March 2019

Potential MBTA Fare Changes in SFY 2020

Potential MBTA Fare Changes in SFY 2020

Final Proposal: Impact Analysis

Project Manager and Data Analyst
Steven Andrews

Project Principal
Katie Pincus Stetner

Map
Ken Dumas

Cover Design
Kate Parker-O'Toole

The preparation of this document was funded
by the Massachusetts Bay Transportation Authority

Central Transportation Planning Staff
Directed by the Boston Region Metropolitan
Planning Organization. The MPO is composed of
state and regional agencies and authorities, and
local governments.

March 2019

To request additional copies of this document or copies in an accessible format, contact:

Central Transportation Planning Staff
State Transportation Building
Ten Park Plaza, Suite 2150
Boston, Massachusetts 02116

(857) 702-3700
(617) 570-9192 (fax)
(617) 570-9193 (TTY)

ctps@ctps.org
ctps.org

Abstract

This study analyzes the various effects of a potential MBTA fare-pricing scenario aimed at raising revenue to help meet revenue targets in state fiscal year 2020. The proposed scenario would raise new revenue stemming from a 5.8 percent average fare increase.

TABLE OF CONTENTS PAGE

APPENDIX

TABLES

Executive Summary

Before considering any changes in fares, the MBTA undertakes a comprehensive process to model the impacts of the changes. This modeling was conducted with the assistance of the Central Transportation Planning Staff (CTPS), which is the staff of the Boston Region Metropolitan Planning Organization (MPO). CTPS examined the impacts on ridership, revenue, and fare equity.

CTPS used an elasticity-based spreadsheet model known as the Fare Elasticity, Ridership, and Revenue Estimation Tool (FERRET) to estimate projected ridership loss associated with the proposed fare increase and the net revenue change that would result from lower ridership and higher fares. The table below summarizes these results. CTPS produced a range of estimates of potential impacts on ridership and revenue and conducted a Title VI of the Civil Rights Act of 1964 (Title VI) fare-equity analysis to determine if the fare changes would result in disparate impacts for minority populations or disproportionate burdens for low-income populations.

On January 28, 2019, a proposed set of fare changes and corresponding fare equity analysis were presented to the MBTA's Fiscal and Management Control Board (FMCB). On March 11, 2019, the FMCB approved an updated set of fare changes. This report, an update of the January 2019 version, presents the impacts of the approved fares.

Table
Revenue and Ridership Projections
for the Proposed Fare Increase: SFY 2020

Analysis Category	Existing Values	SFY 2020 Projections	Projected Change	Projected Pct. Change
Ridership	359.4 M	355.1 M	-4.4 M	-1.2%
Revenue	$710.9 M	$740.3 M	$29.5 M	4.1%

M = Million. SFY = State fiscal year.
Source: Central Transportation Planning Staff.

In CTPS's fare-equity analysis, staff compared the relative fare increases between riders who are minorities and all riders, and between riders who are low-income and all riders. We applied the MBTA's disparate-impact and disproportionate-burden policies and found neither the presence of a disparate impact nor a disproportionate burden.

Chapter 1—Introduction

In past years, the MBTA has managed to balance its budget through cost reductions, special appropriations by the Legislature, and fare and fee increases. In 2007, simultaneous with the introduction of the Automated Fare Collection (AFC) technology, the MBTA restructured its fare system and raised fares an average of 21 percent. The Authority did not raise fares again until July 2012 (State Fiscal Year [SFY] 2013), when it implemented a 23 percent average increase. Almost a year later, the state Legislature—in Chapter 46 of the Acts of 2013: An Act Relative to Transportation Finance—required that the MBTA attain revenue benchmarks, which it could satisfy by changing fares, fees, or any other funds directly collected by the Authority. In response, the MBTA established a pattern of modest, regularly scheduled fare changes, as needed, beginning with fare increases in SFY 2015 and SFY 2017. Following the SFY 2017 fare increase, the state Legislature—in Chapter 164 of the Acts of 2016: An Act Relative to MBTA Fare Increases—amended previous legislation to clarify the parameters by which the MBTA could raise fares. This legislation made it clear that no fare (including pass prices) shall be increased by more than 7 percent during a 24-month period. Under these specifications, the MBTA is continuing its pattern of frequent but modest fare increases by increasing fares in SFY 2020.

1.1 DOCUMENT STRUCTURE

The remainder of this document is organized as follows:

- Review of the methodology used for the analysis (Chapter 2)
- Description of the proposed fare changes (Chapter 3)
- Results of ridership and revenue analyses (Chapter 4)
- Results of a fare-equity analysis (Chapter 5)
- Conclusions (Chapter 6)

A detailed description of the FERRET methodology is provided in Appendix A.

Chapter 2—Methods Used to Estimate Ridership and Revenue

In consultation with the MBTA, CTPS used the spreadsheet application, FERRET, specifically to perform fare-change calculations to estimate the impact of the proposed fare increase on MBTA's ridership and revenue.

2.1 CTPS FERRET APPROACH

FERRET estimates the revenue and ridership impacts of the proposed fare-increase scenario. This model reflects the many fare-payment categories of the MBTA pricing system and applies price elasticities to analyze various changes across these categories. CTPS determined that this methodology met expectations through two post-fare increase analyses: 1) following the SFY 2007 fare restructuring, and 2) following the SFY 2013 fare increase. Following the SFY 2017 fare increase, a researcher reviewed some of FERRET's features, structure, and assumptions. In response to this research, CTPS modified some of the underlying price elasticities.[1]

2.1.1 Modeling of Existing Ridership and Revenue

Inputs to FERRET include existing ridership in the form of unlinked trips by mode, fare-payment method, and fare-media type. An unlinked trip is an individual trip on any single transit vehicle; a single journey, often composed of many unlinked trips on multiple vehicles, is a "linked trip."

The MBTA provided CTPS with existing ridership statistics (to which FERRET applies price elasticity values) for local bus, express bus, and rapid transit networks in the form of AFC data. These data, by station for pre-payment stations and by route for buses and surface light rail segments, show fare payment type (for example, cash, monthly pass, and weekly pass) and fare media (for example, CharlieCard, CharlieTicket, cash).

Because the MBTA has not deployed AFC equipment on the commuter rail or commuter boat systems, CTPS estimated the number of trips made on these modes using sales figures. Single-ride trips on commuter rail and ferry were set equal to the number of single-ride fares sold. Staff estimated the number of trips made using passes on these modes by multiplying the number of pass sales by the estimated average number of trips made using the respective pass type (calculated using survey responses from a corporate pass-users survey

[1] Stutz, Andrew. Transit Fare Policy: Use of Automated Data to Improve Incremental Decision Making. Cambridge: Massachusetts Institute of Technology, 2018.

conducted in spring 2008). In some cases, the total number of trips by fare type was scaled to match the total ridership reported by the MBTA during the state fiscal year being analyzed. The MBTA also provided data for the number of trips made on THE RIDE by fare payment type, and the number of cars parked at MBTA parking lots.

FERRET calculates revenue for single-ride trips by multiplying the number of trips in each fare/mode category by that category's price. FERRET calculates revenue for pass trips by pass type by multiplying the number of pass sales by the pass price. The model distributes pass revenue between mode categories based on each category's ridership and most-equivalent single-ride fare (generally, the lowest-priced adult fare).

2.1.2 Estimation of Ridership Changes Resulting from a Fare Increase

Fares are one of many factors that influence the level of ridership on transit services. Price elasticity is a measure of the rate of change in ridership relative to a change in fares if all other factors remain constant. On a traditional demand curve that describes the relationship between price, on the y-axis, and demand, on the x-axis, elasticities are equivalent to the slope along that curve. Price elasticities are usually negative, meaning that a price increase will lead to a decrease in demand (with a price decrease having the opposite effect). The larger the negative value of the price elasticity (the greater its distance from zero), the greater the projected impact on demand. Larger (more negative) price elasticities are said to be relatively "elastic," while smaller negative values (closer to zero), are said to be relatively "inelastic." Thus, if the price elasticity of the demand for transit were relatively elastic, a given fare increase would cause a greater loss of ridership than if demand were relatively inelastic. Appendix A.5 presents an example of how the concept of price elasticity is applied.

FERRET permits the use of various ranges of elasticities to estimate different possible ridership impacts of price increases. Performing calculations in FERRET with the same prices but with a range of higher and lower elasticities provides a range of estimates. In the present analysis, the model uses the middle range of elasticities, called the base elasticities, as these represent the best estimate of where the elasticities should be set based on past experience. For a description of how we determined the base elasticities, see Appendix A.4. However, we also use both more inelastic and more elastic elasticity values to determine a range of possible effects; the lower and higher ranges are the base value plus or minus 0.10. If adding 0.10 to the base elasticity would result in an elasticity of 0.00, we added 0.05 instead. This serves as a sensitivity analysis of the model's projections of the ridership losses and revenue gains. Table 1 presents the three elasticity ranges used in FERRET for this study's analysis.

FERRET also uses ridership diversion factors. These factors reflect estimates of the likelihood of a switch in demand from one MBTA product type or mode to another resulting from a change in the relative prices of product types or modes. The diversion factors essentially work to redistribute demand between two product types or modes after the model applies the respective price elasticities. Appendix A.6 presents examples of applying diversion factors and the methodology for using combined price elasticities and diversion factors. While diversion factors estimate the migration of riders between MBTA product types and modes based on their price, FERRET can only estimate the total loss of riders from the MBTA transit system, not the diversion of riders to specific non-MBTA modes such as driving, biking, or walking.

