TRANSIT TECHNOLOGY REVIEW
MPO TRANSIT STUDY

TECHNICAL MEMORANDUM
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Hillsborough County
Metropolitan Planning Organization
County Center, 18th Floor
Tampa, Florida 33602
813-272-5940
www.hillsboroughmpo.org
www.mpotransit.org

Prepared by:
PB
5404 West Cypress Street, Suite 300
Tampa, Florida 33607
813-289-5300

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BACKGROUND

In November 2006, the Hillsborough Metropolitan Planning Organization (MPO) commenced the MPO Transit Study to assess transit service needs in Hillsborough County in the context of mobility, economic vitality and overall quality of life. Through public participation, it is intended that the study will articulate a transit vision for the county that encompasses a range of transit technologies serving activity centers and future regional transit connections.

Study findings and recommendations will be considered during the MPO Long Range Transportation Plan update, and will also support updates to local government comprehensive plans and the Hillsborough Area Regional Transit (HART) Transit Development Plan.

This technical memorandum provides a review of different passenger transit technologies that are appropriate for the travel markets in Hillsborough County, and describes the general operating characteristics of each mode. Potential transit corridors and alternative future land use concepts will be evaluated together and evaluated with a set of measures of effectiveness to help determine which corridors and transit modes have the greatest potential for improving mobility in the area. The evaluation process and results will be described in a subsequent document.

The initial range of transit modes includes the following:

- Bus Technologies
  - Conventional Bus
  - Bus Rapid Transit (BRT) on bus lanes, shoulder lanes, or new guideway
  - Commuter Bus on existing roads, bus lanes, or shoulder lanes

- Rail Transit Technologies
  - Light Rail Transit (LRT)
  - Commuter Rail (CRR)
  - Regional Rail

Regional rail is included at this time because some of the corridors connect with adjacent counties and cities that could link together to form a regional transit network. Heavy rail is not being considered in the Tampa area because transit ridership is not expected to be high enough to justify the cost of tunneling and aerial structure.

SELECTION CRITERIA

The selection of a passenger technology for a corridor and related track/alignment design criteria is typically based on several interrelated factors, including:

- Type of passenger service to be provided: urban transit, commuter, or regional. What market is being served?
  - Short-distance urban transit trips favor bus, BRT, and LRT technologies with their ability to provide frequent service, high acceleration, and attractive travel speeds when combined with exclusive or dedicated guideway and signal priority at street crossings.
  - Longer distance commuter trips to city centers favor commuter rail serving communities along designated corridors. Existing rail corridors can make this a reasonably cost effective method for connecting outlying areas.
  - Major cities and towns with significant passenger trips between them may favor a regional rail network using self-propelled vehicles providing regular and reliable service with desired amenities such as reclining seats, tray/work tables, and café car.

- Expected ridership: how many passengers are expected to ride the service? This factor and vehicle passenger loading standards will influence the frequency of service, which will in turn influence the number of required buses or train sets and their resulting capital cost.

- Desired passenger loadings: are all passengers to have seats available or are standees allowed? What is the maximum load point, the segment with the highest number of passengers in a unit of time?

- Desired service frequency: is there a minimum frequency of service or policy headway during peak and off-peak periods? Peak period headways (time between successive trains) are typically a balance between train length, equipment availability and cost, vehicle passenger loadings, and operating costs. Off-peak headways are often based on a policy decision, not necessarily on passenger loadings.

- Desired speed or travel time between major activity centers: how fast should the service be? This will depend on the market served, the distance of the line, number of stations, and the physical constraints of the running way. Speeds should be sufficient to make the service an attractive alternative to the automobile. Reliability is essential to maintain passenger demand.

- Station spacing has a significant effect on maximum speed obtainable as well as total travel time. The number and location of stations is usually a balance between access to the transit network or line and travel time.
- Station design: what is maximum platform length and height? For rail modes, will the platforms be low or high? For commuter and regional rail lines, freight traffic on the line may dictate low platforms or the use of sidings to maintain clearances. BRT stations may have bypass lanes if express service is desired. Most stations will have provisions for feeder bus and kiss-and-ride drop-off, with commuter stations providing all day parking.
- Acceleration rates affect travel time. Some agencies choose technologies with high acceleration rates to compensate for short station spacing and alignment constraints.
- Alignment constraints may affect the maximum speeds obtainable, especially for rail modes. Tight curve radii may limit the maximum speed on that segment of the line.
- Freight traffic significantly affects commuter and regional rail operations. Freight trains accelerate slowly and their maximum speeds are limited to between 60 to 79 mph, with normal speeds much lower. Freight trains also do not operate on a fixed schedule, with arrival times into an area possibly varying by hours, not minutes. Mixing passenger and freight traffic during the same time periods will likely increase passenger travel times and decrease reliability if sufficient track capacity is not constructed.
- FRA crashworthiness: if passenger service is to operate on the same tracks at the same time as freight service, the passenger rail vehicles must meet FRA crashworthiness standards. Commuter and regional rail technologies must meet these standards if operating on existing freight railroad corridors.
- Cost is, of course, another factor that affects the selection of a technology. Is there an upper limit to the absolute capital cost for the entire project? Or an upper limit to the local match? Are there statutory or planning limits to the annual operating cost budget, or a limit to the cost per passenger or passenger mile that the agency wants to subsidize?

The final selection of transit vehicle technology and design criteria will likely be a compromise of these elements as the operating agency strives to provide the best service at a reasonable cost relative to the market being served. As more planning and engineering is performed, the greater level of detail will define the constraints within which the technology and criteria must fall within. Some technologies will then be viewed as inappropriate.

TECHNOLOGY REVIEW

Bus Technologies

Conventional Bus

The 40-foot diesel transit bus is the most commonly used transit vehicle in the world. Available in conventional high-floor or now more popular low-floor configurations, buses offer the flexibility of operation in mixed traffic on city streets and highways as well as in bus-only guideways. Conventional buses provide express, limited-stop, and local circulator service throughout the metro Tampa area, operated by the Hillsborough Area Regional Transit Authority (HART). Buses are expected to remain an essential element of the region's transit system.

Conventional Bus (HART), Tampa *Source: CL*

A bus alternative is typically required by the Federal Transit Administration (FTA) in Alternatives Analysis (AA) and New Starts submittals. A bus alternative can be expected to be defined, modified, and improved throughout the AA process. Typically, based on refinement through the study process, a bus alternative will become the Baseline Alternative for use in comparison with "build" alternatives.

Capital costs for a bus mode alternative are usually fairly low compared to other modes. This is due to the fact that bus services need not require significant new infrastructure. Conventional, 40-foot, low floor transit buses cost about $375,000[1] each. Transit buses with CNG power plants have a unit price of approximately $420,000. If a 40-foot bus is equipped with a hybrid power plant (such as a diesel-electric or hydrogen-electric drive), the per-bus price can be as much as $630,000. Sixty-foot articulated buses, such as those used on some Bus Rapid Transit systems or on higher-density urban transit routes can cost as much as $725,000 to $1.1 million per bus.

The average O&M costs for operating a fleet of conventional 40 foot buses, based on data reported by HART to the National Transit Database, indicates that the per revenue vehicle-mile cost is on the order of $6.00. However, there has been a substantial run-up in the price of diesel fuel during the past two years. Reported increases in the range of 30 to 50% have been documented. If a 40% increase is assumed, and if fuel costs are assumed to comprise about 60% of the O&M cost, the average cost could be closer to $7.00 per revenue vehicle mile.

[1] All prices reflect 2007 dollars

Conventional Bus – Representative Example

New Flyer DE40LF 40-Foot, Low Floor, Diesel-Electric Hybrid Bus

The popularity of diesel-electric hybrid propulsion systems is increasing as transit agencies strive to meet stricter clean air standards. Hybrid buses offer reduced emissions (compared with standard diesel buses) to meet or exceed local emissions standards. Independent testing has shown reductions in particulate matter, CO2 and NOx emissions of up to 90%. New Flyer hybrid engines are EPA certified to 2.5 NOx and 0.05 PM, g/BHP-H.

