FINAL REPORT

CAPE RAIL STUDY

Cape Rail Study

massDOT Massachusetts Department of Transportation

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Cover Photo: Existing Buzzards Bay Station and Cape Cod Canal Railroad Bridge

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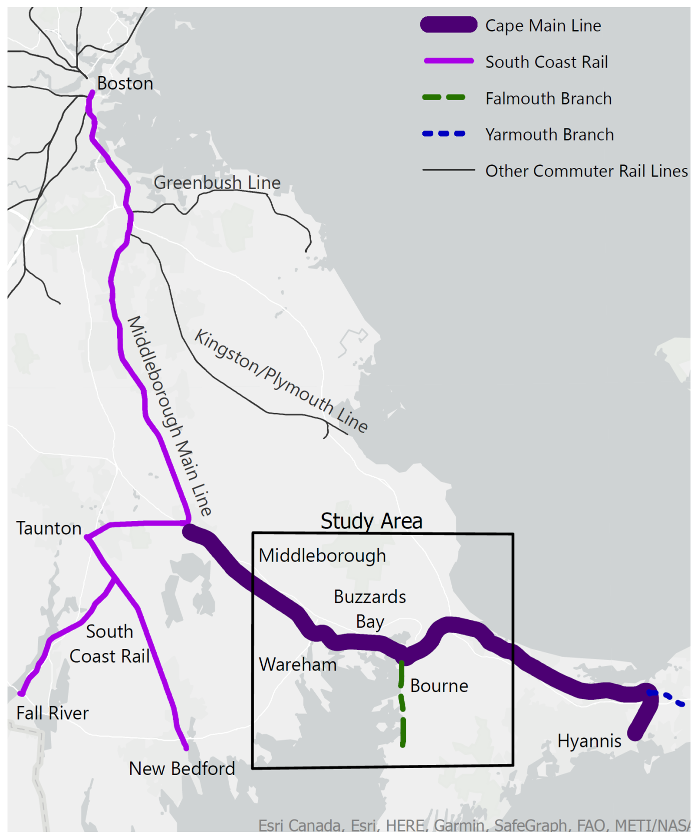
Executive Summary

The Cape Rail Study evaluated potential year-round passenger rail to the Cape Cod region, approximately 50 miles south of Boston. The study, led by the Massachusetts Department of Transportation (MassDOT) with technical support and guidance from the Cape Cod Commission (CCC), considered the options for expanding passenger rail service to Cape Cod with connections to Middleborough, Wareham, and beyond. Figure ES-1 highlights the project study area.

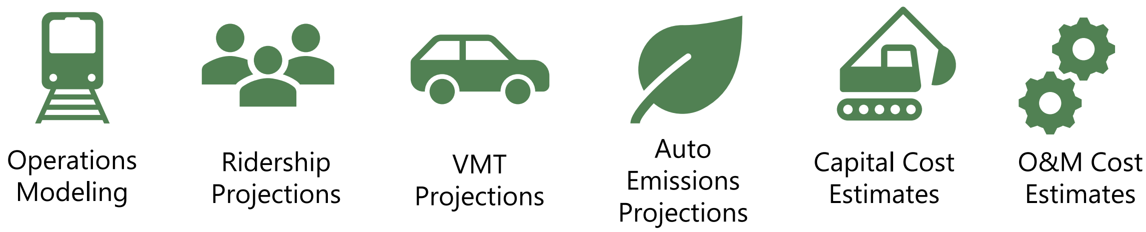
Figure ES-1 Project Study Area



Sources: MassGIS, ESRI

Extending just beyond the Massachusetts Bay Transportation Authority's (MBTA's) existing commuter rail network, the rail connection could enhance public transportation options to the region and provide opportunities for economic development. Cape Cod Regional Transit Authority (CCRTA) currently operates seasonal CapeFLYER rail service between South Station and Hyannis via the Middleborough Main Line and Cape Main Line, with one round trip per day on Fridays, Saturdays, and Sundays during the summer months. The Cape Rail Study evaluated options to expand regular passenger rail service to the Cape Cod region, providing data and information about projected ridership, auto usage, and emissions, and costs (**Figure ES-2**).

Figure ES-2 Evaluation Criteria



The Cape Rail Study considered two alternatives that were developed cooperatively with the Advisory Group, which consisted of elected officials and representatives from the Towns of Bourne, Wareham, and Middleborough; representatives of local interest groups; and representatives of regional agencies and organizations. Each alternative included a range of options that allowed MassDOT and the MBTA to test the benefits and tradeoffs of different service components.

With limited available capacity to support expanded service on the Middleborough Main Line and at Boston South Station, Alternative 1 focused on providing weekday commuter service to and from Buzzards Bay with a stop at Wareham and transfers between Cape trains and South Coast Rail trains at the new Middleborough Station. South Coast Rail Phase 1, which will restore MBTA commuter rail service in 2023 between Boston and southeastern Massachusetts, could enable this transfer connection at the new Middleborough station.

Alternative 2 built on Alternative 1 and increased the level of service. Alternative 2 extended service south of the canal to and from the existing Bourne Station (under the Bourne Bridge), added service outside the traditional commute peak periods, and added service without a transfer to and from Boston. Providing service to Bourne would require further coordination with the U.S. Army Corps of Engineers, which owns and controls the Cape Cod Canal Railroad Bridge that connects Buzzards Bay to Bourne.

Both alternatives meet the MBTA's *Service Delivery Policy* for frequency and span of service standards with the existing single-track sections and passing sidings.[1] Alternative 1 resulted in projected ridership increases, auto diversions, and auto emission reductions. Alternative 2 expanded on these projections with higher frequency service to the south side of the Cape Cod Canal and direct trips to and from Boston. Order-of-magnitude (OOM) capital costs and operations and maintenance (O&M) costs also increased with the expanded service in Alternative 2. Required system improvements largely drove the estimated capital costs, including installing a signal system and positive train control, a signal system that automatically enforces speed restrictions and can positively stop a train for safety purposes. Some of these system improvements may occur irrespective of any new service on the corridor and could potentially be funded through a variety of sources. **Table ES-1** summarizes key evaluation metrics between Alternatives 1 and 2.

[1] Single-track refers to the number of tracks available for train use. In single-track sections, trains traveling in both directions must use the same track at different times. A passing siding is a segment of additional track that allows a train to pass another train traveling in the same area at the same time (typically in the opposite direction). A glossary of railroad-related terms used in this report is included in Appendix A.

Table ES-1 Comparison of Alternatives 1 and 2

Item	Alternative 1	Alternative 2
Terminal	Buzzards Bay	Bourne
Total One-Way Revenue Trips	14	20[1]
Travel Time to Boston	~93 Minutes[2]	~101 Minutes[2]
Projected Daily Boardings	1,710[3]	2,540[3]
OOM Capital Costs (2021$)	$67.2M[4]	$102.6M[4]
OOM O&M Costs/Year (2021$)	$5.0M/Year[5]	$9.3M/Year[5]
Daily Vehicle Trip Reduction	Over 800	Nearly 1,200
Daily Vehicle Miles Traveled Savings	42,718	65,675
Daily Savings in CO2 from Auto Travel	13,628 kg	20,952 kg

Notes:

1. One trip would start in Buzzards Bay and one trip would end in Buzzards Bay.
2. Travel times include 5-minute timed transfer at Middleborough for most trips. Total travel times vary based on scheduled time for SCR trip. One-seat ride trip times in Alternative 2 vary between 87 and 102 minutes.
3. Projected daily boarding values reflect boardings at Pilgrim Junction (southbound), the existing Middleborough/Lakeville station (Alternative 2 only), Wareham, Buzzards Bay, and Bourne (Alternative 2 only). Projected daily boardings include both inbound and outbound boardings.
4. Values shown are rounded to the nearest $100,000 and include soft costs, administrative costs, and contingencies. Values are not escalated to year of construction. Costs assume the continued use of existing station infrastructure at Wareham, Buzzards Bay, and Bourne. Costs exclude any grade crossing or structure improvements, which would be reevaluated and done as needed prior to implementing any service. Costs assume the use of surplus fleet. Any additional fleet procurement, rehabilitation, or overhaul would incur additional cost. The capital cost estimates include improvements necessary to implement service. Many of the proposed improvements would also benefit existing passenger and freight service through the corridor. The capital improvements could be funded through multiple funding sources, other initiatives, and federal, state, or local opportunities. 5. Values shown are rounded to the nearest $100,000. Estimates use unit costs from MBTA systemwide operations, but actual O&M costs may differ due to several factors, including the operator of the service.

While this study provides a foundation for potential future rail service to the Cape Cod region, there are additional systemwide changes and other factors that could affect and inform potential future implementation. Developing a plan for the O&M of a potential future Cape rail service and identifying funding sources and opportunities are critical next steps towards implementation.

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CAPE RAIL STUDY

1 Introduction

The Cape Rail Study, led by the Massachusetts Department of Transportation (MassDOT) with technical support and guidance from the Cape Cod Commission (CCC), evaluated the potential for extending year-round passenger rail to Cape Cod with connections to the communities of Middleborough, Wareham, and beyond. While seasonal weekend passenger service exists today via the CapeFLYER, the Cape Rail Study considered the options for expanding regular passenger rail service to the Cape Cod region. This chapter frames the scope of the study and describes the project context and approach.

1.1 Project Context

The Cape Cod region, located approximately 50 miles south of Boston, extends just beyond the Massachusetts Bay Transportation Authority's (MBTA's) existing commuter rail network. Local and regional stakeholders, including the Cape Cod Metropolitan Planning Organization (MPO), have consistently advocated for a commuter rail service connection to the region, with potential connections to Middleborough, Wareham, Buzzards Bay, and Bourne. This rail connection could build on the success of the seasonal CapeFLYER service to enhance the public transportation options to the region and provide opportunities for economic development.

The project purpose was to **study options to expand passenger rail service to the Cape Cod region** and to **provide the region with data and information about the rail options,** including projected ridership, auto usage and emissions, and costs. Alternatives analysis and findings presented in the study can provide stakeholders with data to inform future policy and decisions.

In addition to evaluating direct service between Boston and the Cape Cod region, the project evaluates a potential connection with Phase 1 of the South Coast Rail (SCR) Project, which will restore MBTA commuter rail service in 2023 between Boston and southeastern Massachusetts. Alternatives could take advantage of service from Buzzards Bay or Bourne to Boston with a transfer connection at the new Middleborough station, where SCR trains will also stop.

The following sections describe the project study area, the stakeholder engagement process, previous and ongoing related studies, and the methodology and approach used to evaluate the rail alternatives.

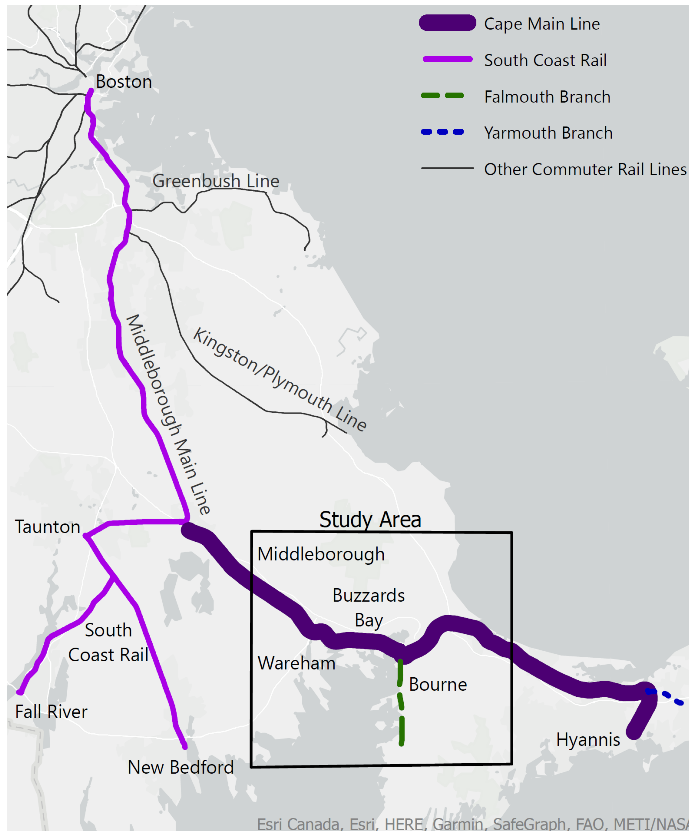
1.1.1 Project Study Area

The project study area focused on the Cape Main Line and included the Cape Cod region. The Cape Main Line extends approximately 43 miles south from Middleborough to Hyannis through Wareham, Buzzards Bay, and Bourne, with mostly single track. The project also considered travel on the Middleborough Main Line, which extends over 35 miles north from Middleborough/Lakeville to South Station in Boston. CapeFLYER, a seasonal service operated by the Cape Cod Regional Transit Authority (CCRTA), operates between South Station and Hyannis via the Middleborough Main Line and Cape Main Line, with one round trip per day on Fridays, Saturdays, and Sundays during the summer months.

The MBTA commuter rail lines closest to the Cape Cod region are the Middleborough/Lakeville and Kingston/Plymouth Lines. The Middleborough/Lakeville Line provides service between South Station and Middleborough/Lakeville (and will be extended to Taunton, Fall River, and New Bedford through SCR Phase 1). The Kingston/Plymouth Line provides service between South Station and Kingston. These two lines meet at Braintree, and then join the Greenbush Line north of Braintree to share the Middleborough Main Line into Boston.

As shown on **Figure 1-1,** the project study area extends south of these existing and planned services, from Middleborough to Bourne, south of the Cape Cod Canal. Two other rail branches—the Falmouth Branch and Yarmouth Branch—do not serve passenger rail but are also shown in **Figure 1-1**.

Figure 1-1 Project Study Area



Sources: MassGIS, ESRI

1.1.2 Stakeholder Engagement

MassDOT and the MBTA coordinated with the CCC to collect stakeholder and community input and feedback throughout the study. At the outset of the study, MassDOT and the CCC convened a study Advisory Group representing a variety of interests in the region, including elected officials and representatives from the Towns of Bourne, Wareham, and Middleborough; representatives of local interest groups; and representatives of regional agencies and organizations (**Table 1-1**).

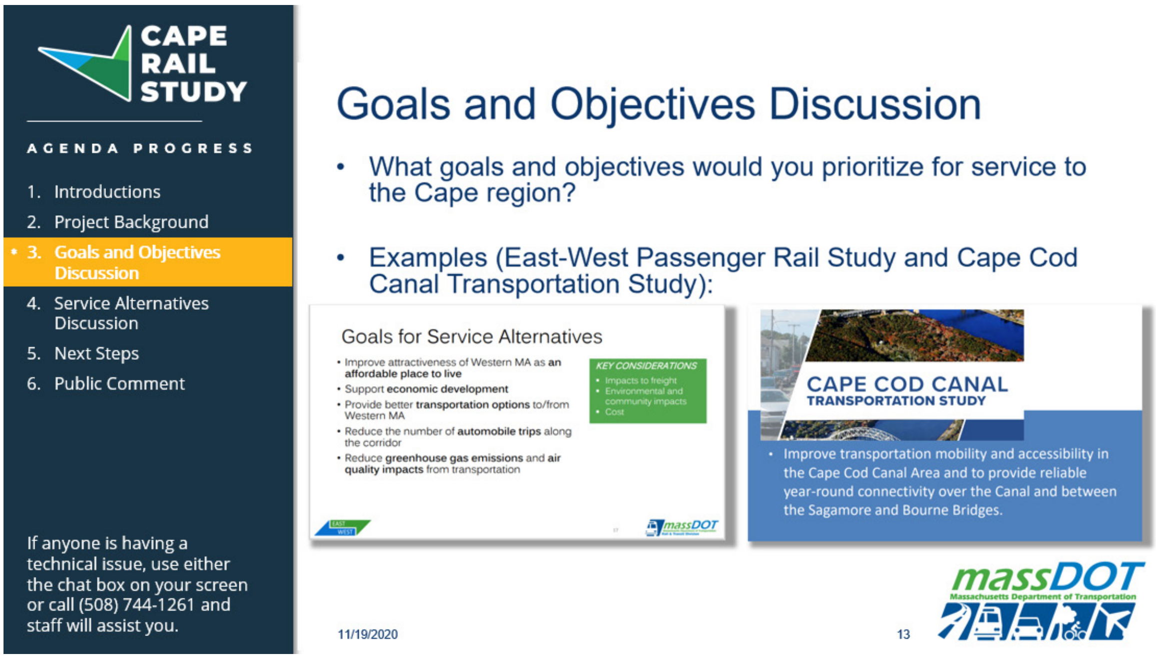
Table 1-1 Advisory Group Members

Name	Affiliation
Elected Officials	
Congressman William R. Keating	US House of Representatives, MA 9th District
Senator Susan Moran	MA Senate, Plymouth and Barnstable District
Representative David Vieira	MA House of Representatives, 3rd Barnstable District
Judith Froman	Cape Cod Metropolitan Planning Organization; Town of Bourne, Select Board Vice-Chair
Peter J. Meier	Town of Bourne, Select Board Chair
Leilani Dalpe	Town of Middleborough, Board of Selectmen Chair
Alan Slavin	Town Wareham, Board of Selectmen
Bourne Town Staff and Committees	
Anthony Schiavi	Town of Bourne, Town Administrator
Glenn Cannon	Town of Bourne, Assistant Town Administrator
Coreen Moore	Town of Bourne, Town Planner
Jeanne Azarovitz	Town of Bourne, Planning Board
Chief Dennis Woodside	Bourne Police Department
Lieutenant Brandon Esip	Bourne Police Department
Deputy Chief Joseph Carrara	Bourne Fire Department
David J. McPherson	Bourne Town Administrator's Advisory Committee on Pedestrian Bicycle Pathway
Local Representation (Institution/Business/Advocacy Group/Resident)	
Maria Oliva	Cape Cod Canal Chamber of Commerce
Admiral Francis X. McDonald	Massachusetts Maritime Academy
Tim Eldredge	Keystone Senior LLC
Nathan Robinson	Friends of the Bourne Rail Trail
Mercedes Rodman	Friends of the Bourne Rail Trail
Joe Gordon	Buzzards Bay Resident
Regional Representation	
Jennifer Tabakin	MBTA
Bob Campbell	MBTA
Jody Ray	MBTA
Ryan Coholan	MBTA
Tom Cahir	Cape Cod Regional Transit Authority (CCRTA), Administrator
George Slade	CCRTA, Bourne Advisory Board Member; Town of Bourne, Select Board Clerk
Kristy Senatori	Cape Cod Commission, Executive Director
Stephen Mealy	Cape Cod Commission, Bourne Representative
John MacPherson	U.S. Army Corps of Engineers, Cape Cod Canal Office Chief
P. Christopher Podgurski	Massachusetts Coastal Railroad/Cape Cod Central Railroad, President & Chief Operating Officer

Advisory Group meetings, hosted remotely by the CCC, were advertised and open to the public, and covered the following topics:

- **Advisory Group Meeting #1** (November 19, 2020) included a project overview and a discussion of the goals and objectives of the study (see **Figure 1-2**). The meeting also defined the alternatives to be analyzed.
- **Advisory Group Meeting #2** (June 9, 2021) reviewed the alternatives analysis framework and presented findings from the alternatives analysis, along with next steps.

Figure 1-2 Discussion Prompt from First Advisory Group Meeting



The CCC also provided additional support by providing feedback about how the project materials could interface with other CCC documents, plans, and policies.

1.1.2.1 Goals and Objectives

Through coordination with the Advisory Group and the CCC, the project developed the following goals and objectives to guide the development of potential service alternatives:

1. Provide safe and reliable public transportation options to, from, and within the Cape and surrounding areas
2. Reduce automobile usage and greenhouse gas emissions
3. Support and strengthen opportunities for economic growth, transit-oriented development (TOD) and access to employment in the Boston region for commuters and occasional riders

The goals and objectives provided a foundation for developing alternatives. Metrics for evaluation were developed that would measure these goals, either directly or indirectly. Chapter 3 describes the framework used to develop and evaluate the alternatives in more detail.

1.1.3 Previous and Ongoing Studies

The Cape Rail Study builds upon the findings from previous studies of service to the Cape Cod region. **Figure 1-3** identifies several related studies and projects, some of which are described in more detail below. Previous studies noted ridership benefits of rail service to the region, local benefits and impacts associated with rail (e.g., transit-oriented development), and the cost of implementation.

Figure 1-3 Previous and Ongoing Studies

Studies of Cape Rail Service

- CTPS Studies (1996-1997, 2007, 2016)
- MassDOT Pilot Service Study
- Local University Research Studies

Related Studies

- CCC Buzzards Bay Commuter Rail Extension: Local Impact Report
- Downtown Bourne Parking Strategy Plan
- CCRTA Study of Buzzards Bay Area Frequency
- Cape Cod Canal Transportation Study

Related Projects

- South Coast Rail
- Cape Code Canal Area Transportation Improvement Program
- Shining Sea Bikeway Extension
- MBTA Rail Transformation

Many previous studies evaluated potential service options to the Cape Cod region. The Central Transportation Planning Staff (CTPS) of the Boston Region MPO initially studied the potential extension in 1996-1997 and updated the study in 2007 and 2016.[2,3] In April 2015, the CCC developed a Local Impact Report for the Bourne Transportation Advisory Committee that considered the local impacts associated with a commuter rail extension to Buzzards Bay. MassDOT also considered operating service to Buzzards Bay as a pilot service, with proposed operations beginning in September 2016.[4] That pilot would have operated a shuttle along 20 miles of track with stops at Buzzards Bay, Wareham Village, and Middleborough/Lakeville. The Cape Rail Study built upon the work of these studies when considering stakeholder objectives for the service and evaluating potential service alternatives. Consistent with potential service options identified in the 2016 CTPS study and MassDOT pilot service proposal, the Cape Rail Study included alternatives that would provide connections to MBTA service at Middleborough.

Meanwhile, the ongoing Cape Cod Canal Area Transportation Improvement Program includes improvements to the Cape Cod Canal area roadway networks, including the replacement of the Bourne and Sagamore bridges.[5] The alternatives analyzed in this study were based on existing roadway infrastructure and did not make assumptions about future roadway infrastructure changes. As was discussed in the Advisory Group meetings, the rail service described in this report could enhance and expand the transportation options between the Cape region and Boston.

[2] CTPS, "Buzzards Bay Commuter Rail Extension Feasibility Study," January 2007.

[3] CTPS, "Buzzards Bay Commuter Rail Extension Feasibility Study: Update of 2007 Study," April 2016.

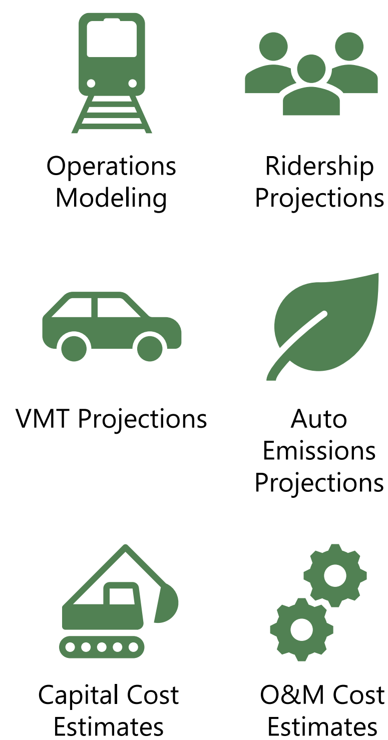
[4] MassDOT, "Commuter Rail Pilots Strategic Discussion," Presented to MBTA Fiscal and Management Control Board on April 4, 2016.

[5] For more information, please see MassDOT, "Cape Cod Canal Area Transportation Improvement Program," https://www.mass.gov/cape-cod-canal-area-transportation-improvement-program.

1.2 Evaluation Methodology and Approach

The Cape Rail Study used a number of metrics to evaluate rail service to the Cape Cod region. Included in this section are brief overviews of the methodology for each metric; more detailed descriptions of the approach and outcomes are provided in Chapter 3. **Figure 1-4** provides an overview of the criteria evaluated for each alternative.

Figure 1-4 Evaluation Criteria



Operations modeling focused on developing rail schedules for alternatives that met the goals and objectives of the service as identified through coordination with the Advisory Group. Operating schedules were built using the final SCR Phase 1 New Bedford/Fall River schedules as a base, and operations modeling used Berkeley's Rail Traffic Controller® (RTC) simulation software to confirm the schedules' operational feasibility.

The CTPS statewide travel demand model integrated the schedules developed from the operations modeling effort with other service characteristics, land use, and travel patterns, to understand travel times and trip frequencies and forecast potential **ridership** for each alternative. The ridership projections further modified the results of the CTPS statewide travel demand model to account for induced demand and recreational ridership.

Through the CTPS statewide travel demand model, the alternatives analysis included the projected auto diversions (existing trips made by auto that would be made by rail instead). Combining these projected auto diversions with their respective approximate trip lengths resulted in projected reductions of **vehicle miles traveled** (VMT). The MassDOT Congestion Mitigation and Air Quality Improvement (CMAQ) Air Quality Analysis Worksheet was used to convert these VMT savings to projected reductions in **auto emissions.**

Order-of-magnitude **capital cost estimates** reflect the costs required to upgrade and improve the physical infrastructure needed to operate rail service in each alternative. Costs were developed using industry standards and the SCR project's current costs due to its similarity in the type of improvement and geography.

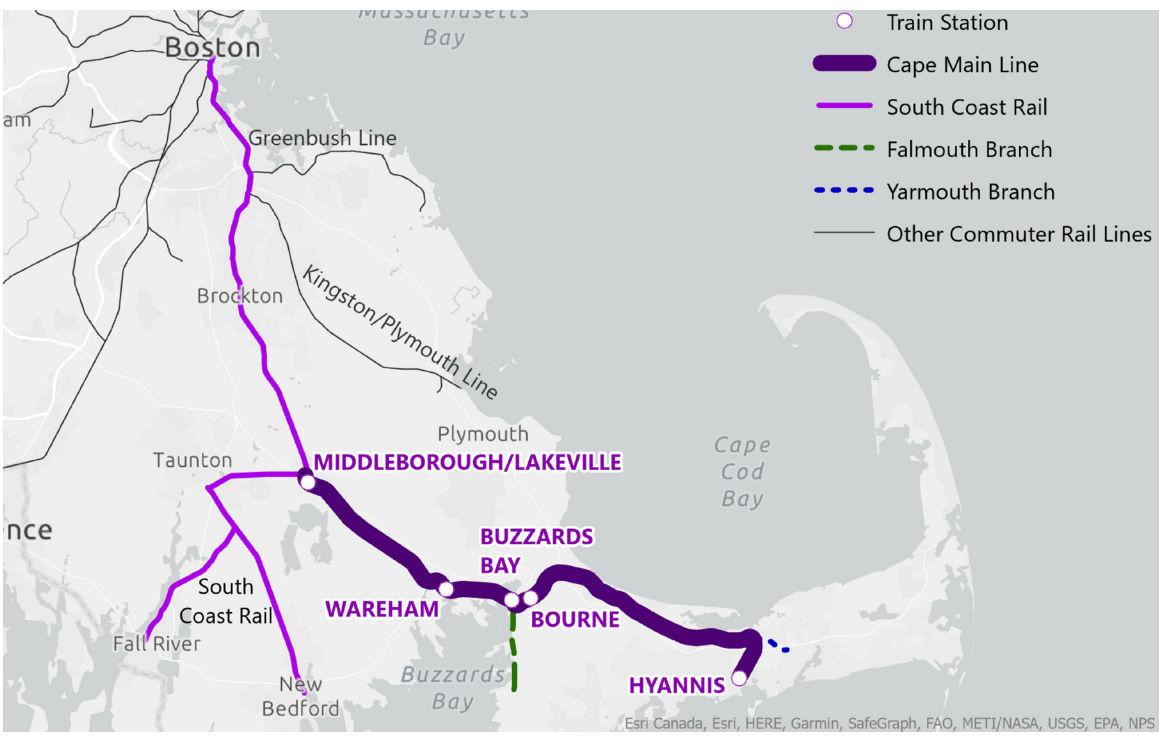
Order-of-magnitude operations and maintenance **(O&M) cost estimates** assess the annual expenses associated with operating the service and accounting for items such as staffing and fuel. The O&M cost modeling considered the number of vehicles needed to operate the service, the distance traveled, and the time traveled in each alternative by applying unit costs developed based on existing MBTA O&M expenses.

2

Baseline Conditions

The Cape Cod region in southeastern Massachusetts is approximately 50 miles south of Boston. While several private buses connect the region to Boston, rail service is limited to seasonal recreational trips on the CapeFLYER, which provides daily service on Fridays and weekends during summer months. The closest MBTA commuter rail services are in Middleborough and Kingston. Middleborough is the current terminus of the Middleborough/Lakeville Line and a future stop on the SCR service to Taunton, Fall River, and New Bedford. Kingston is a terminus on the Kingston/Plymouth Line (Figure 2-1).

Figure 2-1 Existing Rail Lines



Sources: MassGIS , ESRI

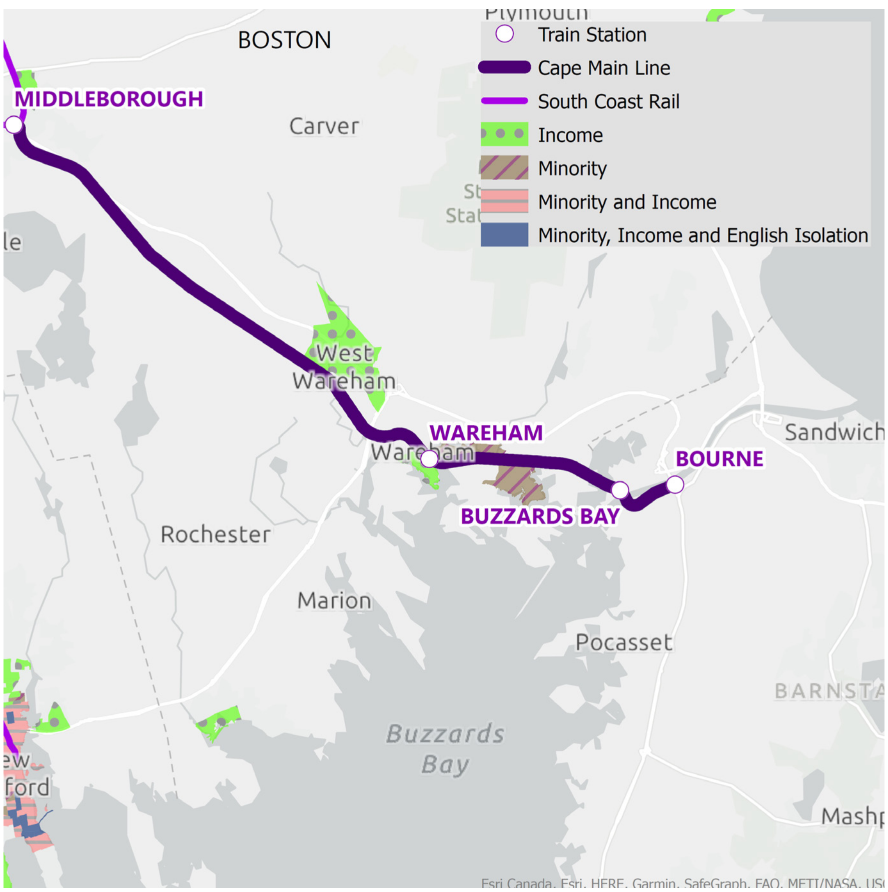
Demographics along the corridor vary, with comparisons to Boston and Massachusetts noted in **Table 2-1**. Both Middleborough and Wareham have Environmental Justice (EJ) communities, as illustrated in **Figure 2-2**. Buzzards Bay and Wareham, two of the targeted areas for this service, have very low public transport mode share, and most commuters drive alone.

Table 2-1 Demographic Characteristics of Selected Locations

Location	Median Household Income	Public Transportation Mode Share
Selected Locations		
Middleborough	$66,525	1.6%
Wareham	$41,250	6.1%
Buzzards Bay	$75,142	2.5%
Barnstable County	$74,336	1.5%
Regional Comparisons		
Boston	$71,115	33.3%
Massachusetts	$81,215	10.4%

Source: United States Census Bureau, American Community Survey, 2015-2019 ACS 5-Year Data Profiles.

