DART 2030 TRANSIT SYSTEM PLAN

Final

Technology Review Report

3191

Support Task for the
DART 2030 Transit System Plan

April 2004

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1.0 INTRODUCTION

The Dallas Area Rapid Transit (DART) 2030 Transit System Plan (TSP) effort was initiated in 2001 to establish the vision and priorities for the DART Service Area as it relates to the provision of mobility services to its 13 member cities. Several supporting tasks were identified to define subjects such as the evaluation framework, service strategies, mobility needs and alternatives to be studied during the development of the 2030 TSP. This report is one of several that serve as supporting documentation for the 2030 TSP.

1.1 Purpose of Report

Previous DART System Plans have been very specific about the types of technology and alignments to be followed, focusing on implementation of major fixed guideway projects. The 2030 Transit System Plan focuses on service strategies and the range of transit vehicle technologies that could meet objectives of selected transit service strategies. Thus, emphasis is placed on applying appropriate transit vehicle performance characteristics to mobility needs with the ultimate technology decision determined during subsequent, more detailed studies and alternatives analysis.

The purpose of this report is to identify and review transit vehicle technologies that could meet the mobility needs of transit corridors identified in the DART 2030 Transit System Plan. A range of transit vehicle technologies is available. The following transit vehicle options are included in this document:

Fixed Guideway

- Light Rail Transit (LRT)
- Regional Commuter Rail (locomotive hauled, diesel multiple unit (DMU), and lightweight DMU)
- Heavy Rail
- High-speed Intercity Rail
- Maglev
- Monorail
- Automated Guided Transit (AGT)
- Personal Rapid Transit (PRT)
- Streetcars
- High Occupancy Vehicle (HOV) Facilities

Fixed and Non-Fixed Guideway

- Conventional Bus Transit
    - ✓ Rapid Bus Transit (operating strategy)
    - ✓ Enhanced Bus (operating strategy)

Non-Fixed Guideway

- Electric Trolley Bus
- Special Vehicles (station cars, paratransit and commuter vanpools)

Some transit vehicle technologies have broad application, while others are more specialized. For each of the technologies identified, the general focus is on operating and physical characteristics.

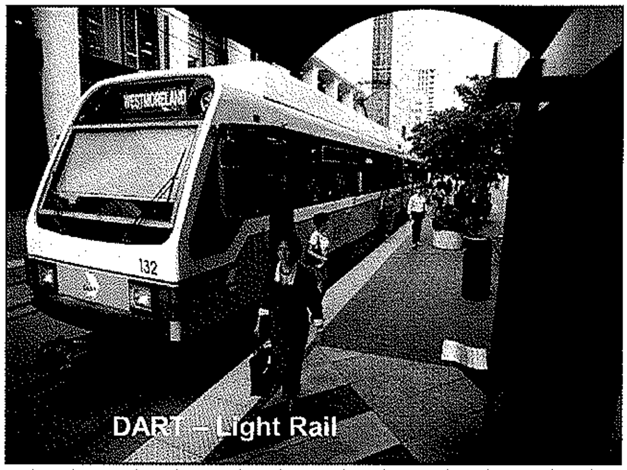
It should also be noted that there may be additional cost effective and environmentally friendly technologies available in the future. Thus, as more detailed studies are done for selected corridors over the next 20 to 30 years, new and emerging technologies should be considered.

2.0 OVERVIEW OF TRANSIT TECHNOLOGIES

The following section provides a brief overview of potentially feasible transit vehicle technologies for consideration in the DART 2030 Transit System Plan. Also included are emerging engineering and design trends and a list of cities or countries where the technology is in use.

2.1 Light Rail Transit

Light Rail Transit (LRT) is a medium to high capacity passenger service that can be used for both short and line-haul trips. LRT technology has evolved from the historic streetcar (Tram) system to a more modern transit system that goes further and faster. It has the flexibility to navigate sharp curves and travel along streets, highways, or in exclusive rights-of-way (ROW). LRT can operate in single-track or double-track configuration. Segments of a light rail alignment may be grade separated, in a tunnel, or elevated for operational, safety or environmental reasons. It is powered by electricity from overhead wiring which is suspended from poles or buildings. Because it is powered by electricity, light rail is generally considered environmentally friendly.



DART – Light Rail

LRT trains can employ a single car or they can operate as a multi-unit train. Maximum LRT train length is sometimes a function of the minimum length of a city block so that stopped vehicles do not block vehicular traffic on cross streets. Light rail cars range in length from approximately 50 feet to over 100 feet. Depending on the vehicle size, number of vehicles, and vehicle headway, a light rail train is capable of carrying up to 20,000 passengers per hour per direction.

LRT vehicles are available in three boarding configurations, high floor, high/low floor, and low floor. A high floor design uses a single articulation (two body shells that share a common center truck). This reduces the track overhang when the vehicle is operated on a curved section of track. The high/low (70% low floor) cars use two articulated sections with a third, short, car body section that shares a truck on both ends with conventional car bodies. The newer 100% low floor design eliminates the interior steps that are used near the ends of a 70% low floor design. This design does not use the conventional motorized trucks of the 70% low floor design. Instead, the 100% low floor design has resulted in several innovative traction motor support arrangements that have yet to be proven in long-term vehicle service.

DART's existing fleet of LRT vehicles is composed of custom-configured conventional light rail vehicles. These vehicles have a high-level interior floor that is reached either by ascending steps from the low-level station platform or from a special high-level boarding platform, while disabled and other mobility-challenged riders board from a "mini-high-block" platform. LRT vehicles do not meet the Federal Railroad Administration (FRA) crash worthiness standards, and for this reason they cannot operate on rights-of-way with freight traffic unless separated spatially or temporally.

The maximum speed of modern LRT systems is 55 to 65 miles per hour. LRT average operating speed varies however, depending on operating conditions. LRT operating speeds are a function of the exclusivity of the right-of-way, track geometry, the number of stops and the application of signal priority or pre-emption. Operating in mixed traffic reduces overall operating speed due to safety concerns, traffic, and speed limits. Station spacing, grade crossings, physical constraints, and mixed traffic operations have significant impacts on LRT operating speeds. Signal improvements, grade separations and other roadway improvement measures may be used to mitigate some of these impacts.

Station development and location are integral parts of an LRT system. Light rail stations range from simple platforms with canopies to complex buildings with offices, elevators, message boards, and information centers. Station spacing for LRT varies within and among systems. LRT stations are typically spaced about one-half mile to two miles apart. Within densely populated activity centers such as a Central Business District (CBD), spacing may be less than one-half mile.

Capital cost for light rail infrastructure ranges from moderate to high, depending on system configuration and where LRT lines are constructed. Where existing rail right-of-way is used, capital cost for LRT can be significantly lower. Capital cost for LRT passenger cars can range from $2 to $3 million. Typical capital cost for a new LRT system averages between $20 to $60 million per mile, with higher per mile costs when significant infrastructure improvements (cut-and-cover, tunnel, etc.) are needed.

Engineering/Design Trends

Light rail development is emphasizing lighter cars, less expensive manufacturing, and standardization. The relatively new 100% low floor car design has been in service for several years. However, the 100% low floor design does not use conventional motorized trucks. This has resulted in several innovative traction motor support arrangements that still have to be proven in long-term vehicle service. Light rail development also includes consideration of other power sources, as discussed below.

<u>Self-Propelled Light Rail</u>

Light rail vehicles can operate with diesel or alternative fuel power. They are similar in other respects to electric light rail vehicles. Self-propelled LRVs produce some emissions in contrast to electric light rail vehicles. However, because of the efficiency of steel wheels on steel rails, they are more fuel-efficient and have lower emission rates than buses. They have similar performance characteristics as electric light rail vehicles except acceleration and deceleration may be slower. Because they have a similar turning radius and vertical grade capability, they can operate on streets.

<u>Dual Powered Light Rail</u>

Light rail vehicles can operate with both self-powered and electric power propulsion in the same LRV. Typically the self-propelled power source drives an electric generator that, in turn supplies electricity to electric motors. They have similar acceleration and deceleration performance characteristics as electric light rail vehicles because of the use of electric motors. These light rail vehicles can travel on electrified track segments using catenary hardware. They can also operate in a self-propelled mode on non-electrified track segments using diesel power or alternative fuel. This type of operation would be suitable where diesel would not be acceptable such as on-airport service and where electrification is not cost effective because of lower ridership.

Self-propelled and dual powered LRV's are available in the market. For example, Houston and San Diego have purchased Seimens Avanto/S70. Both cities have purchased the electric version, however a diesel-electric version is offered. The Seimens Combino is also available in electric or diesel-electric versions. This vehicle has a modular design, which allows for purchasing any type power unit to combine with unpowered cars. Seimens has sold many of the electric versions to various cities in Europe. Nordhausen in Germany has recently purchased a dual diesel-electric powered version.

Examples of Existing Light Rail Transit Systems

- Dallas, TX
- Denver, CO
- Portland, OR
- Salt Lake City, UT

2.2 Regional Commuter Rail

Commuter rail is primarily oriented toward commuter service to outer suburban regions, and as a result it typically serves longer trips than most light and heavy rail transit lines.