Fuel economy improvements with hybrids have been reported at 14-30%, which offers two additional benefits. Using less fuel results in lower fuel costs and ultimately reduces the impact of changing fuel prices on transit agency budgets. It also reduces the amount of time spent refueling buses by up to 30%.

Manufacturer	New Flyer
Maximum Speed	60 mph
Height	132″
Width	8′-6″
Length	41′
Turning Radius	44′
Floor Height	15.5″
Weight	29,900 lbs empty
Passengers (seated)	up to 39
Doors	2

New Flyer hybrid vehicles accelerate smoothly and quickly from 0 to 40 MPH at gross vehicle weight in just 23.3 seconds with top speeds at over 65 MPH. Also, by routing many of the peripheral systems (such as the HVAC system, compressors, etc.) through the electrical system, more power from the engine is dedicated to moving the bus, further increasing performance.

Bus Rapid Transit

Bus Rapid Transit (BRT) combines the flexibility of buses with the frequency and travel time advantages of rail transit. BRT typically offers high capacity, high-frequency bus operation along an exclusive bus-only roadway with high amenity stations. A typical bus rapid transit guideway is a two-lane, bus-only roadway a minimum of 28 feet in width. BRT can also operate in bus-only lanes within limited-access highways and in bus lanes or in mixed traffic on arterial and local streets, often with signal priority to improve travel times and service reliability.

Four lane BRT station in Ottawa, Ontario

The use of exclusive right-of-way, limited-stop operations, and on-line stations provides passengers with quick and reliable service. On-line stations are stops along the guideway right-of-way where a transit vehicle stops without exiting the guideway. BRT operations without on-line stations require the bus to exit at an interchange or intersection, travel to the station area to board and de-board passengers, then re-enter the guideway via the adjacent signalized intersection or interchange. The on-line stations are similar to rail stations providing passengers with seating, shelter, bicycle racks, schedules and maps, park/ride lots, and/or ticket machines.

BRT service is characterized according to levels of service implementation (initial, intermediate and full) as defined by the Federal Transit Administration (FTA). Each level of BRT service includes various technological, operational, and structural elements according to the specific implementation level. Initial BRT is a basic set of amenities for BRT service, intermediate provides a more comprehensive application of transit infrastructure and technology, while full BRT is a developed system that applies the transit elements of initial and intermediate BRT service.

<u>Initial BRT Service</u>

Initial BRT service prescribes minimal improvements to existing bus services that includes an increase in service frequency, a decrease in transit travel time, and the implementation of passenger amenities for the purposes of developing a distinct mode of transportation.

Initial BRT service is typically distinguishable from conventional bus service through vehicle aesthetic improvements and the installation of passenger station amenities. Vehicle improvements range from a color scheme different from existing conventional buses to purchasing new buses that are equipped to provide a more comfortable ride.

Passenger stations are typically upgraded to include curbside concrete hard stands with covered seating areas, adequate lighting, and highly visible signage and route information.

This type of BRT service shares a travel lane to operate in mixed traffic on urban or suburban streets with some level of preferential treatment. The type of preferential treatment for initial BRT service is achieved through a deployment of Intelligent Transportation Systems (ITS) technology such as signal prioritization. A signal prioritization system improves transit travel times by allowing buses to advance, prioritize, or pre-empt traffic lights when approaching a signalized intersection. The components of the system involve a bus-mounted transponder that utilizes an electronic signal to correspond with an intersections traffic signalization system. A signal priority system allows an approaching bus and traffic to pass through an intersection without being interrupted by a stop signal. This improvement minimizes transit travel delays, improves reliability and allows buses to maintain schedule adherence. The installation of an enhanced signalization network may even reduce the number of buses required to operate on a route to meet existing schedules, and thus reduce operating costs.

Los Angeles Orange Line BRT bus at Warner Center Transit Hub

Intermediate BRT Service

Intermediate BRT service utilizes a designated right-of-way that applies various types of infrastructure and technology to reduce dwell time and accelerate transit travel time within a transportation corridor. Intermediate BRT may utilize a designated lane during peak travel times, a fully dedicated lane, or an HOV travel lane that may or may not be barrier separated from other vehicular traffic.

This type of BRT service includes an advanced upgrade of transit vehicles, bus stop amenities, and creation of bus "stations" at key locations in a corridor. Various improvements are applied along a BRT service corridor to speed up passenger boarding and reduce overall travel time. This is achieved using transit vehicles that are designed with low-floors and have multiple, wider doors for faster passenger boardings and alightings. Signage and information system upgrades at bus stops typically utilize the deployment of ITS infrastructure such as passenger information systems to provide riders at bus stops with real-time route and schedule information. Furthermore, improved fare collection systems are also implemented to include off-board fare collection and ticketing systems for this level of BRT. These types of service elements and information increases passenger confidence in using the system, which results in increased transit ridership. Intermediate BRT service also involves measures to improve pedestrian conditions through streetscape and landscaping improvements that facilitate connections to properties and land uses adjacent to stops.

Fully Developed BRT

Full BRT service is defined as a fully separated bus facility, often running alongside or in the median of expressways, or in disused rail corridors. This type of BRT system allows unimpeded travel flow at the legal speed limit and, when combined with on-line stations and park-and-ride lots, can carry volumes and produce travel speeds comparable with light rail transit at a fraction of the initial capital cost.

Full BRT may also include travel lanes typically built in a highway or roadway right-of-way, but are physically separated from the other traffic lanes and intersections and may have exclusive flyover access ramps. The Shirley Highway in Washington D.C., Seattle Bus Tunnel, the East and West Busways in Pittsburgh, several of the regional busways in Ottawa, and the priority lanes on major freeways in Houston, Texas are examples of this type of BRT facility.

Buses using this type of BRT facility normally collect passengers on local streets or at park-and-ride facilities and then enter the exclusive busway and operate much like a rail vehicle on a fixed guideway system. Busways permit the location of stations along the busway at major community origins and destinations. However, compared to HOV lanes, which are generally considered highway facilities, busways are exclusively transit facilities and often must be financed exclusively using local, state and Federal transit funding.

Table 1
Levels of BRT Summary

	Initial BRT	**Intermediate BRT**	**Full BRT**
Right-of-way	Shared lanes in Mixed Traffic	Designated lanes/HOV lanes Barrier separated dedicated lanes	Exclusive alignment with full grade separation
Stations	Improved passenger amenities – lighting, shelter, signage etc.	Enhanced passenger information and fare collection	Enhanced loading and land use features
Service	Improved service frequency	Skip stop service and express services High frequency and reliability	Convenient transfer options
Route Structure	Single route with transfers, connections and color coding	Multiple route operations with transfer facilities Integration with regional transit services	One seat rides Transfer reduction
Intelligent Transportation Systems	Signal priority	Automated passenger information	Vehicle location and system surveillance

Source: Federal Transit Administration

On-line stations, particularly in the medians of expressways, may be less convenient for passengers. However, the characteristics of BRT allow passengers to board in their neighborhoods and alight near their destinations at off-line locations by buses that can then enter the bus lane for the express portion of the trip. A summary matrix that presents key characteristics of each level of BRT service and a summary matrix that provides a comparison of each bus application are presented in the following tables.

