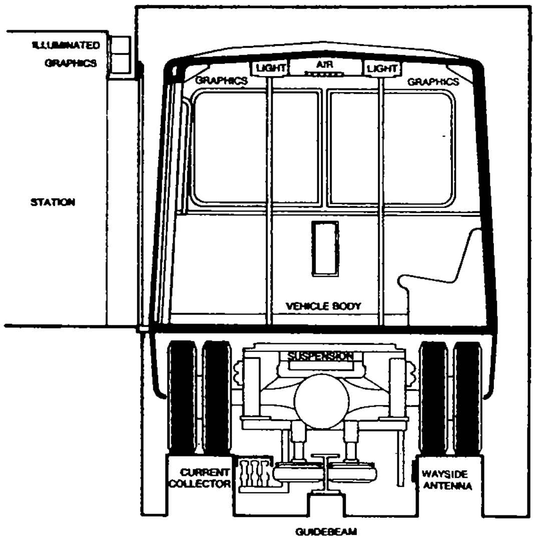
END STATION



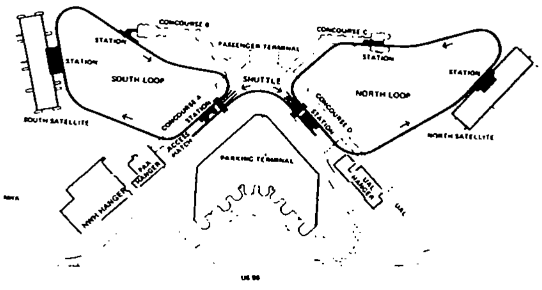
THROUGH STATION



SEATTLE-TACOMA VEHICLE IN TUNNEL



SEA-TAC VEHICLE, GUIDEWAY, & STATION CROSS SECTION (others similar)



SEA-TAC SYSTEM

2.6 SEATTLE-TACOMA INTERNATIONAL AIRPORT SYSTEM (Westinghouse)

The Satellite Transit System at the Seattle-Tacoma Airport is a fully automated shuttle and loop system transferring passengers within the airport area. The system connects the satellite terminals to the main terminal by means of an underground single-lane guideway system. Each of the two loops connects a finger pier and a satellite terminal to a main terminal station. The shuttle services the two main terminal stations.

Stations are integral parts of terminal buildings and can accommodate a two-car train. They are equipped with coordinated doors. No fare collection system is employed; system use is free.

Present fleet size consists of 12 vehicles operated as two-car trains or single vehicles. Vehicles are equipped with automated couplers and have bidirectional capability.

Total underground guideways are 9,007 ft. (4,089 ft for North Loop; 3,718 ft for South Loop; and 1,200 ft. for shuttle), and are equipped with adjacent emergency walkways. Running pads are reinforced concrete construction, the center-mounted guidebeam is a steel I-beam. Tunnels are of poured concrete construction.

TABLE 2.6.1 VEHICLE DESCRIPTION

Operating Configuration	Single unit or 2-car train
Uni- or Bidirectional	Bidirectional
Vehicle Capacity	12 seated, 90 standing
Length, overall	37.0 ft.
Width, overall	9.3 ft.
Height, overall	11.0 ft.
Empty Weight	25,000 lbs.
Gross Weight*	46,700 lbs.
Door Width	8.0 ft.
Door Height	6.7 ft.
Number of Doors	2 - on one side
Number of Motors	1 per vehicle
Type of Motor	100 hp series-wound DC

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*SRI, Assessment of the Satellite Transit System (STS) at the Seattle-Tacoma International Airport, Report No. UMTA-IT-06-0135-77-1, December 1977.

TABLE 2.6.2 SYSTEM OPERATIONAL CHARACTERISTICS

Single Direction Line Capacity	2,350 psgr/hr shuttle 7,650 psgr/hr loop*
Maximum Waiting Time	3.0 min.
In-Station Dwell Time	45.0 sec.
Minimum Headway	105.0 sec.
Operational Headway	2.6 min. shuttle 1.6 min. loop
Maximum Velocity	26.0 mph
Cruise Velocity	26.0 mph
Estimated Average Speed	10.1 mph
Operating Modes	Scheduled and demand
Service Acceleration/Deceleration	0.11 g
Maximum Jerk	0.07 g/sec.
Emergency Deceleration, full vehicle	0.12 g
Stopping Precision in Station	± 12 inches
Maximum Grade	4.3%
Minimum Turning Radius	96 ft.

---

*The system loops operate with two-vehicle trains.

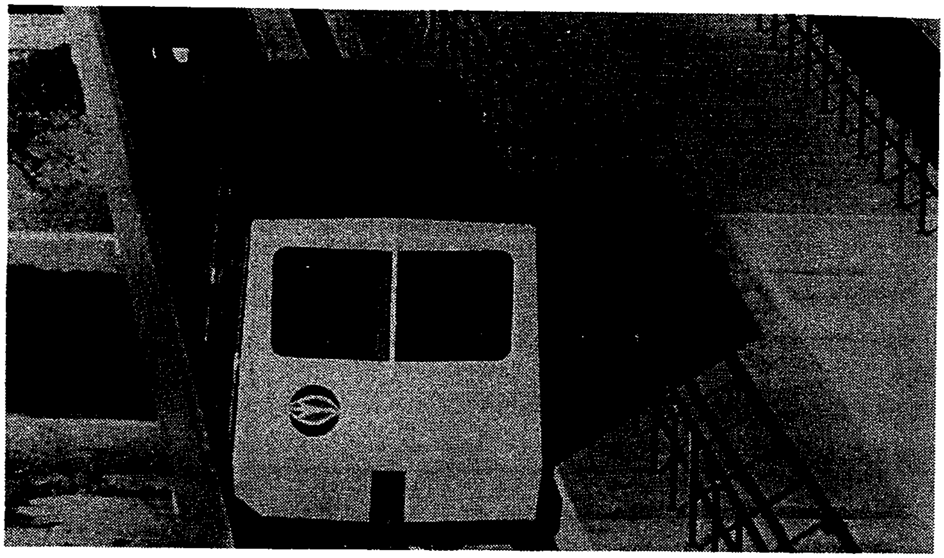
2.7 TAMPA INTERNATIONAL AIRPORT SYSTEM (Westinghouse)

The Tampa Airport system provides shuttle service between four remote "airside" terminals and the main terminal over elevated double-lane guideways. Single vehicles, one to each guideway lane, transfer passengers fully automated between main and airside terminals. The two lanes serving the same building operate synchronously.

The radial double-guideways vary in length from 779 ft. to 1,002 ft. They are constructed of structural steel with cast-on concrete running surfaces. A concrete walkway between the lanes provides emergency egress.

Stations are incorporated in the building structures. Platforms are equipped with coordinated doors. No fare collection system is employed; system use is free.

Vehicles operate fully automated in elevator-like fashion on demand. Total fleet size is eight vehicles, one per guideway lane, two per building to building link.



TAMPA VEHICLE

TABLE 2.7.1 VEHICLE DESCRIPTION

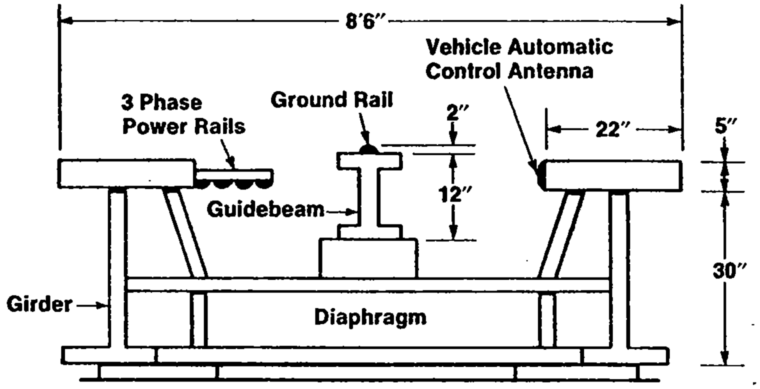
Operating Configuration	Single Unit
Uni- or Bidirectional	Bidirectional
Vehicle Capacity	100 standing
Length, overall	36.3 ft.
Width, overall	9.3 ft.
Height, overall	11.0 ft.
Empty Weight	21,500 lbs.
Gross Weight*	42,400 lbs.
Door Width	8.0 ft.
Door Height	6.7 ft.
Number of Doors	4 - two on each side
Number of Motors	2 per vehicle
Type of Motor	100 hp series-wound DC

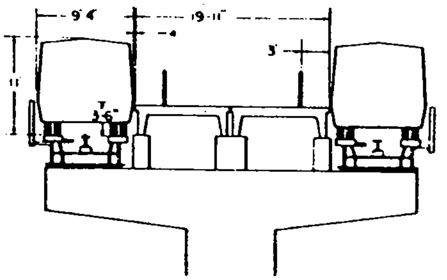
---

*N. D. Lea estimate based on floor area of 235 ft^2 and no seated passengers, 1.8 ft^2 per standing passenger.

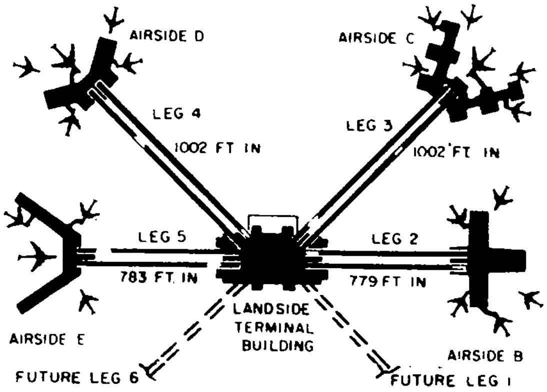
TABLE 2.7.2 SYSTEM OPERATIONAL CHARACTERISTICS

Single Direction Line Capacity	2,570 psgr/hr/lane 5,140 psgr/hr/double-lane
Maximum Waiting Time	45.0 sec.
In-Station Dwell Time, average	30.0 sec.
Minimum Headway	2.88 min./lane 1.17 min./double-lane
Maximum Velocity	30.0 mph
Cruise Velocity	30.0 mph
Estimated Average Speed	15.0 mph
Operating Modes	demand
Service Acceleration/Deceleration	0.09 g/0.13 g
Maximum Jerk	0.07 g
Emergency Deceleration, full vehicle	± 12 inches
Maximum Grade	0%
Minimum Turning Radius	N/A, straight lanes





TAMPA DOUBLE ELEVATED GUIDEWAY



TAMPA SYSTEM

2.8 WEDway PEOPLE MOVER SYSTEM (Community Transportation Systems/Disney)

The WEDway system at WALT DISNEY WORLD in Lake Buëna Vista, Florida, consists of a 4,600 ft. single-lane loop with one station. It is one of the attractions of the theme park and provides a ride for park visitors through one theme area.

Passengers enter and leave the system over a rotating platform at a single station. No schedule is provided, trains leave when loaded. A train consists of five vehicles, each accommodating four seated passengers. Total fleet size is 30 five-vehicle trains. Vehicles are open with a bi-parting door on one side. Protection from inclement weather is provided by a cover over the elevated guideway. The sides are open for visibility.

Propulsion of the system is accomplished by linear induction motors with the active element along the guideway center, the passive element on the vehicle. This configuration allows for a passive vehicle, i.e., no power or signal transfer is necessary.

Attendants at the station platform render aid, if necessary. The fare is collected with the park admission fee.

TABLE 2.8.1 VEHICLE DESCRIPTION

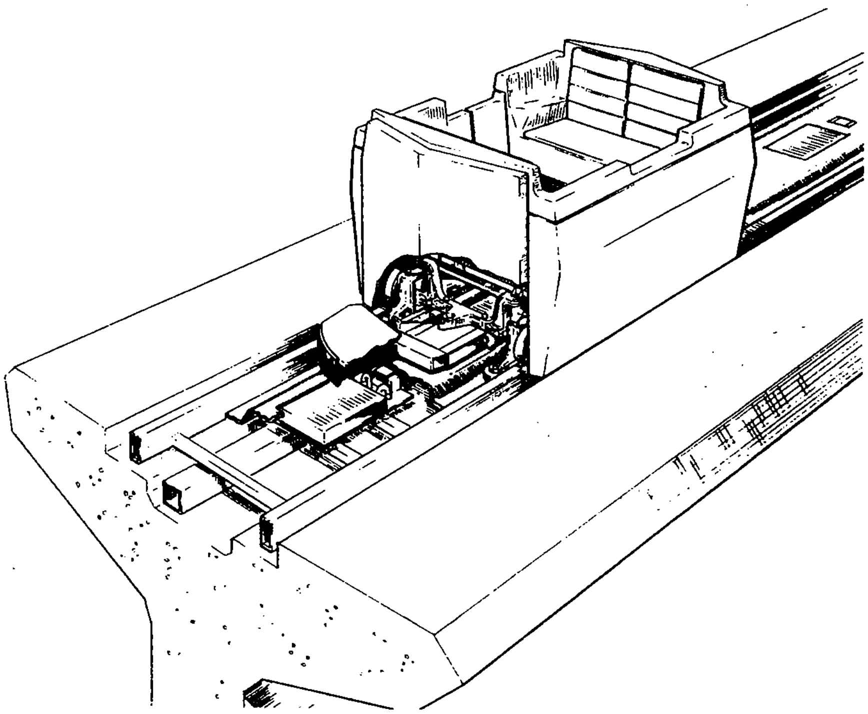
Operating Configuration	Five-car train
Uni- or Bidirectional	Unidirectional
Vehicle Capacity	4 seated
Length, overall	8.3 ft.
Width, overall	4.8 ft.
Height, overall	3.5 ft.
Train length (5 vehicles)	42.0 ft.
Empty Weight, per car	940 lbs.
Gross Weight, per car*	1,540 lbs.
Door Width	24 inches
Number of Doors	1 per car
Number of Motors	1 secondary per car 4-5 primaries per 10 ft. guideway section
Type of Motor	Linear induction motors

---

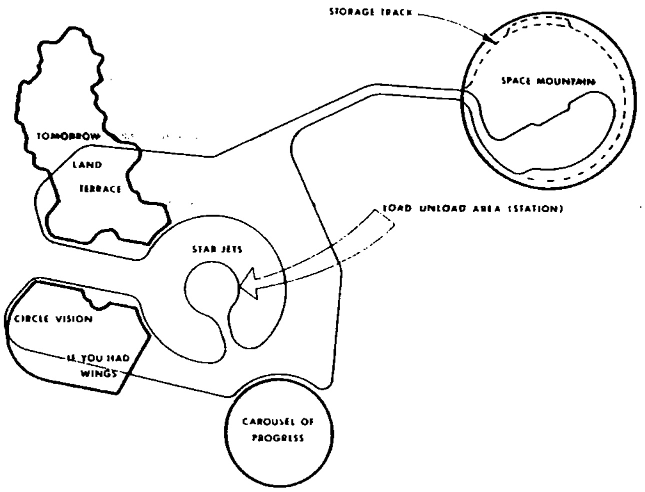
*SRI, Assessment of the WEDway People Mover System at Walt Disney World, Report No. UMTA-IT-06-0135-77-5, December 1977.

TABLE 2.8.2 SYSTEM OPERATIONAL CHARACTERISTICS

Single Direction Line Capacity	3,600 psgr/hr
Maximum Waiting Time, average	1.30 min.
In-Station Dwell Time, average	90.0 sec.
Minimum Headway	14.0 sec.
Operational Headway, average	20.0 sec.
Maximum Velocity	13.6 mph
Cruise Velocity	6.8 mph
Estimated Average Speed	5.2 mph
Operating Modes	Scheduled, dispatch when loaded
Service Acceleration/Deceleration	0.11 g/0.16 g
Maximum Jerk	0.36 g/sec.
Emergency Deceleration, full vehicle	0.16 g
Stopping Precision in Station	± 6 inches
Maximum Grade	0%
Minimum Turning Radius	20 ft.



WEDWAY VEHICLE



WEDWAY SYSTEM LAYOUT

2.9 SUMMARY OF OPERATING AGT SYSTEMS

The eight existing AGT systems discussed in the foregoing sections were built by six system suppliers. Three of these manufacturers (Boeing, Vought and Westinghouse) are in a position to provide equipment which is reasonably compatible with the system characteristics which have been proposed for the Jacksonville Downtown People Mover. All are bottom supported rubber tired systems with medium to large capacity vehicles. The other three manufacturers (DEMAG/MBB, Universal Mobility Inc., and CTS/Disney) have built systems which do not match Jacksonville's system characteristics as closely.

- The CABINLIFT installation in West Germany is a slow speed, limited capacity system which operates as a simple shuttle.
- The King's Dominion system near Richmond, Virginia, is a slow speed amusement park ride with no operational switching capability.
- The WEDway system at Disney World in Orlando, Florida, employs open vehicles which move at very low speeds in a special amusement park application.

Both the Morgantown and the AIRTRANS systems are officially classed as"Group Rapid Transit," employing off-line stations and a highly sophisticated command and control system which permits network type operations at 15 and 18 second headways, respectively. These capabilities are considerably beyond the requirements for the DPM Program which will not involve off-line stations. At Jacksonville "pinched loop" operations employing switch backs at the ends of the legs would necessitate extensive operational switching. However, headways will be 60 seconds or more, which will permit the use of a less complex command and control system.

The three Westinghouse installations at the Tampa and SEA-TAC airports and at Busch Gardens in Williamsburg, are very simple systems, involving simple shuttles and loops. None of these employs operational switching, which is a requirement at Jacksonville. However, as discussed elsewhere in this report, the Atlanta Airport, which is nearing completion, will have a number of operational switches similar to the one which Westinghouse has tested extensively at their West Mifflin, Pennsylvania, manufacturing facility.

3.0 REPRESENTATIVE AGT SYSTEMS IN PROCESS OF DESIGN, CONSTRUCTION OR INSTALLATION

3.1 DUKE UNIVERSITY MEDICAL CENTER (Otis/TTD)

The system presently under construction at Duke University in Durham, North Carolina, connects two hospital buildings and a parking facility. Service between the buildings is provided for staff, patients, carts, and hospital beds over 1,207 ft. of double-lane guideway. One lane extends an additional 560 ft. to a parking facility. Guideways are all concrete construction, partially at-grade, elevated, and below grade.

Vehicles are suspended on air pads instead of conventional wheels. The initial vehicle fleet will consist of four vehicles.

Stations are incorporated into the buildings, station platforms are equipped with coordinated doors.

The system is expected to achieve revenue status by mid-1979; acceptance testing is expected to begin in late 1978.

TABLE 3.1.1 VEHICLE DESCRIPTION

Operating Configuration	Single unit or 2-car train
Uni- or Bidirectional	Bidirectional
Vehicle Capacity	4 seated/18 standing
Length, overall	204.0 inches
Width, overall	89.0 inches
Height, overall	119.5 inches
Empty Weight	10,200 lbs.
Gross Weight*	15,160 lbs.
Door Width	54.0 inches
Door Height	78.0 inches
Number of Doors	2 - one on each side
Number of Motors	2 per vehicle
Type of Motors	Linear induction motor

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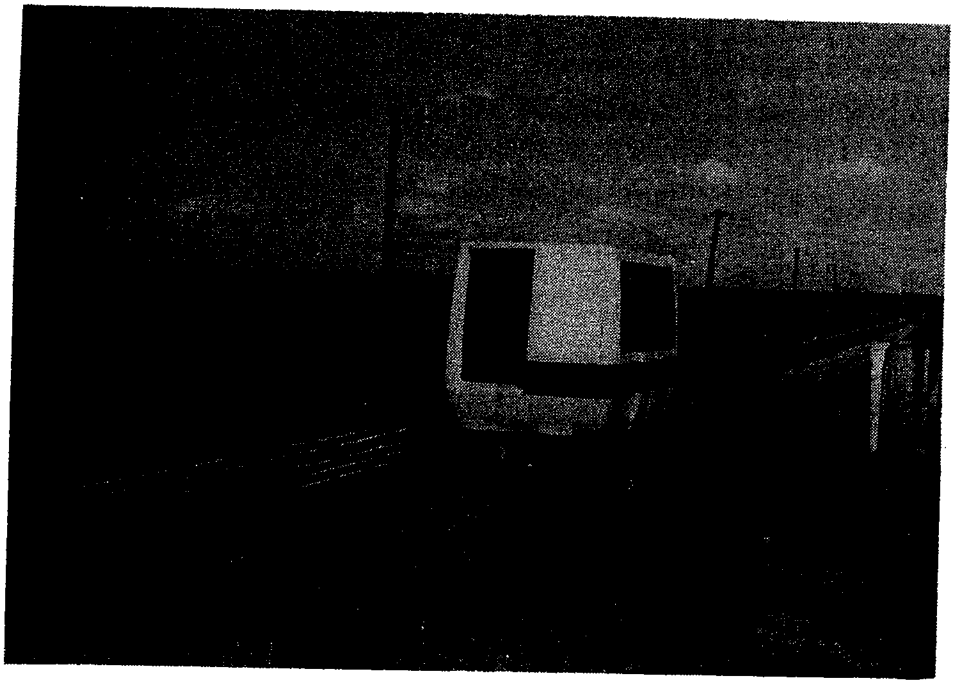
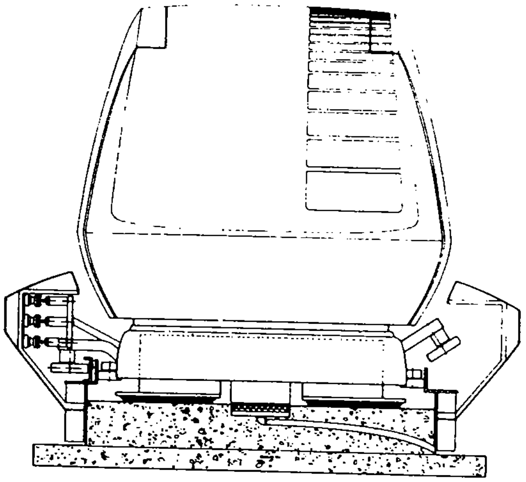
*N. D. Lea estimate based on crush capacity of the cargo vehicle (no seats) of 31 passengers at 1.8 ft^2 and 160 lbs. per passenger.

