SOUTH FLORIDA EAST COAST CORRIDOR STUDY

SOUTH FLORIDA EAST COAST (FEC) ALTERNATIVES ANALYSIS

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SFECC Regional Operations and Maintenance Cost Tech Memo

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STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

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Memorandum

Date:	September 17, 2010
To:	Peter Bromley
From:	David Nelson & Tara Blakey
Subject:	South Florida East Coast Corridor (SFECC) Transit Study Phase II Operations and Maintenance (O&M) Cost Estimation Methodology (Sixth Revision)

Operations and Maintenance (O&M) cost estimates for each service described in the SFECC Alternatives Analysis (AA) were projected to determine cost effectiveness measures and allow for the development of financial plans. This technical memorandum describes the input data, assumptions and calculations employed to estimate operating and maintenance costs for the various service alternatives evaluated for the SFECC AA project. Consistent with Federal Transit Authority (FTA) guidance, estimates of operations and maintenance costs were calculated using a fully-allocated cost model using unit costs based on current local experience to the extent feasible. Where a new transit mode was employed, estimates are consistent with experience in similar settings elsewhere.

Four cost models were developed for the SFECCAA:

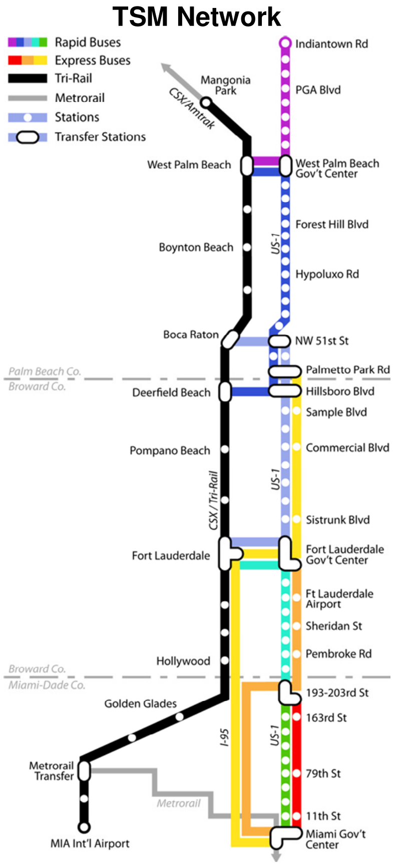
1. Standard Bus Model – based on existing local costs
2. Push-Pull Commuter Rail Model - based on existing local costs
3. Articulated Bus Model – derived from Standard Bus Model
4. DMU Rail Model – derived from Push-Pull Model

Overview of Service Alternatives Being Evaluated

The SFECC AA deals with an approximately 85 mile long corridor along Southeast Florida's east coast between Downtown Miami and Jupiter in North Palm Beach County. A regional solution is being sought by the study partners to relieve roadway congestion while providing for needed freight transport within the area. Additional transit service along the corridor would provide direct service between all the major downtown business districts in the corridor, providing connectivity to existing and proposed transit (Tri-Rail, Metrorail, Miami streetcar, East-West Line in Broward) and connect to the three major airports, Miami International, Fort Lauderdale-Hollywood International and Palm Beach International and the seaports: Port of Miami, Port Everglades and Port of Palm Beach. Four service alternatives are considered for the study corridor[1]:

TSM – The Transportation Systems Management (TSM) alternative attempts to satisfy as much North-South corridor transit demand as possible without a major capital investment. The TSM introduces a Rapid Bus and peak-only Express Bus service. The Rapid Bus would operate from Jupiter to Miami on local arterials making 50 stops within the corridor and connecting to four Tri-Rail stations. The Rapid

[1] The No-build network includes Tri-Rail service on the existing SFRC corridor with peak trains every 20 minutes and off-peak trains every 30 minutes.



Bus runs every 15 minutes in the peak and every 30 minutes during off-peak periods. Due to the length of the study corridor, the Rapid Bus would be operated as five connecting routes. The total time required to traverse the corridor end-to-end using the local Rapid Bus routes would be five hours and twenty minutes, including five minutes of transfer time at each of the four transfer points.