Table 2
Bus Service Summary

	Local On-Street Bus	Express Bus	BRT
Passenger Volumes	Serves light to heavy passenger volumes	Serves medium to high passenger volumes	Serves medium to high passenger volumes
Passenger Capacity	Up to 2,000 to 4,000 passengers per hour per lane one-way	4,000 to 6,000 passengers per hour per lane one-way	6,000 to 12,000 passengers per hour per lane one-way
Speed	Slow speed - 12 to 20 mph average with stops and peak hour traffic	Medium to high speed - up to the legal speed limit depending on traffic conditions	High speed - up to legal speed limit on the use of exclusive lanes
Type of Trips	Dense area-wide network useful for short-to-medium length trips	Serves medium to long trips (depending on operating speed and bus stop spacing)	Primarily serves long distance commuter trips
Stop Frequency	Stops spaced 0.2 to 0.5 miles apart	Typically less frequent stops or point-to-point service; often uses limited access highways, HOV lanes	Typically infrequent stops; point-to-point service
Capital Costs	Low capital cost	Relatively low capital cost unless HOV or park-and-ride facilities are included	Relatively low vehicle cost, but medium to high cost for exclusive busway lanes
Operations and Maintenance Costs	Moderate operating costs per vehicle mile or passenger mile basis. High vehicle maintenance costs.	Moderate operating costs on a vehicle mile or passenger mile basis Average vehicle maintenance costs	Moderate operating costs per vehicle mile or passenger mile basis. High vehicle maintenance cost -- exclusive guideway system is an additional maintenance cost
Right-of-Way Requirements	Uses existing rights-of-way	Uses existing rights-of-way, with the exception of new park-and-ride lots	May require additional rights-of-way for new park-and-ride lots and lane expansions. Operates in mixed traffic HOV lanes or exclusive travel lanes

BRT projects have a wide range of capital costs, driven chiefly by the extent of infrastructure improvements and the nature of the line (extent of aerial structure or subway for example) and the amount of streetscape improvement included in the projects. Most BRT operations have been in or along urban arteries. An average cost per mile for 24 recent BRT projects was $22.5 million/mile. However, these ranged from a low of $0.9 million/mile for a project in Sacramento to a high of $85 million/mile for the MBTA Silver Line. The Silver Line has a considerable amount of bus subway, which is significantly more expensive than a surface right-of-way.

The availability of operating cost data for this mode is limited, since most bus transit operators do not break out the cost of their BRT operations from the rest of their bus system. However, some recent studies have quoted O&M costs in the range of $2.90-$10.55 depending on fuel and propulsion type and operating characteristics. Once again, this mode is subject to the recent steep increases in diesel fuel prices. When the adjustment for fuel price increases is included, the per-mile O&M cost range would be $3.00-$11.10.

The development of BRT vehicles is still in early stages, with manufacturers testing new designs to provide greater passenger comfort, create a more sophisticated image, reduce emissions, while holding operating costs steady. By the time this project selects a technology, more and improved vehicles will likely be available.

BRT Vehicle – Representative Example

NABI 60 BRT Hybrid Bus

Los Angeles, Mesa, AZ, and others are operating the North American Bus Industries (NABI) 60-foot, low floor, diesel-electric hybrid vehicle. This bus is similar to offerings from other manufacturers, with three doors on the right side, an option for two doors on the left side for center platform stations, low-floor for ease of access, diesel-electric, CNG, or LNG propulsion, and an interior to fit the client's needs.

Manufacturer	NABI
Maximum Speed	60 mph
Height	137″
Width	8′-6″
Length	60′
Turning Radius	44′
Floor Height	15.5″
Weight	47,200 lbs empty
Passengers (seated)	up to 62
Doors	3

BRT Vehicle – Representative Example

New Flyer DE60LF 60-Foot, Low Floor, Diesel-Electric Bus

Bus Rapid Transit, or BRT, is gaining momentum in North America as a way to move mass transit riders quickly to a central location. Instead of building a fixed infrastructure, such as seen in rail applications, BRT uses rubber tired buses, express lanes, priority signals, and in some cases, dedicated lanes. Routes can be redirected quickly in the case of minor obstructions, or if traffic patterns change, new routes can be reconstructed without any major impact to investments already made.

New Flyer has been supplying buses to BRT systems for almost 20 years. Articulated, or 60-foot buses, are often preferred for corridors with high ridership levels. Advancements in vehicle and propulsion technology, coupled with New Flyer's modular design, enable them to offer buses suited to any city's BRT system requirements.

Manufacturer	New Flyer
Maximum Speed	60 mph
Height	132″
Width	8′-6″
Length	61′
Turning Radius	44′
Floor Height	15.5″
Weight	43,700 lbs empty
Passengers (seated)	47-62
Doors	2-3
Maximum Grade:	20 percent

Overview of BRT Technologies

Table 3 provide vehicle details for some of the most recent BRT vehicle procurements in the US.

Table 3
Characteristics of Recent US BRT Vehicles

Characteristic	Las Vegas	Los Angeles	Eugene, Or	Seattle
Manufacturer	Civis Bus	NABI	New Flyer	New Flyer
Max. Speed (mph)	60	60	60	60
Min. Radius (ft)	44′	44′	44′	44′
Length	59′	60′	61′	61′
Width	8′-6″	8′-6″	8′-6″	8′-6″
Height	11′-1″	11′-5″	11′-4″	11′
Floor Height	14″	15″	14.5″	14.5″
Doors per Side	3-4	3	3	3
Max. Cars per Consist	1	1	1	1

Typically, each agency develops their own vehicle specifications to fit local constraints. Vehicle manufacturers then bid on those specific specs. Small changes to vehicle dimensions are usually not a significant obstacle to vehicle procurement, although the agency may be able to reduce the total purchase cost by developing specifications that are similar to existing vehicles.

BRT guideway requires additional width and height, beyond the actual vehicle width and height, to operate safely and effectively. This width can vary based upon the location of lane barriers, maintenance walkways, and station configurations. These features might include the following:

- Mountable curbs are sometimes used to separate BRT lanes from adjacent general purpose traffic lanes to provide some type of protection from collision with adjoining automobiles. This allows BRT vehicles to operate at maximum safe speeds.
- Sufficient clearance between the vehicle and wayside obstructions. Additionally, sufficient lane width to allow some degree of weaving within the lane.
- As with LRT, emergency walkways on aerial structure and within tunnels. Emergency egress regulations require emergency walkways adjacent to any portion of LRT tracks where access is otherwise prohibited due to tunnel walls or aerial structure side walls.

These elements are shown in the following BRT guideway cross-sections in Figures 1 and 2.