TABLE 3.1.2 SYSTEM OPERATIONAL CHARACTERISTICS

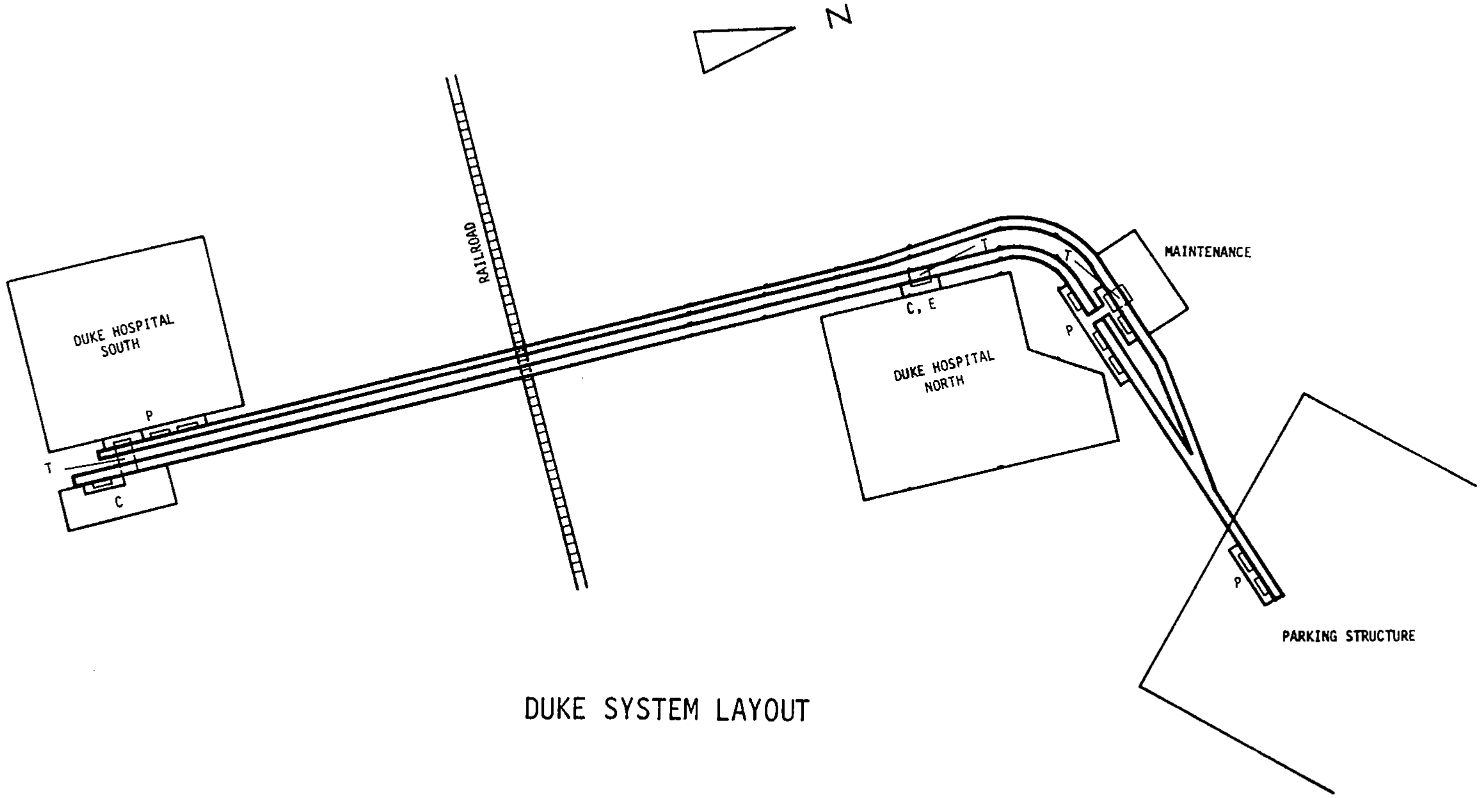
Single Direction Line Capacity, specified	800 psgr/hr
Maximum Waiting Time	120.0 sec.
In-Station Dwell Time	15.0 sec.
Minimum Headway	54.0 sec.
Maximum Velocity	28.0 mph
Cruise Velocity	27.0 mph
Estimated Average Speed	6.6 mph
Operating Modes	Scheduled and demand
Service Acceleration/Deceleration	0.10 g
Maximum Jerk, emergency	0.25 g/sec.
Emergency Deceleration, full vehicle	0.25 g
Stopping Precision in Station	± 6 inches
Maximum Grade	5%
Minimum Turning Radius	87.5 ft.



DUKE VEHICLE ON OTIS TEST TRACK



TYPICAL VEHICLE GUIDEWAY INTERFACE



DUKE SYSTEM LAYOUT

3.2 MIAMI INTERNATIONAL AIRPORT (Westinghouse)

The system at Miami Airport is presently under construction and targeted for passenger service by the end of 1979. The double-lane elevated guideway will connect the remote located International Satellite Building over a distance of 1,358 ft. to the main terminal building.

The guideway is of steel-concrete construction with a wide emergency walkway between the lanes. The structure also carries utility lines and has space for a baggage conveyor system.

One two-vehicle train per guideway-lane will provide fully automated shuttle service including separation of passengers into "free" passengers, and "sterile" passengers, who have to be processed through Customs and Immigration.

Stations are incorporated into the buildings. Platforms are equipped with coordinated doors. Access and egress is accommodated by stairs, elevators, and escalators.

TABLE 3.2.1 VEHICLE DESCRIPTION

Operating Configuration	Two-vehicle train
Uni- or Bidirectional	Bidirectional
Vehicle Capacity	2 seated/96 standing
Length, overall	36.67 ft.
Width, overall	9.33 ft.
Height, overall	11.00 ft.
Empty Weight	25,800 lbs.
Gross Weight*	47,300 lbs.
Door Width	7.00 ft.
Door Height	6.67 ft.
Number of Doors	4 - two on each side
Number of Motors	1 per vehicle
Type of Motor	100 hp series-wound DC

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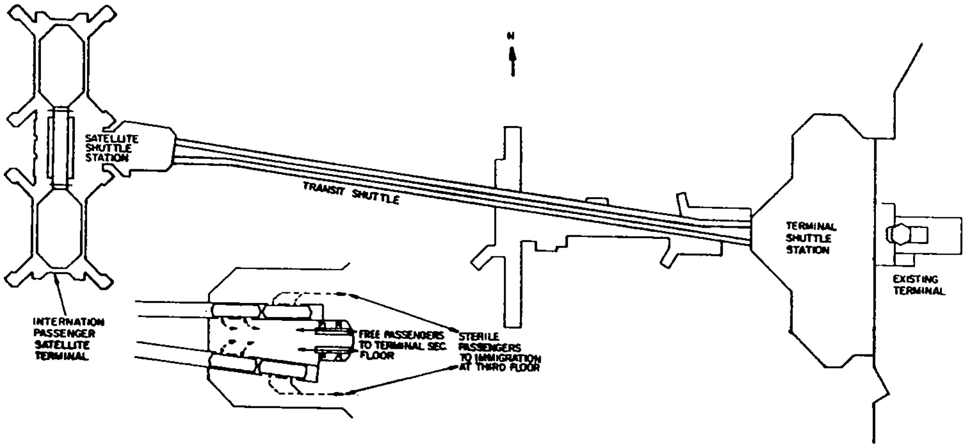
*N. D. Lea estimate based on crush capacity of 134 passengers at 1.8 ft^2 and 160 lbs. per passenger.

TABLE 3.2.2 SYSTEM OPERATIONAL CHARACTERISTICS

Single Direction Line Capacity	3,920 psgr/hr/lane 7,840 psgr/hr/lane
Maximum Waiting Time	1.5 min.
In-Station Dwell Time	35.0 sec.
Minimum Headway	2.5 min/lane 1.2 min/double-lane
Maximum Velocity	30.0 mph
Cruise Velocity	30.0 mph
Estimated Average Speed	16.0 mph
Operating Modes	Scheduled and demand
Service Acceleration/Deceleration	0.09 g
Maximum Jerk	0.07 g/sec.
Emergency Deceleration, full vehicle	0.23 g
Stopping Precision in Station	± 12 inches
Maximum Grade	3.75%
Minimum Turning Radius	200 ft.



MIAMI SYSTEM LAYOUT

Vehicle Configuration similar to Busch Gardens

Guideway Cross Section Similar to Tampa International Airport

3.3 VAL SYSTEM (Engins Matra), Lille, France

The system is presently under construction in Villeneuve d'Ascq-Lille, France. The first section (Line 1) will connect the University of East Lille with the Regional Hospital Center. Revenue service of this line is expected in mid-1980.

The line will consist of 7.9 miles of double-lane guideway and 16 on-line stations and will operate fully automated with a fleet of 38 two-car trains. Vehicles are coupled by automatic coupling devices.

Double-lane guideways will be in part at-grade, with sections elevated and also below grade. Construction is of prestressed or post-tensioned concrete running surfaces with electric heating through a buried cable.

Stations will be equipped with automated ticket dispensing machines and biparting coordinated doors to accommodate a four-vehicle train. Access and egress is accomplished by stairs, escalators, and elevators.

TABLE 3.3.1 VEHICLE DESCRIPTION

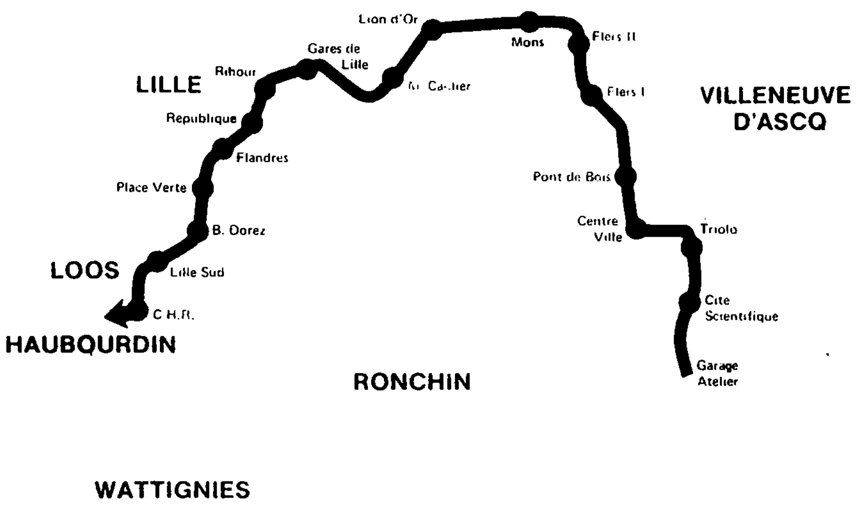
Operating Configuration	Two-car or Four-car trains
Uni- or Bidirectional	Bidirectional
Vehicle Capacity	34 seated/28 standing
Length, overall	41.0 ft.
Width, overall	6.8 ft.
Height, overall	10.7 ft.
Empty Weight	30,470 lbs.
Gross Weight*	50,710 lbs.
Door Width	51.3 inches
Door Height	76.0 inches
Number of Doors	4 - two on each side
Number of Motors	2 per vehicle
Type of Motor	160 hp series-wound DC

---

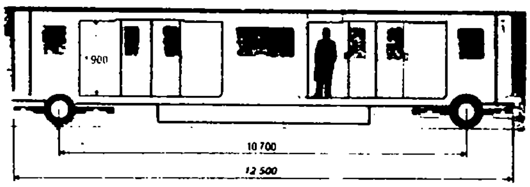
*TSC-IRT, Description of the VAL Automated Guideway Transit System, DOT-TSC-UM836-PM 78-7, March 10, 1978.

TABLE 3.3.2 SYSTEM OPERATIONAL CHARACTERISTICS

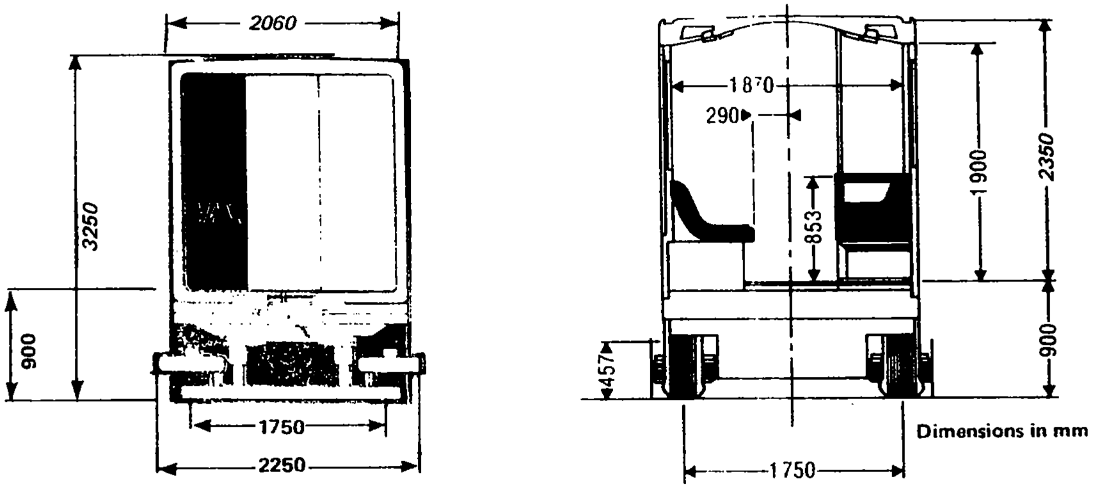
Single Direction Line Capacity	7,440 psgr/hr
Maximum Waiting Time	60.0 sec.
In-Station Dwell Time	30.0 sec.
Minimum Headway	60.0 sec.
Maximum Velocity	50.0 mph
Cruise Velocity	37.5 mph
Estimated Average Speed	21.9 mph
Operating Modes	scheduled
Service Acceleration/Deceleration	0.13 g
Maximum Jerk	0.07 g/sec.
Emergency Deceleration, full vehicle	0.18 g
Stopping Precision in Station	± 12 inches
Maximum Grade	7%
Minimum Turning Radius	100 ft.



ROUTE OF SYSTEM FOR LILLE PROJECT



SINGLE VEHICLE SIDE VIEW



VEHICLE END VIEW

3.4 NANKO PORT TOWN SYSTEM (NTS)

The Nanko Port Town system presently under construction is expected to be completed by 1980. The 4.3 mile line connects the Nanko area to Osaka's subway system. There will be 8 stations, two in the Osaka area, four in the port and industrial area, and two in the Nanko residential area.

Guideways are of steel-concrete construction, the entire system will be elevated. The fully automated system will be operating on a fixed schedule but will allow adjustments for varying passenger demand.

Original fleet size will be 60 vehicles intended to operate in 4-car trains.

Stations will be open, no coordinated doors are planned. Access to the platforms is by stairs.

TABLE 3.4.1 VEHICLE DESCRIPTION

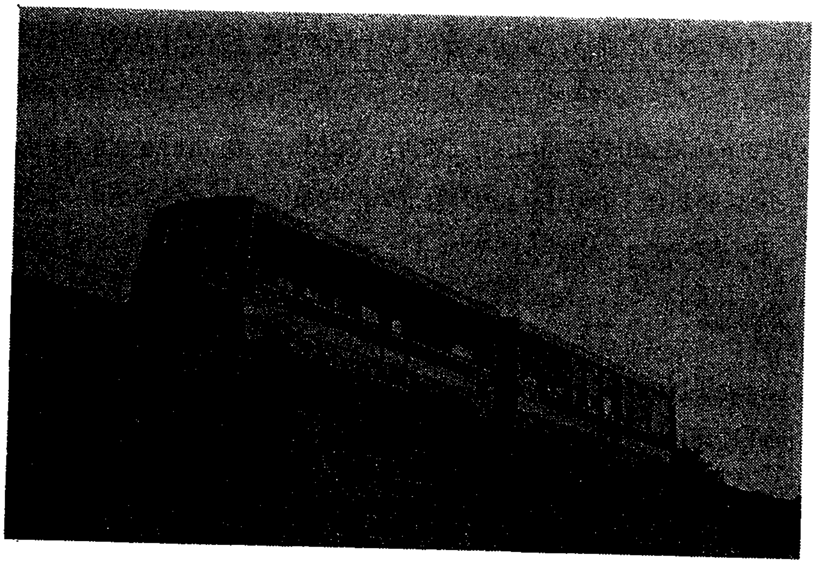
Operating Configuration	Four-car train
Uni- or Bidirectional	Bidirectional
Vehicle Capacity	24 seated/26 standing
Length, overall	24.6 ft.
Width, overall	7.5 ft.
Height, overall	10.0 ft.
Empty Weight, approximately	16,000 lbs.
Gross Weight, approximately*	26,000 lbs.
Door Width	51.2 inches
Door Height	70.9 inches
Number of Doors	2 - one on each side
Number of Motors	1 per vehicle
Type of Motor	95 hp DC shunt motor

---

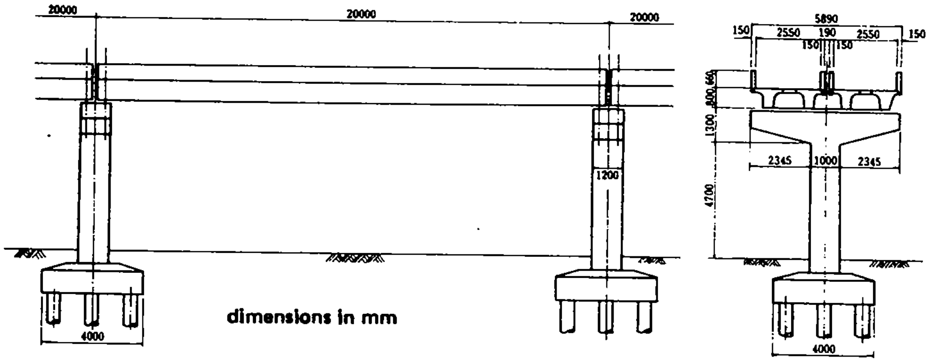
*LEA Transit Compedium

TABLE 3.4.2 SYSTEM OPERATIONAL CHARACTERISTICS

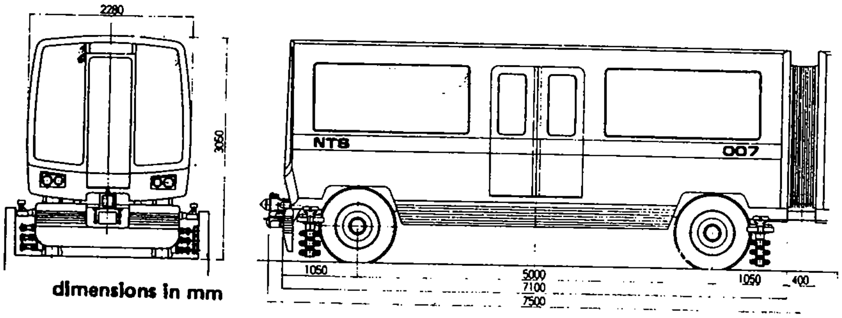
Single Direction Line Capacity	6,000 psgr/hr
Maximum Waiting Time	2.0 min.
In-Station Dwell Time	20.0 sec.
Minimum Headway	2.0 min.
Maximum Velocity	37.5 mph
Cruise Velocity	31.0 mph
Estimated Average Speed	18.1 mph
Operating Modes	scheduled
Service Acceleration/Deceleration	0.1 g
Maximum Jerk	0.08 g/sec
Emergency Deceleration, full vehicle	0.14 g
Stopping Precision in Station	±11.7 inches
Maximum Grade	7%



TYPICAL NTS VEHICLE



ELEVATED GUIDEWAY DIMENSIONS
DOUBLE LANE



VEHICLE DIMENSIONS

3.5 ATLANTA INTERNATIONAL AIRPORT SYSTEM (Westinghouse)

The system presently under construction at Atlanta Airport will connect the new main terminal with four concourses over 12,000 feet of underground guideway. The system is expected to begin operation in mid-1980.

