



**SOUTH FLORIDA EAST COAST (FEC)
ALTERNATIVES ANALYSIS**

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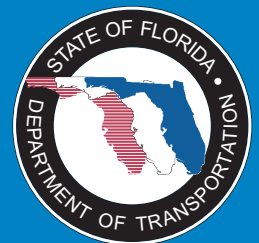
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Modal Technologies Tech Memo

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SOUTH FLORIDA EAST COAST CORRIDOR (SFECC) STUDY PROJECT MODAL TECHNOLOGIES TECHNICAL MEMORANDUM

TO: Scott Seeburger
FROM: Thomas Frawley
DATE: Tuesday 23NOV09; Revised 26JAN10
SUBJECT: Candidate Vehicle Technology Analysis
REFERENCE: Scope of Work Item 3.8.1.6

1.0 PURPOSE

This memo has been prepared to document the gathering of data regarding existing transit vehicles. This memo serves two purposes:

- To support public information workshops or open houses that were held during October 2009, for which vehicle data and images were provided, and;
- To support analyses to be performed subsequently and intended to define the Locally Preferred Alternative (LPA) for the SFECC project.

This memo has been prepared in fulfillment of the contract scope-of-work which calls for:

Consultant will investigate rolling stock options, performance characteristics and costs associated with the five modal technologies carried forward into Phase 2, including appropriate submodal options, as they may apply to fulfilling General Service Characteristics (GSC) requirements ... Investigations will be supported by detailed descriptions, illustrations ... and materials for each mode and submode. Evaluation and recommendations for modal technologies ... shall be summarized in a Modal Technologies Technical Memorandum.

Data gathered were organized into data sheets, each of which generally contains data for one particular vehicle model; these data sheets, along with photographs and manufacturers' literature, are provided in Appendix A to this memorandum.

2.0 OVERALL SUMMARY

This memo documents the characteristics of numerous individual vehicle types and models, and evaluates their applicability to the SFECC Project. Selected characteristics are evaluated in terms of relative advantages and disadvantages of individual vehicle types and models; specifically, operational compatibility with an FRA-regulated freight right-of-way, level boarding, capital cost, and energy reliability. Other considerations are also identified and categorized as relative advantages and disadvantages.

Several characteristics were not evaluated but only documented for use in subsequent analyses, including capacity, vehicle performance, proven design, and product availability.

One mode was identified as potentially not meriting further consideration:

- 7. (I.b.ii) Electric Multiple Unit (EMU) Type 2 – This mode offers no advantages relative to other similar modes, and has never been deployed in the U.S. (Note that Type 2 DMUs are not FRA-compliant.)

3.0 MODES, SUB-MODES AND TECHNOLOGIES

At the conclusion of Phase One of the South Florida East Coast Corridor Transit Study, five transit modes, as well as multiple sub modes, were identified for specific consideration during Phase Two, as shown in the hierarchy presented below:

- I. Regional Rail Transit (RGR)**
 - a. FRA Compliant RGR
 - i. Push-Pull Locomotive and Coaches (Single or Bi-level coaches and cab cars)
 - 1. Diesel Locomotive (DPP)
 - 2. Overhead Electric Locomotive (EPP)
 - 3. Dual Power Diesel-Electric Locomotive (DEPP)
 - ii. Self Propelled Multiple Units (Single or Bi-level vehicles)
 - 1. Diesel Multiple Unit (Type 1 DMU)
 - 2. Overhead Electric Multiple Unit (Type 1 EMU)
 - b. Non-FRA-Compliant RGR (Single or Bi-level vehicles)
 - i. Diesel Multiple Unit (Type 2 DMU)
 - ii. Overhead Electric Multiple Unit (Type 2 EMU)

- II. Light Rail Transit (LRT) (Single level vehicles)**
 - a. Diesel Multiple Unit (Type 3 DMU)
 - b. Overhead Electric Light Rail Vehicle

- III. Rail Rapid Transit (RRT) (Single level vehicles)**
 - a. Electrified Third Rail

- IV. Bus Rapid Transit (BRT) (Single level; non-articulated, and articulated vehicles)**
 - a. Clean Diesel
 - b. Hybrid
 - c. Alternate fuels

- V. Regional Bus Transit (RGB) (Single level; non-articulated coaches)**
 - a. Clean Diesel
 - b. Hybrid
 - c. Alternate fuels

The modes and sub-modes identified during Phase 1 included several vehicle technologies. For purposes of this analysis and memorandum, the five modes are broken down into a total of twelve vehicle technologies, as listed and numbered in the following section. For each mode and sub mode, a basic description and representative photographs of each vehicle type are provided. (Refer to Appendix A for complete data and additional photographs.)

1. (I.a.i.1) Regional Rail, FRA Compliant – (DPP) Push-Pull Diesel Locomotive and Coaches, Bi-level and/or single level

All of the Regional Rail (RGR), FRA-compliant sub-modes, including “Diesel Push-Pull”, are commonly known as “commuter rail”. In the United States, this sub mode is comprised of legacy systems that began operation with steam locomotives in and around older cities in the late nineteenth and early twentieth centuries, and new systems developed in the late Twentieth and early Twenty-First Centuries in metropolitan areas where there typically had never been commuter rail service.

The term “Push-Pull” refers to the operation of the train in either direction without switching the locomotive from one end to the other, so that the locomotive remains at the same end of the train, *pushing* or *pulling* the train as the direction of travel dictates. The last car on the opposite end of the train is equipped with an operator’s cab from which the locomotive, several cars away, can be controlled remotely when *pushing* the train. (This is in contrast to traditional operation, or “Pull-Pull” mode, in which the locomotive is changed from one end of the train to the other so that it is always *pulling* the train in normal revenue operation.) Push-Pull trains, regardless of the type of locomotive propelling them, have their greatest efficiency when train lengths are longer. This is because each additional car represents a substantial addition to the capacity of the train, but simultaneously represents only a relatively small incremental additional operating cost. Historically, push-pull trains are more cost effective at train lengths of more than two or three cars; MUs are generally more cost effective when train lengths are less than four cars.