Figure 1 – BRT Typical Section

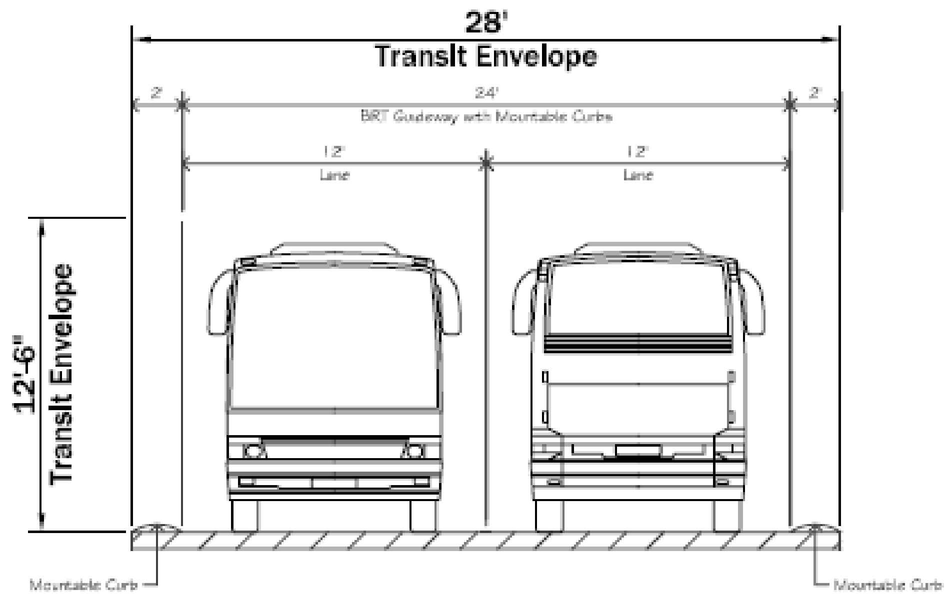
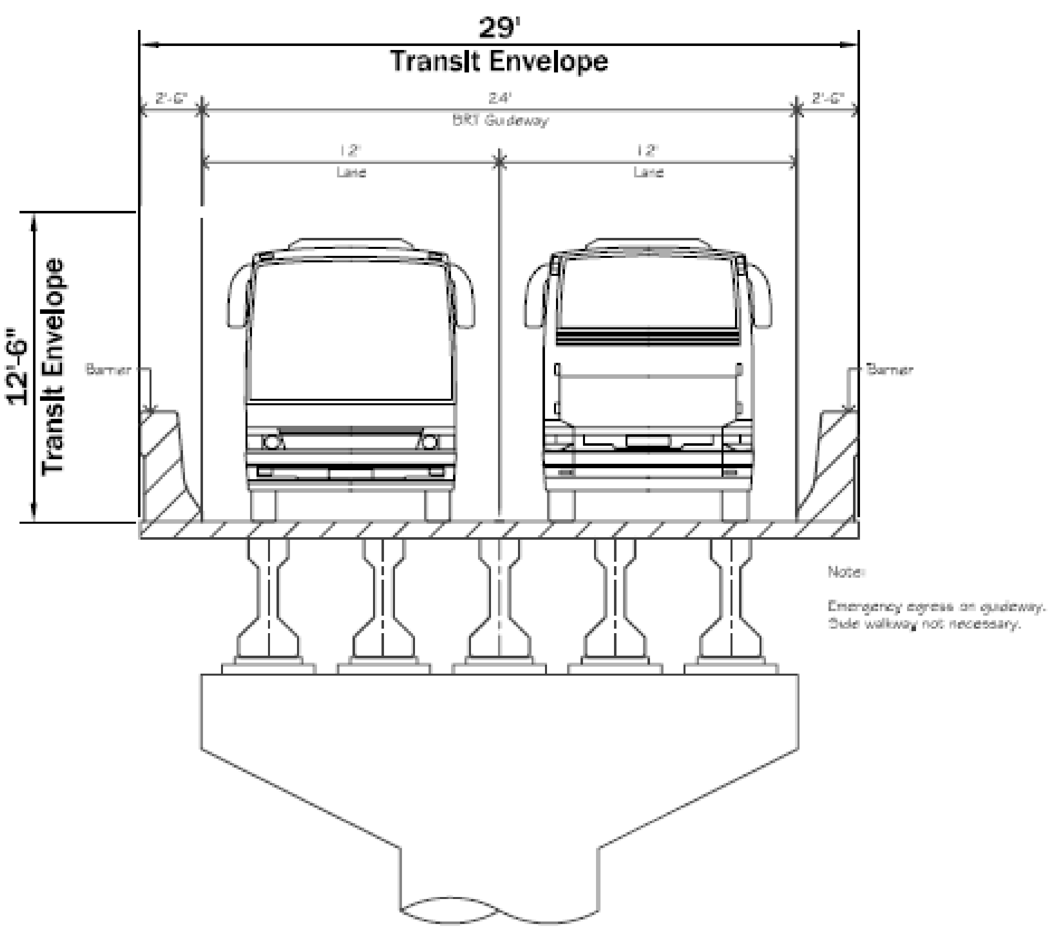


Figure 2 – BRT Typical Section



Commuter Bus


Typical commuter style bus

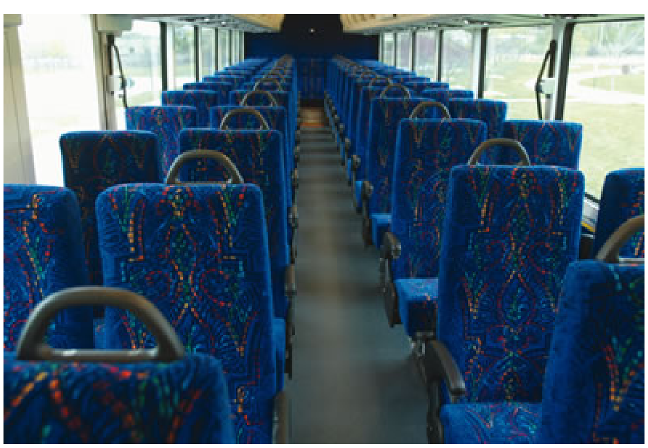
Commuter bus vehicles are usually similar to standard over-the-road coaches used by private tour companies. Commuter bus service typically consists of peak period service in the peak direction (inbound in morning, outbound in evening), serving commuters from outlying park-and-ride lots to the center city. Those outlying communities are often just beyond the transit agency's local bus service area, but not within a dense corridor that could support the volumes necessary for commuter rail. Commuter bus service might serve several park-and-ride lots before operating express to downtown. Service is often contracted out by transit agencies to local providers.

An over-the-road coach costs about $420,000 - 450,000. Operating costs per vehicle mile or per vehicle hour are typically less than for local bus due to their faster operating speeds, but operating costs per passenger may be higher because there is less passenger turnover; i.e., passengers tend to stay onboard for the majority of the trip.

Commuter Bus – Representative Example

MCI D Series Commuter Coach

Commuter buses are typically intercity over-the-road coaches configured for commuter operation. Typical configuration includes 2 x 2 seating with high-back and adjustable seats, armrests, and air conditioning. Major manufacturers include MCI, Provost, Van Hool, and Alexander Dennis.



Manufacturer	Motor Coach Ind.
Maximum Speed	60 mph
Height	137″
Width	8′-6″
Length	40-45′
Weight	30-35,100 lbs empty
Passengers (seated)	49-57
Doors	1

Rail Technologies

Light Rail Transit (LRT)

Light Rail Transit (LRT) is typically comprised of a system of electrically propelled passenger vehicles with steel wheels that are propelled along a track way constructed of steel rails. Propulsion power for the vehicles is drawn from an overhead distribution wire by means of a pantograph and returned to the electrical substations through the track rails. The tracks and vehicles are capable of sharing the streets with rubber tired vehicular traffic and pedestrians, or can be constructed within an exclusive right of way. LRT vehicles are capable of maneuvering through curve radii as sharp as 82 feet, and sometimes even sharper, in order to traverse city streets. LRT vehicles are not constructed to structural criteria necessary to share the same tracks with much heavier commuter rail or freight railroad equipment.

As such, LRT is a flexible transportation mode that can operate in a variety of physical settings. A distinctive feature of LRT is that vehicles draw power from an overhead wire through a raised pantograph which allows LRT systems to be integrated at-grade within pedestrian areas. The pantograph is always in contact with the overhead wire and has a suspension system built into it such that it can move up and down while the vehicle is traversing the alignment. This characteristic enables the overhead wire height to vary throughout any particular alignment. In cases where an LRT traverses beneath a roadway bridge, for example, the overhead wire could be set at a lower height (perhaps around 14 ft), while in other areas the overhead wire could be set at much higher.

LRTs are typically 90′ to 95′ long and range in width from 8 ft-6 in to 8 ft-9in. Operator cabs at both ends of the vehicle allow bi-directional operation, which means that the vehicle does not need to be turned around when changing direction. LRT systems can operate either as a single or multi-car train. The maximum operating speed of modern LRT systems generally ranges from 55 to 66 miles per hour, making it suitable for medium distance trips in suburbs or between central business districts. However, average operating speeds can be reduced to 10 to 25 miles per hour if operating in mixed traffic with frequent stops. The capacity of a typical LRT vehicle ranges between 120 and 150 passengers per car including standees.