The guideway tunnel will accommodate two lanes separated by a pedestrian mall which provides moving walks in both directions and a wide walkway. Each lane of guideway, since it is separated from the pedestrian mall, has an additional emergency walkway.

Station platforms are equipped with coordinated doors to accommodate a four-car train. Access and egress to platforms is through escalators, elevators, stairs, and walkways. A graphics and information system informs passengers about train movement through visual displays.

The system employs 13 newly designed transit switches which allow reverse turn back movement of vehicles.

The vehicles are equipped with audio station and destination information systems and operate fully automated. Total fleet size is 17 vehicles intended to operate as trains with up to four vehicles.

TABLE 3.5.1 VEHICLE DESCRIPTION

Operating Configuration	Single unit, up to four-car trains
Uni- or Bidirectional	Bidirectional
Vehicle Capacity	16 seated/64 standing
Length, overall	39.00 ft.
Width, overall	9.33 ft.
Height, overall	11.00 ft.
Empty Weight	27,500 lbs.
Gross Weight*	46,500 lbs.
Door Width	7.00 ft.
Door Height	6.67 ft.
Number of Doors	4 - two on each side
Number of Motors	2 per vehicle
Type of Motor	100 hp series-wound DC

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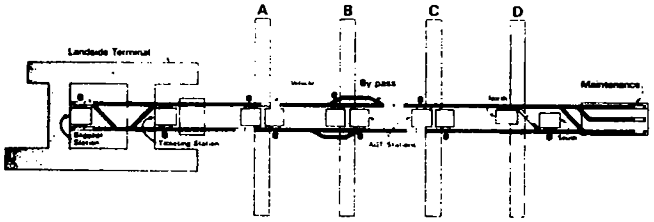
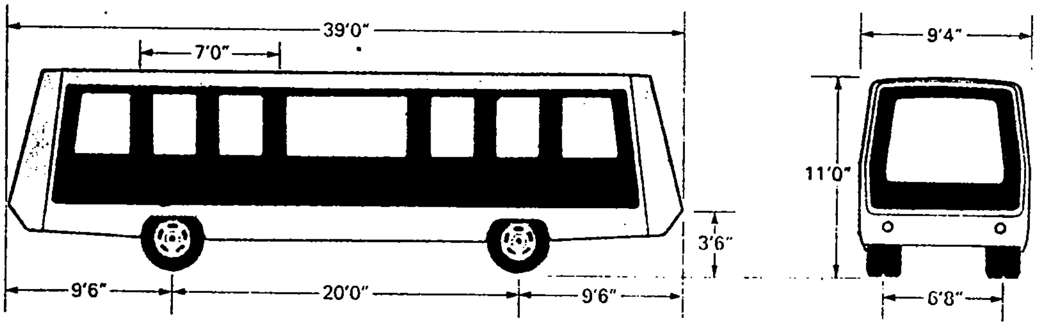
*N. D. Lea estimate based on crush capacity of 118 passengers at 1.8 ft^2 and 160 lbs. per passenger.

TABLE 3.5.2 SYSTEM OPERATIONAL CHARACTERISTICS

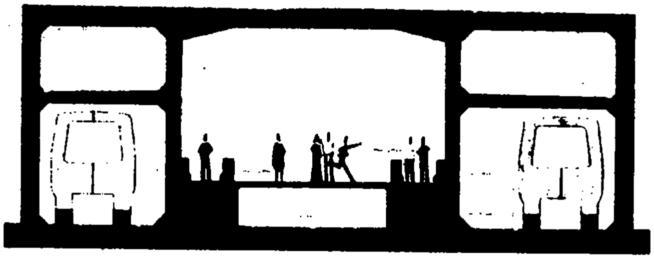
Single Direction Line Capacity (4-car train)	11,560 psgr/hr
Maximum Waiting Time	100 sec.
In-Station Dwell Time	21 sec.
Minimum Headway	99.6 sec.
Maximum Velocity	27 mph
Cruise Velocity	27 mph
Estimated Average Speed	13 mph
Operating Modes	scheduled
Service Acceleration/Deceleration	0.11 g
Maximum Jerk	0.09 g/sec.
Emergency Deceleration, full vehicle	0.23 g
Stopping precision in Station	±12 inches
Number of Switches, converges and diverges	13
Maximum Grade	0%



SYSTEM LAYOUT



VEHICLE DIMENSIONS



GUIDEWAY CONFIGURATION

3.6 KOBE PORT ISLAND SYSTEM (Kawasaki)

The Kobe Port Island system will consist of 5.7 miles of total guideway comprised of 1.8 miles of double-lane guideway and 2.2 miles of single-lane guideway to connect the mainland railroad station with the port area. The system will have four double-lane stations and five single-lane stations. It appears that all guideways and stations will be elevated.

Stations are sheltered dual or single platforms accessible by stairs, ramps, and escalators. Coordinated doors are expected to be employed at least in some stations. A station can accommodate one six-car train per platform.

Guideways are of concrete construction supported by concrete columns. Guideways follow the median or one side of the road requiring no additional right of way.

Passenger service is expected to be provided fully automated by six-vehicle trains consisting of two three-car married units. Vehicles are air conditioned.

Completion of construction and beginning of revenue service is expected during 1981. The system connects Kobe Port Island to a railroad station on the mainland.

TABLE 3.6.1 VEHICLE DESCRIPTION

Operating Configuration	Two 3-car train units
Uni- or Bidirectional	Bidirectional
Vehicle Capacity	20 seated/55 standing
Length, overall	27.89 ft.
Width, overall	7.87 ft.
Height, overall	10.33 ft.
Empty Weight	19,900 lbs.
Gross Weight*	29,800 lbs.
Door Width	68.9 inches
Door Height	73.6 inches
Number of Doors	2 - one on each side
Number of Motors	2 per vehicle
Type of Motor	60 hp shunt/compound DC

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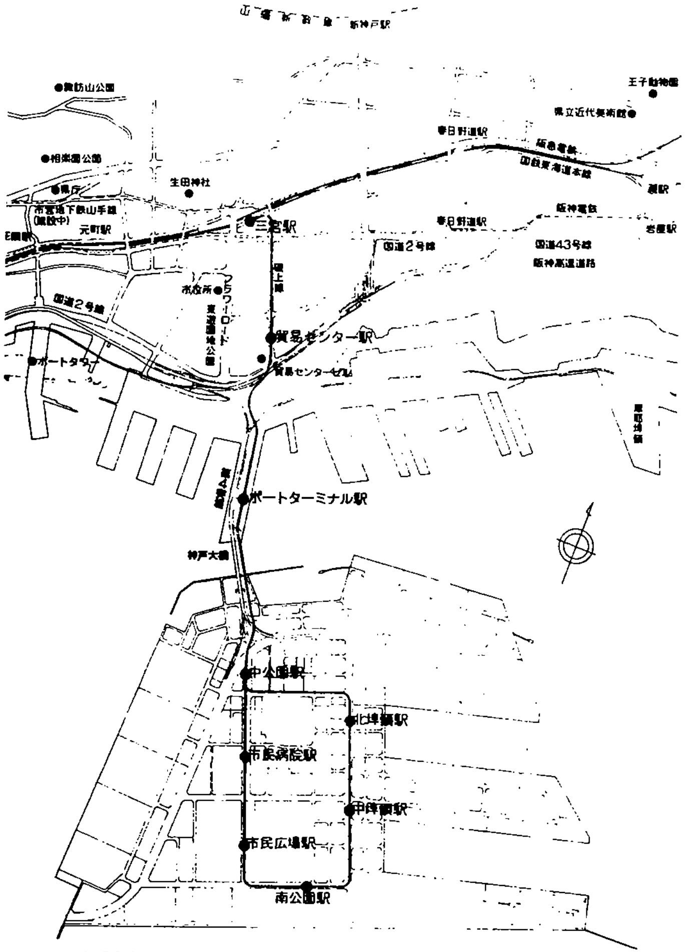
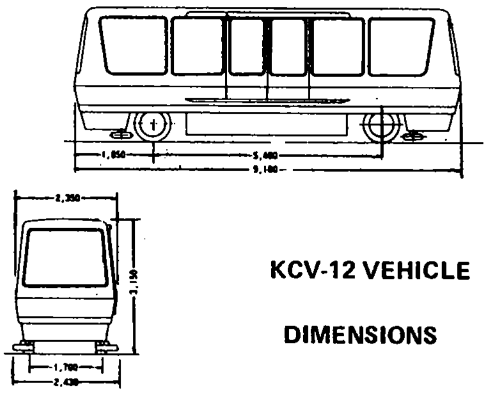
*Lea Transit Compendium

TABLE 3.6.2 SYSTEM OPERATIONAL CHARACTERISTICS

Single Direction Line Capacity	18,000 psgr/hr
Maximum Waiting Time	90 sec. peak; 3-5 min. off peak
In-Station Dwell Time	15 sec. flexible
Operational Headway	90 sec. peak
Maximum Velocity	44 mph
Cruise Velocity	25 mph
Estimated Average Speed	under 18 mph
Operating Modes	scheduled
Service Acceleration/Deceleration	0.12 g
Maximum Jerk	0.10 g
Emergency Deceleration, full vehicle	0.15 g
Stopping Precision in Stations	± 3 to 4 inches
Maximum Grade	5%
Minimum Turning Radius	82 ft.



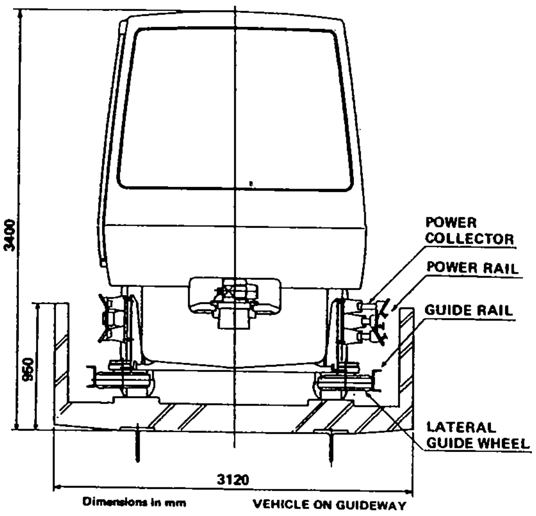
KOBE PORT ISLAND SYSTEM LAYOUT
(1" = approx. 1130m)



KCV-12 VEHICLE

DIMENSIONS

Dimensions in mm



VEHICLE ON GUIDEWAY

3.7 SUMMARY OF SYSTEMS UNDER CONSTRUCTION

Of the six new systems summarized in the foregoing sections, four appear to be comparable in scope and complexity to the proposed Jacksonville Downtown People Mover. The three overseas projects involve urban applications and are worthy of in depth analysis at some future date to determine what lessons applicable to the transportation problem at Jacksonville can be learned. The Atlanta Airport People Mover project is similar in most respects to the Jacksonville DPM. The numbers of vehicles and stations are comparable as is the extensive use of operational switching. However, the guideway system is significantly shorter. Also, because the tempo of activity at the airport is more nearly uniform during the 16 busiest hours of the day, there will be significant differences in the pattern of operations.

Neither the Duke University nor the Miami Airport system is comparable in scope to the proposed Jacksonville DPM. However, OTIS/TTD's air cushion system at Duke will warrant close examination, as this will be the first commercial application of this interesting approach to urban transportation.

Because of its relatively close proximity to Jacksonville, and the essential similarities to a typical DPM installation, the Atlanta Airport People Mover warrants careful study, particularly as regards the level of performance achieved and the effectiveness of the operations and maintenance organization and facilities. With passenger service scheduled to commence in mid 1980, this system should provide an excellent point of reference for the definitive planning and design of the Jacksonville DPM.

4.0 CHARACTERISTICS OF GUIDEWAY/VEHICLE ALTERNATIVES

4.1 VEHICLE SIZE AND CAPACITY

Potentially available vehicles for DPM service have been examined to determine the range of vehicle size and passenger carrying capacities. Vehicle capacity is largely dependent upon the usable floorspace; but other constraints affecting capacity are locations and sizes of wheel wells and doors, which govern seat locations. Shown on Table 4.1 are floor space areas and passenger capacities for most of the potentially available DPM vehicles. As will be noted, passenger carrying capacities were calculated for two alternative combinations of seated and standing passengers.

It will be noted that ten different vehicle systems are proposed for the DPM Program by six major manufacturers. The following is a summary of the development status of the equipment proposed by these manufacturers:

(a) Westinghouse Electric has standardized its Eagle 1 vehicle system, as exemplified by the two vehicles currently operating at Busch Gardens in Williamsburg, Virginia. There are three basic configurations, as illustrated in Figure 4.1. These same vehicles, with minor modifications to suite local requirements, are being supplied by Westinghouse for the Atlanta and Orlando Airports. Four have already been delivered to the Miami Airport.

Westinghouse also has two smaller vehicle systems under development buy not yet deployed. One of these is a medium-sized vehicle with a floor area of 119 sq. ft., i.e., adequate for 45 standees or 12 seated and 26 seated passengers. Their small vehicles are an adaptation of the Rohr Montrain Technology which Westinghouse acquired. These vehicles will operate in trains of 3 to 6 vehicles, each with a capacity of 6 seated and 4 standing passengers. Figure 4.2 indicates the relative size and arrangement of Westinghouse's three classes of vehicles.

TABLE 4.1: CAPACITIES OF POTENTIALLY AVAILABLE DPM VEHICLES

		PASSENGER CAPACITY			
	FLOOR SPACE Sq. Ft.	Case 1 33% Seated 67% Standing	TOTAL	Case 2 20% Seated 80% Standing	TOTAL
WESTINGHOUSE (EAGLE)					
A Vehicle	250	27/54	81	18/72	90
B Vehicle	241	26/52	78	17/70	87
C Vehicle	257	28/56	84	18/74	92
BOEING/VAL	230	25/50	75	16/67	83
VOUGHT (URBAN AIRTRANS)					
A Vehicle	130	14/28	42	9/38	47
B Vehicle	144	16/31	47	10/42	52
C Vehicle	164	18/35	53	12/47	59
BOEING/KAWASAKI	163	18/34	52	12/46	56
BOEING/HABEGGER (II)	53	6/11	17	4/15	19
BOEING (MORGANTOWN)	71	8/15	23	5/20	25
OTIS (DUKE)	60	6/14	20	4/18	22
OTIS (DPM OPTION)	120	13/26	39	9/34	43
UNIVERSAL MOBILITY (DPM OPTION)	117	12/26	38	8/34	42
DEMAG/MBB (MK 18S)	61	7/13	20	4/18	22
CTS-Disney (DPM)	27	3/6	9	2/8	10

NOTE: Capacities calculated on basis of 4.5 sq. ft. per seated passenger and 2.36 sq. ft. per standing passenger.

Actual vehicle capacities may differ slightly due to interior space arrangement, wheel wells, etc.