Diesel locomotives are, in fact, diesel-electric locomotives. They use a diesel engine, coupled to an alternator, to develop electricity that powers traction motors on the locomotive’s axles to propel the locomotive and its train. Diesel locomotive exhaust emissions and noise emissions have declined in recent years, as designs have evolved to respond to applicable environmental regulations. Almost all diesel locomotives use No.2 diesel oil as fuel, but alternate fuels have been applied successfully by several operators, notably the South Florida Regional Transportation Authority



METRA MPI MP36PH

(SFRTA); during late 2008 and early 2009, SFRTA transitioned from a fuel mix that was 80% biodiesel and 20% No.2 diesel oil, to a 99% biodiesel mixture. This mixture meaningfully reduces most types of emissions with only a small penalty in reduced horsepower output.

FRA compliant coaches are available in both single and bi-level configurations, with both high-floor and low-floor level boarding designs, referring to approximately 48" and 18" above the top-of-rail, respectively. Examples of deployments in the United States include Tri-Rail (Florida), NJ Transit (NY Metro Area), SEPTA (Philadelphia), Metra (Chicago) and Metrolink (Los Angeles). Specific locomotives and coaches for which data was sought include:

Diesel Locomotives

- Motive Power Industries MP36PH
- Motive Power Industries MP40PH
- Alstom PL42AC
- General Electric *Genesis*

Coaches

- Bombardier *Comet IV* single-level
- Alstom *Comet V* single-level
- Bombardier "*Lozenge*" bi-level
- Bombardier *Comet VI* multi-level
- Kawasaki multi-level
- Rotem multi-level
- Nippon Sharyo gallery



Tri-Rail Bombardier Bi-Level



NJT Kawasaki Bi-Level Car

2. (I.a.i.2) Regional Rail, FRA Compliant – (EPP) Push-Pull Electric Locomotive and Coaches, Bi-level and/or single level

The Electric Push-Pull submode of Regional Rail is – like Diesel Push-Pull – considered commuter rail, and differs from Diesel Push-Pull only in its use of purely electric locomotives. An electric locomotive does not contain an internal combustion engine to generate electricity, but draws electricity from overhead wires.

(In the past, some passenger rail locomotives in the United States drew energy from an adjacent third rail, but all modern electric passenger locomotives in now operation in the United States utilize overhead wires.) Electric locomotives can typically outperform their comparably-sized diesel counterparts because an electric locomotive can draw additional energy from the overhead wire on a short-term basis to get a heavy train moving from a standing start, or to accelerate quickly to high speed; in contrast, a diesel locomotive is limited by the energy its on-board, diesel power plant can generate. However, electric locomotives bear the disadvantage, relative to their diesel counterparts, of reliance upon extremely expensive electrification infrastructure, the cost of which is typically not offset by any locomotive operating cost advantage.



NJT Bombardier ALP46 Loco

Examples of deployments of the Electric Push-Pull submode in the United States are located on Amtrak’s electrified northeast corridor, and include NJ Transit (NY Metro Area), MARC (Washington DC) and SEPTA (Philadelphia). Coaches that are part of this submode are the same as those included in the Diesel Push-Pull submode; locomotives for which data was gathered in this analysis are limited to those currently in commuter rail operation and/or currently in production.

Electric Locomotives

- Bombardier ALP46A
- Bombardier HHP8

Coaches – Same as in 1 (I.a.i.1)

3. (I.a.i.3) Regional Rail, FRA Compliant – (DEPP) Push-Pull Diesel Electric Dual-Mode Locomotive and Coaches, Bi-level and/or single level

This Regional Rail submode is similar to both the Diesel Push-Pull and Electric Push-Pull submodes, utilizing the same range of coach vehicles with a locomotive that carries both a diesel power plant and the necessary apparatus to operate using only electric energy supplied from an overhead wire or adjacent third rail. Diesel electric dual-mode passenger

locomotives were developed to provide uninterrupted operation between the underground platforms at Grand Central Terminal in New York, and outlying commuter rail destinations located beyond the limits of the electrification infrastructure. As a result of this historical circumstance, current deployments in the United States are located in the New York metropolitan area on the Metro North Commuter Railroad and Long Island Rail Road. In addition to these legacy applications, Bombardier is currently assembling an order of new dual mode locomotives, based on its ALP46A electric locomotive design, which will operate under the Hudson River between Penn Station in New York and non-electrified lines in suburban New Jersey. Dual-mode locomotives included in this analysis consist of those of modern construction and currently in operation, and those currently in production.

- Bombardier Dual Mode (NJ Transit)
- General Electric *Genesis* (Metro North)

This sub mode was originally included in the SFEC study to address proposed crossings of the New River in Fort Lauderdale, which included a variety of tunnel and bridge configurations. In the case of a tunnel under the New River, a dual mode locomotive was envisioned to operate through the tunnel segment using electric energy to avoid the production of diesel exhaust emissions. In the case of a tunnel under, or a bridge over, the New River, such a locomotive could draw additional electric energy to climb steeper grades than those which a conventional diesel locomotive could negotiate, and thereby allow the design of shorter, steeper approaches to the tunnel or bridge.



MNCRR GE P32DM Loco

4. (I.a.ii.1) Regional Rail, FRA Compliant – (DMU Type 1) Diesel Multiple Unit, Bi-level and/or single level

This vehicle type was popular in the late 1940s through early 1960s in the form of the Rail Diesel Car or RDC built by the Budd Company. A later incarnation was developed by Colorado Railcar, with examples being delivered to Tri-Rail (Florida) and Tri-Met (Portland, Oregon). Since the bankruptcy of Colorado Railcar, their assets have been acquired by U.S. Railcar, and their DMU vehicle is still being offered. Because this vehicle is the only Type 1 DMU manufactured after the Budd Company ceased production of its Rail Diesel Car in the early 1960s, it is the only vehicle included in the Type 1 DMU category.

- U.S. Railcar Bi-Level DMU
- U.S. Railcar Single-Level DMU

Manufacturers such as Bombardier, Siemens and Nippon-Sharyo have previously indicated their willingness to manufacture DMU versions of the existing EMU products, or FRA compliant versions of their non-compliant DMU models, if a sufficiently large order were to be placed.

