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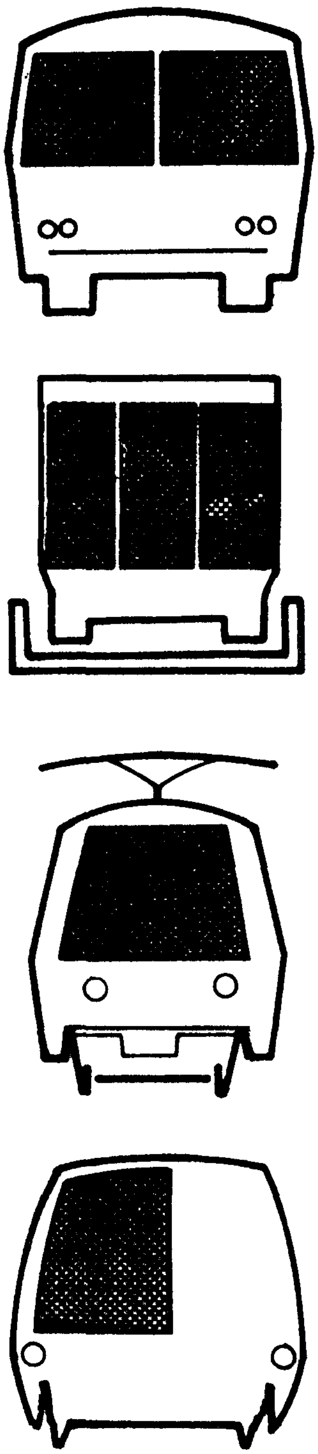
TECHNICAL MEMORANDUM NO. 3

ALTERNATIVE EVOLUTIONARY DESIGN APPROACHES



North Central Texas Council of Governments

TTI
TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY SYSTEM

Technical Memorandum No. 3

ALTERNATIVE EVOLUTIONARY DESIGN APPROACHES

Submitted To

North Central Texas Council of Governments

Arlington, Texas

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by

Texas Transportation Institute
Texas A&M University System
College Station, Texas

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I. INTRODUCTION

INTRODUCTION

Current long-range transportation plans for the Dallas-Fort Worth Metropolitan Area call for the development of several transitways by 1990. These transitways will initially operate with buses and carpools; however, future conditions may make the transition from buses to some other form of mass transit along these same rights-of-way desirable. Hence, the feasibility of designing transit facilities that can be easily adapted to various forms of mass transportation is a legitimate concern.

"Transit Technology Selection Analysis for Dallas-Fort Worth Intensive Study Area" is a study designed to evaluate the feasibility and desirability of designing transitways that can evolve from one form of mass transportation to others. The objectives of this study are as follows:

1. Identify logical evolutionary paths associated with various stimuli for change (capacity, labor intensity, energy considerations, etc.) from buses and evaluate the conditions under which a change in technology would be desirable.
2. Develop a set of alternative transitway designs and evaluate the feasibility and/or limitations of transition from buses to other technologies using each alternative design.
3. Identify pertinent trade-off considerations and implications associated with the evolutionary transitway concept and evaluate the desirability of this approach.

The results of studies conducted to satisfy Objective 1 were documented in a previous technical memorandum ("Analysis and Selection of Transitway Evolutionary Paths"). The following technology evolutionary paths were identified for design evaluation:

(1) Reference Design #1: Narrow Guideway for Buses Only (BRT)*,

(2) Reference Design #2: Wide Guideway for Buses and Carpools,

(3) Evolutionary Path #1: Bus/Carpool →
BRT → Automated Guideway
Transit (AGT) with Off-line Stations,

(4) Evolutionary Path #2: Bus/Carpool →
BRT → Rail Rapid Transit (RRT) with On-line Stations, and

(5) Evolutionary Path #3: BRT →
Rail Rapid Transit (RRT) with On-line Stations.

The purpose of this technical memorandum is to identify through design sketches and narrative descriptions, design approaches for each of the five items listed above. In essence, this report documents the results of the work performed to satisfy the first portion of Objective 2. Subsequent analyses will be performed to accomplish the remaining study objectives.

It should be recognized that, due to limited funding and time constraints, all feasible design approaches could not be evaluated as a part of this study. Hence, the design approaches described herein should not be construed as the best possible designs; rather, they merely represent reasonable design approaches.

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*Bus Rapid Transit

II. COMPONENT IDENTIFICATION AND ANALYSIS

As an initial step toward the development of design approaches, an effort was made to identify all significant components of a transit system for each of the technologies included in the selected evolutionary paths. This section presents information concerning the identification and analysis of components.

First, a set of general requirements are discussed in which all components considered are identified. Then, descriptions of the components deemed appropriate for each of four operational technologies (bus, bus/carpool, AGT, and RRT) are presented. In each case, the component descriptions are discussed in the following order:

Station Considerations and Components

1. Configuration
2. Passenger Facilities
3. Control and Communication Facilities
4. Power System Facilities
5. Transit Vehicle Facilities

Guideway Considerations and Components

1. Structural Configuration
2. Power Distribution
3. Controls and Communication
4. Vehicle Guidance
5. Maintenance and Emergency Provisions

Vehicle Considerations

1. Size and Configuration
2. Performance Capability
3. Power System
4. Special Features

The listings of component requirements presented in this section served as a check-list to insure that all essential factors were considered in the development of various design approaches.

GENERAL REQUIREMENTS

The following listing of general requirements represents an effort to identify all essential components of a transitway system that should be considered, regardless of mode. Certainly, the development of detailed designs for each component is beyond the scope of this study; however, a recognition of the need to include provisions for specific components is essential to the development of suitable design approaches. Thus, an effort is made to identify those components that are critical to this study.

Station Considerations and Components

Although the primary function of a station is to enable passengers to board and depart transit vehicles, several other functions are also logically located at stations. Also, several considerations influence the design of a station. These are identified in the following five sub-topics.

Configuration - The function and configuration of a station varies with its location along the transitway as follows:

Terminal Station (at end of transitway),

Intermediate Station (along a transitway), and

Transfer Station (at intersection of two transitways).

Transfer stations are not considered as a part of this study because the only locations shown in the 1990 plan where transitways intersect are within the CBD. It is assumed that the CBD portion of the transitway will not be constructed until a transition from buses to another technology is made; the transfer stations can be designed at that time. Typical examples of both terminal stations and intermediate stations should be considered for each design approach.

Stations can be elevated, at-grade, or subway. Again, the only subway stations in the plan are to be located within the CBD; they are not considered as a part of this study. Typical examples of both elevated and at-grade stations should be considered for each design approach.

Systems can be designed using either on-line stations or off-line stations for each technology. However, for the purposes of this study, all bus and AGT designs will use off-line stations and RRT designs will use on-line stations.

Passenger Facilities - It is assumed that all stations will include a parking lot for park-and-ride patrons, regardless of mode. Also, it is assumed that certain amenities (benches, telephones, litter bins, and possibly vending machines and restrooms) will be considered regardless of mode. However, the need for fare collection systems (turnstyles, ticket machines, change machines, etc.) and dual level structures (to reach loading platforms) will depend upon the mode.

Control and Communication Facilities - Adequate provisions should be made for equipment required to control AGT and RRT vehicles on that section of guideway assigned to the station control unit. The station control unit also must be tied into the communication network serving the guideway and the central control center.

Power System Facilities - It is assumed that power substations required for AGT and RRT systems will be housed in the stations whenever feasible. All stations should also include adequate equipment room space for the machinery needed to operate the station.

Transit Vehicle Facilities - Platform lengths, switching requirements, and safety measures will vary, depending upon the transit mode using the station. These requirements should be identified for each mode.

Guideway Considerations and Components

Those guideway considerations and components that are deemed critical to this study are identified in the following five sub-topics.

Structural Configuration - The following factors will vary according to the transit mode in use:

Guideway width,

Structural load, and

Roadway deck configuration.

Also, buses and carpools require ramps for entry to and exit from the guideway.

Power Distribution - The guideway design must include provisions for power conduits and conductors as needed for the various transit technologies.

Controls and Communications - The amount of control and communication equipment needed will vary depending upon the transit mode in use. However, considerations should be given to the need for each of the following items:

Control cable conduits,

Control and communication rails,

Vehicle presence detectors,

Control block system, and

Miscellaneous hardware.

Vehicle Guidance System - All guideway input/output elements required in guiding the transit vehicles will fall under this category, including a guidance reference system and switching systems. Provisions must be made in the guideway design to accommodate the elements required for each mode that will be used.

Maintenance and Emergency Systems - Some provisions should be made to accommodate routine maintenance operations and for emergency situations. The following factors should be considered in this category:

Maintenance/emergency walkways,

Guideway lighting,

Safety barriers, and

Provisions for passing stalled vehicles.

Vehicle Considerations

Those vehicle considerations deemed critical to the transitway design are identified in the following four sub-topics.

Size and Configuration - The following vehicles design characteristics influence the transitway system design and should be identified:

Vehicle height, width, and length;

Number and location of doors, and

Maximum number of vehicles per train.

Performance Capabilities - The geometric design of the transitway system must be compatible with the performance capabilities of all vehicles that will use it. The following items are deemed critical to the overall design:

Maximum grade at operating speeds,

Maximum grades for entry and exit speeds, and

Turning radii versus speed.

Power and Steering Systems - RRT and AGT vehicles receive their power and steering from the guideway. All special requirements for vehicle power and steering systems inherent in each transitway design approach should be identified.

Special Components - All special components assumed to be available on each type of vehicle should be identified.

BUS SYSTEM

All transitway designs included in this study must accommodate buses in at least some phases of operation. The following design components and design configurations are considered essential for effective bus operation.

Station Considerations and Components

Configuration - All bus stations are assumed to be off-line stations located adjacent to park-and-ride lots. On-ramps and off-ramps must be provided at each station location. Also, provisions must be made to permit buses to enter or exit the system at each station location. Ramp designs must be developed for stations located on both elevated and at-grade sections of guideway.

Passenger Facilities - Bus stations will have a sheltered waiting area, as a minimum. No provisions for fare collection in the station are deemed necessary for bus operation.