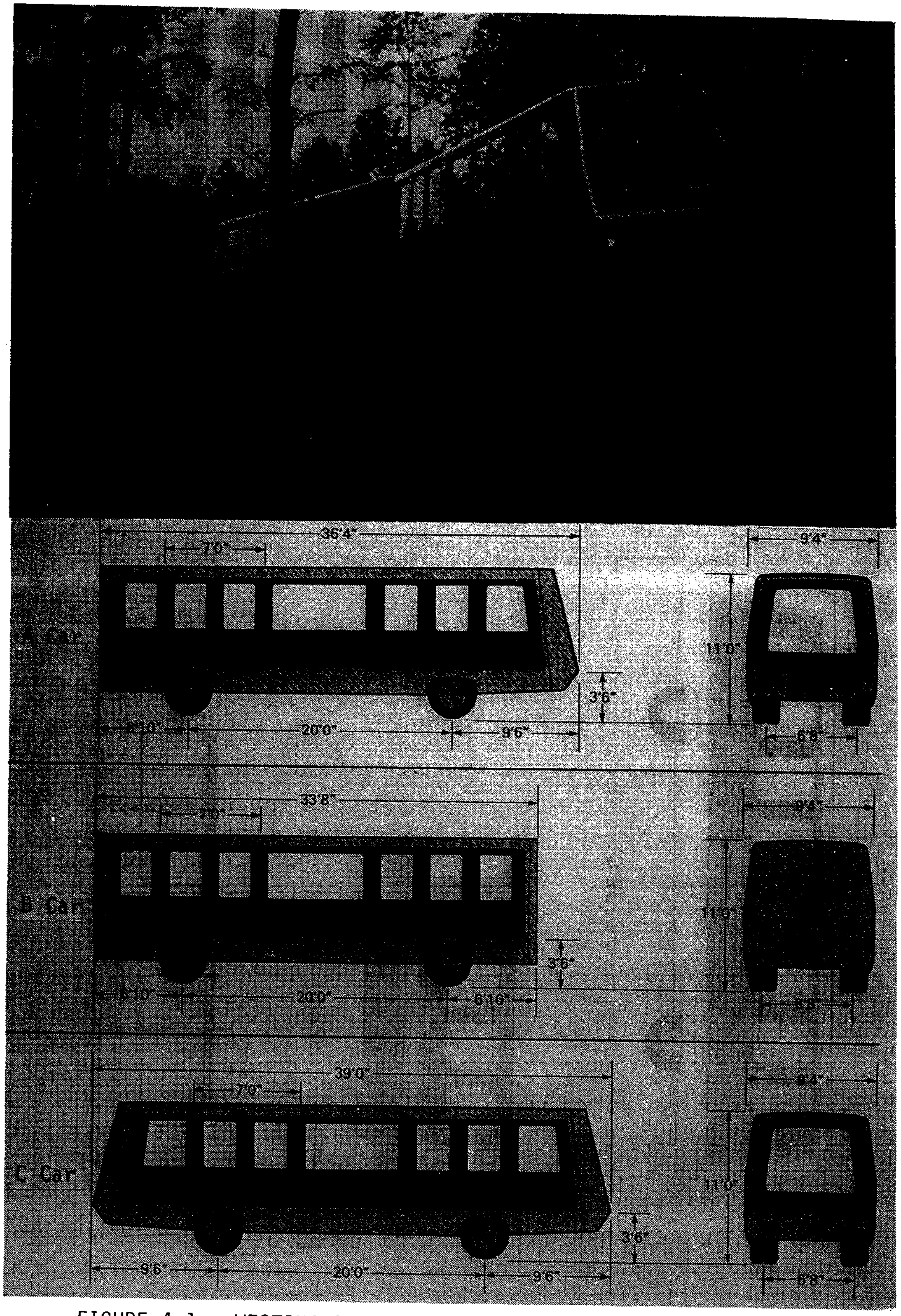


FIGURE 4.1: WESTINGHOUSE EAGLE 1 VEHICLE CONFIGURATION

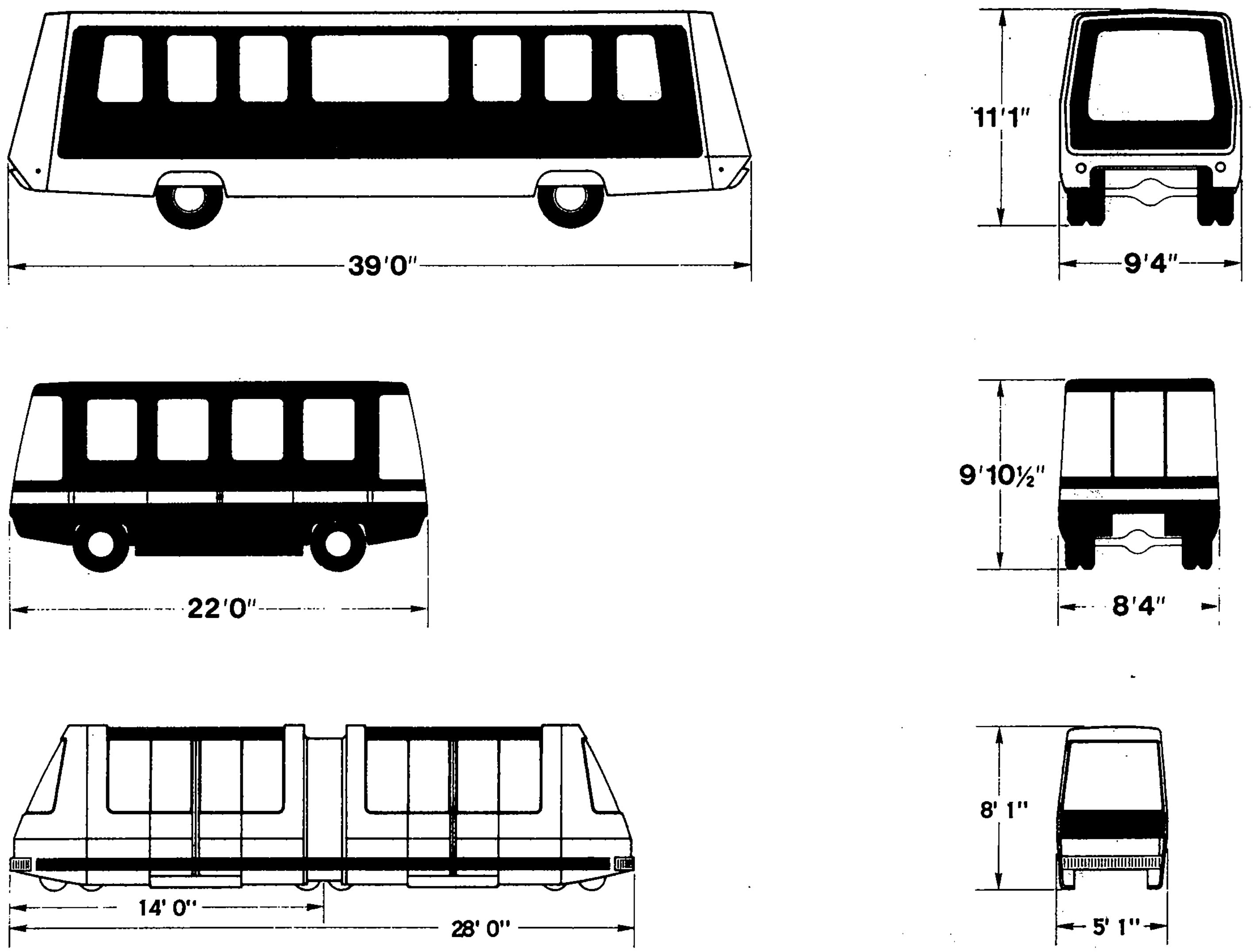


FIGURE 4.2: WESTINGHOUSE FAMILY OF AGT VEHICLES

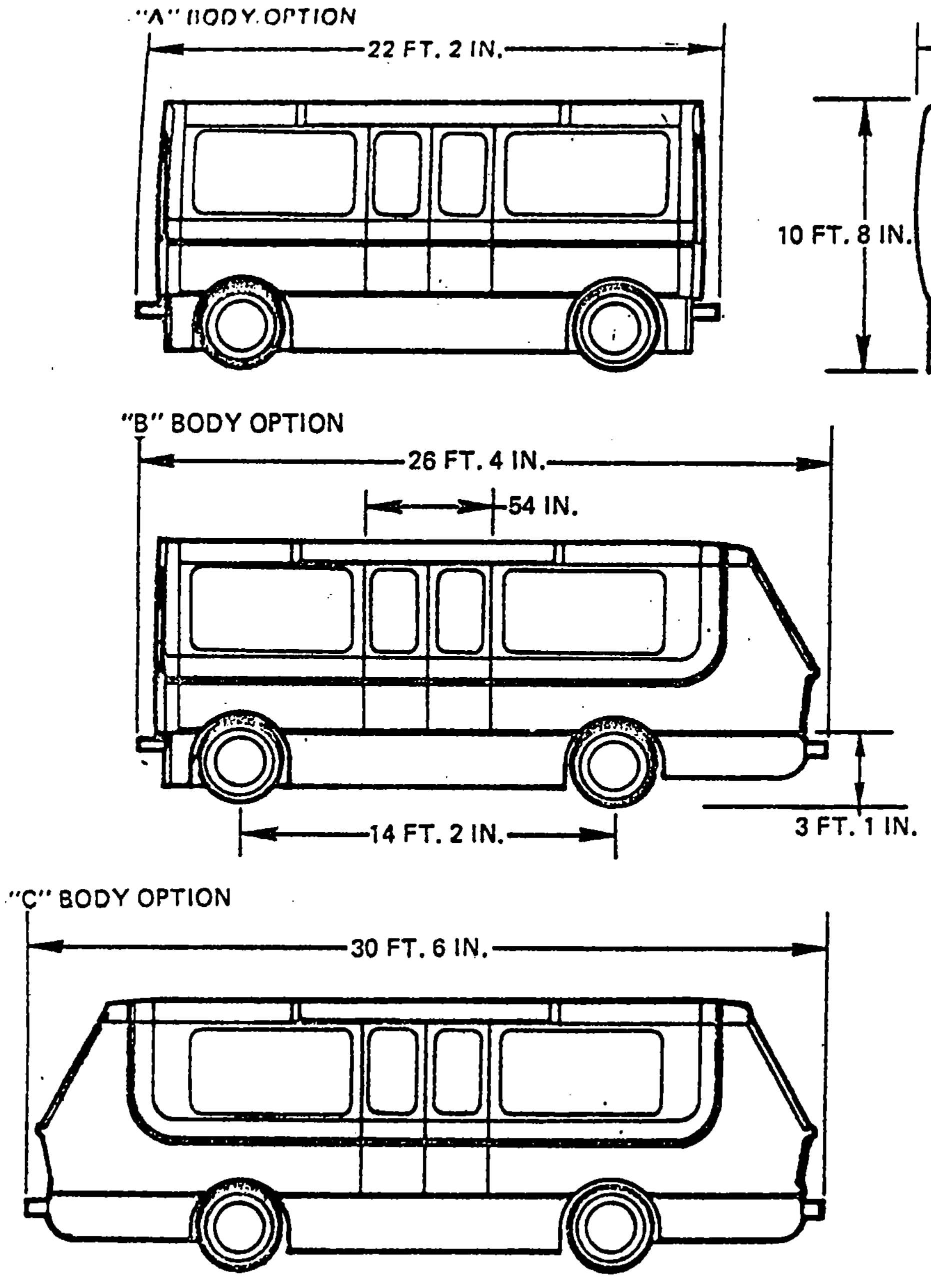
(b) Boeing Aerospace has recently concluded agreements with the following foreign manufacturers to install and integrate their AGT systems in the United States where technically and economically feasible:

- Engins Matra of France, manufacturer of the VAL system which is currently being installed at Lille, France.
- Habegger of Switzerland which developed the "mini rail" system which have been built at a number of amusement parks in Europe, Canada and the United States. Whereas Universal Mobility, Inc. of Salt Lake City has in the past built a number of systems employing the Habegger Technology, Boeing will henceforth represent Habegger as its United States licensee.

  An advanced design, designated as Mark III is currently under study by Boeing and Habegger. This will involve larger vehicles, considered more suitable for general urban applications. However, since no prototype has as yet been tested, the smaller Mark II which is in operation at various locations is currently proposed for the DPM program.
- Kawasaki. This system is currently being installed at the Kobe Port City in Japan, as discussed in paragraph 3.6.

(c) The Vought Corporation has been funded by UMTA to upgrade the AIRTRANS vehicle for urban use. Among the many changes which have been incorporated in the new design, a prototype of which is scheduled for testing in the near future are:

- Increasing the speed from 17 to 30 mph.
- Providing bi-directional capability.
- Reconfiguration of the vehicle body as illustrated in Figure 4.2.



		A BODY	B BODY	C BODY
WEIGHTS	EMPTY CAR, LB.	14,200	15,350	15,850
	NORMAL LOAD, LB.	21,000	23,170	24,180
	CRUSH LOAD, LB.	24,400	27,080	28,260
CAPACITY	INTERIOR FLOOR AREA, SQ.FT.	130	144	164
	SEATED PASSENGERS	16–19	16–20	16–24
	TOTAL PASSENGERS (NORMAL)	40	46	52
	TOTAL PASSENGERS (CRUSH)	60	69	77
PERFOR-MANCE (MAXIMUM RECOM-MENDED)	SPEED, MPH	30		
	NORMAL ACCELERATION, MPHPS	2.63		
	NORMAL SERVICE BRAKING, MPHPS	2.64		
	JERK LIMIT, MPHPS PS	1.54		
	EMERGENCY BRAKING, MPHPS	4.39		
DYNAMIC ENVELOPE	HEIGHT		10'10"	
	WIDTH		9' 5"	
	LENGTH	22'2"	26' 4"	30'6"

FIGURE 4.2 URBAN AIRTRANS VEHICLE CONFIGURATION (Reproduced from Report No. UMTA-TX-06-0020-78-1)

(d) Otis/Transportation Technology Division is currently planning larger vehicles than those built for the Duke University Hospital, for DPM applications. Whereas no prototype has as yet been tested, it is proposed to employ much of the same equipment -- air pads for example -- as in the Duke vehicles. Accordingly, subject to later technical evaluation, this larger version has been listed as potentially available for the DPM Program.

(e) Whereas Universal Mobility has not furnished definitive information on their larger DPM vehicle, they claim to have completed significant new design work. Accordingly, in view of the fact that they have built a number of successful systems and are currently installing a new one at the Minnesota Zoo, their "DPM option" is listed as potentially available.

(f) DEMAG/MBB a West German consortium is currently in the detailed planning stage for an extensive installation in Bremen. Having developed and tested a family of AGT vehicles at Hagen, and built the operational CABINLIFT system at the Ziegenhain District Hospital, the MK 18S is considered potentially available for the DPM Program.

Figure 4.3 indicates graphically for the vehicles listed in Table 4.1, their overall dimensions and passenger capacity. Also shown is the maximum training capability (consist size) for each manufacturer's equipment. These vehicles may be grouped by size and capacity as follows:

- Large - 75 to 90 passengers
  - Westinghouse (Eagle I)
  - Boeing/VAL

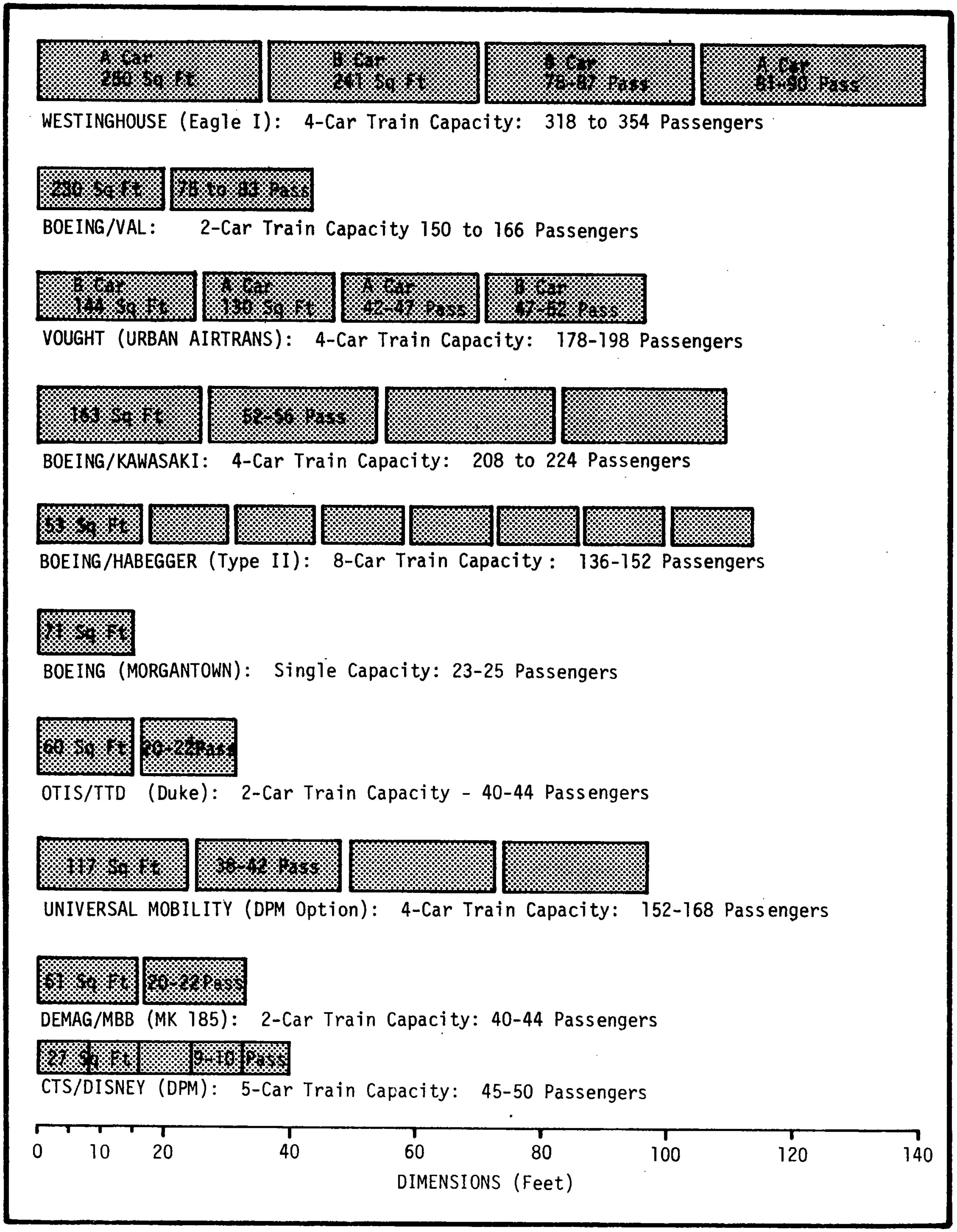


FIGURE 4.3: COMPARISON OF VEHICLE/TRAVELING UNIT SIZES AND CAPACITIES POTENTIALLY AVAILABLE FOR DPM

- Medium - 38 to 59 passengers
    - Vought (Urban Airtrans)
    - Boeing/Kawasaki
    - Boeing/Habegger (II)
    - Univ. Mobility (DPM)
    - OTIS (DPM Option)

- Small - 20 to 25 passengers
    - Boeing (Morgantown)
    - Demag/MBB
    - Otis (Duke)

For all cases, except Boeing/Habegger, the maximum consist size is four vehicles in the large and medium classes of vehicles. The small vehicles are operated either as single cars or two-car trains.

4.2 GUIDEWAY TYPES AND CONFIGURATION

The guideway is generally the most expensive, as well as the most conspicuous feature of any Automated Guideway Transit System. As this is the roadway which both supports and guides the vehicles, its design and configuration must be tailored to both the characteristics of the vehicles as well as the specific site. Because there is a wide variety of vehicles being offered by numerous AGT system suppliers, there is a corresponding range of guideway configurations. However, all guideway systems have the following basic features in common:

- Foundations - The earthworks, sub-base, footings, retaining walls, etc., necessary for support.
- Supporting structures - the columns, piers, slabs or beams which are required to carry the vehicle loads.
- Guidance structures - the finished surfaces which provide vertical and lateral guidance, such as rails, beams, running pads, etc.

The AGT systems which are candidates for the DPM program may be grouped into three categories insofar as their guideways are concerned. These are:

(a) Roadway Systems - involving for the most part rubber tired vehicles which travel along a path about as wide or wider than the vehicle body. Lateral guidance may be provided by a center guidebeam or by curbs along the outside edge of the guideway. The following AGT systems employ this type of guideway:

Westinghouse Eagle I
Boeing/VAL
Vought (Urban Airtrains)

Boeing/Kawasaki
Otis (Duke & DPM)
Boeing/Morgantown
CTS/Disney (DPM)

(b) Beam Riders - involving vehicles which "straddle" beams which are narrower than the vehicles. Examples of this type are:

Boeing/Habegger II
Universal Mobility (DPM)

(c) Suspended Systems - Vehicles hang below the guideway structure. Currently the only DPM candidate system offering this approach is the DEMAG/MBB (MK 18S). Other systems which employed this type of design were the JETRAIL installation at Love Field in Dallas and the Rohr Monocab demonstrated at TRANSPO -72.

Figure 4.4 indicates the configuration and size of a few representative guideways for AGT and other innovative transportation systems. As will be noted, some are fabricated from structural steel shapes, some are built of concrete, and some combine both construction materials. Sizes range from the slender box beam which supports and guides the light weight Universal Mobility monorail systems to the broad Morgantown I structures.

Table 4.2 summarizes the weights and load characteristics for probable DPM candidate systems. Actual guideway designs would be dictated by these and other factors.

UMTA's ongoing AGT Guideway and Station Technology Project addresses this important subject in considerable depth. A series of reports including design guidelines and concepts are in the process of preparation by UMTA's Consultants DeLeuw Cather & Company - ABAM Engineers Incorporated, and should be available in the relatively near future.

TABLE 4.2 VEHICLE WEIGHT AND LOAD CHARACTERISTICS

SYSTEM IDENTIFICATION	VEHICLE WEIGHT		AXLE LOADING AND SPACING			Pounds Per foot of Train Length
	Empty	Crush Loaded*	Load per Axle	Distance Same Veh.	Between Adjacent Veh.	
Westinghouse Eagle I (C Car)	27,500	50,300	25,150	20'0"	14'8"	1,265
Boeing/VAL	30,500	51,000	25,500	35.3	6.0	1,207
Vought (DPM) (B Car)	14,000	23,200	11,600	14'2"	8'0"	1,046
Boeing/Kawasaki (KCV-DPM)	24,134	38,622	19,311	16'4"	10'0"	1,417
Boeing/Habegger II (8 Car Train)	29,120	51,760	6,340	13'5"	13'5"	446
Univ. Mobility DPM	14,000	22,700	11,350	N/A	N/A	1,621
Otis (Duke)	10,200	15,470**	No axles, weight distributed along entire length of vehicle.			
Otis (DPM)	14,000	25,050**				1,031
Boeing Morgantown	8,600	14,900	7,450	10'7"	4'11"	961
Demag/MBB (MK 18S)	6,600	11,422	5,711	N/A	N/A	351
CTS/Disney (DPM) (5 Car Train)	10,000	22,000	2,200	N/A	N/A	550

*Crush loads have been calculated on basis of a passenger load of 160 lbs. per 1.8 sq. ft. of floor space, unless otherwise noted.

**Manufacturers estimate.

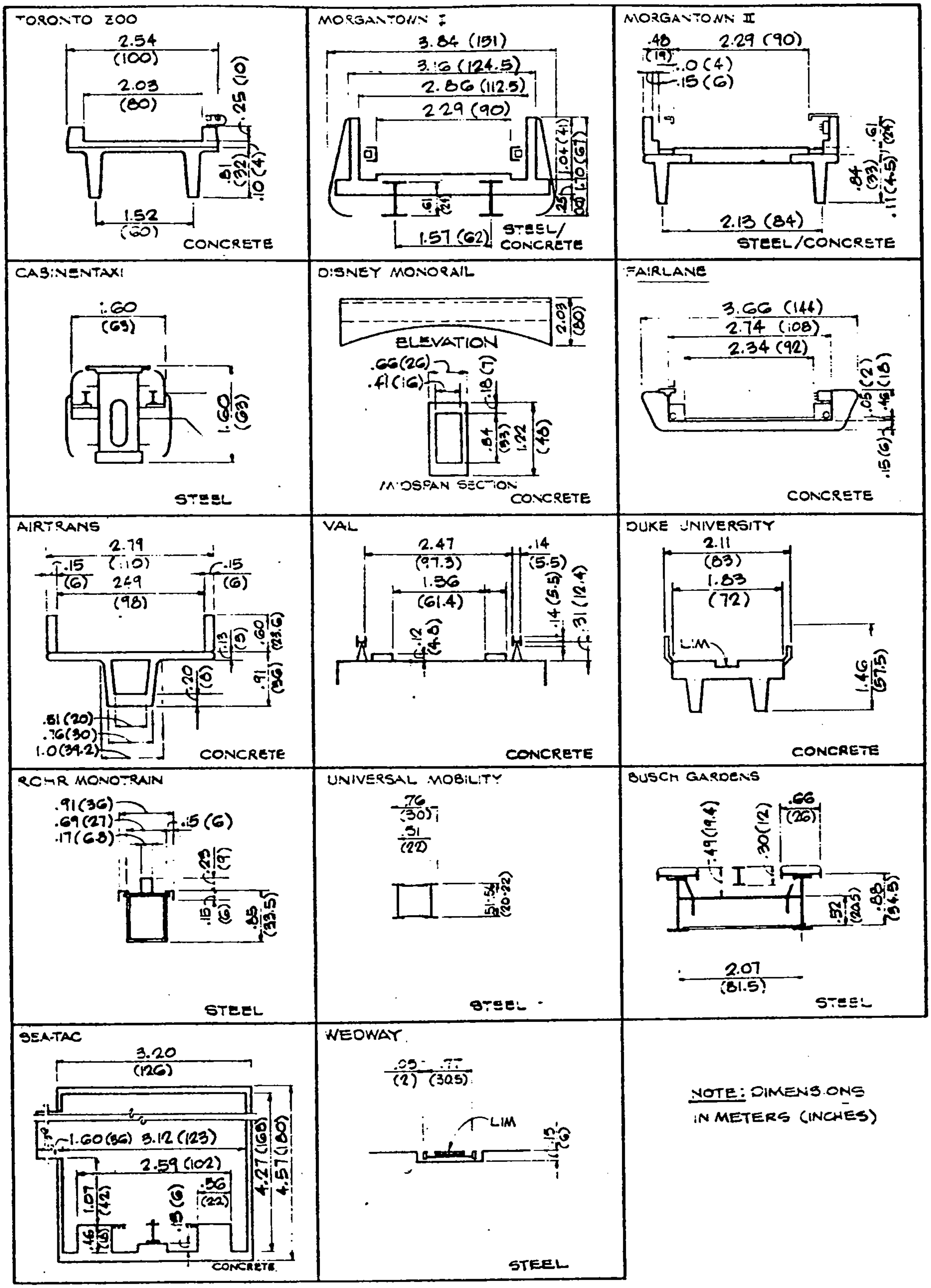


FIGURE 4.4: TYPICAL GUIDEWAY CROSS SECTIONS (Reproduced from Report No. UMTA-IT-06-0152-79-2)

4.3 PROPULSION AND BRAKING

The predominant form of propulsion being supplied for AGT systems is conventional DC motors and traction drive through rubber tires. However, three of the candidate sytems are powered by linear induction motors (LIM): Otis/TTD, Cabinlift and Wedway.

