G Operating Cost Model

This appendix documents the development of the operating and maintenance cost factors and general methodology for the Operating Cost (OPEX) Model. The same model was used for both the Line Level Concept Development and Evaluation and the Systemwide Alternative analysis. The Systemwide Alternative version includes modifications to accept inputs for passengers, passenger miles, and fare revenue from the Central Transportation Planning Staff (CTPS) of the Boston Metropolitan Planning Organization (MPO) instead of the Regional Dynamic Model (RDM). It also includes modifications to accept inputs for operating statistics such as service hours, service miles and vehicles available for maximum service (VAMS) from Rail Traffic Controller (RTC) instead of ATTUne. The Tier 2 version also includes modifications to forecast MBTA commuter rail systemwide impacts by rail line, rather than being driven by the primary timetable changes to an individual rail line as was required in the Line Level Concept version.

Cost Factor Development

Existing operating costs from MBTA Commuter Rail are aggregated to form the basis of the OPEX model cost structure. The structure uses costs from the Keolis Best and Final Offer (BAFO) and the National Transit Database (NTD) for MBTA Commuter Rail for report years 2015 and 2016.

The cost structure is based on the NTD structure's four primary categories: Vehicle Operations, Vehicle Maintenance, Non-Vehicle Maintenance, and General Administration. Within these categories, the OPEX model groups costs on their functionality based on the level of detail available in the BAFO.

Each cost is divided by a cost driver to create a cost per unit for the OPEX model to calculate the resulting cost of each of the proposed service alternatives.

The OPEX model organizes costs into three levels of variability: variable, step, and fixed. Variable costs are those that change in a relatively linear fashion based on the level of train service being

offered, such as fuel and train & engine crews. Step costs are those that tend to vary significantly across different thresholds. For example, while mechanical costs can be viewed on a per car and per locomotive basis, they tend to vary more when the amount of equipment being maintained requires a change in the number of work shifts or number of facilities required. Based on the scale of this effort, we have chosen a more linear set of drivers for these costs. For those costs categorized as fixed, we assume that these costs will not vary based on changing commuter rail service levels. Fixed costs primarily included general administration costs.

These actual costs and statistics are used as the basis for the model. Due to the significance of labor costs within the MBTA Commuter Rail cost structure, the OPEX model separates out all wages, salaries, and employee-related costs as a category, "staff." These costs, which include train and engine crews, uniforms, station staff, vehicle maintenance staff, maintenance of way/non-vehicle maintenance staff, and benefits, are transferred from the standard NTD categories of Vehicle Operations, Vehicle Maintenance, Non-Vehicle Maintenance, and General Administration to Staff. The OPEX Model permits the assignment of individual cost lines to any of the cost categories.

In reviewing the data, the NTD report year 2016 and Keolis BAFO year 2 appear to be a stable year for developing cost factors. Therefore, the OPEX model relies on the 2016/year 2 data for developing its unit costs. There was a difference of $51.72 million between the Purchased Transportation costs reported to the NTD in 2016 and the BAFO fixed-price for year 2. The reason for this difference is for additional work MBTA commissioned Keolis to complete, primarily for various maintenance activities.

MBTA staff also provided some additional information to supplement what was available between the NTD and the BAFO. The one area where this supplemental data was used was for credit and debit card merchant commissions and fees from fare payments. The MBTA provided the specific report year 2016 credit/debit card merchant commissions/fees, totaling $2,2406,705. These are now separated within the NTD General Administration costs.

Note that the nature of this approach assumes a continuation of much of the MBTA's current commuter rail operating practices, methods, and procedures. Only those specific areas where the MBTA does not have specific past experience that are listed in the following section represent a cost approach different from MBTA's current commuter rail operations. This approach represents a fairly conservative operating and maintenance cost forecast as it does not assume any changes from current operating practices. For example, train & engine crew labor is forecast based on the number of train service hours. Therefore, the current Keolis practice as presented in their BAFO of having each train staffed with one engineer, one conductor, and at least one assistant conductor (the average number of train & engine crew members per train is 3.2 based on the Keolis BAFO), is assumed to remain constant within each proposed Rail Vision alternative.

Another example is diesel fuel. The OPEX Model uses a cost per unit (car and locomotive) mile factor, which, from MBTA actual report year 2016 NTD data is a base of $1.60 per unit mile. Therefore, the OPEX Model does not assume any future improvements in diesel-electric locomotive fuel efficiency beyond the 1.85 unit miles per gallon or 0.35 service (train) miles per gallon.[1]

1 Per the Federal Transit Administration's (FTA) National Transit Database (NTD) for MBTA Commuter Rail for Report Year 2016: 23,532,668 actual vehicles/passenger car revenue (unit) miles, 4,385,812 train revenue (service) miles, and 12,704,208 gallons of diesel fuel.