Control and Communication Facilities - No special provisions for control and communication facilities in stations are required for bus operation.

Power System Facilities - Provisions should be made for lighting the park-and-ride lot and the loading area at bus stations. Also, equipment space should be provided for all equipment needed for the more elaborate stations.

Transit Vehicle Facilities - The loading area will be long enough for two to four buses to load simultaneously, depending upon whether it is an intermediate or a terminal station.

Guideway Considerations and Components

Structural Configuration - The guideway provided for BRT operation will be wide enough for two 12-foot travel lanes. Additionally, acceleration and deceleration lanes must be provided for each entrance and exit ramp respectively. Structural capabilities equivalent to typical freeway facilities in Texas are deemed appropriate for buses.

Power Distribution - The only provision for power distribution needed for bus operation is that associated with lighting the roadway. Although continuous roadway illumination may not be considered essential, area lighting in the vicinity of entrance and exit ramps is deemed essential for safe operation during winter months.

Controls and Communications - Some signing will be necessary along the guideway for effective bus operation. Presence detectors are not deemed essential.

Vehicle Guidance System - None required for buses.

Maintenance and Emergency Systems - No special provisions for routine maintenance (painting center stripe, sweeping roadway, etc.) are considered mandatory for bus-only operation. In the event of a stalled vehicle on the guideway, it is assumed that buses will use the lane for oncoming traffic to pass the stalled vehicle.

Vehicle Considerations

Bus performance characteristics and configurations are assumed to be equivalent to the Transbus. Each vehicle is assumed to be equipped with two-way radio communication and a fare collection system.

BUS/CARPOOL SYSTEM

Three of the five designs to be developed must accommodate both buses and carpools during certain operational phases. Those features that must be different from the ones described for BRT operation in order to effectively serve carpools are discussed below.

Station Considerations and Components

The only change needed in the station design to include carpools as well as buses is a provision to permit carpools to enter and exit the system at every station. Desirably, this should be accomplished without routing carpool traffic through the bus loading area.

Guideway Considerations and Components

The guideway will be wider to accommodate carpools. It will be wide enough to include two 12-foot travel lanes, two 10-foot emergency parking shoulders, a concrete median barrier, and parapets on each side. The shoulders may also serve as acceleration/deceleration lanes. Continuous roadway lighting is considered important for safe operation during winter months. Also, a more extensive signing and marking plan will be needed for effective communication with occasional drivers of carpool vehicles.

Vehicle Considerations

No special design features will be required to accommodate automobile performance.

AGT SYSTEM

The transitway design for Evolutionary Path #1 must be able to accommodate an automated guideway transit (AGT) system. The following components and design configurations are considered essential for effective AGT operation.

Station Considerations and Components

Configuration - All intermediate stations will be off-line to enable trains to bypass stations. Terminal stations can be on-line if a one-way loop guideway is used at the end of the line; otherwise, they must be off-line stations designed so that the guideway continues through the station.

Passenger Facilities - Fare collection systems will be required in all AGT stations. All intermediate stations must be dual-level structures to enable passengers to reach the loading platform for either direction. Terminal stations using the one-way loop design can be single level because only one platform will be needed.

Control and Communication Facilities - More control and communication equipment will be required for an AGT system than for any other technology because it is totally automated. Adequate provisions should be made in each AGT station to accommodate computer control units, communication relays, and antennae.

Power System Facilities - Regardless of the type of power system selected in the system design (3-phase AC, single-phase AC, or DC), power substations will probably be required in each AGT station. Also, space must be provided to house the equipment needed to operate the station.

Transit Vehicle Facilities - Station platforms must be long enough to serve four-car trains (approximately 165 feet). Switching facilities must be provided that enable a train to reverse its direction of travel at each intermediate station.

Guideway Considerations and Components

Structural Configuration - The AGT vehicles considered in this study are assumed to be rubber-tired vehicles that exert approximately the same wheel loads as buses so that the structural design requirements are the same as for buses. Each track or lane will be approximately ten feet wide (between guidewalls).

Power Distribution - The power distribution rail will be mounted on the concrete guidewall. An automatic block system that maintains one dead block behind each train is required. The average block length will be 500 feet. Roadway lighting is not considered essential for an AGT system; however, it would provide added safety in the event of an emergency.

Controls and Communications - The AGT control system must provide continuous two-way communication between the vehicle and the control center. Thus, the guideway design should include provisions for control cable conduits, control and communication rails, block system controls, and vehicle presence detectors as well as antennae.

Vehicle Guidance System - The guidance reference system may be mounted on concrete walls on either side of the lane. The specific type of guidance control (i.e., positive capture guidewheel, search and space, etc.) need not be determined for this study; however, the guideway design must provide for a suitable guidance system. Switches connecting the primary lane to off-line stations need only be designed to handle traffic from one direction; however, switches between the two main lanes must be designed to operate in either direction in order to permit trains to reverse their direction of travel as well as to bypass a stalled train.

Maintenance and Emergency Systems - The guideway design must permit self-powered maintenance/service vehicles to operate along the guideway. The switching system must be designed to permit trains to use the left lane to pass stalled trains. Emergency walkways are deemed highly desirable.

Vehicle Considerations

Size and Configuration - For the purposes of this study the AGT vehicles are assumed to be 40 feet long and 9 feet wide, with a total height not exceeding 12 feet. Each vehicle will have four doors--two on each side-- and it will contain 42 seats. The guideway and stations must be designed to accommodate trains of four vehicles.

Performance - A maximum speed of 50 mph is expected between stations. Switches should be designed so that speeds of at least 20 mph can be maintained while switching. Vehicles will be adequately powered to allow them to negotiate grades of up to 3 percent at 50 mph without losing speed when loaded with 42 passengers per vehicle.

Power and Steering - Each vehicle will be individually powered. Vehicles will be designed so that they can pick up power, steering, and control inputs from either side.

Special Components - Each vehicle must be equipped with a voice communication device to permit passengers to talk to the control room in the event of an emergency.

RRT SYSTEM

The transitway designs for Evolutionary Paths #2 and #3 must be able to accommodate rail rapid transit (RRT) operation. The components required for an RRT system are very similar to those required for the AGT system; therefore, the following paragraphs identify only those RRT requirements that differ from the AGT requirements presented on the preceding pages.

Station Considerations and Components

All RRT stations will be on-line stations, and there must be a dual-level structure. The space required for control, communication, and power units will be slightly less than that required in AGT stations.

Platform length requirements will depend upon the maximum number of cars per train. All of the newer RRT systems (BART, Washington, D.C. Metro, and MARTA) are designed to accommodate 10-car trains. However, the plans currently being prepared for the City of Dallas by Parsons-Brinkerhoff-Quade and Douglas only accommodate 4-car trains. For the purposes of developing general evolutionary design approaches in this study, adequate space will be reserved to provide platforms for 10-car trains.

Guideway Considerations and Components

The wheel loads from RRT vehicles will be approximately double those imposed by buses and AGT vehicles; therefore, the guideway will have to be designed for RRT loads. A minimum width of 24 feet is needed for two RRT tracks.

The tracks will provide the guidance for RRT trains, and switches will be required on either side of stations to permit continued operation in the event of a stalled train. Power, control, and communication will be provided through a third rail located on the side of the tracks. One factor that should be considered in the location of the power rail is a provision for passengers to exit a stalled train and walk down the guideway in the event of an emergency.

Vehicle Considerations

Vehicle characteristics for the RRT vehicles being considered in this study are assumed to be the same as the State-of-the-Art Car (SOAC) developed by Boeing for the U.S. Department of Transportation. No special features are deemed essential.

III. DESCRIPTION OF DESIGN APPROACHES

The Component requirements identified in the previous section were used as a checklist in developing design approaches for this study. This section of this report presents descriptions of the design approaches developed for each of the following.

- Reference Design #1: **Narrow Guideway for Buses Only** (BRT)
- Reference Design #2: Wide Guideway for Buses and Carpools
- Evolutionary Path #1: Bus/Carpool → BRT → AGT with Off-line Stations
- Evolutionary Path #2: Bus/Carpool → BRT → RRT with On-line Stations

In reviewing these design approaches, the reader should bear in mind that the total focus of this study is to evaluate the feasibility and desirability of designing transitways that can evolve from one form of mass transportation technology to other forms. In developing these design approaches, every effort was made to ensure that adequate provisions for essential components of each mode and all necessary operational features were included. No effort was made, however, to define design details that do not have a direct impact on the evolutionary process.

A review of the transitway corrdior locations shown in the 1990 plan, as well as the work being done by Parsons-Brinkerhoff-Quade and Douglas, indicates that the majority of the transitway structure will be elevated, approximately one-third of it might be constructed at grade, and a small portion of subways will be required in the CBD of each city. For the purposes of this study, it was assumed that the subway segments would not be designed until a decision had been made to transition to the final technology; thus, subway designs are not included in this study.

The detailed design for column footings on elevated structures and for roadbeds on at grade segments must be keyed to the soil conditions at various locations along the route. Consideration of these structural design features were not deemed essential to this study. Also, because the most constrained situation for guideway geometrics will be on elevated portions, all guideway cross-sections are shown for elevated portions.

Various structural configurations have been used for elevated guideways. Prefabricated concrete I-beams, steel I-beams, rectangular concrete beams poured in place, concrete box girders poured in place, and steel box girders have all been used in the various structural designs reviewed for this study. The prefabricated concrete I-beam design approach was selected for use in this study because specific examples of existing structures were identified to serve as a pattern for each transitway design. It should be noted; however, that more esthetically pleasing designs can be achieved using concrete box girders.

Finally, it should be noted that the design approaches presented in this section are not intended to represent the ultimate or optimum design. Rather, they represent a reasonable, feasible design approach that is suitable for the purposes of this study.

REFERENCE DESIGN #1

NARROW GUIDEWAY FOR BUSES ONLY (BRT)

The narrow guideway for BRT consists of a two-lane roadway without shoulders. A typical cross section of an elevated portion of the guideway is shown in Figure 1. Each bus lane is 12 feet wide. Additional width is required to provide for a double yellow stripe down the center and parapets on each side; consequently, the total width of the guideway is 28 feet. The overall structural design is typical of that used by the State Department of Highways and Public Transportation for ramps at freeway interchanges in Texas (1)*.