Traction Drive

All of the present traction drive systems use DC motors coupled to the drive wheels via a drive shaft and differential; except in the case of King's Dominion, where V-belts are used. In most instances, three-phase AC power (generally 480 V) is distributed along the guideway by power rails and rectified to DC on-board the vehicle. The VAL system is an exception, with 750 VDC power distributed. At Airtrans and Morgantown only the rear axle is powered. The Westinghouse vehicles are offered with either one or both axles powered. These present DC motor/traction drive systems are sized to provide a maximum speed of no more than 30 mph, except for the Westinghouse vehicles where tests have been performed up to 55 mph, and VAL vehicles which are to cruise at 37 mph and reach a maximum speed of 50 mph.

Acceleration performance for potentially available systems is similar and limited to approximately 0.1 g. Motors are sized for such performance with a power to weight ratio of approximately 1.0 watts per pound plus 0.07 to 0.08 watts per pound per mph of maximum speed. For example, a 30 mph cruise speed vehicle of medium size, with a gross weight of 20,000 lbs. would require a power plant rated at approximately 65 KW. For 50 mph cruise speed, approximately 95 KW is required. Single motors are available in this power range. For larger vehicles of over 45,000 lbs. gross weight, the required power is 145 KW to 215 KW for 30 mph and 50 mph, respectively. Therefore, it is often practical to power the larger vehicles with two motors each rated at 75 KW to 120 KW.

In the case of the medium size vehicle, a cost/reliability tradeoff exists in deciding if the vehicle should be supplied with one or two motors. In the case of single car operation, two motors of smaller size will allow the vehicle to move under its own power, should a propulsion failure occur. However, the costs will be greater because of the additional power train gear. If two or more vehicles are to be trained, the needed redundance can be provided by having only one motor per car. For operation on steep grades (greater than 6%) all wheel drive may be necessary to assure adequate traction. Although the terrain in Jacksonville is generally quite flat, steep grades may be required in some parts of the DPM guideway system, such as the approaches to the St. John's River crossing.

Service braking for traction drive systems is applied by both dynamic braking (shunting the traction motor by resistors) and friction braking (disc or drum brakes). In general, AGT suppliers have utilized automotive-type truck brakes. The large size vehicles use both dynamic and friction service brakes because of the severe duty cycle required. The medium size vehicles can be supplied only with friction brakes that will meet the duty cycle requirement; hence, saving some costs due to control switch gear and braking resistors. For the most part, the friction brakes are air operated; however, the Morgantown vehicles were equipped with hydraulically operated brakes.

Emergency brakes can be provided with either a fail-safe design or completely redundant design. However, the latter is more expensive and would not be required for systems where headways of 60 seconds or more are to be operated. The typical fail-safe design supplied is a spring actuated friction brake which is held off by air pressure. In this case, emergency braking is caused by venting the air pressure either by a direct signal or by failure of the compressed air system. Such spring actuated brakes will provide emergency deceleration on the order of up to 0.3 g which is the maximum that should be allowed with standing passengers. The spring actuated emergency brake is a constant force brake and does not provide controlled deceleration. For long headways (e.g., 60 seconds or greater) emergency deceleration in a range of 0.1 to 0.3 g is sufficient.

Linear Induction Motor (LIM) Propulsion

Currently there are three suppliers which use LIM propulsion: Otis/TTD, DEMAG/MBB, and CTS/Disney. The Otis and DEMAG/MBB systems have the active elements of the LIM on the vehicle, with the passive reaction element as a rail or plate along the guideway. The WEDway system at Walt Disney World utilizes totally passive vehicles with the active elements mounted discretely along the guideway.

For the Otis and DEMAG/MBB systems, three-phase AC power is distributed by power rails along the guideway. Speed control is obtained by varying the frequency to the LIM motor, the voltage, or both, using solid state devices. Such forms of propulsion and propulsion control are non-conventional and have not yet been proven in actual transit applications. The Otis system being installed at Duke University Medical Center should provide operating data to assess actual in-service performance. At present DEMAG/MBB has a simplified CABINLIFT system (a single vehicle shuttle) operating in the district hospital at Zeigenhain, West Germany.

The speed of the Otis and DEMAG/MBB vehicles is controlled by equipment on board the vehicle. The speed of the WEDway system is controlled by varying the voltage in response to a velocity signal generated by track based sensors. Since thrust capability descends also upon the spacing between motor primaries located in the guideway, the WEDway type system tends to have a fixed profile along the guideway; whereas the speeds of the Otis and DEMAG/MBB system can be more readily varied according to conditions anywhere along the route.

Servicing braking is provided through the LIM by reverse thrust. This is the only form of braking provided by the WEDway system; however, for the DPM Program, CTS/Disney is proposing friction caliper brakes along the guideway operating on a fin attached to the vehicle. The Otis system, being air levitated, is emergency braked by delevitating on to skids. The skids are equipped with brake pads. This provides a deceleration rate which is less dependent on vehicle weight (i.e., increased vehicle weight increases the frictional force and vice versa). The DEMAG/MBB MK 18S is equipped with hydraulically operated friction brakes on its wheels for low speed and a separate spring actuated emergency brake which is limited to a 0.3 g deceleration rate.

4.4 COMMAND AND CONTROL

The major functions of an AGT Command and Control system are:

- To provide automatic control of the vehicles including maintaining proper time intervals between vehicles or trains to match with schedules or demands (i.e., starting, stopping, speed regulation, station dwell time, etc.), and
- To provide safety (i.e., collision avoidance).

Functional Implementation

These major functions are generally allocated throughout major subsystems such as Central Control and Management, Station Control and Management, Wayside Functions, and Vehicle Functions. The hierarchy in which command and control is implemented varies greatly from supplier to supplier. The following, therefore, gives a general hierarchy which, when modified, will fit most current AGT systems.

Central Management and Supervision

All current AGT systems have some form of central supervisory control which keeps track of system and vehicle status and manages the overall operation. This may be a very simple operation keeping up with vehicle movements, setting schedules, monitoring failures, and providing, for degraded operating maneuvers to cope with unusual conditions. Other systems have a very sophisticated central control which programs schedules or vehicle dispatch rates automatically or in response to passenger requests, keeps track of exact position of vehicles throughout the system, and keeps track of each vehicle's status in a number of vehicle subsystem categories. The Morgantown People Mover is one example where a very elaborate central control was provided. The Otis/TTD Duke University system will include diagnostics to determine problem areas and provide a computerized record.

The central control facility may also include communications equipment which can be used to talk with passengers aboard the vehicles during an emergency, make public address announcements or communicate with personnel throughout the system. In addition, closed circuit T.V. surveillance of station platforms and guideways may be provided if desired.

The primary function of central control is supervision and management of the operating fleet. Vehicle movements through the system can either be rigidly controlled in real time or simply regulated periodically by adjusting the station dwell time. Schedule adherence is accomplished in a variety of ways. One method is to schedule the rates at which vehicles are dispatched from stations. The simplest form is where each section of guideway has a commanded speed and a fixed-block headway control to provide minimum spacing and protection between trains. The Westinghouse systems are examples of this form of management. So long as a delay does not occur, vehicle movement is self scheduling. The schedule, or interval between consecutive trains, is simply set by the round trip length, the average speed and number of trains on the route. One problem with this simplest form of management is bunching. Where the route is not loaded with trains spaced at the minimum headway, delays can cause the trains to eventually close up the intervals to the minimum headway, so that the trains will not be evenly spaced over the route. To prevent such an occurrence, some form of bunch control is required, even if provided manually at the central console, to hold trains in stations and regulate the separation intervals.

Another important function of central management is to match vehicle movement and train length with expected or requested demand. The Morgantown system is the only present AGT system in service which can be operated in an on-demand mode where vehicles remain parked in the stations and passengers can demand service non-stop to more than one location. The Westinghouse shuttle systems at Tampa Airport and Miami Airport and the Otis/TTD Duke system will provide on-demand elevator type service. In the simplest form, schedules and demand are matched by adding or subtracting trains and by varying train length; however, this is generally manually controlled.

Where switching is employed, the central management and supervisory functions must be more sophisticated. For example, different routes can be prescribed for each train. In the case of a simple line haul system, switch backs can provide the capability to switch trains back without the necessity that they complete whole trips between each line end. Therefore, the frequency of service along the line can be varied to coincide more with the expected link loads.

Station Management

In general, the station management functions include deceleration into the station, precision stopping, door operation command, station dwell time, and dispatch control. If the station is off-line, the station management system will probably control the switch which allows divergence from the main line into the station. Vehicle deceleration and acceleration control is generally an on-board function through the vehicles propulsion and braking controller.

Precise stopping in stations is critical where there are coordinated platform/vehicles doors requiring stopping accuracies of ±6 inches. The Westinghouse systems are provided with a stop tape which is mounted along the guideway at station entrances. This tape is basically an antenna with a series of loops formed by crossing the lines (wires) at precise distances (i.e., 6 to 12 inches). This allows precise location of the vehicle or train as it enters the station, so that it can be stopped at the proper position along the platform. The Otis/TTD system also employs a stop tape antenna, but in addition has an active control for final line up with the platform doors. The Morgantown system utilizes an on-board vehicle stop control which is in the form of a programmed stop. Once given the stop command tone by the station controller, the vehicle controller provides a preprogrammed stopping speed command to the brake controller to bring the vehicle to rent within a ±6 inch requirement.

Door control is generally performed aboard the vehicle in response to a station or wayside command. Doors are generally equipped with touch edges and a recycle feature similar to elevator doors. The amount of time that the door remains open is generally governed by a station controller or by central control. Door open time largely sets the station dwell time for simple systems with on-line stations and no precise schedule control. Therefore, if for some reason a passenger interrupts door closing, a delay in the schedule can result.

Wayside Functions

Control functions generally considered as part of the wayside system are data communication with vehicles, speed commands, some stop commands, headway keeping, protection against collisions, switching and detection of vehicle position and movements. Data communication with vehicles is generally provided by direct electrical contact with a signal rail along the guideway or by an inductive loop transmission system. Both forms have been proven successful through a number of existing AGT installations. Voice communication with vehicles is generally provided via a radio link.

Most existing AGT systems provide commanded civil speeds for defined sections of guideway. Speed signals are generally transmitted from the wayside to the vehicle over the data communication system. Stop commands are generally a part of the speed command system except where emergency braking is ordered.

Headway control may be either synchronous or asynchronous. With a synchronous control system, each vehicle is programmed to be at a precise position along the guideway at a specific time. Speed adjustments are made to correct for any position errors. Such systems are commonly referred to as point-follower or moving-block controls.

Asynchronous types of control simply allow vehicles to follow one another so that a safe stopping distance is maintained. The most predominant form of control in this case is conventional fixed-block control. Fixed-block control is also used for protection against collisions even in systems like Morgantown which employ a sophisticated point-follower headway control. The Westinghouse, Otis/TTD Duke, AIRTRANS, and VAL systems use fixed-block headway control. The DEMAG/MBB systems use both moving-block and fixed-block systems as required. The WEDway system controls headway through its track based linear induction motors (vehicles are totally passive).

Switching is accomplished by either wayside or on-board vehicle equipment, or a combination of both. Switching commands are generally transmitted from the wayside, with commands to switch or not to switch coupled with the vehicle management system governing routing. In addition, switch protection must be included with the collision prevention system.

Vehicle detection is generally a wayside function. At Morgantown magnetic actuated reed relays at the start of each block act as presence detectors. The vehicle is equipped with two magnets at its front end each of which actuates separate reed relays in the guideway. The other form of vehicle detection is by shunting between two signal rails as is done in conventional rail transit practice (e.g., Westinghouse, Otis/TTD Duke and AIRTRANS).

- Vehicle Functions

In general, vehicle control functions are accepting wayside commands and communications of status; control of propulsion and brakes to provide proper acceleration, deceleration and speed; direct control of doors; stopping precision in stations; and reaction to emergency signals from wayside or on-board to actuate emergency brakes.

4.5 THE JACKSONVILLE BASELINE SYSTEM

Because of the broad range of AGT hardware which may be considered for the Jacksonville DPM, it has been considered advisable to define a baseline system which generally reflects the capabilities of existing equipment, and at the same time will satisfy the transportation needs of downtown Jacksonville. The characteristics of this baseline vehicle system, as developed by the Consulting Team, the Technology, Planning and Development Sub Committee of the Citizens Advisory Committee, and approved by the Jacksonville Transportation Authority, are as follows:

- Capacity and Size
  - 50 passengers - 10 seated, 40 standing
  - Dimensions - 9' wide, 11' high, 25' long

- Speed
  - Maximum velocity - 30 mph
  - Maximum acceleration velocity - 3 ft/second/second*

- Grades
  - Obtain minimum of 10 percent vertical grade over 1200 feet
  - Capable of 80 ft radius turn at 10 mph

- Propulsion
  - Electrically operated DC motor, 2 per vehicle
  - Capable of bidirectional operation

- Suspension
  - Primary and secondary suspension
  - Pneumatically filled rubber tires with air bag or air cushion

- Consist
  - Operate singularly or in trains of up to 4 vehicles
  - Manual coupling with electric umbilical cord

- Braking
  - Service braking rate - 3 feet/second/second*
  - Emergency braking rate - 8 feet/second/second
  - Combination of pneumatic and mechanical braking systems
- Guidance and Switching
  - Positively entrapped steering with acceptable operational switching possible at all points in system
- Degree of Automation
  - Simple loop or shuttle operation, extensive use of switching and on-line stations
- Command and Control
  - Operate on guideway with fixed block system
  - Completely computer controlled, with operator in attendance on communications and control equipment
  - Operate with scheduled service, off-peak and peak hours
- Failure Recovery and Emergency Evaluation
  - Procedures will include most of the range of available options
  - Operator at central control can override or bypass certain types of failures
  - Vehicles capable of pushing a disabled vehicle to proper location for evacuation of passengers
  - Tug tractor available in case of power failure or major difficulties
  - Vehicles equipped with knock-out panels for extreme emergencies
- Reliability/Maintainability
  - System will maintain between 99.7 and 99.9 percent of fully operational capabilities
  - Maintenance for routine problems will be done on-line at end of last station

- Heavy maintenance done at remote facility, until system or fleet becomes too large, in which case this heavy maintenance facility will have to be located adjacent to guideway for vehicle access without trailering or towing.

- Passenger Comfort and Amenities
  - Vehicles entirely enclosed - forced air ventilation most of the year, air conditioning and heating provided when weather demands it
  - Interior noise levels no higher than 70 dBA
  - Exterior noise levels no higher than 65 dBA, taken at point 20 feet from center line of the guideway

* Note: UMTA has specified lower acceleration and braking rates for other DPM systems, i.e., 2 ft/sec.^{2}

The baseline system employs vehicles in the medium size range -- smaller than the Westinghouse Eagle, but larger than AIRTRANS. They should operate at speeds of up to 30 mph, should be able to be operated in trains of up to four vehicles, and be fully capable of operational switching. Since it may be desirable to employ switch backs at the end of the individual legs, a bidirectional capability has been specified.

These system characteristics have been developed on the basis of a general assessment of the AGT systems which have either been demonstrated in passenger service, are being installed in real life situations, or are being upgraded. By the time the Jacksonville DPM project reaches the bid stage, it is expected that several of the manufacturers will be in a position to propose proven hardware which either meets or closely approximates the desired vehicle and system characteristics. It is further anticipated that some manufacturers may propose alternative approaches which will warrant serious consideration.

5.0 OPERATIONAL CAPABILITIES

This chapter discusses the operational capabilities of potentially available equipment for DPM applications. Many of these capabilities are dependent upon the equipment while others will depend upon site specific characteristics. Because there are a number of very different AGT systems available, the ranges of capabilities are wide. Therefore, care must be taken in defining a generic system which includes compatible characteristics.

5.1 DIRECTION OF OPERATION

Most AGT vehicles may be operated either unidirectionally or bidirectionally. Some of the equipment available is inherently designed for unidirectional operation, requiring turnarounds to be provided in the guideway network. Vehicles which are bidirectional do not require turnarounds, but can be switched back at the end of the line for operation in the opposite direction on the other guideway lane. Shuttle vehicles which are confined to operate on a single guideway lane must obviously be capable of bidirectional operation. The operational directional capabilities of currently available DPM equipment are as follows:

Unidirectional

- Boeing/Morgantown - Inherently unidirectional because of the design of its steering system. Major modifications would be required for bidirectional operation.
- DEMAG/MBB (MK 18 S) - Can be reversed only at very slow speeds.
- Boeing/Habegger - Current Type II equipment cannot be reversed. The Type III Design which is being developed for DPM applications will provide bidirectional capabilities.

- CTS/Disney - The WEDway system at Orlando is unidirectional, but the linear induction propulsion and control system could be modified to provide a bidirectional capability.

- Vought (AIRTRANS) - The vehicles at the Dallas/Ft. Worth airport were designed and are operated unidirectionally. However, the existing design is being modified under the AIRTRANS Urban Technology Program to permit bidirectional operation.

Bidirectional

- Westinghouse (Eagle I)
- Vought (Urban AIRTRANS)
- Boeing/VAL
- Boeing-Kawasaki
- Universal Mobility, Inc. (DPM Option)
- Otis/TTD (Duke and DPM option)

5.2 SPEED

Speed requirements for DPM systems are dependent first, upon the level of service to be provided, and second, upon required vehicle productivity which will effect costs. System characteristics which govern speed are: network configuration (curves, station spacing, and other guideway conditions), station dwell time, and the propulsion and braking capability of the vehicle.

Maximum Speed Capability

Table 5.1 gives the maximum cruise speed capabilities of potentially available DPM vehicles. Two values are presented: The maximum speed demonstrated in regular passenger service and what might be expected to be available for DPM service. The maximum cruise speed demonstrated in regular passenger service is 30 mph by Westinghouse and Boeing (Morgantown). Westinghouse has tested its Eagle vehicle at 55 mph at the South Park site in Pittsburgh. The VAL system, being built for Lille, France, has run at speeds up to 50 mph. Here it is important to note that speeds of 50 mph and 55 mph are being quoted only for very large vehicles. The predominant maximum speed for medium size vehicles is 30 mph. For relatively small network DPM systems cruise speeds up to 30 mph should be adequate, considering relatively short average passenger trip distances and close station spacing. Higher cruise speeds might be considered if the network is to be extended in the future where longer commute trips are to be made.

TABLE 5.1: MAXIMUM CRUISE SPEED OF POTENTIALLY AVAILABLE DPM VEHICLES

Manufacturer	Maximum Speed Demonstrated in Passenger Service (mph)	Speeds Achieved on Test Track or Claimed by Manufacturer	Probable Maximum Cruise Speed for DPM* (mph)
Westinghouse	30	55 (t)	45
Boeing/VAL	-	37-50 (t)	35
Vought-AIRTRANS	17	30 (t)	30
Boeing/Kawasaki		44 (m)	30
Universal Mobility, Inc.	19	35 (m)	20
Boeing-Morgantown	30		30
Demag/MBB (MK 18 S)	-	15.5 (t) 21.5 (m)	22
Otis/DUKE	-	22.5 (t) 31 (m)	30
CTS/Disney (DPM)	7	30 (m)	20

*NDL Judgment

(t) - Tested on test track
(m) - Manufacturer's claim

5.3 TRAVEL TIME

Because the time required to complete a trip is an important consideration in determining ridership, the various factors which effect time required to complete a trip must be kept in the proper perspective. These are summarized briefly in the following paragraphs.

Cruise Speed - This is normally the maximum sustained speed for which the vehicles are designed. The design speed is an important consideration in determining the kinds of power plant and hence effects vehicle cost as well as energy consumption. For most of the AGT systems currently in operation, 30 mph is generally the top cruise speed.

Acceleration/Deceleration Limits - For ride comfort and passenger safety, particularly when standing passengers are to be accommodated, it is necessary to limit acceleration rates. Generally, acceleration/deceleration limits range from about 0.06 g to 0.1 g or 1.9 - 3.2 ft/sec^2. For the DPM systems currently in the preliminary engineering stage, acceleration/deceleration rates of 0.0625 g or 2.0 $ft/sec.^2$ have been specified by UMTA. Significantly higher emergency braking rates of up to .25 g or 8 ft/sec^2 are generally considered within tolerable limits.

In addition to limits on acceleration, it is generally necessary to control jerk rates for the rate of change of acceleration in the interests of ride comfort. Accordingly jerk limits of .026g or 2 $ft/sec.^3$ have been specified by UMTA.

