MBTA Rail Vision

FEBRUARY 2020

FINAL REPORT

Acknowledgements

The preparation of this report has been funded in part through grant[s] from the Federal Highway Administration, U.S. Department of Transportation, under the State Planning and Research Program, Section 505 of Title 23, U.S. Code. The contents of this report do not necessarily reflect the official view or policies of the Massachusetts Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Contents

Tables

Figures


1616
EMERGENCY ENTRY
1616

1 Introduction

Rail Vision will leverage the MBTA's extensive rail network to best meet the transportation and economic growth needs of the region.

Rail Vision is a study to evaluate how the Massachusetts Bay Transportation Authority (MBTA) could leverage its nearly 400-mile Commuter Rail network to meet shifting mobility needs and support both continued economic growth and the Commonwealth's equity and sustainability goals. The study examines what kind of system will best serve the region's riders in the future and what types of investments are needed to support that Vision.

The MBTA is responsible for managing the sixth busiest Commuter Rail system in the U.S., encompassing **388 miles** across **14 rail lines** carrying **over 125,000 passenger trips each weekday**. The system serves Greater Boston, an area facing profound economic growth. As a result, the population has rapidly increased, straining the region's transportation networks and housing availability. Traffic congestion is worsening and regional stakeholders increasingly advocate for improved alternatives, such as a more robust Commuter Rail system.

By 2040, even without service or infrastructure changes, population and employment growth will result in a projected Commuter Rail ridership increase of 24,000 trips, to a total of **150,000 trips per weekday**.

To respond to these challenges, the Rail Vision study sought to investigate several questions:

- Can a transformed rail service ease congestion by attracting drivers during peak periods?
- Will higher frequency service to areas beyond the region's rapid transit network open up new housing opportunities for Boston's workers, easing the pressure on the inner core?
- What will it take in terms of capital investment and operating costs to provide dramatically different service?
- How many more riders would different service patterns attract?

The Rail Vision study evaluated different ways of providing service (increasing frequency, reducing travel time, improving connectivity) and infrastructure improvements (e.g., accessible platforms, electrification, multiple-unit vehicles) to help answer these fundamental questions. The scope of Rail Vision included:

- Analysis of future market trends in the region over the next 25 years;
- Comparison of the existing MBTA system to other U.S. and international peer systems;
- Development of a set of goals and objectives for the 2040 Rail Vision;
- Identification, analysis, and modeling of a number of potential service alternatives;
- Development of ridership and operating costs;
- Identification of capital investments (such as different fleet technologies) needed for each service alternative; and
- Development of final findings and implementation considerations.

Overall Approach to the Study

Establish Study Objectives

Any rail system must balance its service design and delivery model with the needs of different markets. For example, while longer distance passengers may desire limited-stop or non-stop service, intermediate communities require local service. At the outset of the project, the Rail Vision team sought feedback to understand if the purpose of the rail system should be to:

- Reduce highway congestion, auto emissions, and vehicle miles traveled (VMT) by focusing on long-distance trips?
- Provide service in the inner core that operates more like rapid transit?
- Enable access to Boston's employment pool for job clusters beyond the inner core by focusing on reverse commutes?
- Support economic development in the Gateway Cities and other urban areas outside of the inner core by focusing schedules and service on the needs of those communities?

These questions were posed to the MBTA's Fiscal and Management Control Board (FMCB), a Steering Committee of internal stakeholders from the MBTA and the Massachusetts Department of Transportation (MassDOT), and the Rail Vision Advisory Committee comprising regional stakeholders at the outset of the effort. Input received by these groups and the public informed the study objectives:

1. Match service with growth & changing needs of the region
2. Enhance economic vitality
3. Improve passenger experience
4. Provide an equitable and balanced suite of investments
5. Achieve climate change and sustainability targets
6. Maximize return on investments

To evaluate opportunities to meet these objectives, stakeholders identified three primary features to test in Rail Vision:

1. Reduced passenger travel time;
2. Increased frequency in train service; and
3. Improved connectivity throughout the region.

Stakeholder Engagement

Rail Vision aimed to successfully involve stakeholders representing the range of interests across the region, including current and potential future riders. Figure 1-1 provides an overview of the strategy employed, and Appendix A describes it in more detail.

The initial step identified a broad group of stakeholders with an interest in the Rail Vision effort, and identified goals and objectives. The intent of the Systemwide Alternative stakeholder feedback, which consisted of the second and third phases of the stakeholder engagement, was to solicit ideas for new approaches to service delivery, and then to facilitate a discussion around the benefits and trade-offs of these various service options.

Key stakeholders were invited to serve on the **Rail Vision Advisory Committee**. The role of the Advisory Committee was to provide informed advice to MBTA leadership and the project team. The members represented diverse perspectives from across the MBTA service area. Members included elected officials, the business community, and local transportation and planning agencies. The Advisory Committee met seven times at key milestones throughout the study, with the first meeting held on June 28, 2018, and the final one held on October 18, 2019. These meetings were supplemented by a series of optional meetings that provided further details on the tools and methods employed in conducting the evaluation of the different concepts and alternatives.

In addition to the Advisory Committee, **Rail Vision outreach included several different opportunities** for members of the public to share their ideas and pose questions to the team. These opportunities and events included:

- A **non-rider survey** elicited ideas from non-riders about the service features they would seek in a reimagined system. Nearly 3,000 non-riders responded to the survey;
- **Street team** distribution of a project post card at North Station and South Station on February 27-28, 2019 encouraged attendance at the first project open house and sign-ups for the project website to receive future information;

Figure 1-1 Stakeholder Engagement Process

PHASE 1: NEEDS & OPPORTUNITY	PHASE 2: SERVICE ALTERNATIVES	PHASE 3: THE VISION
Outcome: Understand the market potential; define goals and objectives	**Outcome:** Identify and evaluate performance of potential service alternatives	**Outcome:** Define and adopt the vision; develop a plan to move it forward
Tactics:	**Tactics:**	**Tactics:**
Steering Committee (MBTA and MassDOT)	FMCB Presentation and Feedback	FMCB Presentation and Discussion
Stakeholder Interviews	Stakeholder Briefings	Stakeholder Briefings
Form Advisory Committee	Advisory Committee Discussions: "Tradeoffs"	Advisory Committee Discussions: "Recommendations"
Online Survey Priorities: "Non-Rider Survey"	Open House	Public Meeting and Open House

- An **open house,** conducted on March 5, 2019, had 100 attendees and 19 comment forms submitted;
- A **public meeting and open house,** hosted on October 23, 2019, had 81 attendees and nine comment forms;
- **E-blasts** to a database of 1,492 recipients (as of November 2019) announced Advisory Committee and public meetings, the addition of new information or documents to the website, or other major events;
- A total of 45 **briefings and meetings** with communities, organizations, advocacy groups, elected officials, transportation advocates, and regional planning agencies;
- Three **legislative briefings** at the State House (on February 28, 2019, November 1, 2019, and November 7, 2019); and,
- The **MBTA FMCB** was also consulted throughout the Rail Vision effort. Presentations were made at several FMCB regular meetings, which provided an additional opportunity for public comment.

Figure 1-2 highlights the geographic spread of the stakeholder engagement efforts throughout the MBTA service area.

Figure 1-2 Locations of Stakeholder Events, including Advisory Committee and Public Meetings and Stakeholder and Community Briefings

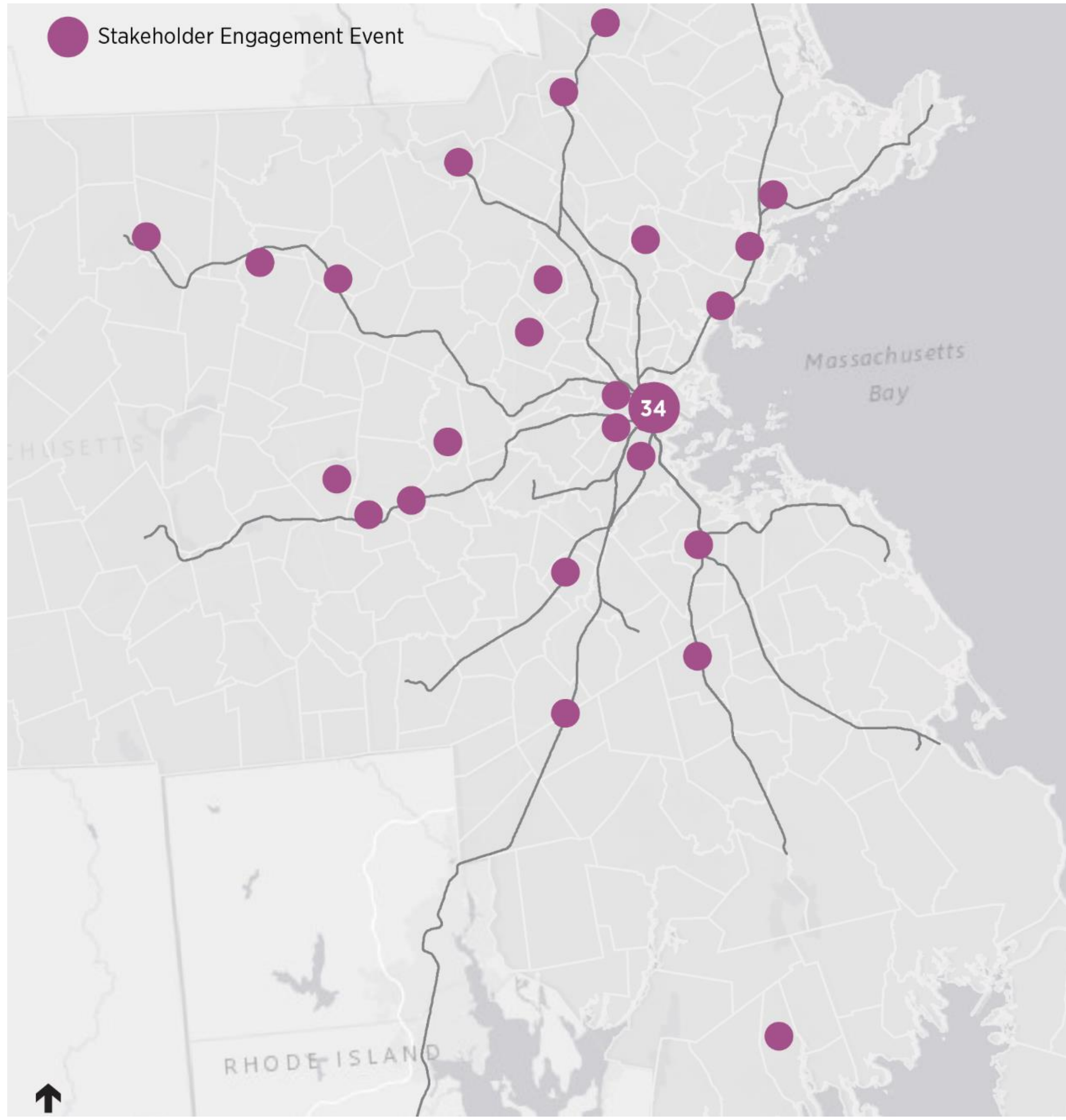
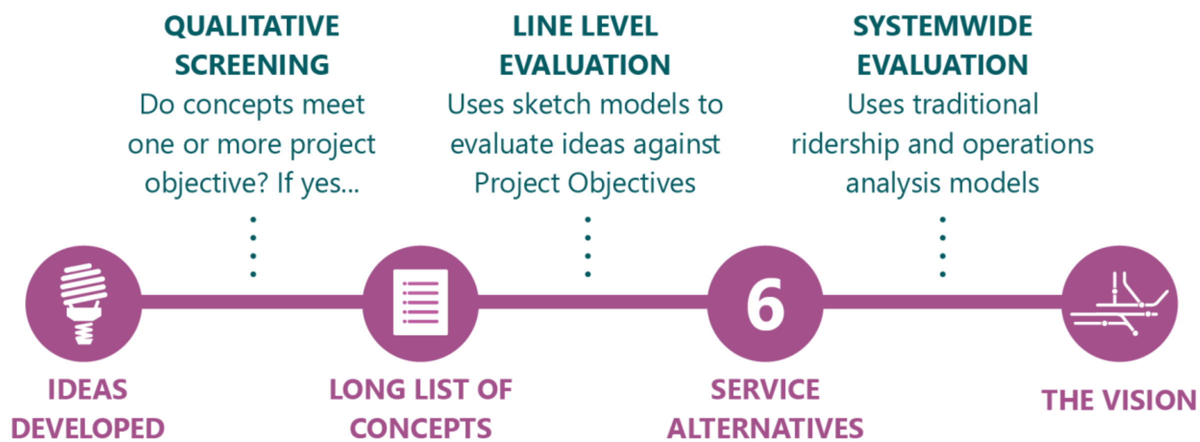


Figure 1-3 Rail Vision Evaluation Approach



Evaluate and Gather Feedback on Service Alternatives

A multi-tiered evaluation approach drove the Rail Vision process (Figure 1-3). The first step included a **Qualitative Screening**, performed on a long list of ideas, which asked whether the idea could provide value or benefit to the MBTA system. All ideas that passed the qualitative screen moved on to the Line Level Evaluation.

