DRAFT

Miami • Miami Beach Transportation Corridor Study

Supplemental Draft Environmental Impact Statement

Bay Link

Technology Assessment

March 2002

Prepared for:

Miami-Dade Metropolitan Planning Organization

Parsons Brinckerhoff Quade & Douglas, Inc.

MIAMI-MIAMI BEACH TRANSPORTATION CORRIDOR STUDY

DRAFT

Technology Assessment Report

(Task 4.1)

Prepared by:

Lea+Elliott, Inc.

for

Parsons Brinckerhoff Quade and Douglas, Inc.

and the

Metropolitan Planning Organization of Dade County

Miami, Florida

Lea+Elliott **March 2002**

EXECUTIVE SUMMARY

Background

On October 10, 1995, the East-West Multimodal Corridor Draft Environmental Statement (DEIS) was executed by the Division Administrator of the Federal Highway Administration (FHWA). The DEIS was subsequently advertised and carried out through the public hearing process in accordance with the National Environmental Policy Act (NEPA) of 1969, as amended.

The DEIS addressed possible solutions to extreme congestion along the State Road (SR) 836/Dolphin Expressway, considered to be the most heavily traveled East-West roadway in Miami-Dade County.

The East-West Corridor DEIS evaluated the following alternatives:

- no-build;
- transportation system management;
- elevated expressway;
- Metrorail via Earlington Heights;
- four State-Road 836 alternatives with thirteen options; and
- the Flagler Street alternative.

This project, the Miami-Miami Beach Transportation Corridor Study (Bay Link), is a re-evaluation of the Miami-Miami Beach segment and includes a supplement of the 1995 DEIS prepared for the East-West Multimodal Corridor Study. All of these transit alternatives included a light rail connection between downtown Miami and South Miami Beach.

Goals and Objectives

Both downtown Miami and South Miami Beach are continuing to grow rapidly and experiencing heavy densification that has exceeded the 2020 projections in a number of locations in the Study Area. The downtown development plans for both Miami and South Miami Beach recognize the need for a public transit investment. The purpose of the Miami-Miami Beach Transportation Corridor Study is to advance the definition of the public transit connection between the Miami Central Business District and Miami Beach Convention Center.

The DEIS identified LRT as the most appropriate transportation mode for the connection between Miami and Miami Beach. This report constitutes the first step of a technology assessment re-evaluation that will identify appropriate technologies for the Corridor.

Scope of Assessment

One of the focuses of this report is to provide an overview of the recent activity that has sparked the Bus Rapid Transit sector and to perform a preliminary screening and analysis of applicable technologies for the connection between Miami and Miami Beach, including LRT, BRT as well as those identified by the public during the scoping process. It will expand on the number of applicable transportation technologies identified in the DEIS and related reports.

This report is generated in accordance with Task 4.1 of Phase 1 of the study which consists of an update to the technological assessment presented in the DEIS. The full assessment of all variables and the recommended technology type will be covered in the future Phase 2 final report.

The Study Area

The Study Area is located in eastern Miami-Dade County. On the Miami side, the Study Area limits are bounded by NW 36th Street to the north, the Miami River to the south, and I-95 to the west. On the Miami Beach side, the Study Area limits are bounded by W 41st Street on the north, Government Center on the south side, and the Atlantic Ocean to the east. For purposes of assessing impacts of the project, those citizens located in the area between W 21st and W 41st will be engaged in the public involvement process. The proposed transit corridor shown in Figure 1-1 extends from a connection to the existing Metrorail line in downtown Miami across the MacArthur Causeway to the Miami Beach Convention Center.

Technology

The following technologies are described and discussed in this report: Light Rail Transit (LRT), Monorail Transit, Automated Guideway Transit (AGT), Rail Rapid Transit (RRT), Bus Rapid Transit (BRT) and Ferry Service.

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List of Abbreviations

ADA	American with Disabilities Act
AGT	Automated Guided Transit
APTA	American Public Transport Association
Bay Link	The name given to the transportation corridor transit system
BRT	Bus Rapid Transit equivalent to Enhanced Bus Service
CAC	Citizens Advisory Committee
Dual-Mode Bus	A bus that can be fed from two sources of energy such as ethanol and gasoline or diesel fuel and electricity
DEIS	Draft Environmental Impact Statement for the East-West Multimodal study. The Major Investment Study (MIS) report was published in October 1995.
DOT	Department of Transportation
EPA	Environmental Protection Agency
FTA	Federal Transit Administration
GLT	Guided Light Transit
GPS	Global Positioning System
Hybrid-Electric bus	A bus that carries at least two sources of motive energy on-board with an electric drive to provide complete or partial drive power to the vehicle's wheels.
ITS	Intelligent Transportation Systems
LPA	Locally Preferred Alternative
LRT	Light Rail Transit
LRV	Light Rail Vehicle
MBTA	Massachusetts Bay Transit Authority

MPO	Metropolitan Planning Organization
NYCTA	New York City Transit Authority
OCTA	Orange County Transit Authority
pphpd	Passengers per hour per direction
PRT	Personal Rapid Transit
ROW	Right of Way
sqft	Square feet
TVM	Ticket Vending Machine

1.0 INTRODUCTION

1.1 BACKGROUND

On October 10, 1995, the East-West Multimodal Corridor Draft Environmental Statement (DEIS) was executed by the Division Administrator of the Federal Highway Administration (FHWA). The DEIS was subsequently advertised and carried out through the public hearing process in accordance with the National Environmental Policy Act (NEPA) of 1969, as amended.

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One of the focuses of this report will be to provide an overview of the recent activity that has sparked the Bus Rapid Transit sector and to perform a preliminary screening and analysis of applicable technologies for the connection between Miami and Miami Beach, including LRT, BRT as well as those identified by the public during the scoping process. It will expand on the number of applicable transportation technologies identified in the DEIS and related reports.

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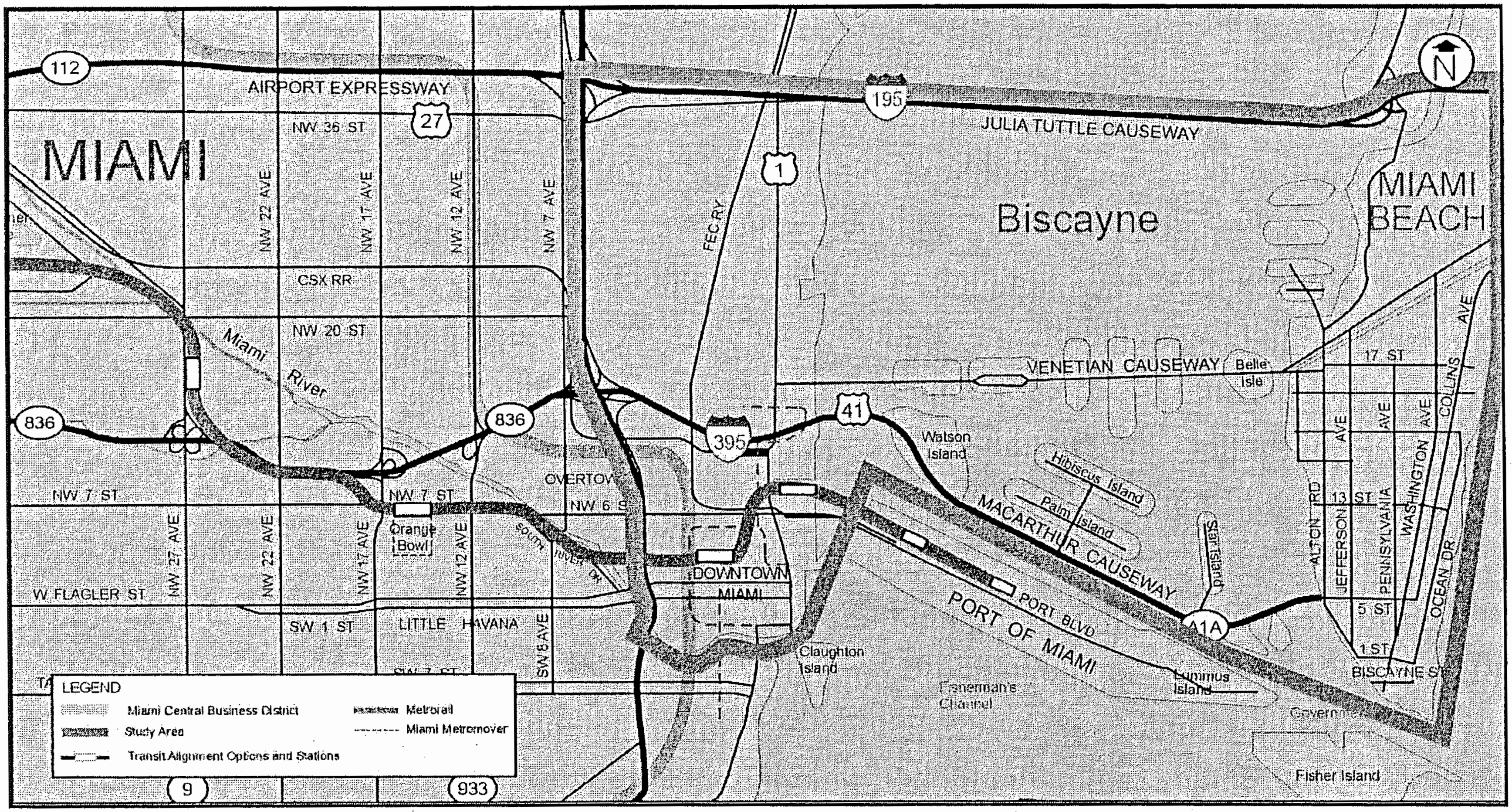


Figure 1-1: Project Study Area

2.0 CANDIDATE TRANSIT MODES

2.1 GENERAL

Transit system technologies can be categorized into several classifications, each of which has particular characteristics that serve to meet certain specific functional requirements. The different technologies serve a variety of mobility needs and settings. For example, the local bus category is best suited for short distance travel in low-density developments. AGT or "people movers" are best suited for high-density developments like downtown areas or airports. For medium distance travel, express buses, bus ways, LRT, and heavy rail are typically solutions, while for long distances, commuter rail or high-speed rail may work best. Not all of these technologies are appropriate for providing service for the Study Area.

A listing of the general characteristics and requirements from previous studies (also presented in Figure 2-1) for the Bay Link transportation system are listed below:

- Modern, attractive, state-of-the-art technology
- Powered in accord with clean air goals
- As fast in overall speed as right-of-way permits
- Capable of quick loading/off-loading
- Comfortable, air-conditioned cars, visually attractive
- A blend of seating and standee space reflecting probable trip length
- Reliability in schedule performance
- Accessible in conformance with Federal ADA requirements

For purposes of evaluation in this report, the identified transit system technologies that generally meet the above requirements include: Light Rail Transit (LRT), Bus Rapid Transit (BRT), Monorail and Automated Guideway Transit (AGT) systems. Rail Rapid Transit will also be briefly discussed based on input from citizens. This section examines these system technology categories, their general operating characteristics, and applications. The reasons for their exclusion in the alternatives analysis will be reviewed briefly.

2.2 LIGHT RAIL TRANSIT

LRT is a flexible transportation mode that can operate in a variety of physical settings. LRT characteristics are listed below:

- Flexible mode in terms of placement
- Has capability of operating at-grade (i.e., street level) with motor vehicles and pedestrians crossing the right-of-way, made possible by the overhead power distribution system
- Large cars running on traditional rails for support and guidance giving simple and fast switching capability

- Manned operations, but with automatic train protection
- Can operate up to 55 mph; make short radius turns; and climb grades up to 7%
- Vehicles are generic and generally non-proprietary in concept, thus attracting strong bid competition
- Overhead power distribution system and support poles cause negative visual impact
- Where placed on elevated structure, represents negative visual intrusion
- Where at-grade, has a potentially negative impact on other traffic movements

LRT uses dual rails for both support and guidance. As the modern technological descendent of the streetcar, a distinctive feature of LRT is that vehicles draw power from an overhead wire. This is in contrast to heavy rail vehicles (Metro Rail) that usually are powered from a track-level third rail. The overhead power collection feature allows LRT systems to be integrated with other at-grade transportation modes and pedestrians. With overhead power collection and the availability of articulated LRT vehicles, LRT can operate in mixed traffic on tracks embedded in the street (like streetcars), on an at-grade right-of-way with street and pedestrian crossings, or on a fully-segregated right-of-way. Overhead catenary can be implemented in a non-intrusive way and blend with the surroundings. The Portland LRT represents a very good illustration of a successful implementation. Similar to AGT and Monorail, LRT can use an at-grade power pick-up when utilized on fully segregated right-of-way. Figure 2-2 reflects the operating characteristics for LRT. Figure 2-3 represents the S70, a low floor Light Rail Vehicle from Siemens. Figure 2-4 illustrates the Dallas LRT. Figure 2-5 and Figure 2-6 reflect how catenary urban design can blend with the surroundings.

The most recent light rail systems in the US use vehicles that are 90 to 95 feet long and up to 9 feet 6 inches wide. Operator cabs at both ends of the vehicle (articulated and non-articulated) allow bi-directional operation. Vehicles can operate either as a single car or in multi-car trains by connecting two or three body halves with a pivoting articulation joint. The capacity of a typical LRT vehicle ranges between 120 and 170 passengers. A three-unit train can carry up to 510 passengers, resulting in a single direction hourly capacity of up to 16,000 persons per hour per direction (pphpd).

The maximum operating speed of modern LRT systems generally ranges between 55 to 65 mph, making it suitable for medium distance trips in suburbs or between central business districts and other major activity centers. However, average operating speeds can be reduced to 10 or 25 mph if operating in mixed traffic with frequent stops.

Depending on the surrounding environment, LRT station design may incorporate high or low platforms. Generally, transit systems with on-street operations, where passengers can walk across tracks, use simple stations with low platforms while systems with reserved right-of-way use high platforms.

Entry into light rail vehicles (LRV's) has traditionally been provided in one of two ways–step entry or level boarding. With passage of the Americans with Disabilities Act of 1990 (ADA), all new rapid transit stations must provide accessibility for the disabled to every car unit. This means that all LRT systems that opened after January 1993 were required to provide level boarding. Level boarding on these systems can be accomplished in one of two ways–high-level station platforms or low platforms matching low-floor vehicles.

Low-floor LRV's were developed by European vehicle manufacturers in response to the prevalent use of LRT in street right-of-way applications in Europe and the demand for easier, faster boarding at stations. Low-floor LRV's are becoming quite common in Europe and they are in operation today in North America in Portland, OR and Hudson-Bergen County, NJ. The Siemens-Duewag SD600 vehicle used in Portland meets ADA regulations and other U.S. standards through the use of vehicle-mounted bridge plates. Low-floor LRV's have also been ordered for Minneapolis. Most US mid-sized cities have adopted LRT systems as their highest capacity form of transit, using the mode as a trunk line or regional radial system. For such U.S. applications, the mode is cost-effective and offers reasonably high capacity and overall speed. Most European cities with LRT systems use LRT in a context different from our cities, a context more like the needs of the Study Area. The European needs have resulted in more use and development of LRT vehicles that are more flexible (two or more articulated joints to traverse sharp turns), less wide and easier to board. A new generation of light rail vehicles (LRV's) have been developed by such suppliers as Siemens, Breda, Bombardier, Alstom and Fiat. It is these vehicles that are most suited to serve in the Corridor.

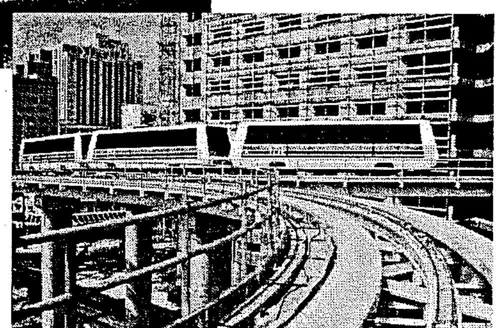
There are over 300 LRT systems in operation in the world today. Twenty-one of these are in U.S. cities including Baltimore, Dallas, Denver, Los Angeles, Portland, San Jose, and St. Louis.

In summary, LRT is a transportation mode that is retained for further consideration.