Commuter rail lines normally extend an average of 10 to 50 miles from a downtown terminus. In some cities, service is offered only during rush hour periods, while in other cities service is operated throughout the weekday, in the evenings, and on weekends. Service is rarely offered more frequently than one train every 30 minutes. Station spacing varies from one system to another, but the typical range is from 2 to 5 miles apart in urbanized areas. Similar to light rail, commuter rail stations vary from simple platforms to complex buildings with offices, elevators, message boards, and information centers.

Commuter rail trains are normally made up of a locomotive and several passenger coaches. Commuter rail uses either single or bi-level passengers cars. The dimensions of commuter rail coach cars are typically 60 to 85 feet long, 10 to 11 feet wide, allowing for a seating capacity of 60 to 170 passengers. Total vehicle capacity ranges from 90 to 300 passengers. The coaches are dimensionally similar to intercity (Amtrak) coaches, but typically have higher density seating, as the average ride is shorter. Passenger capacity and speed are the primary advantages of this transit technology.

Commuter rail vehicles have an on-board operator, who adjusts vehicle speed in response to traffic conditions and railway signaling requirements. The maximum speed for commuter rail ranges from 79 to 100 mph. The average operating speeds in the United States range anywhere between 30 and 50 mph. Where stations are spaced further apart, average operating speeds may be higher.

Most commuter rail systems are implemented within existing railroad rights-of-way. The operating environment for commuter rail tends to be grade-separated in heavily populated urban areas, and at-grade in suburban/rural areas. Commuter rail vehicles have the ability to share track with freight trains and other intercity passenger services such as Amtrak. This attribute makes commuter rail more attractive for long distance service (typically 30 to 100 miles). It generally has less impact than freight traffic in terms of noise and vibration. Rail corridors used for regional rail are upgraded to improve operating speeds and traffic safety at grade crossings.

Commuter rail trains are usually either un-powered cars propelled by a diesel or electric locomotive engine, or self-propelled, Diesel Multiple Unit (DMU) rail cars. The Trinity Rail Express (TRE), a joint rail operation between the DART and the Fort Worth Transportation Authority (The T), operates both locomotive and self-propelled cars. Both conventional diesel and DMU vehicles frequently use a diesel-electric traction system. DMUs may also use mechanical or hydraulic drive systems.

Commuter rail vehicles must meet FRA crash worthiness standards when operating on freight tracks. All locomotive-hauled and the majority of DMU systems in the United States are FRA compliant. The newer lightweight DMU technology is not FRA compliant and requires an FRA waiver to operate on freight trackage.

Capital costs for commuter rail infrastructure range from low to moderate, depending on system configuration and where lines run. Where new rail right-of-way is used, capital cost for commuter rail can be significantly higher. Typical capital cost for commuter rail ranges from $3 to $25 million per mile.

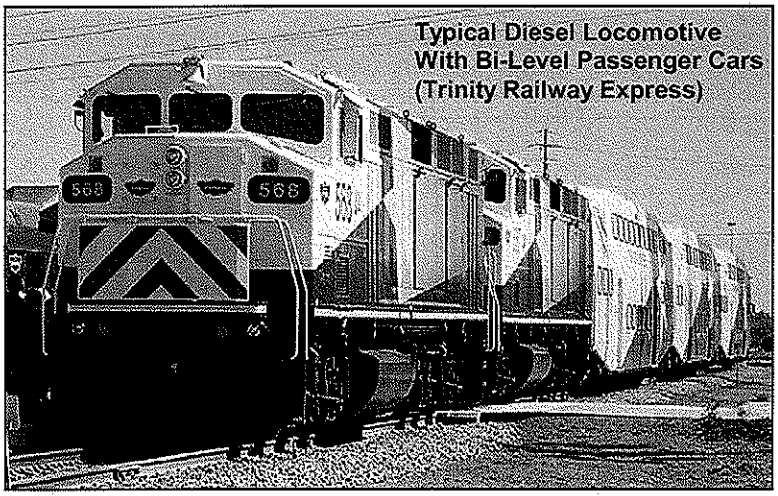
Engineering/Design Trends

New developments in this technology include hybrid propulsion. A gas turbine powered version of this technology has been in operation in New York for several years. Examination of the gas turbine powered technology indicates that the additional horsepower improves train performance. Operational data on maintenance and fuel cost are not readily available.

Examples of Existing Diesel Locomotive Rail Systems

- Baltimore, MD
- New York, NY
- Newark, NJ
- Philadelphia, PA

2.2.1 Regional Commuter Rail – Locomotive Hauled



Typical Diesel Locomotive With Bi-Level Passenger Cars (Trinity Railway Express)

Diesel-powered trains normally use locomotives that are semi-permanently coupled to one end of the train. Trains can also be powered by a gas turbine engine or an overhead electric power line. A set of driving controls at both ends of the train allows the train to be operated in either direction without having to turn the locomotive or the train around upon reaching the end of the line. Diesel-powered trains may operate almost anywhere there is a railroad track, except through long tunnels where exhaust fumes would accumulate. Diesel locomotive engines produce both noise and emissions, with the greatest impacts occurring during acceleration. The commuter coach cars can be either single-level or bi-level in configuration. The number of seated passengers per car ranges from 80 to 170 depending on the vehicle configuration.

Newer locomotives are quieter and less polluting than earlier models built in the 1970s and 1980s. Some commuter rail operators may be considering self-propelled diesel rail cars for less-intensive services because they have fewer environmental impacts than locomotives.

2.2.2 Regional Commuter Rail – Diesel Multiple Unit (DMU)

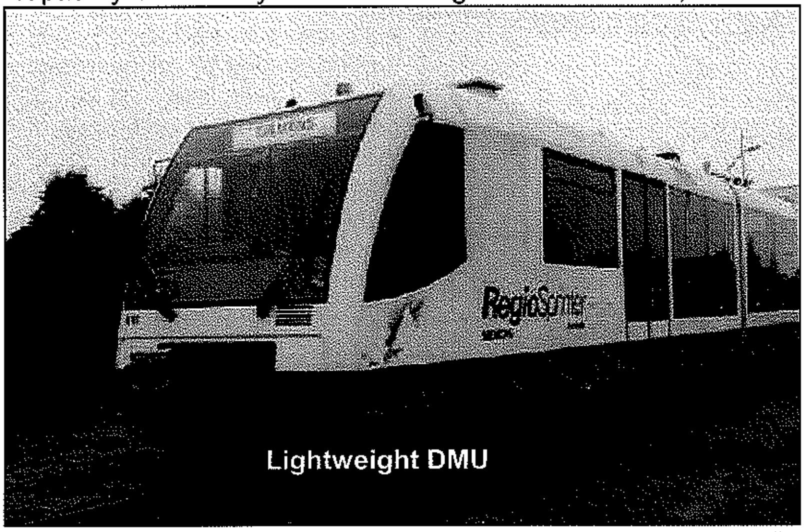
DMU commuter rail trains are self-propelled commuter rail cars that do not require a locomotive to push or pull them. A train typically consists of one to three units. Each car has an operator's cab at each end to preclude having to turn the train at terminal stations.

Diesel Multiple Units (Trinity Railway Express)

Two types of DMU vehicles are in operation today: traditional DMU technology and lightweight DMU (see Section 2.2.3). Traditional DMU technology (such as that used on the TRE) typically consists of non-articulated single or multiple-car trains and is FRA compliant. Traditional DMUs meet FRA standards and can operate with freight or intercity passenger trains.

2.2.3 Lightweight DMU

Lightweight DMU rail vehicles and rail operations have performance characteristics in between light rail and regional commuter rail. Acceleration, deceleration, turning radius and vertical grade capability are usually better than regional rail vehicles, but less than light rail vehicles. These vehicles are designed for regional passenger service primarily in low-density non-electrified corridors up to 30 miles in length that link city centers and mid-sized towns with suburban surroundings. Lightweight DMUs do not meet the FRA's standards for crash worthiness and are not allowed to operate with freight traffic unless separated spatially or temporally. This technology is more common in Europe as a means to extend the benefits of rail transit service over existing railroad lines with minimal capital cost. The smaller DMU vehicle can provide rail transit service in areas where demand does not warrant high capacity rail service. Stations may be spaced every one-half to one or more miles. Since the vehicle acceleration rate is less than that for typical light rail vehicles, wider station spacing is preferable. Trains are typically one to two cars in length.



Lightweight DMU

Several European manufacturers have developed lightweight DMU vehicles. The Siemens Regio Sprinter has been widely tested and operated in regular transit service in Germany. In Europe, lightweight DMU vehicles meet requirements for operating on both mainline freight railways and light rail lines. Because of the potential capital cost savings associated with lightweight DMUs, several manufacturers are developing vehicles for the U.S. market, and some regions have implemented service using lightweight DMUs. For example, New Jersey Transit recently opened the Riverline, connecting Camden and Trenton.

Colorado Railcar Manufacturing

Recently, Colorado Railcar Manufacturing passed a major milestone in the development of lightweight DMU technology by meeting the FRA's new 49 CFR part 238 compression test of 800,000 pounds. Passing this test makes the Colorado Railcar the first and only self-propelled lightweight DMU railcar to qualify for use in mixed rail service in the United States. In March 2004, the Florida Regional Transportation Authority authorized purchase of 3 DMUs for use in a DMU demonstration project.