The **Line Level Evaluation** tested how individual service concepts would perform on a line-by-line basis in relation to a number of criteria, using sketch-level operational analysis, ridership modeling, and cost tools, identifying any major infrastructure or operational challenges. In all, the Line Level Evaluation tested over 60 concepts. Based on the Line Level results, and with input from the Advisory Committee and the public, the concepts with the most benefits shaped the systemwide alternatives evaluated in the final step.

The **Systemwide Evaluation** tested six alternatives featuring a variety of service parameters and components (Figure 1-4), including:

- *Service Focus*
  The evaluation grouped stations into three different categories: Key, Inner Core, and Outer. Key stations are located in dense urban areas outside the inner core and areas important for regional connectivity (highway access points and employment hubs); Inner Core stations are located within the contiguous urban areas surrounding downtown Boston; and Outer Stations are located in lower-density areas outside the inner core. The different alternatives tested varying levels of train frequency to each of these groups of stations.
- *Electrification*
  Currently, the MBTA operates Commuter Rail entirely with diesel-locomotive hauled trains. The alternatives tested a range of options, from electric service on the Providence Line where Amtrak already operates electric trains to electrifying the entire system.
- *Additional Services*
  The alternatives tested three additional services for the Commuter Rail network in different combinations. These were limited to the MBTA service area and included South Coast Rail (both Phase 1 and the Full Build), Foxboro, and Grand Junction. Rail Vision's scope was limited to the existing and committed MBTA Commuter Rail network – that is, the existing rail lines (including South Coast Rail) in terms of geographic coverage – and excludes potential changes to other modes (e.g., the MBTA rapid transit network).

Figure 1-4 Systemwide Service Components

Six commuter rail systemwide alternatives were developed based on the results of the Line Level analysis. The alternatives tested different components systemwide.

SERVICE FOCUS
Key Stations
Inner Core
Outer Stations

FREQUENCY
Peak/Off-Peak Frequency
15 / 30 / 60 Minutes

FARES
Existing Fare Structure
Reduced Urban Rail Fares
Distance-Based Fares

ELECTRIFICATION
Full
Partial
None

STATION ACCESSIBILITY
High Level Platforms
Mini-High Level Platforms
Low Level Platforms

PARKING CAPACITY
Existing Parking Capacity
Unlimited Parking at Select Stations
Unlimited Parking at Most Stations

ADDITIONAL SERVICES
South Coast Rail Phase 1/Full Build
Grand Junction
Foxboro

ROLLING STOCK
Electric / Diesel
Locomotives + Coaches / MUs

TERMINAL CAPACITY
Existing
South Station Expansion
North-South Rail Link

- *Frequency*
  The frequency of trains ranged from every 15 minutes to every 60 minutes to different groups of stations over peak and off-peak hours. The analysis assumed that in each alternative, trains would operate at the same frequency in both the inbound and outbound directions, and on memory-pattern, or clockface schedules, where trains arrive and depart from stations at the same time every hour.
- *Station Accessibility*
  The Commuter Rail system has a mix of passenger platforms at stations, from low-level platforms that require passengers to climb steps into the body of the train, to high-level platforms that provide level-boarding between the station and the train. The analysis assumed a range of investments in high-level platforms for Key, Inner Core, and Outer stations by alternative.
- *Rolling Stock*
  The MBTA operates the entire Commuter Rail network with diesel locomotive-hauled, push-pull trains with single-level and bi-level passenger cars. The different alternatives tested the introduction of diesel-multiple unit (DMU) trains, electric-multiple unit (EMU) trains, and electric locomotive-hauled push-pull trains.
- *Fares*
  The analysis tested three types of fare policies. Most alternatives assumed the existing fare levels. One alternative evaluated a potential fare policy where inner core fares better aligned with MBTA rapid transit fares. This tested whether ridership would respond differently to a service that both operated and was priced more like rapid transit. One alternative assumed a combination of this inner core fare with distance-based fares, which provided a fare structure for through-travel with the North South Rail Link.
- *Parking Capacity*
  As park-and-ride availability drives ridership at many outer/suburban stations, the analysis tested the ridership impacts of limiting parking to current supply (constraining) or assuming unlimited parking capacity (unconstraining) at different groups of stations. Unconstraining parking ensures the ridership results are not capped based on parking availability, demonstrating the potential demand for the service.
- *Terminal Capacity*
  The alternatives included different terminal investments at North and South Stations, ranging from modest investments to South Station Expansion or North-South Rail Link.

The Rail Vision analysis presents a high-level view of how the service could operate in a dramatically transformed Commuter Rail system. The results focus on the potential ridership response and major infrastructure needs associated with such changes to support the evaluation of direction and next steps. The evaluation does not include a detailed analysis of non-revenue needs and other features that would require attention in a next phase of planning. Those features include:

- *Vehicle Maintenance and Layover Locations*
  Each of the Systemwide Alternatives included an expansion of the MBTA Commuter Rail fleet. With additional rolling stock, the MBTA would need additional layover tracks and maintenance capacity. The Rail Vision analysis did not determine where these facilities should be located or whether existing facilities would be expanded or new ones established.
- *Non-Revenue Moves*
  As the Rail Vision analysis did not address the locations of layover and maintenance facilities, the operations analysis did not include when equipment would be scheduled to move between terminal stations and these facilities. Such moves can impact overall track capacity and would require further study when the MBTA evaluates the future locations of layover and maintenance facilities.

- *Fleet Technology Specifications*
  While the evaluation contemplated different fleet types, such as diesel locomotive hauled trains, DMUs, and EMUs, Rail Vision does not establish any design specifications. It also does not recommend any specific vehicle type or manufacturer.
- *Parking*
  While the analysis tested the impact on ridership of whether parking is limited to its existing capacity or not, it did not quantify the amount of parking that could be needed in the future or how it could be provided at specific locations.
- *Fares*
  While the analysis evaluated a variation of the current Commuter Rail fare structure to evaluate the impact on ridership if the proposed Urban Rail services offered a fare structure in line with the MBTA rapid transit fares, Rail Vision does not recommend a future fare structure. As such, a recommendation would require a more thorough analysis. The MBTA concurrently conducted a separate study on potential changes to its fare structure.

A comparative analysis then assessed each alternative against the Rail Vision objectives to understand how different features of the systemwide service alternatives would perform in relation to several key performance metrics, including ridership, mode share, travel time and service frequency, access to jobs, capital needs, costs, and greenhouse gas emissions. Towards the end of the evaluation, the Advisory Committee and other stakeholders provided feedback on the results and input on the priority features the MBTA and MassDOT should pursue.

Identify Implementation Opportunities and Challenges

Rail Vision presents an opportunity to make improvements to the MBTA Commuter Rail system that serve a broader range of riders for a wider variety of trip purposes than the current suburb to central Boston work commute. Translating Rail Vision into an implementable delivery plan would require clearly defining the expected customer experience, service levels, and integration with the rest of the MBTA network and other first/last mile solutions. This effort would need to chart a phased approach to making infrastructure and service improvements based on demand, density, and physical constraints. Ahead of pursuing any improvements, the MBTA and the Commonwealth would need to identify funding and financing to support this undertaking.

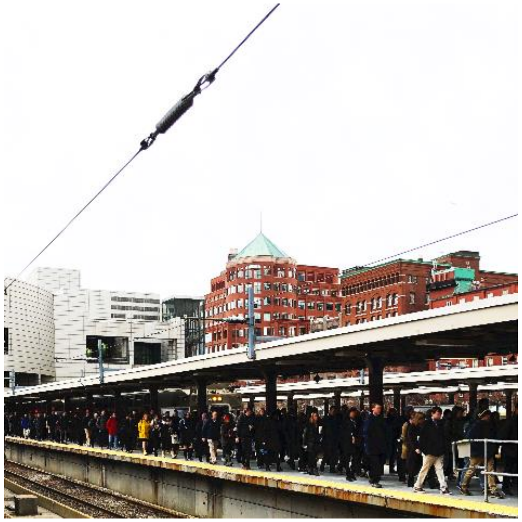
Challenges to this implementation would include governance, financing and funding, planning and programming, project phasing, and procurement of capital construction as well as operations and maintenance services. The MBTA could meet these challenges using a variety of procurement models to deliver improvements to the Commuter Rail system.

REPORT CONTENTS

The remainder of this report summarizes the analysis conducted and the findings of the study, as well as provides a description of the considerations necessary for the implementation of transforming the commuter rail system. The report includes the following:

2 The Problem Statement

The Greater Boston region's population and economy continue to grow, contributing to the further worsening of the region's vehicular traffic congestion. It is likely not feasible, from an environmental or demand perspective, to addressing congestion solely through roadway capacity. The MBTA Commuter Rail provides a viable travel option, although peak trains are already at or near capacity. By 2040, population and employment growth is projected to increase Commuter Rail ridership from 125,000 to 150,000 trips per day. The current system would be challenged to handle this increase, let alone the increase needed to relieve the congestion on other modes.



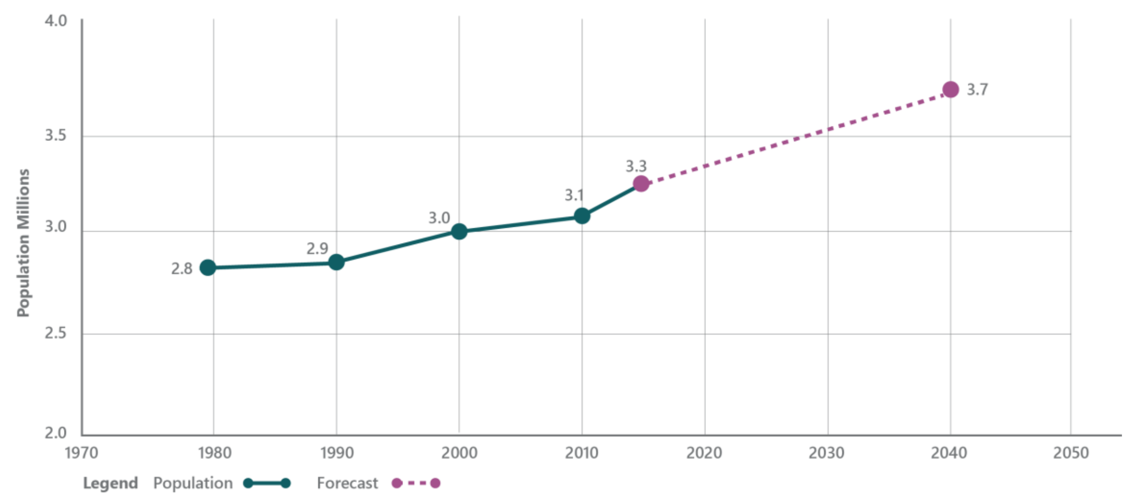
This chapter describes the current context of this challenge. It then identifies the case for improving the rail system and outlines expected benefits for doing so, including through international case studies. Finally, this chapter explains how Rail Vision considers improvements to the rail network in the context of other recent or ongoing Massachusetts transportation initiatives.

Context

Meeting the mobility requirements of a booming economy and a growing population is one of the main challenges in the Greater Boston region. Between 1980 and 2016, population grew 15%, from 2.8 to 3.3 million residents. The Boston Region Metropolitan Planning Organization (MPO) expects growth to continue, with a projected 2040 population of around 3.7 million (Figure 2-1).[1]

Between 2016 and 2040, the MPO expects an 8% increase in jobs and a 21% increase in the number of households (Table 2-1)**.** Such growth will have a direct effect on mobility needs in the region. The challenge consists of accommodating growth and changes in demographic characteristics in an efficient way.

Figure 2-1 Greater Boston Population 1980 – 2040 (Forecasted)



Source: Long-Range Transportation Plan of the Boston Region Metropolitan Planning Organization, 2019.

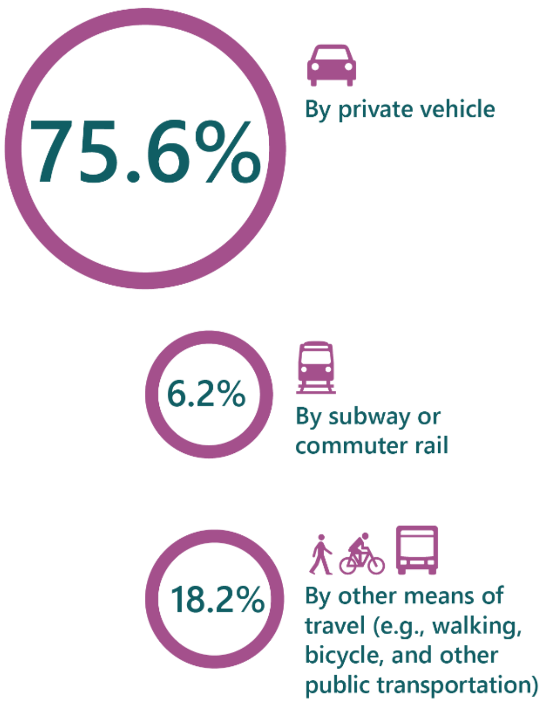
Table 2-1 Greater Boston Region Socioeconomic Variables in 2016 and 2040.