The three TSM Express Bus routes provide connections between Boca Raton, Fort Lauderdale, Aventura and Downtown Miami. These buses would provide peak-only service on 15 minute headways. One-way travel times for each of the Express Bus routes are:

1. Boca Raton to Fort Lauderdale to Downtown Miami – eight stops, one hour 44 minutes one-way.
2. Fort Lauderdale to Downtown Miami – six stops, one hour and 20 minutes one-way.
3. Aventura to Downtown Miami – five stops, fifty-five minutes one-way.

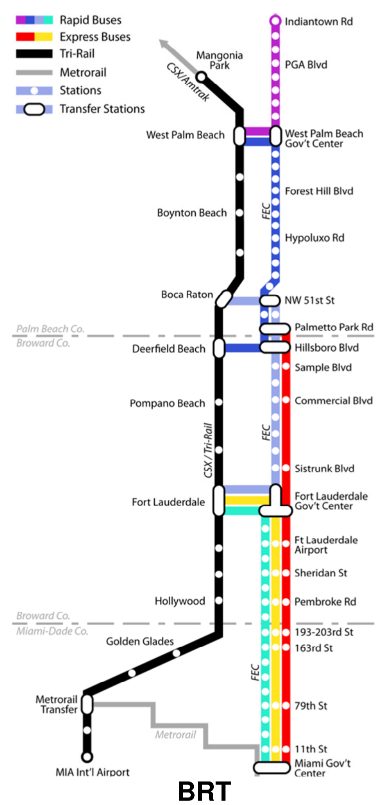
The TSM also includes improved peak headways on Tri-Rail service, with peak headways reduced to 15 minutes.

Two of the four O&M models developed during the SFECCAA were used for the TSM evaluation. Improvements to existing Tri-Rail service were estimated through the Push-Pull Commuter Rail Model which is based on reported costs for Tri-Rail service. All Rapid and Express Bus service would be operated by articulated buses creating a new service type in the region. Unit costs from the Standard Bus model were adjusted to reflect the new service type resulting in the Articulated Bus model.

BRT – The Bus Rapid Transit (BRT) alternative consists of articulated buses operating on exclusive lanes built within the FEC right-of-way between Jupiter and Downtown Miami. The local BRT service would be operated as four connecting routes. The local BRT buses would make a total of 50 stops within the study corridor, requiring four hours and eighteen minutes to traverse the length of the corridor on the local routes including allowances for timed transfers at route connections. Service would be offered every 15 minutes during the peak and every 30 minutes during off-peak periods.

Two BRT Express Bus routes provide connections between Boca Raton, Fort Lauderdale, Aventura and Downtown Miami. These buses would operate on 15 minute headways during peak periods only. One-way travel times for each of the Express Bus routes are:

1. Boca Raton to Fort Lauderdale to Downtown Miami – 14 stops, one hour 53 minutes one-way.



2. Fort Lauderdale to Downtown Miami – ten stops, one hour and 15 minutes one-way.

BRT O&M costs were estimated using the articulated bus model.