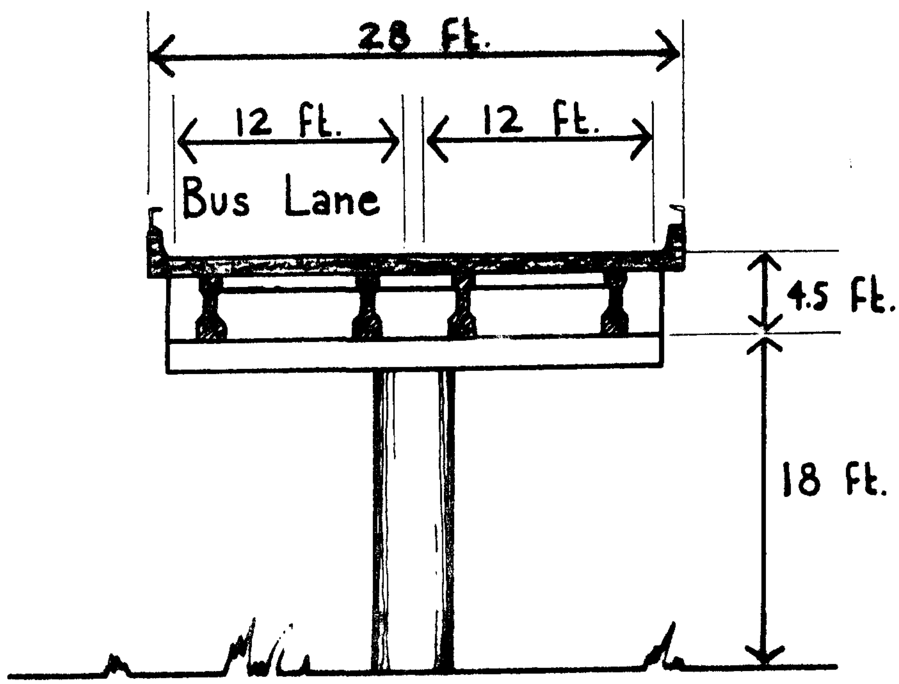

Figure 1: Cross Section of Elevated Structure, Narrow Guideway for Buses Only

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*Denotes number of reference listed at end of report.

A site plan for a typical station along the transitway is shown in Figure 2. The "station" in this instance would be a park-and-ride lot with a sheltered loading area. This design approach will permit a bus to exit the transitway from either direction and stop at the station. The bus would then return to the guideway in either direction of flow. The tie-in of ramps with surface streets would also enable buses serving local neighborhoods to enter or exit the transitway at any station.

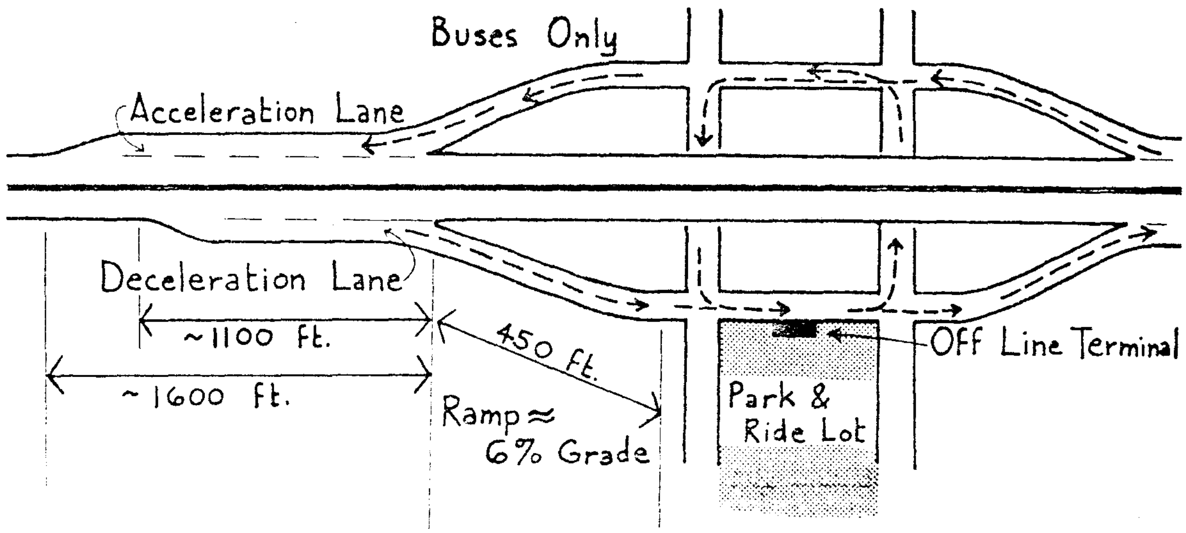

Figure 2: Typical Site Plan at Station, Narrow Guideway for Buses Only

Acceleration and deceleration lanes are added to the basic width of the guideway at each ramp location. The length of these lanes was determined using performance specifications for the Transbus (2). Sufficient length is provided for a bus to accelerate from 30 mph to 50 mph and then merge with traffic from the acceleration lane. This length exceeds the length listed in the AASHO "Redbook" (3) for automobiles, because, even the Transbus will not have acceleration capabilities equal to the average automobile. Conversely, the deceleration lane is long enough to permit a bus to enter it at 50 mph and decelerate to 30 mph before the ramp is reached.

A maximum grade of 6 percent is considered desirable for bus operation. Thus, a minimum of 450 feet will be required for ramps to descend from the transitway level to the street level--normally a 21-foot difference in elevation.

Operational characteristics for the narrow transitway are depicted in Figures 3, 3A and 4. Figure 3 represents a typical design near a station where the guideway is elevated. Figure 3A shows a possible ramp configuration for use along at-grade sections of guideway. As shown in Figure 3, the buses not scheduled to stop at the station will continue on the transitway. Because the ramps connect with surface streets, some protective devices or police enforcement may be required to prevent automobiles from entering the ramp.

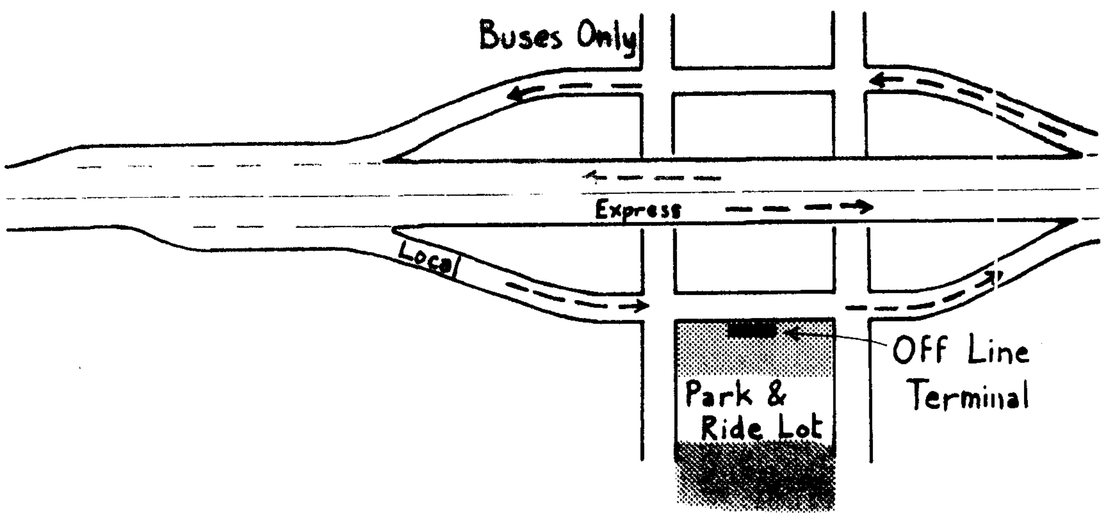

Figure 3: Operational Plan, Narrow Guideway for Buses Only, Elevated Portion

Another design feature that might cause some concern is pointed out in Figure 4. The narrow transitway does not provide shoulders for stalled vehicles or walkways for passengers to exit a bus in an emergency. Assuming that all buses will be in constant two-way radio communication, emergencies can probably be accomodated in a safe, efficient manner. However, these concerns are the primary reasons that it is considered undesirable for car-pools to share a narrow guideway with buses.