Horizontal Turns - In the interests of ride comfort and passenger safety, it is necessary to limit cruise speeds in the areas where the guideway must make horizontal turns. The vehicles must slow down when they approach sharp turns to ensure that acceptable lateral acceleration rates are not exceeded. For transit vehicles, 0.1 g or 3.2 ft/sec^2 is generally considered acceptable. Table 5.2 indicates the maximum speeds for a variety of typical turning radii at various degrees of super-elevation.

TABLE 5.2 SPEEDS FOR VARIOUS TURNING RADII

Radius of Turn	Maximum Speed (mph) at the Super-elevation indicated				
	0	4%	8%	10%	12%
20'	5.5	6.5	7.3	7.7	8.1
40'	7.7	9.2	10.4	10.9	11.5
50'	8.7	10.2	11.6	12.2	12.8
75'	10.6	12.5	14.2	15.0	15.7
100'	12.2	14.5	16.4	17.3	18.1
150'	15.0	17.7	20.1	21.2	22.2
200'	17.3	20.5	23.2	24.5	25.7

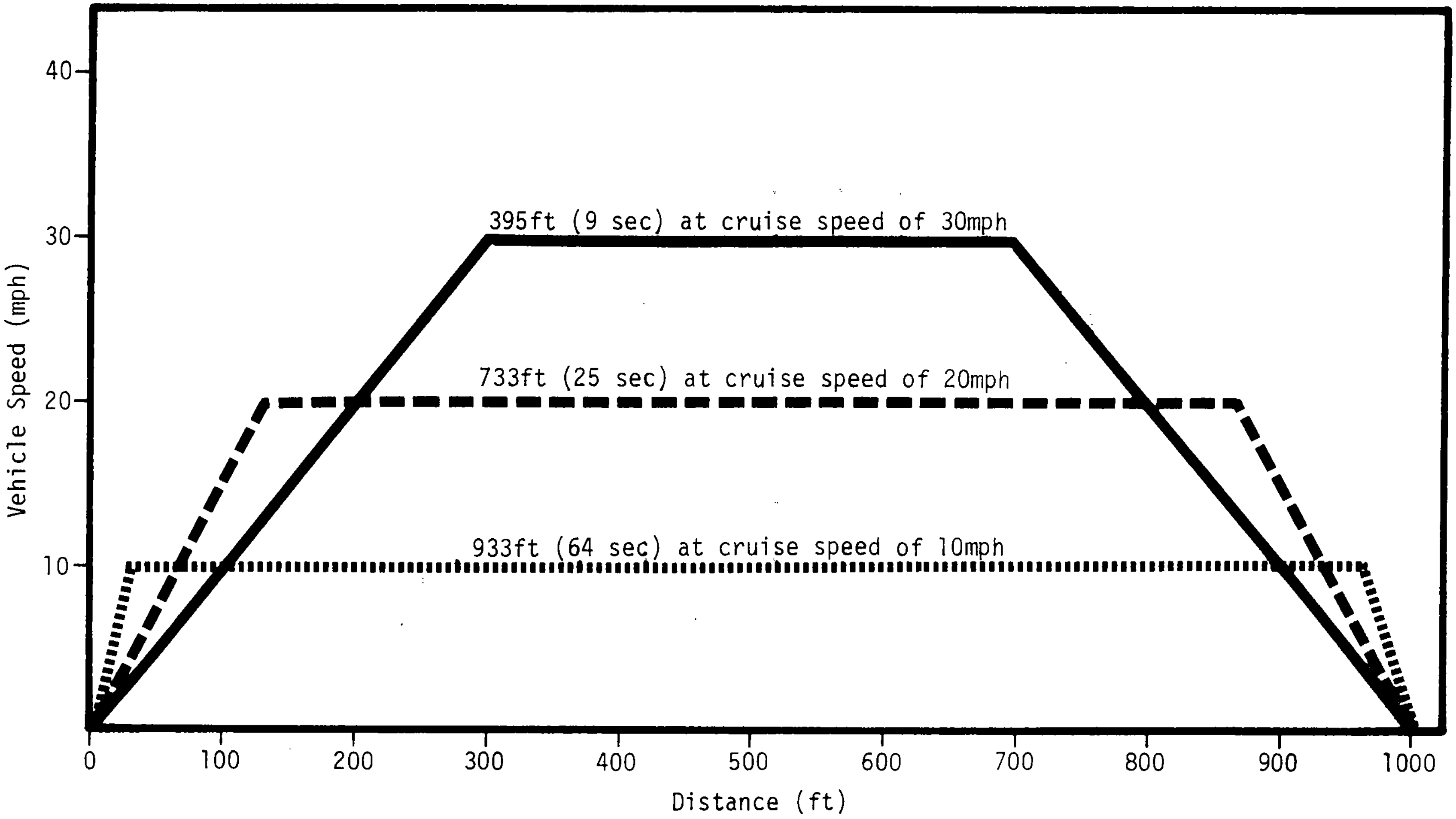
Within the constraints of acceleration rates and jerk rates outlined above, Table 5.3 indicates the travel time between stations spaced at various distances, assuming three typical cruise speeds. Travel time begins the instant the vehicle starts moving until it comes to a full stop at the end of its trip. A hypothetical velocity profile is indicated for illustrative purposes on Figure 5.1. In this example, the vehicle is assumed to accelerate at a uniform rate until it reaches cruise speed. It then travels at cruise speed until it must commence its uniform deceleration. It should be obvious from this sketch that it would be pointless to provide a high cruise speed capability for a system with stations spaced at intervals of much less than 1,000 feet. In such instances, the vehicle would hardly have time to reach cruise speed before it would have to commence deceleration.

When a trip involves a number of intermediate stops, the dwell time in the station will directly effect the time required to complete the trip. For AGT systems, depending on the size of the vehicle and the station configuration, dwell times in the range of 10 to 30 seconds would be appropriate. Using the travel times indicated in Table 5.3, and a 20 second dwell, the time required to complete a hypothetical trip in a vehicle capable of cruise speeds of 30 mph along a straight route 3,280 feet long with one intermediate stop at the mid point, would be .096 + .33 + .906 = 2.142 minutes or 128.5 seconds. This amounts to an average speed for the entire trip of 25.5 ft/sec or 17.4 miles per hour.

TABLE 5.3 AGT TRAVEL TIMES AT VARIOUS CRUISE SPEEDS AND STATION SPACINGS

Station Spacing		TRAVEL TIME IN MINUTES Cruise Speed 10 mph (16.1 Km/h)	Cruise Speed 20 mph (32.2 Km/h)	Cruise Speed 30 mph (48.3 Km/h)
Feet	Meters			
984	300	1.224	.754	.657
1312	400	1.597	.940	.781
1640	500	1.970	1.127	.906
1968	600	2.343	1.313	1.030
2297	700	2.715	1.499	1.154
2625	800	3.088	1.686	1.278
2953	900	3.461	1.872	1.403
3281	1000	3.834	2.059	1.527

Acceleration	2.5 ft/sec^2
Deceleration	3.0 ft/sec^2
Jerk	3.0 ft/sec^3



Note: The minor effect of jerk limits on travel time and distance is not reflected in this diagram. Uniform accelleration/decelleration rate of 0.1g (3.22ft/sec) has been assumed.

FIGURE 5.1: AGT VELOCITY PROFILE FOR 1000ft STATION SPACING

5.4 OPERATIONAL HEADWAYS

The time interval between leading and following vehicles which will insure safety without operational delays is commonly referred to as the minimum operational headway. At the two most sophisticated AGT systems in revenue service in the United States, these minimum headways are 15 and 18 seconds for Morgantown and AIRTRANS respectively.

Operational headway is defined as the average time separation between vehicles or trains which can be sustained on a continuing basis, i.e., for an hour or more of uninterrupted service. For example, an AGT system which operates in scheduled service such that 20 vehicles stop at a typical station each hour, would be achieving 3 minute headways. If more vehicles are added, this time interval may be reduced to the point where the minimum operational headway has been reached. Once this time interval between vehicles has been reached, the frequency of service cannot be increased by the addition of more vehicles, assuming service speed is unchanged.

For relatively simple systems with on-line stations, such as are contemplated for the DPM program, the minimum operational headways may be determined by adding the following time allowances:

- A safe time separation between vehicles to assure that a following vehicle can stop without colliding with the vehicle preceding it. Normal practice assumes a "brick wall" or instantaneous stop of the preceding vehicle and makes allowance, either through safety factors or direct calculation, for reaction times, vehicle overspeed and other tolerances. In addition it is necessary to allow for the uncertainty inherent in a block system, in which vehicle position accuracy is limited to the length of the block.

- A "station catch-up" time allowance to provide an additional interval of time to allow the preceding vehicle to move out of an on-line station before the following vehicle closes to within a safe separation distance. This includes both station dwell time and an allowance for the time the lead vehicle is decelerating and accelerating while the trailing vehicle is still at cruise speed.

- An additional cruise allowance for the length of the vehicles or trains being operated. At 30 mph for example, a four car traveling unit 100 feet long would require a 2.3 second separation to allow for train length.

Assuming acceleration and service braking rate of 2 ft/sec^2, minimum operational headways for systems with service speeds of 20 and 30 mph respectively have been calculated as follows for a two-block and a three-block signaling system to insure safe separation intervals between vehicles:

Components of Minimum Operational Headway (sec)

	Two-Block System		Three-Block System	
Service Speed	20 mph (29.3 ft/sec)	30 mph (44 ft/sec)	20 mph (29.3 ft/sec)	30 mph (44 ft/sec)
Time separation between vehicles	22.0	33.0	33.0	49.5
On-line station catch-up allowance (including 20 second dwell time)	34.7	42.0	34.7	42.0
Train length allowance (assume 50 ft length per train)	1.7	1.1	1.7	1.1
Total	58.4	76.1	69.4	92.6

Whether a two or a three block signaling system will be used will depend upon the control philosophy selected during the course of detailed design. Both approaches are in use in rail rapid transit systems today. With a two-block system, a following vehicle is required to come to a stop in the block immediately behind the one occupied by the lead vehicle. A three-block system requires a following vehicle to stop in the second block behind. As indicated in the above table, the three-block approach results in a greater time separation between vehicles. However it does not necessarily follow that a three-block system is inherently any safer. If close headway is an important consideration, there are a variety of other fully proven and conservative command and control techniques which may be considered during the course of detailed design. Among these is the use of shorter blocks which permit more precise position control, but which are somewhat more costly.

The foregoing simplified discussion of a complicated subject is intended to indicate that sustained operational headways in the range of 60 to 90 seconds are entirely feasible with traditional fixed block control systems.

5.5 TRAINABILITY

The need for vehicles to be coupled into trains depends largely upon the service frequency, as set by maximum wait time, the dynamic occurrence of demand and vehicle capacity. Figure 4.4 of Section 4.1, illustrates the capacities of the various sizes of travelling units available for the DPM Program. Of the currently available DPM candidate vehicles, only the Morgantown vehicles are designed not to be coupled into trains. The systems with small vehicles do not couple more than two cars. The medium and large vehicle systems are capable of operating as four car trains.

Currently available DPM vehicles are coupled using both towbars and automatic couplers. For example, the Duke vehicles by Otis/TTD and the Miami and Busch Gardens vehicles by Westinghouse are coupled using tow bars. At Miami one vehicle in the two-car train is a slave and not capable of being operated alone, having virtually no on-board controls or propulsion power collection equipment. Use of tow bars is feasible only if the consist size need not be varied regularly as in the case of permanently coupled car sets. Under such conditions there can be cost savings because each car will not be required to be implemented with separate controls and other equipment whose redundancy is provided by coupling cars together. Miami vehicles only have one propulsion motor per car with propulsion redundancy provided by permanently coupled two-car sets.

5.6 LINE AND SYSTEM CAPACITY

Line capacity depends upon the flow rate of vehicles (or trains) and vehicle capacity. Basically, it is the product of service frequency and vehicle or train capacity. Figure 5.2 indicates graphically the ranges of available line capacity for different size vehicles and train lengths. For purposes of their illustration, two minimum headways are shown, 100 seconds for large vehicles and 60 seconds for medium and small vehicles. As indicated, the 100 second headways, shown for large vehicles is based upon the conservative views of Westinghouse. On the other hand Vought considers 60 second headways feasible and their value has been used for the other medium and small vehicles as well. From this figure as well as Table 5.4, it will be noted that the maximum single lane line capacity would be somewhat over 13,000 passengers per hour. None of the capacities indicated make any provision for merging.

The headway of a single lane shuttle system is its round trip time. If a center bypass, such as at Fairlane Town Center, is provided, then two vehicles or trains may travel back and forth doubling the shuttle capacity. The total system capacity of a shuttle link is twice that of its line capacity, i.e., capacity in passenger-trips per hour. Shuttle capacity, therefore, is a function of shuttle length and average speed.

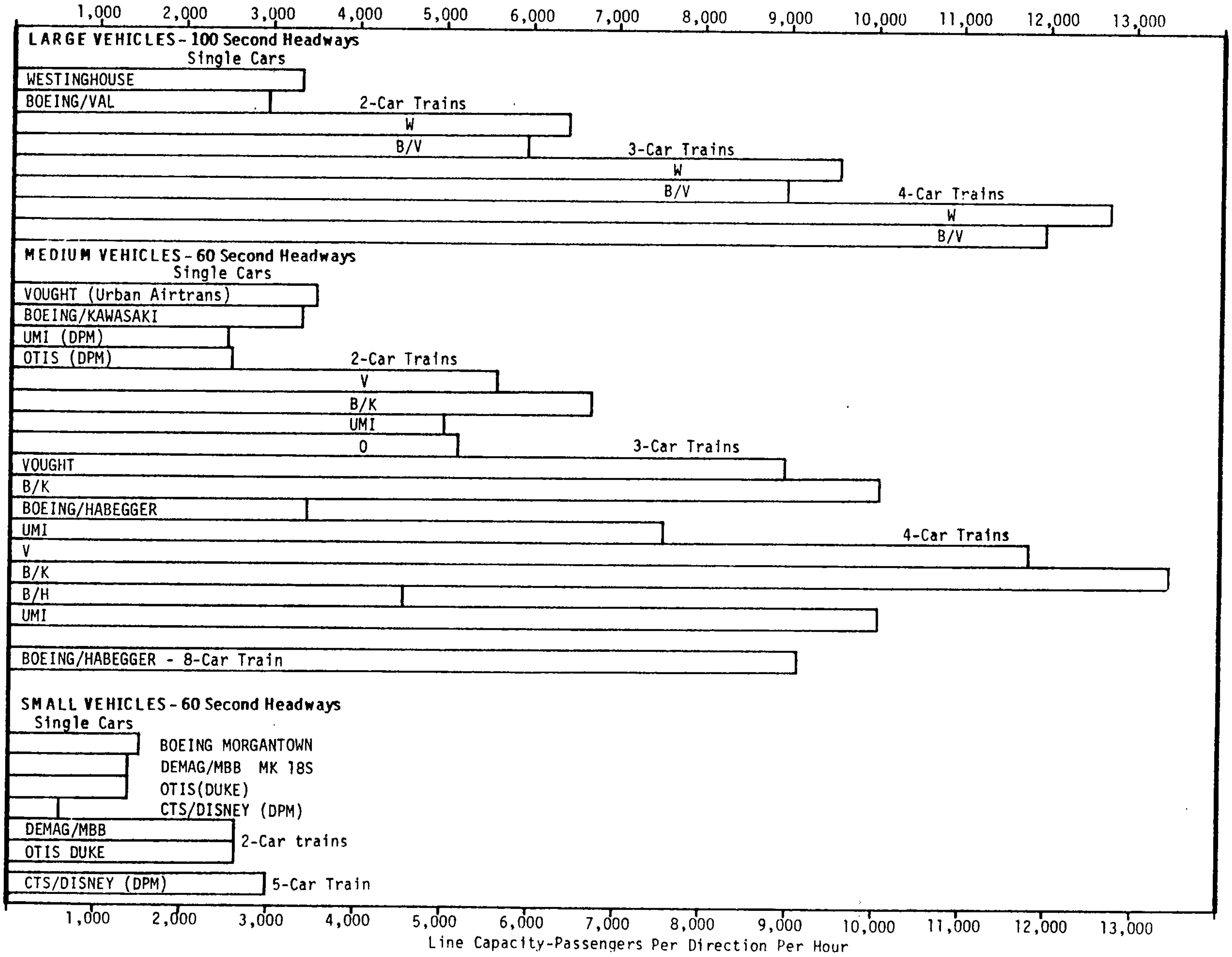


FIGURE 5.2: LINE CAPACITIES OF POTENTIALLY AVAILABLE DPM VEHICLES AND TRAINS OF VEHICLES (BASED ON 20% SEATED, 80% STANDING)

TABLE 5.4 RANGES OF POTENTIALLY AVAILABLE LINE CAPACITIES

	Oper. Head-way	ONE-CAR TRAIN				TWO-CAR TRAIN				THREE-CAR TRAIN				FOUR-CAR TRAIN			
		Veh.Cap.		Line Cap. Per hour		Veh.Cap		Line Cap. Per hour		Veh.Cap		Line Cap. Per hour		Veh.Cap		Line Cap. Per hour	
		Case 1	Case 2	Low	High	Case 1	Case 2	Low	High	Case 1	Case 2	Low	High	Case 1	Case 2	Low	High
LARGE VEHICLES																	
Westinghouse	100*	84	92	3024	3312	162	180	5832	6480	240	267	8640	9612	318	354	11448	12744
Boeing/VAL	100	75	83	2700	2988	150	166	5400	5976	225	249	8100	8964	300	332	10800	11952
MEDIUM VEHICLES																	
Vought (Urban Airtrans)	60*	53	59	3180	3540	84	94	5040	5640	136	149	8160	8940	178	196	10680	11760
Boeing/Kawasaki	60	52	56	3120	3360	102	112	6120	6720	156	168	9360	10080	204	224	12240	13440
Boeing/ Habegger (II)	60	No single car ops.				No 2-car trains.				51	57	3060	3420	68	76	4080	4560
															8-CAR	TRAIN	
														136	152	8160	9120
Univ. Mobility (DPM)	60*	38	42	2280	2520	74	84	4440	5040	114	126	6840	7560	152	168	9120	10080
Otis (DPM Option)	60	39	43	2340	2580	78	86	4680	5160	(Two-car trains only)				--			
SMALL VEHICLES																	
Boeing (Morgan-town)	60	23	25	1380	1500	No training capability				--				--			
DEMAG/MBB (MK 18S)	60	20	22	1200	1320	40	44	2400	2640	(Two-car trains only)				--			
Otis (Duke)	60	20	22	1200	1320	40	44	2400	2640	(Two-car trains only)				--			
CTS/Disney (DPM)	60	45	50	540	600										5-CAR	TRAIN	
														45	50	2700	3000

Case 1 - 33% Seated and 67% Standing.
Case 2 - 20% Seated and 80% Standing.

* Manufacturer's recommendation/estimate

5.7 TURNING RADIUS

There are two limitations on turning radii: one which is a characteristic of the equipment above and another which depends upon not exceeding an allowable lateral g force for passenger safety and comfort. The latter is not a function of the type of equipment and is generally larger than equipment related turning radius. Therefore, the minimum turning radius is considered to be the shortest radius the vehicle is capable of negotiating at very slow speeds. This is important because it governs the size of turnarounds, turnout curvatures, and other curves in stations and yards where speed is slow. The minimum turning radii for the candidate DPM systems are as follows:

	Feet
Large Vehicles	
Westinghouse Eagle I	90
Boeing/VAL	100
Medium Vehicles	
Vought (Urban AIRTRANS)	70
Boeing/Kawasaki	82
Boeing Habegger II	66
Univ. Mobility DPM	50
Otis (DPM Option)	60
Small Vehicles	
Boeing (Morgantown)	30
DEMAG/MBB (MK 18 S)	100
Otis (Duke)	60
CTS/Disney (DPM)	20

5.8 SWITCHING, MERGING AND CROSSOVERS

Switching

With the exception of simple shuttle systems such as the arrangement at the Tampa International Airport, AGT installations require some form of switching. Generally switching functions fall into two categories as follows:

a) Occasional or emergency switching. This includes provision for switching vehicles off of the main line into a maintenance area, either in the event of a failure or for scheduled maintenance. It is also used for adding and removing vehicles to a loop or other route as travel demand fluctuates during the day. Similarly cross-over switches to permit vehicles to move onto an adjacent guideway under special circumstances, are considered in this category.

b) Operational switching involves the regular use of switches in normal vehicle operation. At AIRTRANS and Morgantown, vehicles must switch each time they enter a station and at the Atlanta Airport, switches are used at the ends of the line where vehicles reverse direction and cross over to the opposite guideway lane.

UMTA's current policy is to discourage the use of operational switching for the Downtown People Mover program. This is in keeping with the original Congressional initiative which encouraged the deployment in one or more cities of the simplest type of AGT systems, classed as Shuttle and Loop Transit.