Dual Powered Regional Commuter Rail Transit Vehicles

Multiple-unit regional rail vehicles can operate with both diesel and electric power. These vehicles can travel on electrified track segments using catenary or third rail hardware. They can also operate in a self-propelled mode on non-electrified track segments using diesel power or alternative fuel. This type of operation would be suitable where diesel would not be acceptable or where electrification is not cost effective.

2.3 HEAVY RAIL – (Rail Rapid Transit)

Heavy rail, commonly referred to as rail rapid transit, is a high-capacity, high-speed transit service that operates on exclusive rights-of-way. Heavy rail systems typically consist of large four-axle rail vehicles powered from an electric third rail with no grade crossings. For safety and operational reasons (i.e., speed), this technology requires exclusive rights-of-way and is one of the costliest transit options to construct. Capital cost per mile can range between $50 and $250 million.


Washington D.C. Metro Rapid Rail

Existing heavy rail systems operate in subways, at grade or on aerial structures. Heavy rail is appropriate for corridors or alignments with very high demand for transit. Up to three stations per mile may be found in densely populated areas, but stations are typically one-half to one mile apart in dense urbanized areas and up to several miles apart in suburban areas. The typical maximum speed is 50-80 miles per hour. Typical service frequency is 5-10 minutes during the peak period and 10-20 minutes during off-peak. Heavy rail vehicles are available in lengths of 50 to 75 feet. Carrying capacity per car is 60 to 80 passengers seated and 125 to 150 with standees. An eight-car train can carry between 480 to 1,200 passengers. Cars are often designed as married pairs, where equipment, such as the air compressor and battery are shared between the pair to reduce car weight and cost.

Engineering/Design Trends

Heavy Rail technology has advanced through the design of the latest R-142 and R-143 New York City car designs. These cars offer communication based train control (CBTC). Unlike a wayside signal block system, where each signal controls a fixed block, CBTC is a moving block system. Moving blocks will allow shorter distances between trains resulting in increased train traffic. A fixed block system allows only a limited number of trains in a given area. CBTC will allow for shorter headways and faster speeds.

Another design trend, the automated or driverless metro system, is also becoming more widely accepted. Full automation allows for very precise and rapid service adjustments. New automated metro systems are planned for Nuremberg, Germany and Kuala Lumpur, Malaysia.

Examples of Existing Heavy Rail Systems

- Boston, MA
- Chicago, IL
- San Francisco, CA

2.4 HIGH-SPEED INTERCITY RAIL

Intercity rail, also known as high-speed rail (HSR), is designed for long haul service with correspondingly long distances between station stops. Intercity rail design parameters emphasize stable high-speed running, low noise, and reduced track wear. This technology usually requires upgrades of existing rail line. High-speed trains in Europe typically operate at 150 to 200 mph. Amtrak recently unveiled its new 150 mph train service known as "Acela" that offers high-speed rail service in the Boston-New York-Washington Northeast Corridor. Additional opportunities for high-speed rail systems are being investigated for California, Florida, and Texas. Capital costs for high-speed rail range between $40 and $80 million a mile. It should be noted that there have been discussions at the state planning level to fund studies that would consider high-speed rail applications in Texas.


Amtrak "Acela" High-speed Rail Service

Engineering/Design Trends

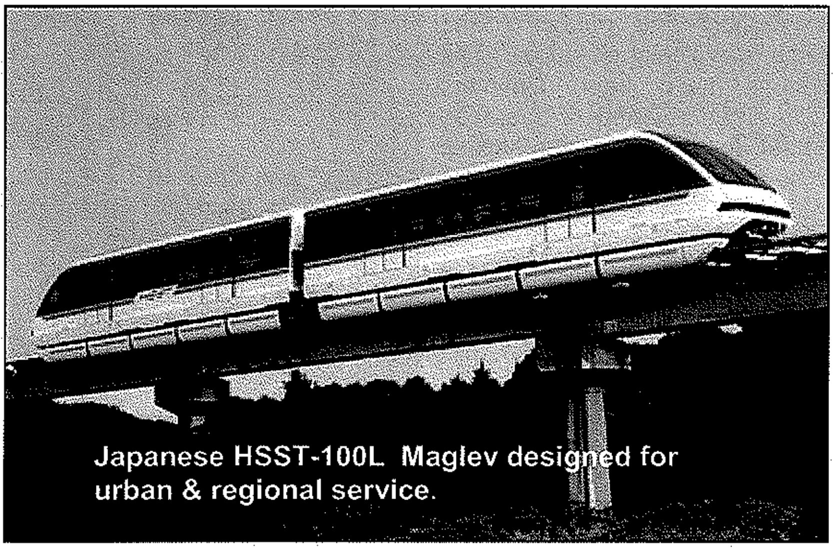
Long-term industry plans call for high-speed rail to reach speeds of 225 mph for commercial use. The French TGV has reached speeds of 320 mph. However, at this speed the French system is not viable commercially because of the following concerns: dynamic pressures experienced by the track are overwhelming and would wear out the tracks faster, plus the train tracks and wheels would have to be in absolutely perfect condition and alignment to run consistently at higher speeds. Given these concerns, many people see the future of high-speed rail in magnetically levitated trains.

Examples of Existing Intercity Rail (HRS) Systems

- Amtrak - New York - Washington D.C. Corridor
- Paris, France
- Frankfurt, Germany

2.5 MAGLEV (Magnetically Levitated Trains)

Maglev (magnetically levitated) service is a line-haul, medium to high capacity transit service. It is a transit system in which a rail vehicle runs levitated from the guideway (corresponding to the rail tracks of conventional railways) by using electromagnetic forces between super-conducting magnets on board the vehicle and coils on the ground. The vehicle floats on a magnetic field and is propelled by a linear induction motor. The fundamental design objective of this technology is to create very high-speed transit, above 300 mph. Maglev can move people and goods with greater mobility and speed, using much less energy, at lower operating cost, and with greatly reduced pollution, compared to the existing rail modes. Germany and Japan have run successful test tracks for years. Maglev technologies are expensive, requiring very large - and generally unaffordable - government subsidies. High-speed trains and other maglevs cost $100 to $300 million a mile to construct. First generation maglev systems have already been developed in Japan and Germany and have run successfully as test tracks for the last two decades, while a second-generation system with enhanced performance capabilities is being developed in the United States.


Japanese HSST-100L Maglev designed for urban & regional service.

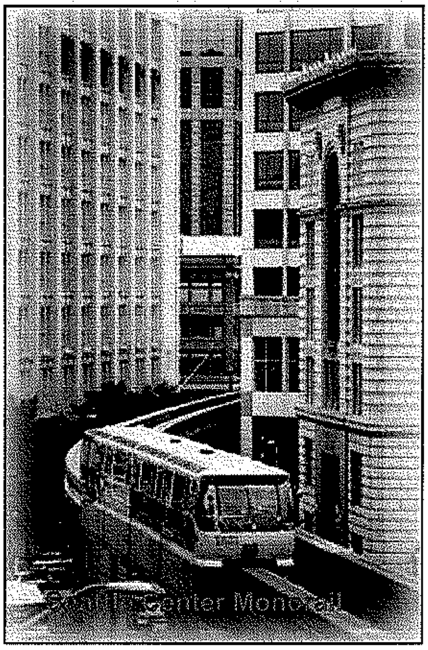
Engineering/Design Trend

The Maglev 2000 of Florida Corporation is developing a second-generation maglev system that is based on prior maglev inventions. This second generation system has improved performance capabilities and reduced costs. A key feature of the M-2000 System is the use of super-conducting quadruple magnets on the maglev vehicles. The quadruple configuration enables the M-2000 vehicles to travel on low cost narrow beam guideways, and to smoothly transition to a flat planar guideway whenever it is desired to be able to switch the vehicle to a second guideway. This switching can take place at high-speed, i.e., 300 mph, without having to slow the vehicle down. The switching process is electronic and does not require mechanical movement of a section of the guideway. Low-speed maglev systems are also being developed.

Examples of Existing Maglev Systems

- China is operating the first commercial system.

2.6 MONORAIL



A monorail system typically provides a line-haul, medium capacity transit service. Physically, it is a variation of a people mover that consists of rubber-tired vehicles that operate along a single rail, or beam. The single rail beam, supported or suspended, provides vehicle support and guidance and contains the power source, which is typically electrical. The majority of monorail installations have been elevated; however, monorail can be designed for a variety of operating environments and is generally used for short distance service (5 to 10 miles). Monorail must be grade separated from other traffic.

Typical services include activity area circulation; shuttle service and in some cases, line haul transit. Generally, monorail consists of one to four vehicles. Station spacing is comparable to light rail or heavy rail, one-third to one-half mile between activity centers and one-half to one-mile or more in other areas. The typical capital cost per mile is $100 to $200 million. In the United States, monorail technology has been implemented in limited applications, including short systems at airports (Newark International Airport), downtowns (Seattle), recreational areas or amusement parks (Disneyland and Walt Disney World, Las Vegas). When extended, the Seattle System will be the longest in the U.S. at 14 miles. Outside the United States, straddle beam, large vehicle monorail systems are in operation in Sydney, Australia and Kitakyushu, Tokyo and Osaka Japan. The Osaka System is the longest operating system at approximately 14 miles long.

Engineering/Design Trends

The monorail design concept is not expected to change significantly. Vehicle size will vary to meet the application requirements, with corresponding changes to the traction motor and drive train.