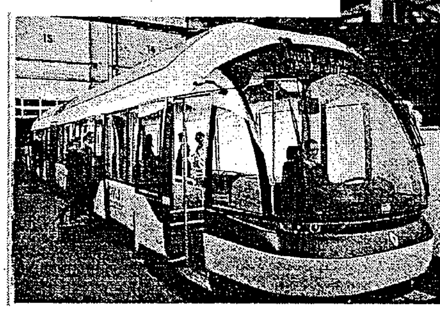
Figure 2-1: Common Technology Characteristics and Requirements

Light Rail Transit
Sacramento

Monorail Transit
Walt Disney World
Transit



Automated Guideway Transit
Miami



Bus Rapid Transit
Lyon, Grenoble

- Modern, attractive, state-of-the-art technology
- Powered, in accord with clean air goals
- As fast in overall speed as right-of-way permits
- Capable of quick loading/off-loading
- Comfortable, air-conditioned cars, visually attractive
- A blend of seating and standee space reflecting probable trip length
- Reliability in schedule performance
- Accessible in conformance with Federal ADA 90

Figure 2-2: Operating Characteristics for LRT

Sacramento LRT

- Flexible mode in terms of placement
- Has capability of operating at-grade (i.e., street level) with motor vehicles and pedestrians crossing the right-of-way, made possible by the overhead power distribution system
- Large, single cars running on traditional rails for support and guidance, giving simple and fast switching capability
- Manned operations, but with automatic train protection
- Can operate up to 55 mph; make short radius turns; and climb grades up to 7%
- Vehicles are generic and generally non-proprietary in concept, thus attracting strong bid competition
- Overhead power distribution system and support poles cause negative visual impact
- Where placed on elevated structure, represents negative visual intrusion
- Where at-grade, has negative impact on other traffic movements

Figure 2-3: Siemens Low-Floor LRV

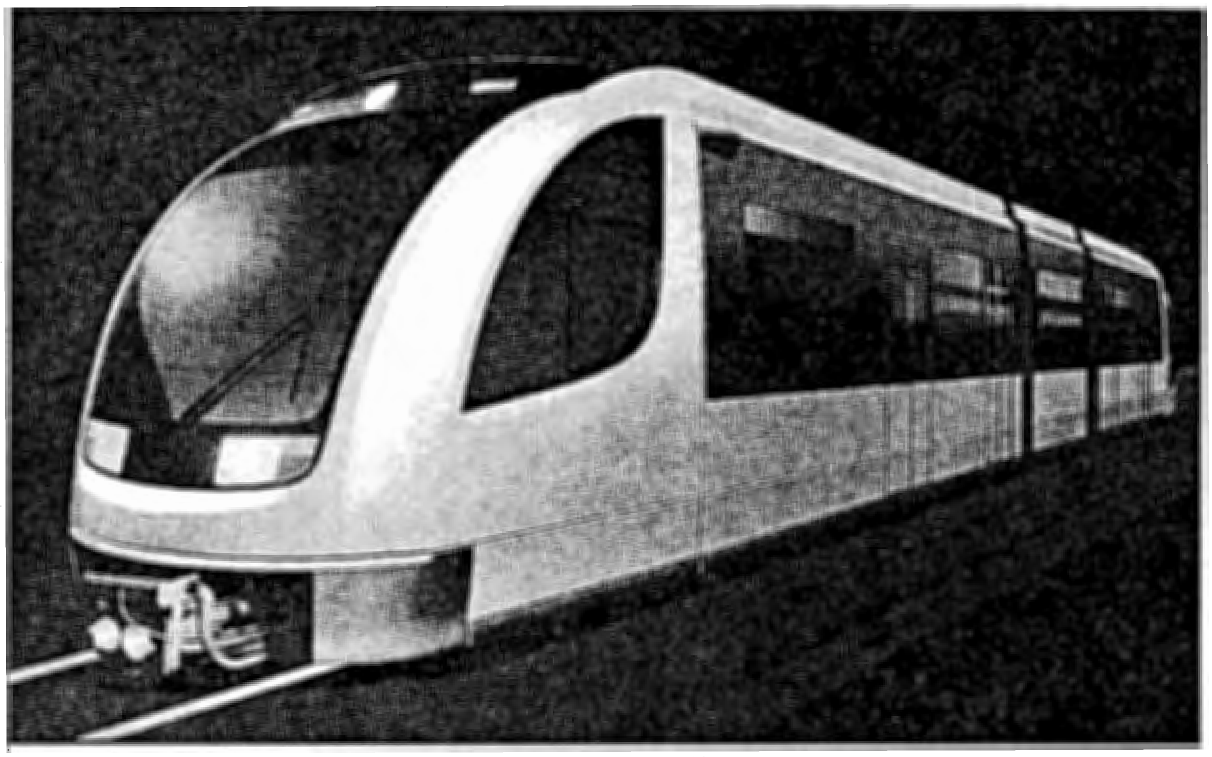


Figure 2-4: Dallas LRT

Figure 2-5: Portland LRT catenary design (1/2)

Figure 2-6: Portland LRT catenary design (2/2)

2.3 MONORAIL TRANSIT

Monorail is a fixed guideway transit mode in which a series of electrically propelled vehicles straddle atop or are suspended from a single guideway beam, rail, or tube. If fully automated, they are similar in operation to AGT systems but are classified separately due to their unique guideway configuration. Figure 2-8 reflects the significant technical features of the Mark VI monorail system that operates at Walt Disney World. Some of the features are listed below:

- Least flexible of modes in terms of placement
- Operates fully-grade separated from all other traffic
- Generally elevated, although can operate close to grade in an isolated right-of-way
- Trains made up of small car modules running on rubber tires and straddling a concrete girder
- Switching is accomplished by beam-replacement transfer table, slower and less reliable than other modes
- Manned operations, but with automatic train protection
- Can operate up to 45 mph; is limited to curves of 175-foot radius or greater; and can climb grade up to 6%
- Vehicle/systems are proprietary
- Dual monobeam structure casts the least shadow of all elevated modes, but does pose a negative visual intrusion, especially at switches, crossovers and branch points
- In any setting, has high relative cost due to uniqueness and geometric limitations

The trains generally consist of permanently coupled cars having suspension, propulsion, and control equipment in common. Electric power is generally picked up by carbon collectors on the bottom of the vehicle in contact with a bus bar mounted on the side of the guideway beam. They can be operated either manually with fail-safe anti-collision systems or in a totally automated mode. Operating and maintenance costs vary according to the level of automation and the required capacity, but can be comparable to conventional grade-separated systems.

The guideway for monorail systems is typically elevated and must be totally grade separated from all other traffic. Emergency egress from vehicles on this elevated guideway has historically been a problem with monorail systems. Potential solutions have included the addition of emergency walkways to the guideway and emergency hatches from the vehicles to permit passenger movement from a disabled vehicle to adjacent vehicles and/or ground level.

Historically, the main disadvantage with monorail systems was their inability to take full advantage of dual-lane guideways. Whole sections of the guideway support beam must be physically moved from one guideway to another during switching or transferred laterally to be replaced by a curved section. This is an operationally slow and maintenance intensive operation. Consequently, the applicability of monorail systems has usually been limited to simple loop and shuttle systems.

Recent improvements in switch design and reliability have allowed for more complex alignment in locations such as Jacksonville.

The vehicles are generally operated as trains under the control of an operator but are capable of being fully automated. The vehicles sit astride a heavy beam structure, riding on rubber tires, with additional stabilizing rubber tires providing guidance laterally. The power is taken from a collector system beneath the cars. System line capacities for large-size monorails generally range from 5,000 to 10,000 pphpd. Representative examples of this technology include:

- ADtranz (Germany) - straddle-beam, small vehicle system at Merry Hill Shopping Center, Birmingham, UK; the Expo '92 site in Seville, Spain; Jurong Bird Park, Singapore; and the Harbour Link in Sydney, Australia (shown in Figure 2-7).
- Hitachi Series 1000 (Japan) - straddle-beam, large-vehicle monorail with systems in operation at Osaka, Kitakyushu, and Tokyo, Japan.
- Bombardier/TGI Mark VI (Canada)- straddle-beam, medium-sized vehicle system in service near Orlando, Florida at the Walt Disney World Resort and at Disneyland in Anaheim, California. This type of Monorail is being implemented for Las Vegas
- Bombardier UMIII in operation in Jacksonville, Florida.

Monorails are excluded from consideration in this report since one of the recommendations that resulted from public consultations during the DEIS generation phase was that an elevated system would not be acceptable in Miami Beach. Moreover, mixed traffic operation of Monorails is not a viable solution.

Figure 2-7: ADtranz Monorail in Sydney, Australia

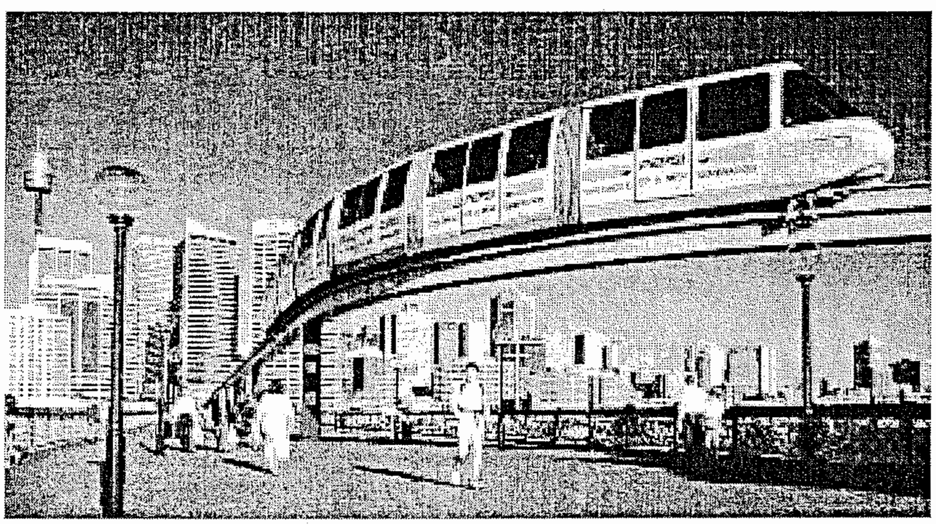
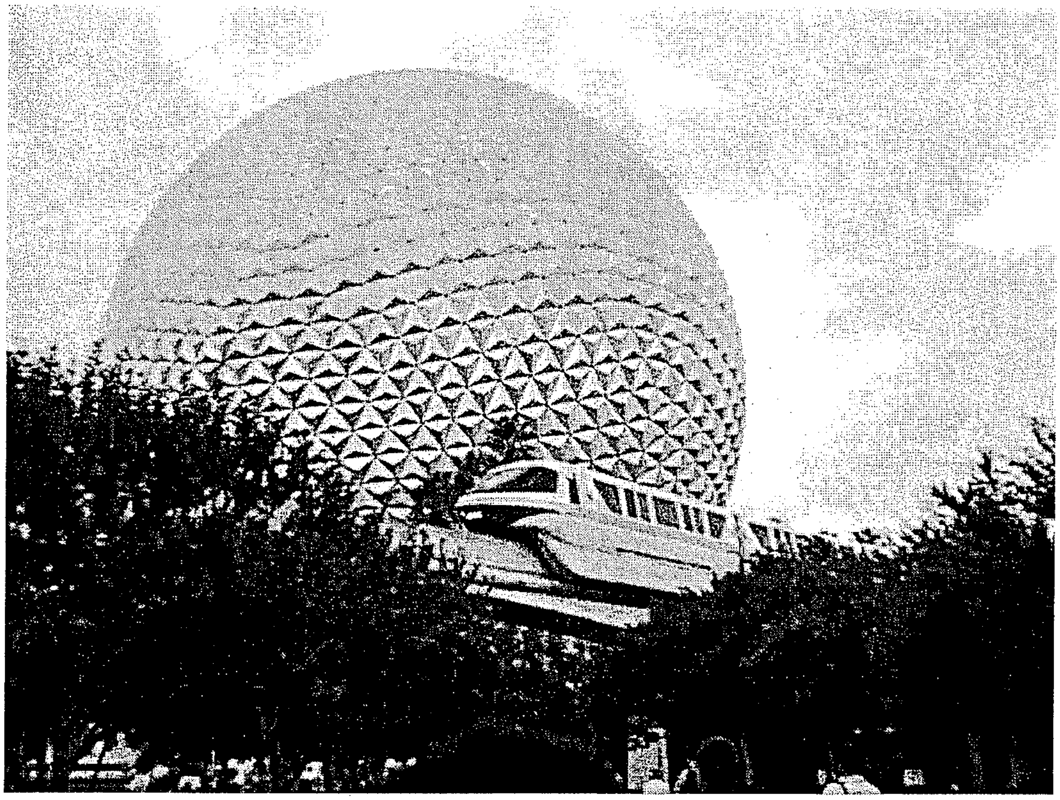


Figure 2-8: Operating Characteristics for Monorail (Bombardier/TGI M-VI Monorail)



Walt Disney World Monorail

- Least flexible of modes in terms of placement
- Operates fully-grade separated from all other traffic
- Generally elevated, although can operate close to grade in an isolated right-of-way
- Trains made up of small car modules running on rubber tires and straddling a concrete girder
- Switching is accomplished by beam-replacement transfer table, slower and less reliable than other modes
- Manned operations, but with automatic train protection
- Can operate up to 50 mph; is limited to curves of 175-foot radius or greater; and can climb grade up to 6%
- Famous "signature image" of Disney Resort Parks
- Vehicle/systems are proprietary
- Public transit version of the deployed Mark VI design requires some product improvement
- Dual monobeam structure casts the least shadow of all modes, but does pose a negative visual intrusion, especially at switches, crossovers and branch points
- In any setting, has high relative cost

2.4 AUTOMATED GUIDEWAY TRANSIT

AGT refers to a broad range of fixed guideway technologies in which the most prominent feature is automatic train operation. AGT technology includes a wide range of service levels, from proven "people mover" systems such as the downtown Miami Metro mover and numerous airport circulators, to experimental systems such as the Personal Rapid Transit (PRT) system once planned for a Chicago suburban commercial area. Figure 2-9 reflects the significant technical features for AGT systems. These features are listed below:

- Fully grade-separated from all other traffic
- Operates fully grade separated; is fully automated or remote controlled; and is typically unmanned
- Generally elevated, but can operate close to grade in an isolated right-of-way
- Trains of small cars, operating on rubber tires bearing on concrete guideway, steered and switched by follower on center guideway
- Can operate up to 50 mph; make short radius turns; and climb grades up to 8%
- Vehicles/systems are proprietary, thus limiting bid completion, but there are comparable designs offered by other suppliers
- System widely deployed in airports worldwide and in other circulator/distributor installations
- In any setting, the most costly of the four modes

At the present time, the majority of AGT systems usually operate as a local distribution system in an environment where there are many trips concentrated over short distances. They are typically found at airports (e.g., Atlanta and Miami), zoos, amusement parks, and in major commercial centers or downtowns (e.g., Harbor Island in Tampa and the Metromover in downtown Miami). However, they have also been used successfully in urban line haul applications in Vancouver, B.C.; Kobe, Japan; and Lille, France. Both Vancouver and Lille have extended their systems and plan future extensions. Increasingly, AGT is being used in urban environments in line haul applications.

The service characteristics of AGT vary considerably. Urban, medium-capacity systems can reach speeds of 50 mph. People movers are generally operated at speeds up to 35 mph. Airport and local circulators typically reach speeds of 30 mph. Passenger capacities are generally less than light or heavy rail systems. This decrease in passenger capacity is due to slower operation on AGT's tighter geometric profile and shorter station spacing. All AGT systems are proprietary. Vehicles can be rubber tired or steel wheeled. Power is supplied by a high voltage contact rail located in the track bed. Therefore, people mover systems must be isolated from other traffic and pedestrians, (i.e., these systems require fully grade-separated rights-of-way). The steel wheeled version requires conventional railroad-type steel rails to be affixed to the guideway, while the rubber-tired version requires a concrete or steel running surface and concrete or steel center or side rails for lateral guidance. The Miami Metromover is an example of a rubber-tired AGT system.

The level of automation as well as operation in mixed traffic required for the Study Area is not consistent with the dedicated right-of-way characteristics of the mode.

Figure 2-9: Operating Characteristics for AGT

Miami Metro mover

- Fully grade-separated from all other traffic
- Operates fully grade separated; is fully automated or remote controlled; and is unmanned
- Generally elevated, but can operate close to grade in an isolated right-of-way
- Trains of small cars, operating on rubber tires bearing on concrete guideway, steered and switched by follower on center guideway
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- Vehicles/systems are proprietary, thus limiting bid completion, but there are comparable designs offered by other suppliers
- System widely deployed in airports worldwide and in other circulator/distributor installations
- In any setting, the second most costly mode (after Rail Rapid Transit).

2.5 RAIL RAPID TRANSIT (RRT)[1]

Rail Rapid Transit refers to heavy rail technology and provides the highest passenger capacity and fastest service possible, but one of the highest capital costs. Also referred to as rapid rail, metro or subway, heavy rail operates in an exclusive right-of-way which must be grade separated because of the high voltage (third) rail which provides electric power to the vehicles. Automobile or pedestrian crossing of the tracks is not permitted.

Besides the contact rail, heavy rail technology is characterized by its very high passenger carrying capacity (up to 40,000 passengers per hour per direction for multi-car trains) and operating speeds (up to 75 miles per hour). Individual cars can carry up to 170 passengers in normal loading situations. Therefore heavy rail is best for high-density corridors in large cities.

Stations outside of densely developed areas need to be far enough apart to allow trains to take advantage of their high-speed capacity. Rail rapid transit stations require high-level platforms.

Examples of heavy rail systems in the US include the Washington Metropolitan Area Transit Authority (WMATA) system, the New York City subway, MARTA in Atlanta, Chicago, SEPTA in Philadelphia, the Boston Red and Orange Lines, and Metrorail in Miami.

Rail Rapid Transit typically consists of large 4-axle rail vehicles (area up to 750 sqft) that operate in trains of up to 10 cars on fully controlled right-of-way, which allows high speed, reliability of service, capacity and rapid boarding.

When compared with LRT, RRT exhibits the following characteristics:

- Higher level of service (speed, reliability and comfort)
- Higher system performance (capacity due to long trains, productivity, efficiency)
- Greater safety (fail-safe signaling throughout the system)
- Stronger image (separate ROW and rail technology)
- Higher maximum speed (up to 70 mph)
- Longer turning radius
- Higher capital cost
- Lower ability to fit into an urban environment
- Less conduciveness to stage construction

The operation in mixed traffic required for the Study Area is not consistent with the dedicated right of way characteristics of the mode.

[1] Reference material from : Vuchan Vuchic,"Urban Public Transportation", Prentice-Hall, 1981.