Depending on the surrounding environment, LRT station design may incorporate high or low passenger platforms. Generally, transit systems with on-street operations, where passengers can walk across tracks, use simple stations with low level platforms, while systems with reserved right-of-way use high level platforms. For low level platforms, passengers would step up from the platform surface to board the vehicle. Ramps would be required to meet ADA requirements. High level platforms are built such that the platform surface is at the same height or level as the vehicle floor; hence additional ramps are not required to meet ADA mandates.

A summary of LRT characteristics includes the following:

- Serves moderate to high passenger volume
- Low to medium speed (depending on exclusivity of right-of-way and distance between stops)
- May serve short to long distance trips
- Stations spaced 0.5 to 1 miles apart
- Uses overhead power collection
- May operate in traffic, with cross-traffic, or on exclusive right-of-way
- Can negotiate steep grades and small radius curves
- Stations may be elaborate or simple. May use low platforms, high platforms, or both
- Vehicles may operate alone or in trains of up to four vehicles
- Numerous vehicle suppliers
- Cannot operate jointly with freight trains or other railroad equipment
- Moderate operating and maintenance cost

The following section provides a description and some of the technical characteristics from two different manufacturers of LRT vehicles.

Light Rail Vehicle – Representative Example

Siemens (Houston, TX)

Siemens made the S70 LRV for Houston as a bi-directional six-axle, low floor articulated light rail vehicle constructed of low alloy high tensile (LAHT) steel and composite materials with concealed couplers. The low floor area comprises 70% of the interior and extends between the end trucks through the articulated center section. The vehicles include a modern, spacious interior ensuring maximum visibility and safety. Eight sliding-plug passenger doors, four per side directly across from one another, are located in the low floor area. The vehicles are equipped with a hydraulic height control system to permit level boarding and meet the requirements of the Americans with Disabilities Act (ADA). Each vehicle includes a passenger information system consisting of automated announcements, public address, passenger-operator intercom and electronic destination signs, as well as an interior and an exterior vehicle surveillance system.

Manufacturer	Siemens
Maximum Speed	65 mph
Height	12 ft (w/o pantograph)
Width	8 ft–8.5 in
Length	96 ft-4 in
Weight	98,500 lbs empty
Passengers (seated)	72
Doors	4 per side
Maximum Grade:	7%

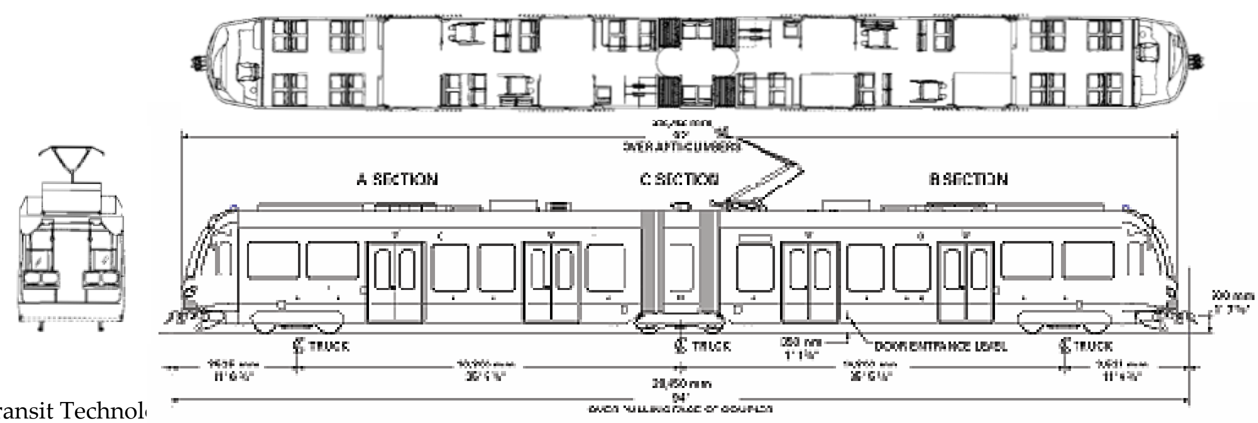
LRT Vehicle – Representative Example

Bombardier (Minneapolis, MN)

Metro Transit, the regional transport authority, launched revenue service on the new Hiawatha Line in June 2004 using 24 Bombardier FLEXITY Swift light-rail vehicles. The low-floor vehicle positions 70% of the vehicle's floor and all the doorways just 14 inches above the top of the rails, a feature that helps transit authorities avoid costly construction of special ramps and access facilities when implementing a new light rail line. This design is particularly useful for wheelchair access; the vehicles are fully compliant with requirements of the Americans with Disabilities Act.

Manufacturer	Bombardier
Maximum Speed	55 mph
Height	12 ft-4 in (w/o pantograph)
Width	8 ft-8 in
Length	90 ft
Weight	97,000 lbs empty
Passengers (seated)	66
Doors	4 per side
Maximum Grade:	7%

The Hiawatha Line LRVs are powered by 140 kW bi-motor power trucks, which are driven by electricity from overhead lines. The vehicles are bi-directional with operator cabs at each end. Each vehicle offers features such as luggage racks, double bike racks, wheel chair locations, roof mounted heating and cooling systems, a sophisticated passenger information system, and video surveillance cameras.



Overview of LRT Technologies

Table 4 provides details for some of the most recent LRT vehicle procurements in the US.

Table 4
Characteristics of Recent US LRT Vehicles

Characteristic	Denver	Houston	Minneapolis	Newark	Phoenix
Manufacturer	Siemens	Siemens	Bombardier	Kinki-Sharyo	Kinki-Sharyo
Max. Speed (mph)	55	66	55	55	55
Min. Radius (ft)	82	82	82	82	82
Length	81′-5″	96.36′	94′-0″	90′-0″	91′-6″
Width	8′-9″	8.7′	8′-8″	8′-9.5″	8′-8.3″
Height (w/o pantograph)	12′-4″	12′-0″	12′-4″	12′-3.25″	12′-2.7″
Floor Height above Rail	39″	15″	14″ (70%)	13.8″ (70%)	Na
Doors per Side	4	4	4	4	4
Max. Cars per Consist	3	4	3	3	3

Typically, each agency develops their own vehicle specifications to fit local constraints. Vehicle manufacturers then bid on those specific specs. Small changes to vehicle dimensions are usually not a significant obstacle to vehicle procurement, although the agency may be able to reduce the total purchase cost by developing specifications that are similar to existing vehicles.

All of the LRT vehicles described above obtain power from overhead catenary wire to drive electrical traction motors on at least 4 axles per car. Not shown here are Hybrid LRT vehicles that use a diesel motor to turn a generator, rather than overhead catenary, to drive the traction motors. These are being used or planned only in New Jersey and Austin, TX, but are in use in many locations in Europe as either light rail or regional rail systems. The vehicle specs for Hybrid LRT could be nearly identical to that shown for conventional LRT except for the elimination of the pantograph for current pickup.

Light Rail guideway requires additional width and height, beyond the actual vehicle width and height, to operate safely and effectively. This width can vary based upon the location of overhead catenary poles, maintenance walkways, and station configurations. These features might include the following:

- Catenary poles and cantilevered arms from which the energized contact wire and supporting cables are strung. Catenary poles may be either a single pole located between the tracks or poles located outside of both tracks.
- Sufficient clearance between the vehicle and the catenary poles. All moving vehicles have a dynamic envelope that accommodates all vehicle movements in the worst case scenarios, such as the compression or failure of the suspension on one side, causing the vehicle to heel

to that side. The side clearance provides for those worst case scenarios without the vehicle hitting the catenary poles or other wayside structures.