Table 1
Single-Ride and Pass Elasticities by Fare Type and Mode

Mode Category	Low	Base	High
Cash Elasticities			
Bus and Trackless Trolley			
Bus-Adult	(0.15)	(0.25)	(0.35)
Bus-Senior	(0.10)	(0.20)	(0.30)
Bus-Student	(0.05)	(0.15)	(0.25)
Subway			
Subway-Adult	(0.15)	(0.25)	(0.35)
Subway-Senior	(0.05)	(0.15)	(0.25)
Subway-Student	(0.05)	(0.10)	(0.20)
Surface Light Rail			
Surface Light Rail-Adult	(0.20)	(0.30)	(0.40)
Surface Light Rail-Senior	(0.10)	(0.20)	(0.30)
Surface Light Rail-Student	(0.05)	(0.15)	(0.25)
Commuter Rail			
Commuter Rail-Adult	(0.10)	(0.20)	(0.30)
Commuter Rail-Senior	(0.05)	(0.15)	(0.25)
Commuter Boat			
Commuter Boat-Adult	(0.20)	(0.30)	(0.40)
Commuter Boat-Senior	(0.15)	(0.25)	(0.35)
THE RIDE	(0.25)	(0.35)	(0.45)
Parking	(0.10)	(0.20)	(0.30)
Pass Elasticities			
Bus	(0.05)	(0.15)	(0.25)
Inner Express	(0.15)	(0.25)	(0.35)
Outer Express	(0.15)	(0.25)	(0.35)
LinkPass	(0.15)	(0.25)	(0.35)
1-Day LinkPass	(0.05)	(0.15)	(0.25)
7-Day LinkPass	(0.20)	(0.30)	(0.40)
Commuter Rail	(0.05)	(0.10)	(0.20)
Commuter Boat	(0.10)	(0.20)	(0.30)
Senior	(0.05)	(0.10)	(0.20)
Student/Youth	(0.05)	(0.10)	(0.20)

Source: SFY 2018 FERRET.

Chapter 3—Description of Proposed Fare Increase Scenario

3.1 FARE CHANGE RATIONALE

It was the MBTA's goal to increase fares in a mostly uniform fashion across fare categories while respecting the 7 percent fare increase limit. When a fare would exceed the limit, the MBTA chose the next smallest fare using the following rounding methodology. Pass prices were generally rounded to the nearest dollar. Fares on the commuter rail and boats were generally rounded to the nearest quarter. Fares on buses and rapid transit were rounded to the nearest nickel. In some cases, the MBTA chose to depart from a uniform fare increase. These anomalies were allowed to prepare for future changes to the way people pay for their trips, to simplify and standardize the existing fare structure, and to address concerns from the public about the impacts of the initially proposed fares.

3.2 FARE CHANGES: SINGLE-RIDE FARES AND PASS PRICES

Table 2 shows key existing and proposed single-ride fares for each fare category, along with the percentage change from existing to proposed price. Table 3 shows the same information for the pass prices. Table 4 presents the value of monthly passes in terms of their single-ride equivalents, also known as a "multiple," a concept discussed at the end of this section. The MBTA is not implementing parking fee increases as part of this fare and fee structure change.

The overall proposed price increase across all modes and fare/pass categories is 5.8 percent. This systemwide average is based on the percentage change between the existing average fare (total revenue divided by existing ridership) and the proposed average fare (total projected revenue divided by total projected ridership). Table 4 presents these average percentage increases by mode category. Percentage changes in price can differ between modes that are similarly priced, such as local bus and the Silver Line–Washington Street, or subway and surface light rail, because of differences in how riders on these modes pay for their trips (if more riders were to use a monthly pass on the subway than on the surface light rail system, for example).

The percentage changes in prices are relatively consistent across fare payment types. The most notable departures from the baseline are:

- Commuter rail interzone 1–3 fares do not increase because the smallest desired increase of a quarter on these fares would exceed 7 percent

- Neither the outer express single-ride fares nor the outer express pass price increases in order to move toward creating a single express bus category
- The reduced inner express and outer express bus fares decrease to half the CharlieCard fare to match the same logic as the reduced fares on the other service types
- The fare for ferry riders traveling from Hingham and Hull to Logan Airport decreases to the same amount as the fare for Hingham and Hull to Boston

On January 28, 2019 a proposed set of fare changes and corresponding fare equity analysis were presented to the FMCB. On March 11, 2019, the FMCB approved an updated set of fare changes. The FMCB's final proposal includes the following departures from the January 2019 proposal:

- The fares on the MBTA's local bus system remain the same
- The reduced fares and passes on the local bus and rapid transit systems remain the same
- The weekend commuter rail pass was made permanent

In the tables in this document that contain specific fares (Table 2, Table 3, and Table 8), these changes from the initial proposal are highlighted in green.

Table 2
Key Single-Ride Fares: Existing and Proposed

Fare Category	Existing Fare	Proposed Fare	Percent Change	Absolute Change
CharlieCard				
Adult				
Local Bus	$1.70	$1.70	0.0%	$0.00
Rapid Transit	2.25	2.40	6.7%	0.15
Bus and Rapid Transit	2.25	2.40	6.7%	0.15
Inner Express	4.00	4.25	6.3%	0.25
Outer Express	5.25	5.25	0.0%	0.00
Senior and Student				
Local Bus	$0.85	$0.85	0.0%	$0.00
Rapid Transit	1.10	1.10	0.0%	0.00
Bus and Rapid Transit	1.10	1.10	0.0%	0.00
Inner Express	2.50	2.10	-16.0%	-0.40
Outer Express	3.50	2.60	-25.7%	-0.90
CharlieTicket or Cash				
Adult				
Local Bus	$2.00	$2.00	0.0%	$0.00
Rapid Transit	2.75	2.90	5.5%	0.15
Bus and Rapid Transit	4.75	4.90	3.2%	0.15
Inner Express	5.00	5.25	5.0%	0.25
Outer Express	7.00	7.00	0.0%	0.00
Commuter Rail				
Zone 1A	$2.25	$2.40	6.7%	$0.15
Zone 1	6.25	6.50	4.0%	0.25
Zone 2	6.75	7.00	3.7%	0.25
Zone 3	7.50	8.00	6.7%	0.50
Zone 4	8.25	8.75	6.1%	0.50
Zone 5	9.25	9.75	5.4%	0.50
Zone 6	10.00	10.50	5.0%	0.50
Zone 7	10.50	11.00	4.8%	0.50
Zone 8	11.50	12.25	6.5%	0.75
Zone 9	12.00	12.75	6.3%	0.75
Zone 10	12.50	13.25	6.0%	0.75
Interzone 1	$2.75	$2.75	0.0%	$0.00
Interzone 2	3.25	3.25	0.0%	0.00
Interzone 3	3.50	3.50	0.0%	0.00
Interzone 4	4.00	4.25	6.3%	0.25
Interzone 5	4.50	4.75	5.6%	0.25
Interzone 6	5.00	5.25	5.0%	0.25
Interzone 7	5.50	5.75	4.5%	0.25
Interzone 8	6.00	6.25	4.2%	0.25
Interzone 9	6.50	6.75	3.8%	0.25
Interzone 10	7.00	7.25	3.6%	0.25
Ferry				
F1: Hingham	$9.25	$9.75	5.4%	$0.50
F2: Boston	9.25	9.75	5.4%	0.50
F2: Cross Harbor	9.25	9.75	5.4%	0.50
F2: Logan	18.50	9.75	-47.3%	-8.75
F4: Inner Harbor	3.50	3.70	5.7%	0.20
THE RIDE				
ADA Service Area	$3.15	$3.35	6.3%	$0.20
Premium Service Area	5.25	5.60	6.7%	0.35

ADA = Americans with Disabilities Act.
Source: Central Transportation Planning Staff.

Table 3
Pass Prices: Existing and Proposed

Pass Category	Existing Fare	Proposed Fare	Percent Change	Absolute Change	Existing Multiple	Proposed Multiple
Local Bus	$55.00	$55.00	0.0%	$0.00	32.35	32.35
LinkPass	84.50	90.00	6.5%	5.50	37.56	37.50
Senior/TAP	30.00	30.00	0.0%	0.00	27.27	27.27
Youth Pass	30.00	30.00	0.0%	0.00	27.27	27.27
Student 7-Day Validity	30.00	30.00	0.0%	0.00	27.27	27.27
1-Day	12.00	12.75	6.3%	0.75	5.33	5.31
7-Day	21.25	22.50	5.9%	1.25	9.44	9.38
Inner Express	128.00	136.00	6.3%	8.00	32.00	32.00
Outer Express	168.00	168.00	0.0%	0.00	32.00	32.00
Commuter Rail						
Zone 1A	$84.50	$90.00	6.5%	$5.50	37.56	37.50
Zone 1	200.25	214.00	6.9%	13.75	32.04	32.92
Zone 2	217.75	232.00	6.5%	14.25	32.26	33.14
Zone 3	244.25	261.00	6.9%	16.75	32.57	32.63
Zone 4	263.00	281.00	6.8%	18.00	31.88	32.11
Zone 5	291.50	311.00	6.7%	19.50	31.51	31.90
Zone 6	318.00	340.00	6.9%	22.00	31.80	32.38
Zone 7	336.50	360.00	7.0%	23.50	32.05	32.73
Zone 8	363.00	388.00	6.9%	25.00	31.57	31.67
Zone 9	379.50	406.00	7.0%	26.50	31.63	31.84
Zone 10	398.25	426.00	7.0%	27.75	31.86	32.15
Interzone 1	$90.25	$90.00	-0.3%	-$0.25	32.82	32.73
Interzone 2	110.25	110.00	-0.2%	-0.25	33.92	33.85
Interzone 3	119.75	120.00	0.2%	0.25	34.21	34.29
Interzone 4	130.25	139.00	6.7%	8.75	32.56	32.71
Interzone 5	148.00	158.00	6.8%	10.00	32.89	33.26
Interzone 6	167.00	178.00	6.6%	11.00	33.40	33.90
Interzone 7	183.75	196.00	6.7%	12.25	33.41	34.09
Interzone 8	202.75	216.00	6.5%	13.25	33.79	34.56
Interzone 9	221.50	237.00	7.0%	15.50	34.08	35.11
Interzone 10	240.50	257.00	6.9%	16.50	34.36	35.45
Commuter Boat	$308.00	$329.00	6.8%	$21.00	33.30	33.74

TAP = Transportation Access Pass.
Source: Central Transportation Planning Staff.