Figure 2-10: Rail Rapid Transit Characteristics

Rail Rapid Transit

Miami Metrorail

- Higher Level of Service (speed, reliability and comfort)
- Higher System Performance (capacity due to long trains, productivity, efficiency)
- Greater safety (fail-safe signaling throughout the system)
- Stronger image (separate ROW and rail technology)
- Higher maximum speed (up to 70 mph)
- Longer turning radius
- In any setting, the higher capital cost of the five modes.
- Lower ability to fit into an urban environment
- Less conduciveness to stage construction

2.6 Bus-Rapid Transit

Low-cost investments in infrastructure, equipment, operational improvements, advanced bus technologies and intelligent transportation systems can provide the foundation for Bus Rapid Transit systems that substantially upgrade bus system performance[2]. Bus Rapid Transit technology has attracted a lot of interest in the last few years and may be considered as a viable alternative to LRT. A list of operating characteristics is presented below (and is also shown in Figure 2-11):

- Most flexible mode in terms of placement
- Evolving and dynamic technology which meets EPA 2004 requirements and 2007 requirements (for certain technologies).
- Has the capability to operate at grade (i.e., street level) with motor vehicles and pedestrians crossing the right-of-way, made possible by the overhead distribution system or heavy-duty diesel electric motor or alternate (fuel cell etc.)
- Large, single or double articulated cars running on rubber tires
- Manned operation
- Can operate up to 44 mph; make short radius turns of 40 ft; and climb grades up to 13%
- Vehicles/systems are somewhat proprietary, bid competition will not be limited, competitive pricing can be obtained if choice is similar to that of various other cities (economy of scale)
- Systems deployed in France and Italy and one being seriously considered in various US cities.
- FTA approval and "Buy America" clause need to be addressed.
- In any setting, the least costly of the modes being considered.
- Bus Assessment Technology Timeline is critical.

An example of BRT is a "tram-on-tire" alternative manufactured by IRIS.BUS. This bus concept is electrically powered and reflects a modern and attractive vehicle. It is in use in Lyon and Grenoble, France, and looks like a modern LRV. It is a single articulated vehicle, with three trucks, rubber tires (i.e., no tracks), 100 percent low floor, 40-foot radius turning capability, 13 percent grade climbing capability and draws power from a dual wire overhead system or from a diesel-electric motor. The IRIS.BUS dual-mode bus may offer low-cost advantages not available with the at-grade LRT. It eliminates the requirement to temporarily close and tear up streets to move utilities and install rails, but may require the installation of traffic sensing loops. It precludes the need to consider stray-current control and related corrosion, a problem with LRT that uses the running rails as a current return path. The dual-wire overhead power distribution system is more obvious than the single wire per track LRT system. It is smaller than a typical LRV at 64 feet long 8.36 feet wide, and seats 45 persons with 47 standees (at 5 sqft per passenger). An 80 ft double articulated version is also available. Vehicles are available in single-sided configurations. Single-sided configuration vehicles permit loading and unloading of passengers from one side of the vehicle. Two-sided configuration vehicles, on the other hand, allow flow-through loading and unloading.

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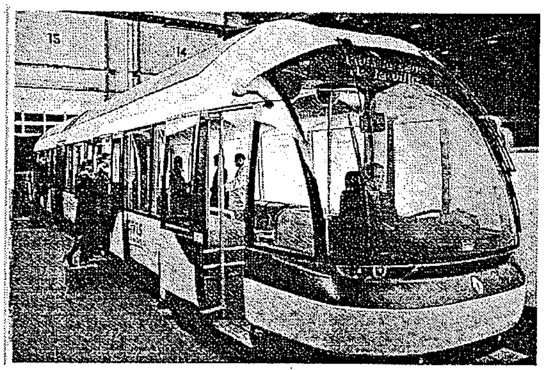
[2] This section uses FTA material published in the Bus Rapid Transit Demonstration Program brochure. The term "Enhanced Bus Service" is also applicable; it can be used interchangeably with BRT.

Figure 2-12 illustrates a single-sided configuration vehicle. In summary, BRT has the potential to be considered as an alternative to LRT and will be retained for further analysis. In the next section, a brief development status of various BRT concepts will be provided.

Figure 2-11: BRT Characteristics



Bus Rapid Transit

GLT
Nancy, France

- Most Flexible mode in terms of placement
- Evolving, dynamic technology which meets EPA 2004 requirements and 2007 requirements (for certain technologies).
- Has the capability to operate at grade (i.e., street level) with motor vehicles and pedestrians crossing the right-of-way, made possible by the overhead distribution system or heavy-duty diesel electric motor or alternate (fuel cell etc.)
- Large, single or double articulated cars running on rubber tires
- Manned Operation
- Can operate up to 44 mph; make short radius turns of 12 m (40 ft); and climb grades up to 13%
- Vehicles/systems are somewhat proprietary, bid competition will not be limited, competitive pricing can be obtained if choice is similar to that of various other cities (economy of scale)
- Systems deployed in France and Italy and being seriously considered in various US cities.
- FTA approval and "Buy America" clause need to be addressed.
- In any setting, the least costly of the modes being considered.

2.6.1 BRT Development Status

In this section, information on recent developments for potentially applicable BRT technologies will be provided. The BRT systems examined here are electric powered, low-floor, rubber tired, articulated vehicles. The electric power for the vehicles is provided either from a "touchable embedded power collection system" that is embedded in the street, or from an on-board diesel-electric hybrid propulsion system.

The status will provide a brief overview on:

- Development
- Design, test, and demonstration data
- Operating statistics and owner satisfaction, where applicable.

2.6.2 Propulsion System Options

BRT system manufacturers are developing different types of electric propulsion systems that could be applicable to the Corridor

- Hybrid Propulsion (diesel/electric using lead-acid batteries and diesel/electric using Super Capacitors)
- Dual-Mode Propulsion
- Fuel Cell Propulsion
- Touchable Embedded Power Collection Systems

These systems are in various stages of development and demonstration. The following is a brief report that will provide information on the recent developments for each of these propulsion systems.

2.6.2.1 Hybrid Powered Vehicles

The industry is focusing primarily on market needs to attract transit agency partnerships that will lead to large vehicle orders. Manufacturers need large vehicle orders to amortize technology development costs over a large (100 units) production line. In particular, the industry has focused on developing technology to meet the 2004 EPA emission guidelines for agencies that will need buses before then. Hence, the technologies that will meet the 2007 guidelines (cleaner all-electric hybrid motors with advanced battery technology and fuel cells) are progressing along in research development programs that will mature in 2005 or 2006. In the 40-foot vehicle length market segment presented below, the industry has focused on providing the hybrid diesel/electric vehicle for New York City Transit (NYTA) and the hybrid LNG/electric vehicle for Orange County Transit Agency (OCTA) to meet 2004 EPA emissions requirements.

2.6.2.1.1 40-foot Hybrid Diesel/Electric Vehicles

In this section, 40-foot hybrid diesel/electric buses are presented. Orion Bus Industries manufactured five prototypes utilizing a diesel Cummins engine and the "Hybridrive" system for on-board battery storage. Regenerative braking energy is used to charge the on-board batteries. Several of these buses were supplied to New York Transit Authority (NYTA) for initial demonstration testing. The past two years has provided two major transit agency-oriented suppliers, Orion Bus Industries and Nova Bus, with a substantial amount of technical operating data to redesign the test vehicles into proven service vehicles. NYTA has also taken advantage of the testing opportunity to understand where these vehicles will best perform and how to provide maintenance.

NYTA recently purchased the first large fleet of hybrid diesel/electric vehicles at a cost of $383,000 per vehicle. The size of this order establishes a relative standard for 40-foot hybrid diesel/electric vehicles.

Bus suppliers have indicated that this technology is not applicable to a larger bus. Lead-acid battery technology constraints limit the ability to provide enough stored power on an articulated bus shell to power the additional weight of a larger vehicle and passenger load. The weight and size of lead acid batteries are the limiting factors.

European manufacturers are also limiting the hybrid diesel/electric technology with on-board battery storage to smaller transit installations, and advocating the use of diesel-electric motors in heavy duty applications where catenary or imbedded power systems are not an option.

2.6.2.2 60-ft Diesel-Electric Vehicles Without On-Board Energy Storage

The industry has learned through the NYTA and OCTA revenue test programs on the 40-foot vehicles that current battery technology is too heavy, large, and limited to extend into a 60-foot vehicle. Hence, there have been no significant developments of a 60-foot hybrid diesel/electric. Transit properties that need a heavy-duty vehicle that will meet 2004 EPA requirements are using electric powered diesel motors without on-board storage (Cummins 330 HP ISL) in combination with smaller electric traction motors in the wheel hubs that independently drive the axles.

2.6.2.2.1 CiViS by IRIS.BUS

IRIS.BUS, a French bus manufacturer, initially developed the CiViS vehicle for heavy-duty bus service in France for applications where rail and overhead catenary were not an option. The rubber-tire vehicle contains a diesel-electric motor (Cummins 330 HP ISL) with Alstom electronic drive motors in the wheel hubs. This motor meets 2004 EPA emission requirements, but not 2007 EPA emissions requirements. The vehicle is a low floor design and comes in various lengths: (40 ft non-articulated, 60 ft articulated and 80 ft double-articulated). Its floor height is 13 inches and is further reduced to 10 inches when kneeling. Propulsion can be either from overhead catenary contact or an on-board hybrid (diesel or CNG)/electric hybrid power system. IRIS.BUS has provided a futuristic looking shell that can be equipped with an automatic optical guidance system provided by MATRA. CiViS can be supplied for manual operation and be steered like a regular bus or can be equipped for automatic guidance provided by MATRA. The automatic guidance system uses an optical sensor system that steers the bus by following two parallel lines painted on the road surface.

MATRA Transport International and IRIS.BUS have been delivering CiViS buses in France during the last two years. The first two contracts were for dual mode vehicles that can be operated in two different modes: powered by an overhead contact wire or with a standard diesel engine. The city of Lyon purchased 67 buses powered by an overhead line with no automatic guidance system. These buses are currently running on three routes, each 18.6 miles long. The city of Grenoble also purchased 35 buses and is currently using them on two 12.4-mile long routes.

The third contract was with the City of Rouen for 57 diesel-electric (Cummins 330 HP ISL) articulated vehicles with automatic optical guidance and no overhead power line or rail. The first two vehicles entered revenue service in January 2001 alongside existing diesel buses. The new fleet will be phased into revenue service on an existing 15-mile diesel service route without interruptions to existing service at a rate of about one per month. The French city of Clermont-Ferrand has also purchased six diesel-electric (Cummins 330 HP ISL) articulated vehicles using the same automatic optical guidance system without overhead power lines or rail infrastructure. The first vehicle has been delivered and a technical trial phase will run from February through June 2001.

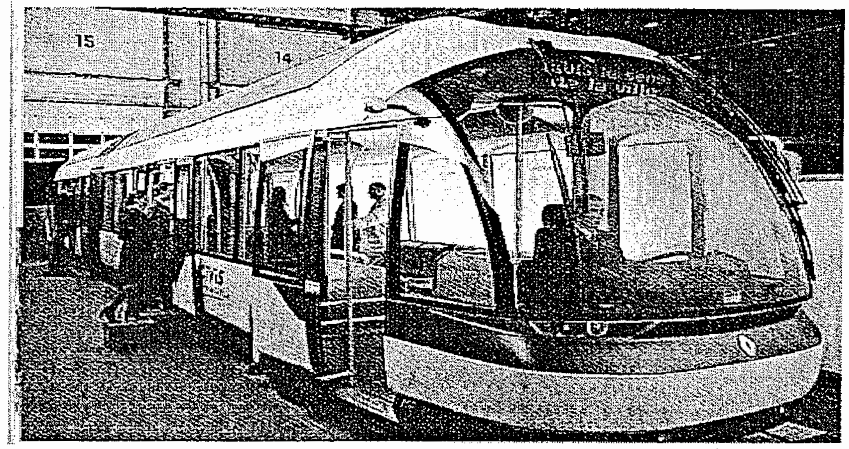
The first US application of the CiViS will be in the City of Las Vegas. The Clark county Regional Transportation Commission recently awarded a contract to IRIS.BUS for a total of ten diesel-electric, optical guidance buses that utilize the Cummins 330 ISL engine with a drive system that has electric motors installed inside specially widened wheel hubs. The first prototype car will be shipped in May 2002 for testing. Clark County hopes to have vehicles in revenue service for the September 2002 APTA convention if the testing is successful. Deliveries will extend into 2003. The vehicles will run on the first phase (four miles) of a six-mile route along North Boulevard. The vehicles are 60 feet long. They contain 31 seats and have room for 110 standees (at 2.7 sqft per passenger). The vehicles will be running at two-minute headways and can reach speeds of 44 mph fully loaded. FTA is allowing the first five vehicles in revenue service, but has indicated that future orders will be subject to DOT testing and US Domestic content requirements. IRIS.BUS is currently negotiating for a US Final Assembly site and will ultimately submit a design to allow Clark County to exercise their options for a total fleet size of ten vehicles under this contract. Each vehicle costs approximately $1.1 Million.

The City of Las Vegas is managing the civil work separately, taking responsibility for integrating the curbs and the signal priority system with the new low floor vehicle optical guidance system. Las Vegas chose to include the optical guidance technology because the automatic docking ability minimizes dwell times. The shorter dwell times are a necessity for maintaining the level of air conditioning required on the vehicles in the summer. Longer door openings and corresponding longer dwell times mean larger energy draws to maintain adequate level of air conditioning.

Although these vehicles will not be manufactured in the U.S., many of the subsystems will be domestic, including the Cummins hybrid diesel-electric engine (powered with Alstom traction motors in the wheel hubs) and the SUTRAK air conditioning system.

MATRA and IRIS.BUS are in the final stages of negotiating a partnership with a U.S. bus manufacturer to expedite the introduction of CiViS to other U.S. cities that have expressed interest in the vehicle, including Cleveland, Ohio; Phoenix, Arizona; and Eugene, Oregon. Cleveland has expressed interest in a dual-sided vehicle with three doors on the right and two doors on the left.

Figure 2-12: CiViS by IRIS.BUS



2.6.2.2.2 NEOPLAN Dual-Mode Bus

Neoplan recently won a bid to provide dual-mode buses for the Massachusetts Bay Transit Authority (MBTA). The bus they will be supplying is very similar to the CiViS design. It uses the same engine and drive technology, but incorporates a dual-mode function: The bus can also be powered by overhead catenary. There are no limitations to how long or how far the bus can be operated off the catenary with the standard Cummins 330 ISL engine. The new vehicles will travel in dedicated right-of-ways on Boston city streets using the Cummins 330 HP ISL motor 90% of the time, and switch to catenary electric power in tunnels on 10% of its route. The vehicle does not have on-board power storage. The vehicle incorporates four slide-plug doors on the right side (Neoplan designed the same vehicle with three doors on the right and two doors on the left in response to preliminary negotiations with the city of Cleveland, Ohio. However, this design has not been tested, nor is it currently in production).

Neoplan has indicated that the bus shell, shown in Figure 2-13, that will be designed for MBTA will be similar to the shell used by Ansaldo in the STREAM application that will be discussed in Section 2.6.2.5, and that the bus could be designed to integrate the STREAM pick-up instead of the catenary power. This bus will undergo DOT testing this summer and be placed in revenue service in 2003. This bus will meet FTA Domestic content and 2004 emission requirements. The articulated bus is expected to meet these emissions guidelines.

Figure 2-13: MBTA Silver line Dual Mode Coach

2.6.2.3 Hybrid Diesel/Electric Vehicles Using Super Capacitors

The Super Capacitor, (sometimes referred to as the Ultra Capacitor), consists of a very large capacitor bank that stores energy by electrostatically separating and accumulating charges physically between internal plates. The Super Capacitor is more of a load-leveling device than an energy storage device because super capacitors efficiently accept larger current ranges during regenerative braking and deliver these currents during acceleration in a heavier bus. The total amount of stored energy would probably give the vehicle a pure electric range of less than a mile.

New Flyer has developed a hybrid diesel/electric 40-foot demonstrator bus and plans to supply test buses for Philadelphia, Portland, Salt Lake City, and Long Beach. These pre-production units will use a Cummins B Series 5.9 diesel engine. Batteries will be mounted on the roof to accept the regenerated power from the braking effort. New Flyer hopes to further develop this bus design by replacing the batteries with Super Capacitors and will later exchange the batteries with Ultra capacitors.

The Super Capacitor energy storage technology will easily extend itself to development in the 60-foot market because it addresses the battery storage needed by the hybrid technology in the 60-foot application. New Flyer reports that the Super Capacitor technology can be easily extended to a 60-foot application. The 60-foot design would follow the 40-foot design by no more than twelve months if an operating agency hosts the prototype testing and invests in the design.

2.6.2.4 Fuel Cell Powered Vehicles

An emerging technology in recent years is fuel-cell propulsion. A fuel cell is an electro-chemical device that directly converts a fuel into electricity. Hydrogen and air are combined in the fuel cell to produce direct current electricity. The byproducts are primarily water vapor and carbon dioxide. Hydrogen can be produced a number of ways, one of which is by separating the hydrogen (H) and oxygen (O) from water (H2O) by electrolysis using electrical power. Another method is to reform the hydrogen from natural gas. In both cases the hydrogen is produced in a stationary facility and stored on board the bus. A recent development has been to reform hydrogen from methanol on board the vehicle to run the fuel cell. Hydrogen is the key ingredient in fuel cell batteries. However, the fuel cell batteries are still expensive to manufacture and the flammable hydrogen fuel is difficult to handle.

The most widely touted fuel-cell technology to have emerged from the laboratory uses what is known as a PEM (Proton or Polymer Exchange Membrane) situated between two electrodes, each coated with a catalyst such as platinum or palladium. When sandwiched together, hydrogen fuel can be made to separate at one electrode into its constituent free electrons and positively charged hydrogen ions, also called protons. The electrons can then be siphoned off as direct current electricity, or converted to alternating current. The protons drift through the PEM, combining with oxygen at the second electrode to produce ordinary water and heat. The individual fuel cells can be arranged in stacks of virtually any size. There is no pollution, and no moving parts to wear out or break down. The process is basically electrolysis in reverse.

Operation at freeway speeds is not expected to be a limitation of fuel cell propulsion. Less power is required to maintain speed than is required for accelerating. Operation at freeway speeds for long distances should be less demanding on fuel cells than street operation at slower speeds but with shorter distances between stops and more speed transitions.