Socioeconomic Variables	2016	2040	Percent Change
Population	3,245,900	3,705,500	14%
Households	1,312,000	1,582,600	21%
Household Size	2.5	2.2	-12%
Total Employment	1,923,600	2,084,700	8%

Source: Long-Range Transportation Plan of the Boston Region Metropolitan Planning Organization, 2019. https://www.ctps.org/data/pdf/plans/LRTP/destination/Destination-2040-LRTP.pdf

1 Long-Range Transportation Plan of the Boston Region Metropolitan Planning Organization, 2019. https://www.ctps.org/data/pdf/plans/LRTP/destination/Destination-2040-LRTP.pdf

Figure 2-2 Most Common Commute Modes in the MA-NH Region in 2013



Source: U.S. Census Bureau: Who Drives to Work? Commuting by Automobile in the United States: in 2013 (2015). https://www.census.gov/content/dam/Census/library/publications/2015/acs/acs-32.pdf

The latest U.S. Census Bureau report on commuting reveals 75.6% of commuters in the metropolitan statistical areas covering Eastern Massachusetts and southern New Hampshire use private vehicles and only 6.2% use subway or commuter rail (Figure 2-2). In the core, the percentage is much higher at around 33%, demonstrating that transit can be a more viable option in denser parts of the region.

Commuting patterns in the region are changing, with a 3.3% reduction in automobile commuting between 2006 and 2013 (second highest in the country). This reduction shows that commuter patterns in Greater Boston are following the trends of regions like San Francisco or New York. In these regions, 69.8% and 56.9% of workers drive to work while 7.6% and 18.9% use public transportation, respectively.

The INRIX Research 2018 Global Traffic Scorecard[2] found that **Boston drivers spend an average of 164 hours and lose $2,291 annually due to traffic.** The highest values assessed domestically that year (Table 2-2), Boston results nearly double national averages of 97 hours and $1,348 lost annually per driver. Defining strategies to give this time back to people could yield real benefits to the region's economic and social well-being.

Table 2-2 Five Most Congested Cities in the U.S., 2018.

City	2018 Global Impact Rank (2017)	Hours Lost in Congestion	Cost of Congestion per Driver	Inner City Travel Time (minutes)	Inner City Last Mile Speed (mph)
Boston	**8 (7)**	**164**	**$2,291**	**6**	**11**
Washington	19 (20)	155	$2,161	5	11
Chicago	23 (24)	138	$1,920	5	12
New York City	40 (43)	133	$1,859	7	9
Los Angeles	47 (48)	128	$1,788	4	14

Source: INRIX Research: Global Traffic Scorecard, 2019.

2 INRIX Research: Global Traffic Scorecard. http://inrix.com/scorecard-city/?city=Boston%2C%20MA&index=8

The *Congestion in the Commonwealth: Report to the Governor 2019* provides ten recommendations to address the traffic congestion challenge. Among them, the most relevant ones for the Commuter Rail are:

- Increase MBTA capacity and ridership;
- Work with employers to give commuters more options;
- Produce more affordable housing, especially near transit; and,
- Encourage growth in less congested Gateway Cities.

Congestion across the Commonwealth is an externality of the economy's positive performance. Economic productivity results in increases in population and roadway use – in a growing economy, more people move to an area and people seek more opportunity and travel more. As demand approaches the capacity of the road network, it reduces the reliability of travel times. People need to set aside more time for trips due to uncertainty of traffic conditions. Beyond travel time, traffic has significant economic, health, and equity impacts (Figure 2-3). Unfortunately, economic growth trends suggest that the situation will worsen.

Congestion has a negative impact on accessibility and connectivity. It affects residents' ability to get to jobs, destinations, and opportunities due to excessive travel times.

Figure 2-3 Socioeconomic and Environmental Impacts of Congestion

Congestion affects the job market as people can less easily access Boston's main employment centers. People's willingness to travel for jobs is subjective: it depends on many factors, which may include the perceived benefits to the employee, the compensation (financial and social), and the cost of doing the job (including the travel time). Congestion constrains economic and labor market growth by limiting the distribution of resources across the region. High travel time costs can deter people from taking better paying jobs, and companies can see lower productivity by not drawing from a wider pool of talent.

Congestion also raises important concerns about equity and social justice. Pollution can have negative effects on human health and contribute to climate change and global warming. It is exacerbated by idle engines in congested roadways. While the rise of electric vehicles may offset some of the worst environmental effects, it does not necessarily address the effects of congestion. Electric vehicles also do not reduce the negative impacts of road traffic, such as traffic crashes and less efficient use of land for traffic lanes, parking, gas stations, etc.

Expanding roadway capacity does not solve congestion. Population and motorization growth rates indicate that if past trends hold, demand will eventually approach capacity for infrastructure services. Other modes, including public transportation, provide a more efficient alternative than automobiles for moving large numbers of people into and out of important regional centers like employment hubs.

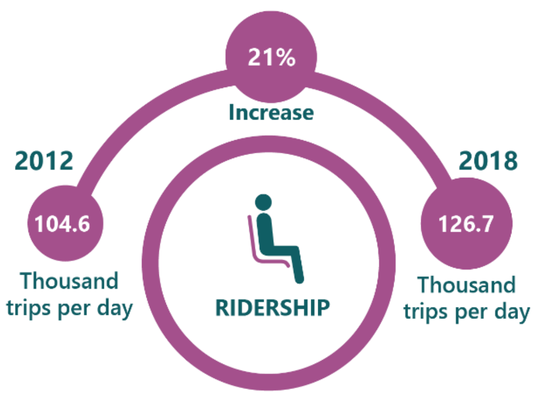
Current State

The MBTA manages one of the largest Commuter Rail networks in the nation, with 14 lines serving over 80 communities. With almost 400 miles of track, 141 stations, and multiple connections with the rapid transit network, the Commuter Rail reaches most of the region's population centers and employment hubs (Figure 2-4). The system has two major terminals providing access to downtown Boston: North Station serving the cities and towns north of the city and South Station serving those to the south.

Figure 2-4 Existing MBTA Commuter Rail System

In terms of ridership, Boston's Commuter Rail stands sixth in the nation behind the systems serving New York City, Chicago, and Philadelphia. The system transported over 32 million passengers in 2018.[3] **Ridership grew from 104,600 to 126,750 trips per day (a 21% increase) between 2012 and 2018** (Figure 2-5). In the same period, ridership on the south side increased 28%, from 65,850 trips to 84,450 trips, while ridership on the north side increased 9%, from 38,750 trips to 42,300 trips.[4]

Figure 2-5 MBTA Commuter Rail Ridership



Source: MassDOT, Commuter Rail Ridership Counts, 2019.

Today's Commuter Rail system provides largely local service geared towards serving work trips into downtown Boston. Some longer lines also have express services that do not make all stops. Table 2-3 details current operating conditions.

Table 2-3 Current MBTA Commuter Rail Operating Conditions

What Exists Today...or in the Near Future	
Typical Frequency	30-75 minutes peak direction
Electrification	None (even on Amtrak line to Providence)
Rolling Stock	Diesel locomotives & mix of single & bi-level passenger coaches
Terminals	Existing (North Station, South Station), with planned North Station capacity upgrades
Additional Services	South Coast Rail Phase 1
Committed New or Upgraded Stations	Pawtucket South Coast Rail Phase 1 stations Other station upgrades
Station Accessibility	Mixed

The Commuter Rail faces important operating challenges:

- Track sharing with Amtrak and freight lines results in a suboptimal use of capacity;
- A fully diesel service leads to longer travel times and local air quality issues; and,
- Largely single tracked lines (e.g., Needham, Middleborough, Plymouth/Kingston, and Greenbush) are less resilient to disruptions. As a result, it is difficult to design optimal schedules that increase frequencies in both directions without further reliability issues.

Despite these challenges, the MBTA Commuter Rail is an underused asset with high potential for improvement. Services are only at or near capacity during the peak and parts of the network have potential to handle additional services with minimal infrastructure investment. Off-peak services are generally lightly used, potentially due to the inflexibility for riders associated with low levels of frequency during these time periods. A well-designed schedule could improve riders' perception and attract commuters currently using personal vehicles by providing better options to meet their needs.

3 National Transit Database, MBTA 2018 Annual Agency Profile.

4 MassDOT. Commuter rail Ridership Counts. 2019 https://cdn.mbta.com/sites/default/files/fmcb-meeting-docs/2019/01-january/2019-01-28-fmcb-commuter-rail-ridership-original.pdf

Case for Change – The Opportunity

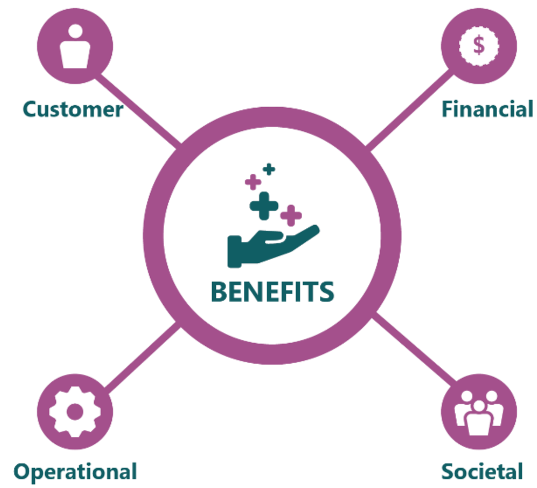
Rail Vision provides a unique opportunity to explore how Commuter Rail could transform regional mobility. Better connectivity would enable economic growth while advancing social and environmental goals. By providing an alternative to roadways, the Commuter Rail has the potential to unlock important benefits that could cascade throughout Greater Boston.

Designing a Vision for the Commuter Rail must consider a number of critical factors. Broadly, they fit into four categories (Figure 2-6):

1. Improved customer experience
2. Better return on investment
3. Social and economic benefits
4. Operational improvements

Several case studies describe how other systems have approached a rail transformation and considered these factors.

Figure 2-6 Categories of Expected Benefits from the MBTA Rail Vision



Improved Customer Experience

Passengers find Commuter Rail attractive for three main reasons:

1. It can be quicker than driving during peak hours;
2. It can be cheaper than parking in downtown cores; and,
3. Passengers do not need to concentrate on driving, making better use their travel time.

Employees with free parking or for whom Commuter Rail does not significantly reduce commute time are less likely to choose this mode. While the MBTA cannot affect the

provision of employee parking, it can seek to improve the other two factors to attract riders.

Passengers are likely to consider the following critical success factors:

- Mobility – The door-to-door travel time is faster and/or more reliable than driving when considering traffic and service frequency;
- Financial – The door-to-door journey costs less than driving and parking at the final destination; and,
- Comfort – The system is easy to access and navigate (ticketing, information, etc.), and the service is clean and not overcrowded.

Better Return on Investment

Taxpayers of the Commonwealth want to see balanced improvements that are fundable, financially responsible, and provide a high quality of service. Any changes would need to balance the needs of Commuter Rail passengers with the needs of residents (including those who continue to drive or are not regular commuters). Important factors to consider include:

- Operations – The per passenger subsidy required to operate the service; and,
- Capital – Funding to deliver improvements must be available, help reduce longer-term subsidies, and not detract from other state priorities.

Social and Economic Benefits

Along with financial imperatives, the MBTA and MassDOT will also want to demonstrate that any changes would improve wider societal outcomes. These considerations include the following:

- Environmental – Reduced emissions and modal change;
- Economic – Unlocked economic growth and access to new jobs through reduced travel times and better connections to existing housing and jobs markets; and,
- Societal – Improved access to employment to reduce income inequality, improved environmental justice, and unlocked potential for provision of additional affordable homes.

Operational Improvements

Lastly, the MBTA and MassDOT would want to ensure that any changes are feasible and are not overly risky. These considerations include the following:

- Deliverability – The market can build and deliver the future state within a reasonable timeline. This would include infrastructure improvements and procurement of rolling stock under Buy America constraints. Buy America regulations require that agencies must use steel, iron, and manufactured goods produced domestically to receive federal funding for a project (e.g., rolling stock procurement).
- Effectiveness – The investment plan minimizes lifecycle costs over the longer-term. This could include ensuring that upfront capital investment would minimize longer-term operating subsidies without increasing risk.
- Opportunity costs – The Commuter Rail currently stands as an underused asset with the potential to redefine mobility in the region. It could efficiently integrate Boston and Gateway Cities in a way that promotes economic growth. These potential benefits may make investing in Commuter Rail a more effective way to solve regional problems compared to investing in roadways.

Case Study: Toronto GO Transit

Toronto's Metrolinx commuter rail system is one of the largest networks in North America. While it has grown significantly from an initial reintroduction in 1967, it primarily operates services during peak periods, with buses providing some service to communities without rail services in off-peak periods or on weekends.