- Emergency walkways on aerial structure and within tunnels. Emergency egress regulations require emergency walkways adjacent to any portion of LRT tracks where access is otherwise prohibited due to tunnel walls or aerial structure side walls.

These elements are shown in the LRT guideway cross-sections in Figures 3 and 4.

Figure 3 – LRT Typical Section

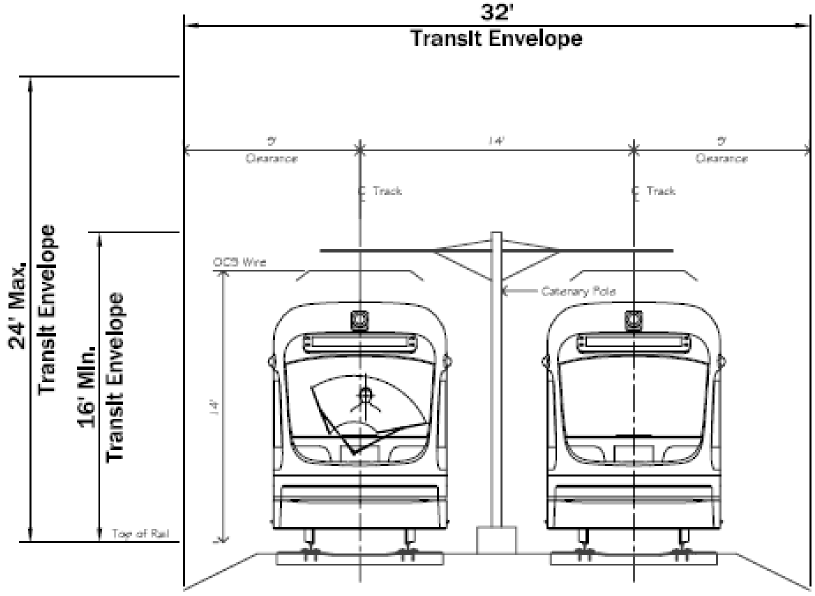
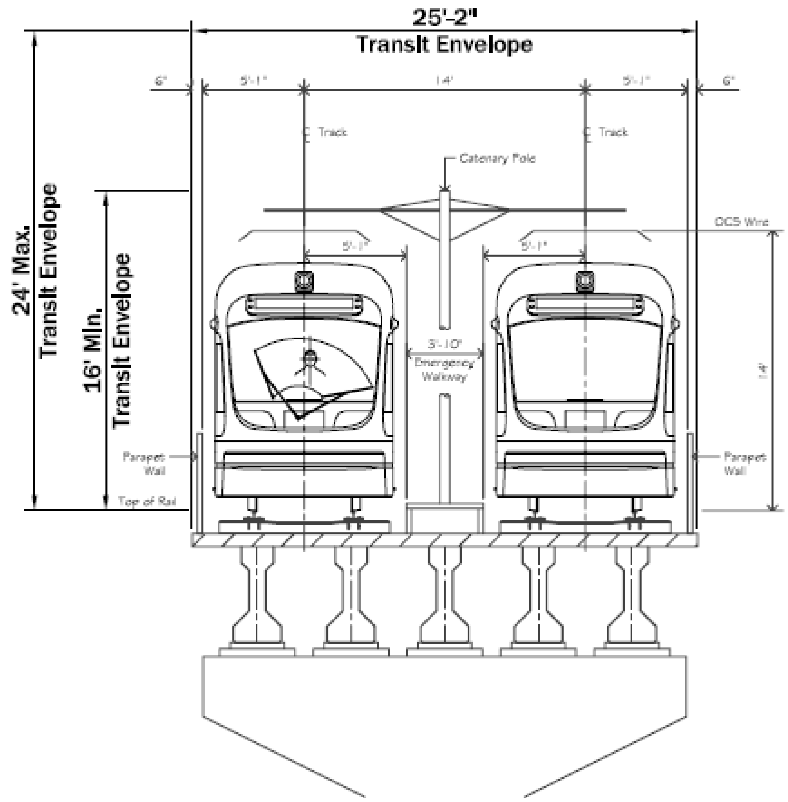


Figure 4 – LRT Typical Section



Commuter Rail

Commuter rail service is defined as high capacity, short distance, passenger rail service that is commonly part of a larger rail system. Commuter rail typically serves trips between outer suburban/exurban areas and city centers, with park-and-ride facilities at most stations. Commuter rail trains can operate over relatively long distances, usually at speeds of up to 100 mph. To provide attractive travel times, stations are often 2-½ to 3 miles apart, or more. Some system schedules incorporate express trains that do not stop at every station during times of peak demand, reducing end-to-end travel time.

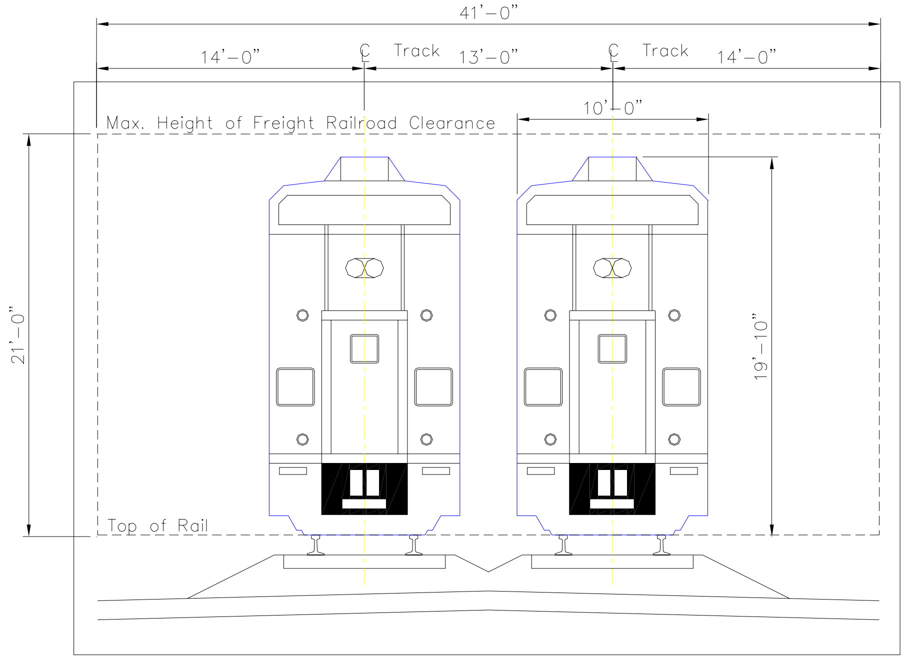
Over 18 North American cities operate commuter rail service, including new lines that have recently opened in Albuquerque and Nashville. RTA (Tri-Rail) operates commuter rail service between Mangonia Park (West Palm Beach) and Miami.

Capital costs for commuter rail lines are typically in the range of $15-26 million per mile but vary by territory. For example, the proposed 6.4-mile extension of the BNSF service from Chicago to Oswego was estimated to cost $16 million/mile. The 7-mile extension of the UP-West Line from Chicago to Elburn was completed at an estimated capital cost of $15.84 million/mile, while the Metra-Southwest Service extension 11 miles in length to Manhattan, IL was estimated to cost $20 million/mile. MBTA's 18 mile extension of commuter rail service to Greenbush has an estimated capital cost of $26.6 million/mile.

The average O&M costs for this mode, based on data reported by eight properties to the National Transit Database, indicates that the per revenue vehicle-mile cost is on the order of $12.00. However, there has been a substantial run-up in the price of diesel fuel during the past year. Reported increases in the range of 30 to 50% have been documented.

Figure 5 shows a typical cross-section of a double-track commuter rail line.