Table 4
Weighted Average Percentage Change in Average Fares, by Mode Category, for Unlinked Passenger Trips

Mode Category	Percent Change
Bus	**0.7%**
Rapid Transit	**7.0%**
Subway	7.1%
Silver Line–Washington St.	0.2%
Silver Line–Waterfront	7.4%
Surface Light Rail	6.9%
Commuter Rail	**6.4%**
Zone 1A	6.9%
Zone 1	6.4%
Zone 2	6.1%
Zone 3	6.9%
Zone 4	6.8%
Zone 5	6.5%
Zone 6	6.7%
Zone 7	6.6%
Zone 8	6.7%
Zone 9	7.0%
Zone 10	7.0%
Interzone	3.7%
Onboard	5.3%
Ferry	**3.0%**
F1: Hingham-Boston	6.3%
F2: Boston	5.9%
F2: Cross Harbor	6.3%
F2: Logan	-51.2%
F4: Inner Harbor	5.6%
THE RIDE	**6.4%**
ADA Service Area	6.3%
Premium Service Area	6.7%
Total System	**5.8%**

Note: Price increases over 7 percent are a result of how pass revenue is allocated in the model. Because the bus fares remain constant, a relatively greater share of LinkPass revenue is shifted to the Rapid Transit system resulting in more revenue being allocated to that mode. No individual fares increase more than 7 percent.
ADA = Americans with Disabilities Act
Source: SFY 2018 FERRET.

Chapter 4—Ridership and Revenue Impacts

4.1 OVERVIEW OF RESULTS

We estimate that these proposed fare changes would increase the MBTA's annual revenue by $29.5 million and decrease annual unlinked passenger trips by 4.4 million.

4.2 FERRET ESTIMATES

4.2.1 Projections

Table 5 presents CTPS's estimates of the fare revenue and ridership impacts of the fare increase produced using FERRET and its base elasticities.[2] The existing fare revenue and ridership numbers in the table represent adjusted existing conditions prior to the fare increase.

The total estimated annual fare revenue increase in this scenario is $29.5 million, a 4.1 percent increase. We estimate that the total estimated annual ridership loss would be 4.4 million unlinked passenger trips, a 1.2 percent decrease. The estimated revenue increases are, on a relative basis, similar for all modes except for the bus and commuter boat systems. The MBTA will derive the plurality of its new fare revenue from the commuter rail system ($13.6 million). A similar amount would be derived from the heavy and light rail systems combined. We expect THE RIDE's fare increase to result in decreased use of the service; we estimate a decline of approximately 47,000 annual trips on THE RIDE.

The model uses diversion factors that account for riders shifting between some modes and fare products. The model does not account for riders shifting from a LinkPass to a monthly bus pass, which may be an option for some riders who can shift most of their travel to buses. The model's diversion factors between the bus and rapid transit system may not be calibrated to account for such a large differential between the two modes' fare increases. As a result, riders may switch from the rapid transit system to the bus system in larger numbers than the values reported here.

Changes in the relative proportions of revenue derived from each mode in the January 2019 version of this document are largely a result of how pass revenue is allocated. Because the single-ride rapid transit prices are proposed to increase and the bus fares remain constant, the model attributes more of the LinkPass revenue to the heavy and light rail systems.

[2] See Chapter 2 for a discussion of the range of elasticities used in this analysis.

Table 5
FERRET Estimates of Annual Revenue and Ridership Impacts
(in Unlinked Passenger Trips)

Mode	Existing Fare Revenue	Revenue Change	Revenue Change	Existing Ridership	Ridership Change	Ridership Change
Bus	$111,783,295	$243,511	0.2%	102,987,254	-621,474	-0.6%
Heavy Rail	217,679,243	11,915,781	5.5%	176,745,633	-2,753,627	-1.6%
Light Rail	69,322,123	3,634,583	5.2%	40,663,085	-645,752	-1.6%
Commuter Rail	245,306,776	13,646,730	5.6%	35,606,990	-287,533	-0.8%
Ferry	9,585,967	185,246	1.9%	1,338,167	-14,017	-1.0%
THE RIDE	6,300,957	253,826	4.0%	2,106,558	-47,154	-2.2%
Parking	50,887,162	-425,801	-0.8%	8,362,257	-63,714	-0.8%
Total System	710,865,523	29,453,876	4.1%	367,809,944	-4,433,271	-1.2%

Parking ridership and revenue losses are not a result of parking price increases; rather they are a result of riders who once parked no longer parking because another part of their trip became more expensive.
In this table, "Fare Revenue" represents the gross revenue generated from parking at lots where the MBTA retains the revenue. "Ridership" includes the number of vehicles that parked at these lots. Ridership losses on the bus system are primarily the result of FERRET predicting people will purchase fewer LinkPasses. The underlying diversion factors in the model are not calibrated to account for such a stark difference in price increases between the bus and rapid transit fare products. The model does not account for riders shifting from a LinkPass to a monthly bus pass.
Source: SFY 2018 FERRET.

4.2.2 Sensitivity Analysis

Table 5 shows the results of FERRET using the base elasticities. Table 6 presents a sensitivity analysis of the model's results, showing the range of estimated fare revenue and ridership impacts using the range of elasticities shown in Table 1. In the ranges of ridership-change estimates in the table, the greater losses are those resulting from higher elasticity assumptions; while in the ranges of fare-revenue-increase estimates, the greater increases are those resulting from lower elasticity assumptions.

Table 6
FERRET Estimate Ranges of Fare Revenue and Annual Ridership Impacts using Low and High Elasticities

Mode	Range of Increases in Revenue ($ in Millions)	Range of Revenue Percent Increases	Difference between Maximum and Minimum	Range of Ridership Changes (Trips in Millions)	Range of Ridership Percent Changes	Difference between Maximum and Minimum
Bus	-$0.2 to 0.6	-0.1 to 0.6%	$0.8	-0.91 to -0.34	-0.9 to -0.3%	0.57
Heavy Rail	$10.5 to 13.3	4.8 to 6.1%	$2.9	-3.81 to -1.73	-2.2 to -1.0%	2.08
Light Rail	$3.2 to 4.1	4.6 to 5.9%	$0.9	-0.88 to -0.41	-2.2 to -1.0%	0.47
Commuter Rail	$12.0 to 14.8	4.9 to 6.0%	$2.7	-0.51 to -0.14	-1.4 to -0.4%	0.37
Ferry	$0.1 to 0.2	1.4 to 2.4%	$0.1	-0.02 to -0.01	-1.5 to -0.6%	0.01
THE RIDE	$0.2 to 0.3	3.3 to 4.7%	$0.1	-0.06 to -0.03	-2.9 to -1.6%	0.03
Parking	-$0.6 to -0.3	-1.3 to -0.5%	$0.4	-0.10 to -0.04	-1.2 to -0.4%	0.06
Total System	$25.2 to 33.1	3.5 to 4.7%	$7.9	-6.29 to -2.70	-1.7 to -0.7%	3.59

*These values refer to the percentage increase for the total changes in revenue or ridership systemwide compared to existing systemwide values. The 4.7 percent relative revenue increase corresponds to a $33.1-million increase. The larger percentage revenue increase and smaller ridership decreases relate to the lower set of elasticity assumptions.
In this table, “Fare Revenue” includes revenue generated from parking at lots where the MBTA retains the revenue. “Ridership” includes the number of vehicles that parked at these lots.
Source: SFY 2018 FERRET.

Chapter 5—Fare Equity Analysis

5.1 REQUIREMENTS

Title VI of the Civil Rights Act of 1964 prohibits discrimination, either intentionally or unintentionally, by recipients of federal financial assistance based on race, color, or national origin. To comply with 49 CFR Section 21.5(b) (2), 49 CFR Section 21.5(b) (7), and Appendix C to 49 CFR Part 21, the MBTA must evaluate any fare changes to fixed-route modes prior to implementation to determine if the proposed changes would have a discriminatory effect. The FTA provides guidance for conducting fare equity analyses in FTA Circular 4702.1B ("Circular"), Section IV.7.b. Prior to a fare change, the MBTA must analyze any available information generated from ridership surveys that indicates whether minority and/or low-income riders would be disproportionately more likely than overall riders to use the mode of service, payment type, or payment media that would be subject to a fare change. In addition, the MBTA must describe the datasets and collection methods used in its analysis.

The Circular states that the transit provider shall:

- Determine the number and percentage of users of each fare media subject to change
- Review fares before and after the change
- Compare the relative cost burden impacts of the proposed fare change between minority and overall users for each fare media
- Compare the relative cost burden impacts of the proposed fare change between low-income and overall users for each fare media

Under Title VI and other directives, the FTA requires that transit agencies develop a policy to assess whether a proposed fare change would have a "disparate impact" on minority populations or "disproportionate burden" on low-income populations. The FTA Title VI guidelines define "disparate impact" as "a facially neutral policy or practice that disproportionately affects members of a group identified by race, color, or national origin, where the recipient's policy or practice lacks a substantial legitimate justification and where there exists one or more alternatives that would serve the same legitimate objectives, but with less disproportionate effects on the basis, of race, color, or national origin," and "disproportionate burden" as "a neutral policy or practice that disproportionately affects low-income populations more than non-low income populations." A finding of disproportionate burden requires the recipient to evaluate alternatives and mitigate burdens where practicable.