Metrolinx developed plans to transform the rail network as part of a more ambitious strategy to embrace smart growth in the region. As Metrolinx developed the case for investment, a cohesive strategy started to emerge including the following improvements, which Metrolinx projects would triple ridership to nearly 600,000 daily trips by 2031:

- Provide all day (including weekends), high frequency services across the Greater Toronto and Hamilton Area (GTHA) megaregion to enable people to get around the region at any time without needing to use automobiles – in 2008, only the Lakeshore Line provided all day service;
- Electrify most, if not all, of seven rail corridors to improve reliability, reduce journey times, and enhance air quality;
- Introduce a new fleet of trains, including the planned introduction of higher-performance multiple units, which can further reduce journey times;
- Convert station platforms to allow level boarding to speed up station dwell times as well as improve accessibility; and
- Develop interchange hubs at GO Transit stations to better integrate with local bus and rapid transit services.

An important element in delivering the plans was identification of incremental pilot projects, or quick wins, that could be implemented without significant investment. This allowed Metrolinx to test the viability of some of its proposals, in particular the value of all-day services, using existing equipment and infrastructure. Importantly, it also provided GTHA people and businesses with early benefits of the long-term plan and confidence that Metrolinx could deliver against its promises.

TORONTO GO TRANSIT

All Day (including weekends), high frequency services;

Electrify seven rail corridors to improve reliability, reduce journey times and enhance air quality;

Introduce a new fleet of trains which can further reduce journey times;

Convert station platforms to allow level boarding to:
- speed up station dwell times
- improve accessibility

Develop interchange hubs to better integrate with local bus and rapid transit services

Metrolinx considered a number of different delivery approaches to best implement its plans. The delivery approach combines public authority led Design-Build contracts with North America's largest public-private partnership (P3) procurement (valued at over $10 billion USD) to design, build, fund, operate, and maintain the new trains, electrify and upgrade tracks, rebuild stations, and operate rail services for 35 years.

Importantly, the successful P3 contractor will finance much of the upfront investment with Metrolinx providing payments against a series of strict performance related targets such as delivery of works, reliability of passenger rail services, and customer satisfaction related factors. The rebuilding of Toronto's downtown Union Station is already underway using a Design-Build approach.

When completed in the late 2020s, the GO Expansion program will transform the existing GO Rail network into a world class rail system. It is part of over $60 billion USD over the next ten years in ongoing provincial investment in public transit that includes rapid transit, light rail, and bus projects. Upon delivery, the GO Expansion program will transform GO Rail from a commuter focused rail system to the backbone of the GTHA's Frequent Rapid Transit Network. Investing in GO Transit will enable seamless travel across the GTHA megaregion (not just to downtown) while making it a more competitive place to invest and do business, increasing productivity and opening up new sites for additional housing.

Trains operating through downtown Toronto.

Case Study: London Overground

Before 2007, London's Silverlink Metro services operated an orbital network of four lines connecting non-central locations and saw little investment for over 30 years. Services were infrequent, unreliable, and offered poor customer experience. Directed by London's Mayor, Transport for London (TfL) negotiated transfer from UK Government (DfT) and rebranded the service as the London Overground. Underlying the change was a vision to:

- Improve service quality
- Increase service frequency
- Upgrade infrastructure
- Expand rail network coverage

TfL developed a plan to transform orbital rail services and implement a comprehensive set of changes including:

- All-day service every 15 minutes to most stations;
- A new fleet of trains that offered more capacity, quicker boarding, and improved reliability;
- Modernization of every station with new waiting rooms, lighting, real-time information (and step-free access at 20 stations);
- Improvements to the signal system and other target infrastructure, focusing on improving reliability/resilience;
- Short extensions to create a fully orbital network (Outer Circle Line); and,
- Introduction of integrated smartcard ticketing (the Oyster card)

The plan transformed the worst railway in the UK into one of the highest performing in Europe. Between 2007 and 2012, the London Overground experienced:

- 200% increase in train revenue miles
- Nearly 400% increase in demand, from 29 million to 136 million trips (and further increasing to 189 million trips by 2018).
- Over 50% reduction in delays
- 25% improvement in Customer Satisfaction
- Over 50% increase in new homes built within 1 mile of Overground station

The London Overground achieved this while reducing the subsidy per passenger by over 75%.

LONDON OVERGROUND
Between 2007 and 2012 experienced:

200%
increase in train revenue miles

Nearly 400%
increase in demand

Over 50%
reduction in delays

25%
improvement in customer satisfaction

Over 50%
increase in new homes built within 1 mile of Overground station

All of this was achieved while reducing the subsidy per passenger by over 75%

The Overground story is very much based around the development of a comprehensive strategy to transform services while identifying early wins to highlight the value in the longer-term vision. Tying projects to a clear case for investment, while considering the operational, economic, financial, and strategic benefits, is also important.

Who is the Customer?

MBTA Commuter Rail riders are from diverse backgrounds and have different mobility needs. While some may use Commuter Rail for specific trip purposes today, with changes to the service they could choose to ride more frequently. For other residents the current service may not meet their needs, but changes to the service could encourage them to use begin using it.

The following personas help illustrate some of the challenges and desired outcomes associated with the rail system for current and potential riders.

Persona #1	Standard Commuter (Fitchburg Line)
Persona #2	Working Family (Worcester Line)
Persona #3	Regional Commuter (Chelsea to Lynn)
Persona #4	Occasional Rider (Needham to Ruggles)
Persona #5	Reverse Commuter (Medford to Lowell)
Persona #6	Lower Income Commuter (Fairmount Line)

Persona #1: Standard Commuter (Fitchburg Line)

Name: Mia Zibkowski
Age: 24
Occupation: Creative Designer for Agency
Location: Waltham

Needs:

Works in downtown Boston for a busy digital marketing agency. Early and long days are the norm, but living in the core allows her to avoid owning a car. Mia is very budget-focused and would like to move out of the core to alleviate housing costs.

Concerns:

While Mia would like to save on housing costs by living in the suburbs, she struggles with the decision due to the Commuter Rail's current schedule. She wants to be able to live within walking distance of the station to avoid parking stress and cost.

What Mia Wants in a Rail System:

Flexible schedules and consistent service both during the weekdays and weekends would positively influence her to make the move out of the core, exploring a mixed-use development that was more affordable than her place in Jamaica Plain. The flexibility would prompt her to embrace the Commuter Rail as her first mode of transportation.

Persona #2: Working Family (Worcester Line)

Name: James & Amanda Hopkins
Age: 44/43
Occupation: Software Engineer/Insurance
Location: West Newton

Needs:

Couple rides the Framingham/Worcester Line every day from West Newton to South Station. Amanda works downtown, while James changes to the Red Line for his commute to Kendall Square.

Concerns:

They have less frequent service from West Newton than other riders who start their commute at the outer stations on the Worcester line as the express trains do not stop for them. This leaves James and Amanda to stagger trips to and from work as well as dropping off kids at school and child care. The schedule has resulted in increased child care costs and is impacting their professional lives.

What the Hopkins' want in a Rail System:

While their travel time is short due to their proximity to Boston, they desire more frequency during the peak, since they both work traditional jobs and they do not need much midday service.

Persona #1	Standard Commuter (Fitchburg Line)
Persona #2	Working Family (Worcester Line)
Persona #3	Regional Commuter (Chelsea to Lynn)
Persona #4	Occasional Rider (Needham to Ruggles)
Persona #5	Reverse Commuter (Medford to Lowell)
Persona #6	Lower Income Commuter (Fairmount Line)

Persona #3: Regional Commuter (Chelsea to Lynn)

Name: Christian Martinez
Age: 28
Occupation: Non-Profit Case Manager
Location: Chelsea

Needs:

Commutes from Chelsea to Lynn five or six times per week. He has the option of taking the train and a bus to his location or several buses, which takes significantly longer.

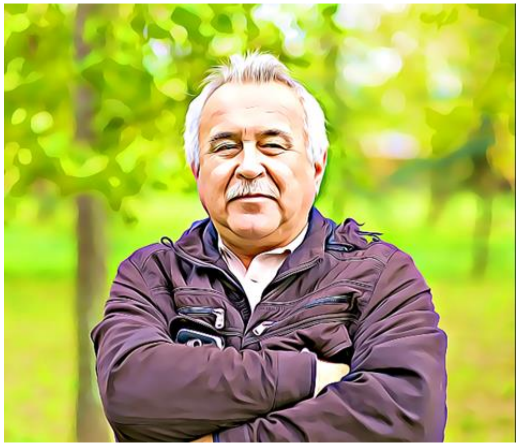
Concerns:

Schedules, delays, traffic, and mostly the cost of the Commuter Rail have shifted his commuting preferences. He would take the Commuter Rail if the cost was closer to rapid transit and if it was convenient.

What Christian wants in a Rail System:

An easier and less expensive commute from where he lives to where he works. A frequent schedule gives him options for starting and finishing work at different times. Lower cost would influence him and many others to use Commuter Rail regularly.

Persona #4: Occasional Rider (Needham to Ruggles)



Name: Jemin Patel
Age: 70
Occupation: Retired Postal Worker
Location: Needham

Needs:

Due to reoccurring healthcare needs, Jemin needs to travel to the Longwood Medical Area for a series of meetings with specialists. He is unable to drive and generally relies on public transportation to get around the community.

Concerns:

He travels to Longwood at least once per month, sometimes two or three times per month. The trip can be challenging without friends or family around to help him get there via car. He's not a rideshare user as he's not comfortable with the experience. There are times he needs to ask for assistance from the local senior service agency.

What Jemin wants in a Rail System:

Accessibility to his team of doctors and specialists, flexibility for time, and less reliance on others to get him to and from his appointments. He would be willing to take the Commuter Rail and then a bus from Ruggles to get to the hospital. However, it would be easier if he didn't need to juggle multiple fare products/tickets.

Persona #1	Standard Commuter (Fitchburg Line)
Persona #2	Working Family (Worcester Line)
Persona #3	Regional Commuter (Chelsea to Lynn)
Persona #4	Occasional Rider (Needham to Ruggles)
Persona #5	Reverse Commuter (Medford to Lowell)
Persona #6	Lower Income Commuter (Fairmount Line)

Persona #5: Reverse Commuter (Medford to Lowell)

Name: Ashlei James
Age: 36
Occupation: Institutional Advancement
Location: Medford

Needs:

Ashlei commutes on the Commuter Rail from Medford to Lowell, where she works at Middlesex Community College as the VP for Institutional Advancement.

Concerns:

Ashlei's direction of travel does not offer the frequency or schedule she desires. She does not own a car and does not have the flexibility of working remotely as she's focused on creating relationships with top individual and corporate donors in the Middlesex 3 area, a group of communities including Lowell to the northwest of Boston.

What Ashlei wants in a Rail System:

Having the option to take public transportation aligns with her environmental ideals and gives her the opportunity to work while commuting.

Persona #1	Standard Commuter (Fitchburg Line)
Persona #2	Working Family (Worcester Line)
Persona #3	Regional Commuter (Chelsea to Lynn)
Persona #4	Occasional Rider (Needham to Ruggles)
Persona #5	Reverse Commuter (Medford to Lowell)
Persona #6	Lower Income Commuter (Fairmount Line)

Persona #6: Lower Income Commuter (Fairmount Line)

Name: Jolie McKenn
Age: 27
Occupation: Retail Manager
Location: Readville

Needs:

Works as a retail manager for a major clothing chain and often picks up additional shifts to increase income and pay for child care and other living expenses. Reducing her travel time by using the Commuter Rail instead of transferring from the bus to rapid transit would help Jolie save on her child care costs.

Concerns:

Would take the Commuter Rail if it was more affordable and flexible for her schedule and, generally, fit into her busy work and lifestyle.

What Jolie wants in a Rail System:

Lower cost and flexibility are key for Jolie and are the reasons why she hasn't embraced the Commuter Rail as a transportation option.