2.6.2.4.1 Status of Specific Fuel Cell Propulsion Systems – 40-foot vehicles

The DBB XCELLIS/BALLARD Phase 3 Fuel Cell buses, formerly owned by Ballard and now jointly owned by Daimler-Chrysler, Ford Motor Company, and Ballard Power Systems have been operating in a demonstration program jointly sponsored by the Chicago Transit Authority (CTA) and the Vancouver Transit Agency (VTA). The six buses featured DBB 280 HP XCELLIS engines and /BALLARD (now owned by DBBBAE) Phase 3 fuel cell buses in a New Flyer shell. Results of the two-year test period have been published. The buses accumulated a total run time of 10,559 hours over 73,327 miles. Specific areas of evaluation during the trial included engine development; chassis integration; garage adaptation (modifications to handle and store hydrogen); system safety during handling and refueling; training; and documentation. The test buses were run on regular routes including high-volume downtown areas to maximize public visibility. Riders in both Vancouver and Chicago had very positive experiences from both a noise and a comfort level. In some cases, passengers would let diesel buses go by to ride a fuel cell bus. Most mechanical problems were minor and easy to fix. The Phase 3 bus was quieter than the diesel buses. Acceleration to 20 mph was about equal to that of diesel buses. Acceleration to 30 mph and to 40 mph was lower than diesel buses because the fuel cell buses are heavier. Interior space, seating and other aspects were unchanged from standard diesel-powered buses.

The results of the Phase 3 bus demonstrations will be used to develop the next generation vehicle for validation testing. The Phase 4 buses will be manufactured in limited quantities, and will be on the streets in revenue service by late 2002 for validation testing. The Phase 4 buses will be lighter and are expected to exhibit better acceleration characteristics. The first Phase 4 bus will be tested at Sun Line Transit Agency in Thousand Palms, California between July 2000 and October 2001.

Several other US transit agencies are buying limited quantities of fuel cell buses for testing purposes. At least three North American bus manufacturers are currently capable of integrating the fuel cell into small production quantities in response to competitive bids for revenue validation vehicles from transit agencies that will need large fleets between 2004 and 2007

European manufacturers are also testing fuel cell buses. IRIS.BUS teamed with Renault, Alstom and Ansaldo to provide demonstration buses in Paris, France; Torino, Italy; and Madrid, Spain. Three 30-foot low floor buses are currently in revenue service for research and development purposes. Ballard also predicts that fuel cell buses with XCELLSIS engines will be on the streets of Europe and North America by late 2002/early 2003.

BALLARD predicts that fuel cell buses will be ready for fleet size revenue service in late 2005. The current price of one of these buses (about $800,000) is high, and will not drop to a figure comparable to a typical bus until after approximately 1500 units have been produced. Fuel cell technology buses are expected to be at a competitive price and in full production time to meet 2007 emissions levels.

2.6.2.4.2 <u>Status Of Specific Fuel Cell Propulsion Systems – 60-foot Vehicles</u>

BAE (formerly Lockheed-Martin) and New Flyer agree that the fuel cell technology will support heavy-duty applications, but are unaware of plans for development of a prototype or demonstration testing integrating a larger 330 HP engine with a fuel cell at this time. If a transit agency expressed interest in hosting a demonstration test for near term fleet procurement, initial production vehicles may be developed as early as 2003. Revenue service production vehicles would be based on a year's collection of reliability data. Revenue service vehicles could be in time to meet 2007 emissions requirements if development started this year.

2.6.2.5 Touchable Embedded Power Collection Systems

The STREAM (see Figure 2-14) embedded power collection system was conceptualized in 1994 and has undergone approximately 7 years of research and design. The vehicle progresses along an imbedded guideway on rubber tires. The power supply is transmitted through the commutation of embedded magnetic discontinuous sectors with magnetic shoe contactors attached to a retriever-like device under the vehicle. Ansaldo has been developing and testing STREAM designs at a facility in Naples, Italy since 1995. The test track can operate buses at 15 mph and has accumulated 620 miles of testing.

The first commercial installation is a demonstration system under construction in Trieste, Italy (see Figure 2-17). The first phase is a 1.24-mile long line. This phase has two stages where the buses are powered through the embedded track, and then switch to battery power. Stage 1 of Phase 1 is complete, and Stage 2 is expected to be completed prior to the end of 2001. In Stage 2, the system continues on an embedded track and then reverts back to batter power again. Phase 2 construction will be delayed until Phase 1 has been successfully operating for six months.

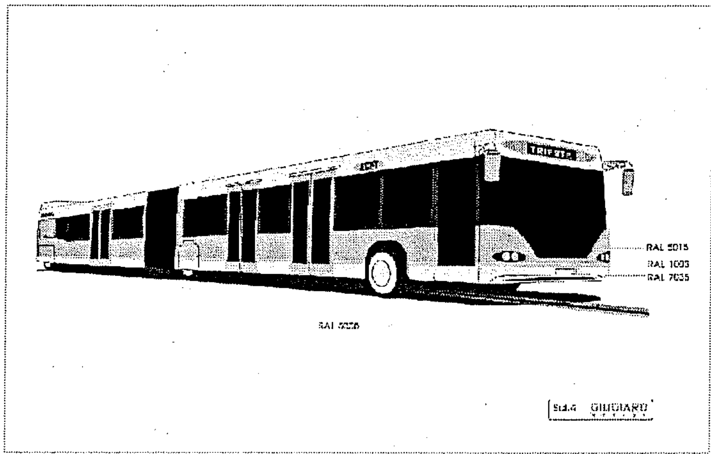


Figure 2-14: STREAM Demonstration Bus

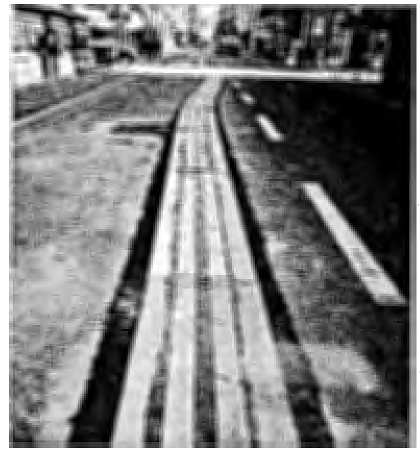


Figure 2-15: Embedded track

The revenue service demonstration line will employ two 40-foot and 60-foot long buses. Buses are equipped with Nickel Metal Hydride batteries that cost approximately $200,000 each and have an unknown life based on a guaranteed 1,00 – 1,500 charge/discharge cycles. The batteries could form a significant part of the operating costs.

Application of this technology in the U.S. will require safety certification. Various design and certification issues should be addressed by the manufacturer in the timeframe for choosing a technology for the Corridor. The applicability to higher speed and higher power is possible, but will require additional development and testing.

Two other embedded technologies are being developed by SPIE (INNORAIL) and Alstom (ALISS) in France. Both technologies are still at the development stage. Unlike STREAM, but like INNORAIL, ALISS is not integrated with a steering mechanism. ALISS requires the vehicle power pick-up to be positioned over the units embedded in the roadway by independent means. The advantages include less maintenance and better performance. There are currently no commercial contracts for integration of the ALISS or INNORAIL systems.

While this technology is not yet service proven, it is expected to be in the near future. The main issues regarding these technologies are safety certification, operating performance under the dynamic environment of normal streets and roads, reliability/dependability, and installation life. Additionally, investment and maintenance of the infrastructure are important cost considerations. These technologies will meet 2007 EPA emission requirements.

2.6.3 Summary

Bus suppliers pursue Research and Development on the basis of short-term customer needs and depend heavily on operating agency involvement to develop technology. For example, Orion was heavily dependent on the NYTA operating experience to develop the hybrid diesel/electric technology and is even more dependent on the 125-bus order to amortize development costs.

Transit agencies have provided less stimulation for development in the 60-foot market mostly because fewer US agencies use articulated fleets. There is currently only one suitable engine

(Cummins 330 ISL) for heavy-duty bus use that meets the 2004 emissions requirements. Additional operator involvement will be necessary to stimulate the 60-foot Hybrid Super Capacitor bus, 60-foot Fuel Cell bus, and the embedded power collection systems.

Federal requirements for DOT's Altoona testing of bus designs and US Buy America requirements are a significant factor for bus suppliers when offering new technology. US applications of the embedded power collections systems may require a significant amount of effort and time to adopt the embedded power supply system technologies.

To compare these technologies and gain an understanding of when the emerging technologies will be progressing through the prototype testing, revenue service validation, or production phase, a Bus Technology Assessment Timeline will need to be developed. The Timeline is a chronological analysis forecasting the future development phases of the technologies and vehicles discussed in this report. The timeline will provide a snapshot to allow comparison of the future progress of electronic transit bus technology developments based on the current development status.

2.7 ADDITIONAL OPTIONS SUGGESTED DURING THE SCOPING PROCESS

During the scoping process, additional alternatives were suggested by citizens. They are described and assessed below. A further assessment against the goals and objectives of the project will be performed in Section **Error! Bookmark not defined.**.

2.7.1 Ferry Service

During the scoping meetings held on November 2001, several citizens expressed the desire to have a water ferry connection between Miami and Miami Beach examined. This technology is discussed herein. The Florida Department of Transportation (FDOT) currently operates a passenger/vehicle ferry service over the 0.4 miles between Fort George and Mayport. Twelve other states operate some form of passenger only or passenger/vehicle ferry service, including Florida, Washington, Massachusetts, Ohio, Texas, Connecticut, California, Louisiana, New York, Virginia, Pennsylvania, Maine and Minnesota.

Figure 2-16 reflects one of the passenger only ferries operated by the Washington State Department of Transportation. The vehicle pictured is a Chinook class high-speed passenger-only vehicle. It is a steel hulled catamaran design. The boat was placed in service in 1998 and is 143 feet - 3 inches in length with a beam of 39 feet - 4 inches and a draft of 5 feet. The boat has a gross weight of 99 tons and a net weight of 67 tons. Cruise speed is 30 to 34 knots per hour (about 35 to 40 mph). The boat is powered by 7,200 horse power four diesel-waterjet engines. Passenger capacity is 350. Hourly capacity is largely governed by the time required to dock, unload and load. For a single dock system, this boat would offer a capacity of a maximum of 1,000 passengers per hour. The boat requires a crew of five.

Figure 2-16: Passenger Only Ferry Boat

Capital outlays for ferry boat systems include the boats, terminals, parking facilities and maintenance facilities. System capital cost would vary significantly depending on the number of boats and docks required. Based on a composite of the service operated nationally, the total operating expense is approximately $120.90 per vehicle revenue mile and $886.75 per vehicle revenue hour. Corresponding cost per passenger mile and passenger trip are $1.46 and $11.52 respectively.

2.7.2 Metromover Extension to 5th and Alton Road

Another alternative identified by the citizens consists of extending Metromover to Miami Beach, namely to the intersection between Alton Road and Fifth Street. Metromover belongs to the AGT technology family and was discussed in Section 2.4, where it was mentioned that the level of automation as well as operation in mixed traffic required for the Study Area is not consistent with the dedicated right-of-way characteristics of the mode.

This suggested alternative does not suffer from the above inconsistency but presents the following characteristics:

- Limited coverage of the Study Area
- Very high capital and Operations and Maintenance costs
- Elevated structure in Miami Beach

2.7.3 Metrorail Extension to 5th and Alton Road

Another proposed alternative is to extend Metrorail to the intersection between Alton Road and Fifth Street in Miami Beach. Metrorail belongs to the RRT technology family. Its characteristics were presented in Section 2.5, where it was mentioned that the operation in mixed traffic required for the Study Area is not consistent with the dedicated right-of-way characteristics of the mode.

This suggested alternative does not suffer from the above inconsistency but presents the following characteristics:

- Limited coverage of the Study Area
- Very high capital and Operations and Maintenance costs
- Elevated structure in Miami Beach

- Inadequacy of the technology to the projected ridership range

2.7.4 Suspended Cable Car

Another alternative identified during the scope process was a suspended cable car system. The proposed system would be suspended from towers erected in Miami near Bicentennial Park, on Watson Island along the MacArthur Causeway and in Miami Beach on 5th Street. The towers would be placed at 200 – 500 foot intervals and ultimately support the cable car system. Gondolas could be sized to carry 6 – 20 passengers. Information about the capital and O&M costs are not available.

The suggested alternative presents some of the following limitations:

- Limited coverage of study area
- Very high elevated structure along the corridor
- Relatively slow restricting capacity
- NFPA safety issues (Emergency evacuation)
- Proprietary technology

2.8 EVALUATION OF ADDITIONAL OPTIONS SUGGESTED DURING THE SCOPING PROCESS

Based on the assessment presented in this report and consistent with the conceptual nature of the alignments, the planning and engineering data available at this point in the project development process, no "fatal flaws" were identified for any of the candidate technologies. In reviewing the various needs for the Corridor, there are, however, some technologies whose application is less responsive to the system technical needs in terms of service requirements, the desires of the citizens and stakeholders, and cost effectiveness of the system.

As an example, RRT (like the Metrorail system) is an over design in terms of speed, capacity and grade separation requirements for the system. The aerial structure required would overwhelm the urban environment it is intended to serve. The capital cost would also be prohibitive, given the projected ridership range.

AGT and Monorail have also major limitations for the corridor under study. The required aerial structure will overwhelm the area it is trying to serve. In addition, the consultation process undertaken during the DEIS phase has indicated that the citizens of Miami Beach are opposed to an elevated transportation system. The capital and O&M costs are also very high.

The concept of ferry service between Miami and Miami Beach has also some characteristics that make it inappropriate for a line-haul public transit system in this application. The system has speed and capacity issues that could only be overcome by an extraordinary investment in docks and boats. These added costs, on a system that already has very high capital and O&M costs, will not prove cost-effective for the Bay Link application. The system has the added disadvantage of delivering a maximum of 1000 riders to which could create a capacity constraint on other transit modes providing transfer services to ferry passengers. The further distribution of the riders would require another distribution system such as buses, or 40 Electric-wave buses to meet each ferry. This added transfer would tend to reduce ridership.

The cable car will present some visual issues due to the aerial nature of the technology. The alternative also will present capacity limitations, NFPA issues, provide limited coverage of the study area and introduce a proprietary technology. Its application in a line haul public transit mode will also suffer from reliability and failure recovery issues. The system, like ferry boats, could be an attraction in itself and may have merit as a private venture.

3.0 TRAVEL DEMAND ASSUMPTIONS

The ridership estimates of the three previous studies ranged from a low of 24,000 daily riders to a high of 33,000 daily riders.

The Miami Beach LRT Feasibility Study predicted 31,000 daily riders for a 15 station, 8.6-mile system. The system relied on its connections to downtown Miami and to the Metrorail System to occur via the Metromover.

The transitional analysis, which analyzed a light rail line between the Overtown station and 71st Street and Collins Avenue, predicted the highest ridership of the three reports examined. This analysis predicts 9.3-mile system to have a high of 33,000 riders per day.

By far the largest market for travel on the line was Intra-Beach travel (207,900 trips) followed by Beach to Other (154,500), Other to Beach (120,100), then South Beach to Central Business District (33,700 trips). These numbers reveal the limitations of a strictly South Beach to CBD system without easy access to other locations in the region.

The ridership forecast for the East-West Multimodal Corridor DEIS is for a 6.5 mile LRT route with 10 stations. The line runs between the Convention Center in Miami Beach and Bayfront Park in Downtown Miami. The LRT line has transfers with the Metromover and the East-West line but not the Stage 1 Metrorail.

The greatest expected peak hour ridership on the Miami-Miami beach line is listed in Figure 3-1. The peak passenger per hour per direction (pphpd) value is used to determine the required fleet size.

Due to the increased connectivity between Bay Link and Metrorail and Metromover and the expected implementation of the Earlington heights connection to the Miami Intermodal Center (MIC), it is expected that the ridership numbers on Bay Link will be higher than the ones published in the DEIS.

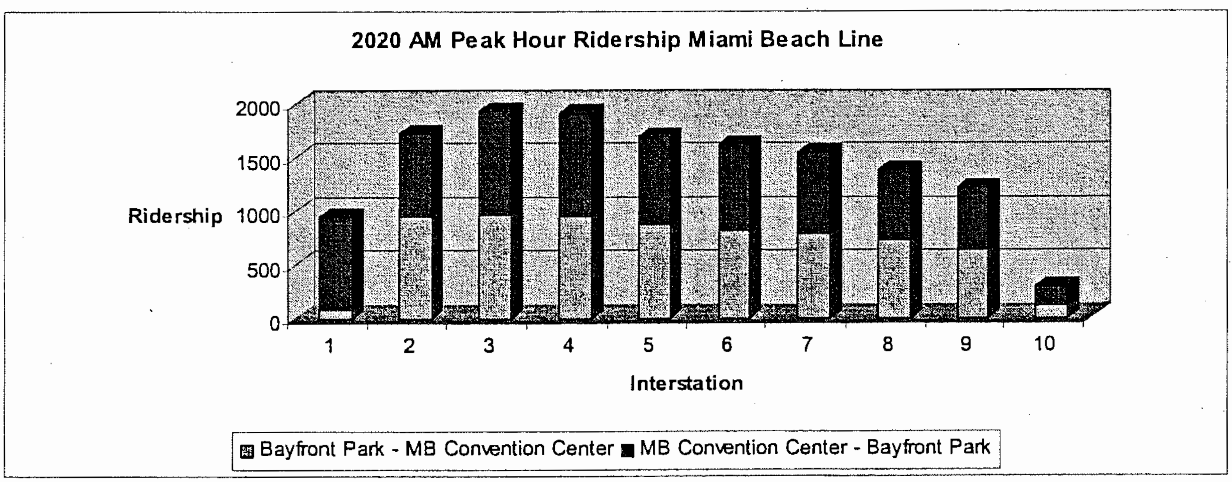


Figure 3-1: 2020 AM Peak Hour Ridership on the Miami Beach Line.