In addition, Rotem won a bid to manufacture new FRA compliant DMUs for Triangle Transit in Raleigh, North Carolina, but this procurement was cancelled. (NJ Transit has considered picking up this order for deployment on the Bergen-Passaic Commuter Rail Project, currently in design.) Because this analysis is limited to existing transit vehicle products, none of these prospective products are included in this analysis.



Tri-Rail CRC Bi-Level Type 1 DMU



Tri-Met CRC Single-Level Type 1 DMU

5. (I.a.ii.2) Regional Rail, FRA Compliant – (EMU Type 1) Electric Multiple Unit, Bi-level and/or single level

This category traces its origins to the electrification of suburban passenger services in the early Twentieth Century in the northeast United States and the Chicago region. Vehicles in this category are essentially FRA-compliant coaches, to which propulsion equipment similar to that in an electric locomotive has been applied. Vehicles of this type have been built to utilize overhead wires as in most examples, third rail electrification as in the case of the Long Island Rail Road and the Metro North Hudson Line, and both overhead wires and third rail as in the case of the Metro North New Haven Line. FRA-compliant EMUs have been built in single-level, bi-level, and gallery arrangements.

FRA-compliant EMUs are used by multiple agencies located along Amtrak’s electrified Northeast Corridor and in the Chicago metropolitan area, by agencies such as NJ Transit (NY Metro Area), Metro North Railroad (NY Metro Area), SEPTA (Philadelphia), Metra (Chicago) and South Shore Line / NICTD (Chicago). The following Type 1 EMUs are included in this analysis:

- Rotem Silverliner V (SEPTA – overhead wire)
- Nippon Sharyo Gallery Car EMU (Metra, NICTD – overhead wire)
- Kawasaki M-8 (MNCRR, ConnDOT – overhead wire and third rail)
- Bombardier M-7 (LIRR – third rail)



NICTD Nippon Sharyo Gallery Type 1 EMU



SEPTA Rotem Type 1 EMU

6. (I.b.i) Regional Rail, Non-FRA Compliant – (DMU Type 2) Diesel Multiple Unit, Bi-level and/or single level

Type 2 DMUs are used by railways overseas in regional and commuter rail applications. These designs are not FRA-compliant, so if used for the SFECC project would require separation – presumably physical rather than temporal – from the Florida East Coast Railway’s freight operations. Type 2 DMUs are available in high and low floor, as well as



Deutsche Bahn Siemens VT644 Type 2 DMU

single and bi-level configurations. Data has been assembled for single-level vehicles of both high and low floor designs. Three of the identified vehicle types have been deployed in North America – two in the United States and one in Canada.

- Siemens Desiro VT642 (NCTD)
- Bombardier Talent (O-Train)
- Stadler GTW (Cap metro, Austin)
- Bombardier AGC
- Bombardier Turbostar
- Bombardier VLocity 160 (Formerly Xplorer and Endeavour)



QR Bombardier VLocity 160 Type 2 DMU

7. (I.b.ii) Regional Rail, Non-FRA Compliant – (EMU Type 2) Electric Multiple Unit, Bi-level and/or single level



NS Bombardier Bi-Level Type 2 EMU



SNCF Bombardier AGC Type 2 EMU

Type 2 EMUs are used by railways overseas on electrified regional and commuter rail lines. Because these designs are not FRA compliant, they could not share track with the Florida East Coast Railway's freight operations. Type 2 EMUs have been built in high and low floor, as well as single and bi-level configurations. No vehicles of this type have been deployed in North America; applications that might be candidates for a Type 2 EMU have to-date been addressed using LRT or Type 2 or 3 DMU technology. Data has been assembled for only one product in this category.

- Bombardier AGC Hybrid single-level

8. (II.b) Light Rail Transit (LRT) – Electric

The term electric Light Rail Transit (LRT) is essentially a new name for an old concept – the trolley car. Invented in the last years of the Nineteenth Century, trolley car systems flourished throughout the United States until automobiles became widely used. The shift to the automobile, particularly after World War 2, accelerated the decline of trolleys – or light rail – that



had begun during the Great Depression, reaching the

Houston Metro Siemens S70 LRV

its nadir in

the 1960s with operations surviving in only a

few major metropolitan areas. In the 1970s, light rail experienced a renaissance in North America, with dozens of new systems beginning operation since then.

Light rail systems can operate in dedicated rights-of-way or in mixed traffic in city streets. Light rail vehicles are available in a range of floor heights, from high floor versions that require an elevated platform, to low floor and ultra low floor designs that permit level boarding at curb height. Data has been assembled for most models that have been deployed in North America and would be expected to be available for order.

- Siemens S70 (Houston, Portland, San Diego, Charlotte)
- Siemens SD160 (Calgary, Denver, San Diego, Valencia Venezuela)
- Bombardier Flexity LRV (Minneapolis)
- Kinki Sharyo LRV (Seattle, Phoenix, Dallas)

9. (II.a) Light Rail Transit (LRT) – Diesel (or DMU Type 3)

Diesel LRT vehicles, otherwise known as Type 3 DMUs, are – like Type 2 DMUs – not FRA-compliant. But Type 3 DMUs differ from Type 2 DMUs in their ability to negotiate smaller radius curves than Type 2 vehicles. Although not able to make turns as tight as those readily traversed by electric light rail vehicles, Type 3 DMUs can operate in city streets and negotiate



NJT Stadler GTW Type 3 DMU

turns at some street intersections, earning the name Diesel Light Rail Transit (DLRT) for this vehicle category. The ability to make tight turns is primarily a function of electric propulsion, as opposed to diesel-hydraulic or diesel-mechanical, as well as vehicle length. The Stadler GTW (an acronym in German for articulated vehicle) version operating on NJ Transit’s RiverLINE is the only Type 3 DMU that has been deployed in the United States. Versions of the GTW with longer passenger compartment sections – such as those delivered to Capital Metro in Austin, TX and those ordered by Denton County Texas – have larger minimum turning radii and are considered Type 2 DMUs rather than Type 3. Consequently, data gathering in the Type 3 category is limited to a single vehicle model.