Figure 5 – Commuter Rail Typical Section



Commuter Rail – Representative Example

EMD F59PHI Diesel Locomotive

The EMD F59PHI diesel-electric locomotive is a common locomotive on passenger trains in North America. It is used to pull Amtrak's Pacific Surfliner, as well as Metrolink and Coaster commuter trains in Southern California, the Cascades trains in the Pacific Northwest, and it is used for commuter operations in Seattle (Sounder), Dallas-Fort Worth (Trinity Railway Express), North Carolina (Piedmont), Vancouver (West Coast Express), and Montréal (AMT).

Manufacturer	Electro-Motive Division
Maximum Speed	110 mph
Height	16'
Width	10'
Length	58'
Weight	268,000 lbs
Horsepower	3,000

This locomotive is equipped with a turbocharged 710E3 12 cylinder, 2-stroke water cooled "Vee" diesel engine (prime mover) that develops 3000 horsepower (2.2 MW) at maximum rpm. The main (traction) alternator converts mechanical energy from the prime mover into electrical energy that is distributed through a high voltage cabinet and rectifier to direct current traction motors on each axle.

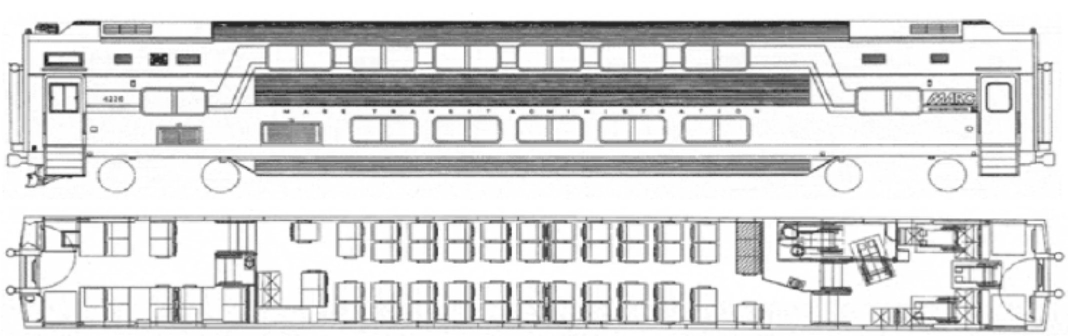
Commuter Rail – Representative Example

Bi-Level Commuter Rail Coach

The majority of commuter rail operators in the U.S. are moving to fleets of all bi-level coaches (except those with height restrictions) to allow commuter service to grow while controlling train length. Many of Chicago's commuter rail carriers, now consolidated under Metra, used and are still using the famous "Gallery" bi-level cars, with a single row of seats on the second level. The new bi-level cars built by Bombardier and Kawasaki are designed with nearly two full levels, greatly increasing capacity and comfort.

The majority of locomotive hauled commuter rail lines operate in push-pull mode, with some coaches built as "cab-cars," located at the end of the train, with duplicate controls in which the engineer/operator sits and controls the train with the engine pushing. This avoids the need to turn the train at each end of the line.

Manufacturer	Kawasaki
Maximum Speed	125 mph
Height	15'-6"
Width	10'
Length	85'
Weight	130,000 lbs (empty)
Passengers (seated)	135
Cars per Train	2-8



Regional Rail

Regional rail is similar to commuter rail but generally refers to longer distance service connecting cities within a region but not necessarily focused on moving commuters to the city center. This type of service is more evident in Europe where transit is more popular and a way of life. Some longer commuter rail routes in the U.S. approach the definition of regional rail, as do some shorter intercity routes. Amtrak operates several short routes across the country that can be characterized as regional routes rather than long distance or intercity routes.

An important issue when considering the use of DMU-type equipment is that the Federal Railroad Administration (FRA) enforces crashworthiness requirements for equipment operating on the standard railroad network, in conjunction with freight trains and/or conventional passenger trains. FRA-compliant DMUs are currently manufactured by Colorado Railcar, two of which (one single-deck car and one of a double-deck configuration) are being test on Florida's Tri-Rail. Other major rail equipment manufacturers including Siemens, Nippon Sharyo, Alstom, and Bombardier either currently have this equipment operating in Europe/Asia or have the capability to produce such vehicles.

A second variant of service and equipment uses completely separate and dedicated right-of-way which permits equipment not in FRA compliance. Examples of this service include the NJ Transit "River Line" between Trenton and Camden, and are being planned for the North [San Diego] County Transit District and elsewhere. Vehicles are similar to light rail vehicles.

Capital costs are likely to be in the same range as the projects listed in the previous section for conventional commuter rail. The New Jersey, North Carolina and San Diego projects all had estimated capital costs in the range of $16.5-$27 million/mile.

Operating cost data for regional or commuter rail operation using modern generation diesel multiple units in North America does not yet exist. Colorado Railcar has provided theoretical data, and reports that its DMU used about 39% less fuel than a conventional diesel-electric locomotive to haul two conventional double-decker railcars while in Tri-Rail demonstration service.

While the majority of regional routes in the U.S. may still be locomotive hauled, with either single or bi-level cars, U.S. railroads in the past and many current train sets in Europe use different propulsion and car configurations that incorporate the propulsion system into one or more of the passenger cars, eliminating the separate engine. These train sets are described as "multiple unit," usually with identical cars, most or all of which are powered.

Diesel Multiple Unit (DMU)

DMU and DEMU were once interchangeable terms but now refer to two specific propulsion types. Diesel Multiple Unit is now more appropriately used for those consists in which the prime mover (diesel engine) is mechanically connected to the drive axles through a transmission.

Diesel Electric Multiple Unit (DEMU)

This form of multiple unit incorporates a diesel engine driving a generator that produces electricity to power electrical traction motors on the drive axles. Several European companies manufacture DEMUs, but none are currently certified to meet FRA crashworthiness standards.

REGIONAL RAIL - DIESEL MULTIPLE UNIT

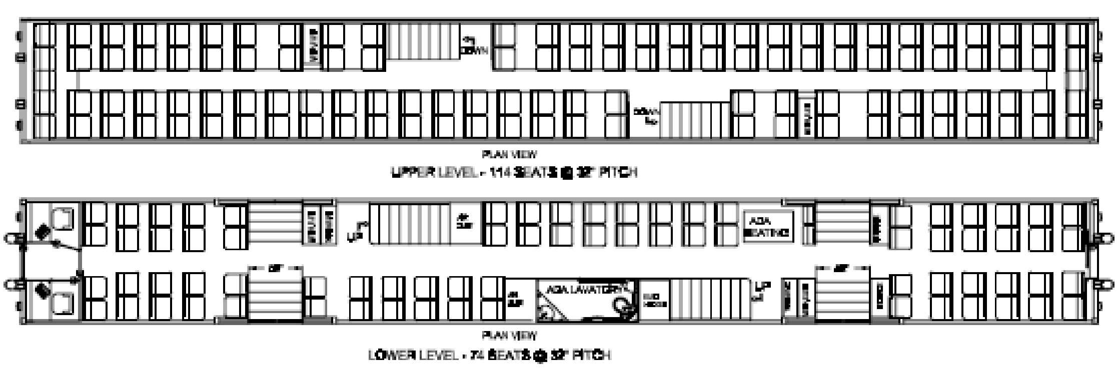
Colorado Railcar – Single and Double Level DMU

The only FRA compliant DMU, Colorado Railcar is a relatively new entry into the commuter and regional rail market. Different from many DMUs from abroad, the powered units from Colorado Railcar are direct drive, with a diesel engine driving a transmission connected to the axles rather than the engine driving a generator that drives traction motors on each axle. The DMU meets all current FRA 49 CFR Part 238, APTA and ADA requirements without waivers, claims greater fuel efficiency compared to locomotive-hauled trains, and can operate in train sets of powered and un-powered coaches. Several commuter rail agencies are testing the units, including Tri-Rail and Alaska Railroad.