Occasional switching can be accomplished by either a slow speed switch or a transfer table, such as Westinghouse installed at the Sea-Tac Airport. Here a vehicle moves along the loop onto the table. The table moves laterally carrying the entire vehicle until it mates with a section of guideway in the maintenance facility. The table has two sections of guideway such that the empty section acts as a filler so that service does not have to remain interrupted on the loop. The transfer table at

Busch Gardens is much simpler and has only one guideway section. Therefore, interlocks are required to stop any approaching vehicle should the table not be inserted with the guideway in a locked position.

Switching equipment may be on-board the vehicle, track mounted based or a combination of both. In a totally track based switch, the vehicle is simply diverted in one or the other directions by guideway elements. The Westinghouse switch illustrated in Figure 5 is typical of this type.

In an on-board switch the active elements and decision of direction are vehicle based. In a steered concept, such as Morgantown, the vehicle is not captured by a guidance rail on the guideway, but steers against either the right or left wall of the guideway. So long as traction is maintained there is no danger of collision with the switch frog. Other types of vehicle-based switches have active elements such as a switching wheel (or wheels) which lock onto a left or right guideway switching rail. In such cases, the vehicle is said to be captured.

Vehicles may have on-board switching wheels which consistently cause the vehicle to follow either the right or the left side of a switch anywhere in the system. In this case, the switching wheel is always set for switching and does not move. This is done at Duke University to insure vehicles cannot use the wrong path in a diverge at Duke Hospital North. A similar procedure was used by Ford at Fairlane Town Center where two vehicles, in a shuttle configuration, bypass each other at the center of the route where a double guideway is provided.

The switching capabilities of potentially available DPM equipment are as follows:

Manufacturer	Type of Switch	Status*
Westinghouse	Transfer Table Track-based	D T
Boeing/VAL	Track-based	T
Vought (AIRTRANS)	On-board, captured	D
Boeing/Kawasaki Boeing/Habegger II	Track-based	T
Univ. Mobility (DPM)	Transfer Table	D
Otis (DPM)	On-board, captured	T
Boeing (Morgantown)	On-board, not captured	D
Otis (Duke)	On-board, captured	T
CTS/Disney (DPM)		
DEMAG/MBB	On-board, captured	T

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* D - Demonstrated in regular passenger service.

T - Tested in full scale operation, but not yet proven in regular passenger service.

Merging

Very few of the existing AGT systems require operational merging and diverging. Only the AIRTRANS and Morgantown systems require merging and diverging as part of regular operations. Otis/TTD has tested their equipment in merging and diverging both at Transpo 72 and at their test track. Westinghouse has not yet operated a system with operational switching, but has one under construction at the new Atlanta Airport. However, this system will not involve merging and diverging. The DEMAG/MBB test track at Hagen, West Germany, includes both merges and diverges. They have carried out many tests of such operations, however, have not yet proven the procedures in regular passenger service. All of the Universal Mobility, Inc. installations have been simple one-way loops without any merging or diverging.

Crossovers

Currently, there are no existing operational AGT systems or known DPM equipment available where at-grade crossovers are allowed. However, some preliminary designs have been proposed. The CVS Personal Rapid Transit System in Japan included an at-grade crossover in its extensive test track which has been dismantled.

5.9 RELIABILITY/DEPENDABILITY

The general subject of system reliability and dependability has been somewhat confusing because of the many definitions currently in use. Each AGT system operator uses a different method to measure reliability, with the result that there is no precise way to compare the performance of any two systems. Nevertheless, where dependability of service is important, as is the case at airports, the system operators generally have developed effective techniques for recording and measuring how well their systems are performing.

The most commonly used measures of reliability/dependability are summarized as follows:

- System Availability. This is the ratio of actual system operating time to total system scheduled time. Stated another way, it is the percentage of system uptime to system uptime plus downtime. Because minor service interruptions are of little consequence, it is customary to ignore system failures which can be corrected in two or three minutes.

- Fleet Availability. This is the ratio of the number of vehicles available for use in a specified period of time to the number of vehicles required to provide the capacity and level of service needed. The average fleet availability for a day would be the ratio of actual vehicle operating hours to scheduled operating hours. For example, Figure 5.3 indicates the required distribution of vehicle operations during a typical weekday for the Jacksonville DPM Proposal alternative. As indicated, this schedule requires 178.5 vehicle operating hours per day. If on a particular day only 17 of the required 19 vehicles were available for service, then the system would be short 5 vehicle operating hours for that day. This would result in a fleet availability of 173.5 ÷ 178.5, or 97.2 percent.

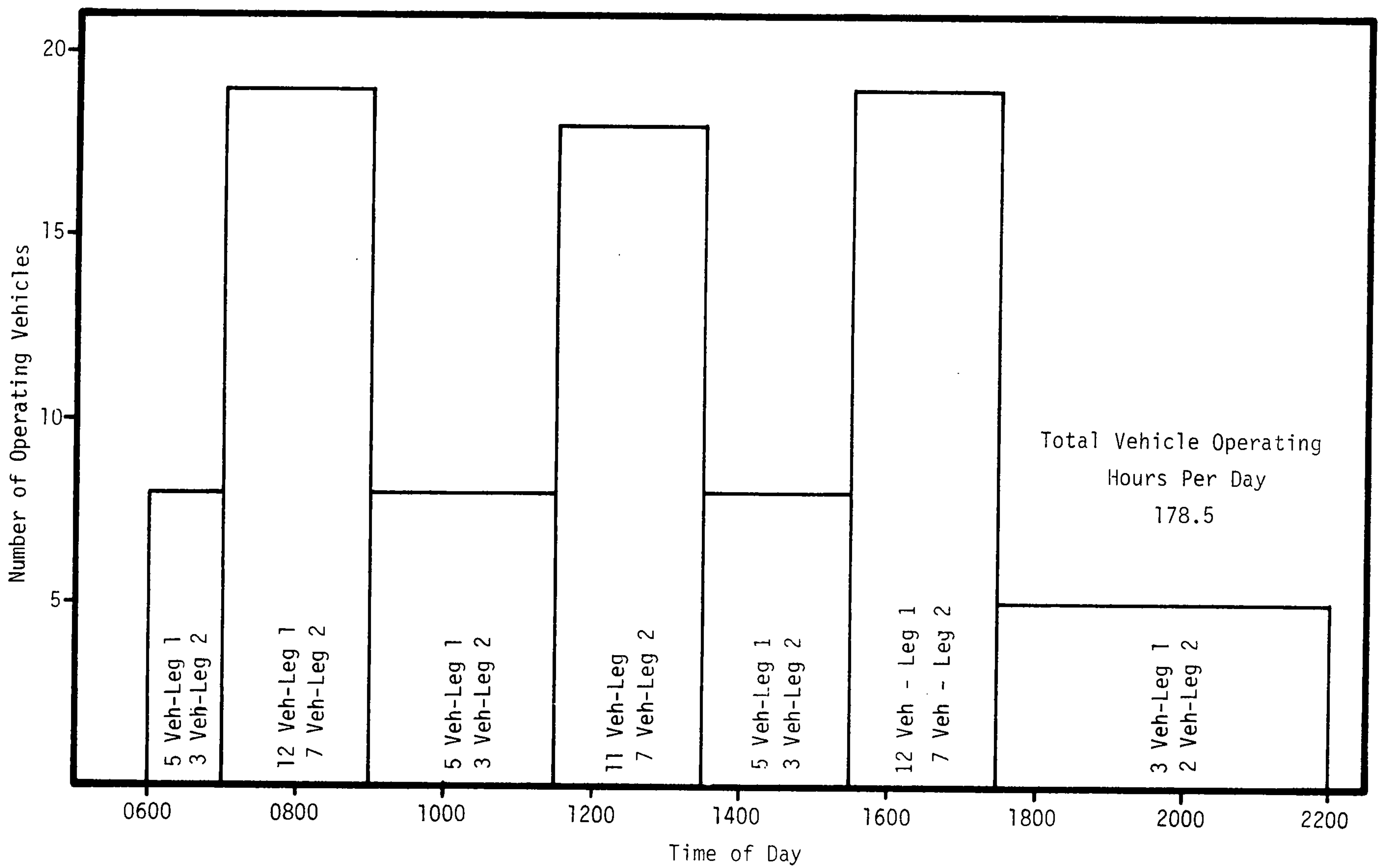


FIGURE 5.3: WEEKDAY DPM VEHICLE UTILIZATION 1995 OPERATIONS
Proposal Alternative - Scheme 2

- Trip Reliability. This is the ratio of the number of vehicle trips completed on time (within a reasonable tolerance) to the total number of trips started. For example, if one of the legs of the Jacksonville DPM requires a 20 minute round trip time, 12 vehicles should be dispatched at 1.67 minute intervals to insure uniform distribution around this leg. The central control computer could readily keep track of the number of trips which deviate from such a schedule by more than say one minute each.

- System Dependability. This is a composite measure of overall reliability. It is the product of the three foregoing measures, i.e., System Availability X Fleet Availability X Trip Reliability. Essentially, System Dependability reflects the probability that the average passenger will be able to board a vehicle and successfully reach his destination with no more than a nominal delay, say two minutes.

Those AGT systems which have reached a steady state of operation have achieved a high level of reliability. This has been an evolutionary process, as indicated by Figure 5.4 which shows how much more dependable the Morgantown system became over the past three years of operation by the University. During the period September 1977 - June 1978, average system availability was 97.1 percent. AIRTRANS had a somewhat higher availability for 1978, averaging according to a recent assessment by the DOT Transportation System Center, 99.3 percent. However, service interruptions of 9 minutes or less were ignored.

At SEA-TAC, the second of the Westinghouse's airport systems, overall system availability averaged about 99.7 percent during 1978, with all service interruptions regardless of duration counted. In the South loop, which is the most heavily traveled, availability averaged about 99.9 percent.

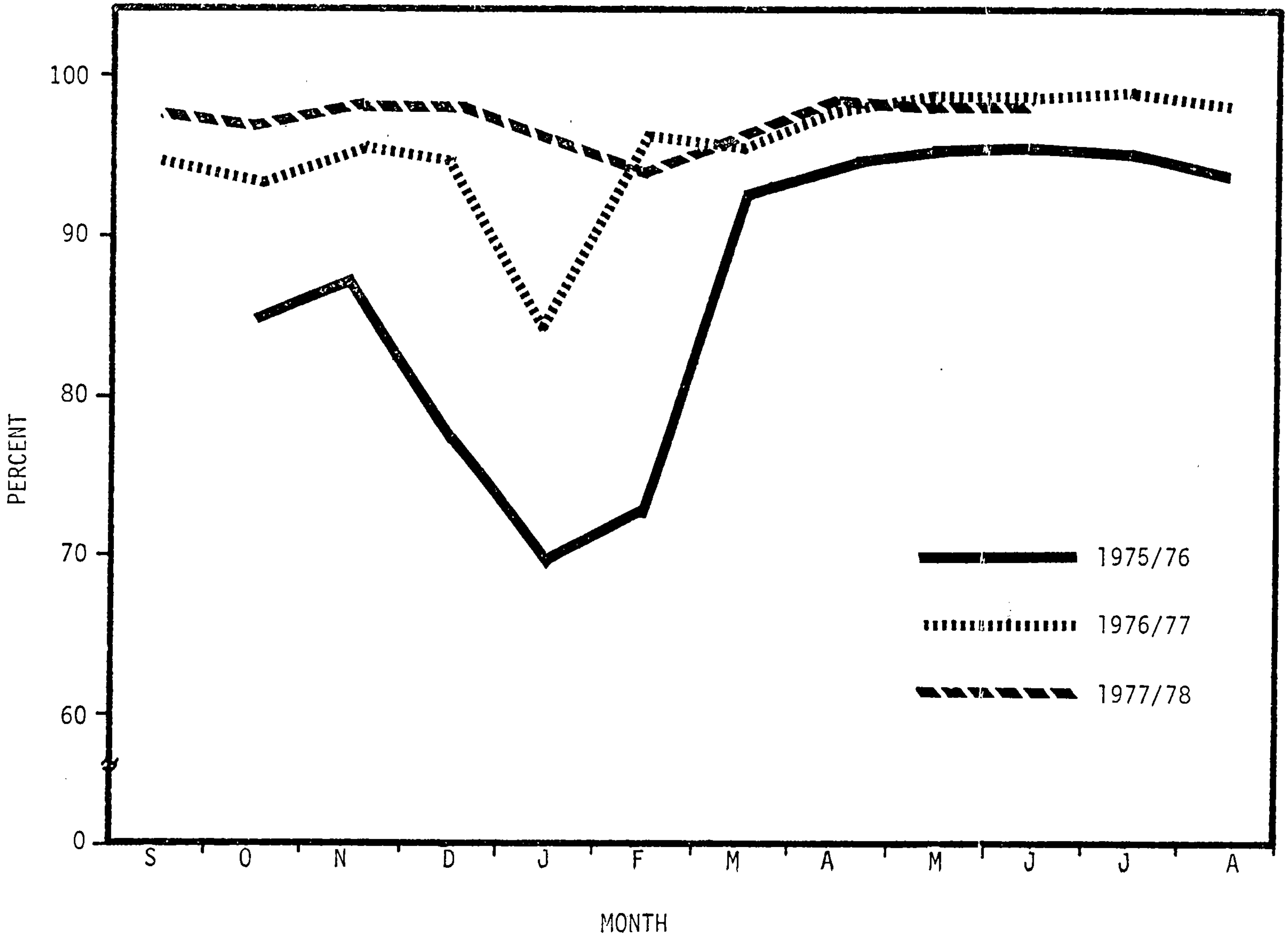


FIGURE 5.4: MORGANTOWN PEOPLE MOVER MONTHLY SYSTEM AVAILABILITY BY OPERATIONAL YEAR

Westinghouse is sufficiently confident of its ability to achieve a high level of availability, that new contracts to install, operate and maintain airport shuttle systems similar to that at Tampa, specify a 99.65 percent availability, with severe penalities for failure to maintain this level. For these contracts, service interruptions, which can be corrected in three minutes or less, are not counted as downtime. Also, a leg (consisting of two simple shuttles) is considered to be available if one channel is operating during periods when passenger demand does not require the two shuttles to be in service. In this regard, Westinghouse would only enter into performance guarantees for systems on which they have responsibility for operations and maintenance.

To achieve a high level of service availability requires a combination of well designed and highly reliable equipment, together with a well trained and effective maintenance organization. Of particular importance in minimizing the duration of service interruptions due to equipment malfunction, are well planned procedures for remedial action. At Dallas/Fort Worth, for example, a large system with over 13 miles of guideways, emergency repair personnel or "rovers" are positioned at strategic points so as to be able to reach disabled vehicles in a minimum amount of time upon radio command from the control center. Depending upon the guideway configuration which is ultimately selected for the Jacksonville DPM, it will probably be necessary to maintain one or more emergency crews in a state of readiness during periods of heavy travel, so as to be able to correct failures in a minimum amount of time. Since most of the guideways at Jacksonville will be elevated, special vehicles equipped with lifts or hoists will be necessary to permit emergency personnel to reach the vehicles expeditiously. Depending upon the design selected for the river crossing, additional features may be necessary to insure that a vehicle stalled at midspan over the St. Johns River can be reached by emergency personnel.

It is obvious that the more complex the system design, the more opportunities there are for equipment malfunction. Also, given the higher probability of failure with a complex system, a greater number of emergency maintenance personnel will be required to insure that such a system can achieve a high level of system availability. This entire subject will require careful study during the definitive design phase of the Jacksonville DPM project, when a number of important trade-offs will have to be made. For example, a simple turnaround at the end of one of the legs would require no switching, thus reducing the probability of malfunction. However, more space would be required to permit the vehicles to turn around. Similarily, the advantages of minimizing transfers must be evaluated in relation to the additional sophistication and consequent increase in the probability of equipment malfunction which would be involved in connecting the two legs by means of operational switches.

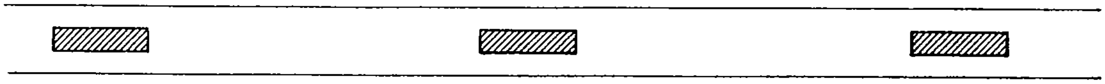
5.10 OPERATING CHARACTERISTICS FOR JACKSONVILLE

Once the optimum locations of stations and guideways have been selected from the point of view of anticipated patronage, and after estimates have been made of the peak volume of passenger traffic, the operational characteristics of the system can be developed. Here the objective is to provide the highest level of transportation service possible at a cost which is reasonable and affordable. Since both capital and the operations and maintenance costs tend to increase with the degree of complexity of the system, it is important to keep the operating characteristics as simple as possible. Additionally, the overall reliability/dependability of an uncomplicated system may be expected to be higher.

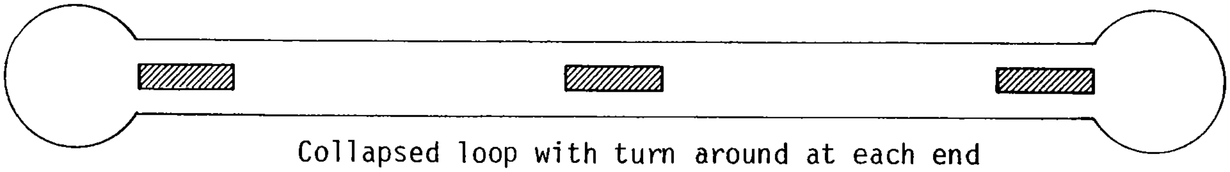
The system configurations under consideration at Jacksonville involve the movement of passengers in essentially four directions from the center of the downtown area at Bay and Hogan Streets. This can be accomplished operationally in a variety of ways, as shown on Figure 5.5. A simple shuttle, with a single vehicle or train of two or more vehicles moving back and forth on an exclusive guideway, would be the least complicated. Conversely, a pinched loop with redundant switch-backs would be the most complicated, but would at the same time permit the greater degree of operational versatility.

Depending upon the level of service desired, the four legs of the Jacksonville DPM system can be operated separately. Alternatively, they can be combined into two separate routes, such as a North-South and an East-West leg, involving a transfer at the point where they cross. A third possible arrangement would be to provide for switching between these two legs, so as to minimize the necessity for transfers.

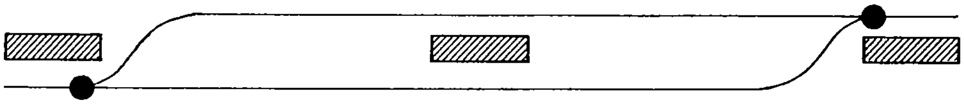
Based upon the projected 1995 patronage for the original DPM Proposal Alternative, a preliminary operational analysis resulted in the following:



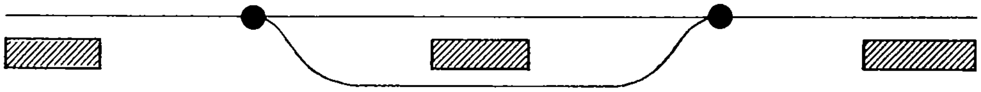
Simple double shuttle with intermediate stop



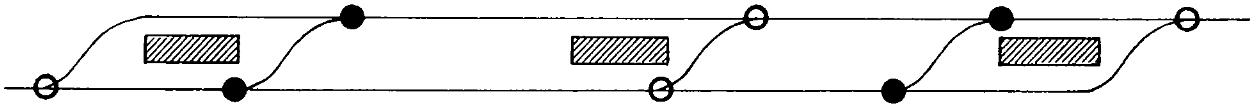
Collapsed loop with turn around at each end



Pinched loop with switch-back at each end



Complex shuttle with intermediate by pass



Pinched loop with redundant switch-backs at each end
and intermediate cross over for emergency use

Legend

▨ Stations

● Operational Switches - used each trip

○ Switches for occasional or emergency use

FIGURE 5.5: ALTERNATIVE OPERATIONAL CONFIGURATIONS

- Round trip time for the North-South leg, including stops at 6 intermediate stations - 20 minutes.

- Round trip time for the East-West leg, including stops at 4 intermediate stations - 12.8 minutes.

- To move the projected maximum of 1,800 passengers per hour between the heaviest traveled link in the North-South leg requires 36 vehicle round trips (at 50 passengers/vehicle). Since each vehicle can make 3 RT/hour, 12 vehicles are required.

- To move 1,650 passengers per hour along the East-West leg requires 33 vehicles. Since each vehicle can make 4.7 RT/hour, 7 vehicles are required.

- Average system speed, including station stops, slowing down for turns, etc. - 15 mph.