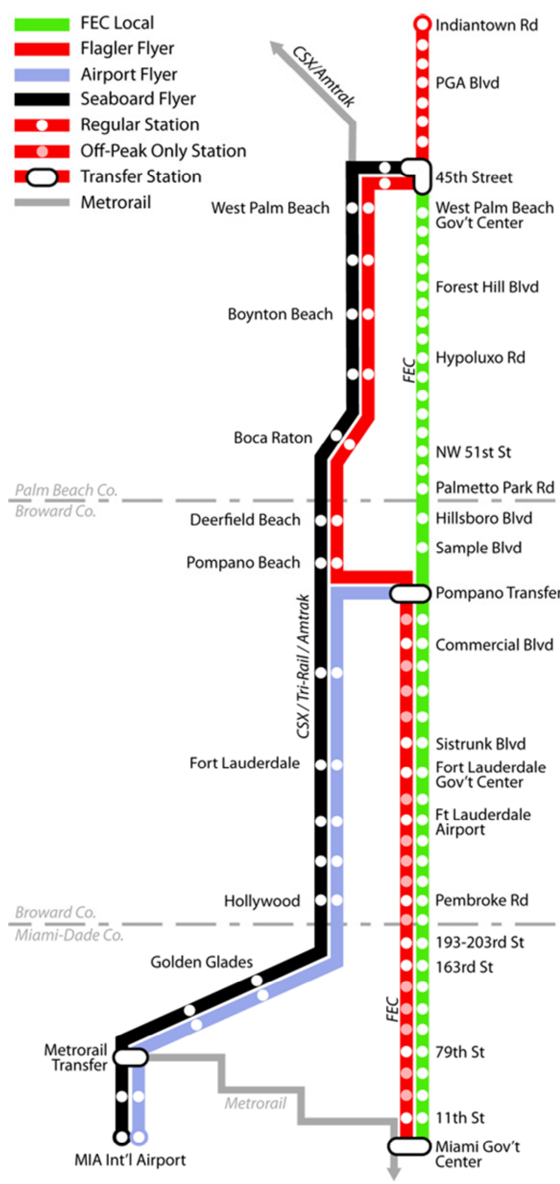
Integrated Rail (DMU) – The Integrated Rail (DMU) Alternative re-introduces passenger rail service to the FEC corridor between Jupiter and Downtown Miami with two services using self-powered rail cars often called diesel multiple units (or DMUs). Passenger service on the FEC would be integrated with rail service on Tri-Rail's SFRTA corridor to the west. The Integrated Rail (DMU) Alternative includes four rail services:

1. **FEC Local** service runs from West Palm Beach to Miami Government Center, making all local stops. Headways are 15 minutes during peaks and 30 minutes during the off-peak. Total end-to-end travel time is two hours and six minutes using DMUs.

2. The **Flagler Flyer**, which begins in Jupiter, connecting to the FEC Local at 45th St, uses the Northwood Connection to run down the SFRTA Corridor before re-joining the FEC at Pompano, supplements FEC Local service in the southern portion of the study corridor. During the peak, the Flagler Flyer makes 11 express stops on the FEC, while in the off-peak, it makes all local stops. Headways are 15 minutes during peaks and 30 minutes during the off-peak. Total end-to-end travel time using DMUs is two hours and five minutes during the peaks and two hours and 26 minutes during the off-peak.

3. The **Airport Flyer** begins at Pompano Transfer and uses the SFRTA Corridor to access Miami Airport. This service, employing push-pull technology as currently employed by Tri-Rail, would be operated every 15 or 30 minutes, depending on time-of-day with an end-to-end travel time of one hour and nine minutes.

4. The **Seaboard Flyer** serves a route comparable to existing Tri-Rail service. The



Seaboard Flyer would take one hour and 59 minutes using push-pull equipment to make all stops between West Palm Beach and the Miami Airport on the SFRTA. This service would operate once an hour during peaks and every two hours during the off-peak.

Services operating solely within the SFRTA corridor would continue to employ the push-pull locomotive equipment currently used for Tri-Rail service. The cost to provide these services was estimated using the Push-Pull Commuter Rail O&M model. In order to take advantage of superior efficiency and operating characteristics, DMUs would operate FEC Local and Flagler Flyer service. A DMU O&M model was developed through adjustments to the Push-Pull model in order to estimate the costs associated with this emerging technology.

Integrated Rail (Push-Pull) – The Integrated Rail (Push-Pull) alternative offers the rail services included in the Integrated Rail (DMU) option with the only difference being that all services are operated with push-pull equipment. Due to the slower equipment, end-to-end travel time on the FEC Local increases by 22 minutes; the Flagler Flyer running time increases by approximately 25 minutes, while the Seaboard Flyer and Airport Flyer remain unchanged.

All Integrated Rail (Push-Pull) O&M costs were estimated using the Push-Pull model.

Development of O&M Cost Model for Existing Service

In order to aid policy makers in their comparison of potential service alternatives, estimates of the on-going costs associated with operating, maintaining and managing each of the potential alternatives were derived. The main components of on-going costs that are typically included in O&M projections pertain to operating staff, maintenance staff, fuel, parts and materials, and administration. These cost components can be classified into four over-arching categories:

1. **Transportation** - Includes operating crews, supervision, dispatching, fuel and train supplies.
2. **Vehicle Maintenance** - Includes labor and materials to maintain revenue vehicles.
3. **Maintenance-of-Way** - Includes labor and materials for all non-vehicle maintenance (e.g. track, signal, stations, buildings) and non-revenue vehicles.
4. **Administration** - Includes labor, materials and services for all functions other than transport operations, maintenance of rolling stock and maintenance of other assets. Functions include marketing, revenue accounting, personnel, human resources, training, information technology and planning, legal, risk management, safety, insurance, etc.