5.2 MBTA TITLE VI DISPARATE-IMPACT AND DISPROPORTIONATE-BURDEN POLICY

5.2.1 Policy Thresholds

The MBTA's January 30, 2017, Disparate Impact/Disproportionate Burden (DI/DB) Policy explains the methodology to be used for fare equity analyses.

> For all fare changes, the MBTA will compare the percentage change in the average fare for minority and overall riders and for low-income and overall riders. For fare-type changes across all modes, the MBTA will assess whether minority and low-income customers are more likely to use the affected fare type or media than overall riders. Any or all proposed fare changes will be considered in the aggregate and results evaluated using the fare DI/DB threshold, below.
>
> The MBTA's threshold for determining when fare changes may result in disparate impacts or disproportionate burdens on minority or low-income populations, respectively, is 10%.
>
> *MBTA Disparate Impact/Disproportionate Burden (DI/DB) Policy*

The policy thresholds are encapsulated in the following equations:

A disparate impact would be found if:

Minority Average Fare Decrease < 90% × All-Rider Average Fare Decrease
Minority Average Fare Increase > 110% × All-Rider Average Fare Increase

A disproportionate burden would be found if:

Low-income Average Fare Decrease < 90% × All-Rider Average Fare Decrease
Low-income Average Fare Increase > 110% × All-Rider Average Fare Increase

> Upon finding a potential disparate impact on minority populations from a proposed fare change, the MBTA will analyze alternatives/revisions to the proposed change that meet the same goals of the original proposal. Any proposed alternative fare change would be subject to a fare equity analysis. The MBTA will implement any proposal in accordance with then current FTA guidance.

> Where potential disparate impacts are identified, the MBTA will provide a meaningful opportunity for public comment on any proposed mitigation measures, including any less discriminatory alternatives that may be available.
>
> Upon finding a potential disproportionate burden on low-income populations from a proposed fare change, the MBTA may take steps to avoid, minimize, or mitigate these impacts, where practicable.
>
> *MBTA Disparate Impact/Disproportionate Burden (DI/DB) Policy*

5.2.2 Demographics and Definitions

Demographics

The systemwide demographic profile in Table 7 shows how the MBTA's ridership characteristics in terms of minority and low-income status vary by mode. Minority and low-income profile data of the MBTA's ridership are from the MBTA 2015–17 Systemwide Passenger Survey report published in May 2018.

Table 7
Demographic Profiles of MBTA Riders by Mode

Mode	Minority	Non-minority	Low-Income	Non-Low-Income
Rapid Transit	30.8%	69.2%	26.5%	73.5%
Bus and Trackless Trolley	48.0%	52.0%	41.5%	58.5%
Silver Line (BRT)	41.7%	58.3%	24.9%	75.1%
Commuter Rail	14.6%	85.4%	6.8%	93.2%
Commuter Ferry and Boat	1.7%	98.3%	3.7%	96.3%
Total	**34.3%**	**65.7%**	**28.8%**	**71.2%**

Source: 2015–17 MBTA Systemwide Passenger Survey.

Minority- and Low-Income Populations

Respondents to the 2015–17 Systemwide Passenger Survey were classified as having minority status if they self-identified as a race other than white and/or were Hispanic or Latino/Latina. Respondents whose household income is less than $43,500—the income category from the survey that most closely matched 60 percent of the median household income for the MBTA service area from the 2013 American Community Survey—were classified as low-income.

5.3 DATASETS, DATA COLLECTION EFFORTS, AND DESCRIPTIONS

CTPS used several datasets in the fare equity analysis:

- CTPS FERRET (which incorporates MBTA ridership and sales data)
- MBTA 2015–17 Systemwide Passenger Survey, published in May 2018

FERRET is an elasticity-based spreadsheet model. CTPS has used this model in the past to provide inputs to the fare-increase analysis process. FERRET takes existing ridership in the form of unlinked trips by mode, fare-payment type, and fare media as inputs. The MBTA provides CTPS with ridership data from the automated fare collection system. For modes that are not part of the AFC system, the MBTA provides data (most notably, sales data for transit passes) to estimate ridership. Using these input data, FERRET employs elasticities and diversion factors to model a range of possible impacts resulting from changes in the MBTA's fares. (See Chapter 2 and Appendix A for further detail.)

The MBTA 2015–17 Systemwide Passenger Survey report, published in May 2018, included all of the transit modes provided by the MBTA—the heavy rail Red, Blue, and Orange Lines; the light rail Green Line and Mattapan Trolley; the Silver Line bus rapid transit; the commuter rail system; the bus system; and the ferry system. The survey did not capture riders of the MBTA's purchased service bus routes; the MBTA is currently planning to conduct a supplemental survey effort to collect data about these routes. The survey asked questions regarding trip origins, destinations, and most important to this equity analysis, fare payment method, trip frequency, race, ethnicity, and income.

CTPS first launched the survey online and advertised its availability throughout the MBTA system. When the response rate to the online survey slowed, staff distributed the survey on paper forms at stations/stops and on vehicles. To compensate for differences in response rates among services, responses from each unlinked trip segment were weighted in proportion to the number of typical daily boardings for a corresponding station, group of stations, route, or route segment. The systemwide survey results were used in conjunction with FERRET to estimate the number of riders using each fare type, and the magnitude of the fare changes for low-income, minority, and all riders.

5.4 EQUITY ANALYSIS AND RESULTS

CTPS used the MBTA Systemwide Survey in conjunction with FERRET to determine the number of riders using each fare type and the price change by fare type for minority, low-income, and all riders. Because the model's ridership values are in trips and the survey's values are in riders, CTPS used the survey responses for the frequency of travel, fare type, and minority/income status to

translate surveyed riders into trips per surveyed rider by fare type by minority status and income status.

We used the equation below to determine the number of days per week a fare is used by riders of a specific demographic classification. We weighted each survey response by the number of days per week the rider made that trip—data we also obtained from the systemwide survey. For example, if 1,000 minority riders use monthly passes to make a trip five days per week and 200 minority riders use monthly passes to make a trip seven days per week, the average weighted usage per week for the minority riders using passes is equal to 5.33 days per week:

$$\text{Minority Rider Pass Usage} = \frac{1{,}000 \times 5 + 200 \times 7}{1{,}000 + 200} = 5.33$$

The response selections for the question “I make this trip on the MBTA…” were “6–7 days a week,” “5 days a week,” “3–4 days a week,” “1–2 days a week,” “1–3 days a month,” and “Less than once a month.” When calculating the above formula, we set the weekly usage rate to 6.5, 5.0, 3.5, 1.5, 0.5, and 0.125 days per week.

We used the equation below to determine the percentage of all users of a given fare type accounted for by minority riders. For example, if minority riders used passes 5.33 days per week, and nonminority riders used passes 4.25 days per week, and minority riders made up 25 percent of the total pass fare responses, the percentage of minority riders using that fare type is:

$$\text{Minority Rider Pass Percentage} = \frac{5.33 \times 25\%}{(5.33 \times 25\%) + (4.25 \times 75\%)} = 29.5\%$$

We used this procedure for each type of fare to estimate the share of riders by demographic classification who use that fare type. We multiplied the resulting percentage by the total number of trips made using a fare type to estimate the number of riders by classification by fare. For example, if the MBTA recorded 50 million total trips made using passes, the minority rider usage would be:

$$\text{Total Minority Rider Usage} = 29.5\% \times 50 \text{ million trips} = 14.8 \text{ million trips}$$

Table 8 provides a snapshot of fare type usage by demographic group.[3] Low-income riders are somewhat less likely to use the monthly LinkPass. When using a single-ride fare, minority riders and low-income riders are more likely to be on a bus and paying a student or senior fare. In an effort to decrease the impact of the fare increase on minority and low-income riders, the MBTA proposal maintains the existing reduced bus and rapid transit fares and passes. The MBTA proposal also maintains the existing bus fares. Riders who currently use a CharlieTicket or pay cash can obtain a CharlieCard to gain access to lower single-ride fares.

Minority and low-income riders are more likely to use a 7-Day LinkPass than a monthly LinkPass compared to all riders.[4] The 7-Day LinkPass allows passengers who cannot afford to—or for some other reason do not—purchase a monthly pass at the beginning of the month to spread their purchases out over a longer period. Four 7-Day LinkPasses cost the same as a monthly LinkPass. The 7-Day LinkPass is also somewhat more flexible—if someone knows they are not going to make enough trips in a given week for the pass to be worthwhile (say, during the winter holidays or school vacation), they can choose not to purchase it for that week.

[3] Minority and low-income riders share some of the same payment characteristics; however, the difference between how low-income riders and all riders pay is significantly more notable than the difference between payment trends of minority riders and all riders.

[4] The 7-Day LinkPass and the monthly LinkPass provide unlimited access to all local bus and rapid transit services.