Figure 2-2 Environmental Justice (EJ) Communities in Study Area



Sources: MassGIS, ESRI

Communities in the study area consider a rail connection to be a benefit for economic development opportunities. In April 2015, the CCC developed a Local Impact Report for the Bourne Transportation Advisory Committee,[6] which evaluated the potential benefits and impacts of a commuter rail extension to Buzzards Bay. The study considered the economic impacts of the rail extension, including to the assessments placed on Bourne and Wareham. The CCC concluded that increased commuter rail service to Buzzards Bay would likely be beneficial for the town, especially with the construction of Transit-Oriented Development (TOD). Similarly, the *Wareham Economic Development Strategy* noted that demand for office space would likely increase with a commuter rail service to the town.[7]

Existing station at Buzzards Bay

[6] Cape Cod Commission, "Buzzards Bay Commuter Rail Extension: Local Impact Report," April 2015.

[7] Town of Wareham, "Wareham Economic Development Strategy," March 2019.

2.1 Existing Transit Services

2.1.1 Rail Services

The **CapeFLYER** passenger service, which connects Boston to the Cape Cod region, is a partnership among the CCRTA, MassDOT, and the MBTA, providing service since 2013. It provides one round trip per day seasonally on Friday evenings, Saturdays, and Sundays between Memorial Day and Labor Day. The service uses the Middleborough Main Line and Cape Main Line to make stops at South Station, Braintree, Brockton, Middleborough/Lakeville, Wareham Village, Buzzards Bay, Bourne, and Hyannis. Travel times on the CapeFLYER are approximately 20 minutes between Middleborough/Lakeville and Wareham Village, 10 minutes between Wareham Village and Buzzards Bay, five minutes between Buzzards Bay and Bourne, and approximately one hour between Bourne and Hyannis. In total, the trip takes approximately two and a half hours between Boston South Station and Hyannis and costs $40 for a round trip or $22 for a one-way trip.[8] Two other rail branches—the Falmouth Branch and Yarmouth Branch—do not serve passenger rail but are shown in **Figure 2-1**.

Track near Wareham Station

[8] CapeFLYER, "Schedule, Fares, and Route Map," available at https://capeflyer.com/reservations-tickets/capeflyer-trainpricing-routes/.

The closest existing MBTA commuter rail lines to the Cape Cod region are the Middleborough/ Lakeville and Kingston/Plymouth Lines (**Figure 2-1**).

With travel times of approximately one hour, the Kingston/Plymouth Line provides service between Kingston and South Station. Kingston Station, located on Marion Drive in Kingston, near Pilgrims Highway (Route 3), is accessible and has approximately 1,030 parking spaces. Kingston Station is in fare zone 8, with a one-way trip to Boston costing $12.25 and a monthly pass costing $388.00.[9] Based on ridership data from 2018, approximately 657 passengers per day board at Kingston Station.

The Middleborough/Lakeville Line connects the Middleborough/Lakeville Station with South Station, with travel times of approximately one hour. Located on Commercial Drive in Lakeville, near I-495, the station is accessible and has approximately 769 parking spaces. Similar to Kingston Station, Middleborough/Lakeville is in fare zone 8, with a one-way trip to Boston costing $12.25 per trip and a monthly pass costing $388.00.[10] Based on ridership data from 2018, approximately 867 passengers per day board at Middleborough/Lakeville Station.

South Coast Rail will provide commuter rail service to New Bedford, Fall River, and Taunton. **SCR Phase 1** will extend the Middleborough/Lakeville Line to these communities using existing active freight rail corridors, with service anticipated to begin in late 2023. MassDOT is also proceeding with design and permitting of the Stoughton Straight Electric Alternative (the "SCR Full Build Project") already reviewed under the National Environmental Policy Act (NEPA) and the Massachusetts Environmental Policy Act (MEPA). This phased approach will provide service to the South Coast region in advance of the SCR Full Build Project, as documented in the January 2018 Draft Supplemental Environmental Impact Report (DSEIR).

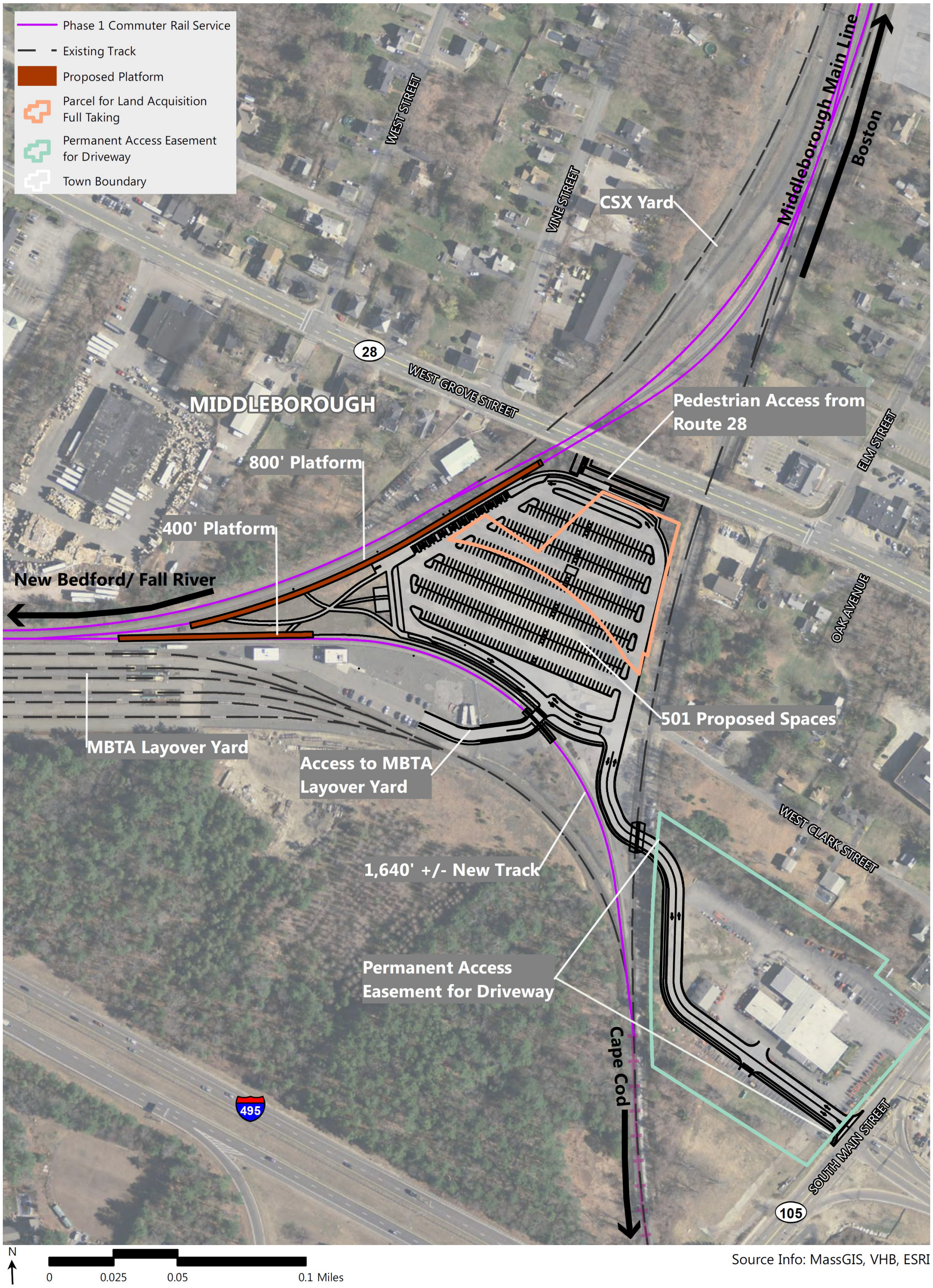
As described in the DSEIR, SCR Phase 1 will create a new station at Pilgrim Junction (Middleborough Station). The SCR project has planned for a connection between the Cape Cod region and SCR Phase 1 service through the potential use of two platforms—one dedicated to Cape service and one dedicated to SCR Phase 1 service—with a short at-grade connection. **Figure 2-3** includes the platform configuration presented in the SCR DSEIR. While the SCR project will only construct the 800-foot platform for SCR trains as part of the project, the planning would enable future construction of the 400-foot platform to serve Cape trains. Although the configuration included in the DSEIR and illustrated in **Figure 2-3** shows the 400-foot platform to the west of the parking lot, locating the platform to the east of the parking lot along the Middleborough Main Line would also be feasible and could be reevaluated during future planning and design development.[11]

[9] Please see https://www.mbta.com/fares/commuter-rail-fares/zones for more detail on commuter rail fares. Fare details reflect full fares, with latest information as of May 2021.

[10] Fare details reflect latest information as of May 2021.

[11] For the purposes of this study, the analysis assumed the platform location as shown in the SCR DSEIR. Prior to advancing any construction of the 400-foot platform, additional coordination and design would determine the exact location of the 400-foot platform within Middleborough Station. The SCR project advanced the track design of the station to accommodate the platform at the location shown in Figure 2-3, which would provide the shortest walking route for passengers transferring between Cape service and SCR trains. The station will also include a path at the northern edge of the parking lot that could accommodate a future connection between the 800-foot platform and a 400-foot platform to the east of the parking lot. Although the potential location to the east of the parking lot would result in a longer walk time between trains and more complex construction due to grade differences, it could allow the same platform to be used for all trains serving the Cape region (including direct trips to or from Boston),

Figure 2-3 Proposed Middleborough Station (as Shown in SCR DSEIR)

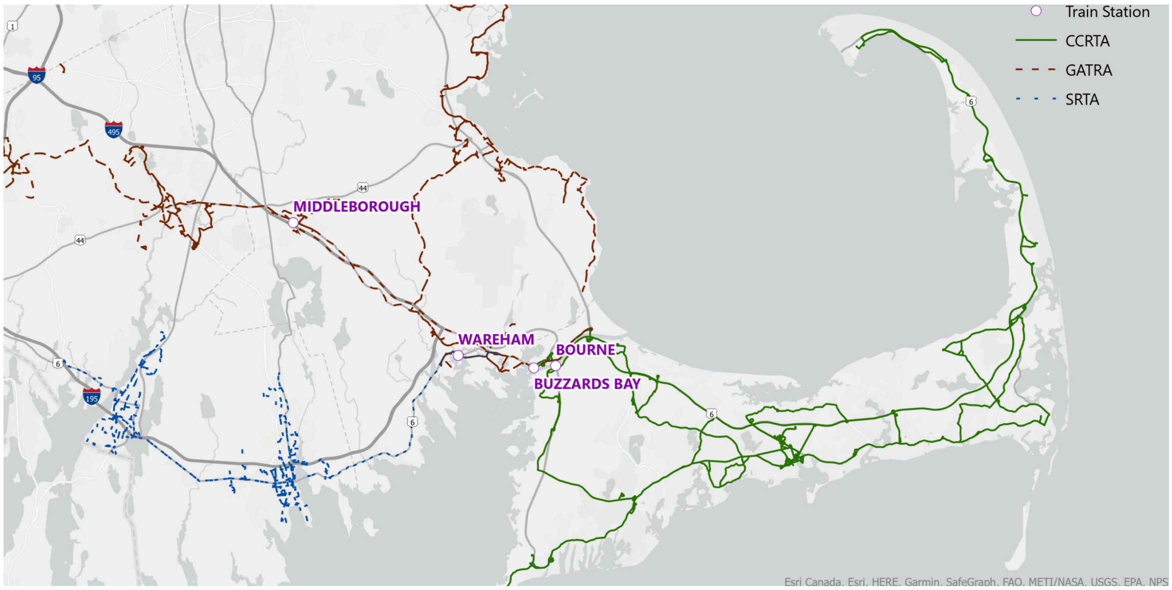


Source: MassDOT, SCR DSEIR, January 2018.

2.1.2 Bus Services

Several regional transit authorities provide service in or near the study area. CCRTA provides service on Cape Cod, while the Greater Attleboro and Taunton Regional Transit Authority (GATRA) provides service to Middleborough and Wareham (**Figure 2-4**).

Figure 2-4 Regional Bus Services



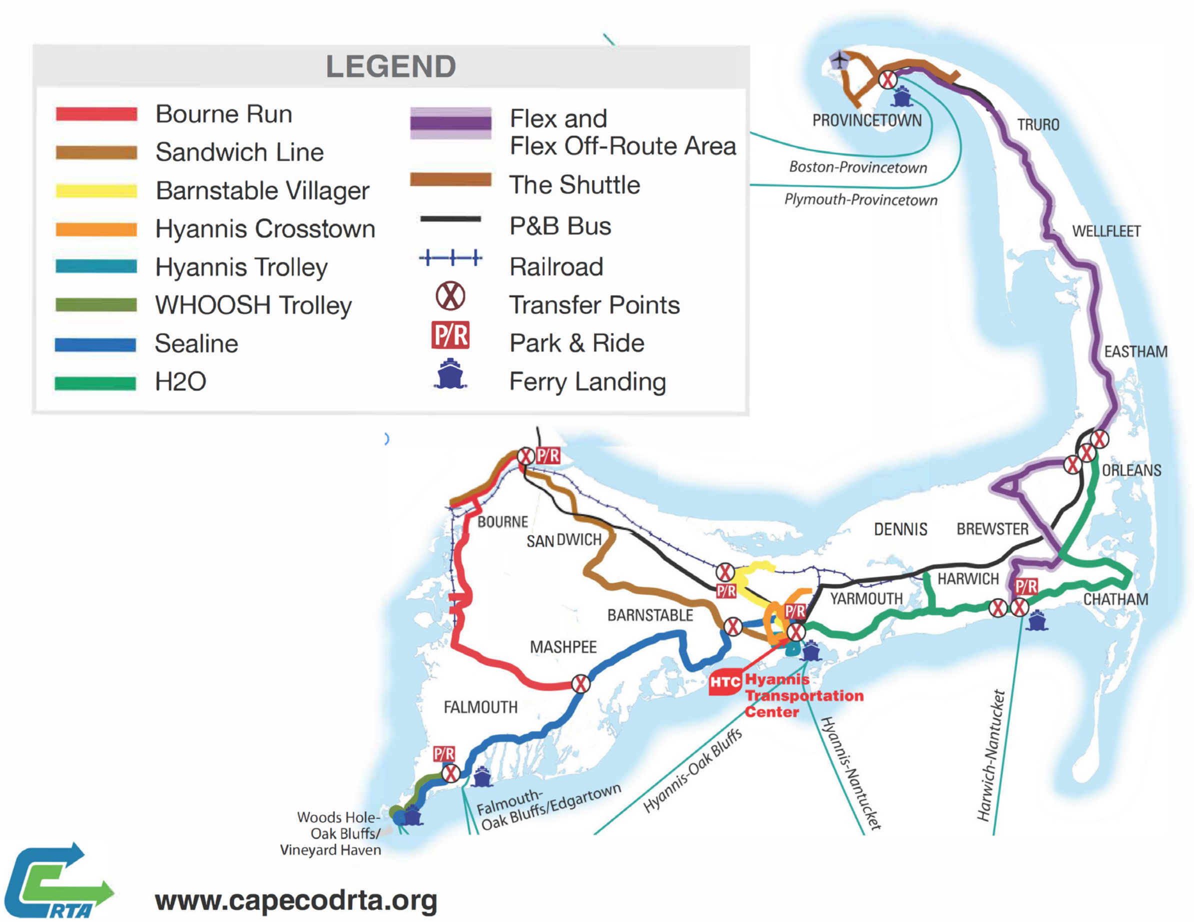
Sources: MassGIS, ESRI

Within the study area, **CCRTA** operates the Bourne Run between the Buzzards Bay train station and Mashpee Commons via Route 28A and Route 151 in Bourne and the Sandwich Line between the Buzzards Bay train station and Hyannis via Sandwich. The CCRTA Buzzards Bay Connector is a high frequency service area within Buzzards Bay/Sagamore that was created from an overlap of the Sandwich Line and Bourne Run (**Figure 2-5**). The high frequency service area exists between the Buzzards Bay train station/Massachusetts Maritime Academy and the Bourne Market Basket via Main St. and the Scenic Highway. CCRTA also offers daily Boston Hospital Transportation, with one weekday trip directly from Cape Cod to Boston area hospitals by reservation, with seven pickup locations between Wellfleet and Sagamore. The trip leaves Sagamore at 8:15 AM, arrives at Boston around 10:00 AM, and leaves Boston by 3:00 PM. **Figure 2-6** highlights existing local CCRTA services.

Figure 2-5 CCRTA Buzzards Bay Connector High Frequency Service Area

Source: Cape Cod Commission CCRTA Route Planner Tool, Courtesy of CCRTA

Figure 2-6 Map of Existing CCRTA Services



Source: Cape Cod Regional Transit Authority

GATRA operates several routes in Wareham and Middleborough. The Wareham – Lakeville MBTA Connector connects Wareham to the Middleborough/Lakeville MBTA station. Link 1 connects Cranberry Plaza and Cromeset with a stop at Wareham Center near the Wareham Village train station. Link 2 connects Bourne and Cranberry Plaza with a stop in Buzzards Bay near the Buzzards Bay train station. The Downtown Middleborough Shuttle offers local service within Middleborough and Lakeville, with a stop at the Middleborough/Lakeville MBTA station. Each of these routes offers multiple trips per weekday. GATRA also operates other routes within the area that do not serve the existing train stations, including a service provided in partnership with the Southeastern Regional Transit Authority (SRTA) connecting Wareham to New Bedford.

The Plymouth & Brockton Street Railway Company (P&B),Peter Pan Bus Lines, and Yankee Line also operate **express-bus service** to the region. P&B operates service between Boston and Hyannis or Woods Hole, with stops in Rockland, Plymouth, Sagamore, Falmouth, and Barnstable. Peter Pan operates service between Boston and Hyannis, Falmouth, Provincetown, Woods Hole, and other locations on Cape Cod. The routing varies somewhat, with some trips stopping in Wareham or Buzzards Bay. Cape Bus operates a luxury service between Boston and Hyannis, with stops in Sagamore and Barnstable.

2.2 Study Corridor Infrastructure

South of Middleborough/Lakeville, the Cape Main Line carries the CapeFLYER seasonal Friday and weekend service and occasional freight service. The following sections describe the infrastructure along this corridor, including stations, track, signals, grade crossings, and structures.

2.2.1 Stations

SCR Phase 1 service between Boston and Fall River/New Bedford will not stop at Middleborough/Lakeville Station but will instead stop at a new **Middleborough Station** to be constructed near Pilgrim Junction (**Figure 2-3**). As described in Section 2.1.1, the SCR project planned for but will not construct the 400-foot platform required to serve Cape trains. The station could include a shelter for passengers transferring between the Cape service and service to/from Boston. Approximately 500 parking spaces would accommodate park-and-ride users of the existing Middleborough/Lakeville station with similar convenience.

Wareham Village is an existing station used by the CapeFLYER service, with a 400-foot high-level timber platform. The platform and one-way access road parallel Main Street and are separated by a row of shops and restaurants; the other side of the track is bordered by the Wareham River. Vehicular access is off Route 6, approximately 1.5 miles from I-195. The existing surface lot has approximately 50 parking spaces, with approximately 100 additional spaces of street parking.

Existing station at Wareham Village

Buzzards Bay is also an existing station used by the CapeFLYER service. Its approximately 500 -foot platform includes a 65-foot mini-high platform and a 40-foot timber mini-high platform that is separated from the rest of the platform by a driveway at-grade crossing that leads to a U.S. Army Corps of Engineers parking lot, which can also be accessed from Academy Drive.[12] The platform abuts Academy Drive and runs parallel to Canal Street, with access from Main Street (close to Route 6). The Cape Cod Canal is 300 feet south of the end of the platform. The station is near the Massachusetts Maritime Academy campus, the Taylor Point Marina, and Buzzards Bay Recreation Area. In addition to a surface parking lot with 60 spaces owned by MassDOT, there are approximately 680 spaces in nearby private and public surface lots and approximately 200 on-street spaces on Main Street.[13]

Existing station building at Buzzards Bay

Bourne, an existing station used by CapeFLYER, has a high-level platform that can accommodate a single coach stopped at the platform. The station is adjacent to the Bourne Bridge, with access from Sandwich Road, and the platform is just to the east of a grade crossing, which provides access between the driveway from Sandwich Road and the Canal Service Road. Although the station is intended mainly for pick-up and drop-off access, there are a limited number of parking spaces adjacent to the station. The station also has access to the Cape Cod Canal Bikeway, which runs parallel to the station, between the station and the Cape Cod Canal.

[12] A mini-high platform is a platform that is raised to allow for level-boarding between the station and the train for some cars on a trainset.

[13] Cape Cod Commission, "Buzzards Bay Commuter Rail Extension: Local Impact Report," April 2015.

Existing platform at Bourne

The **Hyannis Transportation Center** is the existing southern terminus of the CapeFLYER, with an approximately 500-foot high-level platform adjacent to the station building. The station is east of downtown Hyannis, between Iyannough Road (Route 28) and Main Street, with access from Transportation Avenue. CCRTA offers long-term parking for 160 vehicles, with short-term parking also available. The Hyannis Transportation Center also provides bus service, with multiple CCRTA and private bus routes using the facility. CCRTA offices are located in the Hyannis Transportation Center.

Hyannis Transportation Center, Photo Courtesy of CCRTA

2.2.2 Track and Right of Way

The MBTA operates service along the **Middleborough Main Line** between South Station and Middleborough/Lakeville Station. The Middleborough Main Line is a primarily single-track corridor, although there are a few sidings to support operations.[14] SCR Phase 1 will continue to use this corridor and will diverge at the new Middleborough Station to travel along the Middleborough Secondary. The MBTA Kingston/Plymouth and Greenbush Lines also share the northern segment of the Middleborough Main Line; together, these services are called the Old Colony Lines.

Capacity on the Middleborough Main Line is limited. The segment shared by the three Old Colony Lines runs parallel to I-93, limiting opportunities to add double track to support additional service. Meanwhile, all south-side MBTA lines and multiple Amtrak services terminate at **South Station.** The South Station terminal currently operates at its full platform track capacity, limiting the opportunities to support additional service. MassDOT's South Station Expansion Project has evaluated opportunities to expand capacity at South Station, but the full project is not programmed at this time.

South of Middleborough/Lakeville, the **Cape Main Line** connects to Wareham and Buzzards Bay north of the Cape Cod Canal, and then to Bourne and Hyannis south of the Cape Cod Canal. Buzzards Bay is approximately 19 miles from Middleborough/Lakeville; Bourne approximately two miles beyond Buzzards Bay; and Hyannis approximately 22 miles beyond Bourne. The segment of track between Middleborough and Cohasset Narrows (approximate locations) has **mostly single-track,** continuous welded rail with maximum allowable speeds up to 59 miles per hour (mph) in much of this segment. South of Cohasset Narrows,[15] the lower-class joint rail extends all the way to Hyannis, with maximum allowable speeds limited to 30 mph.

North of Buzzards Bay, the Cape Main Line has **two rail sidings** that could be used to stage passenger trains for service. A siding is a second track where a train can wait off the main track while a different train passes in the opposite direction. One of these sidings is located just north of Buzzards Bay station, extending across the Cohasset Narrows. The other siding is approximately eight miles further north, near the border between Wareham and Rochester.

The right-of-way along the Cape Main Line is relatively constrained. Marsh/bog, wooded marsh, salt marsh, cranberry bog, and open water areas are adjacent to some segments of the Cape Main Line. Part of the corridor is also within the Coastal Zone, and Tidelands Chapter 91 Jurisdiction applies to some of the corridor as well. There are large areas of Natural Heritage and Endangered Species Program (NHESP) Priority Habitats of Rare Species and NHESP Estimated Habitats of Rare Wildlife, and the project limits coincide with mapped habitat of Federally Threatened or Endangered species. Cultural resources are located along the rail line and include local historic districts, particularly south of the Cape Cod Canal.

South of the Cape Cod Canal are **two branch lines**. The Falmouth Line branches off the Cape Main Line just south of the Cape Cod Canal Railroad Bridge and extends approximately seven miles to the Joint Base Cape Cod. The Yarmouth Branch extends about three miles off the Cape Main Line to South Yarmouth. Both branch lines have joint rail, with maximum allowable speeds limited to 30 mph on the Falmouth Branch and 10 mph on the Yarmouth Branch.

[14] Single-track refers to the number of tracks available for train use. In single-track sections, trains traveling in both directions must use the same track at different times. A passing siding is a segment of additional track that allows a train to pass another train traveling in the same area at the same time (typically in the opposite direction). A glossary of railroad-related terms used in this report is included in Appendix A.

[15] Approximate locations are provided for context. The transition from continuous welded rail to jointed rail happens at the Taylor interlocking, which is near the Cohasset Narrows.

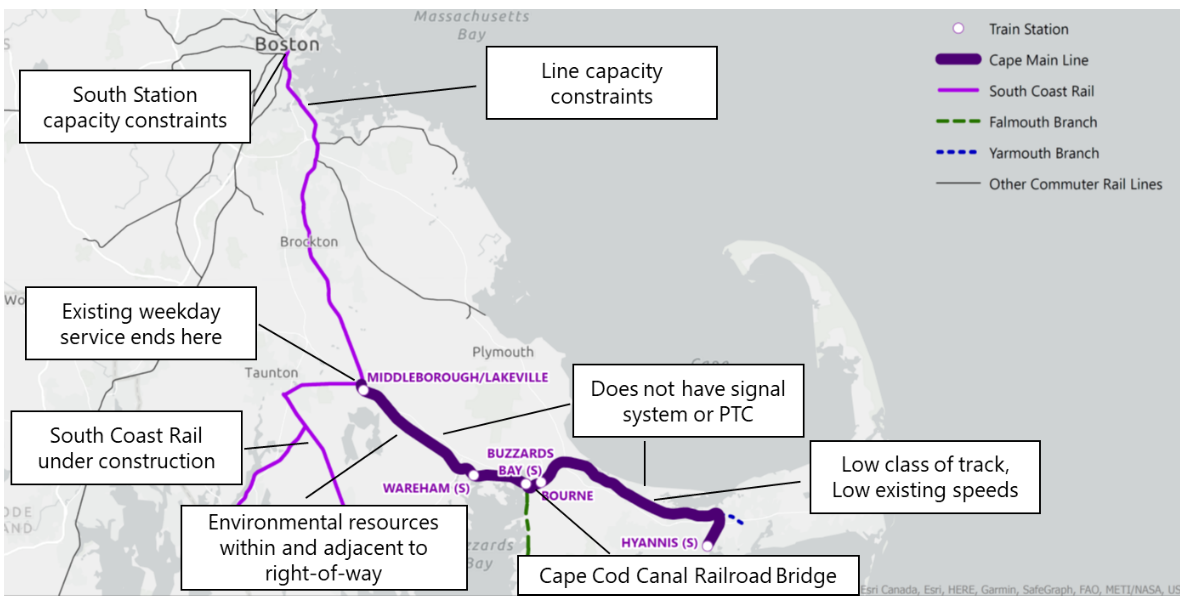
2.2.3 Signals

The Cape Main Line is currently **unsignalized ("dark territory")**, outside of signals associated with an interlocking at the Cape Cod Canal Railroad Bridge. Additionally, **Positive Train Control (PTC)** has not been installed south of the Middleborough/Lakeville station. PTC is a signal life-safety system that automatically enforces speed restrictions. PTC provides both predictive and reactive speed control and can positively stop a train for safety purposes.[16] The MBTA has installed PTC on all commuter rail lines. Through the Rail Track and ROW Modernization and Expansion Programs, and under guidance from the Massachusetts State Rail Plan and other planning efforts, the MassDOT Rail & Transit Division is actively working to improve, modernize, and expand the railroad network statewide. These improvements could include the implementation of PTC in addition to more routine track and asset improvements.

Signals near the Cape Cod Canal Railroad Bridge

North of the Middleborough/Lakeville station, the MBTA uses a cab signal system with PTC. Cab signaling is a signal system that communicates track status and related speed information directly into the locomotive cab, continuously providing updated signal information on an easy-to-read display. **Figure 2-7** summarizes these signal constraints, along with track and right-of-way constraints.

Figure 2-7 Summary of Track, Right-of-Way, and Signal Constraints



Sources: MassGIS, ESRI, VHB

[16] PTC is legislatively required to be fully operational before starting new intercity or commuter rail passenger services after December 31, 2020.

2.2.4 Grade Crossings

To cross a roadway, a track requires either grade separation (with a structure) or a railroad-highway **at-grade crossing**. Public at-grade crossings with active passenger service often include the installation of warning systems and safety protection devices. The following summarizes the grade crossings along the corridor:

- Between Middleborough/Lakeville Station and Buzzards Bay, there are 11 public crossings and three private grade crossings.
- Between Buzzards Bay and Bourne, there is one additional public grade crossing, and there are two additional private grade crossings (including one at the Bourne Bridge access road).
- Between Bourne and Hyannis, there are 22 public crossings and 17 private crossings.

Grade Crossing at Academy Drive just north of Buzzards Bay station

Most public grade crossings on the corridor are equipped with active warning devices, and the MBTA recently upgraded the equipment at a number of these crossings. Nearly all the private grade crossings lack active warning devices.

2.2.5 Structures

Structures along the corridor include **overhead bridges** (where a roadway passes over the railroad tracks), **undergrade bridges** (where a roadway passes under the railroad tracks), and **railroad bridges over water**.

- Between Middleborough/Lakeville Station and Buzzards Bay, there are seven overhead bridges, two undergrade bridges, and three railroad bridges over water (the Nemasket River, Wareham River, and the Cohasset Narrows).
- Between Buzzards Bay and Bourne, there are two overhead bridges (including the Bourne Bridge), one undergrade bridge, and one railroad bridge over water (the Cape Cod Canal).
- Between Bourne and Hyannis, there are four overhead bridges (including the Sagamore Bridge), and three undergrade bridges.

The **Cape Cod Canal Railroad Bridge** is a vertical lift railroad bridge that provides right-of-way for marine traffic over the Cape Cod Canal. The U.S. Army Corps of Engineers owns the bridge and maintains local bridge control, although train movements over the bridge are under control of a train dispatcher operating remotely. Since the U.S. Army Corps of Engineers controls the bridge and the typical position of the vertical lift is raised to allow for marine traffic, train operators must call before arriving at the bridge for it to be lowered, allowing the bridge operator sufficient time to clear related marine traffic. The Cape Cod Canal Railroad Bridge takes approximately 2.5 minutes to lower from its raised position approximately 135 feet above the water.[17]

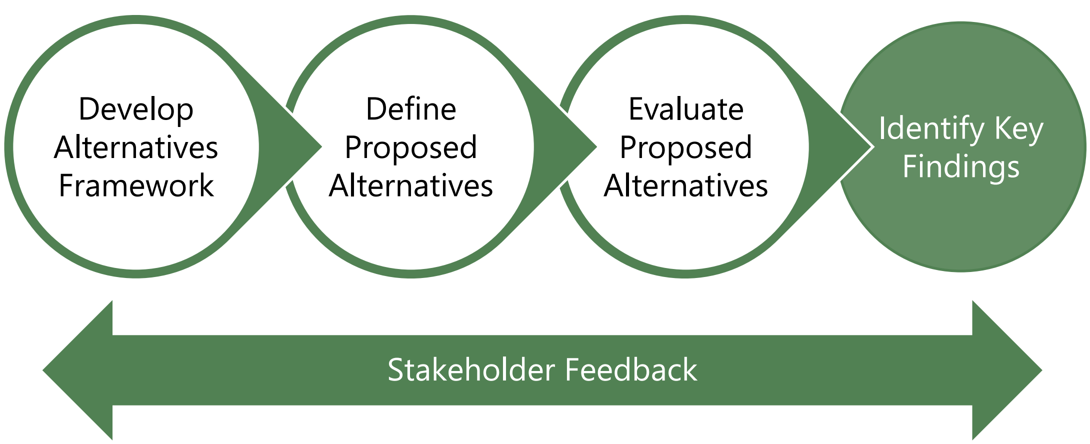
[17] U.S. Army Corps of Engineers, "The Cape Cod Canal's Vertical Lift Railroad Bridge," available at https://www.nae.usace.army.mil/Portals/74/docs/Recreation/CCC/Brochures/Vertical_Lift_Railroad_Bridge_Trifold.pdf.

3

Alternatives Analysis

This study considered two alternatives that were developed in coordination with the Advisory Group. The alternatives include a range of options that allowed MassDOT and the MBTA to test the benefits and tradeoffs of different service components. This chapter describes the service alternatives development process, the proposed alternatives, the evaluation criteria and methodology used to evaluate the alternatives, and summarizes the results and key findings. Figure 3-1 highlights the alternatives analysis process. The project purpose, as well as goals and objectives, were considered at each stage of this process. Results and findings can provide stakeholders with the data and information needed to inform future policy and decisions.