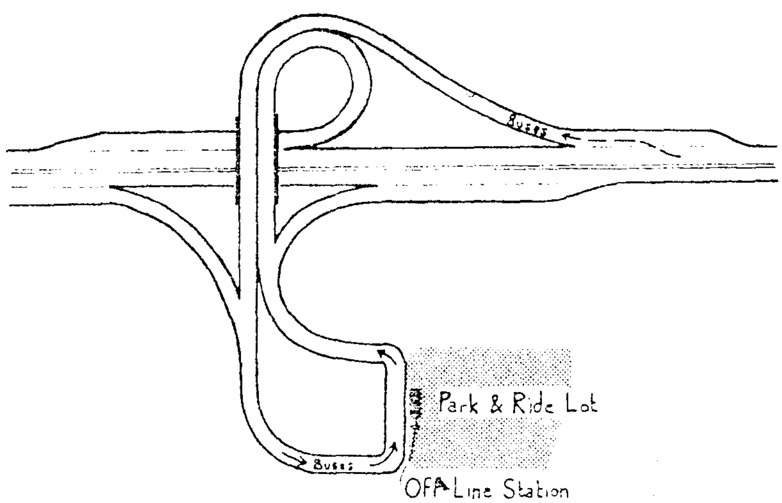

Figure 3A: Operational Plan, Narrow Guideway for Buses Only, at Grade Portion

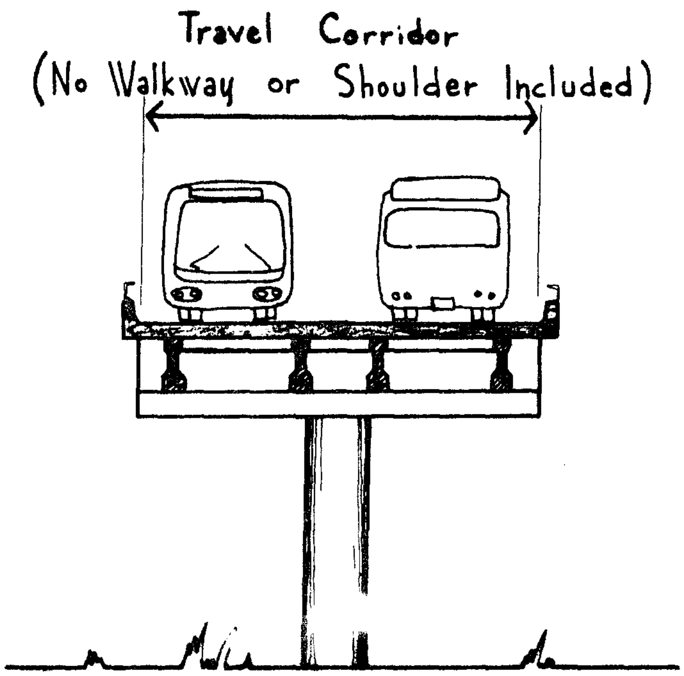

Figure 4: Operation of Lanes, Narrow Guideway for Buses Only

REFERENCE DESIGN #2

WIDE GUIDEWAY FOR BUSES AND CARPOOLS

The data presented in Technical Memorandum #2 of this study concerning the frequency of stalled vehicles on freeways indicates that, unless some provision is made for stalled vehicles, the transitway could be blocked on an average of once per day by stalled cars. Such an eventuality would produce an unacceptably low level of reliability for the total system. Thus, it was decided that all designs considered in this study that are intended to serve carpools as well as buses would provide accommodations for stalled vehicles.

Once the decision was made to provide accommodations for stalled vehicles, then an evaluation of the appropriate type of accommodation was conducted. The three design approaches that were considered are summarized below.

- 2-lane roadway operated as a one-way transitway (inbound in morning and outbound in afternoon).
- 3-lane roadway with the center lane being reversible so that the peak direction of flow would have an emergency shoulder.
- 2-lanes + 2-shoulders--so that both directions of flow would have an emergency parking shoulder.

An evaluation of the operational and safety aspects of each of the design approaches led to the selection of the 2-lane plus 2-shoulders design. This design approach operates the same in morning and afternoons, it provides for the return flow of buses, and, if it is widened slightly more, a median barrier can be included to separate opposing directions of flow.

The wide guideway design for buses and carpools selected for this study consists of two 12-foot travel lanes with continuous 10-foot shoulders on either side. The typical elevated cross section shown in Figure 5 reflects a total width of 50 feet including space for a concrete median barrier in the center and parapets on either edge.

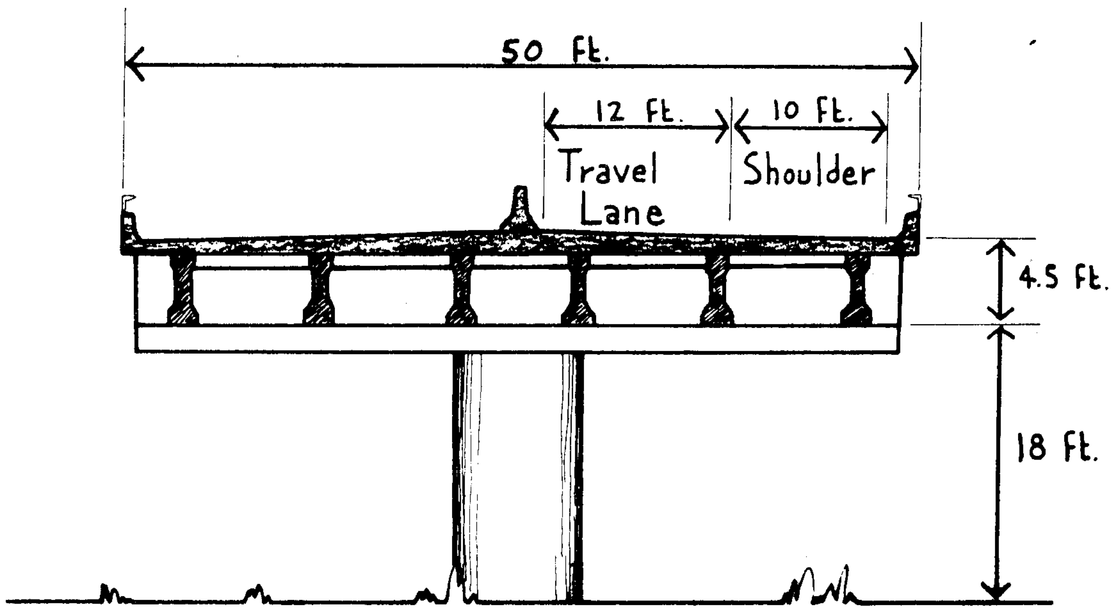

Figure 5: Typical Elevated Cross-Section, Wide Guideway for Buses and Carpools

A concrete median barrier is shown for this design, though there is some disagreement among the research staff as to whether one should be constructed. A median barrier would prevent possible head-on collisions on the guideway, but it would also restrict the flexibility of operation. However, in view of the fact that median barrier designs are now available that can be placed on a roadway without having to be structurally tied to the deck, the research staff chose to make the structure wide enough to accommodate a median barrier, even though one may not be installed.

A typical site plan for an intermediate station along an elevated section of wide guideway is shown in Figure 6. The overall layout is very similar to that used for the narrow guideway. The shoulders will be used as acceleration and deceleration lanes, but the width of the guideway will be held constant. The continuous shoulders will accommodate stalled vehicles, and the shoulders can be used as emergency walkways for the occupants of stalled vehicles to exit the guideway. Along sections where the guideway is at grade, the ramp configuration would have to be modified to permit vehicles on the lane opposite the station to reach the station without crossing a lane of guideway (see Figure 3A for an example).

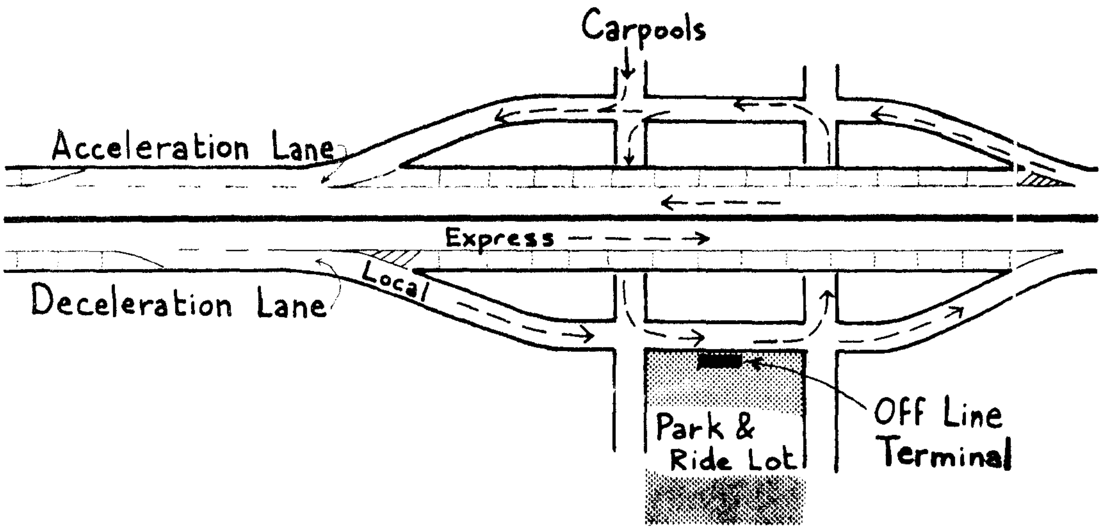

Figure 6: Typical Site Plan at Station, Wide Guideway for Buses and Carpools, Elevated Guideway

If there is little expectation that a guideway might be extended further, operations at the terminal station can be simplified by a station design similar to the one shown in Figure 6A. If it were deemed likely that the guideway would be extended further in the future, the terminal station layout would be similar to Figure 6 with only two ramps and the through lanes stubbed off.

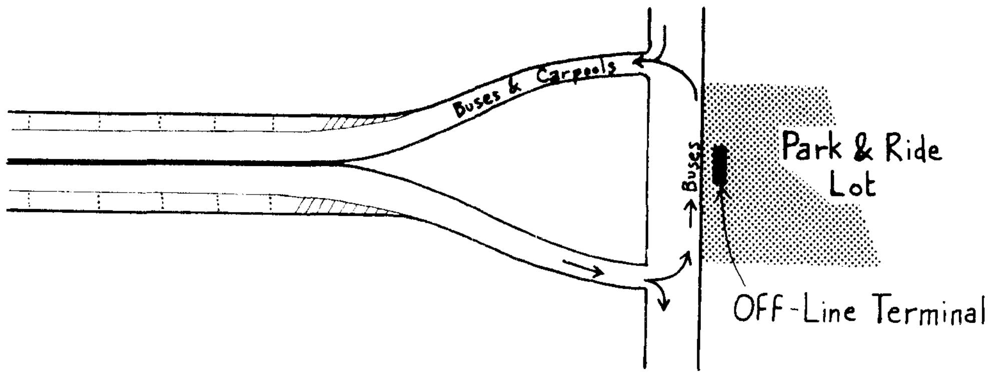

Figure 6A: Typical Site Plan for Terminal Station, Wide Guideway for Buses and Carpools

Operation of the wide guideway will be similar to that of the narrow guideway, except that carpools will be permitted to use it as well as buses. Buses and carpools will be able to enter or exit the guideway at each station (park-and-ride lot). Those vehicles not desiring to leave the guideway can continue straight through.

In essence, the wide guideway will be a two-lane freeway for use by high-occupancy vehicles.