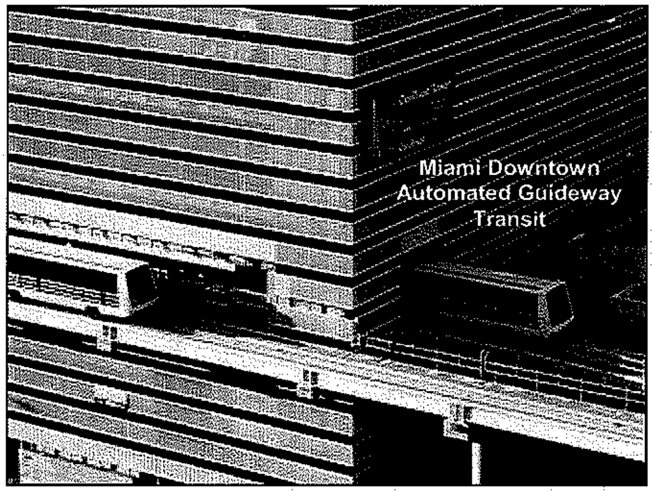
Examples of Existing Monorail Systems

- Las Vegas, NV – Downtown (1 mile) under expansion to 3.9 miles
- Seattle, WA - Built for World's Fair (1 mile) to be expanded to 14 miles
- Newark, NJ - Newark International Airport (3.8 miles)
- Jacksonville, FL – Downtown (4.3 miles)
- Kitakyushu, Japan – Downtown (5.3 miles)

2.7 AUTOMATED GUIDEWAY TRANSIT – (People Mover)

Automated Guideway Transit (AGT) or "People Mover" systems utilize fully automated low to medium capacity vehicles. AGT refers to a broad range of fixed guideway technology in which the most prominent feature is automated train operation. AGT is characterized by steel or rubber-tired vehicles that operate under automated control on an exclusive guideway. AGT can be one of the quietest transit modes when it uses rubber tired vehicles and electric propulsion. Under these circumstances it produces virtually no emissions. In cold climates the guideways must be kept clear of ice and snow. This is typically accomplished through heating devices built into the guideways. It is typically grade-separated from other vehicular traffic.

For technical reasons, at-grade or on-street operation of AGT is not practicable. AGT rights-of-way, other than aerial guideways or tunnels, are virtually unknown. AGTs have high route capacity due to frequent service. Hourly passenger capacity can be comparable to that of light rail. Vehicles typically accommodate fewer passengers than other rail modes. The relatively small cars can be coupled into trains that operate with very short station spacing. Stations are spaced one-quarter mile to one mile apart. Therefore, this transit technology is commonly used at airports, activity centers, and downtown circulators. Unlike most transit modes that use vehicles controlled by a driver, the lack of an operator aboard AGT vehicles makes it possible to provide very frequent service at little additional operating cost. Alternatively, at least one AGT system is known to provide off-peak service on a demand-responsive basis. It has been implemented as a line-haul transit in medium to large metropolitan areas. AGT may use conventional electric propulsion, or alternative types such as linear induction and magnetic levitation. Capital costs for AGT systems range from $50 to $100 million per mile.



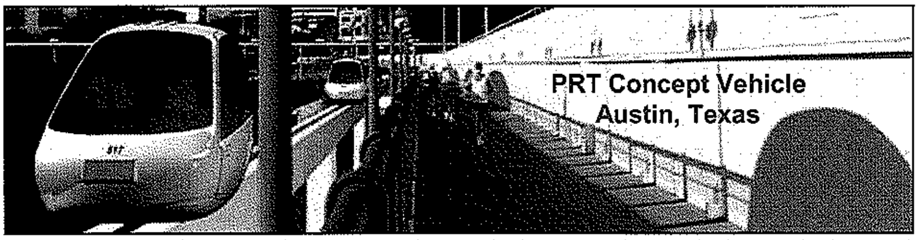
Engineering/Design Trends

New AGT concepts emerge every few years with variations in guideway design and propulsion concepts. Successful vehicles are expected to continue to use the central guide beam concept for support, lateral guidance, and power collection. As technology improves items such as automation, lighter weight vehicles and guideway construction, the AGT technology will benefit.

Examples of Existing AGT Systems

- Downtown Circulator: Detroit, MI; Miami, FL
- Line-Haul Service: Vancouver, Canada; Taipei, Taiwan
- Airport Circulator: Atlanta, GA; Dallas/Fort Worth, TX; Orlando, FL
- Feeder/Distributor Service: Toronto, Canada; Bukit Panjang, Singapore

2.8 PERSONAL RAPID TRANSIT – (PRT)



Personal Rapid Transit is a concept that provides direct point-to-point, demand-responsive transit service to individuals and small parties. An automated control system routes small vehicles along a grade-separated guideway system allowing passengers to reach a selected destination without stops. Similar to AGT, intervals between vehicles are very short. A PRT primarily serves low-density business parks or suburban areas as well as areas where walking distance from transit stops are too great or inconvenient. The level of service is competitive with private vehicle travel.

A passenger summons a PRT vehicle to a stop, and is then transported to his or her destination without intermediate stops. Stops can be designated at very close intervals since they are not subject to intermediate stops after boarding. Capital cost for this technology is not readily available.

Engineering/Design Trend

This technology is not used on a large scale and is still under development. One pilot program is in operation (see below). It is envisioned as competing with the automobile by providing a direct, non-stop trip between origin and destination in private vehicles for up to three passengers.

Examples of Existing PRT Systems

- Morgantown, West Virginia - The 3.6 mile long system is operated by West Virginia University. The single line connects the university's Evansdale and Downtown Campuses with downtown Morgantown. Each car seats eight people with some room for standees, and runs on rubber tires in a U-shaped concrete guideway. No human staff is needed on board the cars or in stations.

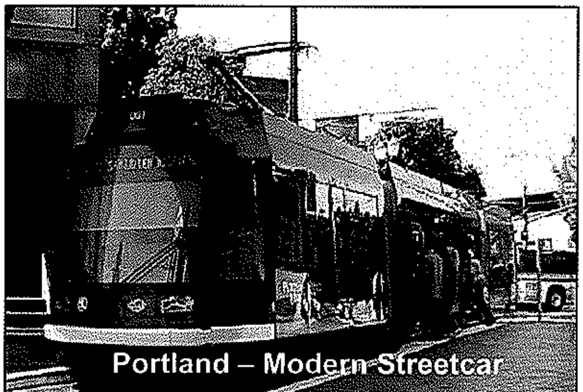
2.9 STREETCARS (Trolley)

Streetcars, also known as trolleys or trams, were once the backbone of urban transit systems until bus and subway transit became more prominent. In the 1980s, streetcars experienced resurgence with the restoration of several historic trolley systems. Today, streetcar service has re-emerged as a viable option for transit service in urban areas.

Streetcars typically operate in mixed traffic on surface streets or in reserved medians, providing short-headway and frequent-stop service. Similar to light rail, streetcars are a low to intermediate capacity intra-urban service. They are well suited to local transit needs in developed urban major activity centers, and are often used as shuttle service to attractions, shopping, downtown circulation, parking areas and airports.

Track and power supply requirements for streetcars are similar to light rail operations. Because of similar operating characteristics, streetcar routes can operate on a portion of modern light rail track, however, light rail as a line-haul service may not be suitable to operate on tracks designed specifically for a streetcar.

Streetcars are electrically powered vehicles of either a small single unit design (two axles assembled into a unit that does not swivel with respect to the car body) or a larger double unit design (four axles). Single unit vehicles are normally less than 30 feet long and can seat up to 30 passengers. Double unit cars are typically 35 to 50 feet and can seat up to 70 passengers. Streetcars are powered via overhead wire; drawing 600 volts of direct current via a streetcar pole.



Maximum speed ranges up to 35 mile per hour. The average operating speed is comparable to local bus operations (8 to 12 miles per hour). Similar to light rail operations, streetcar systems are considered to be environmentally friendly.

Streetcars can be grouped into two categories, modern and vintage (historical) style. Vintage streetcars are typically low capacity and low-speed transit. The McKinney Avenue Trolley is an example of a vintage style streetcar.

Modern streetcars are generally characterized as low to intermediate capacity. Examples of modern streetcars can be found in Portland, Oregon and Tacoma, Washington. Modern streetcars offer the ability to negotiate urban streets with sharp turns. Vehicle capacity and performance characteristics, such as acceleration and maximum speed make historic streetcars less desirable for line-haul service. However, modern streetcars have passenger capacity and operating characteristics approaching those of light rail systems.

Capital cost for streetcars varies but tends to range between $10 and $25 million per mile. However, restoration cost of older trolley cars can range from $400,000 to over $1 million and cost for replica cars can range from $500,00 to $800,000 per car. Minimizing station features and station design can reduce the capital cost for streetcar systems.