Inflation

The OPEX model provides for two steps of inflation. The first step is to bring the base year costs from the NTD report year 2016, which includes a portion of 2015 as the MBTA fiscal year begins on July 1, to 2020 dollars, as 2020 is the Rail Vision baseline year. This inflation factor is 1.13, based on the Consumer Price Index (CPI) from the US Bureau of Labor Statistics (BLS) of 1.09 from 2015 through May 2019 and the Federal Transit Administration (FTA) New Starts 2019 to 2020 forecast inflation rate of 1.035 (Standard Cost Categories for New Starts Projects worksheet, Revision 19, FTA, June 2017).

The OPEX model then inflates the costs from 2021 through 2044 by 1.02 annually.

Additional Cost Factors

The OPEX model includes a sheet, I; Further Scenario Line Items, that provides for the addition of cost factors in areas where MBTA Commuter Rail does not have current historical cost experience. For this version of the OPEX model, the following additional cost factors have been developed and are included in the I; Further Scenario Line Items sheet.

Electric Multiple Unit (EMU) Vehicle Maintenance Costs

The vehicle maintenance costs for EMUs are provided within the OPEX model on a per vehicle unit basis. The operating costs are based on National Transit Database (NTD) data from the 2016 report year from five commuter railroads that predominantly use EMUs within their fleets. These include: MetroNorth Commuter Railroad (MNRR), Northern Indiana Commuter Transportation District (South Shore), Long Island Rail Road (LIRR), Southeastern Pennsylvania Transportation Authority (SEPTA), and the Denver Regional Transportation District (RTD). As Figure G-1 details, the total commuter rail vehicle maintenance costs for each agency are weighted for fleet size based on the number of EMUs available for maximum service versus the total rail VAMS, with the vehicle maintenance salaries adjusted for the Boston cost of living.

As the base costs within the OPEX model are for 2016, the uninflated 2016 average cost per unit weighted by fleet size of $275,797 per EMU car unit is applied as the OPEX model unit cost.

Figure G-1 Commuter Rail EMU annal vehicle maintenance estimate

Commuter Rail EMU Annual Vehicle Maintenance Estimate

Data from 2016 National Transit Database unless otherwise noted

2016	EMU Services				Relative Cost of Maintenance [1]					Veh Maint			Vehicle Maintenance Workers					Annual Inflation:	3%
					1	1.1	0.4	Weighted										2016	2019
State	Agency	Service	VOMS	VAMS	EMUs	Locos	Coaches	Total	%EMUs	($)	wtd $/VAM	$/EMU	Hours	Count	Salary	Avg Hrly [4]	% Veh Maint	%Boston COL [2]	ADJ $/EMU	ADJ $/EMU
NY	MTA	MNRR	1,164	1,206	917	43	246	1062.7	76%	273,134,029	257,019	$ 257,019	2740059	1723	$ 106,090,901	$ 38.72	39%	118%	$ 241,790	$ 264,211
IN	NICTD	South Shore	70	82	82	0	0	82	100%	13,701,317	167,089	$ 167,089	223744	112	$ 5,449,792	$ 24.36	40%	62%	$ 207,823	$ 227,094
NY	MTA	LIRR	1,020	1,185	986	45	154	1097.1	83%	431,291,960	393,120	$ 393,120	4432342	2054	$ 181,076,500	$ 40.85	42%	118%	$ 367,943	$ 402,061
PA	SEPTA	Regional Rail	339	404	351	8	45	377.8	87%	49,450,735	130,891	$ 130,891	766876	369	$ 23,372,576	$ 30.48	47%	83%	$ 143,562	$ 156,875
CO	RTD	Commuter Rail	18	66	58	0	8	61.2	88%	7,695,721	125,747	$ 125,747				$ 35.75	42%	75%	$ 143,338	$ 156,629
				Total	2,394															
																	Average		$ 220,891	$ 241,374
																	Avg Weighted by Fleet Size		$ 275,797	$ 301,371

NOTES

[1] Relative costs of maintenance between vehicle types based on previous work for Caltrain (CA)

[2] Cost of Living Adjustments based on nerdwallet.com. Brooklyn, NY used for LIRR & MNRR; South Bend, IN for NICTD; Philadelphia for SEPTA; Denver for RTD

[3] NTD does not include worker data for RTD; "% Veh Maint" (highlighted in yellow) assumed to be average of other agencies

[4] RTD Average Hourly rate based on experience directly with RTD; provided here for information only

Apply this unit cost to OPEX model

Electric Locomotive Vehicle Maintenance Costs

The vehicle maintenance costs for electric locomotives are provided within the OPEX model on a per vehicle unit basis. A per **vehicle unit cost of $416,409** is applied to the OPEX model based on industry experience, and the US experience that electric locomotives cost approximately 75% more per year to maintain than diesel locomotives in the US. The Keolis BAFO annual diesel locomotive maintenance cost is used as the base, increased by 75%.