Massachusetts Transportation Initiatives

As previously noted, Greater Boston is congested but is one of the fastest growing regions in North America. This growth will continue to increase pressure on the existing system which, if not addressed, will negatively impact people, businesses, and the environment. Several other on-going initiatives are contemplating the future of transportation in the region, including but not limited to:

- **Capital Investment Plan (CIP)** FY2020–2024: Identifies state-of-good-repair (SOGR), reliability, and expansion projects across all modes, as well as funding for continued study, permitting, and/or design of regionally significant projects. Program funding is also identified for system improvements and upgrades; accessibility; expansion; station and facilities; bridges and tunnels; track, signal, and power; and revenue vehicles. The CIP details $8 billion of future spending on MBTA infrastructure programmed through FY2024.
- **Focus40:** Provides a 25-year strategic plan for how the MBTA can provide a highly efficient core system that sustains growth in the region. It highlights long-term performance, reliability, and capacity needs. It defines systemwide and mode-specific investments (Figure 2-7) to improve

Figure 2-7 Mode-specific Objectives of the MBTA's Focus40 Plan

BUS	Achieve a better, faster, lower-emissions service, supported by all-door boarding and exclusive busways, that is more aligned with where riders live, work, and travel
SILVER LINE	Add capacity and connectivity with an expanded and cleaner fleet that serves not only the Seaport but also an expanded Silver Line network extending beyond Chelsea
BLUE LINE	Accommodate growth at Logan Airport and development sites in East Boston and Revere and ensure resiliency to severe weather and sea level rise
GREEN LINE	Increase capacity by at least 50% on the nation's busiest light rail line with redesigned, larger vehicles and modernized infrastructure
ORANGE LINE	Increase peak-hour service to every 4.5 minutes to meet the needs of homes and businesses throughout the growing corridor, serving additional riders from the Lower Mystic region
RED LINE	Enable a modernized line with peak trains every three minutes to connect residents of transit-oriented housing to growing job centers—all connected to a reimagined Mattapan Line
COMMUTER RAIL	Serve more riders and non-commuting trips by providing better connections to more destinations and potentially by implementing one or more new service models, pending results of the Rail Vision study
WATER TRANSPORTATION	Support a financially sustainable multi-provider Boston Harbor water transportation system, connecting more passengers to major destinations with excellent multi-modal access

Source: *Focus40: Positioning the MBTA to Meet the Needs of the Region in 2040*, 2019.

reliability and performance, including Commuter Rail, as well as objectives for accessibility, customer experience, and resiliency.

Focus40 recommends investments in the Commuter Rail over the next five years. These include: South Coast Rail Phase 1; the North Station Drawbridge; Bi-Level Coach Procurement; Locomotive Upgrade and Replacement; Ruggles Station Upgrades; and Positive Train Control (PTC). Longer term, *Focus40* looks to Rail Vision to identify appropriate investments and strategies to improve the network.

- **Massachusetts Rail Plan:** Provides an update to the previous Rail Plan and includes the development of a short-range, four-year program focused on SOGR and a long-range, 20-year vision to facilitate economic growth by improving Massachusetts' intercity and freight rail system. Includes both a near-term 5-year plan, as well as a 20-year, long-term strategy for state investment in rail.
- **Transportation Climate Initiative (TCI):** TCI is a regional collaboration of Northeast and Mid Atlantic states (including Massachusetts) and Washington, D.C. that seeks to establish a cap on global warming pollution from transportation fuels and invest revenue to achieve additional benefits through reduced emissions, cleaner transportation, healthier communities, and more resilient infrastructure.

Rail Vision seeks to complement and build upon the efforts defined in these plans, and align with the accessibility, customer experience, and resiliency objectives set forward in *Focus40*.

Rail Vision

Boston's Commuter Rail system has the potential to **not only alleviate congestion and support environmental goals, but foster further economic growth and prosperity**. Rail Vision provides an opportunity to assess how the Commuter Rail network could achieve these outcomes.

The scope of Rail Vision includes: analysis of future market trends in the region over the next 25 years; comparison of the existing MBTA system to other U.S. and International peer market systems; development of a set of goals and objectives for the 2040 Rail Vision; identification, analysis, and modeling of a number of potential service alternatives; development of ridership and operating costs; identification of capital investments needed for each service alternative; and the development of a final recommendation and implementation plan. Table 2-4 presents a series of frequently asked questions regarding the scope of Rail Vision and how it relates to other studies in progress or recently completed by the MBTA.

Table 2-4 Rail Vision Scope Frequently Asked Questions

What's included in the Vision?	What's not?	Why?	Where do I find more information?
Defining a long-term vision of the commuter rail system	Short-term recommendations for the commuter rail system	Shorter-term recommendations will be addressed in the CIP and Focus 40.	CIP https://www.mass.gov/service-details/capital-investment-plan-cip Focus 40 https://www.mbtafocus40.com/
Identifying potential system service alternatives and recommendations	Single-location specific projects	Single-location specific projects limit scale captured in the operations or ridership models. As appropriate, projects will be included in the base case condition.	CIP https://www.mass.gov/service-details/capital-investment-plan-cip Focus 40 https://www.mbtafocus40.com/
Addressing demand and needs along the commuter rail lines	Addressing larger transportation needs	This plan is specific to commuter rail. Other efforts such as the Long Range Transportation Plan efforts address broader transportation plans for the region.	MPO Long-Range Plans http://www.ctps.org/lrtp
Analyzing growth and demand in the commuter rail service area	Developing trends and plausible futures	Identification of trends and plausible futures are being led by other efforts, such as the Governor's Commission on the Future of Transportation in the Commonwealth.	Governor's Commission on the Future of Transportation in the Commonwealth https://www.mass.gov/orgs/commission-on-the-future-of-transportation
Developing a framework that will inform the next rail services procurement	Developing the next rail procurement contract	Rail Vision will not get to the level of detail needed for the next procurement contract.	Planning for the next procurement will happen by the MBTA concurrent to the Vision.
Considering fares at a system level to inform ridership estimates	Fare payment specifics and recommendations	Fare policies will be identified by the MBTA as the implementation of the Automatic Fare Collection 2.0 (AFC 2.0) program is developed.	AFC 2.0 https://mbta.com/projects/automated-fare-collection-20-afc-20

3 Line Level Evaluation

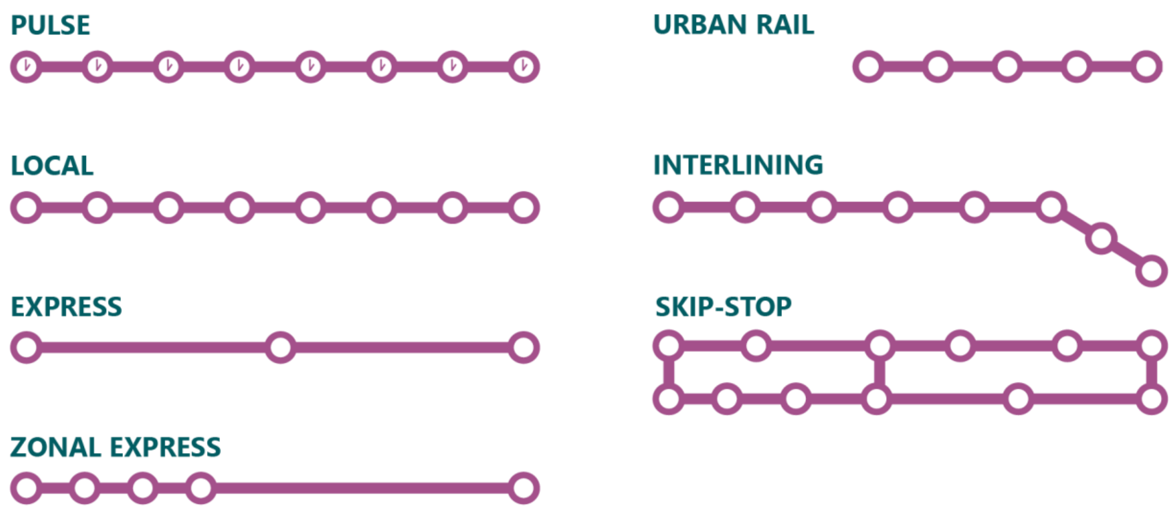
The Line Level Evaluation was the first quantitative step in the Rail Vision analysis, following the Qualitative Screening, which had compiled a long list of concepts drawn from domestic and international systems based on applicability to the MBTA.[5] The purpose of the Line Level Evaluation was to test different strategies, drawn from the Qualitative Screening, to reduce travel time, increase frequency, and improve connectivity at the line level. Figure 3-1 illustrates the seven services types employed to examine these outcomes. Each type offers different trade-offs for different passenger market segments. These include:

- *Pulse*
  A pulse service occurs when trains operate on memory pattern, clockface schedules. Trains arrive and depart at the same times hourly. For example, a train on the Framingham-Worcester line would depart Framingham at 5, 20, 35, and 50 minutes after each hour, providing a consistent departure every 15 minutes. All six Systemwide Alternatives employed a pulse service, as it proved beneficial in this phase of evaluation.
- *Local*
  Trains operating as local stop at all intermediate stations from origin to terminal. This type of service provides consistent access to each community on a line, but makes for slower trips for those passengers traveling the full length or most of the line.
- *Express*
  Express trains operate either non-stop or with just one or two intermediate stops from origin terminal to the destination terminal. Such trains provide reduced travel times for passengers traveling between termini, but offer little to no benefit to intermediate communities.

[5] A review of peer systems is available on the project website at: https://cdn.mbta.com/sites/default/files/2018-11/2018-11-09-railvision-peer-systems-review-accessible.pdf.

- *Zonal Express*
  Zonal express trains provide a combination of local and express service. For half of the line, a zonal express train makes all intermediate stops, but for the other half operates non-stop to the terminal. This service type provides a balanced approach for longer routes, providing quicker trips while serving a mix of intermediate communities.
- *Urban Rail*
  Urban rail service is designed to overlay a high-frequency service on an overall longer rail line, focusing on communities within the inner core of the metropolitan area. Urban Rail can effectively provide frequent service throughout the day for a variety of trip purposes beyond the traditional work commute, with trains making all station stops on the segment to maximize connectivity along the whole corridor.
- *Interlining*
  Interlining occurs when trains from one rail line run through to another, such as Franklin Line trains continuing into Boston on the Fairmount Line to provide direct service between stations on both lines. Interlining improves connectivity with convenient one-seat travel across a larger number of stations.

Figure 3-1 Comparison of Service Types



- *Skip-Stop*
  Skip-stop service occurs when two trains operate along a line, with each making every other stop. This approach reduces total travel time for each train, but limits connectivity between intermediate stations because each train does not make every stop.

The Line Level Evaluation applied these service types in various combinations to each of the MBTA Commuter Rail lines. For example, in some concepts, zonal express trains overlayed with Urban Rail, where the zonal express train shared the last intermediate station as the origin for Urban Rail, to permit passengers to make cross-platform connections to reach intermediate points prior to the rail line's terminal. The concepts also included express trains to complement local trains on longer routes and interlining to create new connections.

Overall, this phase tested over 60 different service concepts across the Commuter Rail system against a set of criteria related to reducing travel times, increasing frequency, and improving system connectivity. Some concepts tested electrified service to evaluate the potential travel time savings. This analysis did not include other variables, such as fare policy or parking availability, as it focused on the service characteristics. It also did not include investments related to terminal capacity or additional services. The following subsections define the evaluation criteria and methodology, and summarize the results of the evaluation.

Evaluation Criteria and Methodology

The Line Level Evaluation used key performance metrics to test how well each concept met the project objectives as compared to a no-build scenario. The no-build represents a service that maintains the current infrastructure and schedules, as well as any programmed improvements such as SCR Phase 1.

Travel Time Savings

For each concept, the project team developed preliminary timetables in ATTUne, a scheduling tool for rail operations. ATTUne checks schedules against planning rules, outputting diagrams showing the time and location of each train and identifying areas that would require new infrastructure to avoid conflict. These preliminary schedules provided the basis to estimate the average in-vehicle travel time savings (in minutes) per stop, compared to the No-Build. The analysis then aggregated these station-level travel time savings to the line, weighting the existing ridership at each station, and identified the **average in-vehicle travel time savings** for each concept.

Frequency

The preliminary timetables developed in ATTUne provided the **total number of train trips** on the line throughout the day. This metric measured frequency along the line as a whole and is not weighted by ridership or number of stations served. The documentation of frequency adjustments associated with each concept in the following sections includes more detail about which stations received the most benefits.

Ridership

The Regional Dynamic Model (RDM) strategic simulation tool provided the rail ridership used to evaluate the **percentage change in ridership** as compared to the no-build projections for each concept.

The RDM evaluates how transportation, land-use, population, and employment interact. Primary inputs into the RDM came from both the ATTUne scheduling tool (details about the service concept) and from the existing Boston MPO Central Transportation Planning Staff (CTPS) travel demand model (existing demand by mode, existing transportation options, anticipated future growth).

Connectivity

The RDM also helped assess t changes in connectivity by calculating the **percentage change of jobs accessible within one hour of Commuter Rail travel**, compared to the No-Build for each concept. This metric used job access as a proxy for general connectivity, since employment centers often overlap activity centers.

Equity

Each service alternative was evaluated in relation to how it would affect (positively or negatively) environmental justice (EJ) communities, defined in Massachusetts as census block groups meeting any of the following criteria:[6,7]

- Annual median household income equal to or less than 65% of the statewide median;
- 25% or more of the residents identify as a race other than white; or
- 25% or more of households have no one over the age of 14 who speaks English only or very well (English Isolation).

This assessment assumed that a station served an EJ community if it is located within 0.5 miles of an EJ community. The analysis then rated each service concept based on anticipated changes in:

- Travel time along the line for trains stopping at stations serving EJ communities;
- Frequency at stations serving EJ communities; and
- Connectivity to/from stations within EJ communities.

The equity analysis rated each service concept on a scale of 1 to 3, where:

1. Improvements provide disproportionate benefits to non-EJ communities;
2. Improvements provide substantially similar benefits to EJ and non-EJ communities; and
3. Improvements provide disproportionate benefits to EJ communities.