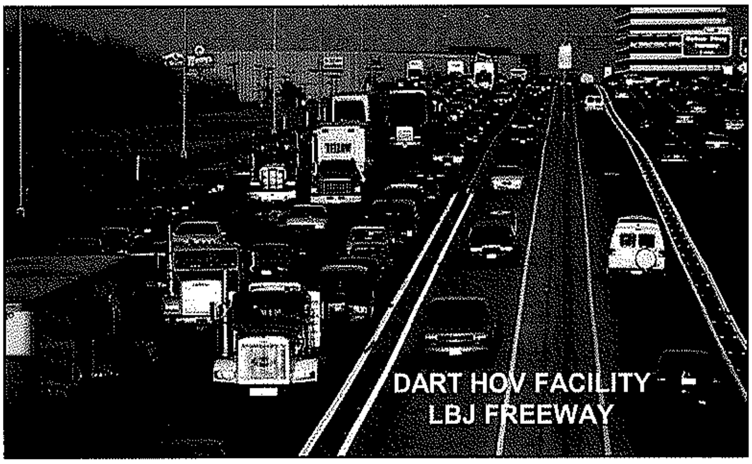
Engineering/Design Trend

Similar to light rail vehicles, streetcar vehicle development is concentrating on lighter vehicles, less expensive manufacturing, and standardization. Modern streetcars resemble modern light rail vehicles. Portland, Oregon and Tacoma, Washington use modern 66-foot, four-axle, double-articulated, low-floor "Astra" vehicles. Some cities are utilizing replica cars that resemble historic streetcars. Unlike historic streetcars, replica cars may include modern features such as air conditioning, and onboard wheelchair lifts.

Examples of Existing Streetcar Systems

- Dallas, TX
- San Jose, CA
- Portland, OR
- Boston, MA
- New Orleans, LA

2.10 High Occupancy Vehicle (HOV) Facilities



High occupancy vehicle facilities are roadway lanes dedicated for high occupancy vehicle movement, i.e., carpools, vanpools, and buses. The primary focus of an HOV facility is to increase the person-movement rather than vehicle movement through a corridor. HOV facilities are one of the many alternatives that metropolitan areas are using to respond to increasing traffic congestion, declining mobility levels, and air quality and environmental concerns. HOV lanes can operate within several types of ROW, including on freeways, arterials, or on separate ROW. There are several operational alternatives within the freeway ROW including: concurrent flow, contraflow, reversible, and bi-directional. Below are the three most common types:

- Concurrent flow HOV facilities are lanes added in the same direction of travel as the general-purpose lanes and are not physically separated from mixed flow traffic. Concurrent flow lanes are normally located on the inside lane or shoulder. Paint striping is used to delineate the HOV lane.

- Contraflow HOV facilities are found where low traffic demand in the off-peak direction will allow for a lane to be used as an HOV lane for the peak direction during the peak travel period. The designated lane is separated by changeable treatments, such as moveable concrete barriers, plastic posts or pylons that can be inserted into holes drilled in the pavement.

- Reversible HOV facilities are typically single-lanes that are separated from the mixed flow lanes by permanent concrete barriers in which the direction of traffic flow can be changed at times of day to match the peak direction of travel during periods of peak demand.

There are also several design alternatives for each including striping-separated and barrier-separated. Two of the most common types of HOV lanes are median concurrent flow lanes and barrier-separated reversible lanes. The City of Houston has the largest system of barrier-separated reversible HOV lanes in the U.S. Concurrent flow median HOV lanes are most common in southern California.

DART currently operates 31 miles of interim HOV lanes on four roadways in the Dallas metropolitan area. On average, these facilities carry 100,000 weekday trips. All of DART's HOV lanes are jointly planned and designed by DART and TxDOT. They are constructed by TxDOT, and DART is responsible for their management, operation and enforcement. Maintenance is jointly performed by both agencies. Buses, vanpools and carpools with two or more occupants as well as motorcycles are eligible to use DART HOV lanes.

Location of interim DART HOV lanes:

- I-35E (Stemmons Freeway)
- I-635 (LBJ Freeway)
- I-30 (East R.L. Thornton Freeway)
- I-35E/US 67(Marvin D. Love Freeway)

LBJ and Stemmons are concurrent flow HOV lanes and have no physical barriers between general purpose and HOV lanes. East R.L. Thornton and Marvin D. Love are reversible and contra-flow HOV lanes, respectively. DART uses dynamic signs, lane control signals, changeable message signs, and cameras to monitor, manage, and respond to traffic operations.

Engineering/Design Trend

Engineering and design criteria for HOV lanes are not expected to change significantly. However, innovative approaches to HOV concepts are being developed, i.e., high occupancy/toll (HOT) Lanes. HOT Lanes are a relatively new approach to improving urban mobility. A HOT lane is an HOV lane that allows lower occupancy vehicle to have access for a toll, while making effective use of available space. HOT lanes offer urban motorists an option of faster, congestion-free travel in dedicated lanes.

Examples of Existing HOV Systems

- Dallas, TX
- Houston, TX
- Minneapolis, MN

2.11 CONVENTIONAL BUS TRANSIT

Buses represent the most common and most flexible type of public transportation. A key attribute of a bus system is the ability to employ buses that combine feeder, line-haul, and distribution functions. Bus transit routes are typically designed to function as a primary trunk or backbone for an urban transit system, to provide regional service between urban areas, and to provide circulator service within communities. Buses are able to respond to increasing passenger demand by increasing vehicle size and bus frequency. Because of this flexibility, buses can serve corridor volumes ranging from about 1,000 to 2,000 passengers per hour to at least 20,000 passengers per hour. This is comparable to the carrying capacity of light rail.


DART 30ft. Liquefied Natural Gas-fueled bus

Historically, bus transit in the United States has been perceived as second-class transit as compared to rail service. However, technological advances in bus vehicle design and operations have improved the buses' image and public acceptance. Today, there is a growing sentiment within the transit industry to consider buses as a viable option. These new service concepts have also shown to be successful in promoting positive changes to the surrounding land use.

Bus services can be designed to meet a variety of physical and operational challenges. Most routes operate on standard roadways. However, bus routes can be tailored to meet the needs of individual communities. In Europe and South America, systems have been designed to operate on dedicated bus shoulder lanes, in the medians of streets, on dedicated right-of-way, and along side railroads and utilities easements.

Buses can operate on fixed-routes or on a demand-responsive basis. Fixed-route bus services can be defined as local or limited stops. Demand responsive services, or paratransit, are those services that provide curb-to-curb services. Local bus route stops are typically as frequent as one every one to two blocks or every one-eighth mile. Express or limited service is characterized by fewer stops and higher average speeds. Bus transit encompasses a wide variety of vehicle types, ranging from converted vans to double-deck and articulated transit buses. Typical transit vehicles operated in fixed-route service may include buses 30 feet long or shorter for neighborhood and feeder service. In the majority of urban and suburban bus services, 35-foot and 40-foot coaches are used. Unlike rail facilities, bus station stops are typically simple, ranging from a bus stop sign to a stop that has a sign and bus shelter. Speed for conventional buses are governed by city-imposed speed limits and by the prevailing traffic conditions, except when operating on an exclusive ROW. The average operating speed for conventional buses, in mixed traffic, is 10 to 12 mph. Capital costs for buses range from $200,000 to $1 million, depending on size and features.

DART has a sizeable fleet of conventional buses. It operates nearly 130 local and express bus routes serving Addison, Carrollton, Cockrell Hill, Dallas, Farmers Branch, Garland, Glenn Heights, Highland Park, Irving, Plano, Richardson, Rowlett and University Park. DART has a total fleet of 759 buses, 14 transit centers, and 12,870 bus stops. The average weekday ridership is 135,623 passengers. In FY2003, the DART bus system provided 39.9 million passenger trips over 1,393.24 route miles.

DART bus services are classified into five service categories: Local, Crosstown, Express, Feeder/Distributors, and Rail Feeder.

- Local routes include both local routes and limited-stop routes.
- Crosstown routes connect non-CBD activity centers together while linking the radially oriented local routes to provide shorter more direct travel.
- Express routes operate non-stop service between transit centers or Park and Ride facilities and downtown Dallas.
- Feeder/Distributor routes operate in a local service mode accommodating trips of relatively low-density population.
- Rail Feeder routes function primarily to collect and distribute riders of light rail and commuter rail service.

The majority of conventional buses operate on diesel power. Two environmental concerns do arise: bus vehicle emissions and noise. Low sulfur or biodiesel fuel is available. The issue of bus vehicle emissions can also be mitigated via alternative fuels such as compressed natural gas (CNG), liquefied natural gas (LNG), electric buses, and fuel cell buses. Fuel cells offer near zero emissions and significant reductions in greenhouse gas emissions, as well as potentially more efficient power generation, improve reliability, and lower maintenance costs. Similarly, noise impacts can be mitigated by electric trolley buses or other noise mitigation measures such as fuel cell transit buses, which are also quieter than conventional buses.

Engineering/Design Trend

Bus technology development continues using improved diesel engines, cleaner fuels, external electric power, batteries, hybrid (combination) systems, and fuel cells. All of these designs are in service. The zero emissions fuel cell design will improve bus acceptance when its price becomes competitive. Today, a 40-foot fuel cell powered bus is about four times the price of a conventional engine powered bus.

Examples of Existing Fixed Route Bus Systems

Hundreds of transit agencies across the U.S. operate fixed route bus systems.

2.11.1 Bus Rapid Transit and Enhanced Bus Transit Strategies

Conventional buses can also be used for different operating strategies including bus rapid transit (BRT). The primary objective of BRT strategies is a reduction in passenger travel time. Busways provide the speed advantages typically associated with fixed guideway systems. A central concept is to give priority to transit vehicles that carry more people than automobiles do. With exclusive lanes, travel time can be substantially reduced relative to conventional bus service. In addition, traffic signal priority and reduced dwell times contribute to reduced travel time. These systems often have fewer stops than conventional bus service.