- Stadler GTW (NJ Transit version)

10. (III.a) Rail Rapid Transit (RRT) – Electric

Rail rapid transit refers to urban metro systems, or when they’re underground, “subways”. Such systems are completely grade separated, and electrified using a third rail, although some systems do use overhead wires. Vehicles typically have two or more doors per side, and often have longitudinal seating to maximize capacity for standees. RRT vehicles have high-floor designs and station platforms are built at the same height to permit level boarding and egress of passengers. Some RRT systems are, or are approaching, a century of operation, such as those in New York, Boston and Philadelphia. Most are, however, much newer and smaller, having been built in the last quarter of the Twentieth Century. The Miami Metrorail is among these new-generation RRT systems.



MDT Budd RRT Car

Representative vehicles recently deployed in New York and Boston have been included in the data gathered for this vehicle category.

- Bombardier R142 (NYCT)
- Kawasaki R68A and R143 (NYCT)
- Siemens (MBTA, Tren Urbano - San Juan PR)

Although relatively high in capital cost because of its exclusive grade separate right-of-way, RRT offers a potential operating cost advantage over other modes, in that the technology utilizes off-vehicle automated fare collection enabling one-person train operation, and is designed to be adaptable to driverless operation. Driverless operation uncouples operating frequency from labor

cost, enabling more, shorter trains to be operated at relatively little incremental cost – while stimulating increased ridership by increasing schedule frequency.

11. (IV.a., b., and c.) (BRT) Bus Rapid Transit – including clean diesel, hybrid and alternate fuels, and non-articulated, single-articulated, and double-articulated variations.

Transit buses useable in BRT service are available in rigid frame and articulated configurations. BRT buses typically have multiple doors per side; seating may be 2-2 or longitudinal or a combination of both. Propulsion technologies include conventional clean diesel, diesel electric hybrid, and alternate fuels



Los Angeles MTA NABI BRT65

engines. Although some engine modifications are included as well, “clean diesel” refers primarily to the diesel fuel itself, and in particular to its sulfur content, which has been reduced dramatically in recent years in response to new environmental regulations. As a result, clean diesel is essentially the baseline for all transit bus engines.

Notably, BRT refers more to the infrastructure configuration than to the type of bus operated, as is evidenced by busways that have been in operation in the United States for years, such as the El Monte busway in Los Angeles and the MLK Jr. busway in Pittsburgh. BRT infrastructure typically includes substantial segments of grade separated, dedicated bus-only right-of-way and “bus stops” that are very similar to rail transit stations.



Los Angeles MTA NABI 45C

Data has been gathered for an articulated bus, developed specifically for BRT operations, and a rigid frame transit bus.

- North American Bus Industries BRT (40, 42, 60 and 65 foot lengths)
- North American Bus Industries Metro 45C

12. (V.a., b., and c.) (RGB) Regional Bus (special situation; West Palm Beach-Jupiter only) – including clean diesel, hybrid and alternate fuels, non-articulated over-the-road motor coaches

This category of vehicle is exemplified by buses operated in intercity and express commuter services, and is usually referred to as an “over-the-road-coach”. These buses have high floors, comfortable seats, and are not intended to carry standees. Boarding and egress is via a single door at the front, right-hand side of the bus; ADA access is achieved through an on-board lift, typically mid-way along the length of the bus.

The baseline fuel for these buses is clean diesel. Some buses of this type are offered as hybrid models; similarly, some are adaptable to using alternate fuels such as biodiesel, subject to specific engine designs and the warranty policies of individual engine manufacturers. (“Hybrid” in this context refers to application of an electric motor and batteries to a bus transmission or transaxle to provide electric propulsion at low speeds and thereby reduce fuel consumption.) Due to issues of fuel capacity, operating range, and support infrastructure needs, buses of this type have not been popular candidates for CNG or LNG alternate fuels conversions. Data have been gathered for clean diesel and diesel electric hybrid designs, from multiple suppliers in the U.S. market.

- MCI D4000CT
- MCI D4500CT
- MCI D4500CT Hybrid
- Prevost X3-45
- Setra S417
- Van Hool C2054E



Van Hool C2054E and 833A

The list of vehicles of a given type for which data has been presented is not intended to be exhaustive of all potential products in that category, nor comprehensive with regard to the information provided. Data presented is believed accurate at the time assembled, but is subject to change.

4.0 KEY CHARACTERISTICS

Certain characteristics of the investigated vehicle types are particularly relevant to whether or not they may be able to meet the needs of the SFECC project. These characteristics include:

- Compatibility with FRA-Regulated Freight Railroad Environment
- Level Boarding
- Capital Cost
- Energy Reliability
- Capacity
- Vehicle Performance
- Technologically Proven Design
- Limited Technology / Product Availability
- Other Considerations

Each of these characteristics is discussed individually in terms of whether it applies favorably or unfavorably to a given vehicle technology, or whether it is neutral across the range of technologies.

4.1 Compatibility with FRA-Regulated Freight Railroad Environment – Because the SFECC project is located primarily within the right-of-way of an FRA-regulated freight railroad, the degree of compatibility with the FRA regulatory environment is an important factor, affecting the potential suitability of a given mode or sub mode. The potential to share track is an obvious and important aspect of using FRA-compliant vehicles. However, this is not to suggest that non-FRA-regulated modes are incompatible with the use of the railroad right-of-way (as opposed to the track); only that they require different infrastructure configurations which in-turn have different costs and operating considerations associated with them. For the purposes of this memo, the candidate modes and sub modes can be considered in three groups:

- FRA-compliant modes
- Non-FRA-compliant rail modes
- Non-rail modes

FRA-compliant modes – are, at the risk of stating the obvious, most compatible with the FRA-regulated freight railroad environment. These modes can share track with freight trains, maximizing track capacity and operational flexibility in terms of enabling trains to pass and overtake as is necessary to support combined express and local schedules. Even if operated on tracks completely segregated from the freight operation, FRA-compliant modes can be located closer to the freight tracks than non-FRA modes.