4.0 TYPICAL STRUCTURES AND STATIONS

4.1 LINE STRUCTURES

Placing a linear fixed guideway system into a built-up system of streets and properties requires some sense of the magnitude and type of structures required for each of the technologies. Both technologies will operate at-grade. Thus, the obvious basic line structures required are:

4.1.1 LRT At-Grade

- With ballasted trackway
- With embedded trackway

Variations on these basic line structures that may be needed due to the topography of the terrain, use of split or center-platform stations, use of single track sections and street-level restrictions include:

- Dual-track/guideway and single-track/guideway
- Variations in placement of support poles for LRT's overhead power distribution system

4.1.2 BRT

- With embedded trackway (Stream, shown in Figure 2-17)
- With regular asphalt guideway (CiViS shown in Figure 4-1). Curbs can also be extended along the roadway to provide a dedicated right-of-way.

Figure 4-1: CiViS on regular asphalt roadway

4.2 STATIONS

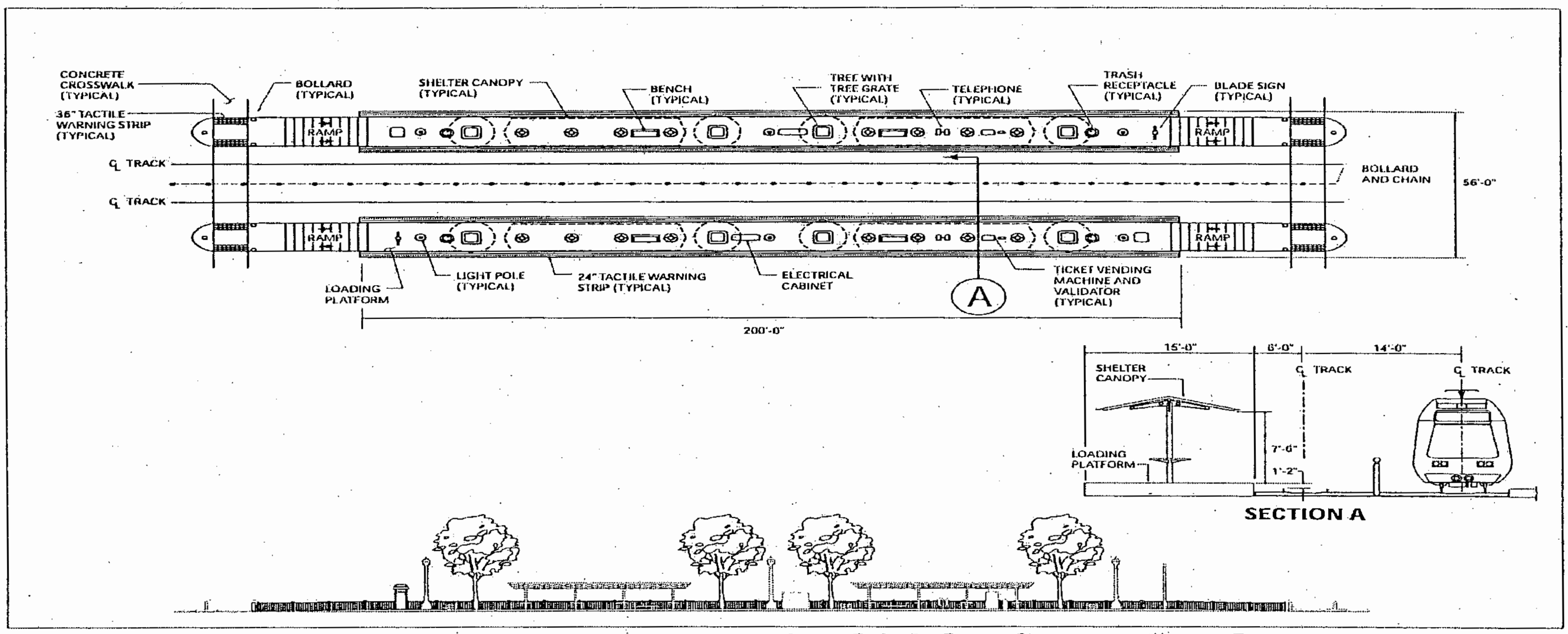
Stations that provide for the loading and off-loading of passengers match the line structure where they have been located. There are certain common provisions among all stations since they must be long enough to accommodate the longest train or bus

The common variations in stations that could be termed "typical" are:

1. At-grade, side platform
2. At-grade, center platform

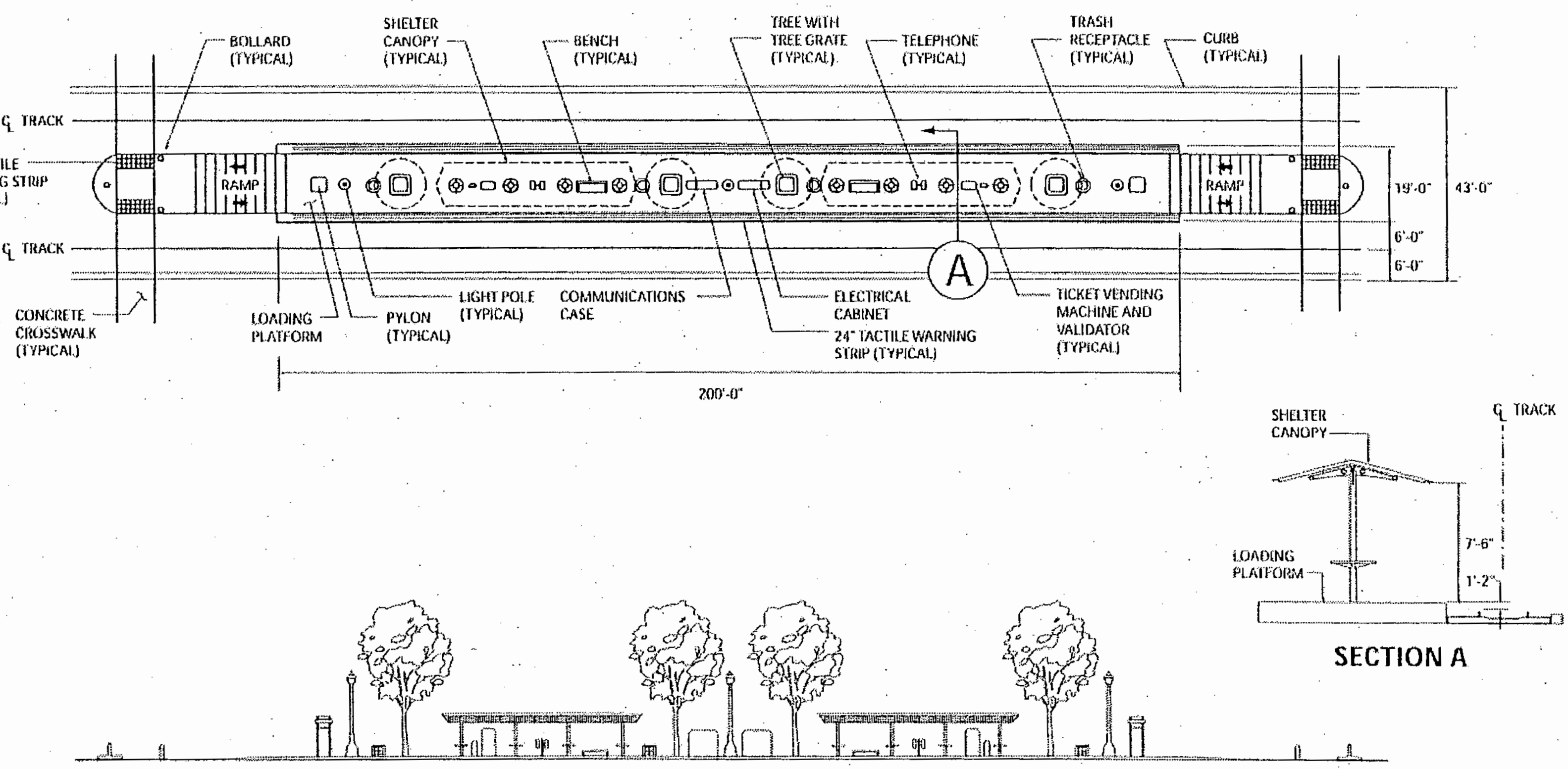
It has been assumed that the fare structure and collection method for the Corridor are conducive to a barrier-free/proof-of-purchase system. This will require ticket vending machines (TVM's) on the platform or beneath the platform level for elevated stations. Additional space is required for a canopy and weather protection. Figure 4-2 and Figure 4-3 illustrate LRT side and center platform typical sections. Figure 4-4 represents a typical BRT side platform station.

Figure 4-2: Light Rail-At-Grade Side Platform Plan, Typical Elevation and Section



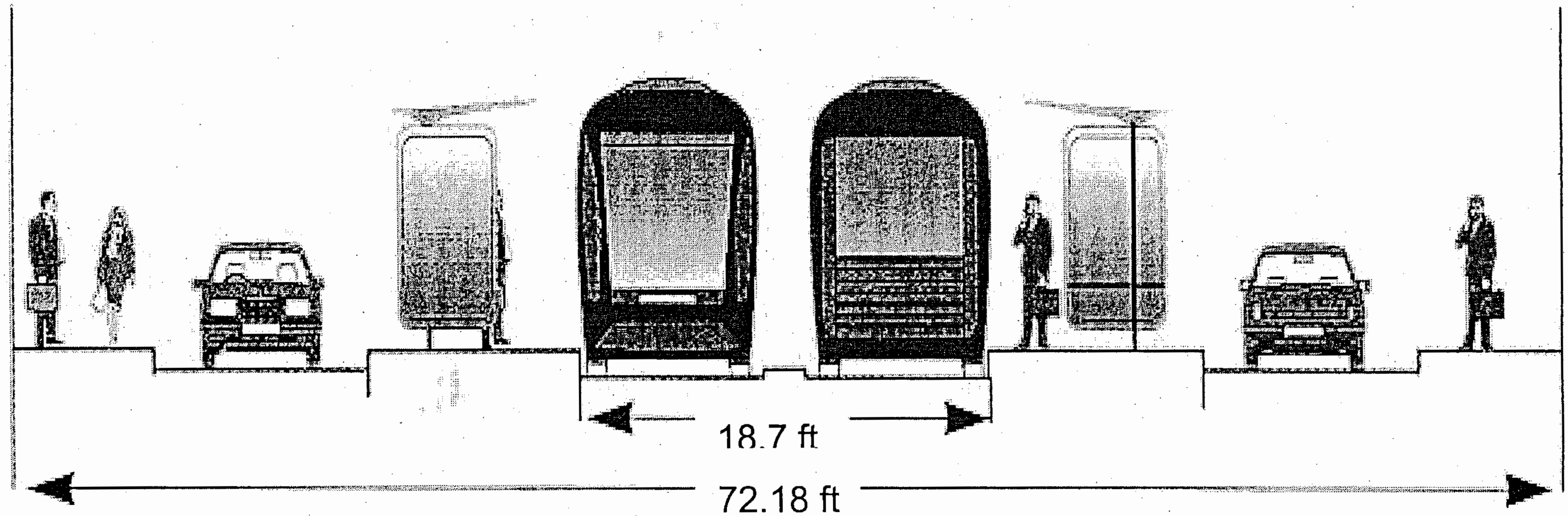
Light Rail–At-Grade Side Platform Plan, Elevation and Typical Section

Figure 4-3: Light Rail-At-Grade Center Platform Plan, Typical Elevation and Section



Light Rail–At-Grade Center Platform Plan, Elevation and Typical Section

Figure 4-4: BRT – Installation of a Station in a Street of Average Width



5.0 PROJECT STUDY PURPOSE/GOALS AND OBJECTIVES

5.1 PURPOSE OF THE PROJECT

The purposes of the Bay Link project, endorsed by the Citizen's Advisory Committee (CAC) in November 2001, are listed below:

1. Connect downtown hotels, activity centers and tourist attractions to the Miami Beach Convention center and other activity areas.
2. Improved transit connection between Miami International Airport and Miami Beach (via the MIC-Earlington Heights Connector).
3. Provide a connection between two of South Florida's highest concentration of residential and commercial activities.
4. Serve existing and future high-density residential populations in Miami and Miami Beach.
5. Provide area residents with enhanced transit options for a variety of trips within the corridor (Miami to Miami Beach and Miami Beach to Miami):
    - Home to work
    - Recreation
    - Tourist
    - Arts and Education
6. Provide a transit option to mitigate the excessive parking demand in Miami and Miami Beach.
7. Tie Miami Beach to the rest of South Florida's transit system.
8. Provide the economic benefits gained from transit capital investment.
9. Connect high-volume pedestrian activity areas.

5.2 GOALS AND OBJECTIVES OF THE STUDY

Several goals and their associate objectives were adopted for the previous East-West Multimodal Corridor DEIS. An evaluation matrix was developed based on the criteria outlined in the goals and objectives and was used to help select alternatives for further evaluation. The proposed alternatives were ranked based on their capacity to fulfill the requirements of each goal and objective.

The goals and general statements that define what needs to be accomplished and the objectives identify the specific expressions of those desires. Criteria are indicators or measures of how well the alternatives succeeds in achieving the desired goals and objectives.

Table 5-1 lists the set of modified goals and objectives as a result of input received during the scoping process.

Table 5-1. Goals and Objectives

Goal No.	Goals	Objectives
Goal 1	Develop a multimodal transportation system	• Improve the transportation system accessibility and connectivity • Reduce the time necessary to travel to the job market in Miami, South Miami Beach, the Airport (MIA) for all modes of transportation • Improve transportation for socially, economically and physically disadvantaged groups • Reduce dependency on automobiles • Provide an alternative to highway travel delays and congestion
Goal 2	Improve the efficiency and safety of existing highways and transit facilities	• Provide direct transit connection from Miami Beach to Miami and MIA. • Provide area residents with enhanced transit options for a variety of trips within the corridor. • Provide a connection between two of South Florida's highest concentrations of residential and commercial activities. • Provide a safe, reliable, and secure transit service. • Add capacity to the MacArthur Causeway and an alternative mode for evacuation.
Goal 3	Preserve social integrity of urban communities	• Connect high volume pedestrian activity centers. • Serve existing and future high-density residential populations in Miami and Miami Beach. • Provide transit investment supportive of Miami and Miami Beach development and land use plans. • Minimize traffic impacts on local streets within the study area. • Minimize impacts during construction. • Minimize right-of-way requirements
Goal 4	Plan for transportation projects that enhance the quality of the environment	• Improve air quality by reducing automobile emissions and pollutants • Protect sensitive areas such as wildlife habitats, wetlands, historic, and cultural sites • Provide a transit option to mitigate the excessive parking demand in downtown Miami and Miami Beach
Goal 5	Define a sound funding base	• Provide equitable transportation services and benefits to all geographic areas and constituencies • Provide a high quality connection between hotels, activity centers, transit attractions and the Miami Beach Convention Center. • Maximize the economic benefits gained from transit capital investments. Involve the community in the decision-making process by providing opportunity for public input • Provide for equitable sharing of the costs of transportation improvements among those who benefit them

6.0 ALIGNMENT ALTERNATIVES

6.1 STUDY AREA CHARACTERISTICS

Different alignment alternatives were identified in the DEIS. The Miami Beach alternatives are described in Figure 6-1 below, while Figure 6-2 describes the Downtown Miami alignment . The Miami Beach segments G1, G2 and G3 identified in the figure correspond to:

- G1: At-grade from either MacArthur Causeway or the south end of Miami Beach northward along Washington Avenue to the Convention Center.
- G2: At-grade from either MacArthur Causeway or the south end of Miami Beach, one-way transit along Washington Avenue to the Convention Center and then the opposite direction on Collins Avenue forming a loop.
- G3: At-grade from either MacArthur Causeway or the south end of Miami Beach northward along Washington Avenue to the Convention Center, turning westward on 17th Street then looping southward on Alton Road.