Electric Traction (Propulsion) Power Costs

The electric traction power costs are developed within the OPEX model as a cost per car revenue mile, and are applied consistently for both EMUs and electric-locomotive hauled trains. The amount of electricity required for traction power is based on NTD data for energy consumption from the 2016 report year from four commuter railroads with electrified operations. These include: MNRR, Northern Indiana Commuter Transportation District (South Shore), Metra, and RTD. The average kilowatt hours (kWh) per car revenue mile is 8.3739.

To develop a cost per kilowatt hour, cost data was gathered from the U.S. Energy Information Agency for Massachusetts. As detailed in Figure G-2, the team decided to use the industrial sector cost of 13.38 cents per kilowatt hour (kWh), as it was relatively constant between 2013 and 2016. This consistency was not the case in the transportation sector, where there was a high degree of unexplained variability in the transportation sector cost (from 13.06 cents in 2013 to 5.94 cents in 2016, a disproportionate decrease compared to all other sectors). At 8.3739 kWh per car revenue mile, the resulting unit cost is **$1.12 per car revenue mile** in 2016 dollars, which is applied as the base unit cost in the OPEX model.

Figure G-2 Electric traction power costs

Electric Traction Power Costs

Kilowatt Hours Consumed (per National Transit Database, Report Year 2016)

NTD ID	Commuter Rail Agency	Electric Propulsionn kWh Consumed[1]	Actual Vehicles/ Passenger Car Revenue Miles[2]	kWh/mi
20078	Metro-North Commuter Railroad Company, dba: MTA Metro-North Railroad	491,058,874	60,153,756	8.1634
50104	Northern Indiana Commuter Transportation District	20,912,500	4,372,436	4.7828
50118	Northeast Illinois Regional Commuter Railroad Corporation dba: Metra Rail	71,319,130	5,088,406	14.016
80006	Denver Regional Transportation District	16,737,801	2,040,331	8.2035
	Total	**600,028,305**	**71,654,929**	**8.3739**

Cost per Kilowatt Hour (cents)[3]

	source key	2013	2014	2015	2016	2017
Massachusetts	ELEC.PRICE.MA-ALL.A					
Massachusetts : all sectors	ELEC.PRICE.MA	14.51	15.35	16.9	16.48	16.14
Massachusetts : residential	ELEC.PRICE.MA	15.83	17.39	19.83	19	18.92
Massachusetts : commercial	ELEC.PRICE.MA	14.23	14.68	15.79	15.6	14.88
Massachusetts : industrial	ELEC.PRICE.MA	13.18	12.74	13.54	**13.38**	13.48
Massachusetts : transportation	ELEC.PRICE.MA	13.06	8.76	7.76	5.94	6.22
Massachusetts : other	ELEC.PRICE.MA	--	--	--	--	--

Electric Traction Power Cost per Vehicle/Passenger Car Revenue Mile

Average kWh/mi	X	$ per kWh	=	Cost per Car Mile	
8.3739		$0.1338		**$1.12**	To OPEX Model

Notes: Only agencies with dedicated EMU (self-propelled passenger car) fleets for electric service are included.
1 Source: National Transit Database, Report Year 2016, Energy Consumption Table
2 Source: National Transit Database, Report Year 2016, Revenue Vehicle Inventory Table
3 Source: U.S. Energy Information Administration, https://www.eia.gov/electricity/data/browser
Because the Transportation Sector cost is markedly low between 2014 and 2017, elected to use the Industrial Sector cost for 2016.

END

Electric Power Distribution Mechanism

After reviewing the available literature on electrification costs, which primarily dates to the 1970's, the project team determined that the best source of publicly-available costs for maintaining overhead electric power distribution systems for rail is Amtrak. The electrified north end of Amtrak's maintained portion of the Northeast Corridor from New Haven to Boston (the New England Division) was constructed in the late 1990's. It is a fairly modern system using a constant-tension catenary.