Non-FRA-compliant rail modes – are able to operate in a shared right-of-way with freight trains, but require greater separation between freight and passenger tracks. Such shared right-of-way configurations have precedents in the U.S. and no insurmountable operational issues are anticipated, including with regard to the design of grade crossing protection apparatus.

Non-rail modes – can, like non-FRA-compliant rail modes, operate in a shared right-of-way with freight trains, but they also require greater separation between the freight tracks and the passenger alignment. Such shared right-of-way configurations have been successfully implemented in the U.S., such as for the El Monte Busway in California, by separating the freight tracks from the passenger bus guideway with highway barriers, and grade separating both the freight tracks and bus guideway from intersecting roadways.

In light of these considerations, and in terms of the FRA compatibility characteristic, there is a substantive advantage associated with FRA-compliant modes, and a lesser advantage associated with non-FRA-compliant rail modes, relative to non-rail modes.

4.2 Level Boarding – Level boarding refers to designs in which the vehicle floor and station platforms are at the same, or essentially the same, level. Level boarding is required by the Americans with Disabilities Act (ADA), and also provides faster passenger boarding and egress times than designs that require passengers to climb steps on the vehicles or the platforms.

Level boarding is achieved by making the vehicle floor height and the passenger station platform height above the top of the running rail approximately the same. The term “approximately” applies because rail vehicle floor height changes as a function of wheel wear, and to a lesser extent as a function of suspension deflection under load to the degree not offset by active suspension leveling systems. To a smaller extent, the platform height above the rail changes over time as well, increasing as a function of rail wear. Bus designs can more readily adapt to variety in curb height, with programmable air suspension systems that can lower the bus entrance to make it “kneel” to near-level boarding height.

The definition of level boarding height varies as well. For buses, it refers to the curb height, which can vary significantly. For rail vehicles, it refers to the vehicle floor height, which is generally 51” above the top-of-rail for high-floor FRA-compliant modes, 25” for low-floor FRA-compliant modes, 40”–45” for RRT, or 20” above the top-of-rail for low floor LRT.

Level boarding also involves the size of the gap between the vehicle door threshold and the platform edge, a dimension regulated under the ADA. For non-FRA compliant modes, this is only an issue of design integration and design tolerance management; for FRA-compliant modes, there is the issue of passenger platforms necessarily being closer to the vehicle door threshold than Association of American Railroads (AAR) standard clearances would permit. This has been proposed to be addressed for the SFECC project with wider vehicles and/or extended door thresholds; however, these solutions raise potential safety issues related to an increased gap between the platform and the vehicle side, as well as larger openings between cars.

Overall, for any mode – including FRA-regulated vehicle designs – that would be operated in an environment segregated from freight traffic, level boarding is, as mentioned previously, only a matter of design integration and design tolerance management. For FRA-compliant designs operating in an FRA regulated environment of mixed passenger and freight traffic, there would be additional design complexities and challenges associated with simultaneously meeting ADA dimensional requirements and AAR clearances without the use of bridge plates or other supplemental apparatus. Consequently, level

boarding as a key characteristic slightly favors any mode – including FRA-compliant designs – that operate in a non-FRA regulated environment.

4.3 Capital Cost – The capital cost for a mode is the product of the unit cost per vehicle and the number of vehicles required for revenue service, plus operating spares that would be available to replace vehicles that fail in service, and maintenance spares that are assumed to be in the shop for programmed maintenance and occasionally for unscheduled maintenance. The number of vehicles needed varies significantly for different modes or vehicle types, and will be evaluated during the analyses to define the Locally Preferred Alternative (LPA).

The unit capital cost of a transit vehicle is driven by more than the fundamental cost of the manufacturing materials and process. Capital costs for vehicles are significantly affected by competitive factors, such as anticipated volume of orders in the market and individual manufacturers' backlogs at the time of the order. Unit capital costs may be estimated using a combination of historical data and a subjective evaluation of market conditions. For purposes of this analysis, individual vehicle unit capital costs have not been forecasted. However, for purposes of this memo, a significant capital cost disadvantage has been cited for electrically powered vehicles because they require capital investment in electrification infrastructure – a substantial expenditure that is not required for internal combustion powered vehicles.

4.4 Energy Reliability – Different rolling stock technologies have different energy reliability strengths and vulnerabilities. In the context of the FEC study corridor there are two primary types of vehicles (based on propulsion): electric and diesel powered. Electric vehicles would be on a regional grid powered by electricity produced primarily from the Florida Power and Light Company (FPL). FPL has various types of energy generating facilities in the region ranging from nuclear, liquid and vapor-phase natural gas, oil, and solar. Having multiple power generating facilities increases the robustness of the regional grid and provides redundancies in the case that any of the other facilities go offline or there are disruptions in the fuel supply. However, electrical vehicles could be vulnerable to electric energy supply disruption as a result of natural disasters, a hurricane striking Florida for example, human caused error, or terrorist attack. In such a circumstance, the envisioned disruption would be to the energy supply from the electric utility, rather than a matter of physical damage to the railway electrification infrastructure.

Vehicles that burn diesel fuel are vulnerable to the same interruptions in petroleum supply that affect all hydrocarbon burning vehicles. These disruptions to the global petroleum supply can be the result of geopolitical circumstances like civil conflict, war, trade sanctions, embargos, criminal activity (piracy), and natural disasters. Such disruptions would not totally eliminate the availability of diesel fuel but they could cause the value of the fuel to increase so greatly, in a dollar sense, that the economical operation of the system can be threatened or reduced. The value of fuel can also play a significant role over a longer time frame, considering a 50 year operational life of the technology, as global demand for hydrocarbon fuels increase while the available supply begins to plateau and is expected to eventually decrease. Regional and national fluctuations in the availability of diesel fuel pose a lesser threat since

regional distribution systems are highly effective and redistributing fuels supplies to areas of greater demand.

Diesel burning vehicles are also at an advantage since they can store and carry a fuel supply on-board whereas electric vehicle require a constant stream of electrical power to operate. This is advantageous when operating in conditions where the regional electric grid is affected yet regular operations may still be required to move passengers and goods, as during post disaster operations for example.