In Miami, there are two potential connections to the existing service:

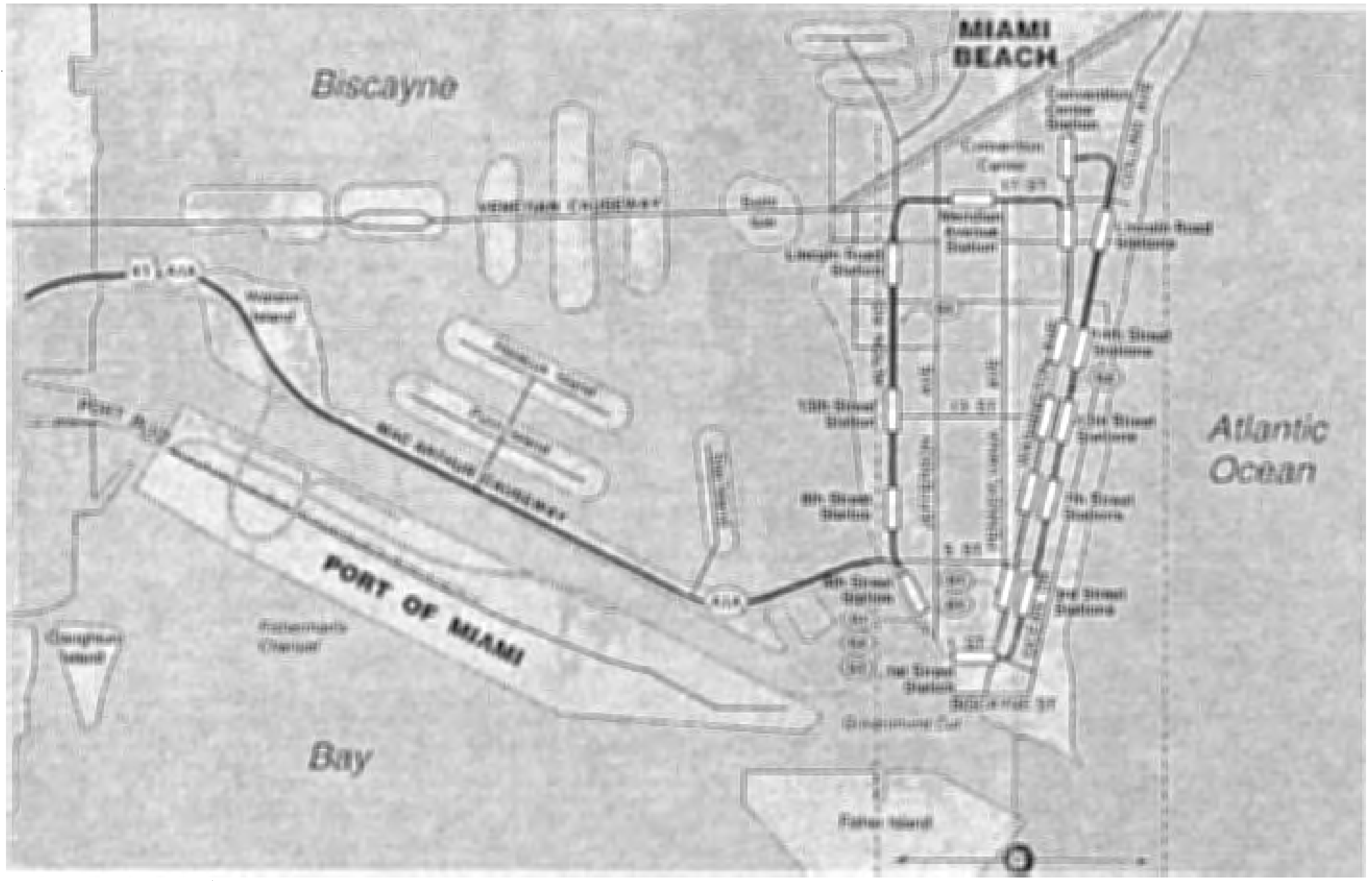
- A connection to Government Center (Metrorail and Metromover)
- A connection to Overtown on 5th, 6th or 7th street (Metrorail)

The salient alignment features are:

- Minimum radius of curvature: 40 ft
- Maximum grade: 5.2 %
- Interstation distance in Miami Beach: 0.25 miles (0.4 km).
- Length: 8.12 miles
- Minimum Headway: Six minutes
- Maximum number of stations (loop option): 15

Based on the recommendations of the Citizens Advisory Committee, other alternatives may be identified. LRT and BRT will be "tested" against those alignment alternatives in the next phase of this study.

Figure 6-1: DEIS Alignment (1/2)



LEGEND

G1

G2

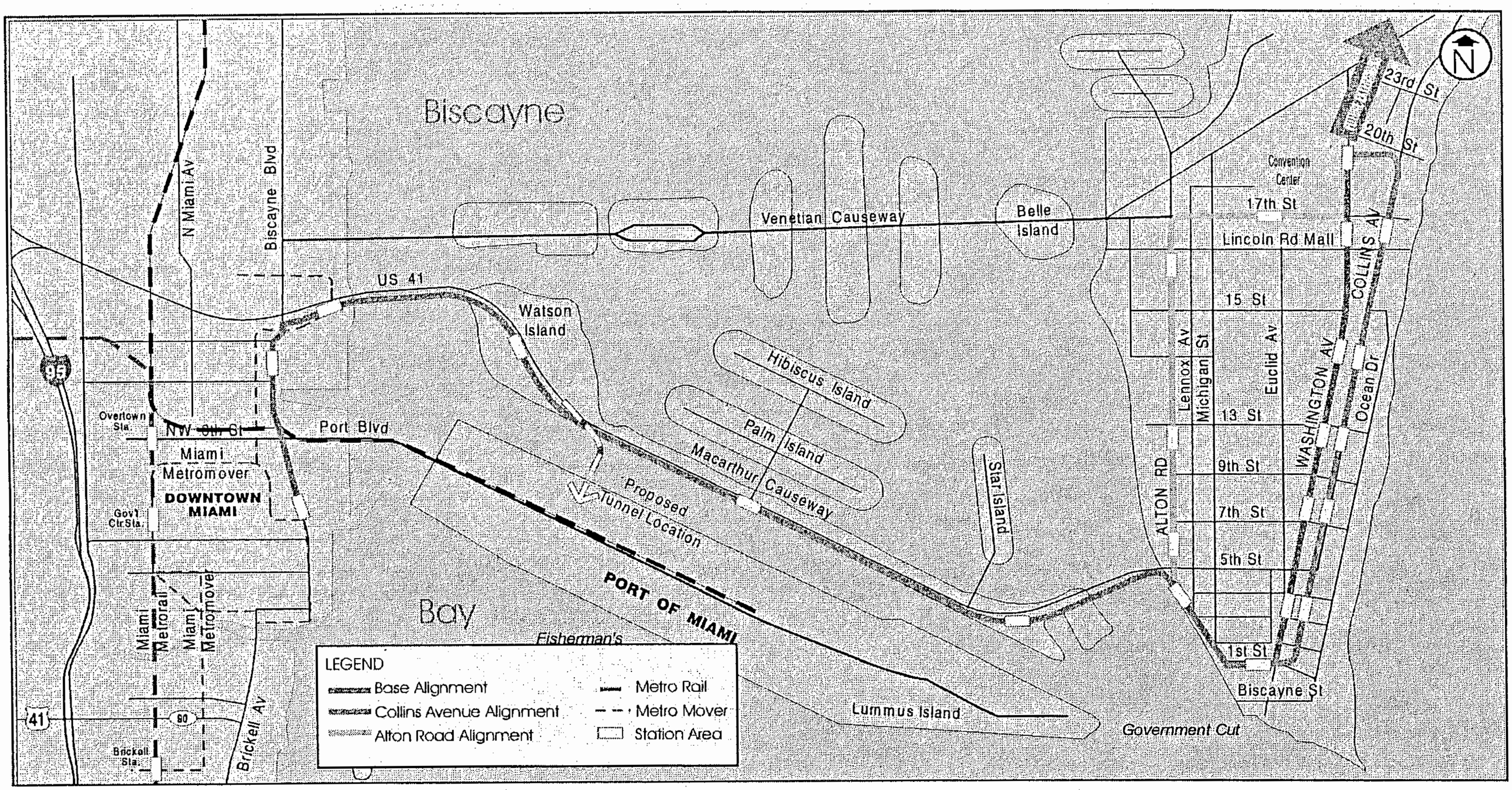
G3

Stations

Miami Central Business District

Segment Boundary

Figure 6-2: DEIS Alignment (2/2)



6.2 STUDY CONCEPTUAL ALIGNMENTS

During the recent scoping meetings, various alignment alternatives were suggested by the citizens and led to the conceptual alignments shown below:

Figure 6-3: Conceptual Downtown Miami Alignment Alternative A1

Figure 6-4: Conceptual Downtown Miami Alignment Alternative A2

Figure 6-5: Conceptual Downtown Miami Alignment Alternative A3

Figure 6-6: Conceptual Miami Beach Alignment Alternative B1

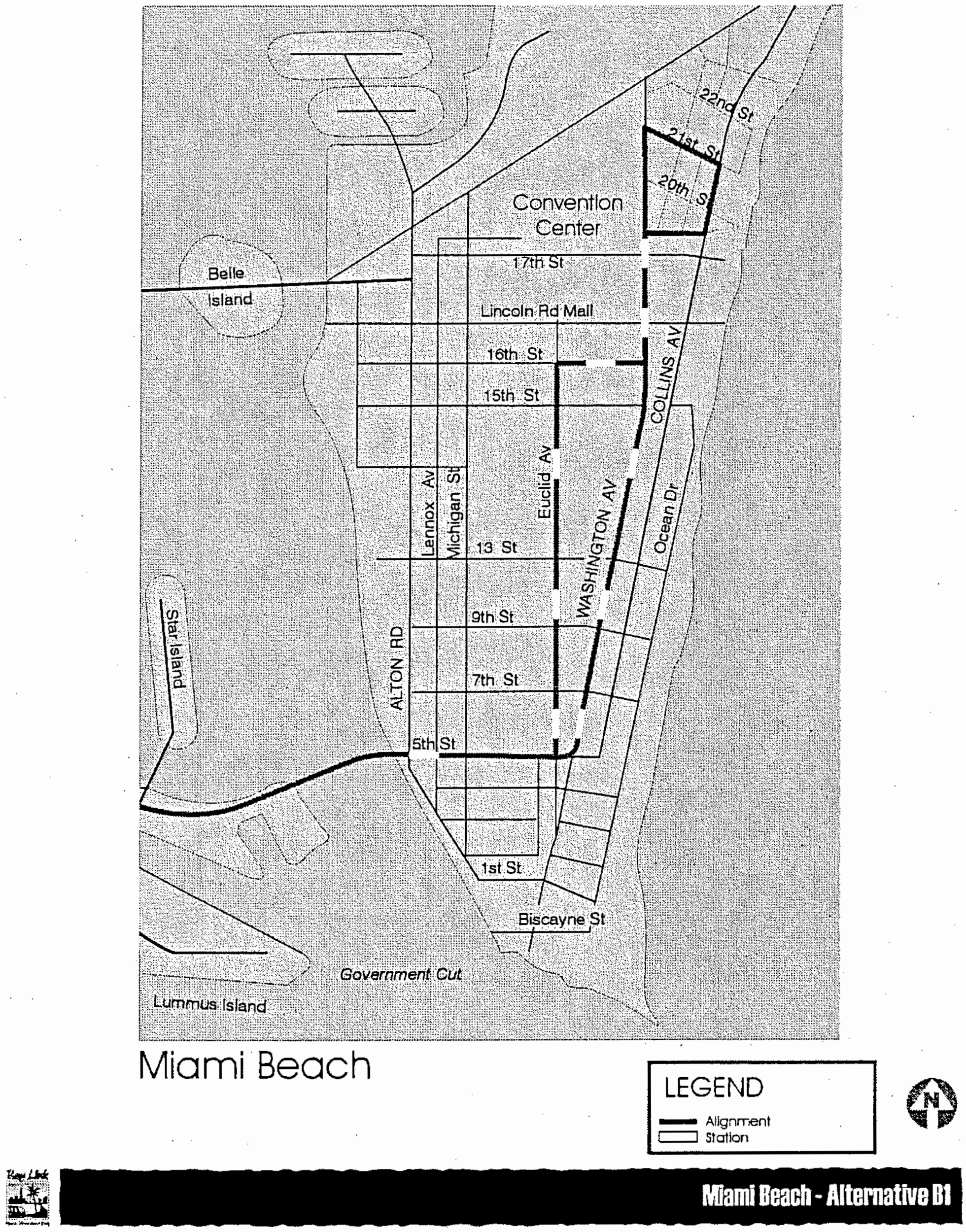


Figure 6-7: Conceptual Miami Beach Alignment Alternative B2

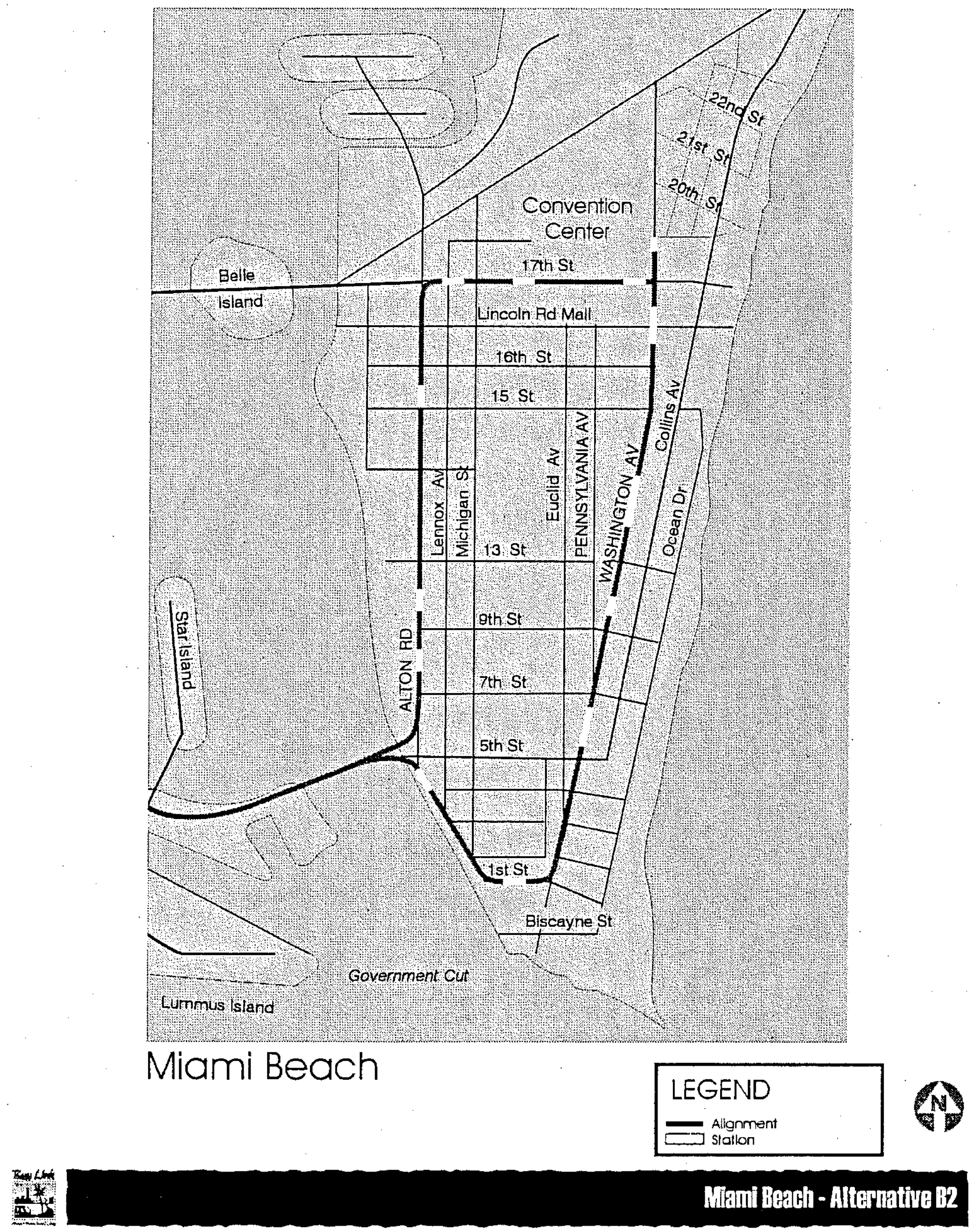


Figure 6-8: Conceptual Miami Beach Alignment Alternative B3

During Phase 2, the retained technologies at the end of Phase 1, will be projected and tested against the detailed alignments to be derived from the conceptual alignments.

7.0 ASSESSMENT METHODOLOGY

This section describes the process used in evaluating the candidate technologies for the Miami-Miami Beach Transportation Corridor Study. The process consists of a two-tier evaluation process. Tier I compares the general characteristics of the technology against the characteristics and general needs of the system defined earlier in this report. The intent of this section is to identify alternatives early in the process that do not appear to be responsive to the technological and service needs of the required transit service.

The remainder of this report will focus on LRT and BRT technologies.

7.1 COMPARATIVE EVALUATION

The second Tier evaluation consists of a detailed evaluation of the technologies surviving the initial screening. A list of technology assessment categories and evaluation criteria has been developed. The evaluation categories include: technical maturity, procurement aspects, competitive procurement, operational characteristics, capital and operations and maintenance costs, and urban integration. For this assessment, the approach has been arranged to promote an initial technology feasibility screening while a more detailed analysis will be performed in the second phase. The evaluation categories and criteria are reflected in Table 7-1 and discussed below. The criteria will be refined and adjusted as necessary based on discussions with the Project Technical Team and the Citizens Advisory Committee.

7.1.1 Technical Maturity

In selecting a technology for a new system, it is important to assess the developmental and implementation risk associated with the technology. Risk can be determined by examining such factors as the years of proven service in similar urban transit applications, the number of systems currently in operation (and future outlooks), and the reliability and safety records of the operational systems. Typically, due to the difference in U.S. and foreign industry standards and federal regulations, only U.S. systems are usually taken into account. Due to the appropriately risk-adverse nature of public projects, failure to meet this criterion is usually considered a fatal flaw. However, one should not preclude emerging technologies that are seeing widespread interest and applications in Europe. This is mainly true for BRT where certain cities in the continental U.S. and Hawaii are considering various BRT applications. Honolulu is considering the STREAM from Ansaldo-Breda, while the CiViS from Iris.Bus is being considered seriously in Las Vegas, Nevada; Cleveland, Ohio; and Eugene, Oregon. The door is therefore left opened for BRT technologies that may prove adequate to the corridor.

7.1.2 Procurement Considerations

An important consideration in selecting a technology for a new system is the number of potential suppliers of the technology. There should be an adequate number of suppliers to ensure that a solicitation for proposals or bids will receive a competitive response. It is equally important that the tenders be based on a non-proprietary concept or design to ensure an acquisition of a good solid technical product at a reasonable price. All vehicles of any technology have some proprietary components. The concern here is for concepts or major assemblies that are unique to only one supplier.

7.1.3 System Capacity

A technology should have the flexibility to meet a range of capacities over a day's operating schedule and over the life of the system. This includes the provision of cost-effective service for peak, non-peak, and special event rider flows during a day for the design years. This includes such factors as the ease with which headways can be changed, train consist can be changed, and other general factors of operational flexibility such as reliability and failure management features.