Modes evaluated for the final SFECCAA alternatives included Push-Pull locomotive trains, articulated buses, and diesel multiple unit (DMU) trains. Data assembled for existing modes and service types led to the development of the Push-Pull model and Standard Bus model as described below.

Selection of Key Driving Supply Variables

Although the standard bus model was not used to estimate costs for any of the alternatives included in the final set of SFECCAA alternatives, the standard bus model was used for preceding alternatives and was also used in the development of the articulated bus model. The key driving supply variables selected for the standard bus model were as follows.

Transportation – For the standard bus model, with bus services provided directly by the associated government agency, it was determined that number of vehicle hours provided would best capture the variability in transportation costs. Since the most substantial costs to provide bus service are those from operating crews, vehicle hours were assumed to correspond with bus transportation costs most accurately as they account for crew time as well as fuel.

Maintenance of Vehicles – Standard bus model O&M estimates were based on the number of buses required for service including spares. This driver was selected based on the assumption that the cost to maintain the bus fleet is most closely linked to the number of vehicles to be maintained.

Maintenance of Way – No maintenance of way costs are required for standard bus service which operates on general use roadways in mixed traffic.

Existing Tri-Rail service is operated by private contractors paid by SFRTA. The driving supply variables for the Push-Pull model reflect the costs that drive actual costs under the current operating contracts. The transportation and vehicle maintenance contractors collect a set fee for each service day, regardless of the amount of service provided, so that the number of service days is a key driving supply variable for the Push-Pull model. Beyond the minimum cost per service day, additional costs are accumulated based on the amount of service provided.

Transportation – Veolia's contract with SFRTA stipulates a set fee for each of service and each train that is operated. Approximately half of Veolia's annual compensation is allocated on the basis of service days while the other half is allocated on the basis of service levels. Using that concept to estimate FEC service costs, Jacobs derived a cost per train mile could be applied to calculate variable transport expenses for the new transport services. Costs for security and fare inspection paid to Wakenhut were allocated on a similar train mile basis. Costs for train dispatching currently paid to Amtrak were allocated on the basis of route miles. Fuel expense was based on reports of actual SFRTA fuel consumption on a train mile basis.

Maintenance of Vehicles – Similar to the Veolia contract, Bombardier is paid a fixed cost for each service day that it maintains SFRTA vehicles. It is also paid a variable cost that varies with the numbers of coach and locomotives in the service fleet. Consequently the key driving supply variables for estimating maintenance of vehicle costs under the Push-Pull model are the number of service days and number of units in the fleet for each service. These cost drivers were selected based on Tri-Rail's contract with the Bombardier to maintain the Tri-Rail's push-pull fleet. (SFRTA also has a new small (4 unit) DMU fleet maintained by a small cadre of SFRTA staff supplemented by specialty contractors as necessary. Records that would be necessary to derive SFRTA's fully allocated cost for DMU maintenance do not exist for this new fleet.)

Maintenance of Way – The State of Florida pays CSX for right of way maintenance under a 22 year old contract. The details of how that contract has evolved in practice since it was originally signed are somewhat obscure. Available records concerning actual costs and allocation of cost were nonspecific and incomplete. Consequently, for the purposes of this study maintenance of rail right-of-way under the Push-Pull costs estimates for this study were driven by mainline track miles required for the passenger operation.

Administration – For both the Push-Pull model and the standard bus model, administrative costs estimates were driven by the value of direct service provided. The key driver designated for the administrative cost category is the total direct costs necessary to operate a service represented by the sum of the estimated transportation, maintenance of vehicles and maintenance of way costs.