Capital Cost

Comparing the ATTUne results to known infrastructure constraints resulted in a list of infrastructure and capital improvements likely required for each of the service concepts.

The analysis also used ATTUne to identify the number of trains required to operate in maximum service. The capital costs identified for each service concept included this additional fleet requirement.

The Line Level Evaluation did not estimate the capital cost associated with each concept, but did identify the items/investments required for each of the service concepts.

6 This analysis uses data from the 2015 American Community Survey (ACS) where available, and the 2010 Census where ACS data is not available. This analysis applied EJ criteria to the 2015 ACS using the methodology defined by MassGIS for the 2010 Census Data ("MassGIS Data – 2010 U.S. Census – Environmental Justice Populations," December 2012), including an adjustment to reflect 2015 income levels in MA.

7 Rhode Island defines EJ areas differently from Massachusetts, identifying census block groups with percentages in the top 15% of the State for low-income residents and/or non-white populations. Rhode Island EJ areas are defined based on 2000 Census Block Groups: Department of Environmental Management, "EJ Areas," available at http://www.dem.ri.gov/envequity/graphics/ejareas.jpg.

Operating Cost

An operating cost model analyzed each service concept to estimate the **incremental percentage change in annual operating costs on the line** compared to the No-Build.

The operating cost model was grounded in existing cost data from current MBTA Commuter Rail costs, sufficiently disaggregated in order to understand how service changes would affect future costs. The model incorporated concept-specific operating projections from ATTUne to produce the projected change in operating costs.

Table 3-1 summarizes the metrics used for the Line Level Concept Evaluation. It identifies how each of these metrics relate to the Rail Vision project objectives.

Table 3-1 Line Level Concept Metrics

Objective	Tier 1 Metric(s)
Match service with the growing and changing needs of the region	***Ridership*** (Percentage change in ridership) ***Connectivity*** (Percentage change of jobs accessible within one hour of travel)
Enhance economic vitality	***Connectivity***
Improve the passenger experience	***Travel Time Savings*** (Average in-vehicle travel time savings) ***Frequency*** (Total number of trips on the line per day)
Provide an equitable and balanced suite of investments	***Equity*** (How benefits to EJ communities compare to non-EJ communities under the concept)
Help the Commonwealth achieve its climate change sustainability targets	***Ridership***
Maximize return on investments (financial stewardship)	***Capital Costs*** (Order-of-Magnitude comparison of major capital cost elements for concept) ***Operating Costs*** (Order-of-Magnitude comparison of incremental annual operating costs for concept)

Initial Line Level Results

While there are some unique characteristics associated with each of the MBTA's individual Commuter Rail lines, several common findings emerged from the service concepts tested in the Line Level analysis:

- **Express and zonal express trains are more effective than skip stop trains** in saving travel time and generating ridership;
- **Urban Rail effectively generates ridership** by providing higher frequency service on most lines;
- Service patterns that require a transfer in the outer part of the network to reach the downtown terminals negatively affect ridership and should be avoided where possible; and,
- **Each line is unique,** and sometimes different stopping patterns benefit different lines.

  The analysis evaluated these results only for individual lines and not in combination with the MBTA Commuter Rail system as a whole. This analysis therefore did not test the operations within the constraints of the terminals, with that level of analysis included in the evaluation of Systemwide Alternatives described in Chapter 4.

The following sections provide a brief summary of the Line Level findings.

North Side Lines

Newburyport/Rockport Line

The two pulse-scheduling improvement concepts (with clockface schedules and additional bi-directional frequency throughout the day) tested on the Newburyport/Rockport Line resulted in the greatest increases in ridership, equity, and connectivity with the lowest increase in costs as compared to the other concepts tested. These two concepts provided the greatest trunk frequency increases (other concepts provided additional branch trips), supporting the growth in ridership. Increasing speeds by removing speed restrictions resulted in additional travel time savings and higher levels of ridership. Electrification resulted in the highest costs and the greatest level of travel time savings but did not generate more ridership than the two improvement concepts forcused only on pulse scheduling.

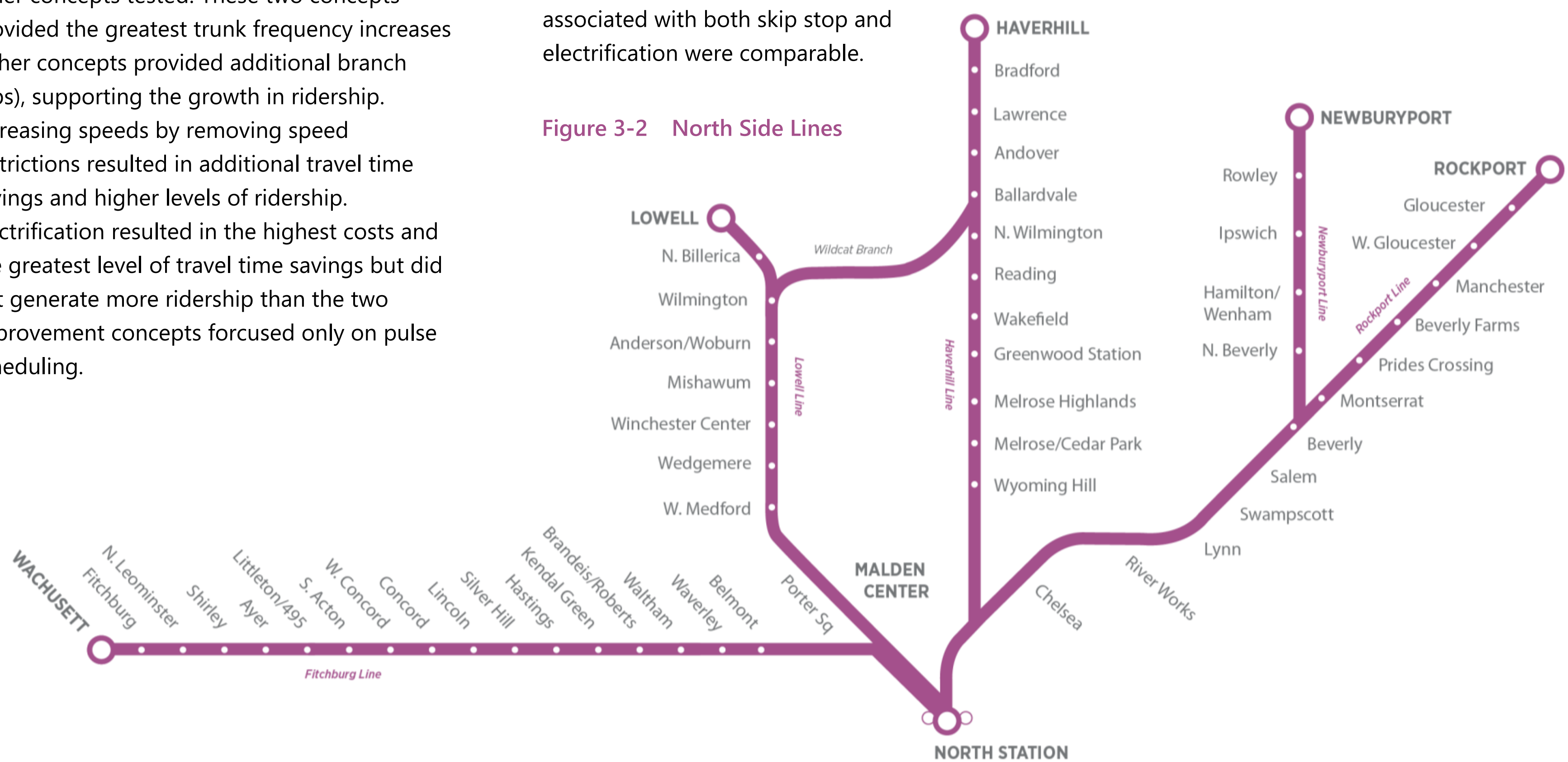
Haverhill and Lowell Lines

The Urban Rail concept running higher frequency service between North Station and Anderson/Woburn and a new station on I-93 provided the highest ridership growth and connectivity, but with comparatively higher operating and capital costs. The pulse and skip stop concepts had lower capital costs than Urban Rail, but the operating costs were comparable while generating less than half the ridership increase. The travel time reductions associated with both skip stop and electrification were comparable.

Fitchburg Line

Electrification, zonal express, and a concept providing a connection to the Orange Line at Sullivan Square generated high levels of ridership. However, the zonal express concept generated comparable ridership at a lower cost and with the greatest improvements in equity. The electrification concepts offered the greatest travel time savings and provided the most frequency and connectivity.

Figure 3-2 North Side Lines



South Side Lines

Worcester Line

Urban Rail service running trains interlined with the Grand Junction to provide service every 7.5 minutes, provided the highest frequency, the largest equity improvements, and the greatest ridership increase but at the highest capital and operating costs. Electrifying the line provided the greatest travel time savings and connectivity, with a ridership gain similar to the urban rail concept at significantly lower operating and capital costs. The pulse concept offered the lowest cost, and provided among the highest improvements in connectivity and equity with a moderate increase in ridership.

Needham Line

The Urban Rail concept provided the highest benefits in terms of travel time savings, frequency, connectivity, and ridership on the Needham Line, but at the highest cost of the concepts tested. Due to the short length of the line, the other concepts tested did not provide the same level of benefits.

Franklin Line

While electrification and interlining zonal express service with the Fairmount Line required the highest operating and capital costs of the concepts tested, these approaches also generated the most ridership, connectivity, and frequency gains, as well as moderate gains in equity. The zonal express concept that did not interline with Fairmount Line was the least costly and generated a ridership gain somewhat higher than the pulse concept due to the travel time savings.

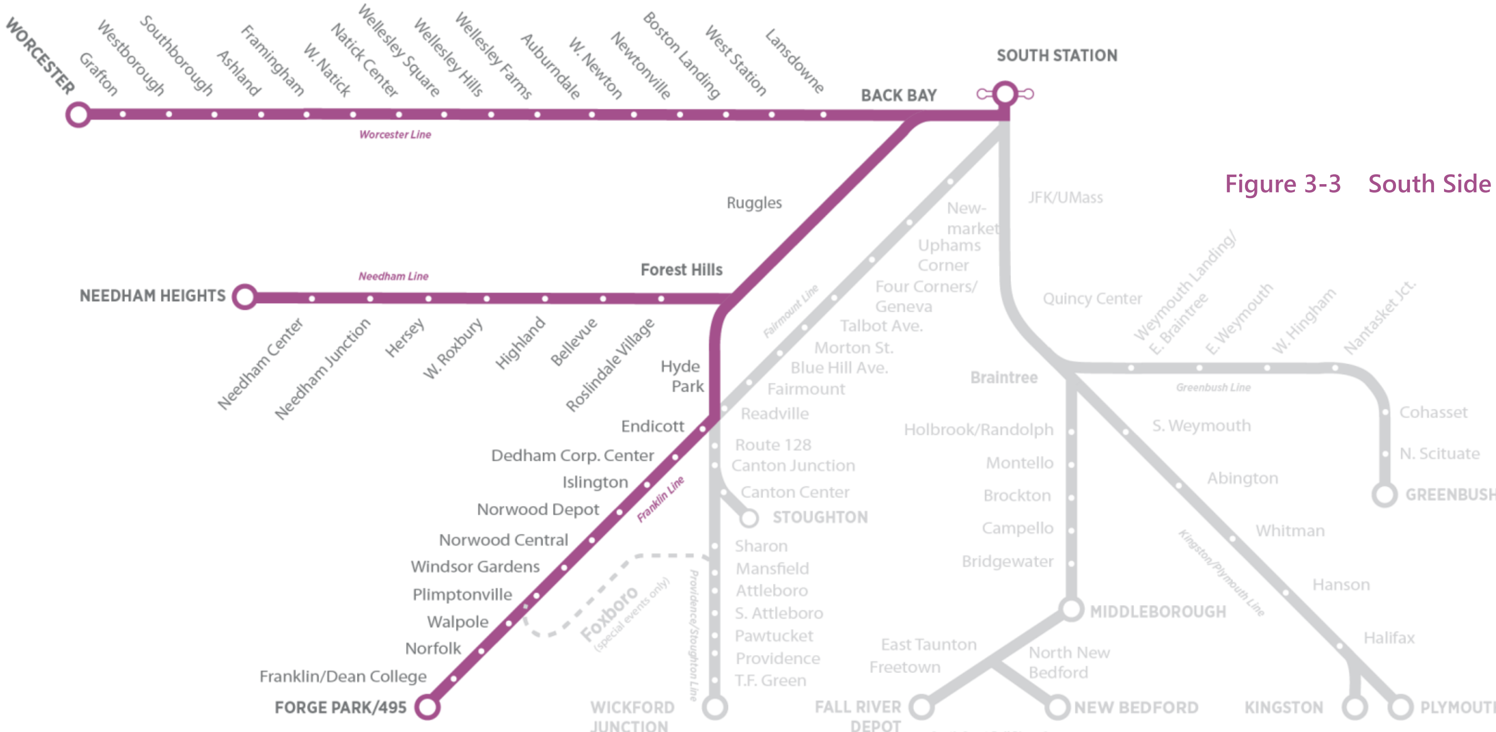


Figure 3-3 South Side Lines

Providence/Stoughton Line

Electrifying the Providence/Stoughton Line provided the greatest benefits in travel time savings, frequency, connectivity, and ridership, but at the highest operating and capital costs. Providing higher frequency with diesel-hauled trains resulted in a lower capital cost than electrification, but did not produce the same travel time savings and generated only two-thirds of the ridership increase associated with high frequency electrified service. While pulse service alone offered the lowest cost, the ridership gain was half as high as with the high frequency electrified service.