Figure 3-1 Alternatives Analysis Process



3.1 Service Alternatives Development

A set of goals and objectives, developed as part of the first Advisory Group meeting, provided a foundation for development of potential service alternatives. These goals and objectives, described in Chapter 1, include:

1. Provide safe and reliable public transportation options to, from, and within the Cape and surrounding areas
2. Reduce automobile usage and greenhouse gas emissions
3. Support and strengthen opportunities for economic growth, transit-oriented development, and access to employment in the Boston region for commuters and occasional riders

To help frame the service alternatives around these goals and objectives, MassDOT, the MBTA and the Advisory Group discussed the priorities associated with the following service components:

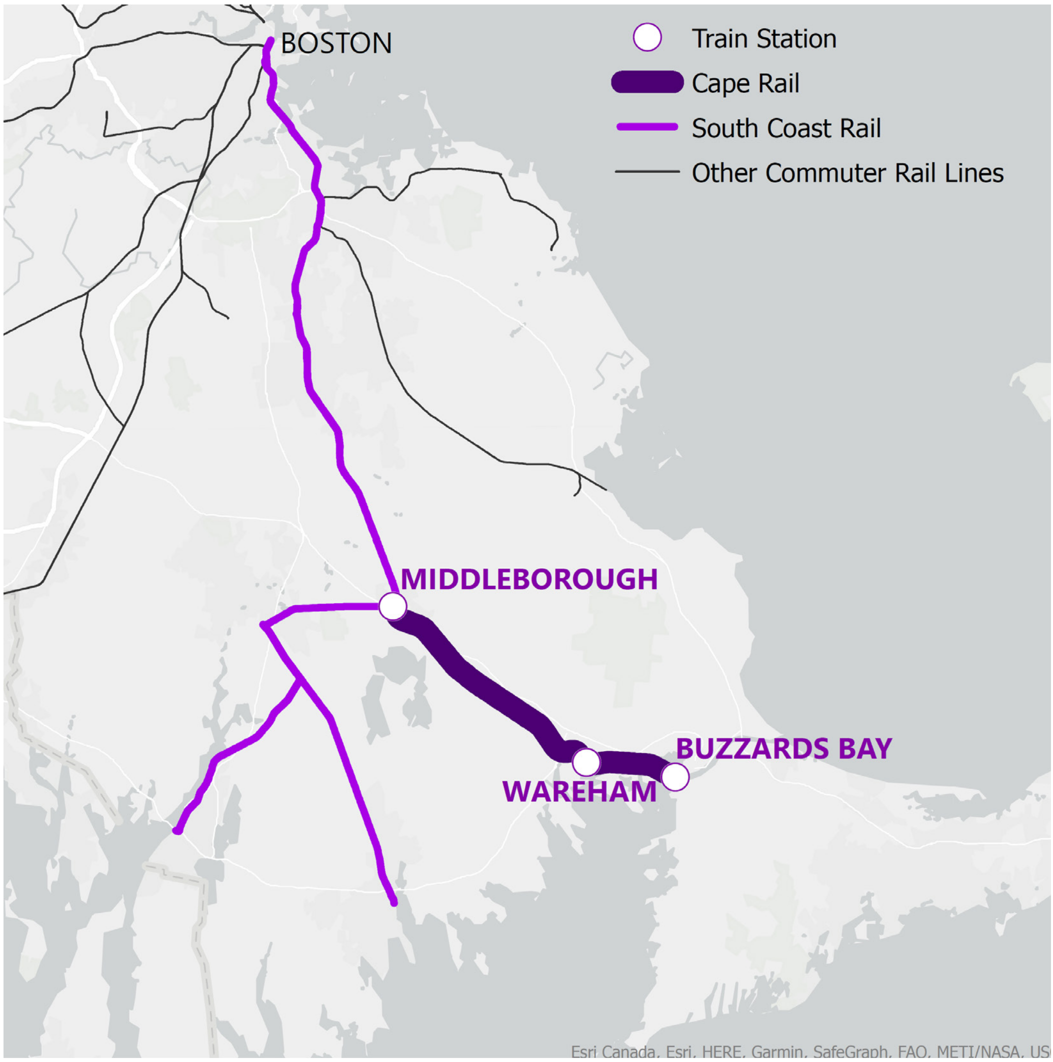
- The **trip purpose** could include commuter trips, recreational trips, or a combination of commuter and recreational trips.
- Scheduling trips could occur during different **time periods** and on different **days of the week**; for example, travel could occur during the weekday peak periods, weekday off-peak periods, bridge peak periods, or on weekends.
- Trips could serve different **station locations**, including the existing stations described in Section 2.2.1 and/or new station locations.
- The **southern terminal** of service represents the first or last stop on a trip; options could include Buzzards Bay, Bourne, Hyannis, or other stations.
- The service alternatives could provide varying levels of **frequency**, including meeting the MBTA *Service Delivery Policy* or providing higher or lower frequency. The MBTA *Service Delivery Policy* defines expected commuter rail frequencies of three trips in the peak direction in the AM Peak, four trips in the peak direction in the PM Peak, and every three hours in each direction in all other periods.
- Service alternatives could require a **transfer** at the new Middleborough Station, described in Section 2.2.1, or could potentially incorporate selected trips without transfers where operating windows are available.

Based on stakeholder feedback, the Cape Rail Study developed service alternatives to evaluate a range of options. This variation allowed the Study to evaluate tradeoffs between service components, with the purpose of providing data and information to the region.

3.1.1 Description of Alternative 1

Alternative 1 focused on providing weekday commuter service to Buzzards Bay with a stop at Wareham and transfers between Cape trains and SCR trains at the new Middleborough Station (**Figure 3-2**). It would provide a frequency consistent with the MBTA *Service Delivery Policy*.

Figure 3-2 Alternative 1



Sources: MassGIS, ESRI

Since SCR Phase 1 will extend all existing Middleborough/Lakeville Line trips to Fall River and New Bedford (and add one peak trip in each direction), capacity limitations on the Middleborough Main Line will limit the opportunities to operate direct trips between Boston and the Cape Cod region. Alternative 1 connected Cape service with SCR Phase 1 to provide service between Boston and Buzzards Bay with a single transfer at the new Middleborough Station. As described in Section 2.2.1, SCR trains will also stop at the new Middleborough Station. Construction of a second platform for Cape service would allow for a cross-platform transfer at Middleborough between SCR and Cape trains (**Figure 2-3**). Alternative 1 would time the trips to provide a coordinated transfer between the two services.

To meet the MBTA *Service Delivery Policy,* Alternative 1 provided three trips in the peak direction in the AM Peak, four trips in the peak direction in the PM Peak, and trips every three hours outside of the peak periods. While Alternative 1 focused on a commuter service, an additional trip was added in the reverse direction to provide service for recreational or reverse commute ridership, with a departure time from South Station of approximately 8:30 AM. Two additional trips were also added in the reverse direction in the PM Peak period, arriving at South Station at approximately 4:30 PM and 6:00 PM.

3.1.2 Description of Alternative 2

Alternative 2 built on Alternative 1 and increased the level of service to make the following adjustments (**Table 3-1** summarizes the differences between Alternatives 1 and 2):

- **Extended service south of the canal to the existing Bourne station** based on discussion with the Advisory Group; this was a key criterion in Alternative 2 to provide insight into the benefits and challenges associated with providing service to the south side of the canal
- **Added service outside the traditional commute peak periods** to capture potential recreational demand that would occur outside of the typical commute
- **Added service directly to and from Boston**, with one round trip outside of existing operating windows (the first trip of the day to Boston and the last trip of the day from Boston), and one midday round trip to Buzzards Bay

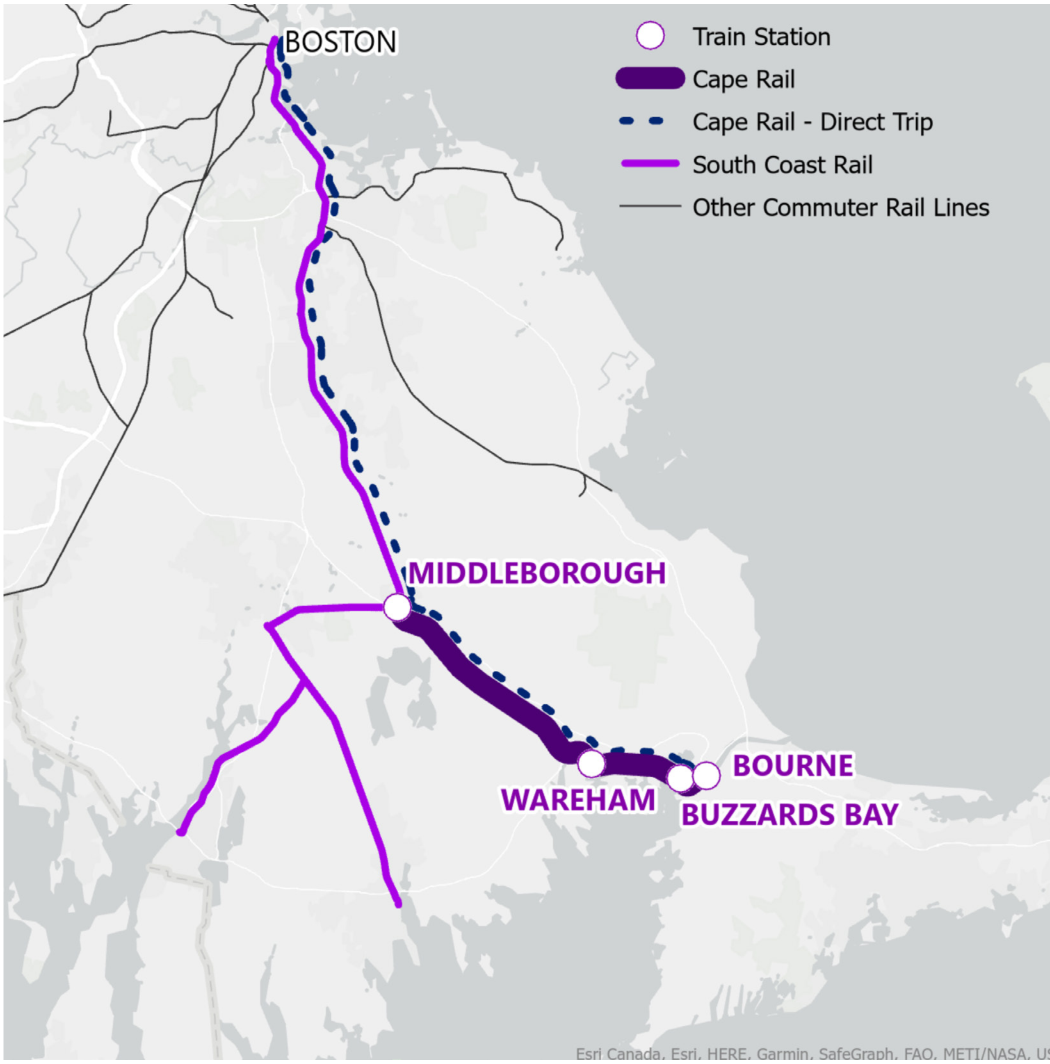
Table 3-1 Summary of Alternatives 1 and 2

Service Characteristic	Alternative 1	Alternative 2
Purpose	Commuter	Commuter + Recreational
Day/Time	Weekday (Peak Focused)	Weekday
Locations	Existing Stations	Existing Stations
Terminals	Buzzards Bay (North of Canal)	Bourne (South of Canal)
Frequency	Consistent with MBTA *Service Delivery Policy*	Higher Frequency
Transfers	One Transfer on All Trips	No Transfers on Selected Trips (Outside of Normal Weekday Operations)

Note: Both alternatives assume continuation of Friday and weekend CapeFLYER service.

Alternative 2 provided service between Bourne and Middleborough, with stops at Buzzards Bay and Wareham and transfers between Cape trains and SCR trains at the Middleborough station. The trips providing service directly between the Cape Cod region and Boston would stop at the existing Middleborough/ Lakeville Station instead of the new Middleborough Station, and make additional stops on the Middleborough/Lakeville Line between Middleborough and South Station. Note that Alternative 2 included one midday round trip that provided direct service between the Cape Cod region and Boston but did not extend to Bourne, with a terminus at Buzzards Bay (as described in more detail in Section 3.3.1.2). **Figure 3-3** highlights the service in Alternative 2.

Figure 3-3 Alternative 2



Sources: MassGIS, ESRI

3.1.3 Other Factors Considered

While **Table 3-1** highlights the differences between Alternatives 1 and 2, there were several other factors considered outside the two alternatives. Specifically:

- **Service to Hyannis** was not included in either alternative. Based on discussion with the Advisory Group, there was interest in including one alternative with a southern terminus north of the Cape Cod Canal and one alternative with a southern terminus south of the Cape Cod Canal. Options for the southern terminus included Bourne, Hyannis, or a different station not currently served by the CapeFLYER. With existing travel times between Buzzards Bay and Hyannis approaching one hour due to a maximum authorized speed of 30 miles per hour, extending service between Bourne and Hyannis would require major track and signal upgrades to support faster, more frequent service, and would require improvements to a number of grade crossings along the corridor. It would also result in greater O&M costs associated with the longer route. Based on these factors, additional outreach to the Advisory Group confirmed an Alternative 2 terminus at Bourne to provide a more direct comparison of service to the north and south sides of the Cape Cod Canal.
- The alternatives did not evaluate different **fare structures**. The MBTA's Fare Transformation program is replacing the current fare payment technology, including on the rail system. While this may provide additional opportunities for fare structures, both Alternatives 1 and 2 assumed a fare structure consistent with the existing MBTA Commuter Rail zonal structure. The following section (Section 3.2) describes these assumptions in more detail.
- Both Alternatives 1 and 2 included some trains that could be used for recreational trip purposes. However, neither alternative modeled additional **weekend service,** instead assuming continued operations of the CapeFLYER (**Figure 3-4**). As described in Section 3.2, the statewide travel demand model is calibrated for weekday travel purposes and would not capture changes in weekend travel or recreational demand. While the ridership projections account for increased recreational demand, they do not account for changes to weekday service.

Figure 3-4 CapeFLYER Weekend Service (2021)

- The alternatives do not account for potential **COVID impacts**. Specifically, the operating plan used the proposed South Coast Rail schedules as a baseline, and the ridership projections did not account for any changes in future ridership patterns due to COVID (with a forecast year of 2030). While COVID may impact how people travel in the future, there is too much uncertainty around long-term behavioral changes to incorporate potential changes into this study.

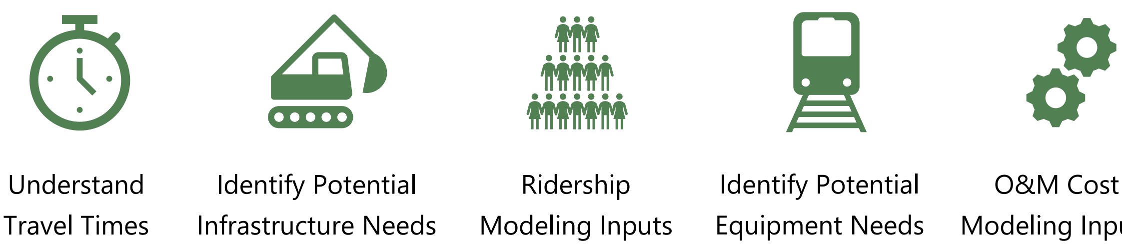
3.2 Methodology and Evaluation Approach

To assess how each alternative met the goals described in Chapter 1, the alternatives analysis evaluated the operations, projected ridership, projected changes in automobile usage and automobile emissions, and order-of-magnitude costs. The following sections describe each of these in more detail.

3.2.1 Schedule Development and Operations Analysis

The operations analysis focused on developing Cape rail service schedules for each alternative using the key service components defined through stakeholder feedback as guidelines for the level of service. The proposed schedules were developed for the purposes of the study and are not intended to be final operating plans. Specifically, the **schedules were used as inputs** into other parts of the alternatives analysis **(Figure 3-5).** The following subsections describe this in more detail.

Figure 3-5 Purposes of Proposed Schedules



To develop the service plans, the SCR Phase 1 final schedules for New Bedford/Fall River were used as the baseline schedules to coordinate with Cape rail service. In both Alternatives 1 and 2, Cape trips were coordinated with these SCR Phase 1 final schedules to allow for timed transfers, typically scheduling five minutes to allow passengers to make the cross-platform transfer. Additionally, the final schedules under SCR Phase 1, including for the Greenbush and Kingston/Plymouth Lines, provided a baseline to determine where direct trips between the Cape Cod region and Boston could be scheduled in Alternative 2. Using the existing CapeFLYER service stopping patterns as reference, the analysis estimated travel times for service between Middleborough and Buzzards Bay or Bourne. Once a schedule was built, Berkeley's RTC simulation software was used to confirm the schedules.

RTC is used to simulate the movement of trains through complex rail networks, such as the Northeast Corridor (NEC) and South Station Terminal, and—in this case—the SCR and potential Cape rail service. Both Alternatives 1 and 2 were simulated in RTC to determine and understand trip run times, schedule openings, locations for trains to pass each other, and potential conflicts. The simulation models were developed by incorporating the proposed SCR Phase 1 infrastructure and operations, including at Pilgrim Interlocking. Once the infrastructure was verified in the RTC models, the future schedules for each alternative were input into each RTC model, dispatched, and watched to understand conflicts. The schedules were then adjusted accordingly and altered based on potential conflicts. The schedules were used to estimate the number of trainsets required to run service in each alternative and identify turnaround times and layover constraints.

General assumptions were made that applied to both alternatives. This included assuming that daily freight services would be scheduled around passenger revenue service and maintaining all rolling stock, dwell times, turn times, and operations assumptions from SCR Phase 1. The operations modeling assumed that all trips between Buzzards Bay or Bourne and Middleborough would use diesel train consists with one F40PH-2C diesel locomotive pulling three coaches, and all trips between Buzzards Bay or Bourne and Boston would have one F40PH-2C diesel locomotive pulling four coaches. The assumed trainsets would be smaller than the trainsets typically used for CapeFLYER service. The Cape Rail Study used this assumption solely for operations modeling, as the fleet would need to be determined prior to the start of a potential future service.

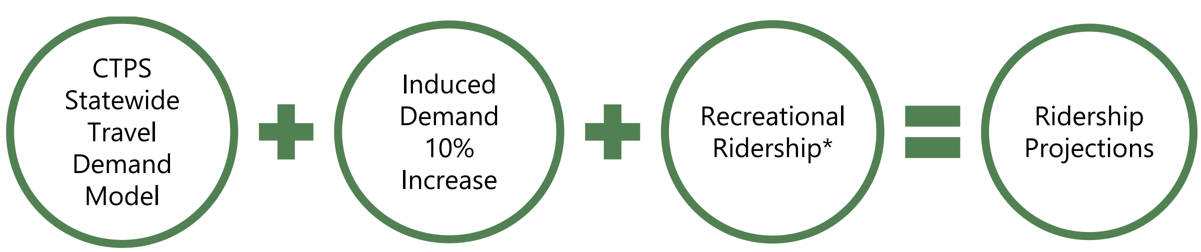
The operations analysis for both alternatives assumed that trains would dwell for 60 seconds at all station stops between Buzzards Bay or Bourne and Middleborough. Three minutes were added to the schedule in Alternative 2 to accommodate travel over the Cape Cod Canal Railroad Bridge to account for potential delays. Alternative 2 specifically assumed that the schedule would be coordinated with bridge operations so that the bridge could be raised and lowered according to the planned schedule. This would require additional coordination with the U.S. Army Corps of Engineers prior to implementation.

In developing the equipment cycle, equipment turn times for the proposed alternatives were assumed to be no less than 20 minutes if possible and 15 minutes at a minimum as part of the MBTA's equipment and schedule objectives, with recovery time included in the travel time. Both alternatives assumed the addition of a PTC-compliant signal system installed on the Cape Main Line, from the proposed Pilgrim Interlocking to Buzzards Bay in Alternative 1 and to Bourne Station in Alternative 2.

3.2.2 Ridership Modeling

Ridership was modeled for future Cape service using the **CTPS Statewide Travel Demand Model**, updated to reflect future land use assumptions in the project area and census demographic data. The CTPS model uses a process consistent with that of other major transportation projects in eastern Massachusetts. This travel demand model was refined specifically for the proposed service, using the current statewide model. Since the CTPS Statewide Travel Demand Model is calibrated to existing travel patterns, additional adjustments were made to reflect induced demand (new trips that occur because of an improvement to the overall transportation system) and recreational ridership (**Figure 3-6**). The following subsections describe the CTPS Statewide Travel Demand Model methodology and the additional adjustments.

Figure 3-6 CTPS Ridership Modeling Methodology



*Up to 70 trips per day, or approximately 15% of weekend CapeFLYER ridership per trip

3.2.2.1 CTPS Statewide Travel Demand Model

The model that CTPS uses for forecasting travel demand is based on procedures and data that have evolved over many years and incorporates assumptions based on accepted practice, professional judgment and policy decisions relating to items such as model method, service plans and demographic assumptions. The CTPS model and its underlying assumptions are subject to review and approval by the Federal Highway Administration and Federal Transit Administration because the model is used to develop the regional emissions estimates, which are used for transportation conformity determinations on the Long-Range Transportation Plan and Transportation Improvement Program.

The CTPS Statewide Travel Demand Model includes all major transit modes, such as commuter rail lines, the subway system (both light and heavy rail lines), ferry service, and bus routes. The model allows for transfers between all modes. Access to the transit system is allowed via walk/bike, transit, park and ride, and kiss and ride modes.

The demographic forecasts were created for the Boston Region Long-Range Transportation Plan, *Destination 2040,* based on projections by the local Regional Planning Agencies in the model area (see Appendix B for more detail on the population projection methodology and the regional projections used as inputs into the CTPS Statewide Travel Demand Model). These demographic forecasts were developed prior to the release of data from the 2020 Census, and therefore do not necessarily reflect the results of the 2020 Census. Transportation improvements included in this study are those projects most likely to be built by 2030 and that are included in *Destination 2040*.

To establish where people are coming from and going to, the model considers the population and employment densities of the region. This is the basis for an origin/destination summary that ultimately translates into the number of potential users. The model also considers station locations and accounts for the proximity of population densities to establish how the riders access the stations.

CTPS developed ridership forecasts for Alternatives 1 and 2 for the 2030 forecast year. The ridership model assumed that the transportation network will be updated to reflect service improvements. Model outputs were compared to 2030 No Build projections to project what changes in travel patterns would occur due to the service improvements. The operating plan input into the ridership modeling was based on the proposed schedules developed for Alternatives 1 and 2.

To plan for a service that accommodates future demand, Wareham, Buzzards Bay, and Bourne were modeled as if there were no constraints on the amount of available parking, with no fee for parking. Running the model unconstrained at these stations allowed the results to reflect the total number of riders who would be expected to use the new service if parking were not a limiting factor. This applied to the riders who will arrive to the station by car. All other modes (such as drop-offs or patrons arriving to the station by walking, riding a bicycle, or using transit) would be unaffected by the parking supply.

The model also considers the economics of using the proposed transit system, which allowed it to weigh the economic attractiveness of riding the proposed system compared to the economics of continuing to drive or using the existing commuter bus service. Fares for the proposed service were based on the current MBTA commuter rail monthly fare structure at the time of the modeling, assuming that Wareham, Buzzards Bay, and Bourne would have fares consistent with the MBTA's fare zone 9.

As part of the CTPS Statewide Travel Demand Model, the mode choice estimation also produces a projected number of trips made by automobile for the No Build and each alternative. The mode choice estimation reflects the mode used for the majority of the full trip (for example, the trip of a person driving from Wareham to Boston is classified as an auto trip, but the trip of a person driving from Wareham to the Wareham station to use the train to travel to Boston is classified as a transit trip). Based on the mode choice estimates, CTPS projected the **number of auto diversions**, (i.e., trips that had occurred predominantly by auto that would instead occur predominantly by transit). The auto diversions could include trips that still access transit by auto, in addition to trips that access transit by non-auto modes such as walk, bicycle, or other transit services.

3.2.2.2 Additional Adjustments

The ridership modeling made two additional adjustments to the ridership projections produced through the CTPS Statewide Travel Demand Model. Ridership projections accounted for induced and recreational ridership; each is described in more detail below.

Induced demand reflects new trips that occur because of an improvement to the overall transportation system (in this case, the expansion of rail service providing a new mode of transportation to the Cape Cod region). Consistent with the ridership modeling in the MassDOT *East-West Passenger Rail Study,*[18] the Cape Rail Study included a 10-percent increase in projected ridership due to induced demand. The *East-West Passenger Rail Study* reviewed rail ridership forecasts in the US and globally and applied the following station-pair level increases, considered the high end of the US rail forecasting practice:

- Rural-Rural: 5% increase
- Rural-Urban: 10% increase
- Urban-Urban: 15% increase

The MassDOT *East-West Passenger Rail Study* considered Boston, Worcester, and Springfield as urban stations and Pittsfield, Lee, Chester, Blandford, and Palmer as rural stations. Consistent with this station typology, the Cape Rail Study considered Boston as an urban station and Middleborough, Wareham, Buzzards Bay, and Bourne as rural stations and applied the 10% increase associated with rural-urban travel. The 10% increase was not applied to the number of auto diversions, as the induced demand reflects new trips that occur because of the improvement in the overall transportation system, so would not include trips that were previously made by auto.

Recreational demand reflects the unique characteristics of the Cape Cod region. Since the CTPS Statewide Travel Demand Model is not calibrated to reflect recreational demand, the ridership projections incorporated a recreational adjustment based on the CapeFLYER service. For planning purposes, the ridership projections included an increase equivalent to approximately 15 percent of weekend CapeFLYER ridership per trip in Alternative 2, or approximately 70 trips per day. These 70 passenger trips per day were split proportionally between Bourne and Buzzards Bay in Alternative 2 based on CTPS Statewide Model results. The recreational trips included in Alternative 2 at Buzzards Bay were also applied in Alternative 1. The recreational demand was not applied to the number of auto diversions, under the assumption that these are not currently trips made by auto.

[18] MassDOT, *East-West Passenger Rail Study*, January 2021, available at: https://www.mass.gov/east-west-passenger-rail-study.

3.2.3 Vehicle Miles Traveled and Emissions

The auto diversions were combined with approximate trip lengths based on the origin and destination transportation analysis zones (TAZs), along with the driving distances to the projected station used. CTPS used this information to estimate the total reduction in **vehicle miles traveled (VMT)** for each alternative compared to the No Build.

Parking area near Wareham Village station

The change in automobile vehicle miles traveled was then used to estimate the **change in automobile emissions** using the Congestion Mitigation and Air Quality Improvement Program (CMAQ) Air Quality Analysis Worksheet. The CMAQ Air Quality Analysis Worksheet is used for projects applying for CMAQ funding,[19] and converts auto VMT changes to auto emission changes (specifically: summer volatile organic compounds [VOCs], summer nitrous oxides [NOx], winter carbon monoxide [CO], and summer carbon dioxide [CO_2]).

Note that the analysis estimates the change in auto VMT and auto emissions for the alternatives compared to the No Build but does not include the change in rail VMT and emissions. The change in rail emissions would be dependent on the future fleet used to operate the service, along with other variables (e.g., consist size, stopping patterns, or source emissions).

[19] The Congestion Mitigation and Air Quality Improvement Program (CMAQ) provides federal funding for states to support projects and programs intended to improve air quality and reduce traffic congestion. CMAQ funds (80 percent federal/20 percent nonfederal) are used for transportation programs and projects that will contribute to the attainment of a National Ambient Air Quality Standard in ozone, small particulates matter, and carbon monoxide non-attainment areas.

3.2.4 Order of Magnitude Cost Estimates

The cost of running a service includes both the initial capital outlay to improve the infrastructure along the corridor and the ongoing costs related to operating the service. The alternatives analysis estimated **order-of-magnitude** (OOM) **capital costs and operations and maintenance (O&M) costs** to provide information about what could be required to implement each alternative.

3.2.4.1 Order-of-Magnitude Capital Cost Estimates

The OOM capital cost estimates were built based on SCR Phase 1 unit costs (escalated to 2021 dollars) due to the similarities between the corridors. The capital costs included the following cost elements:

- **Track resurfacing and tie replacement** between the Nemasket River (just south of the existing Middleborough/Lakeville Station) and Taylor Interlocking (just north of Buzzards Bay station). The existing continuous welded rail (CWR) between the Nemasket River and Taylor Interlocking would undergo a tie replacement program (approximately 20% replacement based on current condition). The entire corridor would be resurfaced with a single tamper pass following the tie program.
- **Track reconstruction** south of Taylor Interlocking, with all new ties, rail, ballast, and subballast. The entire corridor would be resurfaced with a single tamper pass following the track reconstruction.
- Improved **track drainage** on the corridor would support a more frequent service.
- **Cab signaling, PTC, and communications** along the entire corridor. The Cape Main Line is currently unsignalized and would require the design and installation of a cab signal system and PTC. This would include installation of a new signal system at all required control points and end of sidings, and signal upgrades as needed at grade crossings. In addition to the signal upgrades, the implementation of PTC is legislatively required to be fully operational before starting new intercity or commuter rail passenger services after December 31, 2020. The MBTA has installed PTC on all commuter rail lines, and MassDOT may undertake PTC installation on MassDOT-owned rail assets in the Commonwealth in accordance with the State Rail Plan and other planning studies. Signal improvements would also include **end-of-siding interlockings** associated with the passing sidings used for service.
- **A second platform at Middleborough** would provide the northern terminus of Cape rail service trains that provide a transfer to SCR. It would allow passengers to make the cross-platform transfer between the Buzzards Bay shuttle trains and the SCR Phase 1 trains. Capital costs assume the continued use of the existing station infrastructure at Wareham, Buzzards Bay, and Bourne.
- More frequent passenger operations across the **Cape Cod Canal Railroad Bridge,** as discussed in Alternative 2, would require a vital **signal system** interfaced with the bridge operating, locking, and detection systems to ensure safe passenger operations across the bridge.

Cape Cod Canal Railroad Bridge would require additional interfacing to new signal system

The capital cost estimates did *not* include the following:

- **Grade crossing improvements** were excluded from the costs, since the grade crossings along the corridor have recently been upgraded. While initial estimates included improvements at these grade crossings, based on feedback at the Advisory Group meeting, these costs were removed from the alternative costs to reflect that any additional improvements would be reevaluated and done as needed prior to the implementation of any service. All private crossings were assumed to be closed prior to the start of service.
- The analysis assumed that none of the **structures** on the corridor would require improvements.
- **Fleet costs** were excluded, as the analysis assumed the use of surplus fleet. Any additional fleet procurement, rehabilitation, or overhaul would incur additional cost.

The costs presented in the alternatives analysis include 25% burden, 40% design contingency, and 10% construction contingency. The capital costs are presented in 2021 dollars and were not escalated to a year of construction.

3.2.4.2 Order-of-Magnitude O&M Cost Estimates

To estimate the OOM O&M costs, the alternatives analysis compiled unit costs from the MBTA's 2019 data as submitted to the Federal Transit Administration National Transit Database. Like the capital cost estimates, these unit costs were used and scaled up to 2021 dollars.

The MBTA's O&M costs were more than $384 million in 2019, with 436 maximum vehicles in service, nearly 25 million service miles and over 800,000 service hours. Using the proposed schedules and equipment needs for each alternative, the maximum number of vehicles needed to run Cape service, the service miles covered, and the amount of service hours from each alternative were applied to the MBTA's unit costs. While the estimates use unit costs from MBTA systemwide operations, actual O&M costs may differ due to several factors, including the service operator.