Manufacturer	Colorado Railcar
Maximum Speed	90 mph
Height	14'-11"/19'-9"
Width	10'
Length	89'
Weight	171,000 lbs (empty)
Passengers (seated)	94/188
Cars per Train	2-5

94 Seat Single Level DMU

188 Seat Double Deck DMU



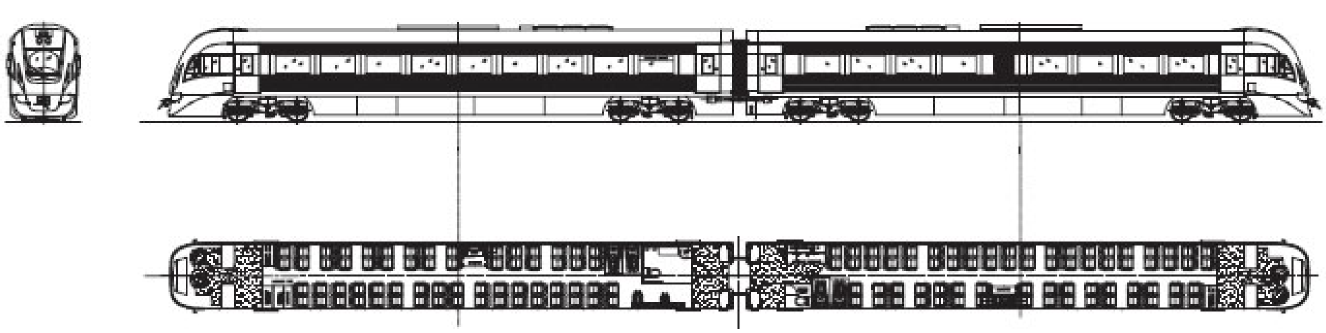
REGIONAL RAIL - DIESEL MULTIPLE UNIT

VLocity 160 Diesel Multiple Unit

Building on over 20 years' experience in Australian regional passenger transport, the VLocity 160 diesel multiple unit (DMU) provides a flexible vehicle solution through the use of technology that has been tried and tested in local conditions. Based on the service proven Xplorer / Endeavour DMUs designed and manufactured at Bombardier Transportation's Dandenong facility, the multiple unit set comprises two permanently coupled cars, with weatherproof inter-car connections, which can be readily coupled to form a train of up to eight cars.

Manufacturer	Bombardier
Maximum Speed	100 mph
Height	13'-6"
Width	9'-7"
Length	83'
Passengers (seated)	72 per car
Cars per Train	2-6
FRA Certified	No

The vehicles are designed to operate at a maximum speed of 100 mph. Proven components and systems ensure high reliability, coupled with diagnostic systems designed to minimize downtime during maintenance. Using a modular approach to both body and interior construction, everything from the propulsion systems through t o seating and luggage facilities have the flexibility to be economically tailored to meet the demands of individual routes. These factors combine to give a very high rate of availability and thus ensure a highly efficient train service.



REGIONAL RAIL - DIESEL ELECTRIC MULTIPLE UNIT

Talent Class 643.2

The Talent multiple unit offers diesel-electric, diesel-mechanical, diesel-hydraulic, or simply electric transmission, high- or low-floor entry and, where needed, tilting technology, independent of the transmission type and number of cars. No-step entry through big and wide doors, free visibility through large windows, and a great deal of freedom of movement in corridors and between seats-all these make regional trips an extremely pleasant experience for passengers. More than 260 Talent multiple units of various types are in use or on order today for train operators in Germany, Austria, Norway, and Canada.

Manufacturer	Bombardier
Maximum Speed	75 mph
Height	11′
Width	9′-7″
Length	113′/car
Passengers (seated)	47/car
Cars per Train	2-6
FRA Certified	No

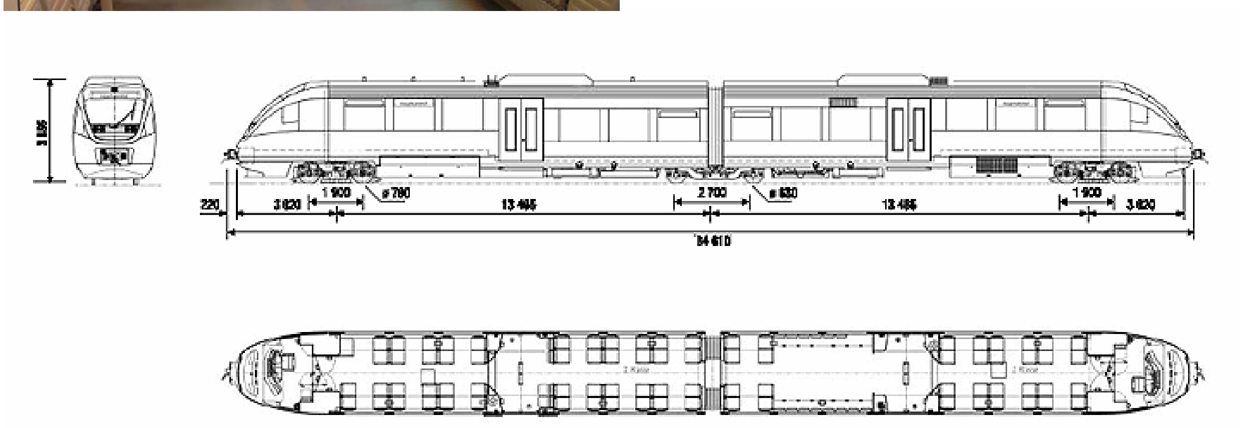


Table 5: MPO Transit Study: Summary of Mode/Technology Characteristics

Mode	Vehicle/ Consist Capacity	Service Configuration	Average Travel Speed	Typical Peak Period Headways	Average Station Spacing	Typical Infrastructure Unit Cost (excluding r/w)	Typical Vehicle Unit Cost (per vehicle)	Operating / Maintenance Costs*
Local Bus	50 / 70	Line service on city streets	10 - 15 mph	3 – 30 min	2 – 4 blocks	Runs on existing streets	$350,000 - $600,000 per vehicle	$5 - $9 per vehicle revenue mile
Bus Rapid Transit	75 / 150	Urban trunk line service on major routes	15 – 25 mph	3 – 10 min	¼ – 1 mile	$1M - $85M per mile Avg = $23M	$0.5M - $1M per vehicle	$3 - $10 per vehicle revenue mile
Commuter Bus	40	Radial Service to CBD on expressways	30 – 50 mph	30 – 60 min	Selected stops at each trip end	Runs on existing streets	$400,000 - $500,000 per vehicle	$8 - $9 per vehicle revenue mile
Light Rail Transit	100 - 200	Urban trunk line service on major routes	15 – 25 mph	5 – 10 min	¼ – 1 mile	$28M - $100M per mile avg=$42M	$2M - $4M per vehicle	$14 per vehicle revenue mile
Commuter Rail (Diesel Push-Pull)	200 / 1800	Radial service connecting suburbs to CBD	25 – 50 mph	20 – 40 min	2 – 5 miles	$15M - $35M per mile	$2M- $4M per Car and $4M - $6M per Locomotive	$11 - $12 per vehicle revenue mile
Commuter Rail (Electrified)	200 / 1800	Radial service connecting suburbs to CBD	25 – 50 mph	20 – 40 min	2 – 5 miles	$25M - $45M per mile	$2M - $4M per vehicle	$12 - $16 per vehicle revenue mile
Regional/Commuter Rail (DMU)	200 / 1800	Connecting suburbs to suburbs or suburbs to CBD	25 – 50 mph	20 – 40 min	5 – 20 miles	$15M - $35M per mile	$2M - $4M per vehicle	$7.00 per vehicle revenue mile

Source: National Transit Database, PB, and various transit agencies

** 2007 dollars*

Note: capital costs vary widely by the specific characteristics of each corridor and the amount of aerial structure and tunnel.