Analysis of means by which to mitigate potential disruptions in electric energy supply or petroleum supply are beyond the scope of the FEC corridor study. Consequently, the issue of energy vulnerability is considered a neutral characteristic for all modes. It is noteworthy that electric vehicle technologies are at a substantial cost disadvantage relative to internal combustion modes, and they are scored accordingly with regard to that characteristic.

4.5 Capacity – Capacity is a function of several factors that are related to the design of the vehicle and how it is operated. The design-side of capacity is primarily “static capacity”, which can refer to how many persons can be carried on board, both seated and standing, but which – for this analysis – refers to the number of seated passengers that can be carried. Alternatively, the overall number of passengers that can be carried by the transit system is “dynamic capacity” or “line capacity”, and – in addition to vehicle seating capacity – is driven by how closely trains can operate to each other (i.e., headway), and at what speeds. Analysis of line capacity will be accomplished during the process of determining the LPA using various simulation tools. This memo documents the static capacities of the candidate vehicle types for consideration in that later analysis. Accordingly, for purposes of this memo, the characteristic of capacity is neutral for all modes and submodes.

Vehicles can be configured in a variety of seating arrangements. This directly affects the numbers of potential seated and standee passengers that could be carried. Standees can range to as many as three and four times the number of seated passengers, depending on the type of vehicle and the seating configuration. Ranges of representative seated and standee capacity values have been identified for each vehicle type based on the majority of vehicles of each type currently in operation. It is also noteworthy that the number of standees is as much a function of established service standards as of available floor space. For example, commuter rail or regional rail services – which have generally longer trip lengths – typically combine train lengths and schedule frequencies that provide essentially all passengers with a seat; in contrast, bus, light rail, and rail rapid transit services – which have generally shorter trip lengths – are assumed to include standees as a significant portion of the passengers carried. The total per-vehicle capacity figures shown are the mid-point values for the range of combined seated and standee passengers.

TYPE OR TECHNOLOGY	SEATS	STANDEES	TOTAL
1 – Diesel Locomotive Commuter Rail	109 - 162	0 - 80	Approx 135
2 – Electric Locomotive Commuter Rail	109 - 162	0 - 80	Approx 135
3 – Dual Mode Locomotive Commuter Rail	109 - 162	0 -80	Approx 135
4 – DMU (Type 1; FRA compliant)	92 - 188	0 - 80	Approx 140
5 – EMU (Type 1; FRA compliant)	96 - 111	0 - 80	Approx 130

6 – DMU (Type 2; non FRA compliant)	70 - 136	90	Approx 193
7 – EMU (Type 2; non FRA compliant)	60-69	66	Approx 131
8 – LRT (Electric Light Rail)	60-72	120-144	Approx 198
9 – DLRT (Diesel Light Rail; DMU Type 3)	70	94	Approx 164
10 – RRT (Rail Rapid Transit)	42-44	240	Approx 283
11 – BRT (Bus Rapid Transit)	47 - 71	Approx 50*	Approx 109
12 – RGB (Regional Bus)	56 - 57	0 -20	Approx 57

The nature of the FEC alignment, with the possibility – especially on local services – of many closely spaced stations, may invite some blending of traditional seated and standee design standards, as the alternative ultimately selected might include an FRA-compliant vehicle, much like commuter rail vehicles in appearance, but operated like a light rail vehicle. The anticipated passenger volume, combined with numerous potentially closely spaced stations, will also affect the relative advantage and disadvantage of different vehicle designs based on their door and vestibule sizes and configurations and the associated effect on boarding and egress rates, and on their ability to minimize travel times between closely-spaced stations, requiring the highest allowable – in terms of passenger comfort – rates of acceleration and braking.

4.6 Vehicle Performance – A transit vehicle’s ability to quickly accelerate, attain and maintain its maximum operating speed, and then quickly decelerate, significantly affects the capacity of a transit system in which the vehicle operates. For many vehicle types, the vehicle’s acceleration and braking capability exceeds the limits of passenger perceptions of comfort, making such capability largely superfluous. Similarly, vehicles in several modes are capable of maximum speeds that would never be attained in a transit environment. However, to the extent that vehicle capabilities fall within the relevant range for passenger safety and comfort, they can be a differentiator among individual vehicle models and modes.

For purposes of this memorandum, the characteristic of vehicle performance is assumed to be neutral across all modes. Many vehicles exceed the “comfortable range” for acceleration and braking (given that some passengers may be standing), and station spacing limits the distance a vehicle can travel at its maximum velocity. A separate work task, Task 3.3.9 Railway Operations Simulation and Analysis, will provide a travel time simulation taking into account various vehicles.

4.7 Technologically Proven Design – Few modern transit vehicles are truly “off the shelf” designs. The deployments of the Siemens U2 Light Rail Vehicle (LRV) in Edmonton, Alberta in 1978 and in Calgary and San Diego in 1981 is perhaps the closest example to “off the shelf”, differing in little more than paint and signage from their original application in Frankfurt, Germany. That being said, the degree of originality of design can vary widely for transit vehicles – from the “evolutionary” substitution of improved individual components, to the “revolutionary” development of a completely new design. Although completely new designs are sometimes necessary and/or desirable, the reliability and lower cost typically associated with “proven designs” generally outweigh any potential advantages of a completely new design. The concept of “proven design” is not limited, however, to an entire vehicle. A new superstructure combined with components that have been used reliably on previous vehicle designs

may constitute a “proven” design, and its reliability evaluated by analysis of individual components rather than the integrated vehicle. It is also noteworthy that use of common, proven designs generally enhances availability and reduces cost of replacement parts.

All of the modes and vehicle types identified in this memo include vehicles that would be considered proven designs if proposed for operation on the SFECC project. Further, depending on the mode ultimately selected, some vehicle manufacturers may propose variations on, or adaptations of, an existing design to meet the identified SFECC requirements. For example, an adaptation of an existing EMU design as a DMU might be a manufacturer’s best approach to providing a fleet of DMUs. If this were the case, individual components could be demonstrated to be proven, and a rigorous systems integration process could minimize risk associated with the new overall vehicle package.