Bus rapid transit is often referred to as a low cost alternative to light rail transit. Under the BRT operating strategy, conventional buses could operate primarily in easily identifiable exclusive busways, HOV lanes or dedicated bus lanes.

An exclusive busway is a special roadway designed for the exclusive use of buses. A busway can be in its own right-of-way, or in a railway or highway right-of-way. Short stretches of streets designated for exclusive buses are sometimes also called busways. A busway can also be built in an active rail corridor. Busways usually have on-line stations.

Bus rapid transit service can be integrated into HOV lanes to provide high-speed and high frequency service. In this operating strategy, BRT buses share the HOV lanes with rideshare vehicles. Buses can use HOV lanes as part of a point-to-point service with no stops on the HOV portion. Buses on HOV facilities can also pick-up and drop-off passengers arriving at on-line stations. To provide an enhanced level of service, HOV lanes may have exclusive on- and off-ramps for BRT vehicles.

A dedicated bus lane is a roadway lane separated from general traffic lanes by barriers, or simply by signage and road markings. On city streets, there are several ways these can be implemented. A two-way street might have one dedicated bus lane in each direction, while a one-way street might have one dedicated lane.

In general, most local bus service in dedicated lanes typically operates at average speeds of 10 to 20 miles per hour. Buses on exclusive busways and HOV lanes average operating speeds that ranges between 20 to 50 miles per hour, depending on the system configuration. Buses on the DART HOV lanes carry approximately 600 passengers per hour during peak service. In 2000, the average operating speed on the I-35 HOV portion of the bus routes was approximately 57 mph.

For the purpose of this study and in the development of the 2030 Transit System Plan, DART defines rapid bus rapid service as transit service with an average operating speeds of 20 to 29 mph, with limited stops. These speeds are higher than the average speeds more commonly found in local bus service throughout the nation, as previously mentioned.

Enhanced bus transit is a service where conventional buses operate on arterial roadways that have dedicated bus lanes and signal priority treatment. Enhanced bus transit service also includes patron amenities, such as attractive stations, and integration of Intelligent Transportation Systems (ITS). ITS technology includes: wireless communication, computer assisted dispatch systems and automated traveler information systems.

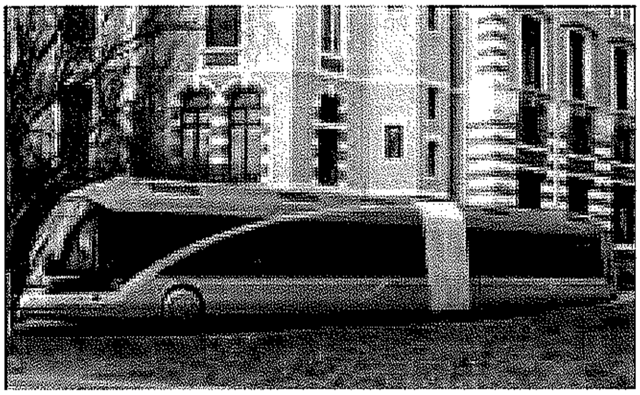
DART is defining enhanced bus transit service as buses that generally operate between 15 to 19 mph, as compared to conventional bus transit which operates between 10 and 12 mph. The key difference between enhanced bus service and rapid bus service is the lower average travel speed and the fact that it does not operate in an exclusive busway. Enhanced bus service, therefore, would provide a less dependable service than BRT.

Capital costs for improved busways, where an exclusive busway is not necessary, are usually lower than capital costs for rail systems. Making use of existing rights-of-way can reduce capital cost. However, a fully featured exclusive busway system can approach the cost of a light rail system. Capital cost for this type of system ranges from $4 to $40 million per mile, depending on system configuration. Enhanced bus strategies generally include low cost operational and physical improvements ranging from $1 to $2 million per mile. These improved busway systems can be incrementally implemented. If properly planned, either of the two service strategies could serve as the initial phase towards the development of a light rail system.

2.12 Electric Trolley Bus

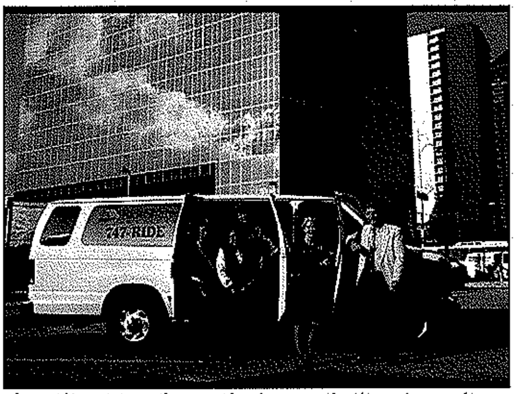
Electric trolley buses are a subtype of a standard bus. This technology was originally implemented as an alternative to the streetcar. Electric trolley buses receive power from an overhead wire. These buses are distinguished from other buses by electric propulsion only; otherwise, they are identical in size to diesel buses and can operate in the same environments, if an overhead power source is available. Electric trolley buses are appropriate for hilly terrain since they can efficiently negotiate steep grades, and for very busy routes characterized by short headways. While once common in many cities, few systems or routes remain. Capital cost for electric trolley buses range between $900,000 and $1.5 million per mile for electrification.

The Electric Trolley Bus design concept is not expected to change significantly. Several manufacturers are attempting to combine the best features of trams and bus characteristics into an electric trolley system. Bombardier with the tram-on-tires, Renault-Matra with Civis and Mercedes-Benz are looking to develop an electrically driven 200 passenger double-articulated bus.



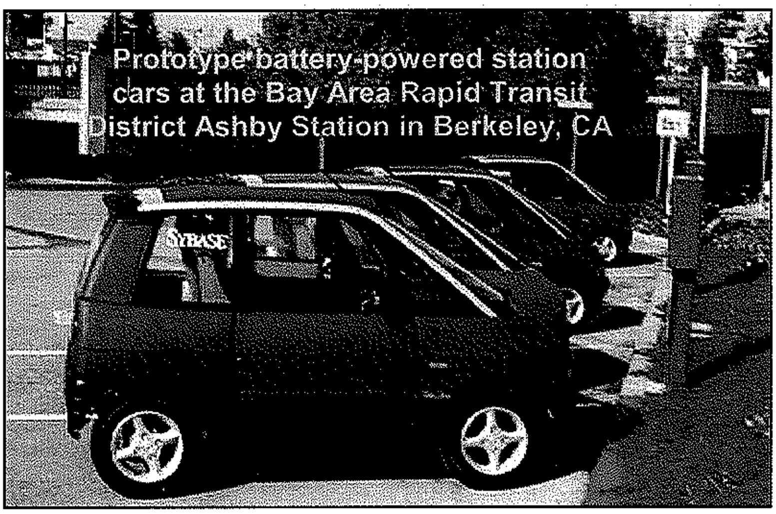
Civis' diesel-electric bus operating in France

2.13 Special Transit Vehicles



To meet the growing and often diverse demand for transit services, transit agencies are focusing their energies on developing an array of transportation services and programs. The growing trend towards suburb-to-suburb travel, increased travel needs of the mobility impaired, and the growth of non-traditional travel markets have resulted in the use of non-traditional transit vehicles. Transit agencies across the country are recognizing the need to have a range of transit programs and vehicles to serve their customers' needs. The use of vans, cars and small buses to address the travel needs of low-density travel markets and the travel needs of the mobility impaired have become standard practice at many transit agencies.

2.13.1 Station Car



The station car concept is a relatively new form of mobility and is similar to the concept of Car Sharing. Both concepts were developed around the same time and are based on the premise that households do not need to own or long-term lease cars to maintain access to goods, services, jobs and other destinations. Subscribers of both services reserve and use the cars for some, or all, of their trip-making needs. In car sharing, one or two cars are parked in several places throughout residential neighborhoods. The station car concept places a number of cars at transit stations.

With regards to transit, station cars can become an extension of a transit system resulting in increased ridership on line-haul routes, i.e., rail, and express bus service. Station cars provide the same instant access and convenient mobility as conventional vehicles. They can serve low-density residential and commercial areas that cannot be well served by traditional fixed route systems.

A typical station car is a small battery-powered electric car, but other types of vehicles can and are being used depending on transit needs and demand. Electric cars are preferred because they are considered to be more environmentally friendly than gasoline or diesel engine vehicles. Electric cars also offer these benefits:

- Significantly reduced maintenance;
- Simplified infrastructure;
- Ease of operation;
- Durability;
- Reliability;
- Safety;
- Reduced dependence on foreign oil; and
- Life cycle cost effectiveness.

The overall objective of the station car concept is the reduction of vehicles on the road. With station cars, different users rent the same vehicle more than once a day. Thus, station cars contribute less to roadway congestion, air, noise and water pollution.

The maximum speed for electric station cars is 50 to 65 mph depending on the manufacturer. Station cars can be recharged at queuing stations located at transit facilities, or recharging can be accomplished at the homes of commuters. The driving range for electric station cars is approximately 45 to 70 miles on a fully charged vehicle, depending on vehicle manufacturer and driving conditions.