This evaluation criterion also includes the ease with which the system can be expanded from the initial operation to more comprehensive coverage, if required. Expansion should be possible without significant disruption to the operating system or the community at large.

7.1.4 Right-of-Way Requirements

The purpose of this criterion is to eliminate technologies that cannot physically operate over the alignment envisioned for the Corridor without undue disruption to current development (i.e., wide radius turns requiring additional right-of-way). These requirements include the geometry of the required alignments in comparison with the performance requirements and constraints of the technologies. For horizontal alignment, this is measured by the minimum curve radius that a technology can negotiate in revenue service and in the yard and shop. This measure also addresses the physical clearance envelope for a given technology. Also included are such factors as the maximum vertical profile gradient that a technology can traverse in regular passenger service and whether grade separation is a requirement or can be provided as needed. Examples of limitations that a technology can impose include structure height, the space requirements of stations, and the practicality of siting a yard/shop facility.

7.1.5 Service Characteristics

Typically, service levels must be high to attract riders. Perhaps the key service indicator is trip time (the combined access, wait, and travel times). The acceleration/deceleration rates and the cruise speed of the technology relative to station spacing are also important considerations. The vehicle speed will be assessed in subsequent phases when more conceptual engineering has been accomplished and a set of alternative alignments is identified.

Other important aspects of the service characteristics are reliability of the service and the responsiveness of the technology to the public's wishes for safe, secure, convenient and comfortable service.

7.1.6 Environmental Impact

Because the environmental impact of the corridor under any alternative routing is predominantly site-specific, it can only be included here in terms of the technologies and their inherent or generic environmental impacts. These relate, in general, to impacts on or of air quality, noise and vibration and visual aesthetics.

7.1.7 Urban Integration

This criteria includes the measure of the less tangible but equally important factors of system success such as: being supportive of the urban design concept for the system; being supportive of the land use/joint development expectations for the area; the visual acceptance of the system and its facilities (supportive of neighborhood characteristics such as the Art Deco district and minimization of aerial structures); the enhancement of pedestrian movement and station access and the ability to pull together and connect the communities in the corridor rather than building barriers between them.

7.1.8 Environmental Justice and Equity

Equity issues are concerned with the distribution of costs and benefits of all alternatives across low-income and transit dependent groups in the study area. Equity considerations generally fall within three classes.

1. The extent to which transit investments improve transit service to various population segments, particularly those that tend to be transit dependent.
2. The distribution of project costs across the population through whatever funding mechanism is used to cover the local contribution to construction and operation.
3. The incidence of any significant environmental impact, particularly in neighborhoods immediately adjacent to the proposed facilities.

7.1.9 Capital Cost

The capital cost of the technology will vary with specific site conditions, system length, employment of alternative structures, number of stations, fleet size and many other variables. Short of development of site specific capital cost estimates of the final set of alignment alternatives, only representative cost ranges for each technology can be used in this evaluation. Those ranges are derived and cited on a unit cost basis for a hypothetical transit line.

7.1.10 Operating and Maintenance Cost

Because O&M cost varies with so many factors related to specific operating plans for each alternative system plan, only ranges of unit costs can be cited in this evaluation based on experience elsewhere. As far as BRT using hybrid or low emission vehicles is concerned, data is not readily available.

7.2 EVALUATION METHOD

Comparative evaluations of the technologies under consideration for the corridor within the Baylink Study are not intended to identify a best or most appropriate choice. They are intended to attach qualitative judgments to each within the various categories of qualities defined above. Most are not susceptible to a mathematical rating, especially on non-site specific bases. Thus, the evaluation made was conducted using a "planning balance sheet" or matrix wherein the qualities being compared are arranged against the technologies. The terms "good," "better," and "best" were judged inadequate. Instead of such terse forms of opinion, sets of statements have been used to better qualify the determinations made. The results are described in Section 8.0.

Table 7-1: Technology Assessment Evaluation Criteria

Technical Maturity	• Has this technology had at least five years of proven service in conditions similar to those of the Corridor? • Are there several operational systems using this technology in the U.S.? • Are there several operational systems using this technology elsewhere? • Is there any foreseeable added technical development in order to conform to a Corridor specification? • Can it be demonstrated that the technical risk of this technology is low? • Are vehicles in this technology generally reliable and safe in operation?
Procurement Considerations	• Are there at least three suppliers worldwide who produce this technology currently? • To what extent does this technological concept appear proprietary? • If this technology becomes selected for an initial order, is it likely additional compatible sets of equipment can be procured in five years under competitive circumstances? • Does this technology drive the scoping of procurement such that the vehicles, guideway and systems must be combined?
System Capacity	• Can this technology be closely tailored in capacity to the system demand? • Will this technology allow expansion of its on-line capacity to meet increasing demand? • What level of initial investment must be made in the guideway structures and stations to facilitate system expansion? • Are there extraordinary requirements or investments to be made to affect switching, branching and crossovers?
Right-of-Way Requirements	• Are the geometric alignment constraints sufficiently low or flexible so as to minimize casual ROW taking and easements? • Does this technology have enough vertical alignment flexibility to minimize guideway costs? • Are there excessive or unusual clearance requirements associated with this technology? • Does this technology require a fully grade-separated operating envelope? • Are there extraordinary requirements of this technology in its storage and maintenance facility location or design?
Service Characteristics	• Does this technology have adequate performance capability to minimize run time, station dwell time and turnback time? • To what degree is this technology controlled remotely or automated? • What dependence on manual operation does this technology require? • How reliable is this technology in maintaining schedule? • Are the vehicles of this technology attractive to the patron in terms of space, comfort, lighting and environment?
Environmental Impact	• Does this technology support and contribute to the community's goals of air quality conformance with EPA standards? • Are noise and vibration generated or caused by the operation of this technology acceptable or manageable? • Are the structures or apparatus of this technology a visual intrusion into the vistas of the Study Area? • Are the vehicles, line structures, stations and system wide elements of this technology as aesthetically pleasing as can be made possible?
Environmental Equity	• Does this technology provide fairness of cost versus benefit across population subgroups? • Does this technology provide financial equity? • Does this technology provide environmental equity?
Urban Integration	• Do the fixed facilities or operations of this technology create real or perceived barriers dividing neighborhoods? • Does this technology and its guideway structures and stations cause diminished capacity for motor vehicle traffic flow and parking in general? • To what extent does a system of this technology fit into urban the fabric of the Study Area? • Does this technology facilitate intermodal transfer movements among public transit service providers and private bus operations?
Capital Cost	• To what extent does this technology represent a cost-effective investment independent of system plan? • Are there front-end costs and time associated with this technology to ready it for implementation? • How flexible is this technology in allowing the owner to vary how the design, construction and procurement are packaged for contracting? • How severe are the secondary costs (utilities, street changes) due to placing this technology and its structures in likely locations? • What is the technical life expectancy of this technology?
O&M Costs	• To what extent does this technology imply a reasonable level of annual costs? • Is this technology labor intensive to operate? To maintain? • Are there any extraordinary power requirements associated with this technology? • Is this technology susceptible to failures of its rolling stock, systems or fixed facilities? • Can the barrier-free, proof-of-purchase fare collection method be used with this technology? • What relative degree of vehicle failure or downtime is likely with this technology? • What level of vehicle spares seems indicated as prudent?

8.0 TECHNOLOGY ASSESSMENT

8.1 TECHNOLOGY RESPONSIVENESS (TIER I)

8.2 COMPARATIVE EVALUATION

Based on the DEIS recommendations and conclusions, the input received during the scoping process, the tier I screening results and the considerations presented in this report, it was decided to perform a detailed technology assessment on the LRT and BRT modes of fixed guideway travel generally described in Section 2. The objective in this section is not to select a preferred or most appropriate technology but to generally assess the relative feasibility of the technologies for application in the study area. The following sections describe the general evaluation results for each candidate technology.

8.3 TECHNICAL MATURITY

8.3.1 At Least Five Years of Comparable Service

- **LRT:** Modern light rail vehicles, as contrasted with the last streetcar – the PCC, have been in service for well over 15 years. Early North American deployments were seen in Toronto, San Diego, Edmonton, Calgary, Philadelphia, Boston, San Francisco and Pittsburgh. Some portions of these systems have site circumstances comparable to the study area, but all pre-date ADA '90. The U.S. systems added car-borne wheelchair lifts or loaded from high platforms. Low-floor, or split-level, LRV's are relatively new in the U.S. but have had over five years comparable service in Europe.
- **BRT**: As discussed in Section 2.0, this mode of transportation is attracting a lot of interest and evolving very rapidly. By the time the Bay Link system will enter revenue service, the hybrid or dual mode bus technology will have accumulated enough reliability data to provide a high level of confidence to the operator.

8.3.2 U.S. Systems Using This Technology

- **LRT:** Yes. There are 17 U.S. cities with LRT lines or systems in revenue service and a few more are under development (e.g., Minneapolis).
- **BRT:** There are a few demonstration projects throughout the U.S. as stated in Section 2.6.1. Examples are Chicago, New York and Las Vegas.

8.3.3 Non-U.S. Systems Using This Technology

- **LRT:** Many medium-sized and large cities throughout the world have operating LRT systems. There are over 300 trams and light rail systems operating worldwide. Most are pre-war streetcar systems, but many are newer and operate using contemporary equipment.
- **BRT:** Many applications are operational in Europe, North and South America. Examples of cities where a BRT system is in operation are Vancouver, Canada; Curitiba, Brazil; Lyon, Nancy and Caen in France.

8.3.4 Need for Technical Development

- **LRT:** No, the favored European low-floor cars are new developments but should present no new-design problems.
- **BRT:** Certain technologies such as the CiViS have to meet FTA requirements but have a track record in other parts of the world. 60-foot fuel cell and super capacitor buses are still in the development phase. STREAM, by Ansaldo-Breda, requires additional developments to demonstrate that it can operate safely and reliably at cruise speeds up to 70 km/h.

8.3.5 Technical Risk

- **LRT:** Only normal levels of technical risk associated with any new system are projected.
- **BRT:** There is a technical risk that can be alleviated by thorough demonstration programs.

8.3.6 Operational Reliability and Safety

- **LRT:** (At-Grade) – Operating LRT at-grade with some exposure through mixed transit/auto/pedestrian traffic has an inherent impact on both reliability of service and safety to the public. However, the LRT vehicles and systems should have acceptable levels of reliability and safety.
- **BRT:** Several BRT applications are undergoing reliability testing and demonstration programs. Buses are less likely to deter cars and trucks from impeding onto the right of way and may be more prone to collisions. This can be mitigated by isolating the bus right-of-way from road traffic. The isolation will have to be urban and environment friendly.

8.4 PROCUREMENT CONSIDERATIONS

8.4.1 Supplier Competition

- **LRT:** There is adequate LRT supplier competition for a new U.S. system.
- **BRT:** Depending upon which BRT system is used, there will be adequate competition for a new system in the U.S.

8.4.2 Proprietary Technology

- **LRT:** The LRT concept has the least proprietary aspects. It is virtually generic.
- **BRT:** Certain BRT systems such as STREAM or GLT are proprietary. Fuel cells and some dual-mode buses are generic.

8.4.3 Future Procurements

- **LRT:** There should be no problem with procuring additional vehicle units five years hence even if the original supplier no longer exists.

- **BRT:** In most cases, there should be no problem with procuring additional vehicle units five years hence even if the original supplier no longer exists. As an example, MBTA buses shell is similar to the one used on the STREAM. Cummings engines are used on the CiViS and Neoplan buses. Alstom produces wheel hub motors used on CiViS.

8.4.4 Scope of Procurement

- **LRT:** No, the scope of an LRT procurement can be varied by the owner over a full-range of possible contract packaging, including the vehicles (and parts) as a separate contract.
- **BRT:** No, the scope of an LRT procurement can be varied by the owner over a full-range of possible contract packaging, including the vehicles (and parts) as a separate contract.

8.5 SYSTEM CAPACITY

8.5.1 Flexibility of Capacity

- **LRT:** Representative LRV's cannot be operated as multiple units. This seems to be the case with most of the new, low-floor, modular cars, unlike with the larger single-articulated units in service in the U.S. Subject to operations planning on the final system alternatives and updated ridership data, a two-module unit would be needed to carry the assumed peak load. It would have no flexibility to be reduced in capacity to match the lighter loads of the base period and night-time service. The reduction in capacity can be achieved through a reduction of service level (greater operating headway).
- **BRT:** Flexibility is similar to the LRT's.

8.5.2 Expansion Capability

- **LRT:** The representative LRV's cannot be operated as multiple units. Expansion of capacity must be achieved by revising downward the peak or off-peak headways. If this is a projected problem, an LRV that can be coupled should be favored.
- **BRT:** The majority of the BRT's discussed in Section 2.0 cannot be operated as multiple units.

8.5.3 Initial Expansion Provisions

- **LRT:** In all cases, the stations where longer trains will operate must have either longer platforms or the space and guideway geometry to facilitate lengthening platforms. This is only possible with LRV's that can operate as multiple units. The locations of future branch lines (if any) should be aligned and built to facilitate branch line construction under traffic conditions.
- **BRT:** The stations have to be built for the longest anticipated bus size. BRT offers more flexibility as far as future branch lines or extension are concerned.

8.5.4 Extraordinary Initial Needs

- **LRT:** None needed.
- **BRT:** None needed.

8.6 RIGHT-OF-WAY REQUIREMENTS

8.6.1 Geometric Alignment Constraints

- **LRT:** In general, LRT poses no abnormal constraints that could impact right-of-way needs, except for placement of catenary's support poles when they cannot be contained within the normal ROW.
- **BRT:** Except for BRT using catenary power where the requirements would be similar to the LRT, there are typically no abnormal constraints. The ability of the STREAM to negotiate the tight radius curves that can be found in Miami Beach needs to be verified.

8.6.2 Vertical Alignment Capability

- **LRT:** There are two concerns with vertical alignment (i.e., profile) – grade-climbing capability (or adhesion) and the rate of change of grades at vertical curves. In general, LRT can climb a sustained grade of 8.0 percent for short durations of time. In order to be conservative, the corridor design criteria should limit grades to 6.0 percent. As far as rate of change of grades at vertical curves, the LRV's articulated joints have limits to the vertical angle adjacent modules can accept. These are anticipated to be manageable without unreasonably long vertical curves along the alignment. The various alignment alternatives identified in the DEIS indicate that the maximum vertical curve radius is 5.2 %.
- **BRT:** This technology can handle grades as high as 13.0 percent. Vertical radius capabilities are unknown at this time and will need to be assessed during the next phase of this study.

8.6.3 Unusual Clearance Requirements

- **LRT:** Yes, for the overhead power distribution system. An at-grade LRT line may conflict with other airspace uses, requiring relocation of those existing lines.
- **BRT**: Yes, for BRT using overhead power distribution system. None for other types of BRT.

8.6.4 Grade Separation Requirements

- **LRT:** Can operate without separation from other motor vehicle or pedestrian traffic. Simulations performed during the DEIS phase have indicated that the required performance can be achieved using traffic signals and without inordinate delays to either mode.
- **BRT:** Same as for LRT.

8.6.5 Yard and Shop Requirements

- **LRT:** Only normal storage yard and repair/servicing shop facilities are required, sized based on projected fleet size.
- **BRT:** Same as LRT. BRT without overhead catenary provides more flexibility with respect to the location of the yard.

8.7 SERVICE CHARACTERISTICS

8.7.1 Performance Capability

- **LRT:** Yes, LRT can meet the required performance capabilities. Run times for any at-grade segments will be impacted by right-of-way conditions (e.g., intersections) but the technology is not the cause.
- **BRT:** Some BRT technologies such as CiViS have very good performance capability. Others such as STREAM will have to demonstrate that they can operate at the high speed required on the MacArthur Causeway.

8.7.2 Manual Operation

- **LRT:** Light rail vehicles require an operator who manually controls train movement, door cycling, station departure, announcements, switching and most other duties. Automation will be required only if possible system extensions require it. Train location may be sensed and transmitted to a central control point or location can be conveyed other ways (radio, GPS).
- **BRT:** BRT requires an operator who manually controls vehicle movement, door cycling, station departure, announcements and most other duties. Vehicle location may also be sensed and transmitted to a central control point or location can be conveyed other ways (radio, GPS).

8.7.3 Schedule Adherence

- **LRT:** The rolling stock itself is fully capable of maintaining a schedule. It is surface level conflicts that will lengthen run time, so schedules must be generated with appropriate margin to accommodate minor delays. Abnormally long delays, caused by crossing traffic blocking an intersection or preventing a turn by the LRT train, will occur at times.
- **BRT:** Same as for the LRT.

8.7.4 Vehicle Attractiveness

- **All Technologies:** To the patron, any of these technologies can be specified with equal attractiveness in terms of seating, standee accommodations, comfort, lighting and ease of boarding. The ride quality is comparable if care is taken during construction to conform to guideway/trackwork design criteria.

8.8 Environmental Impact

8.8.1 Air Quality Goals

- **LRT:** This technology operates using electric power which will divert some number of patrons from auto use. The relative traction power needs are essentially equal for a given operating plan, moving causes of air pollution to the power plants of Florida Power and Light. It was shown in the DEIS that automobile traffic would be diverted from the corridor right-of-way and would increase on Meridian Avenue, west of Washington Avenue. Traffic would also increase along Collins Avenue east of Washington Avenue. As indicated in the DEIS, localized mitigation measures (such as changes to the signal timing or the incorporation of turning lanes) may be required. It was also shown that emissions burdens for CO, NOx and HC decrease when compared to the No Build Alternative.
- **BRT:** The all-electric BRT, such as the STREAM exhibits features similar to LRT. Other BRT technologies, such as hybrid BRT (diesel-electric) for instance, will meet the EPA 2004 emissions requirements but not the 2007 requirements. Additional development is required to meet the 2007 EPA environmental requirements. If procurement is completed prior to 2007, meeting the EPA 2004 emission requirements will be sufficient to operate for the life of the buses (12 to 15 years).