For purposes of this memo, all identified individual vehicles are considered proven, and therefore the issue of a design being “proven” is a neutral consideration among those vehicles.

4.8 Limited Technology / Product Availability – Three of the types of vehicles or technologies surveyed have only limited current availability in the North American marketplace, appearing to be actively offered by only one supplier:

- Diesel-Electric Dual-Mode Locomotives – Study Vehicle Category 3 (DEPP) Regional Rail (Commuter Rail): Diesel-electric, dual-mode locomotives are currently in operation on Amtrak, the Long Island Rail Road (LIRR), and the Metro North Commuter Railroad (MNCRR) in the New York metropolitan area to enable operation underground to and from Penn Station (Amtrak and LIRR) and Grand Central Terminal (MNCRR). These locomotives combine operation as a conventional diesel-electric locomotive, with the ability to operate as an electric locomotive by drawing power from a DC electrified third rail. Dual-mode locomotives that utilize AC power from an overhead wire are on order for New Jersey Transit, but none have been delivered to-date.

Dual-mode locomotives typically exhibit lower reliability than conventional diesel-electric locomotives. The dual-mode locomotives operated by the LIRR were built by Super Steel and Electro Motive in 1995 have achieved MDBF measures between approximately 12,000 and 19,000 during the years 2003-2006. The dual-mode locomotives operated by Amtrak and MNCRR were built by General Electric in 1991 and on MNCRR have achieved MDBF of approximately 27,000 in 2007, with individual measures as high as 35,000. The new dual-mode locomotive being built by Bombardier for New Jersey Transit is based on the “proven” ALP-46 and ALP-46A electric locomotive designs, but its actual reliability remains to be demonstrated.

- FRA-Compliant Diesel Multiple Unit (DMU) – Study Vehicle Category 4 (DMU Type 1) Regional Rail (Commuter Rail): DMUs are passenger vehicles that carry their own diesel power plants on board, so they can propel themselves and do not need to be pulled by a locomotive. They can be built as single-level or bi-level cars. Colorado Railcar (CRC) has

been, in recent years, the leading proponent and supplier of the FRA-compliant DMU. DMUs built by CRC are currently operated in South Florida by Tri-Rail. CRC has recently gone out of business, but its assets have been acquired by U.S. Railcar, which has indicated that it will continue to supply vehicles of this type in the future. Rotem, a South Korean firm whose US operations are based in Philadelphia, had been selected to build an order (26 units) of FRA-compliant DMUs for Triangle Transit in North Carolina, but the order was subsequently cancelled; NJ Transit has considered picking up this order for deployment on the Bergen-Passaic Commuter Rail Project. Rotem is anticipated to be willing to respond to an invitation to bid on the production of a DMU fleet. Siemens has developed an FRA-compliant DMU design and would similarly be expected to bid on future DMU orders. Additionally, other suppliers – notably Bombardier, Nippon Sharyo and Kinki Sharyo – have expressed their willingness to build derivatives of their existing Electric Multiple Unit (EMU) products as DMUs, if the order quantity were sufficient – informally suggested to mean in excess of one hundred vehicles.

- Diesel Light Rail Vehicles – Study Vehicle category 9 (DLRT or DMU Type 3): Diesel light rail vehicles or Type 3 DMUs are self-powered diesel vehicles that can operate around small radius curves, enabling them to run in city streets like an electric light rail vehicle or trolley car – a capability not required for any of the SFECC study alternatives being considered. The NJ Transit RiverLINE service uses vehicles of this type, built by Stadler in Switzerland and designated model GTW. Capital Metro in Austin Texas recently began operation and also uses GTW vehicles, but their version is larger than those on NJ Transit, making them less able to negotiate small curves and consequently less suitable for in-street operation. In addition to Stadler, other manufacturers – notably Kinki Sharyo – have previously proposed to modify their electric LRV products to include a diesel propulsion system. Stadler would likely be receptive to an invitation to build any size order; Kinki Sharyo would presumably require a substantial order quantity in order to have sufficient economic incentive to manufacture such a vehicle.

The limited presence of a particular vehicle type or technology in the marketplace at present is not a sound basis for excluding a vehicle type or technology from further consideration. The willingness of manufacturers to build a particular type of vehicle is primarily a function of the economics of the order size. Given that the SFECC fleet size has the potential to be substantial – in excess of one hundred vehicles under many of the alternatives being considered – it is reasonable to expect that multiple suppliers would respond to an invitation to bid on the manufacture of a fleet of SFECC vehicles, regardless of the type or technology ultimately selected. Accordingly, and for purposes of this memo, this characteristic is considered to be neutral across all vehicle modes.

4.9 “Green” Design Considerations – All modes of transit are considered environmentally friendly in comparison to the predominant transportation mode of single-occupancy automobiles. Further, virtually all types of transit vehicles are continuing to evolve to be more environmentally friendly through various improvements in design and technology that increase operating efficiency.

Environmental considerations may be applied in varying degrees to different technologies and to different individual vehicle types. This topic is addressed in greater depth in the Phase 2 study corridor environmental report, the Detailed Environmental Screening Report (ESR). The following bullet points summarize significant considerations:

- Higher Capacity Vehicles – The move from single-level to bi-level rail cars has significantly increased passenger capacity per car and per train. Similarly, articulated buses have significantly greater passenger capacity per bus than their non-articulated predecessors. These higher-capacity vehicles provide this additional capacity while consuming a less than proportionate amount of additional fuel. Consequently, employing vehicle types with greater individual capacity results in generally lower environmental impacts per passenger.
- Reduced Exhaust Emissions – Exhaust emissions from internal-combustion-powered transit vehicles has been reduced dramatically in recent years in response to increasingly more stringent environmental regulations. Cleaner fuels, for example Ultra Low Sulfur Diesel (ULSD) and biodiesel, have cut exhaust emissions. Exhaust traps have lowered particulate emissions while various intake air treatments, exhaust recirculation, and catalyst systems have reduced emissions of all major air pollutant categories. Some of these improvements will benefit the SFECC project regardless of individual vehicle types ultimately deployed, because such improvements will have become standard due to regulatory requirements. Others will be enhancements above and beyond required levels of performance and will be associated with specific individual vehicle products.
- Reduced Engine Noise – As with exhaust emissions, engine noise levels are regulated and manufacturers have responded with fundamental design improvements to reduce noise emissions. In all likelihood, all such improvements will be part of the baseline of a given vehicle type.
- Higher Efficiency Vehicles – Most types of transit vehicles have improved their energy efficiency in recent years, through improvements in fuel efficiency of internal-combustion engines and/or through software improvements that enable more efficient transfer of power to the wheels, such as “traction control” systems in buses and locomotives. Reductions in energy consumption translate into reductions in environmental impacts per passenger.