Table 1 outlines and compares the key drivers by cost category for both the standard bus and push-pull models

Table 1: Key Drivers by Cost Category

Cost Category	Standard Bus Model	Push-Pull Model
Transportation	Vehicle Hours	Number of Service Days
		Train Miles
		Vehicle Miles
		Route Miles
Maintenance of Vehicles	Number of Vehicles	Number of Service Days
		Number of Vehicles (by type of vehicle)
Maintenance of Way	N/A	Track Miles
Administration	Direct Costs	Direct Costs

Data Assembled
The unit costs in the O&M cost models for existing services were based on actual costs to provide fixed route service in the study area.

Standard Bus Model - Four transit agencies currently operate fixed-route bus service within the study area, PalmTran, Broward County Transit (BCT), Miami-Dade Transit (MDT) and the SFRTA. Because of the need for consistent data sources, the National Transit Database (NTD) was deemed an appropriate source for cost information on existing bus service. Cost data from PalmTran, BCT and MDT were combined to estimate unit costs for the standard bus model.

Push-Pull Model - SFRTA and FDOT budgets and contracts with Veolia Transportation, Wakenhut, Bombardier, Amtrak and CSX were consulted to develop the Push-Pull Model. Tri-Rail-specific data provided to the NTD was also employed where necessary to supplement cost details from current service contracts.

SFRTA's costs for Maintenance-of-Way (MoW) are directly paid by FDOT to CSX. Maintenance-of-Way costs are not shown in SFRTA budgets or financial reports. The current administration of MoW expenses makes it difficult to develop an accurate MoW cost model for the Push-Pull model. Consequently, an estimate of the annual cost to the maintain SFECC rail infrastructure, buildings and stations was derived using industry averages as reported to FTA via the NTD program.

Assignment of Expense Item
Table 2 shows the key driving variable for each expense line item included in the standard bus model.

Table 2: Expense Line Items for Standard Bus Model				
Expense Line Item	Annual Expense	Vehicle Hours	Vehicles	Direct Costs
Transportation	$282,450,546	X		
Maintenance of Vehicles	$89,996,812		X	
Administration	$85,662,892			X
Resource Variable Values		4,351,232	1,725	$372.4M

Table 3 shows the key driving variable for each expense line item included in the Push-Pull model.

Table 3: Expense Line Items for Push-Pull Model								
Expense Line Item	Annual Expense	Train Miles	Route Miles	Track Miles	Loco-motives	Coaches & Cabs	Service Days	Direct Costs
Transportation								
Contract Management	$5,497,679						X	
On-board Staff	$4,038,097	X						
Rail Dispatch	$1,419,534		X					
Fuel	$6,136,842	X						
Maintenance of Equipment								
Contract Mgmt.	$3,405,450						X	
Locomotive Maintenance	$3,348,373				X			
Passenger Car Maintenance	$2,931,540					X		
Maintenance of Way	NA[2]			X				
Administration	$17,929,125							X
Resource Variable Values		986,361	70.9	241.2	12	26	365.25	$37.8M

Calculation of Unit Costs
Table 4 shows the unit cost for each expense line item included in the standard bus model. The resource variable for all three expense line items is equivalent to the supply variables shown in Table 4.

Table 4: Resource Unit Costs for Standard Bus Model				
Expense Line Item	Annual Expense	Vehicle Hours	Vehicles	Direct Costs
Transportation	$282,450,546	$64.91		

[2] Using the most recent NTD reports, Jacobs calculated the average non-vehicle maintenance cost per track mile for the nine US commuter railroads known to primarily operate on their own right of way: LIRR, NJ Transit, Metro North, Metra (Chicago), SEPTA, NICTD (Indiana), MBTA, CalTrain (San Francisco), NCTD (San Diego) and TriRail (e.g. Jacobs tried to avoid using operations on railways owned and maintained by others as comparisons). Averaging over the nine systems the cost per track mile of all non-vehicle maintenance is $87,910.

Maintenance of Vehicles	$89,996,812		$52,172	
Administration	$85,662,892			$0.23
Resource Variable Values		4,351,232	1,725	372.4M

Table 5 shows the unit cost for each expense line item included in the Push-Pull model. The unit cost for fuel corresponds to a resource unit cost of $2.79 per gallon and a consumption rate of 2.2 gallons per train-mile for locomotive-hauled trains. The resource variable for all other expense line items is the same as the supply variables shown in Table 5.