Fairmount Line

Due to the relatively short distance of the Fairmount Line compared to the other MBTA Commuter Rail lines, the two Urban Rail concepts provided the greatest benefits in terms of travel time, frequency, connectivity, equity, and ridership. One Urban Rail concept offered trains every 15 minutes and the other every 10 minutes. Not surprisingly, the 10-minute frequency concept generated both the highest benefits and capital and operating costs. Capital costs were lower for the 15-minute frequency Urban Rail concept as the current infrastructure (double-tracked) can largely handle this level of service. Interlining with the Franklin Line provided similar ridership increases and the lowest operating cost.

Old Colony Lines

The skip stop, skip stop with interlining focus, and electrification concepts provided the greatest ridership increases but also the highest costs, likely requiring continuous double track between Braintree and South Station. The concept requiring a transfer at Braintree for some service resulted in frequency and connectivity improvements but increased travel times for Plymouth/Kingston and Greenbush Line riders. The pulse scheduling increased ridership at the lowest levels.

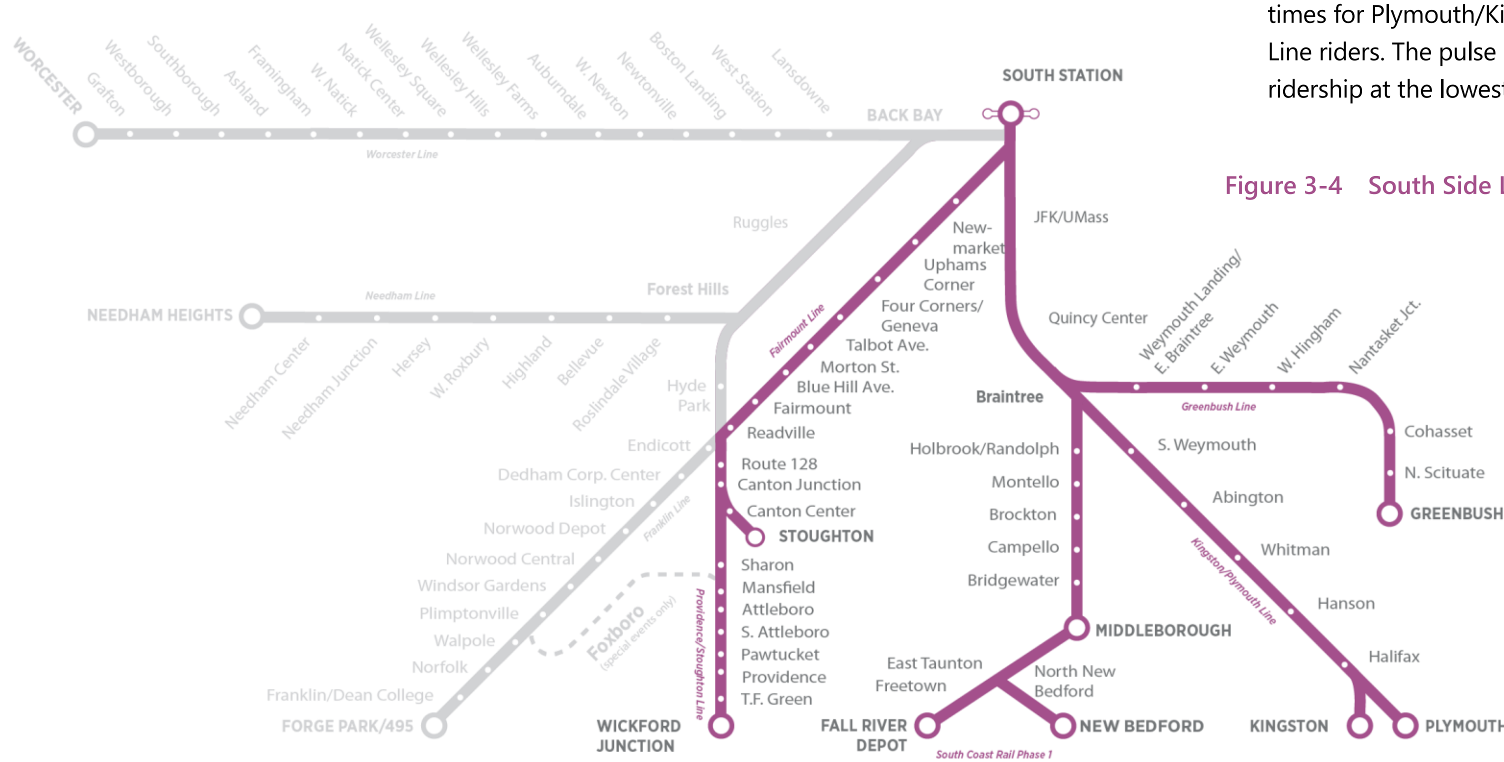


Figure 3-4 South Side Lines (cont.)

4 Systemwide Alternatives

The initial Line Level modeling and stakeholder feedback informed the development of six Systemwide Alternatives, which range from **higher frequency Commuter Rail** with modest infrastructure improvements, to **regional rail and urban rail alternatives**, to a **full transformation** of the system. They include features tested in the Line Level Evaluation, such as express and zonal express service for longer rail lines and employing diesel and electric multiple units to operate Urban Rail service.

The Systemwide Alternatives Evaluation employed a more rigorous modeling approach than the Line Level Evaluation. It used several modeling tools to measure how each alternative met each of the Rail Vision objectives with a greater level of precision than the initial phase.

The purpose of the analysis was to assess the feasibility and effects of the Alternatives across the entire Commuter Rail system, rather than analyze concepts in isolation at the line level. This approach provides insight into how terminal and other system constraints may affect feasibility and how the ridership response to service patterns offered at the system-level.

The rest of this chapter describes the Systemwide Alternative approach. The first section details the content of the six Systemwide Alternatives (see Appendix B for full service plans). The following sections describe the tools and assumptions used in the analysis, and the chapter concludes with descriptions of the metrics used for the evaluation. Evaluation results are summarized in Chapter 5 and detailed in Appendix C.

The Systemwide Alternatives

The Systemwide Alternatives Evaluation compares the alternatives to a No-Build scenario. The following sections describe the No-Build and each of the Alternatives in more detail.

The "No-Build"

The analysis estimated the baseline, or No-Build, ridership in 2040, largely based on existing schedules. By 2040, population and employment growth will result in projected Commuter Rail ridership increase of 24,000 trips, to a total of **150,000 trips per weekday**.

Serving the ridership projected in the No-Build scenario would require some capital investment to increase capacity, replace trains, and renew track, stations, and equipment at the end of their service life. The Rail Vision analysis therefore assumed the following capital improvements, some of which were not programmed at the time of the analysis, in the operations modeling for the No-Build:

- **Fleet upgrades,** including replacement of a portion of the diesel locomotive fleet and replacement of all single-level coaches with bi-level coaches;
- **Systemwide installation of PTC**, a federally mandated safety requirement that enforces signal and civil speed restrictions, automatically stopping or reducing the speed of a train in an unsafe condition;
- **Automatic train control (ATC) on the north side of the system**, which allows engineers to see the signals on a display – ATC will give an engineer a green signal as soon as it is safe so will allow trains to speed up sooner;
- **ATC cab signal systems on the Worcester, Needham, and Franklin Lines** will allow the entire MBTA network to have the same signaling system;
- **Draw 1 replacements** and **Tower A improvements** will improve the access for all trains moving into and out of North Station;
- **Bridge improvements** as part of the MBTA Bridge Bundle will support long term reliability and growth;
- **South Coast Rail Phase 1** will extend the Middleborough/Lakeville Line to New Bedford and Fall River while maintaining the level of service on the Kingston/Plymouth and Greenbush Lines (together referred to as the Old Colony Lines);
- **Gloucester, Beverly, and Saugus Drawbridge replacements** on the Newburyport/Rockport Line will allow trains to travel across the bridges faster and will improve reliability;
- **Haverhill Line improvements** will enhance scheduling flexibility and reliability by adding double track segments to allow trains to pass in opposite directions at the same time;
- **Franklin Line improvements** will enhance scheduling flexibility and reliability by adding a second track between Walpole and Norfolk to allow trains to pass in opposite directions at the same time;
- **Extending the third track on the Providence Line** between Readville and Canton Junction will improve scheduling flexibility and reliability to allow trains to pass in opposite directions at the same time;
- **Adding a third track on the Worcester Line** between Framingham and Auburndale will result in faster trips for express trains by allowing them to pass trains making local stops;
- **Station improvements will provide accessibility upgrades** at Winchester Center, Worcester, Framingham, West Natick, Wellesley Square, Wellesley Hills, Wellesley Farms, Auburndale, West Newton, Newtonville, Natick Center, South Attleboro;
- **An additional platform at Ruggles** will make all three tracks accessible from the platform so that all trains can stop at Ruggles during the peak period;
- **A new station at Pawtucket** on the Providence Line will provide improved access to the Commuter Rail outside of Providence in Rhode Island.

Alternative 1: Higher Frequency

This alternative focused on improving the current system by providing **predictable, frequent, bi-directional service** where major infrastructure investments would not be needed to do so. Across the Commuter Rail system, trains operate every 30 minutes to all stations during peak periods and every 60 minutes during off-peak periods.[8] South Coast Rail Phase 1 (providing service to New Bedford and Fall River via the Middleborough branch) and the associated operating schedules for the Old Colony lines are included in this alternative. On the Haverhill Line, some trains interline, running across the Wildcat Branch and on the Lowell Line south of Ballardvale. Franklin Line trains interline with the Fairmount Line for half of trips during the peak periods. The system operates with a diesel-hauled fleet.

Figure 4-1 Alternative 1: Higher Frequency

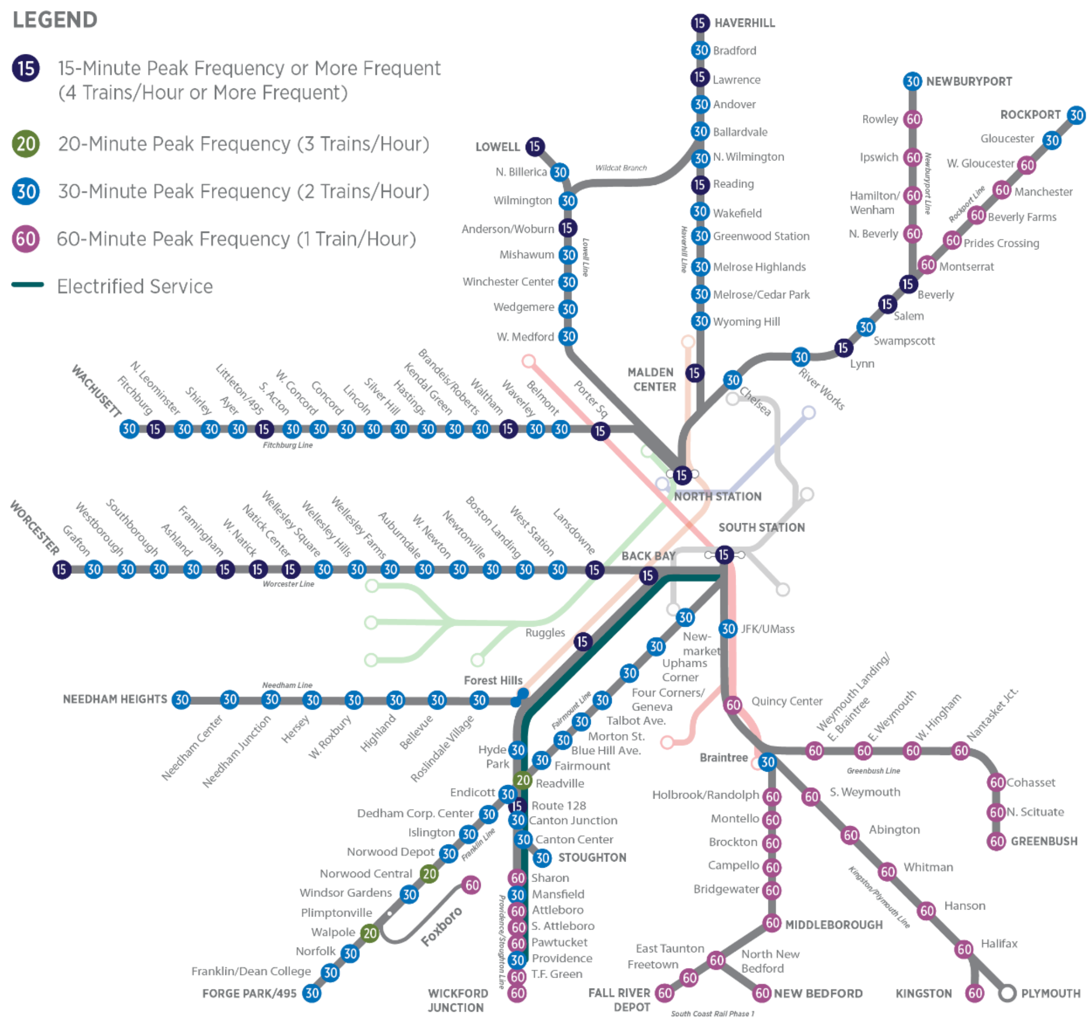
[8] Some stations do not receive service at typical frequency due to operational constraints (e.g., branching) – see Appendix B for service plans.