Capital cost for station cars can range from $15,000 to $25,000 depending on vehicle type, fuel type, and other vehicle options, such as an on-board Global Positioning System (GPS). With federal and state incentives and tax credits the capital cost for station vehicles can be reduced substantially, up to 45% of vehicle cost. The infrastructure cost for vehicles storage/recharging varies by vendor and location.

Cities that have tested Station Cars Programs include:

- San Francisco - 40 electric vehicles at 4 BART stations
- Boston - Test 31 electric vehicles at various rail station and Park & Ride
- Los Angeles - 3 electric vehicles at 2 Metrolink rail stations

2.13.2 Commuter Vanpools

A vanpool is a group of 7 to 15 people who commute together on a regular basis in a van. Riders usually meet at designated pick-up locations like a shopping center, park-and-ride lots, or some other central location. Each vanpool has a designated driver who is responsible for driving to and from work locations.

Vans are low-cost alternatives to traditional transit vehicles, and are geared towards serving long-distance travel markets that are not capable of sustaining traditional fixed route service. From an operations perspective, vanpools are flexible, environmentally friendly, and have the ability to provide riders significant travel time savings by using HOV lanes.

Vanpool programs can be administered in two ways: the transit agency can buy vans and administer the entire program, covering the costs by collecting fares from riders; the transit agency could lease vans and administer either the entire program, some of the program or none of the program-depending on the terms of the lease.

Vanpool vehicles come in various seating sizes: mini-van seats up to seven passengers; standard-van seats up to nine passengers; and maxi-van that seats up to 15 passengers. The average trip length for vanpool service is 34.6 miles. The average operating speed is 31 mph. Capital cost for vans vary based on size and manufacturer. The average cost range is from 20,000 to $30,000.

2.13.3 Paratransit

Paratransit services fall in between conventional fixed-route transit and the personal automobile. The service uses minibuses, vans, taxicabs and/or sedans to provide demand-responsive transportation for people who are mobility impaired. The service is available by reservation or subscription, and usually on a shared-ride basis. Paratransit service typically provides door-to-door service. Some operators provide service from the customer's origin to destination with American with Disabilities Act (ADA) compliant fixed route buses or trains. Another operating strategy is to provide zone-to-zone service that requires a transfer between vehicles.

Paratransit provides, on average, 1.4 passengers per revenue hour or unlinked passenger trip. The average trip length is 8 miles. The average operating speed for paratransit vehicles is 14 to 15 mph.

The fleet size for paratransit services varies and is typically based on the size of the transit agency and the amount of service provided. Small urban transit agencies typically have a paratransit fleet that ranges from 4 to 24 vehicles. In mid-size transit agencies, the fleet size can range from 4 to 75 vehicles. Large urban transit agencies have fleets that can range from 34 to 384 vehicles.

Transit agencies use a mix of vehicles to provide paratransit services. As such, vehicle capital cost varies by agency. Capital cost for paratransit vehicles can range from $30,000 to $70,000 depending on seating capacity, type of wheelchair lifts, and other operating requirements.

Changes in paratransit vehicle design are helping to increase transit productivity and quality of service. For example, in Europe the latest small bus design allows the internal configuration of the bus to be changed quickly. This allows the bus to be used to carry multiple wheelchairs, to carry regular transit passengers to a trunk route in rural transit operations, and for package delivery for special services.

DART paratransit service provides public transportation to people with disabilities who are unable to use standard buses or trains. Paratransit service is a shared-ride service operated with accessible vehicles. Riders who are unable to access vans by using steps may use wheelchair lifts. Paratransit may provide door-to-door service to ADA paratransit eligible individuals who have the ability to use DART bus or rail services. DART has approximately 7,000 eligible patrons in its database. Currently, DART provides about 2,500 trips daily within its service area.

3.0 VEHICLE PROPULSION

In 1998, the U.S. Environmental Protection Agency (EPA) designated the Dallas/Fort Worth area as a serious non-attainment area. As a result, NCTCOG and other governmental bodies started promoting the use of cleaner-burning alternative fuel vehicles as an important air quality control strategy for the region.

Internal combustion engines have been identified as a significant source of volatile organic compounds (VOCs), and oxides of nitrogen (NOx) emissions. Both of which have negative impacts on air quality and the economic viability of a community. This section provides an overview of existing and innovative alternative fuel vehicle technologies.

3.1 Electric Vehicles

An electric vehicle (EV) is a motor vehicle that uses a rechargeable battery for propulsion, replacing gasoline, diesel or other types of combustible fuels. The vehicle is similar in appearance to vehicles powered with internal combustion engines having the same chassis or body, and containing the same accessories as an internal combustion engine vehicle.

The propulsion system of an electric vehicle produces zero emissions and is considered to be more energy efficient then internal combustion engines. Its primary focus is to reduce the amount of noxious gases that are released into the air. An electric vehicle has the following attributes:

- No gaseous emissions;
- Simple (not a lot of moving parts);
- Energy efficient;
- Regenerative braking that provides energy to the batteries;
- Electric motor is quiet; and
- Does not utilize a transmission.

An electric vehicle's battery defines the range, acceleration ability and recharge time for the vehicle. Today's batteries do not provide electric vehicles with the same drive range as internal combustion engines. Also, there is the lack of uniformity among electric vehicle manufacturers when it comes to a standard for a vehicle's nominal battery voltage. This lack of uniformity means that different manufacturers may use different charging specifications. Thus, developing charging stations for vehicles would be difficult. There are efforts to create "smart" chargers that are microprocessor based. The chargers would be able to access the vehicle's data bank and would be able to regulate the charge according to the manufacturer's specification.

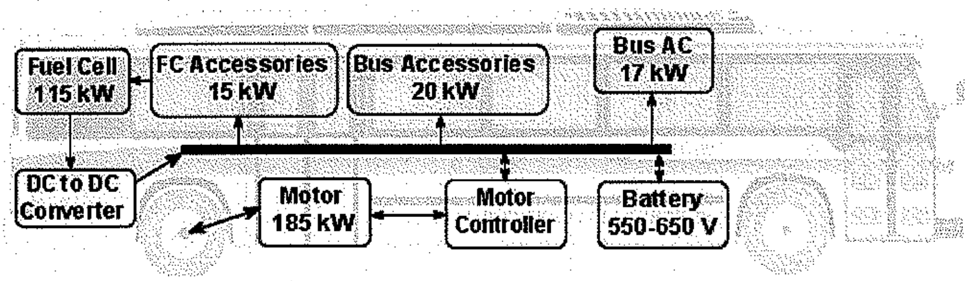
Electric or hybrid-electric (utilizing either clean diesel engines, alternative fuels engines, gas turbines or fuel cells in conjunction with batteries) buses are being used at several transit agencies around the country. These agencies include the RTD in Denver, the City of Miami Beach, the Grand Canyon National Park, and the New York Transit Authority. A telephone survey of transit agencies in Denver, the City of Miami, and the Electric Transit Vehicle Institute resulted in the following findings:

- EV buses are quiet and well accepted by the community;
- EV buses typically operate as shuttle buses in the downtown area or mall area;
- Seating capacity is less than conventional buses;
- Typical operating speed range between 15 and 25 mph;
- Capital cost for vehicles is higher than conventional buses (20 to 40 percent);
- Operating cost tend to be lower (due to reduced maintenance);
- Lifecycle cost is about even; and
- EV can be used for low speed, low to high capacity corridors.

3.2 Fuel Cell Vehicles

Fuel cell vehicles are an attractive step-up from battery-powered vehicles. They offer the advantages of battery power, but can be re-energized quickly and could go longer between refueling. A fuel cell produces electricity by reacting hydrogen and oxygen with a catalyst to form water. The chemical energy is converted to electrical energy with high efficiency.

Fuel cells are now being evaluated or developed for a variety of mass transit applications, including locomotives, transit buses, people movers and taxis. There are many different types of fuel cells under development. The most common type is known as the Proton Exchange Membrane (PEM) fuel cell.



XCELLSiS X1 Bus Hybrid Propulsion System Layout

The first bus powered by a pre-commercial fuel cell engine was developed by Ballard Power Systems and XCELLSIS Fuel Cell Engines. Fuel cell engines, based on the Ballard fuel cell, will be comparable to conventional engines in size, weight, operating life, acceleration and speed, range and refueling time. Today, there are several developers conducting research, demonstration or evaluation on fuel cell transit vehicles.

The Department of Energy's National Renewable Energy Laboratory (NREL) is working with transit agencies and other partners to determine the test and evaluation protocols needed to advance implementation of fuel cell technology, as well as document the necessary modifications to transit agencies' maintenance and operations infrastructure. Several prototype fuel cell buses have been demonstrated in the U.S. and Canada and are expected to be available commercially on a limited basis by 2003.

3.3 Clean Diesel

One type of clean diesel fuel is a specially refined fuel that lowers sulfur content and thereby reduces harmful emissions that can hurt air quality. The sulfur content of clean diesel ranges from 15 to 30 parts per million (ppm). Regular diesel has a maximum sulfur content of 500 ppm. Clean diesel vehicles utilize emission reduction equipment, such as particulate filters, that reduces emissions of fine particulates and toxic air particles by more than 90 percent and emissions of hydrocarbons to nearly undetectable levels.

Ultra-low sulfur diesel fuel has no negative impact on vehicle performance. It provides the same energy and performance as regular highway diesel and meets all specifications for regular on-highway diesel.