The estimated O&M costs were separated into the following categories:

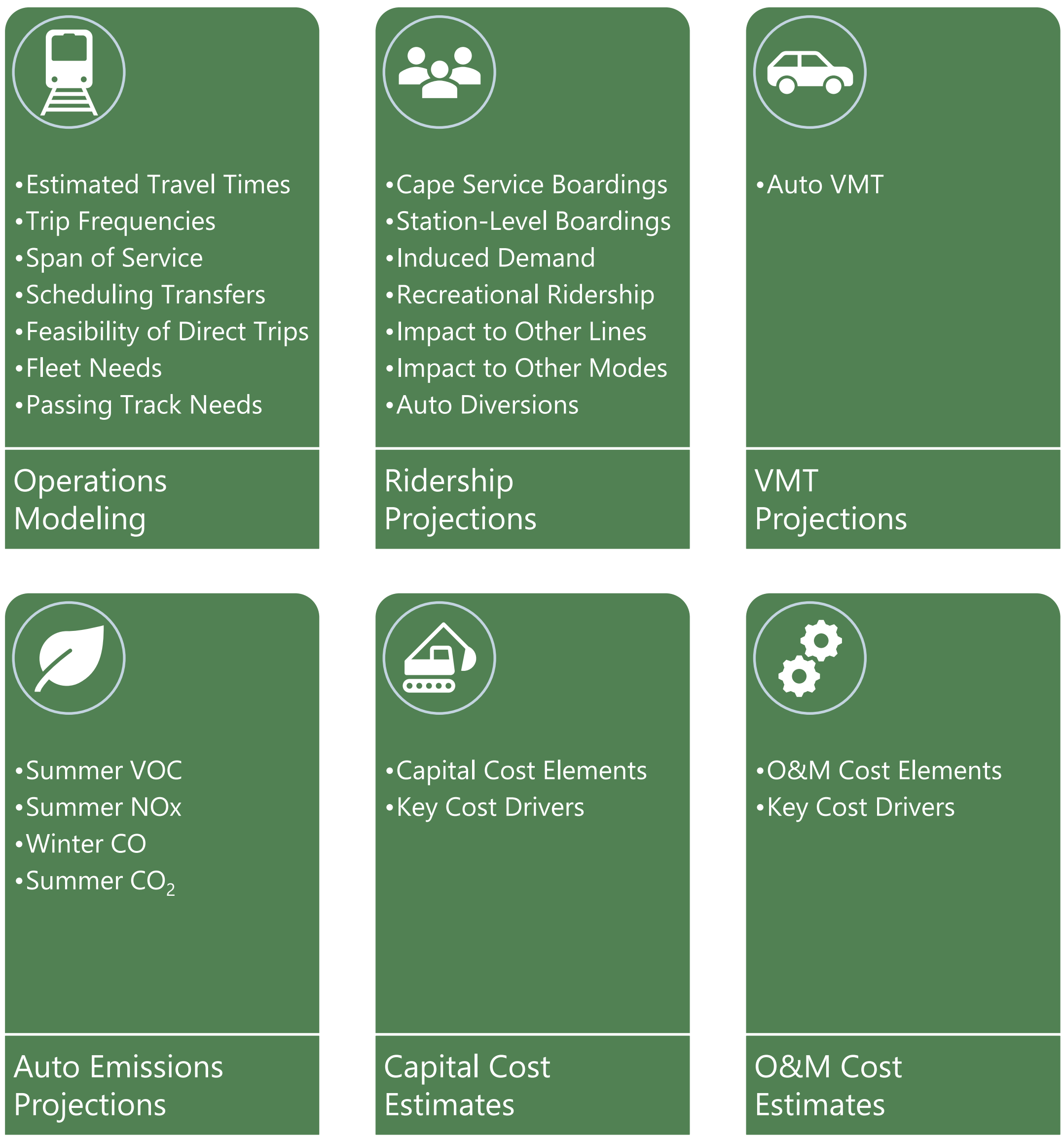
- **Vehicle operations**, which include costs such as operating crew and fuel costs. Since the MBTA reports all vehicle operations costs under a single purchased transportation subcategory, a single unit cost for vehicle operations was developed based on the service hours in operation. The vehicle hours in operation were further adjusted with a factor to account for the length of revenue service compared to likely crew hours, given the peak service and shift requirements.
- **Vehicle maintenance**, which includes costs such as maintenance staff and materials. Since the MBTA reports all vehicle maintenance costs under a single purchased transportation subcategory, a single unit cost for vehicle maintenance was developed based on the maximum vehicles in service.
- **Facility maintenance**, which includes costs such as staff and materials, including building, structures, and track maintenance. Since the MBTA reports nearly all facility maintenance costs under a single purchased transportation subcategory, a single unit cost for facility maintenance was developed based on the maximum vehicles in service, as equipment drives facility costs.
- **General administration**, which includes costs such as MBTA and contractor management and support. Since the MBTA reports nearly the majority of general administration costs under a single purchased transportation subcategory, a single unit cost for general administration was developed based on the maximum vehicles in service, which is typically used as a proxy for this cost category.

3.3 Results and Key Findings

The following sections describe the results of the alternatives analysis. These results identify quantitative findings from the alternatives analysis related to operations, ridership, automobile diversions and emissions, and costs. The results are intended to inform regional stakeholders about the tradeoffs in implementing different service patterns, but do not represent a final condition.

Figure 3-7 summarizes some of the information and data included in the results and key findings.

Figure 3-7 Information Included in Results and Key Findings



3.3.1 Operations

3.3.1.1 Alternative 1 Operations

The proposed Alternative 1 schedule proposed weekday service focused on peak commuting at a frequency consistent with the MBTA *Service Delivery Policy*. All trips were between Buzzards Bay and Middleborough, with a timed cross-platform transfer of five minutes (with one exception) to and from SCR service.[20] This allows for some flexibility for unexpected delays at the Middleborough Station.

The proposed schedule included three peak-direction trips in the AM Peak period, four peak-direction trips in the PM Peak period, and service in each direction approximately every three hours during all other time periods for 14 total trips. To provide some recreational or reverse commute opportunities, Alternative 1 included one morning southbound trip with a departure time from South Station of approximately 8:30 AM and two afternoon trips arriving at South Station at approximately 4:30 PM and 6:00 PM. Only one SCR trip leaves earlier than the 8:30 AM. trip in the southbound direction, and potential transfers from this trip would conflict with peak direction Cape service. The schedule also met the MBTA's weekday span of service standards identified in the *Service Delivery Policy,* with the first trip arriving at South Station before 7:00 AM and the last trip departing South Station after 10:00 PM.

All trips were scheduled to operate Monday-Friday, with one exception in the PM Peak Period, where one train would operate Monday-Thursday only and the existing southbound Friday CapeFLYER trip providing the fourth trip during the PM Peak period. Alternative 1 assumed that the CapeFLYER would continue to provide Friday and weekend service. The Alternative 1 schedule can be found in Appendix C.

Alternative 1 would result in a travel time of 31 minutes between Buzzards Bay and Middleborough Station, and approximately 93 minutes between Buzzards Bay and Boston (including the five-minute transfer time). The Alternative 1 schedule would require three trainsets, not including spare trainsets, and would have only one equipment turn scheduled for less than 20 minutes.

Figure 3-8 Alternative 1 Operations by the Numbers

14	Total trips
31	Minute travel time Buzzards Bay-Middleborough
5	Minute typical transfer at Middleborough
93	Minute typical travel time Buzzards Bay-Boston
3	Trainsets, excluding spares
1	Existing passing siding used to stage trains

The Alternative 1 schedule assumed that the existing Middleborough Yard would serve as the primary layover facility for midday and overnight layovers. Due to the layover location, the Alternative 1 schedule included a double draft deadhead movement in the early morning before the first scheduled trip and in the late evening when no service is scheduled in the opposite direction. During service hours, Alternative 1 used the double track just north of Buzzards Bay over the Cohasset Narrows to stage trains as needed. Use of this double track could prevent non-revenue trains from affecting revenue service, eliminate the need for frequent deadhead trips from Buzzards Bay to Middleborough, and enable the equipment to stay closer to Buzzards Bay.

[20] One reverse direction PM Peak trip has a timed cross-platform transfer of 16 minutes to allow the train the minimum 15 minutes to turn and operate as a peak direction PM Peak trip with a 5-minute cross platform transfer. See Appendix C for more details.

3.3.1.2 Alternative 2 Operations

Alternative 2's proposed operating plan expanded on Alternative 1 with **higher frequency** where possible, in addition to extending service to south of the Canal **to Bourne** and including one-seat rides with **direct service to/from Boston** during the early morning, midday, and late evening periods. The one-seat ride trips are scheduled to avoid conflicts with SCR and Old Colony Lines trips.

All trips between Bourne and Middleborough maintained the timed cross-platform transfer of five minutes (with three exceptions) connecting Cape service to SCR trips.[21] The schedule also met the MBTA's frequency and span of service standards identified in the *Service Delivery Policy* as the proposed schedule expanded on the Alternative 1 schedule with the addition of one AM Peak period trip in the peak direction, one midday trip in the northbound direction, and four one-seat ride trips. Alternative 2 included one-seat ride trips from Bourne to Boston before the start of other service, a round trip between Boston and Buzzards Bay in the midday, and a trip from Boston to Bourne after the end of other service. The Alternative 2 midday one-seat rides used Buzzards Bay as the southern terminus since layover space limitations and tight operating windows within the SCR and Old Colony Lines schedules prohibited the longer travel time required to travel across the bridge to Bourne.

Like in Alternative 1, all trips were scheduled to operate Monday-Friday, with the exception of one evening trip that would operate Monday-Thursday; the existing southbound Friday CapeFLYER trip would provide the fourth trip during the PM Peak period. Alternative 2 also assumed that the CapeFLYER would continue to provide weekend service (see Appendix C for the Alternative 2 schedule).

Alternative 2 would result in a travel time of 39 minutes between Bourne and Middleborough Station, and approximately 101 minutes between Bourne and Boston (including the transfer time), with shorter travel times on the one-seat rides. A three-minute buffer time between the departure and arrival times at Buzzards Bay, in both directions, was built into the schedule to account for potential delays in travel across the Cape Cod Canal Rail Bridge. Due to the additional service, the Alternative 2 schedule would require five trainsets, including the trainset required to operate the one-seat ride service, but not including spare trainsets. Like Alternative 1, the Alternative 2 schedule assumed that the existing Middleborough Yard would serve as the primary layover facility for midday and overnight layovers.

The Alternative 2 schedule also included a double draft deadhead movement in the early morning before the first scheduled trip and in the late evening after Cape service has completed. Additionally, deadhead movements to/from Buzzards Bay and Bourne were required throughout the day to avoid midday layovers at Bourne, and to stage trains on the double track just north of Buzzards Bay over the Cohasset Narrows, as in Alternative 1.

Figure 3-9 Alternative 2 Operations by the Numbers

20	Total trips, including four one-seat rides
38	Minute travel time Bourne-Middleborough
5	Minute typical transfer at Middleborough
101	Minute typical travel time Buzzards Bay-Boston
5	Trainsets, excluding spares
2	Existing passing sidings used

[21] In addition to the cross-platform transfer noted for Alternative 1, one trip has a similar transfer of 17 minutes to turn and operate as a reverse direction AM Peak trip with a 5-minute cross platform transfer. The third exception is a midday southbound trip, which has a timed cross-platform transfer of 17 minutes to allow the northbound direct trip to Boston to pass. See Appendix C for more details.

Overall, the increase in service required more deadhead movements to/from Middleborough and Bourne throughout the day compared to Alternative 1. With the additional volume of trains, Alternative 2 also uses the existing Tremont Siding just north of Wareham Station so that revenue service can pass non-revenue trains on the single-tracked Cape Main Line.

3.3.1.3 Summary and Key Findings

Alternative 1 provided rail service between Buzzards Bay and Middleborough Station, while Alternative 2 extended rail service to Bourne and provided one-seat rides to/from Boston and Bourne/Buzzards Bay. Both alternatives were coordinated with timed transfers to/from SCR Phase 1 service to provide typical travel times of approximately 93 minutes between Buzzards Bay and Boston and (in Alternative 2 only) 101 minutes between Bourne and Boston, with both times including the five-minute transfer time.

Both alternatives met the MBTA's *Service Delivery Policy*, with Alternative 2 providing additional service, including direct service without a transfer between the Cape Cod region and Boston. To provide some recreational or reverse commute opportunities, both alternatives included one morning southbound trip with a departure time from South Station of approximately 8:30 AM and two afternoon trips arriving at South Station at approximately 4:30 PM and 6:00 PM. **Table 3-2** identifies the number of trips by period for each alternative.

Table 3-2 Number of Trips by Alternative and Period

Alternative	Sunrise/ Early AM	AM Peak*	Midday or Reverse Peak	PM Peak*	Evening/ Night	Total
Alternative 1	0	3	5	4	2	14
Alternative 2	1	4	8	4	3	20

Note: The AM Peak and PM Peak number of trips shown are for the peak direction for purposes of comparison to the *Service Delivery Policy*. Reverse peak travel is included in the Midday or Reverse Peak column. In Alternative 2, one one-seat ride trip occurred in the Sunrise/Early AM, two occurred in the Midday, and one occurred in the Evening/Night periods.

In developing the schedules, the existing infrastructure (including long segments of single track and layover locations), and coordination with the SCR Phase 1 schedule defined the windows available to operate service to the Cape Cod region.

In both alternatives, the Cape Main Line was single tracked, meaning there were no opportunities for an inbound and outbound revenue train to pass each other outside of existing passing sidings north of Buzzards Bay and north of Wareham Station. The result is that some trips to and from the Cape that could otherwise be coordinated with the SCR Phase 1 schedule would come into conflict with service going in the opposite direction. This limited opportunities to operate reverse-direction trains during the peak periods (e.g., a southbound train during the AM Peak period).

In both alternatives, service is feasible with layover at Middleborough Yard and the staging of trains in the double track section over Cohasset Narrows. In Alternative 2, layover space limitations, particularly the lack of a layover space at Bourne, required multiple deadhead movements between Bourne and either the Cohasset Narrows staging location or the Middleborough Yard. This resulted in some extended transfer times at Middleborough beyond five minutes and required the midday one-seat ride to stop at Buzzards Bay instead of extending to Bourne.[22]

With service to Bourne, Alternative 2 would require frequent travel over the Cape Cod Canal Railroad Bridge, particularly during peak periods. While the alternatives analysis assumed that the schedule could be coordinated with marine traffic to lower the bridge as needed, additional coordination would be required with the U.S. Army Corps of Engineers.

Alternative 2 also required additional equipment compared to Alternative 1. While Alternative 1 required three trainsets (excluding spares), Alternative 2 requires five trainsets (excluding spares) due to the increased frequency and direct trips between the Cape Cod region and Boston.

3.3.2 Projected Ridership

Alternative 1 resulted in a projected increase of **1,710 daily boardings** compared to the No Build. This included 630 daily boardings at Buzzards Bay, 240 daily boardings at Wareham, and 840 daily boardings at Middleborough.[23] These values include the 10% increase in induced demand (accounting for approximately 150 of these daily boardings) and recreational ridership (accounting for approximately 50 of these daily boardings, evenly split between Buzzards Bay in the northbound direction and Middleborough in the southbound direction).

Alternative 2 resulted in a projected increase of **2,540 daily boardings** compared to the No Build. Alternative 2 resulted in greater projected ridership than Alternative 1 because of the greater frequency and the extension to Bourne provided in Alternative 2. The projected boardings in Alternative 2 included 650 daily boardings at Bourne, 390 daily boardings at Buzzards Bay, 230 daily boardings at Wareham, and 1,270 daily boardings at Middleborough.[24] These values include the 10% increase in induced demand (accounting for approximately 220 of these boardings) and recreational ridership (accounting for approximately 140 of these daily boardings, with approximately 70 at Middleborough in the southbound direction, 25 at Buzzards Bay in the northbound direction, and 45 at Bourne in the northbound direction). In addition to the 2,540 daily boardings, the CTPS Statewide Travel Demand Model projected that the additional service on the direct trips to/from Boston would result in additional daily boardings between Middleborough and South Station due to the higher frequencies at those stations.

[22] Due to the limited available operating windows on the Middleborough Main Line during the midday, extending the midday one-seat ride to Bourne would not be possible and would require two separate consists to reduce the time between arrival and departure times at Bourne. This is not feasible without additional layover space, so the midday one-seat ride trip included in Alternative 2 terminated at Buzzards Bay.

[23] The boardings at Middleborough reflect boardings associated with the Cape service in the southbound direction. They do not include boardings on SCR trains (including northbound transfers from Cape service) to avoid double-counting Cape Cod region passengers.

[24] The boardings at Middleborough include 30 boardings at the existing Middleborough/Lakeville station that would use the one-seat ride trips. These trips were not adjusted to account for induced demand since the station is served today. The remainder of the boardings at Middleborough reflect boardings associated with the Cape service in the southbound direction. They do not include boardings on SCR trains (including northbound transfers from Cape service) to avoid double-counting Cape Cod region passengers.

Table 3-3 compares the projected ridership by alternative and station. The values shown in this table include the adjustments to account for induced demand and recreational ridership.

Table 3-3 Projected Ridership by Alternative and Station

Station	Alternative 1	Alternative 2
Middleborough (Cape Service)	840	1,270
Wareham	240	230
Buzzards Bay	630	390
Bourne	-	650
Total	**1,710**	**2,540**

Notes: Projections are rounded to the nearest 10. Boardings include adjustments to the outputs from the CTPS Statewide Travel Demand model to account for induced demand and recreational ridership. Middleborough boardings in Alternative 2 include 30 boardings at the existing Middleborough/Lakeville station on one-seat ride trips.

As illustrated in **Table 3-3**, Alternative 2 resulted in more than 800 additional boardings compared to Alternative 1. The projected daily boardings at Wareham were relatively consistent between Alternatives 1 and 2, indicating that any additional frequency and direct service at Wareham is offset by the additional service provided south of the Cape Cod Canal. Meanwhile, the projected daily boardings at Buzzards Bay decreased from Alternative 1 to Alternative 2 due to passengers choosing to use the Bourne station to the south of the Cape Cod Canal. However, the combined increase from Alternative 1 to Alternative 2 at the Buzzards Bay and Bourne stations demonstrates some additional demand generated by service at higher frequencies and to the south of the Cape Cod Canal. Not all of the trips at Bourne are passengers that would use Buzzards Bay in Alternative 1.

Bourne station platform and Bourne Bridge

CTPS also projected the number of auto diversions associated with the projected ridership, as described in Section 3.2.2. Alternative 1 was projected to result in approximately **810 daily auto diversions**, and Alternative 2 was projected to result in approximately **1,180 daily auto diversions.** In both alternatives, most of the trips diverted from auto would still access the rail station by auto, but rail is the primary mode of transportation for the trip. **Table 3-4** includes the breakdown by alternative of auto diversions and access to transit.

Table 3-4 Projected Auto Diversions by Alternative and Mode of Access

Access Type	Alternative 1	Alternative 2
Walk Access to Transit	140	200
Drive Access to Transit	670	980
Total	**810**	**1,180**

Note: Projections are rounded to the nearest 10.

Parking area next to Buzzards Bay station building

Notably, **the ridership modeling projected that diversions would not occur from other modes of transit or other rail lines**. CTPS projected essentially no change to the number of passengers using private buses. Similarly, it projected essentially no change to the ridership on the Greenbush Line, Kingston/Plymouth Line, and on SCR south of Middleborough. As noted above, the additional frequency provided in Alternative 2 north of Middleborough was anticipated to result in additional ridership between Middleborough and South Station.

3.3.3 Projected Changes in Vehicle Miles Traveled (VMT) and Emissions

As described in Section 3.2.3, the projected changes in VMT and emissions reflect changes from automobile travel only. Increases in VMT and emissions associated with the new rail service are not included in these estimates.[25]

Based on the auto diversions summarized in **Table 3-4**, CTPS projected that Alternative 1 would result in a reduction of nearly 43,000 VMT per day, while Alternative 2 would result in a reduction of nearly 66,000 VMT per day. Annualizing these values with a factor of 250 days per year equates to more than **10 million VMT annually** in Alternative 1 and over **16 million VMT annually** in Alternative 2.[26]

Since the VOC, NOx, CO, and CO_2 emissions were developed using emissions factors per VMT, the projected reductions in these emissions were proportional to the VMT reductions noted for Alternatives 1 and 2. For example, the VMT projections for Alternative 1 resulted in reductions of nearly 14,000 kilograms (kg) of Summer CO_2 per day, or over **3,400 metric tons of CO_2 annually**. The VMT projections for Alternative 2 resulted in reductions of nearly 21,000 kg of Summer CO_2 per day, or more than **5,200 metric tons of CO_2 annually**.

Table 3-5 summarizes the projected daily changes in vehicle miles traveled and emissions by alternative. **Table 3-6** summarizes the projected annual changes in VMT and emissions by alternative. Note that each pollutant uses both an annualization factor and a seasonal adjustment factor to estimate the projected annual change.

Table 3-5 Projected Daily Auto VMT and Auto Emissions Reductions

Daily Change in	Alternative 1	Alternative 2
Auto Diversions	810	1,180
Auto VMT	-42,718	-65,675
Summer VOC (kg)	-1.28	-1.97
Summer NOx (kg)	-3.89	-5.98
Winter CO (kg)	-75.48	-116.05
Summer CO_2 (kg)	-13,628	-20,952

Note: Values shown for VMT and emissions reductions are for auto travel only and do not include the increase in train VMT or train emissions. Summer CO_2 projections are rounded to the nearest whole number.

Table 3-6 Projected Annual Auto VMT and Auto Emissions Reductions

Annual Change in	Alternative 1	Alternative 2
Auto Diversions	202,500	295,000
Auto VMT	-10,679,500	-16,418,750
VOC (kg)	-326	-502
NOx (kg)	-990	-1,522
CO (kg)	-18,516	-28,467
CO_2 (kg)	-3,406,965	-5,237,895

Note: Values shown for VMT and emissions reductions are for auto travel only and do not include the increase in train VMT or train emissions. Emissions projections are rounded to the nearest whole number.

[25] For example, all alternatives presented in the MassDOT *East-West Passenger Rail Study* projected auto VMT savings but overall increases in emissions when incorporating diesel train-based emissions.

[26] For reference, the alternatives presented in the MassDOT *East-West Passenger Rail Study* projected auto VMT savings ranging from 23.4 million VMT per year to 40.8 million VMT per year.

3.3.4 Order-of-Magnitude Cost Estimates

3.3.4.1 Order-of-Magnitude Capital Cost Estimates

The capital cost estimates include improvements necessary to implement service. Many of the proposed improvements would also benefit existing passenger and freight service through the corridor.

The OOM capital cost estimate for Alternative 1 included the following cost elements, described in more detail in Section 3.2.4:

- **Track resurfacing and tie replacement** between the Nemasket River (just south of the existing Middleborough/Lakeville station) and on the passing siding just north of Buzzards Bay station
- **Track reconstruction** between Taylor Interlocking and Buzzards Bay
- Improved **track drainage** on the corridor to support a more frequent service
- **Cab signaling, PTC, and communications** along the entire corridor
- **Interface** with the existing signal system at the northern end of the signal improvements
- **End-of-siding interlockings** at each end of the passing siding north of Buzzards Bay
- **A second platform at Middleborough**

Alternative 1 included approximately $14.8 million of track and right-of-way improvements, approximately $45.8 million of systems improvements (including signals and communications), and approximately $6.6 million of improvements to Middleborough Station. More than half of the total estimated costs were associated with installing a signal system and PTC, improvements that would also benefit the existing CapeFLYER service and freight service that use the corridor.

The cost for Alternative 2 included the elements described above and added the following elements, described in more detail in Section 3.2.4:

- **Additional track resurfacing and tie replacement** on the passing siding just north of Wareham station
- **Extension of track reconstruction, track drainage, cab signaling, PTC, and communications** between Buzzards Bay and Bourne stations
- **End-of-siding interlockings** at each end of the passing siding just north of Wareham station
- **Signal interfacing with the Cape Cod Canal Railroad Bridge**

Alternative 2 included approximately $21.5 million of track and right-of-way improvements, approximately $74.5 million of systems improvements (including signals and communications), and approximately $6.6 million of improvements to Middleborough Station. Like Alternative 1, most of the total estimated costs were associated with systems improvements.

The extension of service across the Cape Cod Canal would require additional track and signal improvements that drive the differences in the cost estimates between Alternatives 1 and 2.

Table 3-7 includes the order-of-magnitude cost estimate by cost element for Alternatives 1 and 2. The cost included for each element in Table 3-7 reflect all-in costs that include 25% burden, 40% design contingency, and 10% construction contingency. Costs are presented in 2021 dollars and are not escalated to a year of construction. **While these costs reflect the estimated expenses associated with implementing the services developed for each alternative, a variety of funding sources could be used to make these improvements prior to the start of a potential future service.** For example, some of these improvements could be implemented as part of systematic safety improvements on the rail network, irrespective of a potential service increase on the corridor.

Table 3-7 Order-of-Magnitude Capital Costs by Alternative (in millions of 2021$)

Cost Element	Alternative 1	Alternative 2
Track and Right-of-Way		
Track Resurfacing and Tie Replacement	$7.4M	$7.7M
Track Reconstruction	$1.3M	$7.1M
Track Drainage	$6.1M	$6.7M
Subtotal	**$14.8M**	**$21.5M**
Systems		
Cab Signals (ATC), PTC, and Communications	$37.8M	$42.1M
Signal Interface at Middleborough	$0.5M	$0.5M
End of Siding Interlockings	$7.5M	$15.0M
Cape Cod Canal Railroad Bridge Interface	-	$16.9M
Subtotal	**$45.8M**	**$74.5M**
Station Improvements		
Middleborough Station Platform	$6.6M	$6.6M
Subtotal	**$6.6M**	**$6.6M**
Total	**$67.2M**	**$102.6M**

Note: Values shown are rounded to the nearest $100,000 and include soft costs, administrative costs, and contingencies. Values are not escalated to year of construction. Costs assume the continued use of existing station infrastructure at Wareham, Buzzards Bay, and Bourne. Costs exclude any grade crossing or structure improvements, which would be reevaluated and done on as needed prior to the implementation of any service. Costs assume the use of surplus fleet. Any additional fleet procurement, rehabilitation, or overhaul would incur additional cost.

Table 3-7 highlights some differences between Alternative 1 and Alternative 2. The costs in Alternative 2 increased for a few key reasons:

- The segment between Buzzards Bay and Bourne would require full track reconstruction for a more frequent passenger service, which increased the costs associated with track and right-of-way improvements.
- The segment between Buzzards Bay and Bourne would require an extension of the signal, PTC, and communications improvements included in Alternative 1. This would include a complex interface of the signal system with the Cape Cod Canal Railroad Bridge.
- The use of the Tremont siding north of Wareham would require additional end-of-siding interlocking improvements.

3.3.4.2 Order-of-Magnitude O&M Cost Estimates

The OOM O&M cost estimates are based on MBTA unit costs and are driven by the maximum vehicles in service and service hours. These costs are provided for information and planning purposes. Actual O&M costs may differ due to several factors, including the operator of the service and the final operating plan.

The projected O&M costs for Alternative 1 were based on the 14 trips included in the Alternative 1 schedule and an assumption that the service would be operated by three train consists in service, each with a locomotive and three coaches. This service operated **over 19 miles and approximately 31 minutes** per one-way trip. Based on these inputs, the estimated OOM O&M costs for Alternative 1 are approximately $5.0 million per year.

The projected O&M costs for Alternative 2 were based on the 16 trips included in the Alternative 2 schedule between Bourne and Middleborough, and the four trips included in the Alternative 2 schedule between either Bourne or Buzzards Bay and Boston. Projected O&M costs assumed that the service between Bourne and Middleborough would require four train consists in service, and the Boston trips would be served by a dedicated fifth consist. Service to Bourne **added nearly two miles and approximately eight minutes per trip**. Based on these inputs, the estimated OOM O&M costs for Alternative 2 are approximately $9.3 million per year.

Table 3-8 provides a breakdown of the estimated O&M costs by cost category. In both Alternatives 1 and 2, the vehicle maintenance costs accounted for over half of the estimated annual O&M costs. Since the maintenance is driven by the fleet operated, the greater fleet size in Alternative 2 resulted in an increased vehicle maintenance cost estimate. After vehicle maintenance, vehicle operations are the second highest cost category within the O&M costs. Since Alternative 2 included higher frequency service, this resulted in higher vehicle operations costs, such as crew time and fuel.

Table 3-8 Order-of-Magnitude O&M Costs by Alternative (in millions of 2021$)

Cost Category	Alternative 1	Alternative 2
Vehicle Operations	$1.4M	$3.0M
Vehicle Maintenance	$2.8M	$4.8M
Facility Maintenance	$0.6M	$1.1M
General Administration	$0.2M	$0.4M
Total	**$5.0M**	**$9.3M**

Note: Values shown are rounded to the nearest $100,000. Estimates use unit costs from MBTA systemwide operations, but actual O&M costs may differ due to several factors, including the operator of the service.

3.3.5 Summary

Alternative 1 provided a level of service to Buzzards Bay that is consistent with the MBTA's *Service Delivery Policy* and resulted in more than 1,700 additional projected daily boardings compared to the No Build. Alternative 2 built on Alternative 1 with higher frequency service extended to Bourne, and additional one-seat rides between the Cape Cod region and Boston. Key takeaways include:

- Both alternatives were able to meet the MBTA's *Service Delivery Policy* frequency and span of service standards with the existing single track sections and passing sidings.
- Travel times between Buzzards Bay and Boston are typically just over an hour and a half, including a timed transfer at Middleborough. Extending service to Bourne adds about eight minutes, including extra time to account for potential bridge delays.
- Direct trips between the Cape Cod region and Boston are feasible in limited select operating windows, including before and after the start of service, and potentially during the midday.
- Alternative 1 provided a ridership base for service to the Cape Cod region, which includes induced demand and some recreational trips. That ridership expanded in Alternative 2 with higher frequency service to the south side of the Cape Cod Canal and direct trips to and from Boston.
- The service is projected to divert travel currently done by auto to rail. It is not projected to divert ridership from other transit modes or lines.
- The projected auto diversions resulted in reductions in VMT and auto emissions. These reductions were approximately proportional to the change in auto trip diversions from Alternative 1 to Alternative 2.
- The greatest capital cost elements of providing passenger service to the Cape Cod region are associated with systems improvements, including installing a signal system and PTC. Extending the systems to Bourne would incur additional costs due both to the additional mileage and complex interfacing with the Cape Cod Canal Railroad Bridge.
- O&M costs are driven by vehicle maintenance and vehicle operations. Both cost categories increased from Alternative 1 to Alternative 2 due to the increased fleet size and usage.

Table 3-9 summarizes key metrics between Alternatives 1 and 2.

Table 3-9 Comparison of Alternatives 1 and 2

Item	Alternative 1	Alternative 2
Terminal	Buzzards Bay	Bourne
Total One-Way Revenue Trips	14	20[1]
Travel Time to Boston	~93 Minutes[2]	~101 Minutes[2]
Projected Daily Boardings	1,710[3]	2,540[3]
OOM Capital Costs (2021$)	$67.2M[4]	$102.6M[4]
OOM O&M Costs/Year (2021$)	$5.0M/Year[5]	$9.3M/Year[5]
Daily Vehicle Trip Reduction	Over 800	Nearly 1,200
Daily Auto VMT Savings	42,718	65,675
Daily Savings in CO2 from Auto Travel	13,628 kg	20,952 kg

Notes:

1. One trip would start in Buzzards Bay and one trip would end in Buzzards Bay.
2. Travel times include 5-minute timed transfer at Middleborough for most trips. Total travel times vary based on scheduled time for SCR trip. One-seat ride trip times in Alternative 2 vary between 87 and 102 minutes.
3. Projected daily boarding values reflect boardings at Pilgrim Junction (southbound), the existing Middleborough/Lakeville station (Alternative 2 only), Wareham, Buzzards Bay, and Bourne (Alternative 2 only). Projected daily boardings include both inbound and outbound boardings.
4. Values shown are rounded to the nearest $100,000 and include soft costs, administrative costs, and contingencies. Values are not escalated to year of construction. Costs assume the continued use of existing station infrastructure at Wareham, Buzzards Bay, and Bourne. Costs exclude any grade crossing or structure improvements, which would be reevaluated and done on an as-needed basis prior to the implementation of any service. Costs assume the use of surplus fleet. Any additional fleet procurement, rehabilitation, or overhaul would incur additional cost.
5. Values shown are rounded to the nearest $100,000. Estimates use unit costs from MBTA systemwide operations, but actual O&M costs may differ due to several factors, including the operator of the service.

4

Next Steps

While this study provides a foundation for potential future rail service to the Cape Cod region, there are next steps that could affect and inform potential future implementation. This chapter includes a discussion of some of these next steps at the systemwide, corridor, and local levels.

4.1 Systemwide Changes

As described in Chapters 2 and 3, the baseline conditions for the Cape Rail Study assume the start of **SCR Phase 1** operations. Construction on SCR Phase 1 is underway, with the start of service anticipated by the end of 2023. The Cape Rail Study accounts for and builds on this future service, integrating Cape Cod region trips with transfers to and from SCR Phase 1. In addition to SCR Phase 1, the MBTA has other programs that could affect future service levels across the MBTA commuter rail system.

One of these programs, **Forging Ahead**, adjusted service levels to reflect changing ridership patterns associated with COVID-19. The MBTA planned the Forging Ahead program to preserve access and quality of service available to transit-critical customers. The MBTA incorporated stakeholder feedback into a December 2020 proposal, which preserved most pre-pandemic service, aligned service levels with changing ridership and demand, and maintained service for those who depend on public transit while reducing primarily non-essential services. Due to an infusion of federal funding, as of April 2021, the MBTA was able to begin bringing service back to 100% pre-pandemic levels. However, the Forging Ahead initiative incorporated some systemwide changes that the MBTA may carry forward. For example, the MBTA may continue to operate a regional rail service model, providing more consistent, clockface service all day, serving travel needs outside the AM and PM rush hours. As the MBTA builds back up, the aim is to create a system that reflects changing travel behaviors and ridership needs—building back to reflect changing ridership patterns.