EVOLUTIONARY PATH #1

BUSES AND CARPOOLS → BRT → AUTOMATED GUIDEWAY TRANSIT WITH OFF-LINE STATION

Evolutionary Path #1 utilizes a wide guideway in evolving through three types of operation. Initially, buses and carpools will share the guideway. Then carpools will be eliminated and buses will continue to use the guideway. During construction work for the transition to Automated Guideway Transit operation, buses can continue to use the shoulder portion of the guideway. Finally, the guideway will be dedicated entirely to AGT.

No significant changes in the guideway design are required to accommodate the eventual transition to AGT. As shown in Figure 7, concrete guidewalls will be installed on the existing roadway deck when the transition is to take place.

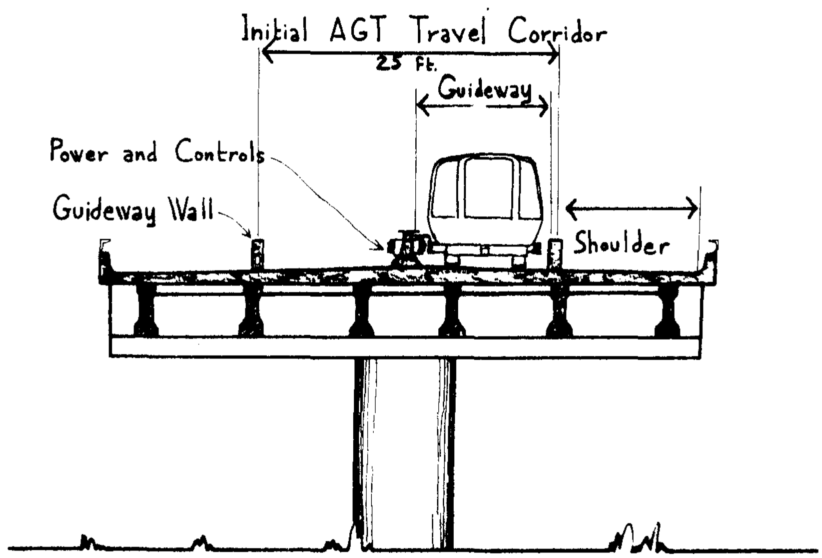

Figure 7: Cross-section of Guideway, Evolutionary Path #1

All power rails, signal controls, and guidance mechanisms can be mounted on the guidewalls. If a concrete median barrier is used during bus/carpool operation, it can be designed to accommodate power and control rails at a later date.

Stations for the AGT will be constructed around the guideway adjacent to park-and-ride lots. During the initial construction phase, buses will continue to operate on shoulders as depicted in Figure 8 (elevated guideway) and Figure 8A (at grade guideway). As the conversion process is nearing completion, all buses will have to exit on the ramps at each station because the shoulder portion in the AGT station will serve as the off-line bay for the AGT (see Figure 9). Finally, after the AGT is in full operation, the bus ramps may be removed (see Figure 10 for intermediate station and Figure 10A for terminal station).

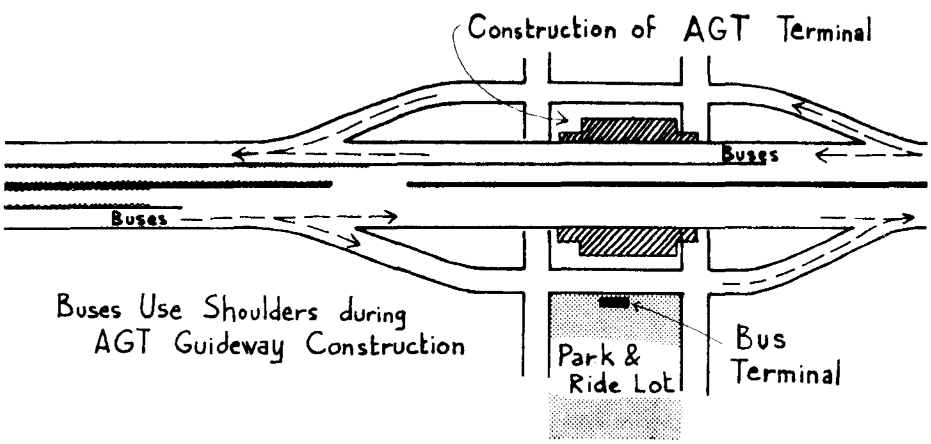

Figure 8: Initial Construction Phase for Transition to AGT at Station on Elevated Portions, Evolutionary Path #1

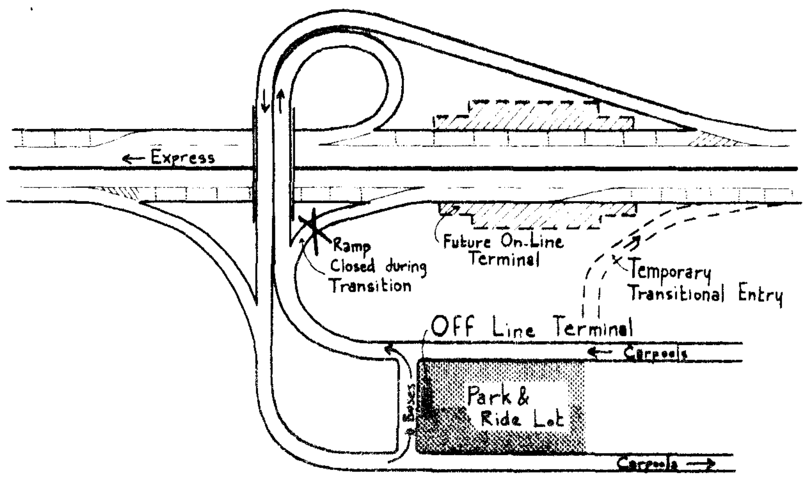

Figure 8A: Initial Transition to AGT at Station on At-Grade Guideway, Evolutionary Path #1

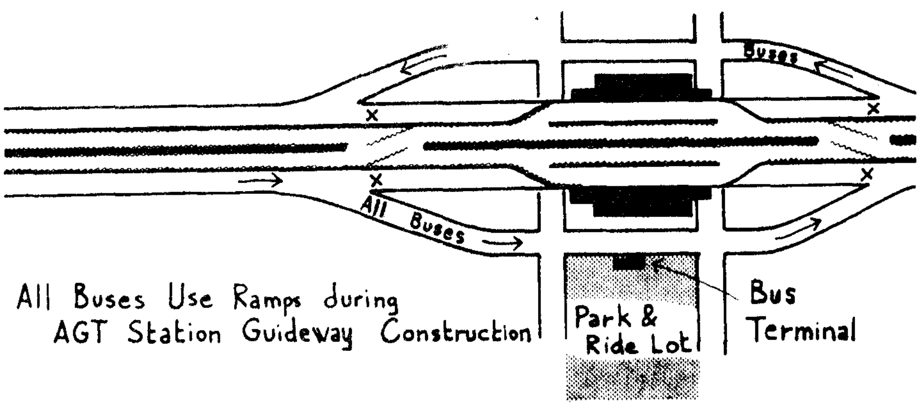

Figure 9: Final Construction Phase f. Transition to AGT, Evolutionary Path #1

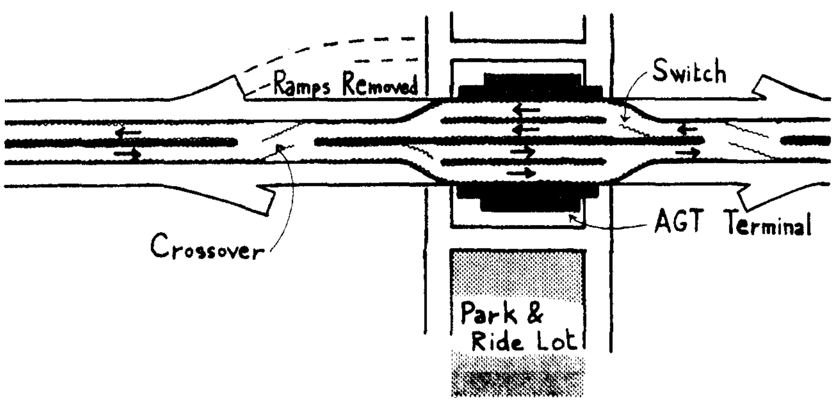

Figure 10: AGT Operation on Guideway, Evolutionary Path #1

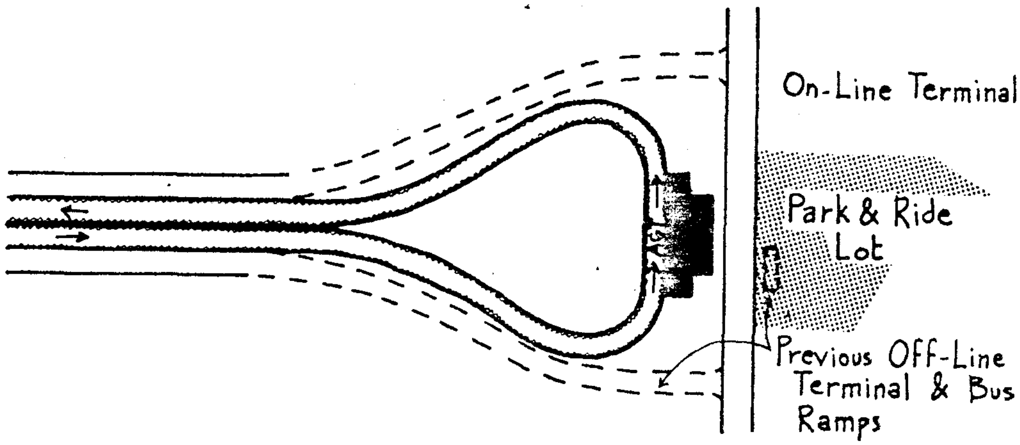

Figure 10A: AGT Operation at Terminal
Station, Evolutionary Path #1

The resulting guideway design fully accommodates AGT operation. The shoulders remaining alongside the AGT lane can serve as maintenance platforms and emergency walkways. Hence, they will continue to provide benefits after the final transition is made. Also, the shoulders provide an opportunity for further development of the system.