Table 8
Minority, Low-Income, and All Riders Using Each Principal Fare-Payment Type

	Price		Change		Annual Usage in Unlinked Trips			Annual Usage Share of Group Total		
Fare-Payment Type	Existing	Proposed SFY 2020	Absolute	Percent	Minority	Low-Income	All Riders	Minority	Low-Income	All Riders
Local Bus										
Local Bus Pass	$55.00	$ 55.00	$ 0.00	0.0%	2,441,000	1,876,000	4,651,000	1.8%	1.5%	1.3%
Local Bus (Adult)	1.70	$ 1.70	0.00	0.0%	6,580,000	5,689,000	13,627,000	4.7%	4.6%	3.7%
Local Bus (Senior)	0.85	$ 0.85	0.00	0.0%	1,357,000	2,308,000	3,245,000	1.0%	1.9%	0.9%
Local Bus (Student)	0.85	$ 0.85	0.00	0.0%	1,145,000	969,000	1,501,000	0.8%	0.8%	0.4%
Local Bus (CharlieTicket)	2.00	$ 2.00	0.00	0.0%	380,000	460,000	692,000	0.3%	0.4%	0.2%
Local Bus (Cash)	2.00	$ 2.00	0.00	0.0%	856,000	1,045,000	1,676,000	0.6%	0.8%	0.5%
Express Bus										
Inner Express Pass	128.00	136.00	8.00	6.3%	740,000	350,000	2,123,000	0.5%	0.3%	0.6%
Inner Express (Adult)	4.00	4.25	0.25	6.3%	173,000	186,000	496,000	0.1%	0.2%	0.1%
Inner Express (Senior)	2.50	2.10	-0.40	-16.0%	24,300	29,600	65,100	0.0%	0.0%	0.0%
Inner Express (Student)	2.50	2.10	-0.40	-16.0%	16,700	24,000	26,300	0.0%	0.0%	0.0%
Inner Express (CharlieTicket)	5.00	5.25	0.25	5.0%	8,800	10,900	15,100	0.0%	0.0%	0.0%
Inner Express (Cash)	5.00	5.25	0.25	5.0%	23,700	39,600	62,700	0.0%	0.0%	0.0%
Outer Express Pass	168.00	168.00	0.00	0.0%	125,000	17,900	359,000	0.1%	0.0%	0.1%
Outer Express (Adult)	5.25	5.25	0.00	0.0%	11,000	7,700	95,800	0.0%	0.0%	0.0%
Outer Express (Senior)	3.50	2.60	-0.90	-25.7%	NR	NR	14,500	0.0%	0.0%	0.0%
Outer Express (Student)	3.50	2.60	-0.90	-25.7%	NR	NR	500	0.0%	0.0%	0.0%
Outer Express (CharlieTicket)	7.00	7.00	0.00	0.0%	NR	NR	2,400	0.0%	0.0%	0.0%
Outer Express (Cash)	7.00	7.00	0.00	0.0%	NR	NR	3,900	0.0%	0.0%	0.0%
Bus and Rapid Transit										
Bus and Rapid Transit (Adult)	2.25	2.40	0.15	6.7%	2,958,000	2,455,000	7,160,000	2.1%	2.0%	2.0%
Bus and Rapid Transit (Senior)	1.10	1.10	0.00	0.0%	474,000	824,000	1,347,000	0.3%	0.7%	0.4%
Bus and Rapid Transit (Student)	1.10	1.10	0.00	0.0%	360,000	313,000	483,000	0.3%	0.3%	0.1%
Bus and Rapid Transit (CharlieTicket)	4.75	4.90	0.15	3.2%	4,000	4,900	7,900	0.0%	0.0%	0.0%
Rapid Transit										
LinkPass	84.50	90.00	5.50	6.5%	27,712,000	19,738,000	80,844,000	19.9%	16.0%	22.2%
Senior/TAP Pass	30.00	30.00	0.00	0.0%	5,517,000	7,232,000	12,227,000	4.0%	5.9%	3.4%
Youth Pass	30.00	30.00	0.00	0.0%	716,000	653,000	1,000,000	0.5%	0.5%	0.3%
Student 7-Day	30.00	30.00	0.00	0.0%	8,589,000	7,633,000	11,821,000	6.2%	6.2%	3.3%
1-Day Pass	12.00	12.75	0.75	6.3%	631,000	587,000	791,000	0.5%	0.5%	0.2%
7-Day Pass	21.25	22.50	1.25	5.9%	24,991,000	23,781,000	36,669,000	18.0%	19.3%	10.1%
Rapid Transit (Adult)	2.25	2.40	0.15	6.7%	11,035,000	8,466,000	33,710,000	7.9%	6.9%	9.3%
Rapid Transit (Senior)	1.10	1.10	0.00	0.0%	906,000	1,668,000	3,714,000	0.7%	1.4%	1.0%
Rapid Transit (Student)	1.10	1.10	0.00	0.0%	918,000	873,000	1,331,000	0.7%	0.7%	0.4%
Rapid Transit (CharlieTicket)	2.75	2.90	0.15	5.5%	4,050,000	4,874,000	12,703,000	2.9%	4.0%	3.5%
Rapid Transit (Cash)	2.75	2.90	0.15	5.5%	NR	41,300	196,000	0.0%	0.0%	0.1%
Commuter Rail										
Zone 1A–10 Pass	$84.50–$398.25	$90.00–$426.00	$5.50–$27.75	6.5%–7.0%	5,648,000	2,197,000	31,540,000	4.1%	1.8%	8.7%
Zone 1A	$ 84.50	$ 90.00	$ 5.50	6.5%	1,501,000	680,000	4,631,000	1.1%	0.6%	1.3%
Zone 1	200.25	214.00	13.75	6.9%	380,000	38,500	1,892,000	0.3%	0.0%	0.5%
Zone 2	217.75	232.00	14.25	6.5%	592,000	208,000	4,625,000	0.4%	0.2%	1.3%
Zone 3	244.25	261.00	16.75	6.9%	709,000	263,000	4,761,000	0.5%	0.2%	1.3%
Zone 4	263.00	281.00	18.00	6.8%	737,000	218,000	4,428,000	0.5%	0.2%	1.2%
Zone 5	291.50	311.00	19.50	6.7%	397,000	218,000	2,432,000	0.3%	0.2%	0.7%
Zone 6	318.00	340.00	22.00	6.9%	681,000	277,000	4,417,000	0.5%	0.2%	1.2%
Zone 7	336.50	360.00	23.50	7.0%	347,000	130,000	2,072,000	0.2%	0.1%	0.6%
Zone 8	363.00	388.00	25.00	6.9%	294,000	152,000	2,215,000	0.2%	0.1%	0.6%
Zone 9	379.50	406.00	26.50	7.0%	6,500	8,500	43,500	0.0%	0.0%	0.0%
Zone 10	398.25	426.00	27.75	7.0%	3,500	4,600	23,600	0.0%	0.0%	0.0%

Fare-Payment Type	Price		Change		Annual Usage in Unlinked Trips			Annual Usage Share of Group Total		
	Existing	Proposed SFY 2020	Absolute	Percent	Minority	Low-Income	All Riders	Minority	Low-Income	All Riders
Zone 1A–10 Single Ride	$2.25–12.50	$2.40–13.25	$0.15–0.75	3.7%–6.7%	1,313,000	855,000	10,662,000	1.0%	0.8%	2.9%
Interzone 1–10 Pass	$90.25–221.50	$90.00–237.00	-$0.25–15.50	-0.3%–7.0%	19,000	7,500	127,900	0.0%	0.0%	0.0%
Interzone 1–10 Single Ride	$2.75–6.50	$2.75–6.75	$0.00–0.25	0.0%–6.3%	44,800	29,100	363,600	0.0%	0.0%	0.1%
Ferry										
Commuter Boat Pass	$ 308.00	$ 329.00	$ 21.00	6.8%	13,200	19,900	361,000	0.0%	0.0%	0.1%
F1: Hingham	9.25	9.75	0.50	5.4%	5,700	NR	438,000	0.0%	0.0%	0.1%
F2: Boston	9.25	9.75	0.50	5.4%	14,000	21,100	288,000	0.0%	0.0%	0.1%
F2: Cross Harbor	9.25	9.75	0.50	5.4%	NR	NR	1,200	0.0%	0.0%	0.0%
F2: Logan	18.50	9.75	-8.75	-47.3%	NR	NR	25,200	0.0%	0.0%	0.0%
F4: Inner Harbor	3.50	3.70	0.20	5.7%	NR	700	261,000	0.0%	0.0%	0.1%
Free Transfers and Other Fares										
In-station Transfers	Free	Free	-	-	17,665,000	16,029,000	46,745,000	12.7%	13.0%	12.9%
AFC Noninteraction[1]	Free	Free	-	-	7,790,000	7,790,000	22,508,000	5.6%	6.3%	6.2%
Free trips[2]	Free	Free	-	-	1,153,000	1,608,000	3,851,000	0.8%	1.3%	1.1%
Short fares[3]	Variable	Variable	-	-	1,321,000	1,686,000	2,940,000	0.9%	1.4%	0.8%

Notes: Values greater than 100,000 are rounded to the nearest 1,000. Values less than 100,000 are rounded to the nearest 100. Percentages are calculated using unrounded values. NR indicates that no riders from a given classification responded to the survey.
[1] AFC noninteraction is an estimate of the number of riders who do not interact with the AFC. The noninteraction categories include children aged 11 or younger, who are not required to pay a fare when riding with an adult; MBTA employees who are waved onto vehicles or otherwise bypass the AFC equipment; passengers who are allowed by MBTA employees to enter the paid area of a station without interacting with the AFC equipment; passengers who show an operator a valid pass rather than interacting with the farebox; passengers who board certain vehicles via the rear door; and passengers who simply do not pay a fare (not all of these categories apply to every mode).
[2] Free trips include people who are not required to pay a fare. Some of these people pay with the Blind Access Card.
[3] Short fares are fares paid less than the full fare.
AFC = Automated fare collection. NR = No responses to the 2015–17 systemwide passenger survey. SFY = State Fiscal Year. TAP = Transportation Access Pass.
Source: Central Transportation Planning Staff.

5.4.1 Minority Riders Compared to All Riders and Low-Income Riders Compared to All Riders

Table 9 presents existing and proposed average fares, and absolute and relative price changes for minority riders, low-income riders, and all riders. As the Circular indicates, fare equity analyses are applicable only to fixed-route modes; neither THE RIDE nor parking is included in the following analysis. Minority and low-income riders pay lower average fares compared to the overall average fare for all riders. This is largely because nonminority and non-low-income riders use the commuter rail system and other more expensive modes more than minority and low-income riders. At the proposed fare levels, minority and low-income riders would continue to pay lower average fares.