The **Rail Transformation** program will expand on the work completed through the Rail Vision project to provide a strategic plan for the MBTA's rail network moving forward. The Rail Transformation Office will plan for the upcoming operating contract procurement, develop a fleet procurement strategy, advance rail improvement projects, and support service planning and pilot efforts, among other initiatives. The Rail Transformation program will influence how, when, and where the MBTA operates future rail service.

4.2 Governance

Developing a plan for the **operations and maintenance** of a potential future Cape rail service is a critical next step towards implementation. Specifically:

- MassDOT does not operate rail service; the MBTA, or other operators, provide passenger rail through the region.
- Middleborough, Wareham, and Bourne are a part of the MBTA's service district. The MBTA's commuter rail service is currently operated by Keolis Commuter Services and includes the existing Middleborough/Lakeville Line (and future SCR Phase 1 service).
- CCRTA operates the CapeFLYER service, through coordination with the MBTA and MassDOT.
- Cape Rail, Inc., currently operates rail service in the region. Cape Rail's Massachusetts Coastal Railroad currently operates freight rail service on the Cape Main Line and on other lines in the region. Cape Rail's Cape Cod Central Railroad operates seasonal recreational passenger service on the Cape Main Line.

Some of or all these entities, along with other agencies and potential operators, may be involved in future operations and maintenance. At a minimum, the future operator would need to coordinate with these entities and others to provide service. There may be additional opportunities to take advantage of efficiencies in operations and maintenance. For example, the MBTA may be able to provide fleet that has been retired from active service, which could reduce the need for fleet procurement (which is excluded from the OOM capital cost estimates in Chapter 3).

As passenger rail options expand throughout the Commonwealth, developing a plan for governance will continue to be an important next step towards implementation. While the alternatives evaluated in the Cape Rail Study would operate within the MBTA service district, MassDOT has previously noted the potential to advance discussion of the Commonwealth's passenger rail governance structure.[27] Since the proposed operations evaluated in this study would largely connect to the existing and planned MBTA network, any discussion around statewide governance could affect the operations and maintenance of a potential future Cape rail service.

Beyond the O&M of a potential future service, another factor in operating service is the **Cape Cod Canal Railroad Bridge.** As described in Chapter 2, the U.S. Army Corps of Engineers owns and maintains local bridge control, with train movements over the bridge under the control of a remote train dispatcher. Operating service to the south of the Cape Cod Canal requires coordination with the U.S. Army Corps of Engineers to cross over the bridge. CCRTA and the MBTA currently coordinate with the U.S. Army Corps of Engineers for the CapeFLYER, which travels over the bridge twice per day on Fridays and weekends. Alternative 2 proposed in this study would cross the bridge at a much higher frequency (with 18 revenue trips to or from Bourne, and additional non-revenue moves to prevent idling at Bourne). While this study assumed for the purposes of modeling operations that the bridge could be lowered as needed to support the Alternative 2 schedule, this would require additional coordination and ultimately an agreement among MassDOT, the service operator, and the U.S. Army Corps of Engineers to support a higher level of service.

[27] MassDOT, *East-West Passenger Rail Study*, January 2021, available at: https://www.mass.gov/east-west-passenger-rail-study.

Cape Cod Canal Railroad Bridge

4.3 Financial Case

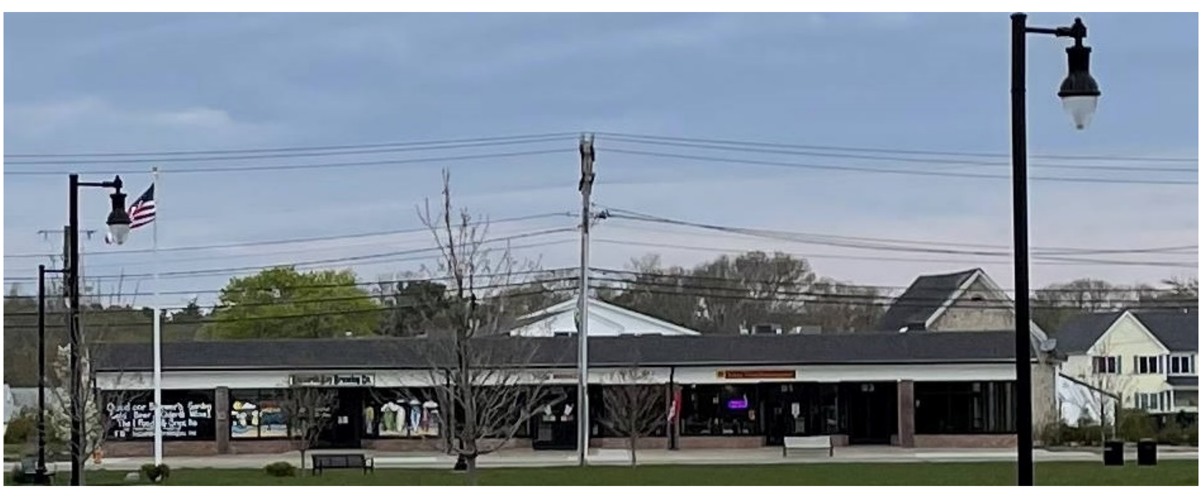
Chapter 3 identified order-of-magnitude capital and O&M costs associated with the service provided in the two alternatives modeled through the Cape Rail Study. The capital improvements could be funded through multiple **funding sources and** federal, state, or local **opportunities**. Some of the proposed improvements would also benefit existing passenger and freight service through the corridor and could be funded through other initiatives.

The Advisory Group noted the concept of project phasing. Capital improvements would not need to happen concurrently and could be phased over time as funding becomes available, while providing benefits to the existing services. Similarly, the extent of the operations could expand over time as more funding becomes available.

Discussion in the Advisory Group meetings also highlighted that rail service would provide **economic benefits** to the region by encouraging economic development. This could occur in multiple ways, such as:

- Supporting year-round population and activity
- Improving the commute between the Cape Cod region and Boston or within the Cape Cod region
- Providing reverse commute opportunities to foster additional employment opportunities in the Cape Cod region
- Increasing connectivity between the Cape region and the larger commuter rail network, including South Coast Rail
- Enhancing options for recreational travel to the Cape Cod region throughout the year

While the Cape Rail Study adjusted the outputs of the Statewide Travel Demand Model to account for induced demand and recreational demand, the study does not assess how rail service would affect economic growth or the access to opportunities. The region has developed policies that would promote economic growth around rail service, and evaluating these potential benefits is an important next step in understanding the full value of providing rail service to the region.



Commercial Space in Buzzards Bay near Buzzards Bay Station

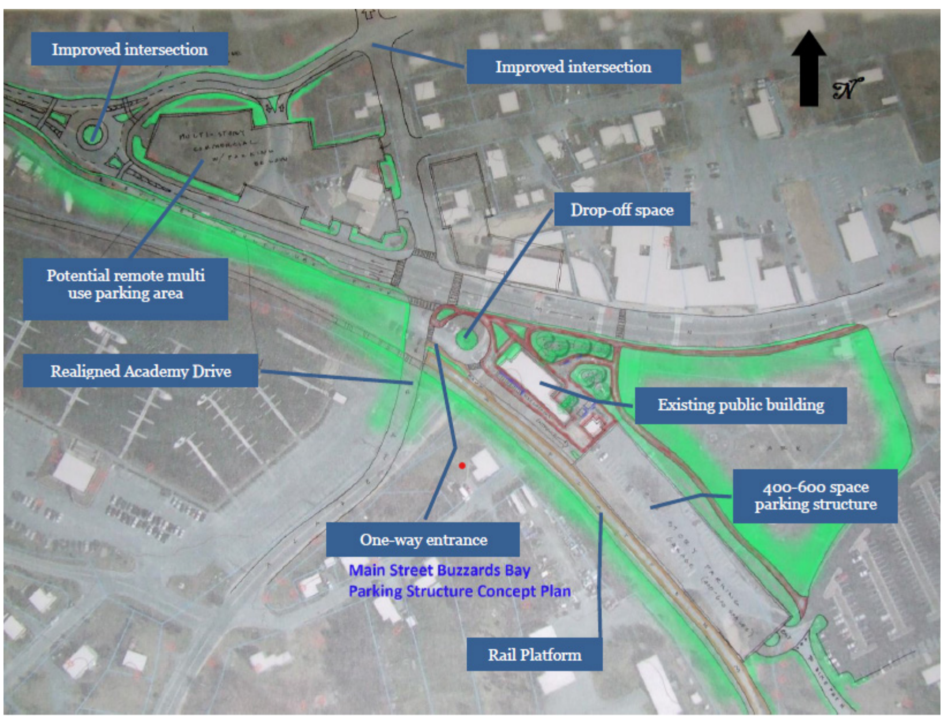
4.4 Other Considerations

There are several other considerations that would affect the implementation of any future service, including fare structure, parking, and connectivity. While this study made assumptions around these considerations for the purposes of planning and evaluating potential alternatives, the next steps would need to further assess these in more detail.

The **fare structure** of a potential future service would affect the desirability and demand for the service. This study assumed that the fare structure would reflect the existing MBTA fare structure, with Wareham, Buzzards Bay, and Bourne categorized as fare zone 9 stations. The MBTA's Fare Transformation program may provide additional opportunities for alternate fare structures. Additionally, with the potential for the service to be operated by a different operator and many trips likely requiring a transfer between Cape service and SCR Phase 1, there are opportunities to apply a different model.

The study also assumed unlimited free **parking** at Wareham, Buzzards Bay, and Bourne for the purposes of modeling ridership demand. The demand projected by the study would exceed the existing parking availability at these stations, and to fully realize the potential demand, additional parking may be required near stations served by Cape Rail. For example, a recent study by the Town of Bourne noted that the commuter rail extension would influence demand for parking,[28] and the Cape Cod Commission has previously evaluated opportunities for expanding parking at Buzzards Bay, with a 120-space alternative and a 400-600 space alternative identified in the *Buzzards Bay Commuter Rail Extension: Local Impact Report* (**Figure 4-1**).[29]

Figure 4-1 Example Buzzards Bay 400-600 Space Parking Alternative (CCC Local Impact Report)



Source: Cape Cod Commission, "Buzzards Bay Commuter Rail Extension: Local Impact Report," April 2015. Figure 4.

[28] Town of Bourne, "Downtown Bourne Parking Strategy Plan," Final Recommendations, May 5, 2021.

[29] Cape Cod Commission, "Buzzards Bay Commuter Rail Extension: Local Impact Report," April 2015.

Finally, this study does not evaluate **connectivity** to the proposed Cape rail service. **First-mile and last-mile connections** are critical to the success of a rail service. This would be particularly important for a rail service that does not extend beyond Buzzards Bay or Bourne, as connectivity to the rest of the Cape and surrounding towns could significantly affect the demand for the rail service and the benefits to the region. CCRTA bus service could connect to future rail service and unlock some of this demand. As described in Section 2.1.2, CCRTA has recently established the Buzzards Bay Connector as a high frequency service area that includes the Buzzards Bay train station (**Figure 2-5**). There are several examples in Massachusetts of regional transit authority integration with rail, such as CCRTA connecting to existing CapeFLYER service and GATRA connecting to the Middleborough/Lakeville MBTA station. In addition, the region has an extensive network of bicycle and pedestrian shared-use paths that could support non-motorized access to the stations. The Cape Cod Canal Bikeway runs parallel to the Cape Cod Canal and could provide a direct connection to the Bourne station. Similarly, the Shining Sea Bikeway extends between Woods Hole and Falmouth, with an extension into Bourne under design by the towns of Bourne and Falmouth.

Cape Cod Canal Bikeway, Cape Main Line, and Cape Cod Canal Railroad Bridge

Appendices

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A

Glossary of Terms

Auto Diversion: A trip previously taken by auto that would be taken by a different mode due to a change in service.

Cab Signal System: A signal system that communicates track status and related speed information directly into the locomotive cab, continuously providing updated signal information on an easy-to-read display.

Deadhead: A non-revenue trip (a trip without passengers) used to move trainsets from one location to another.

End-of-Siding Interlocking: Infrastructure that enables trains to transition between segments of single-track and double-track.

Grade Crossing: A location where the track and roadway cross at-grade.

Induced Demand: New trips that occur because of an improvement to the overall transportation system.

Passing Siding: A segment of additional track that allows a train to pass another train traveling in the same area at the same time (typically in the opposite direction).

Positive Train Control: A signal life-safety system that automatically enforces speed restrictions. Positive Train Control provides both predictive and reactive speed control and can positively stop a train for safety purposes.

Single-Track: Single-track refers to the number of tracks available for train use. In single-track sections, trains traveling in both directions must use the same track at different times.

South Coast Rail: A project that will restore MBTA commuter rail service in 2023 between Boston and southeastern Massachusetts.

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CAPE RAIL STUDY

B

Massachusetts Population Projections by Regional Planning Area

The following pages detail the population projections methodology and regional projections used as inputs into the CTPS Statewide Travel Demand Model. These documents and related materials are also available at:

https://www.mass.gov/lists/socio-economic-projections-for-2020-regional-transportation-plans.

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Massachusetts Population Projections by Regional Planning Area

Projections Methodology

September 12, 2018

UMASS DONAHUE INSTITUTE

Massachusetts Population Projections by Regional Planning Area

Projections Methodology

Prepared by the UMass Donahue Institute's
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We wish to acknowledge the work of **Dr. Henry Renski**, Associate Professor of Regional Planning at the University of Massachusetts in Amherst for his work in developing the methodology and methods report for the *Long-term Population Projections for Massachusetts Regions and Municipalities* published by the UMass Donahue Institute in 2013 and 2015. Much of the writing in the present report was taken or adapted from the previously published methodology statements for these two series.

UMASS DONAHUE INSTITUTE

Contents

List of Tables and Figures

Introduction

In 2015, with support from the Massachusetts Secretary of the Commonwealth, the UMass Donahue Institute (UMDI) published a public-use series of population projections to 2035 by age, sex, municipality, and Massachusetts regions[1].

More recently, in 2017 and 2018, UMDI worked in agreement with the Massachusetts Department of Transportation (MassDOT) to update these projections for each Municipal Planning Organization (MPO) for use in their Statewide Transportation Planning Model. For the revised population projections, UMDI worked in collaboration with a Projections Advisory Committee that included representatives from each of the Massachusetts Regional Planning Agencies, including the Metropolitan Area Planning Commission, the Central Transportation Planning Staff of the Boston Region Metropolitan Planning Organization (CTPS), and Massachusetts DOT as well as other interested stakeholders. The Advisory Group provided input on model updates including the integration of an updated launch population; decisions around which period rates to use for fertility and mortality; and model modifications for improved performance in their regions.

This methodology report details both the 2015 series projections (V2015) methods and data sources as well as the updates and changes applied to these for the 2018 vintage projections (V2018).

It is important to note that modeled projections cannot and do not purport to predict the future, but rather may serve as points of reference for planners and researchers. Like all forecasts, the UMDI projections rely upon assumptions about future trends based on past and present trends which may or may not actually persist into the future. The V2018 series employs a *status-quo* model approach to predict future population change. It assumes that recently observed trends in the components of population change, including birth, death, and migration rates, will persist in future years. It is also a demographically-based model, assuming that population change is driven by births, deaths, and the persistence of historic migration rates into the future.

[1] *Long-Term Population Projections for Massachusetts Regions and Municipalities.* UMass Donahue Institute. March 2015. http://www.donahue.umassp.edu/business-groups/economic-public-policy-research/massachusetts-population-estimates-program/population-projections

Method Overview

UMDI produces cohort-component model projections for two different geographic levels: municipalities and eight sub-state regions defined specifically for the model. These sub-state regions include the Berkshire/Franklin, Cape and Islands, Central, Greater Boston, Lower Pioneer Valley, MetroWest, Northeast, and Southeast regions. The UMDI projections are produced at five-year intervals beginning in 2015 and ending in 2040 by sex and by five-year age groups, from 0-4 through 85+.

We use a cohort-component model based on a combination of trends in fertility, mortality, and migration from 2000 through 2015. Our regional-level method makes use of American Community Survey sample data on migration rates by age and uses a gross, multi-regional approach in forecasting future levels of migration. Our municipal-level estimates rely on residual net migration rates computed from vital statistics and decennial Census data. Municipal age/sex projections are controlled to the regional projections age/sex projections and are then summed up to MPO totals by aggregating all age/sex/town cohorts that fall within the MPO. RPAs are then given the opportunity to re-distribute these regional totals within their own catchments areas. Appendix A to this report shows the geographic correspondence between municipalities and their respective UMDI model and MPO regions.

While most MPO regions in the state are modelled identically, we adjust the model to account for specific data issues in the Cape Cod and Island Regions. We also make an adjustment to the 2015 base population distribution in the Greater Boston region due to specific concerns related to college students in the region. These variations are discussed in further detail in the Technical Discussion of Methods and Assumption section of this report.

Technical Discussion of Methods and Assumptions

This section provides a technical description of the process used to develop 1) sub-state regional and 2) municipal-level population projections. While both levels of projections are prepared using a cohort-component method, the major methodological difference is in the way migration is modeled: the municipal-level estimates (also referred to as Minor Civil Divisions, or MCDs) rely on residual net migration rates computed from vital statistics, while the sub-state regional projections use gross domestic migration rates based on the American Community Survey Public Use Microdata (ACS PUMS). MCD projections are controlled to projections developed for eight sub-state regions in order to smooth out variations due to data quality issues at the MCD level and ensure more consistent and accurate projections at higher-level geographies. These controlled MCD projections are then be re-aggregated to MPO regions and provided to RPAs for customized distribution. In the final population projections published by MassDOT, some Regional Planning Agencies maintained the original town-level age/sex projections prepared by UMDI to create the MPO projections, while others redistributed these according to specific emergent economic developments or planning initiatives in their regions.

Regional-Level Methods and Assumptions

Summary

This section describes the process and data used to develop the regional population projections. These projections were developed separately for eight Massachusetts regions, although each region was produced following the same framework, with some variations applied to the Cape and Island and Greater Boston regions. The methodology describing how the regional projections were used to estimate municipal population projections follows in Part B of this section.

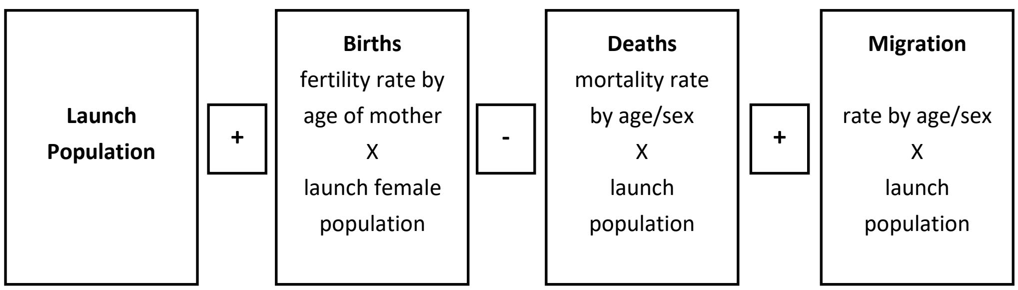
Our regional projections are based on a demographic accounting framework for modeling population change, commonly referred to as a cohort-component model. The cohort-component method recognizes that there are only four ways that a region's population can change from one time period to the next. It can add residents through either births or in-migration, or it can lose residents through deaths or out-migration. In our regional-level model, we further divide migration by whether domestic or international, and use separate estimation methods for each.

The cohort-component approach also accounts for population change associated with the aging of the population. The current age profile is a strong predictor of future population levels, growth and decline and can differ greatly from one region to another. For example, the Greater Boston region has a high concentration of residents in their twenties and early thirties, while the Cape and Islands have large shares of near and post-retirement age residents. Furthermore, the likelihood of birth, death, and in- and out-migration all vary by age. Because fertility rates are highest among women in their twenties and early thirties, a place that is anticipating a large number of women coming into their twenties and thirties in the next decade will likely experience more births. Similarly, mortality rates are notably higher for persons 70-years and older, such that an area with a large concentration of elderly residents will experience more deaths in decades to come.

Developing a cohort-component model involves estimating rates of change for each separate component and age-sex cohort (i.e. age-specific fertility rates, survival rates, and in- and out-migration rates) - typically based on recent trends. It then applies these rates to the current age profile in order to predict the likely number of births, deaths, and migrants in the coming years. The changes are added to or subtracted from the current population, with the resulting population aged forward by a set number of years (five years, in our case). The result is a prediction of the anticipated number of people in each cohort X years in the future. This prediction becomes the new starting baseline for estimating change due to each component an additional X years in the future. The process is repeated through several iterations until the final target projection year has been reached.

Figure 1. Cohort Component Method

For each age/sex/geography cohort:

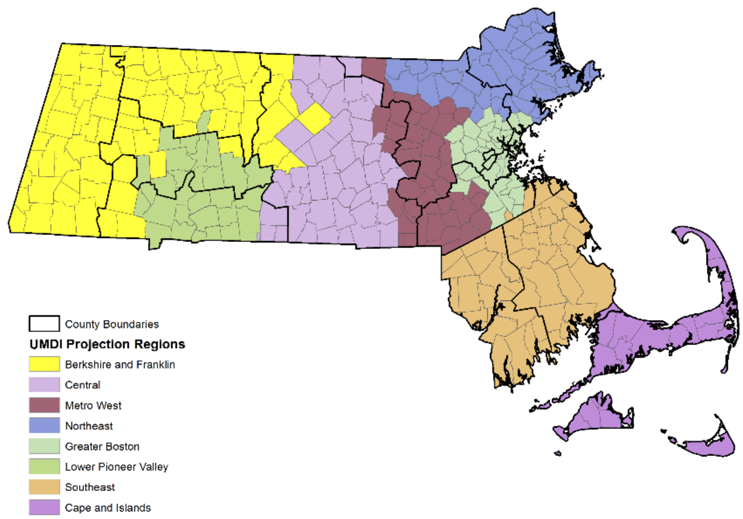


Regional definitions

A preliminary step in generating our regional projections was to determine the boundaries for each of our study areas. We use the definitions for the MassBenchmarks regions as a starting point. The Benchmarks regions were designed by the UMass Donahue Institute to approximate functional regional economies (sets of communities with roughly similar characteristics in terms of overall demographic characteristics, industry structure, and commuting patterns). These Benchmarks regions constitute a widely accepted standard among policy officials and analysts statewide that meet common perceptions of distinct regional economies in Massachusetts.

We then compared the Benchmarks regions to the boundaries of Public Use Micro-Sample Areas, also known as PUMAs. PUMAs are the smallest geographic units used by the U.S. Census Bureau for reporting data taken from the detailed (micro) records of the American Community Survey (ACS) – our primary source of migration data. PUMA boundaries are defined so that they include no fewer the 100,000 persons, and thus their physical size varies greatly between densely settled urban and sparsely settled rural areas. And although PUMAs do not typically match county boundaries, in Massachusetts individual PUMAs can be grouped together to form regions whose outer boundaries match aggregated groups of individual municipalities. This critically important feature allows us to match Census micro-data with other Census data and State vital statistics estimates we obtained at the municipal level (i.e. births and deaths). We performed our regional grouping using Geographic Information System mapping software. The resulting study regions are presented in Figure 2 and are cross-walked to municipalities in Appendix A to this report.

Figure 2. UMDI Projection Regions



Estimating the components of change

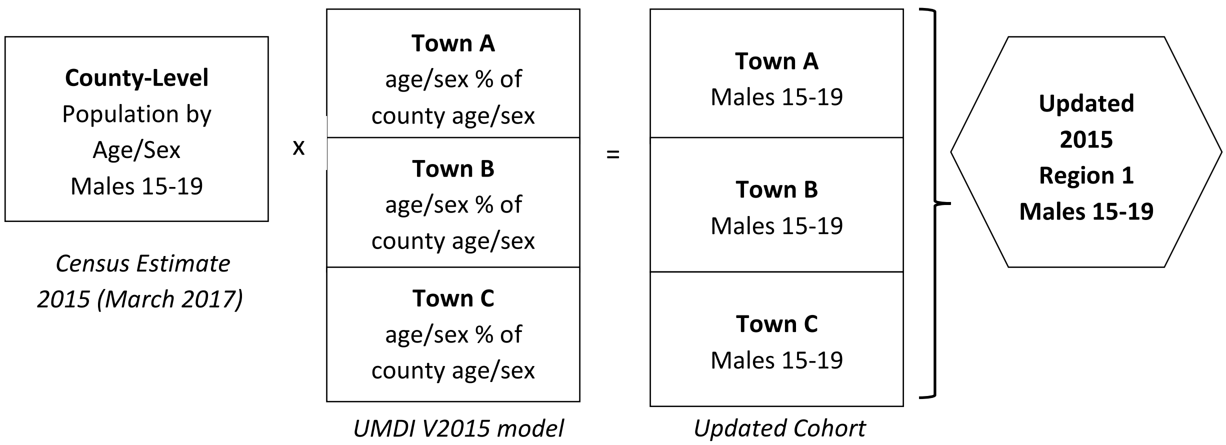
Determining the launch year and cohort classes

We begin by classifying the composition of resident population into discrete cohorts by age and sex. Following standard practice, in the 2015 vintage series, we used five year age cohorts (e.g. 0- 4 years old, 5- 9,… 80-84, and 85-and older) and developed separate profiles for males and females, based on information provided in the 100% Count (SF 1) file of the 2010 Decennial Census of Population to serve as the starting point (i.e. launch year) for generating forecasts.

In the current vintage 2018 (V2018) series for the MassDOT project, we instead launch the projections from the year 2015, to better capture the rapid growth experienced in Massachusetts following the last Census. Population counts or estimates by age, sex and municipality are not produced by the Census Bureau in non-decennial years, although they do produce estimates by age, sex, and county. Therefore, to estimate the needed 2015 "launch" cohorts by age, sex, and municipality, we take the UMDI V2015 projected populations by age, sex, and municipality for 2015 and control these to the most current U.S.

Census Bureau estimates of the 2015 population by age, sex, and county.[2] Specifically, we control each age/sex/MCD cohort within a county to its corresponding age/sex/county cohort total. For example, if a town included 10% of a county's age/sex cohort in the UMDI V2015 projected population for 2015, it is assigned 10% of the Census Bureau's updated county cohort population as its new base or "launch" population. The new municipal-level age/sex cohorts are then summed to their respective regions for updated 2015 launch populations in the regional model. See Figure 3 below for illustration.

Figure 3. Municipal-Level 2015 Launch Populations



The Greater Boston study-region is treated slightly differently in the launch re-set method. The U.S. Census Bureau's Vintage 2016 age/sex estimates for Suffolk County were showing a very large increase in persons in the age 25-29 cohort. This could represent real population change, or it could be an artifact of U.S. Census Bureau estimation techniques. Because the post-census estimates are not actual counts, it is hard to determine. Suffolk County is home to a large number of college and graduate students who might have been aged forward in the Census Bureau estimates when they should have been out-migrated and replaced with new students instead. The concept of treating college students as a "revolving door" population is called the "college fix", and it is a method applied by the Census Bureau in many other "college counties." Because Suffolk County is over the population-size threshold for the Bureau's college fix, this method was not applied by the Bureau in our study year.[3] For this reason, UMDI determined, in agreement with the region's MPO, to control the UMDI V2015 age/sex/MCD estimates to the *total* county population instead of controlling to the Census 2015 age/sex cohort totals. The resulting Suffolk County age/sex/municipal cohorts are the summed and added to the other municipal cohorts in the Greater Boston study region to comprise the new 2015 age/sex launch

[2] Annual Estimates of the Resident Population for Selected Age Groups by Sex for the United States, States, Counties, and Puerto Rico Commonwealth and Municipios: April 1, 2010 to July 1, 2016. (Table PEP_2016_PEPAGESEX). U.S. Census Bureau, Population Division. Release Date: June 22, 2017.

[3] The college fix WAS applied to Hampshire County in the U.S. Census Bureau's V2016 estimates series, another Massachusetts county with a large percent of population enrolled in college in the county.

populations for the regional model. In this way, the resulting population sum is the same as the Census Bureau's estimated 2015 population, but the distribution of population follows the UMDI V2015 age/sex distribution.

Deaths and Survival

The first component of change in our model is survival. Our projections require an estimate of the number of people in the current population who are expected to live an additional five years into the future. Estimating the survival rate of each cohort is fairly straightforward. For the UMDI V2015 series, the Massachusetts Department of Public Health provided us with a detailed dataset that included all known deaths in the Commonwealth that occurred between 2000 to the end of calendar year 2009. This database includes information on the sex, age, and place of residence of the deceased, which we aggregated into our study regions by age/sex cohort. In the regional model, we estimate the five-year survival rate for each cohort (*j*) in study region (*i*) as one minus the average number of deaths over the past five years (2005 to 2009) divided by the base population in 2005 and then raised to the fifth power, or:

$$Survival\ Rate_{i,j} = \left[1 - \left(\frac{Deaths_{i,j}}{Population_{i,j}}\right)\right]^5. \qquad (1)$$

Following the recommendations of Isserman (1993), we calculate an operational survival rate as the average of the five-year survival rates across successive age cohorts. The operational rate recognizes that, over the next five years, the average person will spend half their time in their current age cohort and half their time in the next cohort. We estimate the number of eventual survivors in each cohort by 2015 by multiplying the operational survival rate against the cohort population count as reported by the 2010 Census.

For the V2018 MassDOT updates, we updated births and deaths to a more current period. Because the lead time required to obtain birth and death data by age at the town level was beyond the scope of this project timeline, we reviewed publicly available state-level fertility and mortality by age over the 2003 through 2015 time series, the latest data we were able to obtain by age and sex.[4] Figures 4 and 5 below display Massachusetts male and female mortality by age from 2003 through 2015.

As rates change over time, we next had to determine whether it was more reasonable to use the most recent 5-year period rates or use a longer period of up to 15 years to project forward in our model. Figure 6 compares combined male and female deaths by age using averaged 2005-2010 rates (used in our last V2015 model) as versus longer term 2005-2015 averaged rates and most recent 2010-2015 rates. Figures 7 and 8 display this same information for the population under 50 and the population aged 50-plus, respectively. After discussion and an examination of the projected impact by region, the

[4] Source of births and deaths rates: United States Department of Health and Human Services (US DDHS) Centers for Disease Control and Prevention (CDC) National Center for Health Statistics (NCHS). See Data Sources Notes in Appendix B to this report for additional source detail. Calculations of percent change in rates by UMDI.

Projections Advisory Committee and the UMDI projections team agreed to use the most recent 5-year period of 2011-2015 as a basis for projecting forward.

To update our model, we calculate the percentage change in deaths per thousand by age and sex between the averaged 2005-2009 rates already in our model and the updated averaged 2011-2015 rates. We then apply this percent change to deaths by age in our existing regional model, shifting deaths by age to align with more current trends. The updated deaths by age are then used to calculate survival rates as described earlier in this section.