From the Update on the Methodology for Amtrak Cost Accounting Amtrak Performance Tracking (APT) prepared by the USDOT's Volpe Transportation Center, Volume 1, page 81, electric traction maintenance costs made up 5.9% of the total maintenance of way costs for Amtrak's New England Division. Per this source, which relied on fiscal year 2014 data, Amtrak's annual electric traction maintenance cost is $4.1 million. With the 322 miles of electrified track between New Haven and Boston, this amounts to approximately $13,000 per track mile per year. These costs include, "catenary and support apparatus, transmission systems between power plants and the network, power substations along the corridor, and building and structures that house these systems" (page 74).

The report also states that for the Amtrak New England Division the share of these costs of the total Division's maintenance of way cost is 5.9%. In applying this rate to the MBTA Commuter Rail's experience, Commuter Rail's baseline $116.6 million annual maintenance of way (non-vehicle maintenance) total cost is first divided by 983 miles of track tp arrive at a total maintenance of way unit cost of $119,000 per track mile per year. Applying Amtrak's electric power distribution cost experience, the likely cost per track mile of maintaining the electric transmission system would be $7,000 per track mile. The lower cost is expected due to the MBTA's overall lower cost structure due to its contractual relationship and reduced wear as the MBTA maintains a predominantly 79 mph track network versus Amtrak's 150 mph track. This reduction is u nlikely to apply to the incremental cost of maintaining electric traction assets, and therefore Amtrak's $13,000 per track mile was initially recommended. After consultation within the team, a slightly conservative final cost of $13,600 per track mile is used as the unit cost within the OPEX model due to the potentially more complex network MBTA commuter rail will require versus Amtrak's single corridor.

Diesel Multiple Unit (DMU) Vehicle Maintenance Costs

The vehicle maintenance costs for DMUs are provided within the OPEX model on a per vehicle unit basis. The operating costs are based on NTD data from the 2016 report year from the three commuter/hybrid railroads that exclusively use DMUs within their fleets. These include: Denton County Transportation Authority (DCTA), Capital Metro Transportation Authority (CapMetro, or CMTA), and the Tri-County Metropolitan Transportation District (Tri-Met).

As Figure G-3 details, the total rail vehicle maintenance costs for each agency are adjusted for the Boston cost of living. Unfortunately the US experience in operating DMUs is relatively recent in addition to being limited to these three services. The costs appeared exceptionally low for DCTA and Tri-Met. These low costs are likely due to their individual procurement arrangements and warranties that result in a far lower figure than the more typical annual cost that will be incurred in future years. Therefore, only the CMTA MetroRail figure of $593,143 is used.

As the base costs within the OPEX model are for 2016, the uninflated 2016 average cost per unit is applied as the OPEX model unit cost. The CMTA figure is for a complete four-car DMU trainset. Therefore, this cost is divided by four, arriving at a per DMU car unit cost of $148,275 that is applied within the OPEX model.

Figure G-3 Commuter Rail DMU annual vehicle maintenance estimate

Commuter Rail DMU Annual Vehicle Maintenance Estimate

Data from 2017 National Transit Database unless otherwise noted

2016	DMU Services												Annual Inflation:	3%
									Veh Maint				2016	2019
State	Agency	Service	VOMS	VAMS	DMUs	Locos	Coaches	Total	%DMUs	($)	$/VAM	$/DMU	%Boston COL [2]	ADJ $/DMU	ADJ $/DMU
TX	DCTA	DCTA	8	11	11	0	0	11	100%	$353,519	32,138	$ 32,138	69%	$46,577	$50,896
TX	CMTA	MetroRail	4	6	6	0	0	6	100%	$2,348,845	391,474	$ 391,474	66%	**$593,143**	$648,143
OR	Tri-Met	Westide Express Svc	4	6	6	0	0	6	100%	$1,757,909	292,985	$ 292,985	86%	$3[illegible]0,680	$372,270
				Total	23										
												Average		$3[illegible]6,800	$357,103
												Avg Weighted by Fleet Size		$2[illegible]5,882	$290,536

NOTES

[1] Cost of Living Adjustments based on nerdwallet.com. Dallas, TX used for DCTA; Austin, TX for CMTA; Portland, OR for Tri-Met

(2) Only CMTA MetroRail cost is used as DCTA figures appear to be incorrect due to extremely low value, and TriMet WES includes a mix of equipment where some "units" are the equivalent of 4 cars and some are older single-car units.

(2) Apply this unit cost to OPEX model (base data is 2016 NTD)

END