5.4.2 Results from Applying the Disparate-Impact and Disproportionate-Burden Policy Thresholds

The results of the equity analysis, shown in Table 9, show that there is no disparate impact on minority riders and no disproportionate burden on low-income riders when considering the relative fare changes.

Table 9
Existing and Proposed Average Fares and Price Changes
(Weighted by Fare Usage Frequency)

Rider Classification	Existing Average Fare	Proposed Average Fare	Absolute Price Change	Percentage Price Change
Minority	$1.39	$1.45	$0.06	4.40%
Low-income	$1.25	$1.30	$0.05	3.85%
All Riders	$1.83	$1.92	$0.10	5.21%

Note: The values in this table are rounded to the nearest cent or the nearest hundredth of a percent. All calculations were performed using unrounded values. The systemwide "All Riders" percentage price change reported here is different from the values reported in other parts of the report because we exclude revenue changes associated with THE RIDE or parking.
Source: SFY 2018 FERRET.

Application of the disparate-impact policy threshold shows the relative increase (or the change taken as a percentage of the initial fare) in the average fare for minority riders is 85 percent of the relative increase in the average fare for all riders.

Application of the disproportionate-burden policy threshold shows the relative increase in the average fare for low-income riders is 74 percent of the relative increase in the average fare for all riders.

Because all differences in impacts are less than the 10 percent threshold in the disparate-impact and disproportionate-burden policy, we do not find a disparate impact on minority populations or disproportionate burden for low-income populations.

5.4.3 A New Fare Product: Weekend Commuter Rail Pass

On the weekend of June 9, 2018, the MBTA started a pilot program that offered a $10 weekend pass, which is valid for unlimited travel on the commuter rail system for a single weekend. Riders are able to purchase this fare product at ticket windows, onboard the train, and using the mTicket mobile app. The MBTA decided to offer this product to encourage people to try the commuter rail service on weekends, when there is typically capacity for additional riders.

This section of the fare equity analysis presents a more detailed look at the riders who use this new fare type, the benefits they receive in fare savings, and how those benefits relate to the larger fare change analysis.

Weekend Pass User Surveys

Over three weekends, MBTA staff conducted in-person surveys of commuter rail riders at North and South stations.[5] Riders primarily completed the surveys in the afternoons between 2 PM and 6 PM. The MBTA asked riders questions to gather the following information:

- whether they planned to purchase their ticket at a ticket window, onboard a train, or through the mTicket app
- the destination of their trip
- how many one-way trips they planned to make during the given weekend
- their race, ethnicity, and income

To conduct the equity analysis, CTPS analyzed the responses from riders who said they planned to travel using a weekend pass.

In total, 180 surveyed riders said they planned to use the weekend pass to travel, although not all of those riders provided enough information to determine their minority and income statuses.

During a similar period, the MBTA also sent a survey to a sample of mTicket users and asked the same demographic questions. The intent of this survey was to attach demographic classifications to data for actual trips instead of relying on riders to accurately recall and report their trips. After reviewing the results, we determined that the trip-making data were not complete enough to use confidently for its intended purpose. However, the survey provides some insight about the demographics of riders who used the weekend pass over a longer period than the in-person survey. Riders who used the service from the onset of the pilot could have been selected to participate in the survey.

Demographics of Weekend Pass Users

While the new weekend pass fare product will be included in the equity analysis as part of the aggregate package of fare changes, CTPS first compared the demographics of weekend pass users to systemwide averages. Table 10 shows the number and proportion of In-person Commuter Rail Survey respondents by rider classification. The proportion of weekend pass riders who are classified as minority riders or low-income riders is significantly higher than the commuter rail

[5] MBTA staff surveyed riders in 2019 at North Station on February 10, 16, 17, and 24, and South Station on February 16, 17, and 24.

rider population, 15 percent and 7 percent, respectively, based upon the 2015–17 MBTA systemwide survey. The demographics of these riders are more similar to those of the rapid transit, bus, and trackless trolley riders based on the systemwide survey (see Table 7).

Table 10
Number and Proportion of Survey Respondents by Rider Classification

Rider Classification	Number of Respondents	Proportion	Margin of Error
Minority	58	37.6%	± 6.1%
Low-income	65	41.1%	± 6.8%

Note: 141 respondents provided enough information to determine their minority status, and 173 respondents provided enough information to determine their income status. The margin of error is based on a 90 percent confidence level.
Source: MBTA In-person Commuter Rail Survey (February 2019).

Of the mTicket users who took the online survey, approximately 25 percent ± 3 percent of the riders were classified as minority riders and approximately 31 percent ± 3 percent of the riders were classified as low income. Based on the in-person survey, riders classified as minority riders or low-income riders were more likely to pay in person rather than use the mTicket app.

Using the in-person survey, the estimate of the proportion of riders classified as minority riders is greater than the system average from the systemwide passenger survey (34.3 percent), but the lower bound of the estimate is lower that the systemwide average. Using the mTicket rider survey, the proportion of riders classified as minority riders is likely lower than the system average. Using either the in-person or the mTicket survey, the proportion of low-income riders is greater than the system average from the systemwide survey (28.8 percent).

The Weekend Pass in Combination with the Full Fare Increase

Even though the in-person survey suggests that the proportions of riders in protected classes who are benefitting from this new pass product are likely greater than the proportion of riders in the MBTA's general population, we included the effects of this new fare product as part of the larger fare change package. To complete this analysis, CTPS converted the benefit of the weekend pass into values we could incorporate into FERRET's fare equity analysis methodology.

The MBTA provided the number of weekend passes sold by sales channel for the first nine months of the weekend pass pilot. CTPS scaled those numbers up to annual sales values.

CTPS used the in-person survey data to estimate what riders would have paid for all of their trips if those riders had paid full price. We then subtracted the purchase price of the weekend pass from the full price of their trips to estimate the net benefit of each weekend pass. We calculated the average savings by rider classification and sales channel.

For each sales channel, we estimated the total benefit attributable to each protected class of riders by multiplying the number of passes sold by the proportion of tickets sold to each class of rider by the estimated benefit per weekend pass for the respective class.

We used the total savings by class of rider to adjust their proposed average fare. Table 11 presents the existing average fares and the proposed average fares with the weekend pass.

Table 11
Existing and Proposed Average Fares and Price Changes

Rider Classification	Existing Average Fare	Proposed Average Fare with Weekend Pass	Absolute Price Change	Percentage Price Change
Minority	$1.39	$1.42	$0.04	2.63%
Low-income	$1.25	$1.27	$0.02	1.67%
All Riders	$1.83	$1.90	$0.07	3.95%

Note: The values in this table are rounded to the nearest cent or the nearest hundredth of a percent. All calculations were performed using unrounded values. The existing average fare column matches the column in Table 9. The new proposed average fares with the weekend pass are lower than the proposed average fares in Table 9.
Source: SFY 2018 FERRET.

Application of the disparate-impact policy threshold shows the relative increase (or the change taken as a percentage of the initial fare) in the average fare for minority riders is 67 percent of the relative increase in the average fare for all riders.

Application of the disproportionate-burden policy threshold shows the relative increase in the average fare for low-income riders is 42 percent of the relative increase in the average fare for all riders.

Because all differences in impacts are less than the 10 percent threshold in the disparate-impact and disproportionate-burden policy, we do not find a disparate impact on minority populations or disproportionate burden for low-income populations.

Chapter 6—Conclusions

CTPS conducted an analysis of the impacts of fare changes on ridership and revenue using a methodology based on established data inputs. These analyses show that the MBTA fare proposal would generate approximately $29.5 million of additional revenue, with an anticipated ridership decrease of 4.4 million trips annually.

Staff applied the MBTA's disparate-impact and disproportionate-burden policy thresholds to assess the estimated Title VI and environmental justice impacts of the proposed fare changes. We do not expect the fare increase to cause disparate impacts or disproportionate burdens.

Appendix A: FERRET Methodology

A.1 APPORTIONMENT OF EXISTING RIDERSHIP

One of the first steps in starting a new iteration of Fare Elasticity, Ridership, and Revenue Estimation Tool (FERRET) is collecting new Automated Fare Collection (AFC) and sales data—these data represent the largest share of the MBTA's ridership and revenue—and revenue and ridership reports for the ferries, THE RIDE, and the MBTA's parking lots.

The MBTA provides CTPS with AFC data summarized by hour, by day, for the various combinations of fare type, fare mode, and fare media (Table A-1). After processing, AFC data can be attributed to each mode, fare type, and station (or Green Line branch). The fares for approximately 87 percent of all trips made on the system are paid using the AFC system.

The remaining trips are made using transit modes on which fares are not paid using the AFC system: commuter rail, commuter boat, THE RIDE, and parking. For these modes, we rely on fare-mix reports (that indicate how riders pay), various CTPS passenger surveys, and other ridership and revenue reports provided by the MBTA.

Table A-1
AFC Fare Categories

Fare Type	Fare Mode	Fare Media
Adult/Senior/TAP/Student/Free	Single-Ride	CharlieCard CharlieTicket Onboard Cash
Adult/Senior/TAP/Student	Transfer	CharlieCard CharlieTicket
Short (fares below the full value)	Single-Ride	Onboard Cash
Bus/Inner Express/Outer Express	Pass	CharlieCard CharlieTicket
LinkPass: Monthly/1-Day/7-Day	Pass	CharlieCard CharlieTicket
Commuter Rail Zone and Interzone/Commuter Boat	Pass	CharlieCard CharlieTicket
Senior/TAP/Student/Youth	Pass	CharlieCard CharlieTicket

AFC = Automated Fare Collection. TAP = Transportation Access Pass.
Source: Central Transportation Planning Staff.