The total capacity for AGT operation, as depicted in Figure 10, is 21,000 seats/hour in each direction. Should this capacity prove insufficient at some future date, the guideway can be modified to accommodate dual tracks in each direction to double the capacity. Design sketches depicting how this ultimate dual track operation can be accommodated are shown in Figures 11 and 12. Additional guideways will be constructed at each station, but the total construction process can be completed while the AGT continues to operate in the inside track.

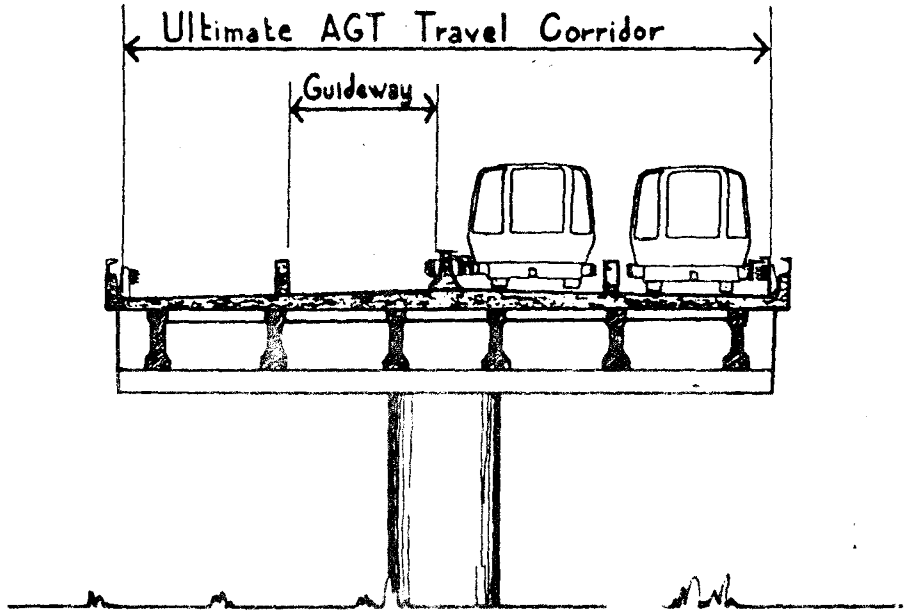

Figure 11: Dual-Track AGT [illegible]tion, Evolutionary Path #1

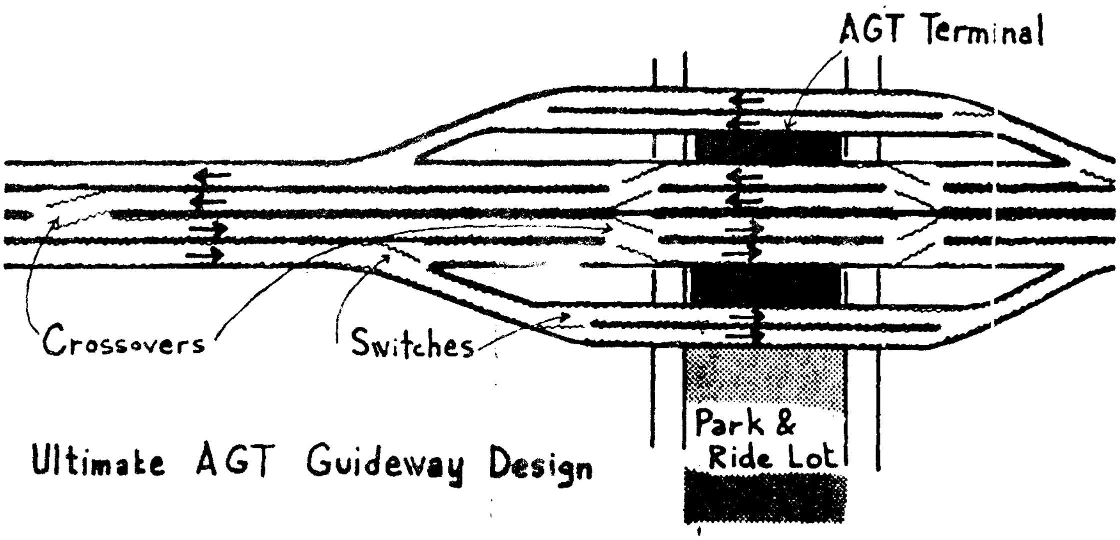

Figure 12: Station Operation for Dual-Track AGT, Evolutionary Path #1

EVOLUTIONARY PATH #2

BUSES AND CARPOOLS → BRT → RAIL RAPID TRANSIT WITH ON-LINE STATIONS

In order to accommodate Evolutionary Path #2, the structural design of the guideway must be modified significantly from that shown for Reference Design #2 (compare Figure 13 with Figure 5). However, once the heavier guideway is constructed, it will operate just as envisioned for Reference Design #2 during its initial phase serving buses and carpools (see Figure 14). Then carpools will be banned and the facil[illegible] will serve buses only (see Figure 15). Buses will continue to operate on the shoul[illegible] of the guideways during track construction [illegible] RRT (see Figure 16).