5.0 RELATIVE ADVANTAGES AND DISADVANTAGES

The following table summarizes the relative advantages and disadvantages of the candidate vehicle types or technologies. Generalized scorings of “high” (●), “medium” (◐), and “low” (○) have been applied consistent with the evaluations discussed in Section 4.0. A scoring of “High” implies a greater advantage than “medium”, which in-turn implies a greater advantage than “low”.

TYPE OR TECHNOLOGY	FRA Compatibility	Level Boarding	Capital Cost	OTHER ADVANTAGES	OTHER DISADVANTAGES
1 – Diesel Locomotive Commuter Rail	●	○	○	<ul style="list-style-type: none"> • Efficient for longer trains • Strictly “off-the-shelf” • Less maintenance and inspection than MUs • In regulatory “comfort zone” • 3 or 4 track flexibility 	<ul style="list-style-type: none"> • Slower accel and decel than MUs • Platforms required for level boarding interfere with freight if tracks are shared with freight trains
2 – Electric Locomotive Commuter Rail	●	○	●	<ul style="list-style-type: none"> • Efficient for longer trains • Mostly “off-the-shelf” • Less maintenance and inspection than MUs • Energy flexibility • In regulatory “comfort zone” • 3 or 4 track flexibility 	<ul style="list-style-type: none"> • Slower accel and decel than MUs • Infrastructure visual impacts • Electrification freight clearance requirement • Platforms required for level boarding interfere with freight if tracks are shared with freight trains
3 – Dual Mode Locomotive Commuter Rail	●	○	●	<ul style="list-style-type: none"> • Efficient for longer trains • Electric locomotive performance in electrified territory • Less maintenance and inspection than MUs • In regulatory “comfort zone” • 3 or 4 track flexibility 	<ul style="list-style-type: none"> • Slower accel and decel than MUs • Platforms required for level boarding interfere with freight if tracks are shared with freight trains • Historically less reliable than diesel-electric or electric locomotives
4 – DMU (Type 1; FRA)	●	○	○	<ul style="list-style-type: none"> • Efficient for shorter trains • Fast accel and decel 	<ul style="list-style-type: none"> • Platforms required for level boarding interfere with

TYPE OR TECHNOLOGY	FRA Compatibility	Level Boarding	Capital Cost	OTHER ADVANTAGES	OTHER DISADVANTAGES
compliant)				<ul style="list-style-type: none"> • In regulatory “comfort zone” • 3 or 4 track flexibility 	<ul style="list-style-type: none"> • freight if tracks are shared with freight trains • New design may be needed
5 – EMU (Type 1; FRA compliant)	●	○	●	<ul style="list-style-type: none"> • Very fast accel and decel • Energy flexibility • Mostly “off the shelf” • In regulatory “comfort zone” • 3 or 4 track flexibility 	<ul style="list-style-type: none"> • Infrastructure visual impacts • Platforms required for level boarding interfere with freight if tracks are shared with freight trains • Electrification freight clearance requirement
6 – DMU (Type 2; non FRA compliant)	○	●	○	<ul style="list-style-type: none"> • Can design platforms for level boarding • Mostly “off the shelf” • Less vehicle visual impact 	<ul style="list-style-type: none"> • Track spacing; regulatory approvals • 2 track maximum – no sharing with freight
7 – EMU (Type 2; non FRA compliant)	○	●	○	<ul style="list-style-type: none"> • Very fast accel and decel • Energy flexibility • Can design platforms for level boarding • Mostly “off the shelf” • Less vehicle visual impact 	<ul style="list-style-type: none"> • Infrastructure visual impacts • Track spacing; regulatory approvals • 2 track maximum – no sharing with freight
8 – LRT (Electric Light Rail)	○	●	●	<ul style="list-style-type: none"> • Very fast accel and decel • Energy flexibility • Can design platforms for level boarding • Mostly “off the shelf” • Less vehicle visual impact 	<ul style="list-style-type: none"> • Infrastructure visual impacts • Potentially limited top speed • Track spacing; regulatory approvals • 2 track maximum – no sharing with freight

TYPE OR TECHNOLOGY	FRA Compatibility	Level Boarding	Capital Cost	OTHER ADVANTAGES	OTHER DISADVANTAGES
9 – DLRT (Diesel Light Rail; DMU Type 3)	○	●	○	<ul style="list-style-type: none"> • Can design platforms for level boarding • Less infrastructure visual impact than Electric LRT 	<ul style="list-style-type: none"> • Potentially limited top speed • Track spacing; regulatory approvals • 2 track maximum – no sharing with freight
10 – RRT (Rail Rapid Transit)	○	●	●	<ul style="list-style-type: none"> • Complete grade separation • Very fast accel and decel • Energy flexibility • Level boarding • Automated fare collection and single-operator • Potential for driverless • Mostly “off the shelf” 	<ul style="list-style-type: none"> • Potentially limited top speed • 2 track maximum – no sharing with freight
11 – BRT (Bus Rapid Transit)	○	●	○	<ul style="list-style-type: none"> • Off-ROW flexibility • Can design platforms for level boarding • Strictly “off the shelf” • Less vehicle visual impact 	<ul style="list-style-type: none"> • Grade crossing safety • Potentially limited top speed • Guideway spacing, under most circumstances
12 – RGB (Regional Bus)	○	○	○	<ul style="list-style-type: none"> • Off-ROW flexibility • Strictly “off the shelf” • Less vehicle visual impact 	<ul style="list-style-type: none"> • Grade crossing safety • Potentially limited top speed • Guideway spacing