A.2 PRICE ELASTICITY

Price elasticity measures the rate of change in ridership relative to a change in fares if all other factors remain constant. On a traditional demand curve that describes the relationship between price, on the y-axis, and demand, on the x-axis, elasticities are equivalent to the slope along that curve. Price elasticities generally are expected to be negative, meaning that a positive price increase would lead to a decrease in demand (with a price decrease having the opposite effect). The more negative (farther from zero) the value of a price elasticity, the larger the projected decrease in demand. More negative price elasticities are said to be relatively "elastic," while smaller negative values, closer to zero, are said to be relatively "inelastic." Thus, if the price elasticity of the demand for transit is assumed to be elastic, a given fare increase would cause a greater loss of ridership than if demand were assumed to be inelastic.

At its most elemental, FERRET is based on this simple price elasticity relationship, and requires four inputs: 1) original demand, 2) original fare, 3) new fare, and 4) price elasticity. The formula for calculating new demand is:

$$\text{New Demand} = \text{Original Demand} \times [1 + \text{Price Elasticity} \times (\text{New Fare} \div \text{Old Fare} - 1)]$$

As an example, assume that original demand equals 100 and that the impact we are modeling is a 10 percent fare increase from $1.00 to $1.10. Also assume that the price elasticity is -0.25.

$$\text{New Demand} = 100 \times [1 + -0.25 \times (\$1.10 \div \$1.00 - 1)] = 97.50$$

Thus, using an elasticity of -0.25, a simple price elasticity model projects that a 10 percent increase in price will lead to a 2.50 percent decrease in demand. With the fare increased from $1.00 to $1.10, this simplified example projects a 7.25 percent increase in revenue ($100.00 to $107.25).

A.3 DIVERSION FACTORS

FERRET's calculations are more comprehensive than a simple elasticity calculation. The model's greater detail lays in its use of ridership diversion factors. Diversion factors reflect estimates of the likelihood of a switch in demand for one type of good or service to another resulting from a change in the relative prices of those goods or services. In FERRET, we use such factors to estimate the number of riders who would choose to divert from one fare/mode to another.

Using cash tickets and passes as an example, assume that original ridership equals 100 cash riders and 1,000 pass riders. Also assume that original prices for cash tickets and passes equal $2.00 and $100.00, respectively, and that the

new prices are set at $1.50 for cash tickets and $50.00 for passes, representing price decreases of 25 percent and 50 percent, respectively. Assume that the cash price elasticity equals -0.35 and the pass price elasticity equals -0.25. Finally, assume a cash-to-pass diversion factor of 0.05 and a pass-to-cash diversion factor of 0.00.

In these calculations, one of the diversion factors must always equal zero, indicating that the diversion is expected to occur in one direction only. The direction of the diversion, and thus the diversion factor value, depends on the respective price changes of the two types of goods. The category with the greater relative price decrease (or the smaller relative price increase)—in this case, passes, for which the price decrease is 50 percent, compared to cash tickets, for which the price decrease is 25 percent—would gain riders from the diversion, while the other category, with the smaller relative price decrease (or the greater relative price increase), would lose riders from the diversion. Therefore, one would therefore expect that cash customers would switch to passes, but not that pass customers would switch to cash tickets, resulting in the 0.05 cash-to-pass and 0.00 pass-to-cash diversion factors.

The diversion factors essentially work to redistribute demand between the two categories after the respective price elasticities have been applied. For instance, after the cash fare is decreased from $2.00 to $1.50, the projected effect of price elasticity is that cash demand grows to 108.75 riders. Similarly, the pass price decrease from $100 to $50 leads to a projected increase in pass demand, because of price elasticity, to 1,125, for a total ridership of 1,233.75. However, the percentage decrease in the pass price is larger than that in cash fares (50 percent versus 25 percent); thus, one would expect some customers to switch from cash to pass.

This diversion is estimated by taking the ratio of new-to-original cash prices ($1.50 ÷ $2.00, or 75 percent), dividing that ratio by the ratio of new-to-original pass prices ($50 ÷ $100, or 50 percent), subtracting 1, and multiplying this result by the 0.05 diversion factor and the price-elasticity-estimated cash ridership (108.75). The number of riders “diverted” from cash to pass equals 2.72, giving final ridership estimates of 106.03 for cash and 1,127.72 for pass (still summing to a total ridership of 1,233.75).

New Cash Demand (Price Effect):

$$Cp = 100 \times [1 + -0.35 \times (\$1.50 \div \$2.00 - 1)] = 108.75$$

New Pass Demand (Price Effect):

$$Pp = 1{,}000 \times [1 + -0.25 \times (\$50 \div \$100 - 1)] = 1{,}125.00$$

Total Demand = 108.75 + 1,125.00 = 1,233.75

$$\text{Diverted Riders from Cash to Pass} = \left(\frac{\$NewCash/\$OldCash}{\$NewPass/\$OldPass} - 1\right) \times \text{Diversion} \times C_P$$

$$\text{Diverted Riders from Cash to Pass} = \left(\frac{\$1.50/\$2.00}{\$50/\$100} - 1\right) \times 0.05 \times 108.75 = 2.72$$

New Cash Demand = Cp − Diverted Riders from Cash to Pass = 106.03
New Pass Demand = Pp + Diverted Riders from Cash to Pass = 1,127.72
Total Demand = 106.03 + 1,127.72 = 1,233.75

We used diversion factors to estimate diversions between

- Cash and pass categories (for example, bus cash versus bus pass, subway cash versus subway pass)
- Bus and rapid transit (in other words, bus cash versus subway cash, bus pass versus subway pass)
- CharlieTicket/onboard cash and CharlieCard (for example, bus onboard cash versus bus CharlieCard, subway CharlieTicket versus subway CharlieCard)

Initially, we developed a range of diversion factors based on results of the 2007 Post-Fare Increase Impacts Analysis. We used these factors in the SFY 2013 fare increase analysis, and continued to use them in the SFY 2015 analysis. After reviewing the impacts of the SFY 2013 fare increase, we found sufficient evidence that the willingness of people to divert between passes and cash on the subway and light rail system would increase slightly.

Following a review by Andrew Stuntz, we increased the cash-pass diversion ratio even higher.[6] His research suggested that approximately 3 percent to 5 percent of riders switched from using passes to some form of single-ride fare. We changed the cash-pass diversion factor in the SFY 2017 version of FERRET until we found a decrease in pass usage by approximately 3 percent. This resulted in the factor increasing from 0.08 to 0.70—a significant increase.

A.4 PRICE ELASTICITY ESTIMATION

CTPS estimated the price elasticity of demand for the both the SFY 2015 and the SFY 2017 versions of the fare increase model based on a review of the changes in ridership, revenue, and price following implementation of the SFY 2013 fare increase. We used the demonstrated elasticities, which we calculated following our analysis of the impact of the SFY 2013 fare increase to guide our decisions about modifying the previously used set of elasticities. However, because factors

[6] Stutz, Andrew. Transit fare policy: use of automated data to improve incremental decision making. Cambridge: Massachusetts Institute of Technology, 2018.

in addition to fare changes also likely influenced the changes in ridership, we did not use the demonstrated elasticities for the SFY 2015 or SFY 2017 iterations of FERRET directly.

The following sections explain the process CTPS used to modify elasticities for the SFY 2015 and SFY 2017 iterations of FERRET, using the SFY 2013 demonstrated elasticities. The latest iteration of FERRET used most of the elasticities from previous years.

A.5 CALCULATING THE DEMONSTRATED ELASTICITY OF EACH FARE TYPE

To calculate the demonstrated elasticity for a given fare, we used two pieces of information: the percentage change in fares and the percentage change in ridership. For each fare payment type on each mode, we calculated the percentage change between full SFY 2012 (before the fare increase) and full SFY 2013 (after the fare increase) ridership and fares using the formula:

$$\text{Percentage Change} = \frac{X_2 - X_1}{\left(\frac{X_2 + X_1}{2}\right)}$$

Where:
X1 = SFY 2012 value (the year before the fare changes)
X2 = SFY 2013 value (the year after the fare changes)

This formula provides the percentage change between X1 and X2 relative to the midpoint of X1 and X2. For example, if X1 = 10 and X2 = 20, the formula would indicate that the percentage change relative to the midpoint (15) is equal to 66 percent.