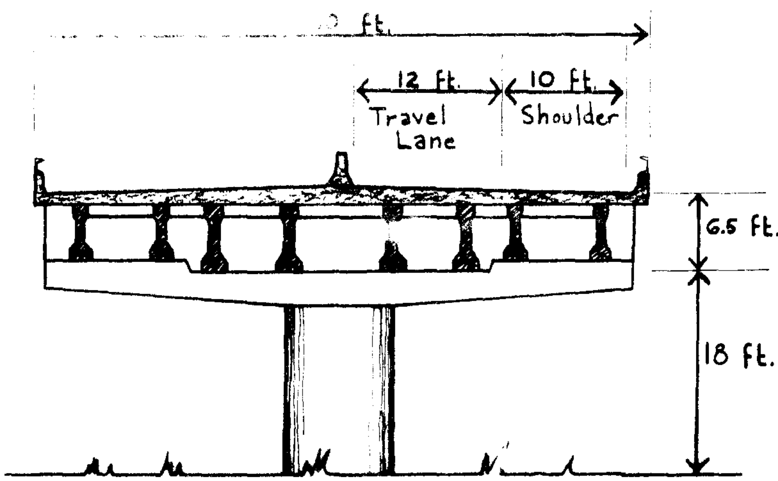

Figure 13: Wide Guideway Designed to Accommodate RRT, Evolutionary Path #2

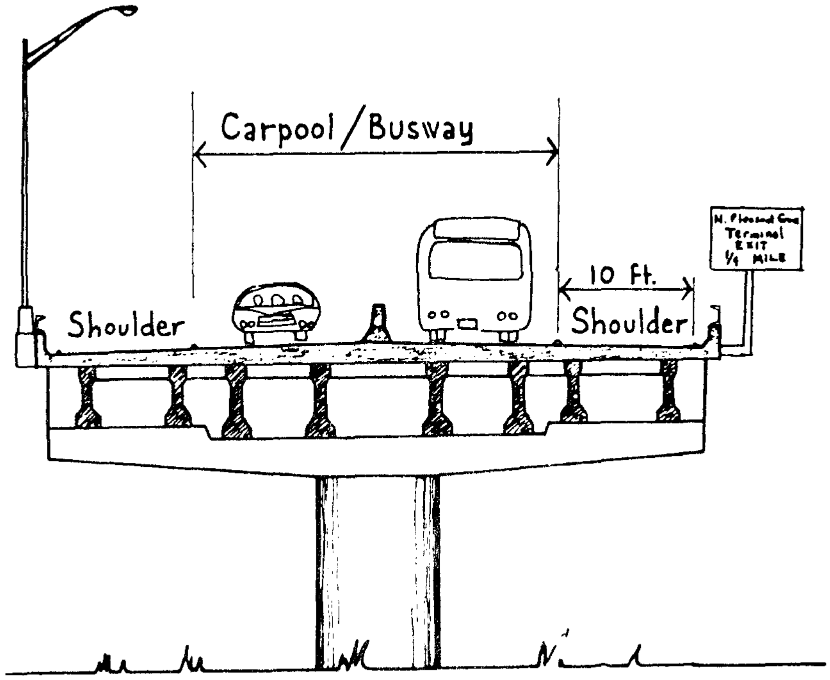

Figure 14: Operation with Buses and Carpools, Evolutionary Path #2

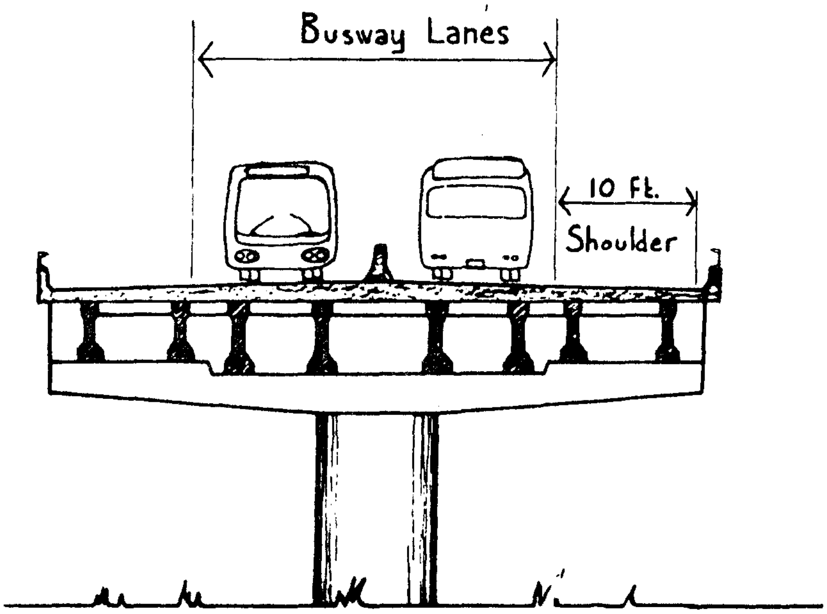

Figure 15: Operation with Buses Only, Evolutionary Path #2

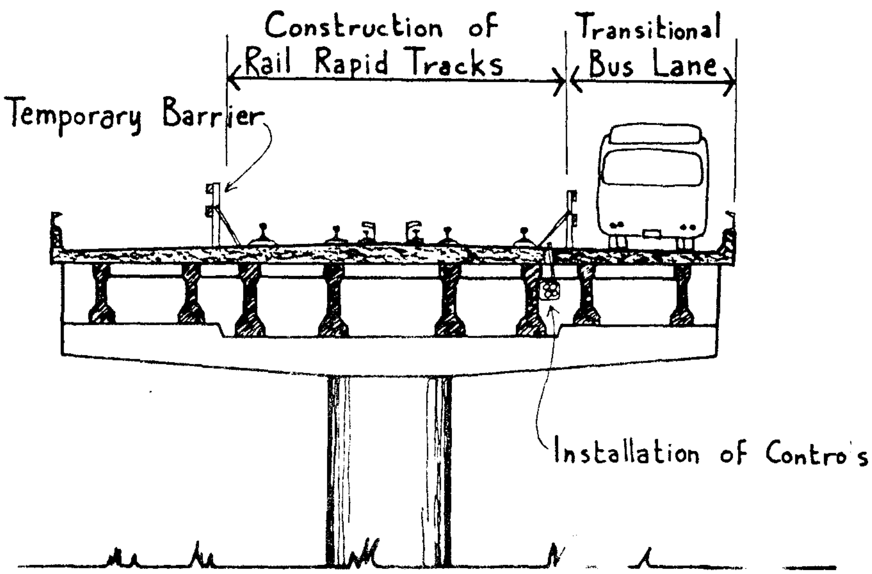

Figure 16: Operatic Buses during RRT Construc..on, Evolutionary Path #2

RRT stations, similar to those designed by Parsons-Brinkerhoff-Quade and Douglas for the City of Dallas, can be constructed around the guideway adjacent to each park-and-ride lot. During initial construction, buses would continue to operate on the guideway shoulders as depicted in Figure 17. Ultimately, the shoulder portion of the guideway near the stations will be used for the RRT loading platforms as shown in Figure 18; thus, during the latter stages of conversion, all buses will have to exit the guideway at each ramp.

Although most RRT systems place the power rail on the outside of the guideway, this design approach anticipates that the power rails will be located in the center portion of the guideway (see Figure 19). Hence, the total guideway will be divided into a power corridor in the center, travel corridors on each side of the power corridor, and emergency walkways on either edge (see Figure 20). Thus, the wide guideway, initially constructed to accommodate carpools, will be an asset to the RRT operation as a maintenance platform as well as an emergency walkway.

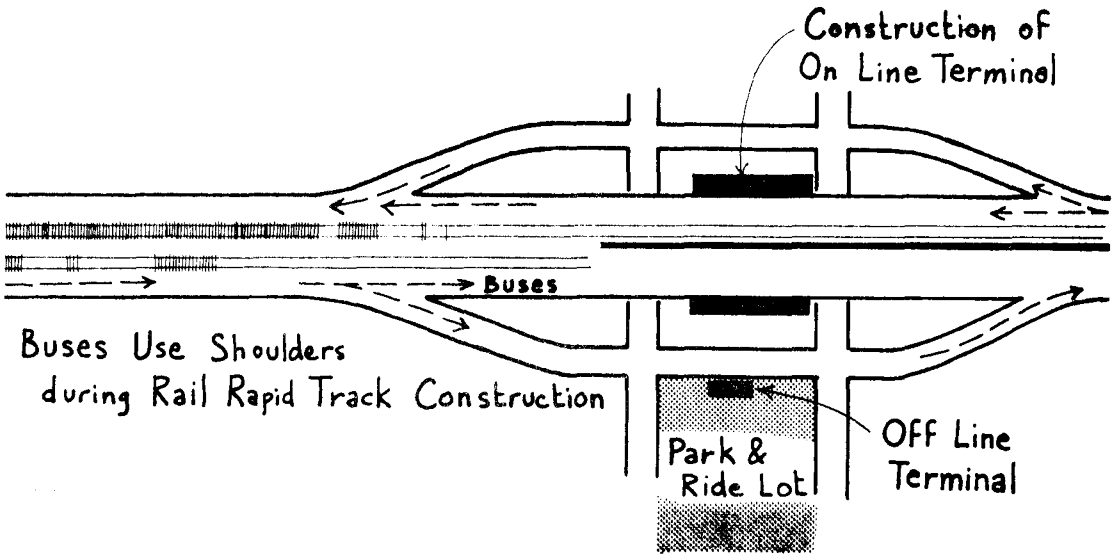

Figure 17: Operation near Stations during Initial RRT Construction, Evolutionary Path #2

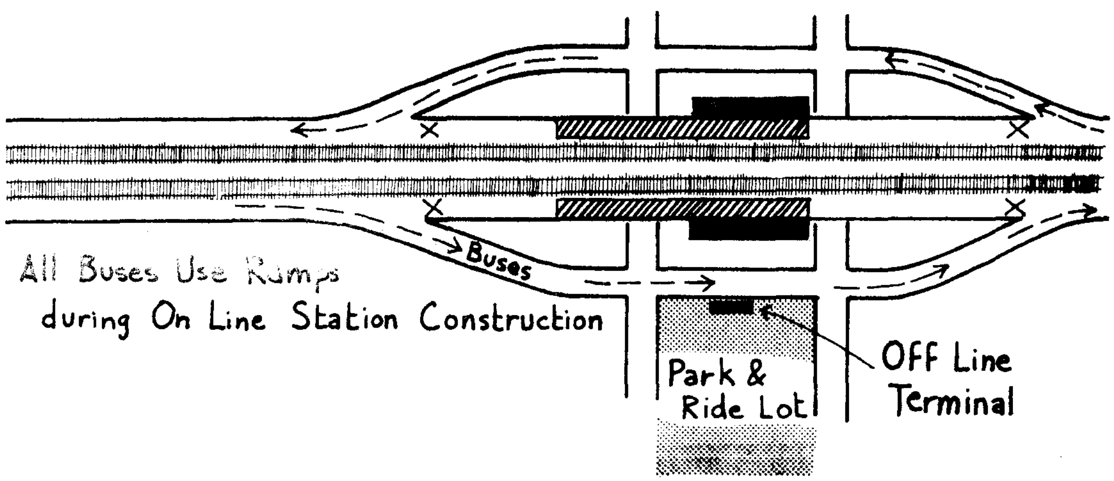

Figure 18: Operation during Final Stages of Conversion, Evolutionary Path #2

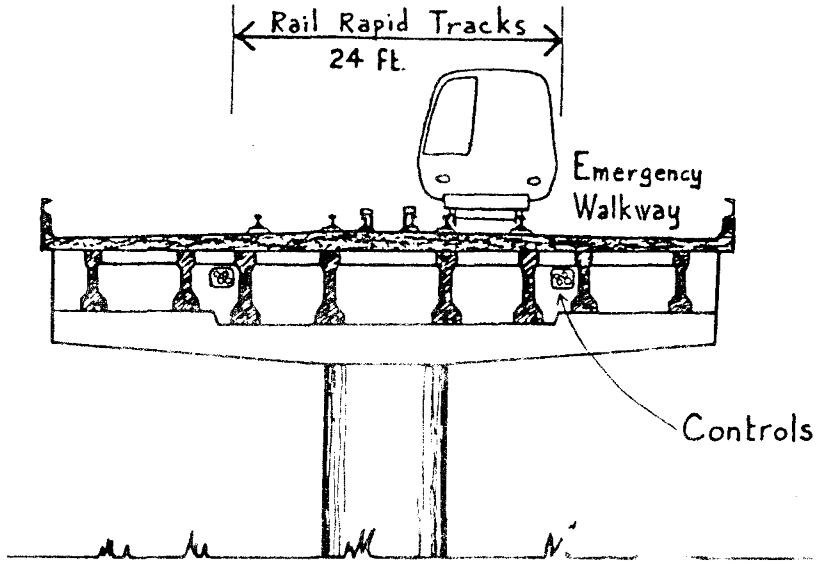

Figure 19: RRT Opera... ..., Evolutionary Path #2

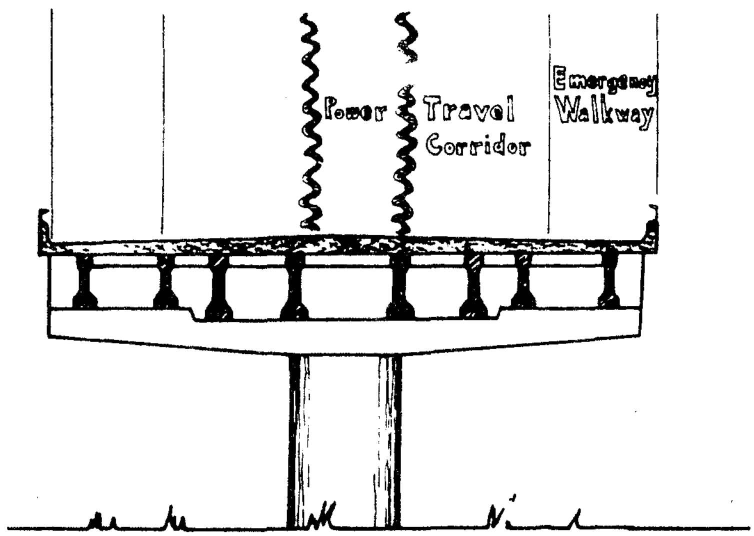

Figure 20: Corridors along the RRT Guideway, Evolutionary Path #2

EVOLUTIONARY PATH #3

BRT → RAIL RAPID TRANSIT WITH ON-LINE STATIONS

Evolutionary Path #3 more nearly resembles the universal guideways mentioned in the literature. It utilizes a narrow guideway that will be used by buses initially and later be used by RRT trains (see Figures 21 and 22).