Table 5: Resource Unit Costs for Push-Pull Model								
Expense Line Item	Annual Expense	Supply Variable Unit Cost Rate						
		Train Miles	Route Miles	Track Miles	Loco-motives	Coaches & Cabs	Service Days	Direct Costs
Transportation								
Contract Mgmt.	$5,497,679						$18,292	
On-board Staff	$4,038,097	$6.73						
Rail Dispatch	$1,419,534		$20,022					
Fuel	$6,136,842	$6.22						
Maintenance of Equipment								
Contract Mgmt.	$3,405,450						$9,330	
Powered Vehicle (Locomotive) Maintenance	$3,348,373				$279,031			
Passenger Car Maintenance	$2,931,540					$112,752		
Maintenance of Way	NA			$87,910				
Administration (Tri-Rail)	$19,285,017							51%
Administration (other Rail)	NA							23%
Resource Variable Values		986,361	70.9	241.2	12	26	365.25	37.8M

Based on the data assembled, it was determined that Tri-Rail accrues approximately $0.51 in administrative costs for each dollar spent on the direct costs necessary to operate the rail service (i.e. those for transportation, equipment maintenance and maintenance of way). Using NTD data, the study team computed that the typical ratio of administrative costs to the sum of reported direct costs is 23% for all US commuter railroads. This ratio ranges from highs of 165% for Nashville[3] , 55% for West Bay ACE, and 51% for SFRTA to lows of 11% for Philadelphia, and 17% for Boston. It was decided to apply 23% to estimated direct operating costs to account for administrative costs for future, expanded rail operations consistent with robust rail networks around the country.

[3] Nashville is excluded from this calculation

Development of O&M Cost Model for New Service Modes

Some of the service options developed for this alternatives analysis introduce new transit vehicle types to the region.

- Articulated Bus
- Single Level Diesel Multiple Unit (DMU) Rail Cars.

Cost information for these new vehicle types is not locally available consequently the articulated bus model adjusts locally reported costs for standard bus service to reflect the cost to operate and maintain articulated buses while the Push-Pull model was adjusted to reflect the costs of operating DMU service.

Development of O&M Cost Model for Existing Service

The unit costs in the O&M cost models for existing services were based on actual costs to provide fixed route bus service costs at PalmTran, BCT and MDT for the standard bus model; and to provide Tri-Rail service, for the Push-Pull model..

Key standard bus cost drivers are:

1. Transportation – Vehicle Hours
2. Vehicle Maintenance – Number of Buses
3. Administration – Direct Costs

The standard bus model assumes that no maintenance-of-way costs would be incurred by buses operating on general purpose roadways.

Key push pull cost drivers include

1. Transportation – Train Miles, Route Miles, and Service Days
2. Vehicle Maintenance of – Service Days, Number of Locomotives, Number of Passenger Cars
3. Maintenance-of-Way – Track Miles
4. Administration – Direct Costs

Adjustment of Productivity Ratios and Addition of New Expense Line Items

Because articulated buses are longer and contain more mechanical equipment than standard buses, costs for transportation and vehicle maintenance are expected to be greater for an articulated bus than for a standard bus providing equivalent levels of service. The articulated bus model was developed by adjusting the standard bus model's unit costs for transportation and maintenance of vehicles as well as adding an expense line item for Maintenance of Way (where applicable[4]) as shown in Table 6.

Table 6: Resource Unit Costs for Articulated Bus

Expense Line Item	Existing	New Unit	Supply Variable	Resource

[4] Although articulated buses do not require maintenance of way (MoW) costs when operating in mixed traffic, as under the TSM, a MoW expense line item was included in the articulated bus model for alternatives which propose operating articulated buses within an exclusive ROW, as under the BRT.

	Unit Cost Adjusted	Cost Added		Unit Cost
Transportation	X		Vehicle Hours	$81.14
Maintenance of Vehicles	X		Articulated Buses	$70,177
Maintenance of Way		X	Dedicated Lane Miles	$6,282
Administration			Direct Costs	$0.23

Based on a Jacobs survey of industry experience, the costs associated with standard bus transportation were increased by 25% to represent articulated bus transportation costs.[5] The costs associated with standard bus maintenance were increased by 35% to represent articulated bus maintenance costs, consistent with empirical data reported in TCRP synthesis 75[6]. A unit cost of $6,282 per dedicated bus lane mile for right-of-way maintenance was included in the articulated bus model based on FDOT costs for maintenance of highways[7].