Currently, ultra-low sulfur diesel fuel costs more than regular diesel because of production costs. However, it is expected that as more private and governmental entities convert to clean diesel and more distribution centers come on-line, the production cost of clean diesel fuel will go down.

Another type of clean diesel fuel, biodiesel, is an oxygenated fuel made from soybean oil, other vegetable oils or animal fats. Biodiesel is a mixture of many chemical constituents and is therefore relatively difficult to reform. Researchers have recently successfully demonstrated the use of regular diesel fuel with a solid oxide fuel cell. They hypothesize that biodiesel would have similar characteristics, though sulfur removal would be necessary.

DART currently uses a contractor to supply Ultra Low Sulfur Diesel (ULSD) fuel that meets federal clean air regulations set to take effect in 2006. At that time, diesel fuel sold for use in heavy-duty, on-road vehicles must meet a 15 p.p.m. (parts per million) sulfur limit, compared to the current standard of 500 p.p.m. of sulfur. Diesel trucks and buses equipped with the latest engine control technologies and with the special exhaust filters installed on the majority of DART's diesel buses must use ULSD to achieve the remarkable reductions in emissions already demonstrated.

3.4 Natural Gas Vehicles

Natural gas may be used as a transportation fuel in two forms: compressed natural gas (CNG), and liquefied natural gas (LNG). Compressed natural gas is pressurized natural gas that is stored in cylinder tanks at pressures up to 3,600 pounds per square inch. Liquefied natural gas is cooled to a temperature of about –260 degrees Fahrenheit at atmospheric pressure where it is condensed to a liquid state. LNG is stored in tanks that are double-walled with insulation between the walls. The difference between the two forms of natural gas is density. Liquefied natural gas carries more energy per pound than compressed natural gas.

Natural gas transit vehicles have been in operation for more than a decade and have the following benefits:

- Lower emissions as compared to gasoline or regular diesel; and

- Lower fuel cost.

Operating issues/concerns associated with the use of natural gas are vehicle reliability, vehicle maintenance cost, and vehicle/facilities capital cost.

Reliability

Liquefied natural gas vehicles have had a problem with engine/fuel-related systems, i.e., fuel leaks, fuel filters, and running out of fuel. It is expected that with advances in fuel technology, this problem will be remedied.

Maintenance Cost

Maintenance costs for the engine/fuel-related systems on LNG vehicles have been significantly higher than those of diesel buses. Problems with the engine gas injectors, fuel system leaks, and false alarms by the leak detection system have been a source of increased cost in LNG vehicles. Engine related maintenance costs for CNG vehicles are slightly higher than diesel vehicles. Most of the cost can be attributed to extra tune-ups required for the spark-ignited CNG engines.

Capital/Operating Cost

Adding natural fuel vehicles to a transit fleet requires not only the purchase of alternative fueled vehicles, but also entails additional expenses for refueling and maintenance facilities. The capital costs for new facilities or modifying existing facilities vary by agency. The operating costs of maintaining storage and refueling facilities also vary depending on the size and complexity of the facilities.

4.0 Intelligent Transportation Systems

Intelligent Transportation Systems (ITS) involve the application of computer, communications, traffic control, and information processing technologies to improve transportation operations, safety, air quality and mobility. The use of electronic systems for information storage, processing and communication is changing the way transit agencies communicate to the public, and in turn, the way the public interfaces with transit systems. The application of ITS in fare collection, and passenger information systems are two areas that are impacting transit riders.

4.1 Multi-modal Travel Information Systems

Multi-modal traveler information systems provide travelers with real-time transit and traffic information. It gives transit riders the ability to make fully informed decisions, both pre-trip and en route. Transit riders are provided up-to-date information about the transportation system, i.e., when the next bus or train will arrive or what is the anticipated travel time from one transit stop to the next or roadway incident information. This information is disseminated via telephone, television monitors, radio, electronic signs, kiosks, personal computers, pagers, handheld electronic devices, on-board communication systems, and the Internet. Traveler information systems can be categorized into four areas: Pre-Trip, In-Terminal and Wayside, In-Vehicle Information Systems, and Dynamic Ridesharing.

- Pre-trip information systems provide travelers with pertinent information before they begin a trip. This information generally consists of transit routes, schedules, fares and other pertinent information. Traditionally, this information is obtained via telephone, however many transit agencies now provide the same information over the Internet. Transit agencies are also looking at station kiosks and automated telephone trees as another way to communicate to transit customers.

- In-Terminal and Wayside Information Systems provide travelers with arrival and departure information, schedule updates, transfer information via electronic signs, kiosks and television monitors. In-Terminal and Wayside Information Systems are not widely used because of the cost associated with deployment.

- In-Vehicle Information Systems are similar to In–Terminal and Wayside Information Systems, except information is provided inside transit vehicles via small electronic displays and annunciators. On rail vehicles, annuniciators are frequently used to announce the next stop.

- Dynamic ridesharing systems automate the arrangement of carpools by using advanced computer and telephone technologies. Drivers and riders call a central clearinghouse where a computer searches a database and finds the best available match for riders and ride seekers. Dynamic ridersharing systems streamline the ridematching process, and increase the usage of HOV modes.

4.2 Electronic Fare Payment/Smart Cards

Electronic Fare Payment (EFP) systems use electronic communications, data processing and data storage techniques to automate manual fare collection processes. EFP systems benefit both transit authorities and customers. For transit authorities, EFP systems reduce labor-intensive cash handling costs, risk of theft, improve reliability and maintainability of fare boxes, and permit sophisticated fare pricing based on distance traveled and time of day. For customers, transit becomes easier to use because exact change is not necessary and only a single fare card is needed to use the system.

EFPs can be grouped into three categories: smart cards; magnetic strip cards; and contact cards. Magnetic strip cards and contact cards are older EFP technologies and have been in use by a number of transit agencies. For the purpose of this study, only the smart card technology is reviewed.

A smart card is a credit card-sized plastic card with an embedded integrated circuit (IC) chip. This IC chip contains a central processing unit (CPU), random access memory, and non-volatile data storage similar to that found in a personal computer. These properties make the smart card a portable database capable of processing, storing, and safeguarding thousands of bytes of data, and a bridge to other databases, allowing communication between disparate computer systems.

Smart cards are relatively new and are being used in operational tests. The Ventura County Transit Commission, in Ventura, CA, coordinates the operations of seven municipal transit authorities in the county. Ventura has about 2,200 smart cards in operation. If the initial program proves successful, plans are to implement smart cards across all seven agencies. The Washington Metropolitan Area Transit Authority (WMATA) is also testing smart cards. WMATA is selling approximately 7,000 smart cards a month and is expected to have close to 250,000 cards in use in the near future.

Smart cards, unlike contact cards and magnetic strip cards, do not have to make contact with the read/write units. This eliminates the wear and tear associated with running the card through, or holding the card against a read/write unit. Smart cards are generally designed to communicate with a base unit, one to six inches away. The modulated radio frequency (RF) signal transmitted from base unit to the card also carries power to the card's circuitry.

With smart cards transit riders need only purchase a card embedded with a computer chip that is loaded with a dollar value, stored rides, or monthly passes. Transit riders will be able to flash the card without having to remove it from their wallets or purses. Smart cards cost more than magnetic strip card, but offer advantages such as, card reliability, and greater security against tampering.

4.3 DART ITS Program

DART has eight major ITS elements that will have to work together to provide necessary information to riders. These elements are Bus Dispatch, Transit Police, Light Rail Transit, Commuter Rail, High Occupancy Vehicle Lanes, DART DATA Warehouse, DART Customer Service and Paratransit. All of these functions will have to be integrated into a common system to share transit information. Towards this end, DART is developing a comprehensive ITS Plan. The comprehensive plan would also have the ability to integrate with the regional ITS system. This will enable DART to receive and submit data and video information.

4.3.1 Current and Future DART ITS Efforts

Key efforts associated with the DART ITS Program are summarized below:

On-Line Trip Scheduling – Currently, DART Customer Service staff use trip-scheduling software to assist customers in planning their trips. DART staff input origin and destination information, and then the software determines which routes should be used at what time. A Travel Planner is also available on the DART website.

DART E-mail – Currently, DART passengers can visit the DART website at www.dart.org to view rider alerts and other transit related issues, such as construction projects that impact transit service. Passengers can then submit their e-mail addresses to receive periodic updates on transit service changes/options.

On-Board Global Positioning Systems – DART currently utilizes on-board GPS to facilitate automatic passenger counts and automated stop announcements. Based on GPS data, the bus records how many passengers board at a specific location, or announces the correct stop to passengers.

Future GPS efforts would provide transit customers with information on the location and arrival time of a bus or train. GPS data could also be used to improve passenger connections. Currently, when a transit vehicle is late approaching a transfer location, passengers can miss connections and be required to wait for the next vehicle. During off peak periods, this could mean a sixty-minute wait. Using automatic passenger counter data and GPS location information, "real time" decisions in the control center can be made to hold a vehicle for connecting passengers.

Traffic Signal Priority - Computerized signal timing can improve transit travel time and reliability. In high demand corridors, transit travel time is impacted by signalized intersections. Computerized and coordinated signals that respond to transit vehicle priority reduce delays and allow for better transit travel times. Sophisticated signal timing programs allow signals to adjust green or red time to provide transit vehicles priority when approaching intersections.

APPENDIX A

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