For example, in SFY 2012, single-ride bus ridership was 22,441,080. SFY 2013 ridership was 21,237,096. The percentage change in ridership between these two years is:

$$\text{Percentage Change} = \frac{21{,}237{,}096 - 22{,}441{,}080}{\left(\frac{21{,}237{,}096 + 22{,}441{,}080}{2}\right)} = -5.5\%$$

For each relevant fare payment type, we calculated the demonstrated elasticity with respect to fares using the following formula:

$$\text{Elasticity} = \frac{\Delta\text{Ridership (in \%)}}{\Delta\text{Fare (in \%)}}$$

For example, the percentage change in single-ride ridership on MBTA buses from SFY 2012 to SFY 2013 was -5.5 percent. The percentage change in the fare was 19.5 percent. The demonstrated elasticity is calculated as follows:

$$\text{Elasticity} = \frac{\Delta\text{Ridership (in \%)}}{\Delta\text{Fare (in \%)}} = \frac{-5.5\%}{19.5\%} = -0.28$$

As another example, the total change in LinkPass ridership was -0.3 percent. The change in the average LinkPass trip price was 17.4 percent. The demonstrated elasticity is calculated as follows:

$$\text{Elasticity} = \frac{\Delta\text{Ridership (in \%)}}{\Delta\text{Fare (in \%)}} = \frac{-0.3\%}{17.4\%} = -0.02$$

A.5.1 Modifying the Elasticities of Each Fare Type for the Current Projection

Because the demonstrated elasticity values only incorporate the changes in fares and do not account for other factors that affect transit ridership—such as gas prices, employment levels, and development—we do not advise using the elasticities calculated based on results of the SFY 2013 fare increase in the SFY 2017 model. Some of the demonstrated elasticities could indicate that other factors are affecting ridership, especially for those results with positive values that appeared to indicate that ridership increased in response to the fare increase. Therefore, we only used the demonstrated elasticities, along with the following heuristics, to inform the modification of the SFY 2012 elasticities:

- If the value of a demonstrated elasticity was close to zero or positive, we modified the value to make it more inelastic (closer to zero)
- No elasticity was set to be greater than -0.10 (closer to zero)
- If an elasticity was used in SFY 2012 and the demonstrated elasticity was roughly similar, we did not modify the elasticity
- If the demonstrated elasticity was significantly more negative than the one we used in SFY 2012, we decreased the elasticity (made it more negative or more elastic)

Table A-2 presents the elasticities we used to predict what might have happened following the SFY 2013 fare increase, the elasticities we calculated based on the actual changes between SFY 2012 and SFY 2013, the elasticities we used to project the effects of the SFY 2015 fare changes, and the estimated 2017 base elasticity.

Andrew Stuntz estimated elasticities for the LinkPass users in the corporate pass program and LinkPass users who are not in the corporate pass program. His analysis suggests that our selected elasticities for the LinkPass fare product are too low. To address these points, we increased the base elasticities for the LinkPass (a combination of people participating and not participating in the corporate pass program). We increased the elasticity of the 7-Day LinkPass to a value slightly above the monthly LinkPass.

Table A-2
SFY 2012, Demonstrated, and SFY 2015 and SFY 2020 Elasticities

Mode Category	Estimated SFY 2013 Elasticity	Demonstrated SFY 2013 Elasticity	Values from A. Stuntz Thesis	Selected SFY 2020 Base Elasticity
Cash Elasticities				
Bus and Trackless Trolley				
Bus-Adult *(from example)*	(0.20)	(0.28)		(0.25)
Bus-Senior	(0.15)	(0.26)		(0.20)
Bus-Student	(0.15)	0.30		(0.15)
Subway				
Subway-Adult	(0.25)	(0.26)		(0.25)
Subway-Senior	(0.15)	(0.18)		(0.15)
Subway-Student	(0.15)	1.80		(0.10)
Surface Light Rail				
Surface Light Rail-Adult	(0.25)	(0.29)		(0.30)
Surface Light Rail-Senior	(0.20)	(0.19)		(0.20)
Surface Light Rail-Student	(0.20)	1.96		(0.15)
Commuter Rail				
Commuter Rail-Adult	(0.35)	0.01		(0.20)
Commuter Rail-Senior	(0.25)	0.37		(0.15)
Commuter Boat				
Commuter Boat-Adult	(0.30)	(0.34)		(0.30)
Commuter Boat-Senior	(0.20)	(0.75)		(0.25)
THE RIDE	(0.12)	(0.39)		(0.35)
Parking	(0.20)	(0.18)		(0.20)
Pass Elasticities				
Bus	(0.30)	(0.09)		(0.15)
Inner Express	(0.20)	(0.33)		(0.25)
Outer Express	(0.20)	(0.33)		(0.25)
LinkPass *(from example)*	(0.30)	(0.02)	Greater than -0.15, less than -0.30	**(0.25)**
1-Day LinkPass	(0.35)	0.41		(0.15)
7-Day LinkPass	(0.35)	0.09	Set to slightly higher than LinkPass	**(0.30)**
Commuter Rail	(0.10)	(0.17)		(0.10)
Commuter Boat	(0.25)	(0.17)		(0.20)
Senior	(0.15)	0.23		(0.10)
Student/Youth	(0.15)	(0.04)		(0.10)

Notes: The estimated SFY 2013 elasticity is the one we used to estimate the effects of the SFY 2013 fare increase.
The demonstrated SFY 2013 elasticity is the one we calculated based on ridership changes following the SFY 2013 fare increase.
The estimated SFY 2020 base elasticity is the elasticity we used to estimate the effects of the SFY 2020 fare increase.
SFY = State Fiscal Year.
Source: Central Transportation Planning Staff; A. Stuntz 2018.

A.6 EXAMPLES OF RIDERSHIP AND REVENUE CALCULATIONS

A.6.1 Simple Example: Price Elasticity Only

Given:

Original Demand: 100,000
Original Fare: $1.50
New Fare: $2.50
Price Elasticity: -0.05

New Demand =
Original Demand × [1 + Price Elasticity × (New Fare ÷ Old Fare − 1)]

New Demand =
100,000 × [1 + −0.05 × ($2.50 ÷ $1.50 − 1)] = 96,666.67

A.6.2 More Complex Example: Price Elasticity plus Ridership Diversion—Cash to Pass

Given:

Original Cash Demand: 10,000
Original Cash Fare: $2.25
New Cash Fare: $2.00
Cash Price Elasticity: -0.30

New Demand =
Original Demand × [1 + Price Elasticity × (New Fare ÷ Old Fare − 1)]

New Cash Demand (Price Effect),
C_p = 10,000 × [1 + −0.30 × ($2.00 ÷ $2.25 − 1)] = 10,333.33

Given:

Original Pass Demand: 5,000
Original Pass Price: $71.00
New Pass Price: $50.00
Pass Price Elasticity: -0.25

New Pass Demand (Price Effect),
P_p = 5,000 × [1 + −0.25 × ($50 ÷ $71 − 1)] = 5,369.72

Total Demand = 10,333.33 + 5,369.72 = 15,703.05

Percentage Change in Cash Price: $2.25 to $2.00: -11%

Percentage Change in Pass Price: $71 to $50: -30%

Given:

Cash-to-Pass Diversion Factor: 0.05
Pass-to-Cash Diversion Factor: 0.00

Diverted Riders from Cash to Pass = $\left(\frac{\$NewCash/\$OldCash}{\$NewPass/\$OldPass}-1\right)\times Diversion\times C_P$

Diverted Riders from Cash to Pass = $\left(\frac{\$2.00/\$2.25}{\$50/\$71}-1\right)\times 0.05\times C_p=135.48$

New Cash Demand = C_p – Diverted Riders from Cash to Pass = 10,197.85

New Pass Demand = P_p + Diverted Riders from Cash to Pass = 5,505.20

Total Demand = 10,197.85 + 5,505.20 = 15,703.05

A.6.3 Another Complex Example: Price Elasticity plus Two Ridership Diversions

Single-Ride CharlieCard (SR-CC) to Pass, and Single-Ride CharlieTicket (SR-CT) to Single-Ride CharlieCard (SR-CC)

Given:

Original Single-Ride CharlieCard Demand: 10,000
Original Single-Ride CharlieCard Fare: $2.20
New Single-Ride CharlieCard Fare: $3.50
Single-Ride CharlieCard Price Elasticity: -0.30

New SR-CC Demand (Price Effect),

$CC_p = 10{,}000 \times [1 + -0.30 \times (\$3.50 \div \$2.20 - 1)] = 8{,}227.27$

Given:

Original Pass Demand: 50,000
Original Pass Price: $71.00
New Pass Price: $90.00
Pass Price Elasticity: −0.25

New Pass Demand (Price Effect),

$P_p = 50{,}000 \times [1 + -0.25 \times (\$90 \div \$71 - 1)] = 46{,}654.93$

Given:

Original Single-Ride CharlieTicket Demand: 5,000
Original Single-Ride CharlieTicket Fare: $2.50
New Single-Ride CharlieTicket Fare: $4.50
Single-Ride CharlieTicket Price Elasticity: −0.30

New SR-CT Demand (Price Effect),

$CT_p = 5{,}000 \times [1 + -0.30 \times (\$4.50 \div \$2.50 - 1)] = 3{,}800.00$

Total Demand = 8227.27 + 46,654.93 + 3,800.00 = 58,682.20

Given:

Single-Ride CharlieCard-to-Pass Diversion Factor: 0.05
Pass-to-Single-Ride CharlieCard Diversion Factor: 0.00
Single-Ride CharlieCard to Single-Ride CharlieTicket Diversion Factor: 0.00
Single-Ride CharlieTicket to Single-Ride CharlieCard Diversion Factor: 0.25

Percentage Change in Single-Ride CharlieCard Fare: $2.20 to $3.50: 59.09%

Percentage Change in Pass Price: $71 to $90: 26.76%

Percentage Change in Single-Ride CharlieTicket Fare: $2.50 to $4.50: 80.00%

Diverted Riders from SR-CC to Pass = $\left(\frac{\$3.50/\$2.20}{\$90/\$71}-1\right) \times 0.05 \times CC_p = 104.92$

Diverted Riders from SR-CT to SR-CC = $\left(\frac{\$4.50/\$2.50}{\$3.50/\$2.20}-1\right) \times 0.25 \times CT_p = 124.86$

New Single-Ride CharlieCard Demand =

CC_p – Diverted Riders from SR-CC to Pass + Diverted Riders from

SR-CT to SR-CC = 8,247.21

New Pass Demand = Pp + Diverted Riders from SR-CC to Pass = 46,759.85

New Single-Ride CharlieTicket Demand =

CT_p – Diverted Riders from SR-CT to SR-CC = 3,675.14

Total Demand = 8,202.15 + 46,759.85 + 3,720.20 = 58,682.20

Note: As we introduce additional ridership diversion factors, and more cells in the spreadsheet become linked, the complexity of FERRET increases significantly. However, the basics of the methodology explained above regarding price elasticities and ridership diversion factors remain the same.