Table 7 summarizes the adjustments made to the Push-Pull model to construct the DMU model. No new expense line items were required to produce the DMU model.

Table 7: Resource Unit Costs for DMU Model					
Expense Line Item	Push Pull Cost Applied	Existing Unit Cost Adjusted	New Unit Cost Added	Supply Variable	Resource Unit Cost
Transportation					
Contract Mgmt.	X			Service Days	$18,292
On-board Staff	X			Train Miles	$6.73
Rail Dispatch	X			Route Miles	$20,022
Fuel		X		Powered vehicle miles	$1.40
Vehicle Maintenance					
Contract Mgmt.	X			Service Days	$9,330
Powered Vehicle Maintenance		X		DMUs	$209,273
Maintenance of Way	X			Track Miles	$87,910
Administration	X			Direct Costs	$0.23

The two unit costs that were adjusted to reflect differences between locomotive-hauled and DMU operations were those for fuel and vehicle maintenance. The unit-cost for fuel per powered vehicle mile was based on Tri-Rail's current cost for fuel, $2.79 per gallon, and a fuel consumption rate of 0.5 gallons per mile as specified by the DMU manufacturer Colorado Rail Car. Jacobs estimated that each DMU would maintenance cost for each DMU would be 75% of the annual cost to maintain locomotive.

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[5] Demery, L, (2007). Publictransit.us Working Paper 02-01. Detroit's "SpeedLink" Bus Rapid Transit (BRT) Proposal: A Critique of Operating Cost Estimates. Retrieved from http://www.publictransit.us/ptlibrary/specialreports/sr11.Detroitspeedlink.pdf; and
Booz Allen Hamilton (2006). Honolulu BRT Project Evaluation, page 5-12. Prepared for the FTA.
[6] Transit Cooperative Research Program (2007). TCRP Synthesis 75, "Uses of Higher Capacity Buses in Transit Service", page 49.
[7] US Department of Transportation, Federal Highway Administration. *Highway Statistics 2007*. Retrieved from http://www.fhwa.dot.gov/policyinformation/statistics/2007/.

Projected Costs for SFECCTA Final Series Alternatives

The estimated values for each of the key cost drivers and the resulting O&M cost projections are presented in Table 8. The Integrated Rail (DMU) and Integrated Rail (Push-Pull) alternatives, which involve a substantial increase in rail service over the No Build, are expected to have the highest annual O&M costs of the four alternatives. The rail options would cost approximately $190 million per year with the push-pull rail option estimated to cost 3% more than the DMU rail option. The TSM and the BRT would require $135 to $145 million per year to operate.

Table 8: SFECCAA Series 11 O&M Cost Estimates[8]

	Demand Data[9]		Values for Key Cost Drivers					Equipment Required (Including Spares)				Annual O&M Costs (millions)				
Alternative	Typical Weekday Boardings	Weekday Passenger Miles	Consist Miles	Vehicle Miles	Consist Hours	Route Miles	Track or Lane Miles	Articulated Buses	DMU	Locomotive	Rail Passenger Coach	Transportation	Maintenance of Equipment	Maintenance of Way	Administration.	Total
No-Build	29,050	661,487	6,098	18,295	168	73	145			14	42	$32.5	$12.0	$13.4	$29.5	$87.5
TSM	39,255	818,144	22,554	29,550	1,188	73	146	128		21	42	$58.7	$23.0	$13.5	$39.6	$134.8
BRT	49,948	930,849	29,349	36,346	1,464	171	342	123		21	42	$65.2	$22.6	$14.7	$41.3	$144.0
IR (DMU)[10]	59,125	1,180,087	19,002	46,059	642	153	349		105	20	40	$75.0	$45.7	$31.4	$35.0	$187.1
IR (P-P)[11]	52,409	1,015,141	19,006	38,012	714	153	349			72	142	$86.4	$39.5	$31.4	$36.2	$193.5