Figure 4. Massachusetts Female Mortality Rates by Age, 2003-2015

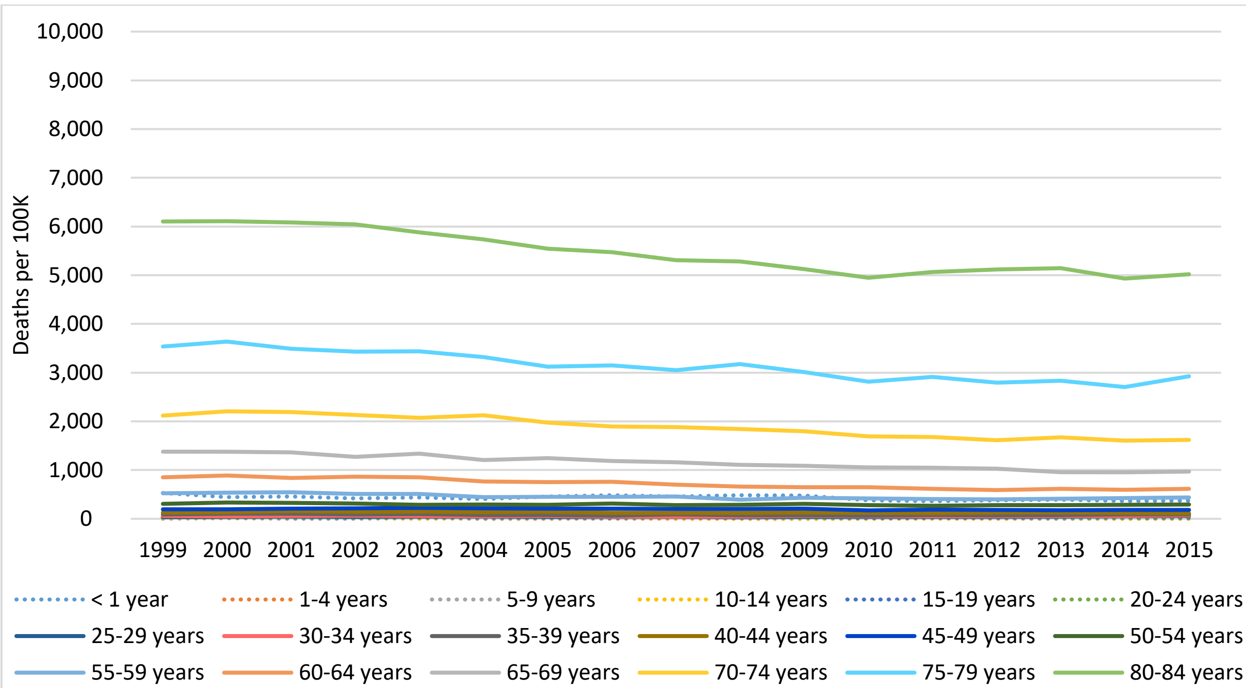


Figure 5. Massachusetts Male Mortality Rates by Age, 2003-2015

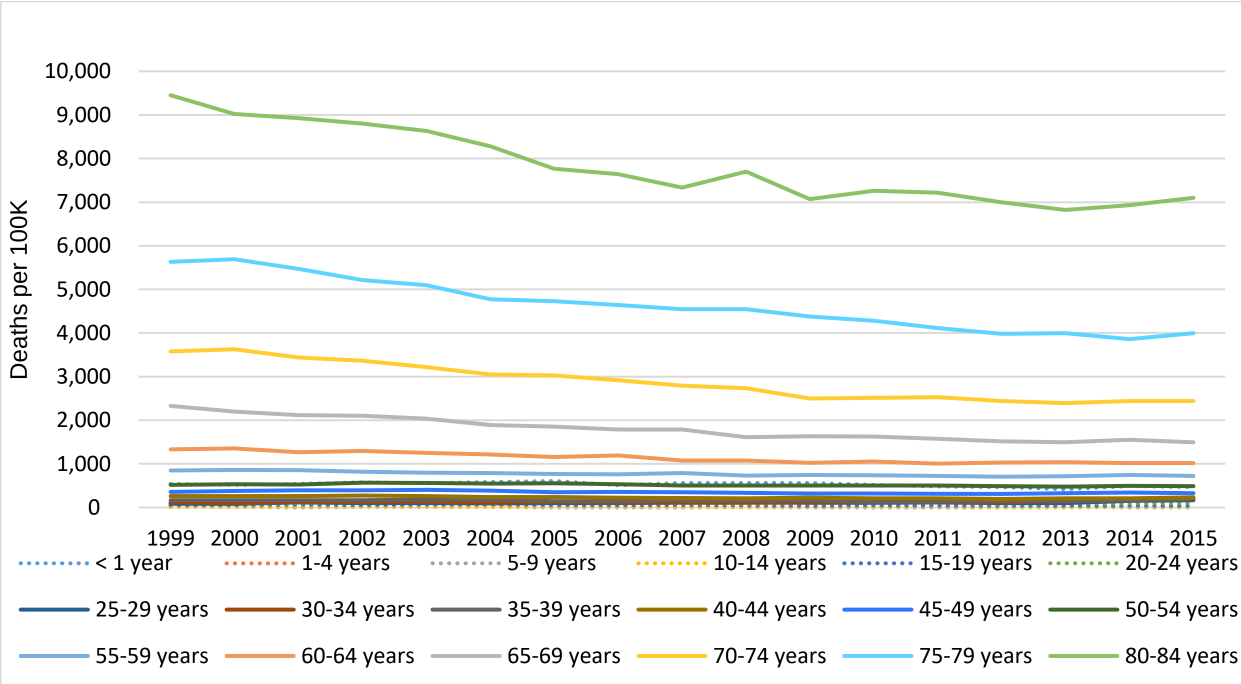


Figure 6. Massachusetts Mortality Rates by Age Comparison: 2005-2010, 2010-2015, and 2005-2015

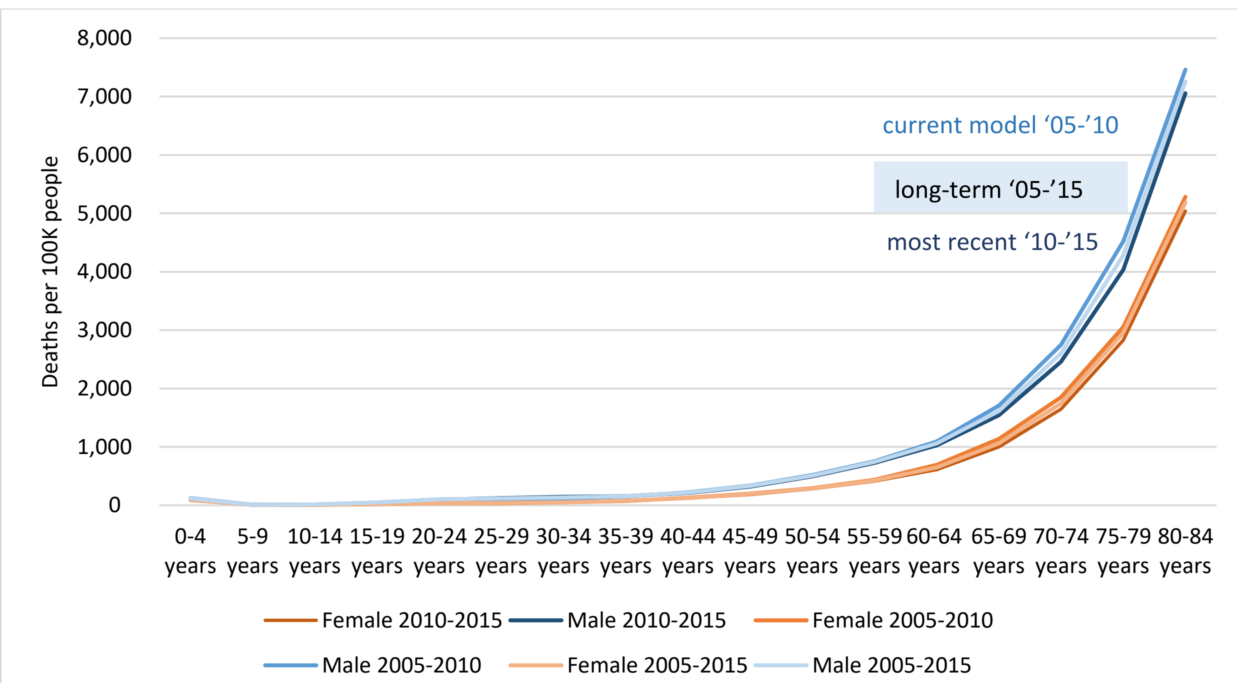


Figure 7. Massachusetts Mortality Rates by Age <50, Comparison: 2005-2010, 2010-2015, and 2005-2015

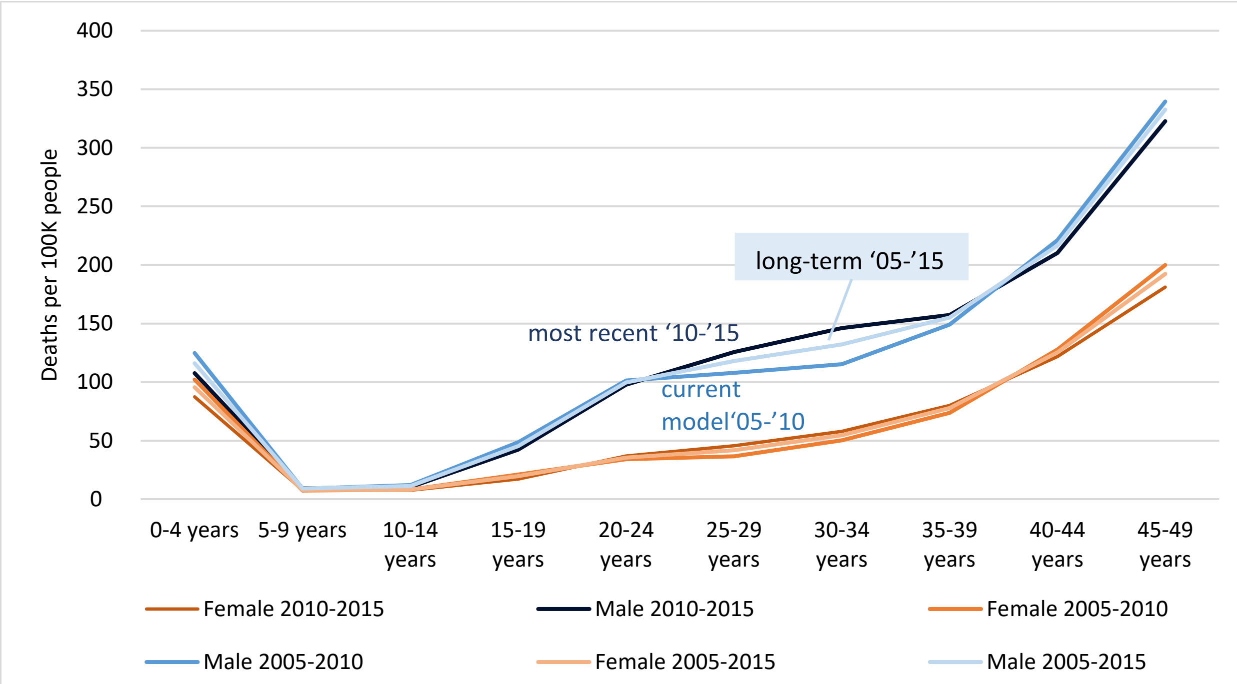
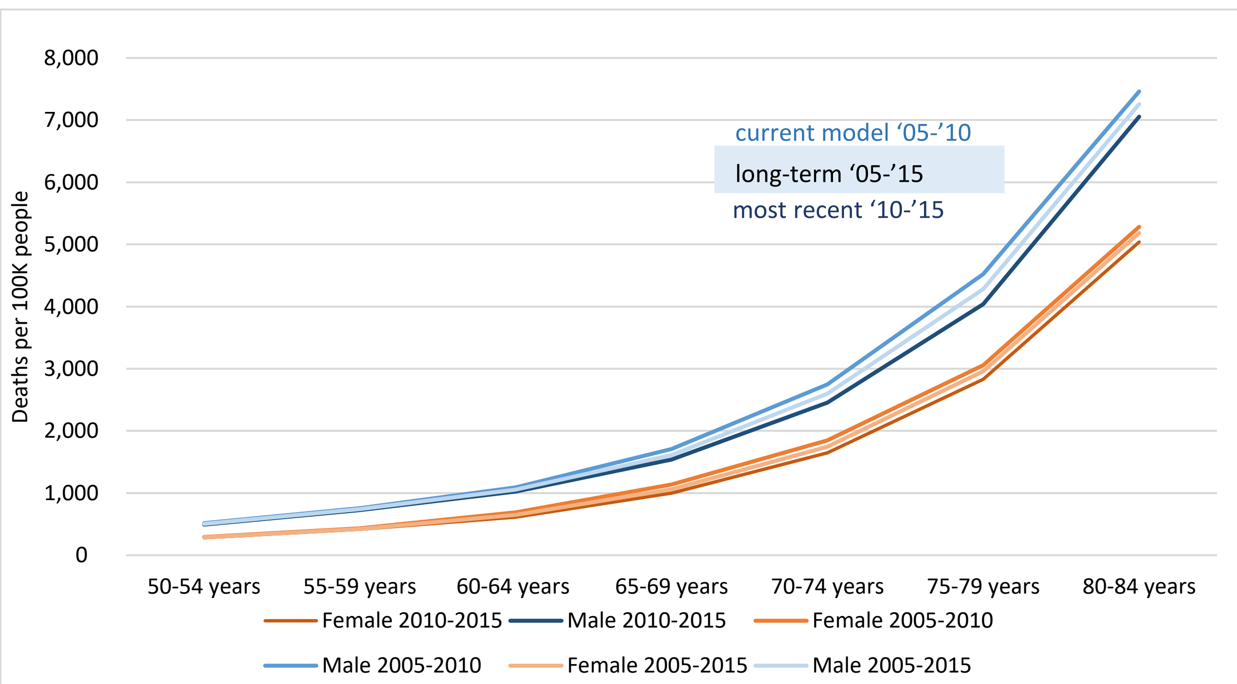


Figure 8. Massachusetts Mortality Rates by Age 50+, Comparison: 2005-2010, 2010-2015, and 2005-2015



Domestic Migration

Migration is the most dynamic component of change, the most difficult to estimate, and the most likely source of uncertainty and error in population projections. Whereas fertility and mortality follow fairly regular age-related patterns, the migration behavior of similar age groups is influenced by regional and national differences in socio-economic conditions. Furthermore, the data needed to estimate migration is often restricted or limited; especially for many small areas. Even when it is available, it is based on statistical samples and not actual population counts, and thus is prone to sampling error – which will be larger for smaller regions.

Due to data limitations and the other methodological challenges, applied demographers have developed a variety of alternate models and methods to estimate migration rates. No single method works best in all circumstances, and we evaluated numerous approaches in the development of our projections. Those presented in this report are based on a particularly novel approach known as a multi-region gross migration model as discussed by Isserman (1993); Smith, Tayman and Swanson (2001); and Renski and Strate (2013). Most analysts use a net migration approach, where a single net migration rate is calculated as the number of net new migrants per cohort (in-migrants minus out-migrants) divided by the baseline cohort population of the study region. Although common, the net migration approach suffers from several conceptual and empirical flaws. A major problem is that denominator of the net migration rate is based purely on the number of residents in the study region. However, none of the existing residents are at risk of migrating into the region – they already live there. While this may seem trivial, it has been shown to lead to erroneous and biased projections especially for fast growing and declining regions.

A gross-migration approach calculates separate rates for in- and out-migrants. Beyond generating more accurate forecasts in most cases, it has an added benefit in that it connects regional population change to broader regional and national forces – rather than simply treating any one region as an isolated area. This type of model is made possible by utilizing the rich detail of information available through the newly released Public Use Micro-Samples (PUMS) of the American Community Survey (ACS). The ACS is a relatively new data product of the U.S. Census Bureau that replaced the detailed information collected on the long-form of the decennial census (STF 3). It asks residents questions about where they lived one year prior, which can be used to estimate the number of domestic in- and out-migrants. Unfortunately, the ACS does not report enough detail to estimate migration rates by detailed age-sex cohorts in its standard products. This information can be tabulated from the ACS PUMS – which is 5% random sample of individual records taken drawn the ACS surveys[5]. Each record in the PUMS is given a survey weight, which we use to estimate the total number of migrants by detailed age and sex cohorts. In our model, we develop migration rates using data from the 2005 to 2009 ACS PUMS as well as the 2007 to 2011 ACS

[5] To account for small or missing samples in some cohorts in some regions, we make some limited adjustments to the ACS PUMS data before calculating migration rates based on the data. In the Berkshire/Franklin region, male and female migrants under the age of 15 are assigned the male/female average number of migrants before a rate is calculated in order to smooth out male/female ratios resulting from small sample sizes. In other regions, cohorts under age 75 with a sample size of zero in the ACS data are assigned values from the opposite gender when it is available to reduce instances of rates calculated from a null value.

PUMS, the most recent five-year dataset available at the PUMA level of geography. [6] Before moving ahead with the 2005-2011 rates, we first reviewed the domestic migration component trend in Massachusetts from 2005 through 2015 to make sure that more recent net migration levels in the state were comparable to the ACS data period in our model. See figure 9 and Table 1 below for comparisons by period.

Figure 9. Massachusetts Estimated Migration, 2000-2016

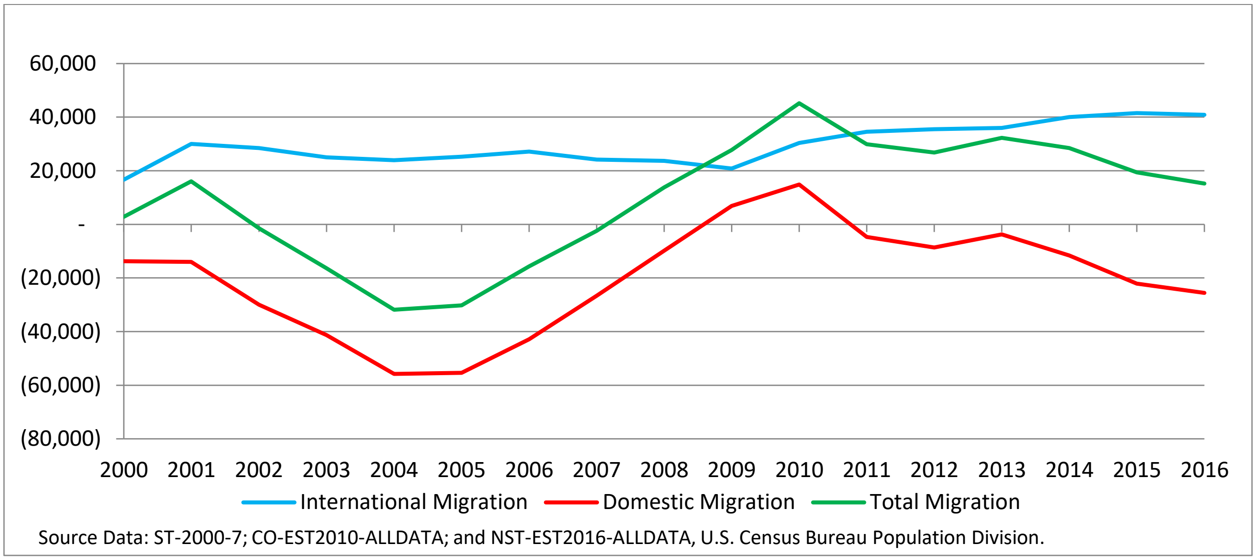


Table 1. Comparison of Massachusetts Net Migration Average by Period

Average Annual	2005-2011 *In model*	2007-2016 *Last 10 years*	2012-2016 *Last 5 years*
Domestic	-1,243	-9,107	-14,329
International	23,287	32,757	38,787
Total Net	22,044	23,650	24,458

It is very important to realize that the PUMS records are based on small, although representative, samples – and that the smaller the sample the greater the margin of error[7]. Sample sizes can be

[6] Starting with the 2012 American Community Survey, migration by age/sex estimates are no longer tabulated by the U.S. Census Bureau for PUMAs, but only much larger MIGPIMA geographies. These MIGPUMAs do not allow for the geographic specificity desired in the MA DOT model.

[7] While we are aware of the potential for sampling error in using ACS PUMS data for these small regions, it is the only direct source of gross migration by age available to us at this time. IRS data on migration does include gross migration data for tax-filers at the county level; however the released data does not include age detail. The Current Population Survey, another

particularly small when distributed by age and sex cohorts for different types of migrants, especially in small regions. For this reason, the Berkshire/Franklin and Cape & Islands are two regions that can be treated with more skepticism in our projections results and which lend themselves to greater cross-examination by alternative methods[8]. These two regions were counted at fewer than 250,000 persons each in the 2010 Census and are subject to larger sampling error than the other six sub-state regions which all number more than 600,000 persons, and sometimes over 1 million. The Cape & Island Region also further breaks out into three distinct MPO regions in the MA DOT projections series. For these reasons, we use an alternative migration model in our projections for the Cape & Islands, described later in this report.

Estimating domestic out-migration is largely similar to estimating net-migration. Because current residents of the study region (*i*) are those who are 'at risk' of moving out, so the appropriate cohort (*j*) migration rate is:

$$Out\ Migration\ Rate_{i,j} = \left(\frac{OutMigrants_{i,j}}{Population_{i,j}}\right). \qquad (2)$$

Because migration in the ACS is based on place of residence one-year prior, the out-migration rate reported in equation (2) is the equivalent of a single year rate. We multiply this by five to estimate the five-year equivalent rate, and, as we did with survival rates, average the five year rates across succeeding cohorts to craft an operational five year rate.[9] The operational rate for each cohort is then multiplied against the number of eventual survivors in 2015 to estimate the number of likely out-migrants from the surviving population.

In-migration is more challenging. The candidate pool of potential domestic in-migrants is not those currently living in the region, but people living elsewhere in the U.S. Modeling in-migration thus requires collecting data on the age-sex profile of not only the study region, but for other regions as well. We model two separate regions as possible sources of incoming migrants in the multi-regional framework - those originating in neighboring regions and states (New York, Connecticut, Rhode Island, New Hampshire, and other Massachusetts regions) and those coming from elsewhere in the U.S. By doing so, we recognize that most inter-regional migration is fairly local and that the migration behavior of the Northeast is likely to differ considerably from that of the rest of the nation – in part due to our older and less racially diverse demographic profile.

sample survey product from the U.S. Census Bureau, provides migration data by age, but only down to the U.S. regional level of geography. Other methods commonly used to estimate migration do so using an indirect method of calculating net migration by age as a residual of a cohort-survival method

[8] For information on alternative projections methods and results for the Berkshire/Franklin and Cape & Islands regions, researchers may contact the Population Estimates Program of the UMass Donahue Institute.

[9] This differs from calculating the five-year survival rate, where the one-year rate was taken to the fifth power. Survival is modeled as a non-recurring probability, since you can only die one. However, we assume that any individual migrant could move more than once during the study period, and multiply the single year rate by five to estimate a five-year equivalent.

Thus the in-migration rates characterizing migration behavior from neighboring regions (*NE*) to study region (*i*) and from the rest of the United States (U.S.) are calculated as:

$$In\ Migration\ Rate_{NE\ to\ i,j} = \left(\frac{InMigrants_{NE\ to\ i,j}}{Population_{NE,j} - Population_{i,j}}\right) \quad (3)$$

$$In\ Migration\ Rate_{US\ to\ i,j} = \left(\frac{InMigrants_{US\ to\ i,j} - InMigrants_{NE\ to\ i,j}}{Population_{US,j} - Population_{NE,j}}\right). \quad (4)$$

As with the out-migration, each single-year in-migration rate is converted into a five-year operational migration rate. Unlike out-migration, these in-migration rates are not multiplied against the surviving regional population for the study region but instead the cohort population for the region of origin (neighboring regions for equation 3 or the rest of the U.S. for equation 4) to reflect the true population at risk of in-migration. The data for estimating the launch year cohort size for other regions is aggregated from the 2010 Census of Population (SF 1), with the study region cohort population subtracted from the base of neighbor regions and neighbor populations subtracted from the United States cohort population.

College Migration

Tracking the migration of college students is often problematic for researchers, as neither the ACS nor conventional tax-return migration data seems to capture their movement comprehensively or accurately. For this reason, the U.S. Census Bureau applies a “college fix” in their annual county-level population estimates to areas that meet their criteria for percent of population enrolled in college and other population thresholds[10]. In the basic application of the “college fix”, the college-enrolled population in a region is held back from aging and migration experienced by the non-college population over the specified time period, and is then restored to the region at the end of the period. In this way, the college-enrolled population remains more or less fixed for a region while other cohorts migrate and age over time.

In both the UMDI Vintage 2015 and the updated 2018 projections models, we apply a “college fix” method to the 15-19, 20-24, and 25-29 age cohorts in three regions: Greater Boston, Lower Pioneer Valley, and the Central Region. According to ACS 2007-2011 data, these regions all show significant percentages of college enrollment as follows:

[10] *The “College Fix”: Overcoming Issues in the Age Distribution of Population in College Counties*. Ortman, Sink, King. Population Division, U.S. Census Bureau. October 2014.

Table 2. ACS 2007-2011 Population Enrolled in College or Graduate School by Region

UMDI Region	Greater Boston		Lower Pioneer Valley		Central Region	
Age cohort	# enrolled	% of cohort	# enrolled	% of cohort	# enrolled	% of cohort
15-19	55,018	39%	19,565	36%	14,207	27%
20-24	97,496	54%	30,255	57%	22,624	49%
25-29	44,479	24%	5,557	15%	5,613	14%

The UMDI college fix method, like the Census Bureau's, holds out the college enrolled portion of these three cohorts from aging and migration and then adds it back into its original cohort five years later. For each of the "College Fix" regions, we use 2007-2011 ACS data to determine the share of population enrolled in college or graduate school in each of the age cohorts. The share is based on the region's enrolled cohort as a percent of the total U.S. cohort. We apply this share by age and sex to the base year population in order to estimate the regional college population and then subtract this from the total regional population. The difference is the estimated "non-college" population. This non-college population is subject to the same migration method described in the domestic migration section above, except that the migration rates are based solely on the non-college population and migrants in the ACS data. The resulting net number of non-college domestic migrants is added to each non-college cohort, which is then aged forward by five years. Finally, the enrollment share for each cohort is applied to the latest U.S. cohort total to determine a new estimate of the college-enrolled population for the region. This updated college estimate is added to the projected population. Below is an example for the 2015 to 2020 period.

Figure 10. College Fix Method Example

2015		2020
non college pop 10-14	*age 5 years and add net migrants 2015-2020→*	non-college pop 15-19
college pop 15-19	*not aged; apply % enrolled to 2020 U.S. population 15-19→*	college pop 15-19
non college pop 15-19	*age 5 years and add net migrants 2015-2020→*	non-college pop 20-24
college pop 20-24	*not aged; apply % enrolled to 2020 U.S. population 20-24→*	college pop 20-24
non college pop 20-24	*age 5 years and add net migrants 2015-2020→*	non college pop 25-29
college pop 25-29	*not aged; apply % enrolled to 2020 U.S. population 25-29→*	college pop 25-29
non college pop 25-29	*age 5 years and add net migrants 2015-2020→*	non college pop 30-34

Because the college population is held out of the aging process, and because migration is only captured for the non-college population, we had to make two additional adjustments to our model. First, we allow portions of the college-enrolled population aged 20-24 and 25-29 to age forward into the non-college population[11]. This accounts for the college-enrolled population that ages in place into the non-college population (i.e. those that come for college or graduate and stay). Additionally, we account for the region's non-college population that joins the college population upon migrating out of the region (i.e. those who leave their homes in Massachusetts to attend college elsewhere in the U.S.) by capturing them as out-migrants[12].

International Migration (immigration and emigration)

International immigration in our model is estimated according to the number of international migrants, by age and sex, indicated for each region by the ACS 2007-2011 PUMS dataset. Unlike domestic migration in our model, however, the estimates of international immigrants from the ACS are not then converted to rates. With domestic migration, we can more comfortably make the assumption that there is a relationship between the number of migrants (our numerator) and another region (our denominator) that might be expected to remain relatively constant over time - for example the number of out-migrants relative to the region's population or the number of in-migrants relative to the U.S. population. In the case of international migration, it is harder to make an assumption that, for example, as the world population by age increases, the region's immigrants will increase at the same rate. In reality, a great number of factors not related to any particular region's current population will influence future immigration levels, including federal immigration policy change, college recruitment policies, and labor needs, to name just a few. Instead of trying to guess at which way these changes will affect immigration to each region, we assume that the levels experienced in recent history, in this case the 2007 to 2011 period, will be sustained, and in our Vintage 2015 model the number of immigrants by cohort remain constant over the time period.

There is no consensus on how best to deal with emigration in a gross-migration context. One quirk of the ACS is that while it does contain information on the residence of recent international immigrants, it contains no information that might be used to estimate emigration. This is because the ACS only surveys people currently living in the U.S. This includes recent immigrants, but not people that moved out of the nation during the last year.

But, while we cannot directly estimate the number of emigrants in a five-year period using regional level ACS data, there are alternative methods that can be borrowed to at least approximate the number for each region. The U.S. Census Bureau developed emigration rates for the foreign born population -- the population most prone to emigration -- for a demographic analysis of net international migration. The rates were developed using a residual method and data from Census 2000, the American Community

[11] To determine this proportion we applied a residual survival method using estimates of the college-enrolled and total populations by age in 2005 and 2010, based on enrollment levels by age indicated in the ACS 2005-2009 PUMS data. In an adjusted to the Greater Boston regional model, we also allow some portion of the 15-19 year old college enrollees to age in place into the non-college population. This age group did not appear to be aging into non-college in the two other college regions based on our residual calculations.

[12] Out-migrants that are enrolled in college in regions outside of the study area, as captured in the ACS PUMS datasets.

Survey, and life tables from the National Center for Health Statistics[13]. They estimated emigration rates ranging from of 12.8 to 15.5 per 1,000 among the population of recently arrived foreign born (those entering the U.S. within 10 years prior to the survey) and rates of just 1.7 to 3.5 per 1,000 for the foreign born population with longer residency – (those arriving more than ten years prior to the survey).

To estimate emigration in our model, we first use ACS 2007-2011 information on the foreign born population by age and by decade of entry to create two estimates of the foreign born population for each state region: one recent-arrival group and one longer-residency group. Using a simplified survival method, we age these two populations forward every five years, decreasing them by letting the 85-and older population fall out (a rough proxy for mortality) and increasing them by the addition of new immigrants (using ACS 2007-2011 levels). After 10 years, new immigrants are moved into the longer-residency group. We apply the Census Bureau's middle-range rates for recently-arrived and longer-residency distinctly to each group in order to estimate the total number of emigrants by cohort in each time period.

It should be noted that in the Greater Boston, Central, and Lower Pioneer Valley regions, emigrating international students are already accounted for by the "revolving-door" approach of the college-fix method. In these three regions, we calculate international immigration and emigration only for the non-college population. College students in our model are withheld from the population at-risk for migration and aging. As such, they are not being counted as "immigrants" in the conventional sense, but instead are lumped in with all other college students, as a constant relative to the entire national population. In the Greater Boston region, college-enrolled immigrants ages 15-29 account for 30% of all international immigrants in the 2007-2011 ACS period, while in the Lower Pioneer Valley, they account for about 36%. These proportions can be thought of in our model as now removed from the foreign born population that would typically drive both immigration and emigration numbers, and so reduces the effect of any error in estimating emigration based on foreign born population estimates.

Finally, international immigrants who become part of the resident population are then subject to the same out-migration rates as the general population. If they move on to other parts of the U.S., they are captured as out-migrants in the next five-year period.

The final step of the migration model adds the estimated net number of domestic migrations (in-migrants minus out-migrants) and the estimated international migrants to the expected surviving population in order to estimate the expected number of "surviving stayers." This is an estimate of the number of current residents who neither die nor move out of the region in the coming five years, plus any new migrants to the region. These surviving stayers are then used as the basis for estimating anticipated births.

[13] Source: Population Division Working Paper No. 97: *Estimating Net International Migration for 2010 Demographic Analysis: An Overview of Methods and Results,* U.S. Census Bureau, February 2013.

Births and Fertility

The last component in our regional cohort-component model requires estimating fertility rates using past data on the number of live births by the age of the mother. Like survival, information on births in comes from the Massachusetts Department of Public Health and is aggregated, by region, into our five-year age cohorts according to the mother's age, and averaged over five years (2005 to2009). The number of births is then divided by the corresponding number of women in 2005 for each cohort to generate an approximate age-specific fertility rate. The births of males and females are modeled separately in our approach, however, in both cases it is only the number of women in each cohort that represents the population 'at risk' and appears in the denominator of the fertility rate. This single year fertility rate is multiplied by five to estimate a five-year equivalent, or:

$$Fertility\ Rate_{i,j} = 5\left[\left(\frac{Births_{i,j}}{Number\ of\ Women_{i,j}}\right)\right]. \tag{7}$$

Next, the estimated fertility rates are multiplied against the number of females in the child-bearing age cohorts among the number of 'surviving stayers' as estimated in the previous step. This provides an estimate of the number of babies that are anticipated within the next five years, and this number is summed across all maternal age cohorts.