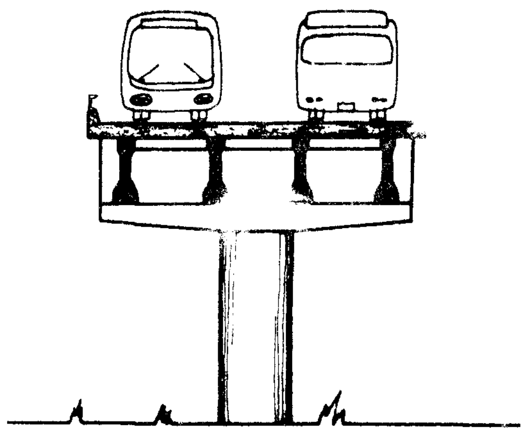

Figure 21: Initial Use by Buses, Evolutionary Path #3

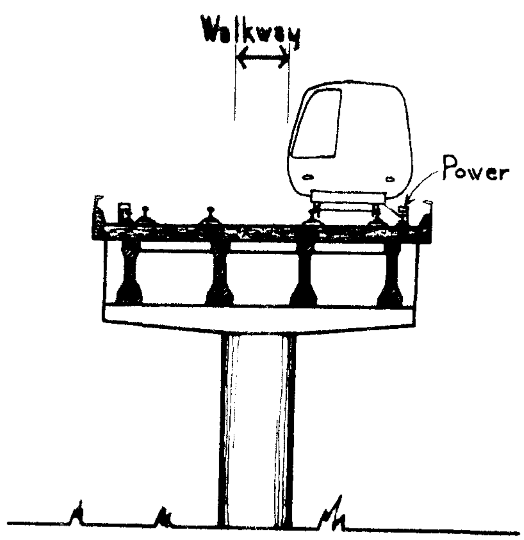

Figure 22: Ultimate Use by RRT Trains, Evolutionary Path #3

A cross-section of the guideway design for this path is shown in Figure 23. The thickness of this guideway is signficantly greater than that shown for Reference Design #1 (see Figure 1). Also, the column supporting the structure is larger. The design shown in Figure 23 is very similar to that used for the Lindenwold Line, a rail rapid transit facility (4). This particular design was selected because it is most similar to typical designs for highway structures used as a reference for busway designs. BART and MARTA use concrete box beams, while Washington, D.C. Metro uses a box beam to support the span between columns.

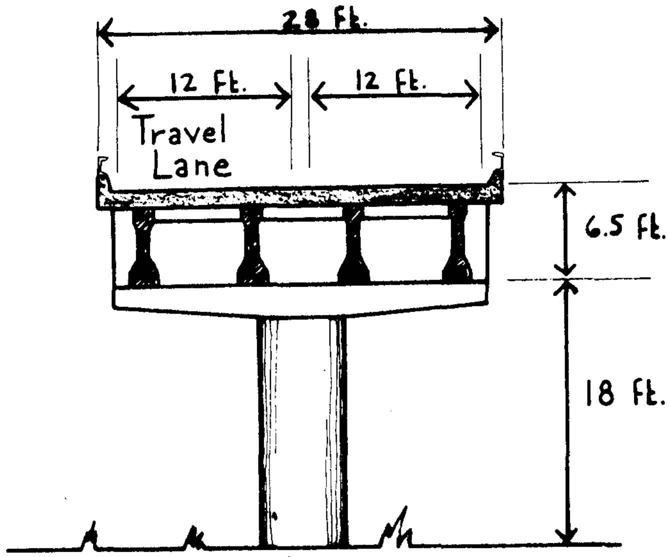

Figure 23: Guideway Design, Evolutionary Path #3

This narrow guideway cannot accommodate bus operation during the transition to RRT use even though no portions of the guideway will have to be destroyed in order to accommodate RRT. Stations will be constructed in areas reserved for that purpose adjacent to park-and-ride lots (see Figure 24). The ramps used by buses will be removed as a part of the transition process;

however, acceleration and deceleration lanes will not be removed. They will serve as safety islands for pedestrians exiting RRT trains during emergencies (see Figure 25).

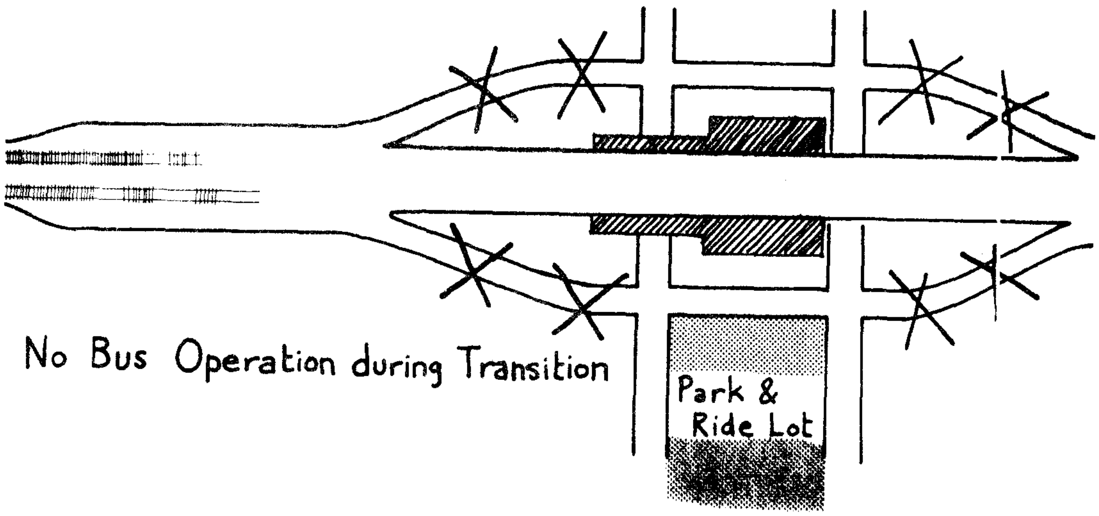

Figure 24: Transition to RRT, Evolutionary Path #3

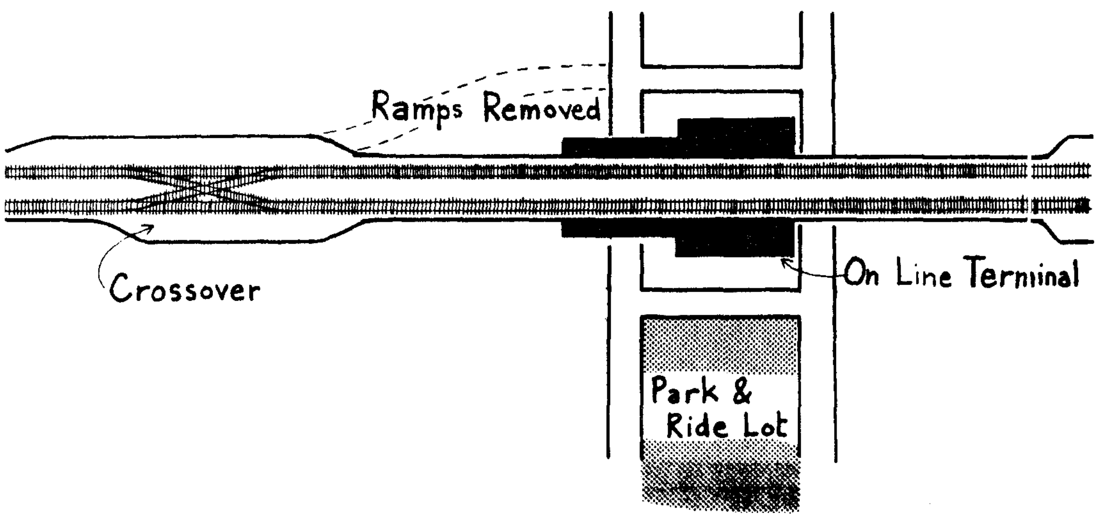

Figure 25: Operation of RRT, Evolutionary Path #3

IV. CONCLUDING REMARKS

At the initial coordination meeting for this study, North Central Texas Council of Governments staff members, members of the Advisory Committee for this project, and study staff personnel discussed their primary concerns for this study. All participants generally agreed that it would be technically feasible to design a transitway so that it could accommodate different operational technologies; however, serious doubts were expressed concerning the following two questions.

1. Can a transitway design be developed that will accommodate continuous operation of one mode while the transition is being made to another mode?
2. If it is possible, will the evolutionary design be so complicated that it is economically impractical?

The most significant findings of this study to date are that an evolutionary design which accommodates continuous operation during transition is feasible and that the design approach is strikingly simple. The key to the whole approach is the use of a wide guideway.

We, the members of the study team, would like very much to claim that through our far-sightedness and outstanding ingenuity we were able to perceive this solution immediately. However, such is not the case. Our initial attitude was that the wider guideway was a feature that was dictated solely by the need to accommodate carpools during initial phases of operation. It was not until we were well into our efforts to develop design approaches that we began to perceive the benefits that the guideway shoulders offered.

Not only does the wider guideway enable buses to continue to use the transitway during the transition period, but the resulting shoulders also provide significant benefits to the final operational phase (either AGT or RRT). Indeed, the only features incorporated in the initial design for

Evolutionary Path #1 (Bus/carpool → BRT → AGT) that are not needed in the final phase are the entry and exit ramps and the passenger shelters located in the park-and-ride lots. It may even be desirable to retain the entry and exit ramps at a few locations to provide access to the guideway for self-propelled maintenance and emergency vehicles.

The design approach shown for Evolutionary Path #2 (Bus/carpool → BRT → RRT) could even be considered a "Universal Guideway" design. It is designed with the structural capability to accommodate any mode, and the decision concerning the specific mode could be postponed until conditions developed that stimulated a need to change. However, the increased structural capability is a costly feature that might never be used.

Subsequent efforts under this study will address the question of costs and benefits of the five design approaches described in this report. The analytical procedures to be used will be described in the next technical memorandum issued under this study. The final report for the study will contain the results of those analyses.

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3. American Association of State Highway and Transportation Officials, A Policy on Design of Urban Highways and Arterial Streets, 1973.

4. Lindenwold designs obtained from Don Wold, Superintendent of Way and Power, Port Authority Transportation Company, Philadelphia, Pennsylvania, February 25, 1977.

5. Aerial Structure Standard for Metropolitan Atlanta Rapid Transit Authority, Parsons Brinkerhoff-Tudor-Bechtel, July 21, 1975.

6. Elevated guideway design drawings for the Huntington Route on the Washington Metropolitan Area Transit Authority, Richardson, Gordon, and Company, September, 1973.