8.8.2 Noise and Vibration

- **All Technologies:** Although BRT runs on pneumatic tires and LRT runs on steel wheels on steel rails, the noise and vibration generated by operations are not that different and are well within acceptable limits based on measurements taken of other similar systems. Where problems could occur and where special mitigation measures may be needed are where LRT must negotiate short radius curves (wheel squeal) and where Bay Link passes close to a sensitive land use or structure. Included in this category are hospitals and medical offices using sensitive equipment, schools, churches and television broadcasting stations, some of which do exist in the study area. Noise and vibration produced by Bay Link operations under any mode can be mitigated by design and site specific measures.

8.8.3 Visual Intrusion

- **LRT:** Elements of the at-grade LRT may be classified as visual intrusion for the study area. They are:
  - Fixed facilities, generally limited to the at-grade stations, especially structures on the low platforms (canopy, TVM's, wind/weather protection), and any grade-separation or bridge structures used to traverse freeways or major arterials;
  - Systems, limited to the overhead power distribution system including its support poles; and
  - Vehicles moving through the streets.

- As stated in the DEIS, the stations in Miami Beach would be designed to complement the surrounding Art Deco structures. In aesthetically sensitive areas, a fixed tensioned low-profile (or simple wire) would be considered during final design. Vegetation could be added or preserved to maintain a visual buffer.
- **BRT:** Visual BRT intrusion will be somewhat higher than the LRT for BRT solutions using overhead catenary. Since the return current will not be able to flow through the running rails, more wires are needed that the simple, compact, LRT catenary. For some BRT solutions not using overhead catenary, the visual intrusion will be less. Technologies using the embedded contact concept will require addition of apparatus on the roadway. Detailed design will have to ensure that this is not visually intrusive.

8.8.4 Visual Aesthetics

- **LRT:** Under the best of design choices, the traction power distribution system that follows the at-grade trackway is a visual aesthetic distraction. It can be made lighter, but only to a point, using thinner, more closely-spaced poles, and short-span contact wire without suspension cables. The network of support elements is particularly dense at line curves and line junctions. The class of LRV's under consideration for the corridor includes fairly attractive exterior designs.
- **BRT:** The overhead catenary will be slightly more of an aesthetic distraction for the BRT with catenary solution. The BRT vehicles have also fairly attractive exterior designs.

8.9 Environmental Justice and Equity

- **All Technologies:** At this stage of the assessment, and considering the alignment identified in the DEIS, all technologies are considered equivalent. This topic will be addressed in more details in the subsequent phases of this study.

8.10 Urban Integration

8.10.1 Barrier Effects

- **LRT:** (At-Grade) – The trackway of an at-grade LRT line creates some measure of a barrier, although it is porous. That is, no pedestrian barrier is created. This can be mitigated to some extent by placement of crosswalks to organize such movements. In order to reduce incidents of LRV and motor vehicle collision or other blockage of the trackway, the LRT ROW will include design features that discourage random crossing of the trackway by autos and trucks. This includes use of a slightly raised, but mountable, track bed, distinctive pavement (e.g., pavers or cobblestones), and bollards along the centerline or on either or both sides of the LRV clearance diagram. Thus, a barrier to some degree will exist, inhibiting left turns by motor vehicles and requiring U-turns at organized locations. Neighborhoods or districts are not isolated by this degree of barrier.

- **BRT:** Similar measures will have to be adopted for BRT. This will have to be considered in subsequent phases of the Study. Typically, BRT systems do not offer the same level of barrier effects as the LRT. This accounts for a reduction in capital costs.

8.10.2 Street Capacity Impacts

- **All technologies**: Overlaying LRT or BRT on existing streets will have impacts in Miami Beach. The alignments along the MacArthur Causeway are in exclusive new lanes and should have a minimal impact on traffic. The degree of impact will depend on the location selected and width of the existing right-of-way. LRT and BRT generally require the equivalent width of two traffic or parking lanes. Generally the design of the system provides a net addition in people carrying capacity within the installation of LRT or BRT. The design intent is not to decrease the level-of-service (LOS) of the street facilities below that projected. This is accomplished by upgrading traffic signal controllers, street light coordination with train movements, reductions in bus traffic and other traffic calming efforts such as the provisional adequate facilities for timing.

8.10.3 Blending with Existing Fabric

- **All Technologies:** Bay Link will have a physical presence that cannot be denied. Landscaping and design measures can act to soften that presence, given added space for screening and landforms that will help blend the corridor structures.

8.10.4 Intermodal Transfers

- **All Technologies:** Transfers to and from Bay Link from other modes of travel will include connections to MetroRail, MetroMover, the ElectroWave, other buses and autos. This will be further detailed as the design progresses. At the time this report was generated, two main interface points were considered: Government Center or Overtown in Miami, and the Convention Center on Miami Beach. For the purposes of this assessment, all technologies are equivalent.

8.11 CAPITAL COST

8.11.1 Cost-Effectiveness

- **LRT:** (At-Grade) –Absolute capital cost does not equate to cost-effectiveness, which incorporates added value as a transportation system and includes attracted ridership. That assessment of value depends on the specific layout of the corridor and its service area coverage. It will be detailed during subsequent phases of this study. U.S. LRT systems have been built for as little as $6 million per mile (original San Diego South Line) and as much as $113 million per mile (Niagara Frontier – Buffalo Line). The likely range of an at-grade LRT line at today's price levels is $30 to $40 million per mile, without ROW.

- **BRT:** For a given length of corridor system, the BRT configuration will likely demand the least capital cost, principally because of its lesser cost line structures and stations. The BRT database is not as rich as the LRT's. An estimate, based on the STREAM, generated for the Honolulu In-Town BRT has resulted in a capital cost around $15 million per mile.

8.11.2 Front-End Cost Requirements

- **LRT:** No unusual front-end costs are anticipated.
- **BRT:** No unusual front-end costs are anticipated.

8.11.3 Contracting Flexibility

- **LRT:** This is the most flexible technology in terms of contract packaging. The vehicle/wayside interface is virtually standard and generic. The whole range of contracting options is available to the owner.
- **BRT:** This is a flexible technology in terms of contract packaging. The whole range of contracting options is available to the owner.

8.11.4 Secondary Costs

- **LRT:** (At-Grade) – Light rail at-grade in existing streets will cause the greatest amount of secondary costs, including:
  - Relocation of underground parallel utilities from beneath the proposed trackway.
  - Relocation of overhead utility lines in conflict with the catenary.
  - Possible street widening to create the required LRT reservation without loss of traffic lanes, including relocation of storm drainage systems and roadside appurtenant structures.
  - Installation and revision of traffic signal detection loops and related cabling.
  - Stray current corrosion mitigation measures.
- **BRT:** Bus Rapid Transit in existing streets will probably cause the least amount of secondary costs which may include:
  - Relocation of underground parallel utilities from beneath the proposed trackway (for touchable embedded propulsion BRT technologies)
  - Relocation of overhead utility lines in conflict with the catenary for some technologies.
  - Possible street widening to create the required reservation without loss of traffic lanes, including relocation of storm drainage systems and roadside appurtenant structures.
  - Installation and revision of traffic signal detection loops and related cabling.

8.11.5 Technological Life Expectancy

- **LRT:** The life expectancy of LRV's is around 25 to 30 years and is in generally higher than BRT.
- **BRT**: Typically, the life expectancy of buses is 15 years, lower than LRV's. One should note that the Bombardier GLT has a design life of 30 years. However, Bombardier is seemingly not interested in marketing the product in North America. Therefore, the design life of BRT is taken as 15 years.

8.12 OPERATIONS AND MAINTENANCE COST

8.12.1 Reasonableness of Annual Costs

- **LRT:** Given a system with a well-conceived operational plan, LRT operations and maintenance (O&M) costs are the lowest of the rail technologies. Although the new modular LRV's have a limited track record in terms of failure rates, time to repair, etc. no unreasonable experience is anticipated.
- **BRT:** Estimation performed by a TCRP panel of experts indicate that, in the long run, hybrid or dual mode buses O&M costs will be lower than those of diesel buses. In general, buses have higher operating costs than LRV's. This will be detailed further in the second phase of this study.

8.12.2 Labor Intensiveness

- **LRT:** LRT's maintenance tends to be routine and non-demanding in terms of sophistication. Car damage may occur due to collisions with motor vehicles, probably adding to the fleet spares and the labor and parts cost of repair.
- **BRT:** Maintenance is non-demanding in terms of sophistication. It may be more intensive than LRV's if on-board batteries are used. Car damage may occur due to collisions with motor vehicles, probably adding to the fleet spares and the labor and parts cost of repair. Due to the lower barrier effect of BRT, car damage due to collisions with motor vehicles may be higher than for LRT.

8.12.3 Costs Experienced Elsewhere

- **LRT:** Indices of O&M costs are in terms of the level of service provided. Two of these are cost per vehicle mile and cost per passenger mile. The range of these costs for LRT is \$6.75 to \$9.60 per vehicle-mile and \$0.45 to \$0.55 per passenger-mile.
- **BRT:** The database is not as rich as for LRT systems. The range of cost for bus operation is wider than for LRT and spans, according to the National Transit Database, between \$0.20 and \$2.1 per passenger-mile.

8.12.4 Power Requirements

- **All Technologies:** There are no extraordinary power requirements.

8.12.5 Foreseeable Failure Rates

- **LRT:** LRT is a mature technology, less likely to experience failures.
- **BRT:** Hybrid and Dual mode bus reliability data is being accumulated on various sites. This will be addressed further in the second phase of this study. It will be considered, at this stage that the failure rates are higher than for LRT.

8.12.6 Fare Collection Compatibility

- **All Technologies:** Use of the barrier-free, proof-of-purchase system of fare collection is equally applicable to all technologies. Ticket Vending Machines (TVM's) would be located on platforms for all modes. Security of TVM's must be provided by roving patrols of police and by use of intrusion alarms or CCTV systems, as warranted. Fare evasion is discouraged by use of roving checkers with authority to impose fines (issue tickets) to offenders. The cost-effectiveness of these measures has to be evaluated against Bay Link fare schedule.

8.12.7 Spare Vehicle Needs

- **LRT:** Vehicle spares are needed by any system to ensure the fleet is large enough to meet the peak period schedule requirements. Spare vehicles are needed because at any time some of the vehicles (or trains) will be out-of-service for scheduled maintenance, minor repair, major repair or overhaul. New designs where used will experience the greatest rate of unavailability. A rule-of-thumb allowance for spares is 15 percent of the total fleet.
- **BRT**: Due to the state of technological development and to the lower barrier effect, a more conservative allowance of spares of the order of 20 % of the total fleet will be considered.

9.0 ASSESSMENT SUMMARY

9.1 GENERAL

The previous sections of this report:

- identified a range of prospective system technology categories;
- established their general operating characteristics and applications;
- defined the criteria to be used in the evaluation; and
- evaluated the identified technologies with respect to the goals and objectives and the transportation requirements of the project.

This section summarizes the results of the technology assessment.

Each of the technologies was reviewed and evaluated for potential application on the conceptual alternative alignments. The alignments will need to be revised as necessary as a result of citizen and agency input and further engineering and design. The purpose of this assessment is not to select the most appropriate, most cost-effective or preferred technology. The objective is to generally assess the relative feasibility of each technology for application in the study area in response to the goals and objectives and transportation needs. The final assessment and recommendation for technology will be undertaken as part of the evaluation process in arriving at a Locally Preferred Alternative (LPA).

Enumerated in Section 8.0 are nine categories of comparison and many sub-categories. Although those findings and results are summarized herein, there is no attempt to weight or rank the relative value or importance of each category or sub-category. This activity should be done by the regions' stakeholders and the ultimate selection of an LPA by the MPO.

9.2 COMPARATIVE QUALITIES SUMMARIZED

Table 9-1 presents a tabular summary of the narrative assessment contained in Section 8.0. Figure 9-1 provides the evaluation scale used in the tabulation of the comparative characteristics. Some attempt is made to show in this decision matrix the relative worth of each technology but only within each sub-category of assessment.

Figure 9-1: Summary of Comparative Results

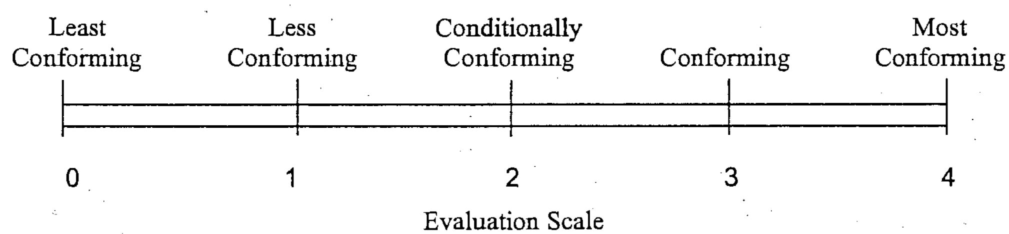


Table 9-1. Summary of Comparative Results

Quality Compared		Technology LRT	BRT
8.2	**Technical Maturity**		
8.2.1	Five Years' Service	4	2
8.2.2	Deployed U.S. Systems	4	2
8.2.3	Non-U.S. Systems	4	3
8.2.4	Development Needs	4	2
8.2.5	Technical Risk	4	2
8.2.6	Reliability/Safety	3	2
8.3	**Procurement Considerations**		
8.3.1	Supplier Competition	4	3
8.3.2	Proprietary Issues	4	3
8.3.3	Future Procurements	4	4
8.3.4	Scope of Procurement	4	4
8.4	**System Capacity**		
8.4.1	Flexibility	3	3
8.4.2	Expansion Capability	3	3
8.4.3	Initial Provisions	4	4
8.4.4	Extraordinary Needs	4	4
8.5	**Right-Of-Way Requirements**		
8.5.1	Horizontal Alignment	4	4
8.5.2	Vertical Alignment	3	4
8.5.3	Clearances	2	2
8.5.4	Grade Separation	3	3
8.5.5	Yard & Shop	3	4
8.6	**Service Characteristics**		
8.6.1	Performance	4	4
8.6.2	Manual Operator	3	3
8.6.3	Schedule Maintenance	4	4
8.6.4	Vehicle Attractiveness	4	4
8.7	**Environmental Impact**		
8.7.1	Air Quality Goals	3	2
8.7.2	Noise & Vibration	3	4
8.7.3	Visual Intrusion	4	4
8.7.4	Visual Aesthetics	3	3
8.8	**Environmental Justice and Equity**		
8.8.1	Fairness of cost versus benefits across population subgroups	3	3
8.8.2	Financial equity	3	3
8.8.3	Environmental equity	3	3
8.9	**Urban Integration**		
8.9.1	Barrier Effects	3	3
8.9.2	Street Impacts	2	2
8.9.3	Blending In	3	3
8.9.4	Intermodal Transfers	3	3
8.10	**Capital Cost**		
8.10.1	Cost-Effectiveness	3	4
8.10.2	Front-End Costs	4	4
8.10.3	Contracting Flexibility	4	4
8.10.4	Secondary Costs	2	3
8.10.5	Life Expectancy	3	2
8.11	**O&M Costs**		
8.11.1	Reasonableness	3	3
8.11.2	Labor Intensity	3	3
8.11.3	Cost Experience	4	2
8.11.4	Power Demand	3	3
8.11.5	Failure Rates	3	2
8.11.6	Fare Collection	3	3
8.11.7	Vehicle Spares	3	2

9.3 CONCLUSIONS

Based on the assessment presented in this report and consistent with the conceptual nature of the alignments and the planning and engineering data available at this point in the project development process, no "fatal flaws" were identified for any of the candidate technologies. In reviewing the various needs for the Corridor, there are, however, some technologies whose application is less responsive to the system technical needs in terms of service requirements, the desires of the citizens and stakeholders and cost effectiveness.

As an example, RRT (like the Metrorail System) is an over design in terms of speed, capacity and grade separation requirements for the system. The aerial structure required would overwhelm the urban environment it is intended to serve. The capital cost would also be prohibitive, given the projected ridership range, in determining the systems effectiveness.

AGT and Monorail have also major limitations for the corridor under study. The required aerial structure will overwhelm the area to be served. In addition, the consultation process undertaken during the DEIS phase has indicated that the citizens of Miami Beach are opposed to an elevated transportation system. The capital and O&M costs are also very high.

The concept of ferry service between Miami and Miami Beach has some characteristics that make it inappropriate for a line-haul public transit system such as the Bay Link. The system has speed and capacity issues that could only be overcome by an extraordinary investment in docks and boats. These added costs, on a system that already has very high capital and O&M costs, will not prove cost-effective for the Bay Link application. The system has the added disadvantage of delivering only 1000 riders to a terminal during peak trips. The further distribution of the riders would require another distribution system such as buses, or 40 Electric-wave buses to meet each ferry. This added transfer would tend to reduce ridership.

Based on this general assessment with no weighting of the evaluation criteria, only LRT and BRT were considered appropriate technologies for further consideration.

The following are intended to summarize the major points resulting from the assessment:

- Both LRT and BRT technologies could be used for the Corridor, subject to further studies on the recommended alignment alternatives.
- None have technically "fatal flaws".
- Each has its own level of technical risk to the owner considering all pertinent criteria. LRT presents the least technical risk, BRT the most. Acceptance of risk must be made in light of advantages gained.
- The least cost alternative is probably BRT.
- All technologies present acceptable environmental impacts.
- Both BRT and LRT give the owner flexibility in packaging design, construction and procurements.
- The capital cost for BRT is the lowest, while O&M cost for LRT may be lowest.

Cost-effectiveness or value is indeterminate without a valid estimate of ridership, level of service and other site-specific factors. This can be addressed in subsequent phases.