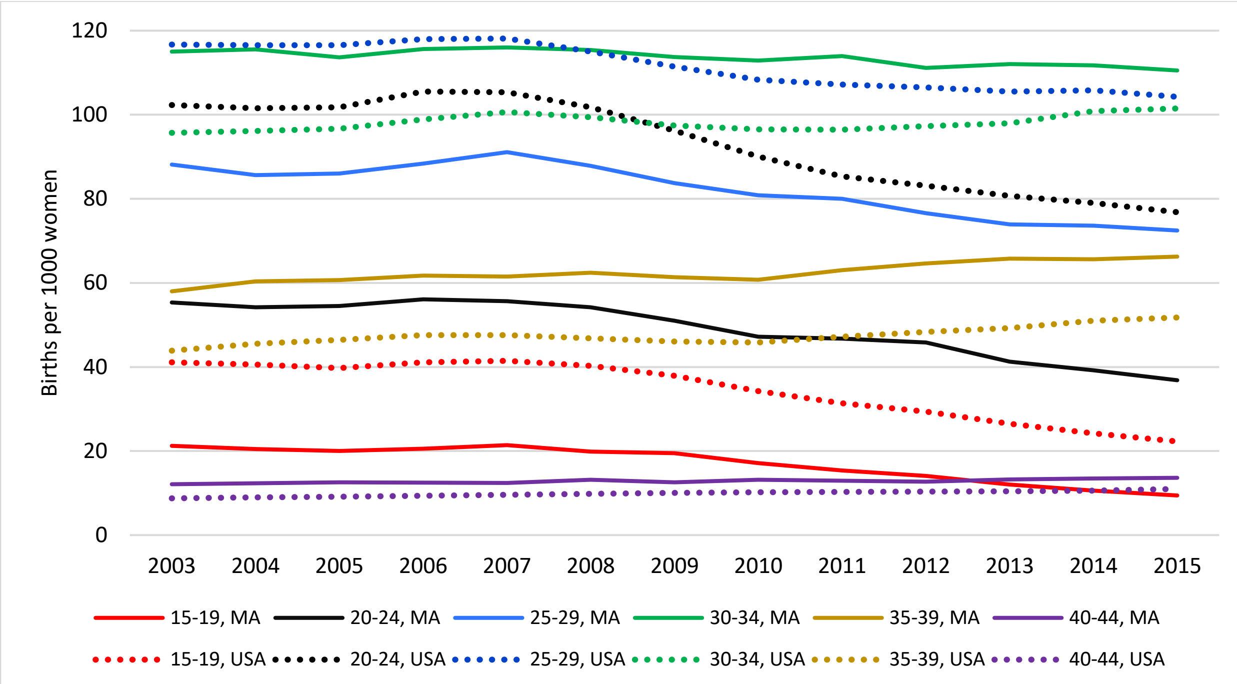
As with mortality, for the V2018 MassDOT projection series we also update births to reflect more recent fertility trends. We reviewed publicly available state-level births by age of mother over the 2003 through 2015 time series, the latest data we were able to obtain by age and sex.[14] Figure 10 below displays changes in fertility by age for both Massachusetts and the U.S. from 2003 through 2015. Notably, fertility is declining significantly in the age cohorts that contribute the greatest number of births per thousand women – ages 20-24, 25-29, and 30-34. Teen births are also declining while most other age-cohorts remain relatively level in their rates. The only cohort showing a significant increase is the 35-39 cohort, indicating that women are postponing fertility now compared to previous years.

Here again, as with mortality, we next had to determine which period rates to average and project forward in our model. After discussion and an examination of the projected impact by region, the Projections Advisory Committee and the UMDI projections team agreed to use the most recent 5-year period of 2011-2015 as a basis for projecting forward, the same period we chose for mortality.

To apply these updates to our model, we calculate the percentage change in births per thousand by age between the averaged 2005-2009 rates already in our model and the updated averaged 2011-2015 rates. We then apply this percent change to births by age by region in our existing regional model. The updated births by age are then summed for all maternal cohorts in the region and added to the next period as aged 0-4 population, as described earlier in this section.

[14] ibid

Figure 10. Massachusetts and US Fertility Rates by Age-of-Mother, 2003-2015



Aging the population and generating projections for later years

Having already re-set the 2015 base as described earlier, the next step in generating our first set of five year forecasts (for year 2020) is to age the surviving stayers in all cohorts by five years. The first (0- 4) and final (85+) cohorts are treated differently. The number of anticipated babies estimated in the previous step becomes the number of 0- 4 year olds in 2020. The number of persons in the 85+ cohort in 2020 is the number of surviving stayers in the 80- 84 age cohort (in 2015) added to the number of surviving stayers in the 85 and older cohort. As we made separate estimates for males and females, the two populations are added and summed across all cohorts to determine the projected number of residents in 2020.

This process is essentially repeated for all future year projections, except that the rates developed from historic data remain the same throughout the forecast horizon. Our 2020 projection becomes our launch year population for estimating the 2025 population, which in turn is used to launch the 2030 population and so-forth. The only notable difference in the process used to generate the later year forecasts is the need to have outside projections of future population levels for the nation as a whole and for neighboring states. This is necessary for estimating population 'at-risk' of domestic in-migration. We use the U.S. Census Bureau's December 2014 national population forecasts which are based on information from the 2010 Decennial Census.[15] Unfortunately, the Census Bureau no longer generates detailed state-level long-term projections; their last state-level projections were developed in 2005. So for estimating future in-migrants from neighboring Northeast states, we use the state-level age/sex projections developed by the University of Virginia's Weldon Cooper Center for Public Service[16] (release 2013).

Municipal-Level Methods and Assumptions

MCD-Level Model Overview

Municipal, or "MCD-level" population projections served as stand-alone output products in the UMDI V2015 Long-Term Population Projections for Massachusetts Municipalities series (V2015). For the UMDI Vintage 2018 updated series for MA DOT (V2018), they serve multiple purposes. Primarily, the V2018 municipal age/sex projections are aggregated to form the regional age/sex projections for each MPO, each of which conforms to municipal boundaries. Also, while some MPOs created their own sub-regional population distributions based on local knowledge of new or anticipated development at the town-level, other MPOs were able to use the V2018 projections as they were. Finally, municipal age/sex projections were used as a basis for employment and household projections for some areas as part of the larger transportation planning process.

As described in the regional-level methods section of this report, separate projections are produced for the 351 MCDs and for the eight state sub-regions made up of aggregate PUMAs. The MCD results are then controlled to the corresponding projected regional cohorts to help smooth any inconsistences in the MCD-level results and to reflect migration trends that may be more accurately reflected by the regional projection methodology.[17] While both of the regional and MCD-level projections are prepared using a cohort-component method, the MCD estimates rely on residual net migration rates computed from vital statistics, while the sub-region projections use gross domestic migration rates based on the American Community Survey Public Use Microdata (ACS PUMS).

The population aged five and over is projected by the mortality and migration methods, while the population age 0-4 is projected by the fertility method. The initial launch year is 2010, with projections made in five-year intervals from 2015 to 2035 using the previous projection as the new launch population. Projections for eighteen five-year age groups (0-4, 5-9 …80-84, and 85–and older) are reported for males and females. (Throughout this document, the term "age" refers to a five-year age cohort). The cohort-component method is used to account for the effects of mortality, migration, and

[15] Source: http://www.census.gov/population/projections/

[16] Source: *Population Projections by Age for the U.S. and States*. Updated August 9, 2013. Weldon Cooper Center for Public Service, University of Virginia. http://www.coopercenter.org/demographics/national-population-projections

[17] The regional projection methodology, discussed at length in Section 3.A. of this report, projects domestic migration using migration data from the American Community Survey, therefore explicitly accounting for recent domestic migration trends. As explained in this section, the MCD methodology uses a "residual" method based on vital statistics to project migration.

fertility on population change. For the V2018 series, the 2015 launch population by age, sex, and MCD is is first controlled to the U.S. Census Bureau's Vintage 2016 population estimates by age, sex, and county for 2015 before launching to the 2020 projection.[18]

Population projections for each age and sex cohort for each five-year period are created by applying a survival rate to the base population, adding net migration for each age/ sex/ MCD cohort, and finally adding births by sex and mother's age, as shown in the table below.

Table 3. Projection Method by Component

Component	Projection
Mortality	Survived population by age/sex
Migration	Net migration by age/sex
Fertility	Births by sex and mother's age
Launch	2010 Census count by age/sex for 2015 projection, controlled to Census age/sex/county estimates for 2015; five year projection thereafter

Data Sources

The launch populations by sex, age cohort, and MCD were obtained from U.S. Census 2010 data[19]. UMDI estimated population by age and sex for 2005 from the 2000 and 2010 U.S. Censuses using a

[18] See Section 3.A. of this report, subsection "*Determining the launch year and cohort classes" for a more detailed description of this process.*

[19] An exception is made in our model for the town of Lincoln, Massachusetts. For the Lincoln base we have instead created 2010 age/sex estimates using cohort-change ratios observed in the 1990-2000 period applied to the Census 2000 age/sex base. We do this because Lincoln was counted in Census 2010 with a significantly reduced population. This happened because, at the time of the Census count, a large number of the housing units at a military base had been demolished, with their replacement happening only later in 2011. This gave the town a Census 2010 base count that was out of trend with its population in the years right before and again shortly after, with population reduced by as much as 21%. While the 2010 Census may be considered as a relatively accurate point-in-time count, using it as a point of reference in a residual net migration model will create drastically altered migration rates for the town, and using it as the population base for future years will also produce unreasonably low projections.

simple linear interpolation by age and sex. The 2015 age/sex/MCD distributions were then controlled to the U.S. Census Bureau's Vintage 2016 estimates of population by age, sex, and county. [20]

UMDI requested and received confidential vital statistics data for births and deaths from January 1, 2000 through December 31, 2009 from the Massachusetts Department of Public Health. From these, UMDI estimated survival, birth and residual net migration rates.

MCD Projections Launch Population

Initial Launch Population

The initial launch population for the 2015 projection is the 2010 Census population by age/sex for each MCD[21]. Corrected census counts from the Count Question Resolution (CQR) program are incorporated where applicable. Each projection thereafter uses the previous projection as the launch population (i.e. the 2020 projection uses the 2015 projection as the launch population). As mentioned above, in the V2018 series, the projected 2015 launch population by age, sex, and MCD is controlled to the U.S. Census Bureau's most recent county-level population estimates by age and sex for 2015 to create an updated launch population.[22]

MCD Projections: Mortality

Forward Cohort Survival Method

The forward cohort survival method is used to account for the mortality component of population change. This procedure applies five-year survival rates by age/sex to the launch population by age/sex for MCDs in order to survive their populations out five years, resulting in the expected population age five and over before accounting for migration.

Five-Year Survival Rates by Age/Sex

UMDI calculated five-year survival rates by age and sex using deaths by age, sex and MCD from 2000 to 2009 (January 1, 2000 through December 31, 2009). Survival rates by age, sex and MCD were assumed to be constant for the duration of the projections at the MCD level, but note that in the V2018 series

[20] Annual Estimates of the Resident Population for Selected Age Groups by Sex for the United States, States, Counties, and Puerto Rico Commonwealth and Municipios: April 1, 2010 to July 1, 2016. (Table PEP_2016_PEPAGESEX). U.S. Census Bureau, Population Division. Release Date: June 22, 2017.

[21] See footnote (above) on exception in the town of Lincoln.

[22] Annual Estimates of the Resident Population for Selected Age Groups by Sex for the United States, States, Counties, and Puerto Rico Commonwealth and Municipios: April 1, 2010 to July 1, 2016. (Table PEP_2016_PEPAGESEX). U.S. Census Bureau, Population Division. Release Date: June 22, 2017.

these rates are later adjusted at the regional level after MCDs are summed to their respective regions.[23] Survival rates for each age cohort up to 80-84 were averaged with the next-older cohort to account for the fact that roughly half of each cohort would age into the next cohort over the course of each five-year period. The 85-and older cohort's survival rate was used as-is, since there was no older cohort to average.

MCDs with smaller populations demonstrated a degree of variability in survival rates that we considered too broad for optimal results. Therefore, for MCDs with populations lower than 10,000 as of the 2000 Census, we used regional survival rates by age and sex instead of MCD-specific rates to smooth the results.

Survived Population for MCDs

The base population by age/sex for MCDs is survived to the next five-year projection by applying the corresponding averaged five-year survival rates by age/sex.

Key Assumptions

The methodology assumes that survival rates vary most significantly by age and sex. To some extent, the use of MCD-specific rates will also indirectly account for varying socioeconomic factors, including race and ethnicity, which vary by MCD and may affect survival rates. The methodology assumes that survival rates by age, sex and MCD will stay constant over the next 25 years.

MCD Projections: Migration

Residual Net Migration from Vital Statistics

The residual net migration method is used to account for the migration component of population change. "Residual" refers to the fact that migration is assumed to be responsible for past population change after accounting for births and deaths. This residual net migration is then used to estimate past migration rates. The procedure applies the resulting net migration rates by age/sex estimated for each MCD to the MCD's survived population by age/sex in order to project net migration by age/sex for the population ages five and older. For the population ages 0-4, it is assumed that residence of infants will be determined by the migration of their birth mothers. For MCDs with 2000 Census population below 10,000, a linear migration assumption (described below) is used to smooth migration.

Determination of Net Migration Rates

Vital statistics are used to infer net migration totals for 2000 to 2009. In order to calculate five-year net migration by age, sex and MCD, natural increase (births minus deaths) by age/ sex for 2000 to 2005 is added to the 2000 population by age/ sex for each MCD. The results are then subtracted from the

[23] See the regional methodology section of this report for additional detail.

interpolated 2005 population by age/ sex for each MCD to estimate net migration by age/ sex and MCD for 2000 to 2005. A similar process calculates migration between 2005 and 2010.

For MCDs with 2000 population equal to or greater 10,000, the two five-year net migration estimates are averaged and rates are then calculated for each age, sex and MCD. The resulting rates are applied to the base population to project five-year net migration. The resulting average five-year net migration rates by age/sex are held constant throughout the projection period.

For MCDs with 2000 population under 10,000, five-year net migration by age, sex and MCD is held constant, and population cohorts are never allowed to go below zero. This avoids applying unrealistically high migration rates to small populations. For instance, if an MCD starts with four males aged 70-74 and net migration shows four more move in over five years, the result is a migration rate of 2. This results in highly variable and unrealistic results in some cases. In this example, holding migration linear means that in each five-year projection period, four males aged 70-74 will move into the MCD. UMDI conducted sensitivity testing for this method and found that the model with constant migration for small places in most cases resulted in more realistic, gradual population growth or decline, as well as more realistic sex and age profiles for these MCDs.

Key Assumptions

The use of a net migration rate relies on a base for migration that includes only current residents – in other words, only those at risk of out-migration. Nonresidents who are at risk of in-migration are not explicitly accounted for in the MCD method, and this results in some inaccuracy which is minimized by the process of controlling to regional total projections that are based on a gross migration model.

We assume that age, sex and MCD are the key factors by which migration rates vary. Other factors, including non-demographic factors such as macroeconomic factors or local policy changes, are not explicitly included in this model. Future projection models may incorporate these or other factors.

MCD Projections: Fertility

Vital Statistics Method

We apply age-specific fertility rates to the migrated female population by age to project births by age of mother, followed by survival rates for the population aged 0-4. Total survived births are then derived by summing across all maternal age groups, and the results represent the projected population age 0-4. For each MCD, the number of males and females is assumed to be the same as the proportion of male or female births statewide.

Fertility by Age of Mother

Average births by age of mother for each MCD are calculated for two five-year periods (2000 to 2005 and 2005 to 2010) using nine maternal age groups, from 10-14…50-54. As with mortality, in the V2018 series fertility rates are adjusted at the regional level after MCDs are summed to their respective regions.[24]

Fertility Rates

Age-specific fertility rates are computed for each time period by dividing the average number of births by age of mother by the corresponding number of females of that age group. The average age-specific fertility rates are held constant throughout the projection period. The base population for launching a new five-year projection is the survived, post-migration projected female population by age.

MCDs with smaller populations demonstrated a degree of variability in fertility rates that we considered too broad for optimal results. Therefore, for MCDs with populations lower than 10,000 as of the 2000 Census, we used regional fertility rates by age and sex instead of MCD-specific rates to smooth the results[25].

Key Assumptions

We assume age, sex and MCD to be adequate indicators of fertility rates for MCD for the first vintage projections. We assume that the proportion of male to female births does not vary significantly by geography or maternal age. We assume that fertility rates by maternal age and MCD will not change significantly over time. Future iterations of the projections may amend these assumptions based on available data.

Controlling to the Regional-level Projections

The resulting MCD-level projected cohorts are finally controlled to the regional-level projected cohorts. To do this, we assume that each MCD's share of the region's population, for each age and sex cohort, is given by the MCD population projections. Those shares are then applied to the regional projections to arrive at adjusted age/ sex cohorts for each MCD.

[24] See the regional methodology section of this report for additional detail.

[25] While MCDs with populations less than 10,000 are given the regional rate in this model, we make exception for "college bedroom" towns. Because fertility rates are generally lower among females enrolled in college compared to the general population of the same age group, applying regional fertility rates to small towns with high percentages of college-enrolled population resulted in inflated births. We developed criteria for identifying "college bedroom" towns and applied town-specific fertility rates to these instead of the regional rates. Criteria is: population under 10,000 in 2010; >20% of 18 and over female population is enrolled in college or graduate school according to 2008-2012 ACS; and use of regional fertility rate resulted in a ≥25% Increase in the 0-4 age group from 2010 to 2015. The three MCDs subject to the "college bedroom" exception include Wenham, Sunderland, and Williamstown.

Alternative Model for Cape & Island Regions

In the regional methodology section of this report, we discuss the limitations of using ACS data to calculate migration rates in small regions, specifically due to the small sample size available in the Census Public-Use Microdata Sample (PUMS) data, the only direct source of migration by age and sex available at the sub-state, regional level. Because the Cape and Island Region is one of the smallest study regions in the model, there are concerns about the margins of error associated with ACS rates by age/sex specifically for this region. In addition, this very small model region breaks out even further into three distinct MPO regions in the statewide travel model. Furthermore, in component data available through U.S. Census annual estimates, these three sub-regional MPOs display differing and sometimes opposite trends in fertility and migration.[26] All of these reasons make this a challenging region to work with in our existing regional model, and caused concern over applying the UMDI V2018 statewide method to this unique region.

On a positive note, because these three Cape & Island MPO regions align with county boundaries - unlike other MPO regions around the state – we are able to access specific county-level data resources that are not available in other state regions not conforming to county boundaries. These county-level resources include both migration-by-age estimates from the University of Wisconsin and county-level fertility rates by age from vital statistics. Given both the challenges and data opportunities available in this region, the Projections Advisory Committee and UMDI decided to use an alternative method to model Cape & Island projections, completing distinct county-level estimates for each using the same basic framework.

For each Cape & Island County, including Barnstable, Dukes, and Nantucket, UMDI used a cohort-component model. This is the same model concept used statewide; we start with a base population to which we apply migration, fertility, and mortality rates by age and sex to estimate the next launch population, and then apply rates again. This process is repeated until we reach the end of the projection term.

Migration

The differences in the custom Cape models and the statewide V2018 method include the source and type of migration and source of fertility data. While in the statewide model we use a gross migration rates, estimating in, out, and net international migrants separately, for the Cape & Islands regions we instead use *net* migration rates, which combine in, out, and international migrants into one combined rate by age and sex. We obtain these rates from the University of Wisconsin, which uses decennial Census counts by age, sex, and county together with birth and death counts by age, sex, and county over

[26] Population, population change and estimated components of population change: April 1, 2010 to July 1, 2016 (CO-EST2016-alldata). U.S. Census Bureau, Population Division. Release Date: March 2017.

the intercensal years to calculate residual net migrants by age, sex, and county.[27] This removes concerns about error margins associated with ACS data for small areas, as rates instead are based on full count and complete vital statistics data instead of survey sample data. These 10-year migration rates by age and sex are first converted to 5-year rates in our application so that populations can be projected in 5-year intervals as in our statewide method. As with our statewide method, the first launch period is 2015. For the Cape & Island counties we use the Census Bureau's latest annual estimates of population by age, sex, and county for 2015 without first needing to reallocate to regions as we do in the main model.[28]

Fertility and Survival

For fertility rates in the Cape & Island counties, we use the most specific fertility data we can obtain for each county.[29] For Barnstable County, the largest of the Cape & Island counties, we are able to use county-specific fertility rates by age for 2011-2015.[30] For Nantucket and Dukes counties, fertility rates by age are modeled using 5-year fertility rates by age from 2000-2009 specific to each county – which we calculated from town-level births by age for our V2015 series - that are then controlled to 5-year birth *totals* from 2011-2015 for each county. Note that current rates by age for Dukes and Nantucket are not available in the CDC Wonder datasets due to small cohort sizes.

Survival rates are used from UMDI V2015 Cape & Islands Region updated by percent changes in statewide rates, as with the statewide V2018 method. We need to revert to the regional rates in this instance because the specific county-level rates included too many "unreliable" rates by age in the 2011-2015 CDC Wonder datasets.

Customizations to the Cape & Island data sources resulted in projections that were slightly higher than the statewide method in the short term, and also showed a smoother age-cohort progression over time.

[27] Age-Specific Net Migration Estimates for US Counties, 1950-2010. Applied Population Laboratory, University of Wisconsin-Madison, 2013. Web. [Downloaded 12/1/2017.] < http://www.netmigration.wisc.edu/>.

[28] Annual Estimates of the Resident Population for Selected Age Groups by Sex for the United States, States, Counties, and Puerto Rico Commonwealth and Municipios: April 1, 2010 to July 1, 2016. (Table PEP_2016_PEPAGESEX). U.S. Census Bureau, Population Division. Release Date: June 22, 2017.

[29] Source of births and deaths rates: United States Department of Health and Human Services (US DDHS) Centers for Disease Control and Prevention (CDC) National Center for Health Statistics (NCHS). See Data Sources Notes in Appendix B to this report for additional source detail.

[30] except for maternal cohort aged 45-49, which we take UMDI V2015 Cape & Islands Region updated by % changes in statewide rates. Current Massachusetts and Barnstable rates are not available for this age group.

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Appendix A: Crosswalk of Municipalities by MPO Region, County, and UMDI Migration Region

MPO Region	MCD Name	County	UMDI Migration Region
BRPC	Adams	Berkshire	Berkshire and Franklin
BRPC	Alford	Berkshire	Berkshire and Franklin
BRPC	Becket	Berkshire	Berkshire and Franklin
BRPC	Cheshire	Berkshire	Berkshire and Franklin
BRPC	Clarksburg	Berkshire	Berkshire and Franklin
BRPC	Dalton	Berkshire	Berkshire and Franklin
BRPC	Egremont	Berkshire	Berkshire and Franklin
BRPC	Florida	Berkshire	Berkshire and Franklin
BRPC	Great Barrington	Berkshire	Berkshire and Franklin
BRPC	Hancock	Berkshire	Berkshire and Franklin
BRPC	Hinsdale	Berkshire	Berkshire and Franklin
BRPC	Lanesborough	Berkshire	Berkshire and Franklin
BRPC	Lee	Berkshire	Berkshire and Franklin
BRPC	Lenox	Berkshire	Berkshire and Franklin
BRPC	Monterey	Berkshire	Berkshire and Franklin
BRPC	Mount Washington	Berkshire	Berkshire and Franklin
BRPC	New Ashford	Berkshire	Berkshire and Franklin
BRPC	New Marlborough	Berkshire	Berkshire and Franklin
BRPC	North Adams	Berkshire	Berkshire and Franklin
BRPC	Otis	Berkshire	Berkshire and Franklin
BRPC	Peru	Berkshire	Berkshire and Franklin
BRPC	Pittsfield	Berkshire	Berkshire and Franklin
BRPC	Richmond	Berkshire	Berkshire and Franklin
BRPC	Sandisfield	Berkshire	Berkshire and Franklin
BRPC	Savoy	Berkshire	Berkshire and Franklin
BRPC	Sheffield	Berkshire	Berkshire and Franklin
BRPC	Stockbridge	Berkshire	Berkshire and Franklin
BRPC	Tyringham	Berkshire	Berkshire and Franklin
BRPC	Washington	Berkshire	Berkshire and Franklin
BRPC	West Stockbridge	Berkshire	Berkshire and Franklin
BRPC	Williamstown	Berkshire	Berkshire and Franklin
BRPC	Windsor	Berkshire	Berkshire and Franklin
CCC	Barnstable	Barnstable	Cape and Islands

CCC	Bourne	Barnstable	Cape and Islands
CCC	Brewster	Barnstable	Cape and Islands
CCC	Chatham	Barnstable	Cape and Islands
CCC	Dennis	Barnstable	Cape and Islands
CCC	Eastham	Barnstable	Cape and Islands
CCC	Falmouth	Barnstable	Cape and Islands
CCC	Harwich	Barnstable	Cape and Islands
CCC	Mashpee	Barnstable	Cape and Islands
CCC	Orleans	Barnstable	Cape and Islands
CCC	Provincetown	Barnstable	Cape and Islands
CCC	Sandwich	Barnstable	Cape and Islands
CCC	Truro	Barnstable	Cape and Islands
CCC	Wellfleet	Barnstable	Cape and Islands
CCC	Yarmouth	Barnstable	Cape and Islands
CMRPC	Auburn	Worcester	Central
CMRPC	Barre	Worcester	Central
CMRPC	Berlin	Worcester	MetroWest
CMRPC	Blackstone	Worcester	MetroWest
CMRPC	Boylston	Worcester	Central
CMRPC	Brookfield	Worcester	Central
CMRPC	Charlton	Worcester	Central
CMRPC	Douglas	Worcester	Central
CMRPC	Dudley	Worcester	Central
CMRPC	East Brookfield	Worcester	Central
CMRPC	Grafton	Worcester	Central
CMRPC	Hardwick	Worcester	Berkshire and Franklin
CMRPC	Holden	Worcester	Central
CMRPC	Hopedale	Worcester	MetroWest
CMRPC	Leicester	Worcester	Central
CMRPC	Mendon	Worcester	MetroWest
CMRPC	Millbury	Worcester	Central
CMRPC	Millville	Worcester	MetroWest
CMRPC	New Braintree	Worcester	Berkshire and Franklin
CMRPC	North Brookfield	Worcester	Central
CMRPC	Northborough	Worcester	Central
CMRPC	Northbridge	Worcester	Central
CMRPC	Oakham	Worcester	Central
CMRPC	Oxford	Worcester	Central
CMRPC	Paxton	Worcester	Central

CMRPC	Princeton	Worcester	Central
CMRPC	Rutland	Worcester	Central
CMRPC	Shrewsbury	Worcester	Central
CMRPC	Southbridge	Worcester	Central
CMRPC	Spencer	Worcester	Central
CMRPC	Sturbridge	Worcester	Central
CMRPC	Sutton	Worcester	Central
CMRPC	Upton	Worcester	MetroWest
CMRPC	Uxbridge	Worcester	Central
CMRPC	Warren	Worcester	Central
CMRPC	Webster	Worcester	Central
CMRPC	West Boylston	Worcester	Central
CMRPC	West Brookfield	Worcester	Central
CMRPC	Westborough	Worcester	Central
CMRPC	Worcester	Worcester	Central
FRCOG	Ashfield	Franklin	Berkshire and Franklin
FRCOG	Bernardston	Franklin	Berkshire and Franklin
FRCOG	Buckland	Franklin	Berkshire and Franklin
FRCOG	Charlemont	Franklin	Berkshire and Franklin
FRCOG	Colrain	Franklin	Berkshire and Franklin
FRCOG	Conway	Franklin	Berkshire and Franklin
FRCOG	Deerfield	Franklin	Berkshire and Franklin
FRCOG	Erving	Franklin	Berkshire and Franklin
FRCOG	Gill	Franklin	Berkshire and Franklin
FRCOG	Greenfield	Franklin	Berkshire and Franklin
FRCOG	Hawley	Franklin	Berkshire and Franklin
FRCOG	Heath	Franklin	Berkshire and Franklin
FRCOG	Leverett	Franklin	Berkshire and Franklin
FRCOG	Leyden	Franklin	Berkshire and Franklin
FRCOG	Monroe	Franklin	Berkshire and Franklin
FRCOG	Montague	Franklin	Berkshire and Franklin
FRCOG	New Salem	Franklin	Berkshire and Franklin
FRCOG	Northfield	Franklin	Berkshire and Franklin
FRCOG	Orange	Franklin	Berkshire and Franklin
FRCOG	Rowe	Franklin	Berkshire and Franklin
FRCOG	Shelburne	Franklin	Berkshire and Franklin
FRCOG	Shutesbury	Franklin	Berkshire and Franklin
FRCOG	Sunderland	Franklin	Lower Pioneer Valley
FRCOG	Warwick	Franklin	Berkshire and Franklin

FRCOG	Wendell	Franklin	Berkshire and Franklin
FRCOG	Whately	Franklin	Berkshire and Franklin
MAPC	Acton	Middlesex	MetroWest
MAPC	Arlington	Middlesex	Greater Boston
MAPC	Ashland	Middlesex	MetroWest
MAPC	Bedford	Middlesex	MetroWest
MAPC	Bellingham	Norfolk	MetroWest
MAPC	Belmont	Middlesex	Greater Boston
MAPC	Beverly	Essex	Northeast
MAPC	Bolton	Worcester	MetroWest
MAPC	Boston	Suffolk	Greater Boston
MAPC	Boxborough	Middlesex	MetroWest
MAPC	Braintree	Norfolk	Greater Boston
MAPC	Brookline	Norfolk	Greater Boston
MAPC	Burlington	Middlesex	Northeast
MAPC	Cambridge	Middlesex	Greater Boston
MAPC	Canton	Norfolk	Greater Boston
MAPC	Carlisle	Middlesex	MetroWest
MAPC	Chelsea	Suffolk	Greater Boston
MAPC	Cohasset	Norfolk	Southeast
MAPC	Concord	Middlesex	MetroWest
MAPC	Danvers	Essex	Northeast
MAPC	Dedham	Norfolk	Greater Boston
MAPC	Dover	Norfolk	Greater Boston
MAPC	Essex	Essex	Northeast
MAPC	Everett	Middlesex	Greater Boston
MAPC	Foxborough	Norfolk	MetroWest
MAPC	Framingham	Middlesex	MetroWest
MAPC	Franklin	Norfolk	MetroWest
MAPC	Gloucester	Essex	Northeast
MAPC	Hamilton	Essex	Northeast
MAPC	Hanover	Plymouth	Southeast
MAPC	Hingham	Plymouth	Southeast
MAPC	Holbrook	Norfolk	Greater Boston
MAPC	Holliston	Middlesex	MetroWest
MAPC	Hopkinton	Middlesex	MetroWest
MAPC	Hudson	Middlesex	MetroWest
MAPC	Hull	Plymouth	Southeast
MAPC	Ipswich	Essex	Northeast

MAPC	Lexington	Middlesex	Greater Boston
MAPC	Lincoln	Middlesex	Greater Boston
MAPC	Littleton	Middlesex	MetroWest
MAPC	Lynn	Essex	Greater Boston
MAPC	Lynnfield	Essex	Northeast
MAPC	Malden	Middlesex	Greater Boston
MAPC	Manchester-by-the-Sea	Essex	Northeast
MAPC	Marblehead	Essex	Northeast
MAPC	Marlborough	Middlesex	MetroWest
MAPC	Marshfield	Plymouth	Southeast
MAPC	Maynard	Middlesex	MetroWest
MAPC	Medfield	Norfolk	MetroWest
MAPC	Medford	Middlesex	Greater Boston
MAPC	Medway	Norfolk	MetroWest
MAPC	Melrose	Middlesex	Greater Boston
MAPC	Middleton	Essex	Northeast
MAPC	Milford	Worcester	MetroWest
MAPC	Millis	Norfolk	MetroWest
MAPC	Milton	Norfolk	Greater Boston
MAPC	Nahant	Essex	Greater Boston
MAPC	Natick	Middlesex	MetroWest
MAPC	Needham	Norfolk	Greater Boston
MAPC	Newton	Middlesex	Greater Boston
MAPC	Norfolk	Norfolk	MetroWest
MAPC	North Reading	Middlesex	Northeast
MAPC	Norwell	Plymouth	Southeast
MAPC	Norwood	Norfolk	MetroWest
MAPC	Peabody	Essex	Northeast
MAPC	Quincy	Norfolk	Greater Boston
MAPC	Randolph	Norfolk	Greater Boston
MAPC	Reading	Middlesex	Northeast
MAPC	Revere	Suffolk	Greater Boston
MAPC	Rockland	Plymouth	Southeast
MAPC	Rockport	Essex	Northeast
MAPC	Salem	Essex	Northeast
MAPC	Saugus	Essex	Greater Boston
MAPC	Scituate	Plymouth	Southeast
MAPC	Sharon	Norfolk	MetroWest
MAPC	Sherborn	Middlesex	MetroWest