[8] All options include costs for service on the SFRC.
[9] Including trips made on the SFRC for all options.
[10] Integrated Rail (DMU)
[11] Integrated Rail (Push-Pull)

Figure 1: Series 11 O&M Estimates by Cost Category[12]

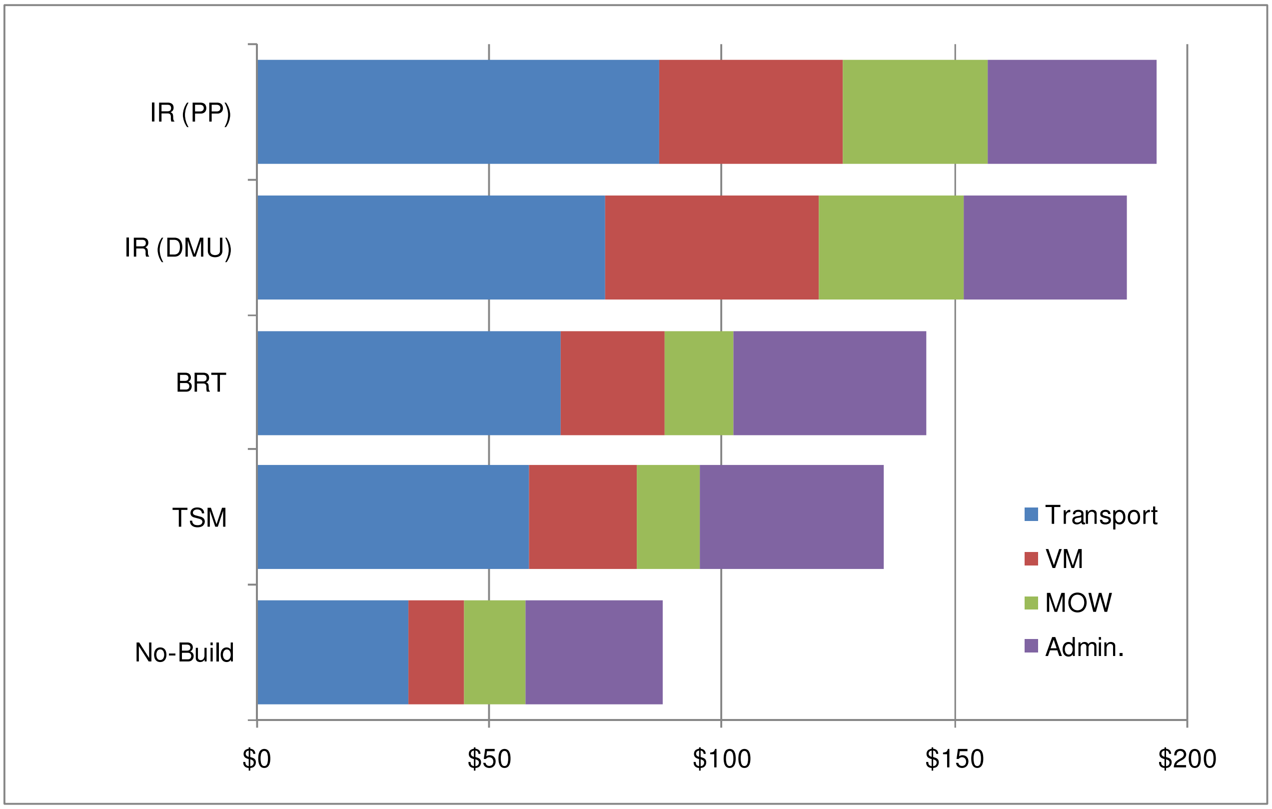

Figure 1 illustrates the cost estimates for each service alternative, separated into the four major cost categories.

While vehicle maintenance (VM) costs for the DMU option are greater than for the push- pull option, the transport costs are greater for the Push-Pull option making the Push-Pull option the more expensive of the rail options to operate.

The BRT and TSM, which provide similar levels of service both using articulated buses, have similar annual costs for each cost category. The major differentiator between TSM and BRT annual costs are the cost for transportation. Because BRT express services would require two articulated buses per headway to fully accommodate the forecast demand at the maximum load point, the BRT is requires more vehicles and vehicle hours than the TSM.

[12] All options include costs for service on the SFRC.