- Service frequency during peak periods:
  North-South Leg - Every 100 seconds
  East-West Leg - Every 110 seconds

To accommodate the estimated 1995 weekday ridership of 64,800, and at the same time provide an acceptable frequency of service during off peak hours, the vehicle fleet would have to operate 178.5 vehicle hours per day, as shown previously on Figure 5.3. For this level of operation, Figure 5.6 shows the estimated distribution of DPM system ridership as compared to the capacity of the system. During the off peak hours, the frequency of service on the two legs would be as follows:

	0600-0630 0900-1130 1330-1530	1730-2200
North-South Leg	4 minutes	6.7 minutes
East-West Leg	4.3 minutes	6.4 minutes

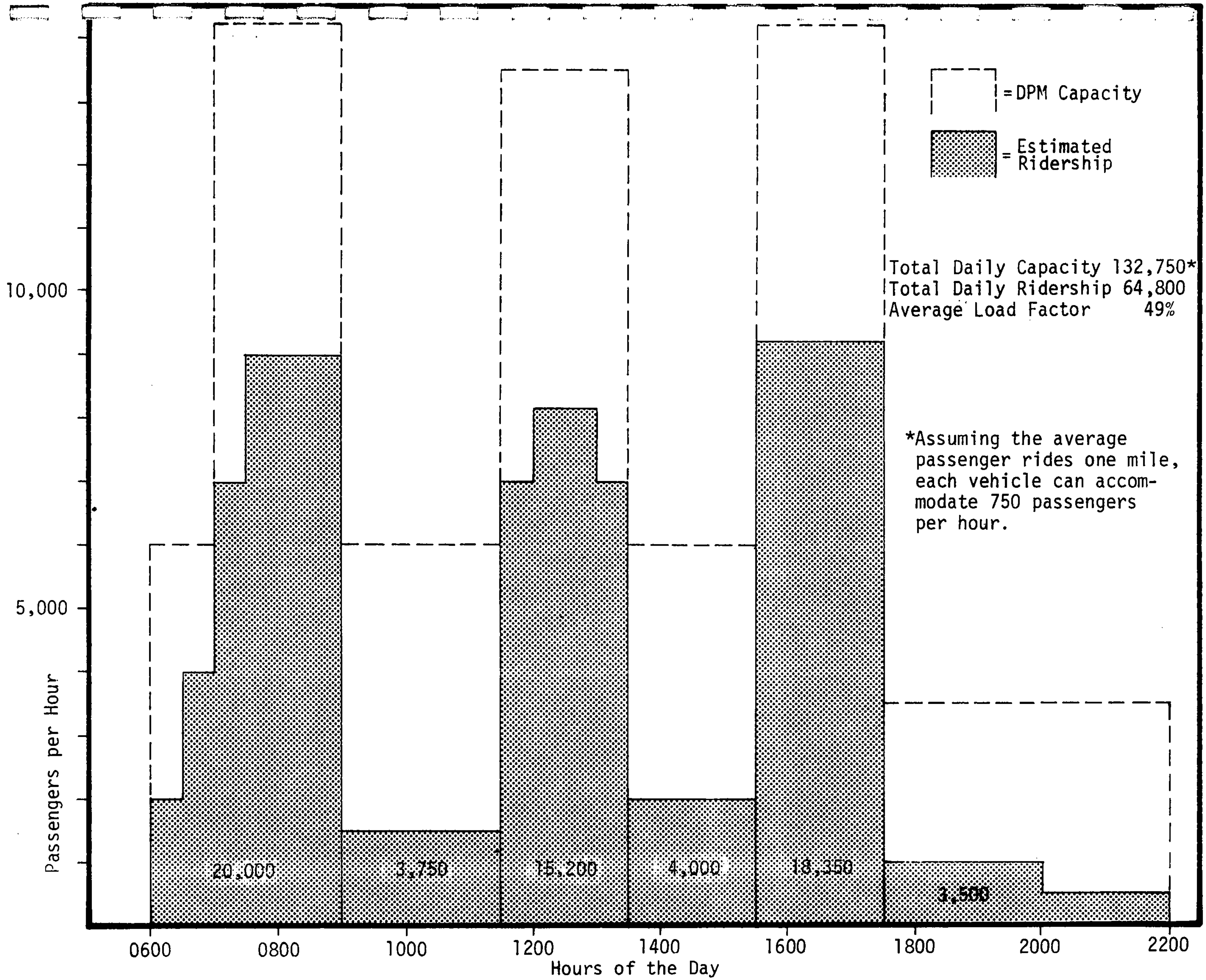


FIGURE 5.6: WEEKDAY DISTRIBUTION OF DPM 1995 RIDERSHIP AS RELATED TO SYSTEM CAPACITY
Proposal Alternative - Scheme 2

Actual operating characteristics for Jacksonville will, of course, differ somewhat, depending on the final system configuration and level of service which is incorporated into the system design. However, the foregoing is typical of the kind of transportation service which can be provided within the current state-of-the-art for downtown Jacksonville.

6.0 SYSTEM SAFETY AND SECURITY

Automated Guideway Transit systems have achieved a commendable safety record. During the past three years, 1976-1978, AGT systems in the United States have carried between 40 and 50 million passengers per year with no passenger fatalities, and only a few superficial injuries which were suffered when two AIRTRANS vehicles collided following a system malfunction involving moving of a vehicle under manual control. In September 1978, AIRTRANS carried its 20th million passenger with a commendable safety record.

Understandably, the inherent safety of an automated driverless vehicle system such as is proposed for the Jacksonville Downtown People Mover, is of overriding importance to all concerned with planning and implementing the project. Accordingly, it is considered appropriate to review the safety criteria which will be applicable to the design of ultimately selected systems. It is also important to review how component and equipment failures can be controlled and to indicate how the security of passengers and employees can be assured.

6.1 SAFETY CRITERIA

The safety criteria discussed below are based upon existing conventional transit practice. In all cases, the objective of these criteria is to provide safety at least equivalent to that of conventional transit systems. This means that vehicles are permitted to proceed only when it is known that it is safe to do so. Otherwise, an alternate safe course of action is enforced; usually this requires a vehicle to stop.

It must be reemphasized that in the development of a new transit system, particular attention should be given to any safety-related system elements which differ in philosophy, concept, or hardware from those currently in transit use. The attention given to those new elements should involve the analysis and the implementation of the concepts, as well as extensive testing of the elements on a test track and ultimately in an operating transit environment. This procedure will be necessary to ensure safety performance in the new system comparable to that provided by the existing equipment, criteria, and practices.

The Safety Criteria for AGT systems is summarized as follows:

a. Collision Avoidance

The criterion with regard to collision avoidance is that the vehicles must not under any circumstances collide with each other or with elements of the guideway.

If the "brick wall" hypothesis is assumed in which a lead vehicle can stop instantly, as though it has collided with a "brick wall," an instantaneous stop of the lead vehicle requires that the following vehicle(s) be able to stop safely without colliding with the stopped vehicle ahead.

Head-on collisions shall be prevented by assuring that all vehicles in a guideway lane are traveling in the same direction. Vehicle movement against the current of traffic will be prohibited.

Side-swipe collisions shall be prevented by safely controlling the presence and movement of all vehicles on the approach to a switch. Consideration must be given to the overhang of vehicles at both merge and demerge areas.

Rear-end collisions shall be prevented by assuring that there are no vehicles or obstructions ahead of any vehicle within a safe stopping distance. In the event that a vehicle approaches within a safe stopping distance of a vehicle ahead, emergency braking of the trailing vehicle must be assured.

b. Overspeed Protection

The overspeed protection system enforces the vehicle speed commands which have been sent to the vehicle by the collision avoidance system. It accomplishes this by using the command signals and a signal representing actual vehicle speed as inputs and generating a signal that holds off the emergency brakes unless the maximum safe speed is exceeded.

The criterion with regard to overspeed protection is that the vehicles must not under any circumstances exceed the maximum safe speed. This is the value of speed used in the following section to determine the safe braking distance. A speed in excess of that which is safe could allow the vehicle to overturn due to centrifugal forces associated with the transit of curves or be unable to negotiate a switch safely, or it could cause a rear-end collision if the vehicle was unable to stop in the clear distance ahead.

The maximum safe speed is the function of the vehicle location and the factors cited below. The governing factor is the one which results in the lowest maximum safe speed. The factors are:

- Civil restrictions due to curves, grades, and slow-speed turnouts or switches to assure dynamic stability,

- The assured clear distance ahead of the vehicle, and

- An arbitrary maximum speed of the system.

In order to guarantee that the maximum safe speed is never exceeded, it is necessary that the emergency brakes be applied at some speed lower than the maximum safe speed and/or at a time (lead time) prior to the attainment of the maximum safe speed.

c. Emergency Brakes

The emergency brake system receives a signal from the overspeed protection system (also from other sources) to hold off the emergency brakes as long as the vehicle speed is below the initiate-emergency-brakes speed.

The criterion with regard to the emergency brakes is that the vehicle emergency brakes shall operate safely under all conditions. In a well designed transit system, emergency braking will not be required when the system is functioning properly. However, emergency braking must be guaranteed when other portions of the system have failed and emergency braking is needed.

Safe emergency braking requires that a safe braking distance be maintained at all times. This safe braking distance must be maintained under "worst case" conditions. Safe emergency braking also requires that the controls for the emergency braking initiate braking action while the distance or velocity profile is still adequate for safety. In addition, it must be guaranteed that the braking force necessary to stop within the braking distance actually occurs when emergency braking is commanded.

During automatic operation, the emergency brakes are withheld only when circuits are activated indicating that it is safe to proceed. These activating circuits must be safe even with multiple failures. That is, the activating circuits must provide an output only when it is safe for the vehicle to proceed. The safety of the activating circuits must not be dependent upon the presence of electrical, hydraulic, or pneumatic power sources.

When the emergency brakes are applied, it is required that tractive effort (propulsion) be removed unless it can be guaranteed that the braking effort will be sufficient to overcome the full forward traction effort of the propulsion equipment and still stop the vehicle within the safe braking distance.

d. Switch Operation

The criterion with regard to switch operation is that vehicles shall merge and demerge safely under all conditions. This applies to guideway-mounted switches and those on board the vehicles.

Safe switch operation requires that vehicles be protected against the following:

- Collisions at merges and demerges
- Entering a switch which is not positioned safely for passage of the vehicle
- Switch movement when a vehicle is traversing the switch or after a vehicle has beem committed to enter a switch but has not yet passed through the switch.

Collisions at merges and demerges are prevented by defining a switch area which includes the switch and enough guideway adjacent to the switch to provide vehicle clearances. The interlocking must be such that when one vehicle has been authorized to enter the switch area, no other vehicle is allowed to enter the switch area until the first vehicle has departed.

Another function of the interlocking is to allow a vehicle to enter the switch area only when the switch is positioned so that the vehicle can proceed safely. Thus, the switch must be in a safe position, power removed from the switch mechanism, and the switch mechanism locked before a vehicle is authorized to enter the switch area.

e. Proper Direction of Travel

The criterion with respect to proper direction of travel is that all vehicles must travel only in the correct direction. This requirement is necessary to protect against head-on collisions and collisions caused by a vehicle backing up.

It is necessary that all vehicles in a continuous section of guideway travel in the same direction. This must be guaranteed. If it is necessary to change the direction of travel in a section of guideway, it is necessary that the guideway section be empty and that no authorization for entrance into it has been given. The signals (gates) at each end of the section must be set to prevent the entry of any vehicle into the section.

f. Door Safety

The criterion with regard to door safety is that operation of the vehicle and/or station doors must not endanger the passengers. The doors must not crush a passenger when they close. In addition, the vehicle doors and the station doors (if used) must open only when a vehicle is properly positioned in a station. The vehicle must be allowed to proceed only when all vehicle doors are closed. Similarly, vehicles in a guideway section adjacent to a station should be allowed to proceed only when the station doors are closed.

g. Vehicle and Station Emergency Evacuation Procedures

The procedures must include the manner of their implementation. Because of the diversity of the AGT systems, the evacuation procedures must be system specific. Evacuations could be necessary because of fire, flooding, storm damage, bomb threats, civil disturbance in addition to equipment malfunction.

With regard to the vehicles, it is assumed that evacuation will be necessary only if the vehicle is disabled or otherwise unable to proceed. If the vehicle is not disabled, there are situations where it would not be possible to move a vehicle because of an obstruction on the guideway or because of another vehicle disabled ahead of the one in question.

h. Site Hazard Protection

The criterion with regard to site hazard protection is that all persons within the transit system must be safeguarded at all times. This includes passengers, system employees, and even unauthorized persons such as trespassers. The site hazards include those on board the vehicles, in the stations, along the guideway, in the station parking lots, and the maintenance facilities.

In the stations, a major safety hazard in current systems is the stairways. Other passenger and employee needs in the station include the following:

- Protection from falling or being pushed onto the guideway; this could be provided by station doors or gates
- Protection from falling caused by slippery floors, and/or debris on the floor

- Adequate lighting

- Clear, unambiguous displays and fare collection devices, so that an orderly passenger flow occurs, even with persons not familiar with the system

- Security from persons who might engage in robbery, assault, or vandalism; the same as in a vehicle.

i. Fire Hazards and Materials Flammability

To minimize the risk of injury to passengers as a result of fire onboard a vehicle, careful attention must be given to the selection of materials from which the vehicles are fabricated. In general, flammable materials, or those which give off noxious fumes when heated to high temperatures, such as polyvinyl chloride, polyurethane foam, polystyrene foam or foam rubber, will be excluded by the vehicle specifications. Thus the materials used are either inherently non-combustible or treated to reduce their flammability. Stainless steel and aluminum have been used extensively for transit vehicle bodies but the use of fiberglass and plastics should be treated with caution.

Notwithstanding careful selection of the materials of construction, the substantial amount of electrical equipment on an AGT vehicle does involve some risk of fire resulting from short circuits or other malfunctions. Thus provision must be made for effective detection of any fire on board a vehicle as well as means for suppression. This is particularly important at Jacksonville where the possibility exists that a vehicle fire might occur on the St. Johns River crossing where emergency evacuation might be awkward. Thus the vehicle specifications should require thermal overload protection as well as temperature sensors to warn of overheating. Additionally, it is customary to provide dry powder type fire extinguishers in the passenger compartment. Removal of such extinguishers from their mounting location should activate an alarm in the control center as well as an audible alarm on the vehicle.

Under normal circumstances, when a fire is detected aboard a vehicle, the Central Control Operator will route it to the next station for evacuation. If the vehicle cannot be moved, then emergency evacuation of passengers will be necessary. How this is accomplished will depend on the characteristics of the vehicle-guideway system selected for Jacksonville. However the specifications should require that passenger evacuation be accomplished by one of the following means:

a) Emergency doors may be provided at the ends of vehicles to permit discharge of passengers onto the guideway or another vehicle.

b) In the event of evacuation onto the guideway, it should have side walls 18 inches high or a solid surface without open areas.

c) An emergency walkway may be provided.

Whatever method is selected, a crush loaded vehicle should be evacuated within two minutes. Further, the evacuation technique must not expose passengers to risk of falls, high voltage or injury from street traffic.

j. Recovery of Disabled Vehicles

The criterion with regard to the recovery of disabled vehicles is that the procedure must be performed without endangering the passengers in the system or the operating personnel. The procedure and the equipment must permit the safe recovery of a disabled vehicle at any point in the transit system. This is particularly important at Jacksonville, where failure of a vehicle in that portion of the guideway which is over the river, might present special problems.

A disabled vehicle can be recovered by pushing or pulling with a recovery vehicle or with another passenger vehicle. However, to do this requires that some safety features normally enforced be overridden. For example, to allow an operating vehicle to approach a disabled vehicle to push or pull it, requires that a portion of the collision avoidance system be overridden.

This override must be carefully applied so that the override does not remove the collision avoidance protection for a period of time longer than necessary. In addition, procedures must guarantee that the vehicles continue to remain protected against collisions.

k. The Effects of the Loss of Prime Electrical Power

The criterion with regard to the loss of prime electrical power is that such a loss shall not degrade the safety of the transit system or create an unsafe condition.

When prime electrical power is lost, emergency lighting must be provided in the vehicles and in the passenger stations. It is desirable that the command and control equipment continue to operate when a power outage occurs.

When prime electrical power is restored after an outage, it is essential that the presence and location of all vehicles in the system be known prior to the resumption of operations.

6.2 CONTROL OF COMPONENT AND EQUIPMENT FAILURES

The fail-safe principle has been and continues to be the foundation for railway signaling and control practices. This principle has had several definitions in the past, but the definition which best expresses the railroad application is as follows, "If any failure occurs, the system will revert to the condition known to be safe."

Railway signaling and control equipment has been in the process of evolution and improvement for over a hundred years. From extensive experience, the failure rates of most of the components and items of equipment used in railroads and similar transportation systems have been determined. Also during this period equipment and components have been developed which fail so seldom that to all practical purposes the probability of failure can be neglected.

Until relatively recently, practically all of the railway signaling and control design, development and application was accomplished in the traditional manner, using the fail-safe principle as described above. During the last twenty years, space-oriented designers and engineers have entered the field of command and control as applied to ground-guideway-transportation systems. However, there is a fundamental distinction due to the difference in the basic transportation problem. In railway signaling, there was a mode of operation available that was safe mode, namely, the stopping of the vehicle. In air and space operations, however, there is no such safe mode, since stopping a vehicle could be more dangerous than allowing it to proceed. Therefore, space technologists developed techniques involving assessments of the probability of failure and reliance on redundant systems to reduce the probability of unsafe incidents occurring. To do this the space engineer had to take into account every possible mode of failure and its probability of occurrence.

In today's design of AGT systems two safety principles are generally followed:

- Fail Safe Principle. All possible failures for all of the components incorporated into the design are identified. Under the assumption that all of these failures, or partial combinations of failures can occur simultaneously, the design must be such that an unsafe condition can not occur.

- Checked Redundancy Principle. This design philosophy relies upon the principle of redundancy, or the provision of back up circuits or equipment, to reduce the probability of an unsafe condition occurring to the point where the risk is negligible. With known failure rates for individual components, techniques and procedures may be established for checking each failure and taking corrective action such that the system will revert to a condition known to be safe. The objective of such analysis and design is to reduce virtually to zero the probability of an unsafe condition developing due to any possible permutation of failures.

Regardless of the technique used in designing the control system, operational safety is a dominant consideration in the design of any AGT system. Fortunately designers and manufacturers of such equipment can draw upon the extensive body of experience developed over more than a hundred years by the railroad industry as well as the innovative techniques developed by the aerospace industry in the past twenty years. In both instances the basic objective is to so design and operate the system that any possible failure will cause it to revert to a condition known to be safe.

6.3 SECURITY CONSIDERATIONS

The Jacksonville DPM system does not appear to present any unusual security problems. However, since it will be built in an urban environment and will be accessible to both the law abiding and undisciplined elements of the population, this important consideration is deserving of thoughtful attention.

A primary consideration in the design of an AGT system is the security provided to the patrons and users of the system. A further consideration is the security provided to the employees and to the property and equipment of the system. Aspects of security cover criminal acts and acts of vandalism.

Criminal acts can be minimized by:

- Security guards patrolling the station areas or other places where crimes are likely to occur,
- Constant monitoring of the closed circuit TV, and the other forms of communication connecting the vehicles, stations, and Central Control,
- Prompt dispatching of proper authorities to the scene of any actual or potential violent crime,
- Surveillance of suspicious persons by the security attendants,
- Provide a method of rerouting a train that contains persons that should be apprehended to a special location where they can be met by security personnel.

Vandalism can be controlled and/or minimized by:

- Preventing easy access to the system through such devices as fences located strategically throughout the system,
- Use of the closed TV Monitoring system,
- Vandal-proof housing for the command and control equipment located along the right-of-way and in the station and maintenance areas,
- Entrance to enclosures, containing power distribution services should be provided with jimmy-resistant locks and intrusion alarms. They also should be posted with suitable warning signs and secured from public admittance,
- The Central Control equipment should be protected from vandalism, unauthorized personnel intrusion, etc., by means of security doors,
- The vehicle should be designed to minimize major damage due to vandalism. Seats and other equipment should be fastened to preclude easy removal. Seats and interior compartment surfaces should be resistant to graffiti and be easy to clean. Two-way voice communication between passengers and Central Control should be considered.

Apprehension of persons causing security problems can be effected by providing in the system design a capability for changing the route of an individual train on short notice by action of the Central Control. This technique has been employed successfully at Morgantown for the apprehension of obstreperous students. Also, provision can be made for holding a train at points other than at a station. If a crime has been committed on a vehicle, and if notification of this fact can be given to Central Control before the train reaches a station, then the Central

Control can (1) re-route the train to a location where the security police would be waiting, or (2) hold the train just prior to entering the next station long enough for the security police to reach the station, at which time the train could be moved up to the station and the criminal apprehended. This implies that there must be a means of communicating between the vehicle and the Central Control that is easily accessible and convenient to use.

Fencing of accessible areas should be provided for in the design. In this regard:

- The system design should be such that unauthorized persons or vehicles are denied access via overhanging or adjacent structures or roads to the guideway running surface, maintenance area, power distribution stations or other operating or hazardous areas,
- The at-grade guideway should be protected against vandalism by the installation of an adequate fence. Gates should be provided at strategic locations for controlled access to the guideway and to allow contingent evacuation of passengers.
- Vehicle storage areas, yards and maintenance areas should be protected against vandalism by an adequate fence.

Communications between vehicles, stations and Central Control are particularly important in dealing with acts of crime or vandalism. Examples are:

- Closed Circuit Television, with cameras placed so as to discourage vandalism,
- Two-way radios connecting each vehicle and Central Control,

- Public Address system for general announcements, and for contacting individual vehicles on the right-of-way,
- Telephones in stations,
- Intrusion detectors may be considered.