MAPC	Somerville	Middlesex	Greater Boston
MAPC	Southborough	Worcester	MetroWest
MAPC	Stoneham	Middlesex	Greater Boston
MAPC	Stow	Middlesex	MetroWest
MAPC	Sudbury	Middlesex	MetroWest
MAPC	Swampscott	Essex	Northeast
MAPC	Topsfield	Essex	Northeast
MAPC	Wakefield	Middlesex	Northeast
MAPC	Walpole	Norfolk	MetroWest
MAPC	Waltham	Middlesex	Greater Boston
MAPC	Watertown	Middlesex	Greater Boston
MAPC	Wayland	Middlesex	MetroWest
MAPC	Wellesley	Norfolk	Greater Boston
MAPC	Wenham	Essex	Northeast
MAPC	Weston	Middlesex	Greater Boston
MAPC	Westwood	Norfolk	MetroWest
MAPC	Weymouth	Norfolk	Southeast
MAPC	Wilmington	Middlesex	Northeast
MAPC	Winchester	Middlesex	Greater Boston
MAPC	Winthrop	Suffolk	Greater Boston
MAPC	Woburn	Middlesex	Greater Boston
MAPC	Wrentham	Norfolk	MetroWest
MRPC	Ashburnham	Worcester	Central
MRPC	Ashby	Middlesex	Central
MRPC	Athol	Worcester	Berkshire and Franklin
MRPC	Ayer	Middlesex	MetroWest
MRPC	Clinton	Worcester	Central
MRPC	Fitchburg	Worcester	Central
MRPC	Gardner	Worcester	Central
MRPC	Groton	Middlesex	Northeast
MRPC	Harvard	Worcester	MetroWest
MRPC	Hubbardston	Worcester	Berkshire and Franklin
MRPC	Lancaster	Worcester	MetroWest
MRPC	Leominster	Worcester	Central
MRPC	Lunenburg	Worcester	Central
MRPC	Petersham	Worcester	Berkshire and Franklin
MRPC	Phillipston	Worcester	Berkshire and Franklin
MRPC	Royalston	Worcester	Berkshire and Franklin
MRPC	Shirley	Middlesex	MetroWest

MRPC	Sterling	Worcester	Central
MRPC	Templeton	Worcester	Central
MRPC	Townsend	Middlesex	MetroWest
MRPC	Westminster	Worcester	Central
MRPC	Winchendon	Worcester	Central
MVC	Aquinnah	Dukes	Cape and Islands
MVC	Chilmark	Dukes	Cape and Islands
MVC	Edgartown	Dukes	Cape and Islands
MVC	Gosnold	Dukes	Cape and Islands
MVC	Oak Bluffs	Dukes	Cape and Islands
MVC	Tisbury	Dukes	Cape and Islands
MVC	West Tisbury	Dukes	Cape and Islands
MVPC	Amesbury	Essex	Northeast
MVPC	Andover	Essex	Northeast
MVPC	Boxford	Essex	Northeast
MVPC	Georgetown	Essex	Northeast
MVPC	Groveland	Essex	Northeast
MVPC	Haverhill	Essex	Northeast
MVPC	Lawrence	Essex	Northeast
MVPC	Merrimac	Essex	Northeast
MVPC	Methuen	Essex	Northeast
MVPC	Newbury	Essex	Northeast
MVPC	Newburyport	Essex	Northeast
MVPC	North Andover	Essex	Northeast
MVPC	Rowley	Essex	Northeast
MVPC	Salisbury	Essex	Northeast
MVPC	West Newbury	Essex	Northeast
NMCOG	Billerica	Middlesex	Northeast
NMCOG	Chelmsford	Middlesex	Northeast
NMCOG	Dracut	Middlesex	Northeast
NMCOG	Dunstable	Middlesex	Northeast
NMCOG	Lowell	Middlesex	Northeast
NMCOG	Pepperell	Middlesex	Northeast
NMCOG	Tewksbury	Middlesex	Northeast
NMCOG	Tyngsborough	Middlesex	Northeast
NMCOG	Westford	Middlesex	Northeast
NPEDC	Nantucket	Nantucket	Cape and Islands
OCPC	Abington	Plymouth	Southeast
OCPC	Avon	Norfolk	Southeast

OCPC	Bridgewater	Plymouth	Southeast
OCPC	Brockton	Plymouth	Southeast
OCPC	Duxbury	Plymouth	Southeast
OCPC	East Bridgewater	Plymouth	Southeast
OCPC	Easton	Bristol	Southeast
OCPC	Halifax	Plymouth	Southeast
OCPC	Hanson	Plymouth	Southeast
OCPC	Kingston	Plymouth	Southeast
OCPC	Pembroke	Plymouth	Southeast
OCPC	Plymouth	Plymouth	Southeast
OCPC	Plympton	Plymouth	Southeast
OCPC	Stoughton	Norfolk	Greater Boston
OCPC	West Bridgewater	Plymouth	Southeast
OCPC	Whitman	Plymouth	Southeast
PVPC	Agawam	Hampden	Lower Pioneer Valley
PVPC	Amherst	Hampshire	Lower Pioneer Valley
PVPC	Belchertown	Hampshire	Lower Pioneer Valley
PVPC	Blandford	Hampden	Berkshire and Franklin
PVPC	Brimfield	Hampden	Central
PVPC	Chester	Hampden	Berkshire and Franklin
PVPC	Chesterfield	Hampshire	Berkshire and Franklin
PVPC	Chicopee	Hampden	Lower Pioneer Valley
PVPC	Cummington	Hampshire	Berkshire and Franklin
PVPC	East Longmeadow	Hampden	Lower Pioneer Valley
PVPC	Easthampton	Hampshire	Lower Pioneer Valley
PVPC	Goshen	Hampshire	Berkshire and Franklin
PVPC	Granby	Hampshire	Lower Pioneer Valley
PVPC	Granville	Hampden	Berkshire and Franklin
PVPC	Hadley	Hampshire	Lower Pioneer Valley
PVPC	Hampden	Hampden	Lower Pioneer Valley
PVPC	Hatfield	Hampshire	Lower Pioneer Valley
PVPC	Holland	Hampden	Central
PVPC	Holyoke	Hampden	Lower Pioneer Valley
PVPC	Huntington	Hampshire	Lower Pioneer Valley
PVPC	Longmeadow	Hampden	Lower Pioneer Valley
PVPC	Ludlow	Hampden	Lower Pioneer Valley
PVPC	Middlefield	Hampshire	Berkshire and Franklin
PVPC	Monson	Hampden	Lower Pioneer Valley
PVPC	Montgomery	Hampden	Lower Pioneer Valley

PVPC	Northampton	Hampshire	Lower Pioneer Valley
PVPC	Palmer	Hampden	Lower Pioneer Valley
PVPC	Pelham	Hampshire	Berkshire and Franklin
PVPC	Plainfield	Hampshire	Berkshire and Franklin
PVPC	Russell	Hampden	Lower Pioneer Valley
PVPC	South Hadley	Hampshire	Lower Pioneer Valley
PVPC	Southampton	Hampshire	Lower Pioneer Valley
PVPC	Southwick	Hampden	Lower Pioneer Valley
PVPC	Springfield	Hampden	Lower Pioneer Valley
PVPC	Tolland	Hampden	Berkshire and Franklin
PVPC	Wales	Hampden	Central
PVPC	Ware	Hampshire	Lower Pioneer Valley
PVPC	West Springfield	Hampden	Lower Pioneer Valley
PVPC	Westfield	Hampden	Lower Pioneer Valley
PVPC	Westhampton	Hampshire	Berkshire and Franklin
PVPC	Wilbraham	Hampden	Lower Pioneer Valley
PVPC	Williamsburg	Hampshire	Lower Pioneer Valley
PVPC	Worthington	Hampshire	Berkshire and Franklin
SRPEDD	Acushnet	Bristol	Southeast
SRPEDD	Attleboro	Bristol	Southeast
SRPEDD	Berkley	Bristol	Southeast
SRPEDD	Carver	Plymouth	Southeast
SRPEDD	Dartmouth	Bristol	Southeast
SRPEDD	Dighton	Bristol	Southeast
SRPEDD	Fairhaven	Bristol	Southeast
SRPEDD	Fall River	Bristol	Southeast
SRPEDD	Freetown	Bristol	Southeast
SRPEDD	Lakeville	Plymouth	Southeast
SRPEDD	Mansfield	Bristol	Southeast
SRPEDD	Marion	Plymouth	Southeast
SRPEDD	Mattapoisett	Plymouth	Southeast
SRPEDD	Middleborough	Plymouth	Southeast
SRPEDD	New Bedford	Bristol	Southeast
SRPEDD	North Attleborough	Bristol	Southeast
SRPEDD	Norton	Bristol	Southeast
SRPEDD	Plainville	Norfolk	MetroWest
SRPEDD	Raynham	Bristol	Southeast
SRPEDD	Rehoboth	Bristol	Southeast
SRPEDD	Rochester	Plymouth	Southeast

SRPEDD	Seekonk	Bristol	Southeast
SRPEDD	Somerset	Bristol	Southeast
SRPEDD	Swansea	Bristol	Southeast
SRPEDD	Taunton	Bristol	Southeast
SRPEDD	Wareham	Plymouth	Southeast
SRPEDD	Westport	Bristol	Southeast

Appendix B: Data Source Notes on Fertility and Mortality

Fertility

Statewide yearly fertility rates for cohorts 15-19 years, 20-24 years, 25-29 years, 30-34 years, 35-39 years, and 40-44 years in Massachusetts are sourced from WONDER data (SEE CITATION) and averaged to create 5-year fertility rates for 2005-2009 and 2011-2015 for each cohort. USA data is used for cohorts 10-14 and 45-49 years, due to lack of available statewide data. The ratio of the 2011-2015 rate over the 2005-2009 rate for each cohort was used as a multiplier to adjust births from 2009 levels within the model. No fertility data were available for the 50-59-year cohort, so fertility rates were not altered from the 2005-2009 model.

2005-2006 Massachusetts data from United States Department of Health and Human Services (US DDHS) Centers for Disease Control and Prevention (CDC) National Center for Health Statistics (NCHS) “Natality Public-use data 2003-2006” on CDC WONDER Online Database, March 2009. Accessed at http://wonder.cdc.gov/natality-v2006.html.

2007-2015 Massachusetts data from US DDHS CDC NCHS “Natality Public-use data 2007-2015” on CDC WONDER Online Database, February 2017. Accessed at http://wonder.cdc.gov/natality-current.html.

USA data from US DDHS CDC NCHS “The Public Use Natality File—2015 Update” Accessed at ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/DVS/natality/UserGuide2015.pdf

Mortality

Because of how data is organized by age in the data available to us, two CDC datasets were used for informing the model. These datasets come from the same source of raw data, but have differently amalgamated cohorts, as well as other health and demographic details, for use in various health related analyses. These are the Compressed Mortality file and Multiple Cause of Death Files.

For cohorts 0-4, 5-9, 10-14, 15-19, 20-24, and 85+ Compressed Mortality data are used. Within this dataset, death rates are flagged as “unreliable” when the rate is calculated from fewer than 20 deaths. This occurred in several years for cohorts 14 years and younger for both sexes. However, because we calculated 5-year average mortality rates for 2005-2009 and 2011-2015, and the fact that there were so few deaths overall for these cohorts, we used the information gleaned from these rates in the model. For all other cohorts, the Multiple Cause of Death 1999-2015 dataset is used. For all mortality rates, except cohort 0-4, a 5-year average of annual mortality rates provided by the appropriate data set over the 2005-2009 and 2011-2015 time periods were calculated for each sex. Mortality rates if cohort 0-4 was calculated by UMDI from the total deaths of the 0-4 population divided by the sum of the 0-4 population for the 2005-2009 and 2011-2015 time periods. The ratio of 2011-2015 over 2005-2009 for each sex and age cohort was calculated and used as a multiplier to adjust deaths from 2009 levels within the model.

Compressed: Centers for Disease Control and Prevention, National Center for Health Statistics. Compressed Mortality File. 1999-2015 on CDC WONDER Online Database, released December 2016. Data are from the Compressed Mortality File 1999-2015 Series 20 No. 2U, 2016, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program. Accessed at http://wonder.cdc.gov/cmf-icd10.html on Sep 18, 2017.

Multiple: Centers for Disease Control and Prevention, National Center for Health Statistics. Multiple Cause of Death 1999-2015 on CDC WONDER Online Database, released December, 2016. Data are from the Multiple Cause of Death Files, 1999-2015, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program. Accessed at http://wonder.cdc.gov/mcd-icd10.html on Jul 5, 2017.

REGIONAL POPULATION PROJECTIONS for 2020 RTPs

RPA	Census 2010	Population 2020	Population 2030	Population 2040	% Change '10-'20	% Change '10-'40
BRPC	131,219	127,986	128,548	128,063	-2.5%	-2.4%
CCC	215,888	210,930	199,466	176,007	-2.3%	-18.5%
CMRPC	556,698	588,141	619,815	641,260	5.6%	15.2%
FRCOG	71,372	70,804	70,925	69,477	-0.8%	-2.7%
MAPC (97)	3,087,975	3,356,151	3,568,967	3,704,533	8.7%	20.0%
MRPC	236,475	243,607	247,899	245,705	3.0%	3.9%
MVC	16,535	18,156	19,584	19,793	9.8%	19.7%
MVPC	333,748	357,622	370,611	380,912	7.2%	14.1%
NMCOG	286,901	299,617	298,889	295,061	4.4%	2.8%
NPEDC	10,172	11,206	11,804	12,212	10.2%	20.1%
OCPC	362,406	379,936	391,583	396,418	4.8%	9.4%
PVPC	621,570	632,012	647,277	656,992	1.7%	5.7%
SRPEDD	616,670	637,719	650,104	653,966	3.4%	6.0%
Massachusetts	6,547,629	6,933,887	7,225,472	7,380,399	5.9%	12.7%

Jobs 2010	Jobs 2020	Jobs 2030	Jobs 2040	% Change '10-'20	% Change '10-'40
60,150	59,772	57,864	57,639	-0.6%	-4.2%
88,596	88,953	81,880	75,299	0.4%	-15.0%
224,059	238,486	240,984	244,265	6.4%	9.0%
25,684	26,055	25,163	24,622	1.4%	-4.1%
1,823,515	1,993,310	2,041,465	2,084,667	9.3%	14.3%
77,199	80,996	79,726	79,098	4.9%	2.5%
7,731	8,256	8,349	8,362	6.8%	8.2%
145,374	158,793	159,763	161,742	9.2%	11.3%
119,332	128,420	127,398	127,359	7.6%	6.7%
5,699	6,227	6,256	6,212	9.3%	9.0%
140,572	149,986	149,870	150,406	6.7%	7.0%
252,156	261,527	260,253	260,838	3.7%	3.4%
229,400	242,461	242,848	243,002	5.7%	5.9%
3,199,467	3,443,242	3,481,819	3,523,509	7.6%	10.1%

Jobs/per 2010	Jobs/per 2020	Jobs/per 2030	Jobs/per 2040
0.46	0.47	0.45	0.45
0.41	0.42	0.41	0.43
0.40	0.41	0.39	0.38
0.36	0.37	0.35	0.35
0.59	0.59	0.57	0.56
0.33	0.33	0.32	0.32
0.47	0.45	0.43	0.42
0.44	0.44	0.43	0.42
0.42	0.43	0.43	0.43
0.56	0.56	0.53	0.51
0.39	0.39	0.38	0.38
0.41	0.41	0.40	0.40
0.37	0.38	0.37	0.37
0.49	0.50	0.48	0.48

RPA	Census 2010	Households 2020	Households 2030	Households 2040	% Change '10-'20	% Change '10-'40
BRPC	56,091	58,453	60,341	60,055	4.2%	7.1%
CCC	95,755	97,410	93,355	82,313	1.7%	-14.0%
CMRPC	210,870	234,781	256,845	270,061	11.3%	28.1%
FRCOG	30,462	32,675	34,478	34,427	7.3%	13.0%
MAPC (97)	1,216,543	1,377,472	1,505,119	1,582,644	13.2%	30.1%
MRPC	89,816	98,864	105,522	107,413	10.1%	19.6%
MVC	7,368	8,368	9,180	9,359	13.6%	27.0%
MVPC	123,577	140,546	152,363	159,348	13.7%	28.9%
NMCOG	104,022	116,271	121,559	122,740	11.8%	18.0%
NPEDC	4,229	4,644	4,787	4,780	9.8%	13.0%
OCPC	129,490	143,521	152,908	156,069	10.8%	20.5%
PVPC	238,629	255,326	270,293	278,094	7.0%	16.5%
SRPEDD	240,223	261,815	277,728	284,421	9.0%	18.4%
Massachusetts	2,547,075	2,830,145	3,044,477	3,151,722	11.1%	23.7%

Jobs 2010	Jobs 2020	Jobs 2030	Jobs 2040	% Change '10-'20	% Change '10-'40
60,150	59,772	57,864	57,639	-0.6%	-4.2%
88,596	88,953	81,880	75,299	0.4%	-15.0%
224,059	238,486	240,984	244,265	6.4%	9.0%
25,684	26,055	25,163	24,622	1.4%	-4.1%
1,823,515	1,993,310	2,041,465	2,084,667	9.3%	14.3%
77,199	80,996	79,726	79,098	4.9%	2.5%
7,731	8,256	8,349	8,362	6.8%	8.2%
145,374	158,793	159,763	161,742	9.2%	11.3%
119,332	128,420	127,398	127,359	7.6%	6.7%
5,699	6,227	6,256	6,212	9.3%	9.0%
140,572	149,986	149,870	150,406	6.7%	7.0%
252,156	261,527	260,253	260,838	3.7%	3.4%
229,400	242,461	242,848	243,002	5.7%	5.9%
3,199,467	3,443,242	3,481,819	3,523,509	7.6%	10.1%

Jobs/HH 2010	Jobs/HH 2020	Jobs/HH 2030	Jobs/HH 2040
1.07	1.02	0.96	0.96
0.93	0.91	0.88	0.91
1.06	1.02	0.94	0.90
0.84	0.80	0.73	0.72
1.50	1.45	1.36	1.32
0.86	0.82	0.76	0.74
1.05	0.99	0.91	0.89
1.18	1.13	1.05	1.02
1.15	1.10	1.05	1.04
1.35	1.34	1.31	1.30
1.09	1.05	0.98	0.96
1.06	1.02	0.96	0.94
0.95	0.93	0.87	0.85
1.26	1.22	1.14	1.12

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C

Operating Plans Developed for Alternatives Analysis

Alternative 1

Alternative 2

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Project #14796.04

Cape Rail Study
Alternatives Analysis
DRAFT Proposed Alternative 1 Weekday Schedule
Buzzards Bay Connecting to Middleborough/SCR

January 2021

DRAFT - Cape Rail Study

Northbound	000	002	BB-004	004	BB-006	006	008	BB-010	010	012	BB-014	014	016	BB-018	018	BB-020	020	022	BB-028	028	Cape Flyer
Fall River		4:51				6:28			7:38			10:51			14:57			17:40			
Freetown		4:59				6:36			7:46			10:58			15:04			17:47			
New Bedford	4:40			5:30			6:46			8:57			12:58				16:12			20:55	
Chruch Street	4:45			5:35			6:51			9:02			13:03				16:17			21:00	
East Taunton	5:00	5:10		5:50		6:47	7:06		7:58	9:17		11:09	13:18		15:15		16:32	17:57		21:15	*Friday Only*
Hyannis																					21:00
Bourne			*Mon-Fri*		*Mon-Fri*			*Mon-Fri*			*Mon-Fri*			*Mon-Fri*		*Mon-Fri*			*Mon-Fri*		21:55
Buzzards Bay			5:26		6:23			7:33			10:44			14:50		16:00			20:50		22:00
Wareham			5:36		6:33			7:43			10:54			15:00		16:10			21:00		22:10
Lakeville			-		-			-			-			-		-			-		22:30
Middleborough	5:12	5:22	5:57 →	6:02	6:54 →	6:59	7:17	8:04 →	8:09	9:28	11:15 →	11:20	13:29	15:21 →	15:26	16:31 →	16:47	18:11	21:21 →	21:26	-
Bridgewater	-	5:32		6:12		7:09	7:27		8:19	9:38		11:30	13:39		15:36		16:57	18:20		21:36	-
Campello	-	5:40		6:20		7:17	7:36		8:27	9:46		11:38	13:47		15:44		17:05	18:31		21:44	-
Brockton	-	5:44		6:24		7:21	7:40		8:31	9:50		11:42	13:51		15:48		17:10	18:35		21:48	22:46
Montello	-	5:47		6:27		7:24	7:43		8:34	9:53		11:45	13:54		15:51		17:14	18:38		21:51	-
Holbrook/Randolph	-	5:52		6:32		7:29	7:48		8:39	9:58		11:50	13:59		15:56		17:20	18:43		21:56	-
Braintree	5:40	5:59		6:39		7:36	7:55		8:46	10:05		11:57	14:06		16:03		17:31	18:55		22:03	22:59
Quincy Center	-	-		x		x	x		-	x		12:02	x		-		-	-		x	-
JFK/UMass	-	6:12		-		7:49	8:08		x	-		-	-		-		-	-		-	-
South Station	6:00	6:19		6:58		7:56	8:15		9:06	10:24		12:17	14:25		16:24		18:06	19:14		22:22	23:17
Travel Time	*1:20*	*1:28*	*0:31*	*1:28*	*0:31*	*1:28*	*1:29*	*0:31*	*1:28*	*1:27*	*0:31*	*1:26*	*1:27*	*0:31*	*1:27*	*0:31*	*1:54*	*1:34*	*0:31*	*1:27*	

Southbound	003	005	BB-005	007	009	BB-009	015	017	BB-017	019	BB-019	021	BB-021	023	Cape Flyer	123	025	BB-025	027	029	BB-029
South Station	6:35	8:24		10:00	11:56		14:04	15:43		16:40		17:10		17:45	18:10	18:25	18:52		20:05	22:30	
JFK/UMass	6:41	-		10:06	-		-	15:49		-		-		x	-	-	-		20:11	-	
Quincy Center	x	-		x	x		x	x		x		x		x	-	-	x		x	22:43	
Braintree	6:55	8:45		10:20	12:15		14:23	16:03		16:59		17:29		18:04	18:30	18:44	19:11		20:25	22:50	
Holbrook/Randolph	7:03	8:51		10:27	12:22		14:30	16:10		17:06		17:36		18:11	-	18:51	19:18		20:32	22:57	
Montello	7:08	8:56		10:32	12:27		14:35	16:15		17:11		17:41		18:16	-	18:56	19:23		20:37	23:02	
Brockton	7:12	8:59		10:35	12:30		14:38	16:18		17:14		17:44		18:19	18:43	18:59	19:26		20:40	23:05	
Campello	7:22	9:03		10:39	12:34		14:42	16:22		17:18		17:48		18:23	-	19:03	19:30		20:44	23:09	
Bridgewater	7:36	9:11		10:47	12:42		14:50	16:30		17:26		17:56		18:31	-	19:11	19:38		20:52	23:17	
Middleborough	7:46	9:21 →	9:26	10:57	12:52 →	12:57	15:00	16:41 →	16:46	17:36 →	17:41	18:06 →	18:11	18:41	-	19:21	19:48 →	19:53	21:02	23:27 →	23:32
Lakeville			-			-			-		-		-		19:00			-			-
Wareham			9:47			13:18			17:07		18:02		18:32		19:25			20:14			23:53
Buzzards Bay			9:57			13:28			17:17		18:12		18:42		19:35			20:24			0:03
Bourne			*Mon-Fri*			*Mon-Fri*			*Mon-Fri*		*Mon-Fri*		*Mon-Fri*		19:40			*Mon-Thurs*			*Mon-Fri*
Hyannis															20:35						
East Taunton	7:56	9:34		11:07	13:02		15:09	16:52		17:47		18:17		18:52	*Friday Only*	19:32	19:59		21:12	23:37	
Church Street	8:12			11:23			15:26			18:04				19:09			20:16			23:53	
New Bedford	8:17			11:28			15:31			18:09				19:14			20:21			23:58	
Freetown		9:46			13:14			17:04				18:29				19:44			21:24		
Fall River		9:53			13:21			17:11				18:37				19:52			21:31		
Travel Time	*1:42*	*1:29*	*0:31*	*1:28*	*1:25*	*0:31*	*1:27*	*1:28*	*0:31*	*1:29*	*0:31*	*1:27*	*0:31*	*1:29*		*1:27*	*1:29*	*0:31*	*1:26*	*1:28*	*0:31*

Indicates peak hour trains
Indicates extended peak hour trains

Peak Periods Identified per MBTA Schedules Effective May 20, 2019
Based on SCR Phase 1 Final Design Schedules
Train 000 & Train 123 are new proposed New Bedford/Fall River trips

Middleborough / New Bedford
Middleborough / Fall River
Proposed Buzzards Bay
Cape Service Running Monday-Thursday Only
Cape Flyer Service (Running Friday, Saturday, & Sunday)

Blue Indicates L stop (regular stop, but train may leave ahead of schedule)
Red Indicates f stop (train will not stop unless passengers notify conductor they wish to get off or passengers are visible waiting on the platform)
X:XX Indicates a proposed new station stop
x Indicates a proposed removed station stop

Project #14796.04

Cape Rail Study
Alternatives Analysis
DRAFT Proposed Alternative 2 Weekday Schedule
Bourne Connecting to Middleborough/SCR

March 2021

DRAFT - Cape Rail Study

Northbound	BB-100	000	BB-002	002	BB-004	004	BB-006	006	008	BB-010	010	BB-012	012	BB-014	014	BB-102	016	BB-018	018	BB-020	020	022	BB-028	028	Cape Flyer
Fall River				4:51				6:28			7:38				10:51				14:57			17:40			
Freetown				4:59				6:36			7:46				10:58				15:04			17:47			
New Bedford		4:40				5:30			6:46				8:57				12:58				16:12			20:55	
Chruch Street		4:45				5:35			6:51				9:02				13:03				16:17			21:00	
East Taunton		5:00		5:10		5:50		6:47	7:06		7:58		9:17		11:09		13:18		15:15		16:32	17:57		21:15	*Friday Only*
Hyannis	*Mon-Fri*		*Mon-Fri*		*Mon-Fri*		*Mon-Fri*			*Mon-Fri*		*Mon-Fri*		*Mon-Fri*		*Mon-Fri*		*Mon-Fri*		*Mon-Fri*			*Mon-Thurs*		21:00
Bourne	3:56		4:38		5:18		6:15			7:25		8:32		10:36				14:42		15:52			20:42		21:55
Buzzards Bay DPT	4:04		4:46		5:26		6:23			7:33		8:40		10:44		12:37		14:50		16:00			20:50		22:00
Wareham	4:14		4:56		5:36		6:33			7:43		8:50		10:54		12:47		15:00		16:10			21:00		22:10
Lakeville	4:35		-		-		-			-		-		-		13:06		-		-			-		22:30
Middleborough	-	5:12	5:17 →	5:22	5:57 →	6:02	6:54 →	6:59	7:17	8:04 →	8:09	9:11 →	9:28	11:15 →	11:20	-	13:29	15:21 →	15:26	16:31 →	16:47	18:11	21:21 →	21:26	-
Bridgewater	-	-		5:32		6:12		7:09	7:27		8:19		9:38		11:30	13:18	13:39		15:36		16:57	18:20		21:36	-
Campello	-	-		5:40		6:20		7:17	7:36		8:27		9:46		11:38	13:26	13:47		15:44		17:05	18:31		21:44	-
Brockton	4:51	-		5:44		6:24		7:21	7:40		8:31		9:50		11:42	13:30	13:51		15:48		17:10	18:35		21:48	22:46
Montello	-	-		5:47		6:27		7:24	7:43		8:34		9:53		11:45	13:33	13:54		15:51		17:14	18:38		21:51	-
Holbrook/Randolph	-	-		5:52		6:32		7:29	7:48		8:39		9:58		11:50	13:38	13:59		15:56		17:20	18:43		21:56	-
Braintree	5:05	5:40		5:59		6:39		7:36	7:55		8:46		10:05		11:57	13:45	14:06		16:03		17:31	18:55		22:03	22:59
Quincy Center	-	-		-		x		x	x		-		x		12:02	x	x		-		-	-		x	-
JFK/UMass	-	-		6:12		-		7:49	8:08		x		-		-	-	-		-		-	-		-	-
South Station	5:25	6:00		6:19		6:58		7:56	8:15		9:06		10:24		12:17	14:04	14:25		16:24		18:06	19:14		22:22	23:17
Travel Time	*1:29*	*1:20*	*0:39*	*1:28*	*0:39*	*1:28*	*0:39*	*1:28*	*1:29*	*0:39*	*1:28*	*0:39*	*1:27*	*0:39*	*1:26*	*1:27*	*1:27*	*0:39*	*1:27*	*0:39*	*1:54*	*1:34*	*0:39*	*1:27*	

Southbound	003	005	BB-005	007	BB-101	009	BB-009	015	017	BB-017	019	BB-019	021	BB-021	023	Cape Flyer	123	BB-123	025	027	029	BB-029	BB-103
South Station	6:35	8:24		10:00	10:40	11:56		14:04	15:43		16:40		17:10		17:45	18:10	18:25		18:52	20:05	22:30		23:55
JFK/UMass	6:41	-		10:06	10:46	-		-	15:49		-		-		x	-	-		-	20:11	-		0:01
Quincy Center	x	-		x	x	x		x	x		x		x		x	-	-		x	x	22:43		x
Braintree	6:55	8:45		10:20	11:00	12:15		14:23	16:03		16:59		17:29		18:04	18:30	18:44		19:11	20:25	22:50		0:15
Holbrook/Randolph	7:03	8:51		10:27	11:08	12:22		14:30	16:10		17:06		17:36		18:11	-	18:51		19:18	20:32	22:57		0:22
Montello	7:08	8:56		10:32	11:13	12:27		14:35	16:15		17:11		17:41		18:16	-	18:56		19:23	20:37	23:02		0:27
Brockton	7:12	8:59		10:35	11:17	12:30		14:38	16:18		17:14		17:44		18:19	18:43	18:59		19:26	20:40	23:05		0:30
Campello	7:22	9:03		10:39	11:27	12:34		14:42	16:22		17:18		17:48		18:23	-	19:03		19:30	20:44	23:09		0:34
Bridgewater	7:36	9:11		10:47	11:41	12:42		14:50	16:30		17:26		17:56		18:31	-	19:11		19:38	20:52	23:17		0:42
Middleborough	7:46	9:21 →	9:26	10:57	-	12:52 →	13:09	15:00	16:41 →	16:46	17:36 →	17:41	18:06 →	18:11	18:41	-	19:21 →	19:26	19:48	21:02	23:27 →	23:32	
Lakeville			-		11:51		-			-		-		-		19:00		-				-	0:52
Wareham			9:47		12:12		13:30			17:07		18:02		18:32		19:25		19:47				23:53	1:13
Buzzards Bay AR			9:57		12:22		13:40			17:17		18:12		18:42		19:35		19:57				0:03	1:23
Buzzards Bay DPT			10:00				13:43			17:20		18:15		18:45		-		20:00				0:06	1:26
Bourne			10:05				13:48			17:25		18:20		18:50		19:40		20:05				0:11	1:31
Hyannis			*Mon-Fri*		*Mon-Fri*		*Mon-Fri*			*Mon-Fri*		*Mon-Fri*		*Mon-Fri*		20:35		*Mon-Thurs*				*Mon-Fri*	*Mon-Fri*
East Taunton	7:56	9:34		11:07		13:02		15:09	16:52		17:47		18:17		18:52	*Friday Only*	19:32		19:59	21:12	23:37		
Church Street	8:12			11:23				15:26			18:04				19:09				20:16		23:53		
New Bedford	8:17			11:28				15:31			18:09				19:14				20:21		23:58		
Freetown		9:46				13:14			17:04				18:29				19:44			21:24			
Fall River		9:53				13:21			17:11				18:37				19:52			21:31			
Travel Time	*1:42*	*1:29*	*0:39*	*1:28*	*1:42*	*1:25*	*0:39*	*1:27*	*1:28*	*0:39*	*1:29*	*0:39*	*1:27*	*0:39*	*1:29*		*1:27*	*0:39*	*1:29*	*1:26*	*1:28*	*0:39*	*1:36*

Indicates peak hour trains

Indicates extended peak hour trains

Peak Periods Identified per MBTA Schedules Effective May 20, 2019

Based on SCR Phase 1 Final Design Schedules

Train 000 & Train 123 are new proposed New Bedford/Fall River trips

Middleborough / New Bedford

Middleborough / Fall River

Proposed Bourne

New Alternative 2 Proposed Cape Service

Cape Service Running Monday-Thursday Only

Cape Flyer Service (Running Friday, Saturday, & Sunday)

Blue Indicates L stop (regular stop, but train may leave ahead of schedule)

Red Indicates f stop (train will not stop unless passengers notify conductor they wish to get off or passengers are visible waiting on the platform)

X:XX Indicates a proposed new station stop

x Indicates a proposed removed station stop