Alternative 2: Regional Rail to Key Stations (Diesel)

Alternative 2 provided **Regional Rail service,** that is, **high-frequency service to key stations**. Key stations are in areas outside the inner core that have potential for higher ridership due to surrounding land use, including Gateway Cities and other dense communities and locations that provide regional access and transit connectivity.[9] This alternative includes high-level boarding platforms and assumes unlimited (unconstrained) parking in the ridership modeling at all key stations.

The alternative includes diesel-hauled trains on all lines expect for between Boston and Providence, where it tests using electric-hauled trains. The operating plan provides 15-minute frequencies all-day to most key stations on the north side of the system, but every 30-minutes all-day to most key stations on the south side of the system due to limited capacity at South Station. Most lines include 30-minute peak and 60-minute off-peak frequencies for non-key stations.[10] This alternative includes South Coast Rail Phase 1 and the associated operating schedules. It also includes service to Foxboro. Due to limited South Station capacity, all Fairmount Line trains interline with Franklin Line trains.

Figure 4-2 Alternative 2: Regional Rail to Key Stations (Diesel)



[9] Key stations include Gloucester, Newburyport, Beverly, Salem, Lynn, Haverhill, Lawrence, Reading, Malden Center, Lowell, Anderson/Woburn, Fitchburg, Littleton/495, Waltham, Porter Square, North Station, Worcester, Framingham, Natick Center, West Station, Lansdowne, Back Bay, Ruggles, Forge Park/495, Walpole, Norwood Central, Providence, Mansfield, Route 128, Fall River Depot, New Bedford, Brockton, Braintree, Kingston, and South Station.

[10] Some stations do not receive service at typical frequency due to operational constraints (e.g., branching) – see Appendix B for service plans.

Alternative 3: Regional Rail to Key Stations (Electric)

Alternative 3 was similar to Alternative 2 in that it provided **Regional Rail service to key stations** to test providing frequent, direct services to locations outside the inner core with the likelihood for higher demand (ridership) due the surrounding land use. Like Alternative 2, the analysis assumes high-level boarding platforms and assumes unlimited (unconstrained) parking in the ridership modeling at all key stations. However, this alternative uses EMUs on all lines, requiring full system electrification, and assumes South Station Expansion and service on the Grand Junction between a future West Station and North Station with a stop at Kendall Square.

The operating plan provides 15-minute frequencies all-day to most key stations across the system, as South Station Expansion enables additional south side service.[11] Most lines include 30-minute peak and 60-minute off-peak frequencies for non-key stations. South Coast Rail Full Build (providing service via the Stoughton branch) is included in this alternative, enabling additional service to the Old Colony Lines. Half of Franklin Line trains interline with the Fairmount Line. On the Old Colony Lines, some Greenbush and Kingston trains require a transfer at Braintree for service to downtown Boston.

Figure 4-3 Alternative 3: Regional Rail to Key Stations (Electric)

[11] Some stations do not receive service at typical frequency due to operational constraints (e.g., branching) – see Appendix B for service plans.

Alternative 4: Urban Rail (Diesel)

This alternative provided **Urban Rail** service, that is, **high-frequency service to inner core stations**. Inner core stations are located in dense urban environments up to 15 miles from downtown Boston. This alternative tests the ridership response to providing higher all-day frequencies to areas of the network with similar land use patterns as areas served by rapid transit. The analysis assumes high-level boarding platforms at inner core stations, and unlimited (unconstrained) parking at the termini of the urban rail service (the last station in the inner core in the outbound direction) in the ridership modeling. DMU trains provide service to inner core stations, and diesel-hauled trains operate to the outer stations.

The operating plan provides 15-minute frequencies all-day to inner core stations across the system (enabled by the inclusion of South Station Expansion) and 30-minute peak and 60-minute off-peak frequencies to most other stations.[12] South Coast Rail Phase 1 (providing service to New Bedford and Fall River via the Middleborough branch) and the associated operating schedules for the Old Colony lines are included in this alternative. South Station Expansion was also included within this alternative.

Figure 4-4 Alternative 4: Urban Rail (Diesel)

[12] Some stations do not receive service at typical frequency due to operational constraints (e.g., branching) – see Appendix B for service plans.

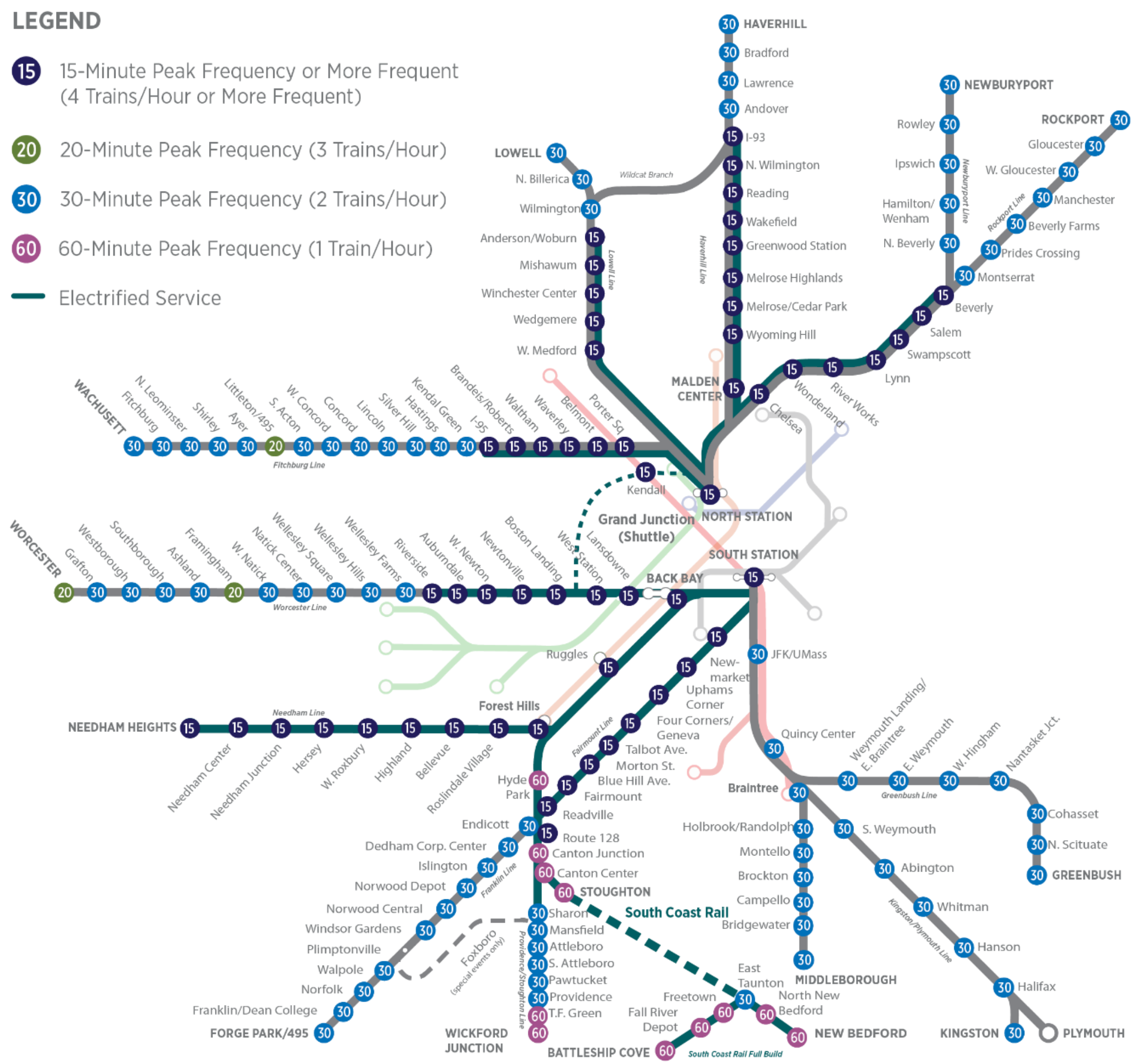
Alternative 5: Urban Rail (Electric)

Alternative 5 was similar to Alternative 4 in that it provided **Urban Rail service to inner core stations** to test the ridership response to providing higher all-day frequencies to dense urban areas around downtown Boston. However, this alternative uses EMUs to serve inner core stations, requiring partial system electrification, and service on the Grand Junction between a future West Station and North Station with a stop at Kendall Square. Like Alternative 4, the analysis assumes high-level boarding platforms at inner core stations and unlimited (unconstrained) parking at the termini of the urban rail service (the last station in the inner core in the outbound direction) in the ridership modeling.

The operating plan nearly matches Alternative 4, except it includes shuttle service between West Station and North Station on the Grand Junction and additional peak period frequencies to the Old Colony lines, enabled by South Coast Rail Full Build switching access to Fall River and New Bedford via the Stoughton line.[13]

In addition, **a variation of this alternative tested a new fare structure that included a flat $3.40 fare between Urban Rail stations**, unless the current fare between the two stations is lower. All other fares, such as between Urban Rail and non-Urban Rail stations, were unchanged.

Figure 4-5 Alternative 5: Urban Rail (Electric)



[13] Some stations do not receive service at typical frequency due to operational constraints (e.g., branching) – see Appendix B for service plans.

Alternative 6: Full Transformation

The Full Transformation provides **high frequency service across the entire system** using EMUs on a fully electrified network. All stations are fully accessible with high-level boarding platforms, and the ridership modeling unconstrained parking at all stations with more than 50 parking spaces.

The operating plan provides 15-minute peak period frequency to most stations, with some branches receiving 30-minute peak frequencies.[14] Urban Rail service uses the North-South Rail Link, creating one-seat rides across inner core stations on the north and south sides for certain pairs of lines (see Appendix B for detailed service plan). Grand Junction offers shuttle service between West and North Station. South Coast Rail Full build stations receive service levels matching the operating plan for that project. All Franklin Line trains would interline with the Fairmount Line.

Figure 4-6 Alternative 6: Full Transformation

[14] Some stations do not receive service at typical frequency due to operational constraints (e.g., branching) – see Appendix B for service plans.

Table 4-1 Service Characteristics of the Systemwide Alternatives

Systemwide Alternative	Typical Frequency (Peak/Off-Peak minutes)	Typical Stop Pattern	Train Type(s)	Additional Services	Access
1) Higher Frequency Commuter Rail	30/60	Varies by line, but with clockface schedules	Diesel-hauled	South Coast Rail Phase 1	Existing or Programmed Upgrades
2) Regional Rail to Key Stations (Diesel)	Key Stations (North Side): 15/15 Key Stations (South Side): 30/30 All Other Stations: 30/60	Local all-stop trains alternate with limited-stop trains serving only key stations	Diesel-hauled Electric-hauled (Providence)	South Coast Rail Phase 1 Foxboro	High-Level Platforms at Key Stations Unconstrained Parking at Key Stations
3) Regional Rail to Key Stations (Electric)	Key Stations: 15/15 All Other Stations: 30/60	Local all-stop trains alternate with limited-stop trains serving only key stations	EMU	South Station Expansion South Coast Rail Full Build Grand Junction (Shuttle) Foxboro	High-Level Platforms at Key Stations Unconstrained Parking at Key Stations
4) Urban Rail (Diesel)	Inner Core: 15/15 All Other Stations: 30/60	Urban Rail trains make all local stops Regional express trains make all stops to Route 128 beltway, express to/from Boston	DMU – Urban Rail Diesel-hauled (all other)	South Station Expansion South Coast Rail Phase 1	High-Level Platforms in Inner Core Unconstrained Parking at Urban Rail Termini
5) Urban Rail (Electric)	Inner Core: 15/15 All Other Stations: 30/60	Urban Rail trains make all local stops Regional express trains make all stops to Route 128 beltway, express to/from Boston	EMU – Urban Rail Electric-hauled (Providence) Diesel-hauled (all other)	South Station Expansion South Coast Rail Full Build Grand Junction (Shuttle)	High-Level Platforms in Inner Core Unconstrained Parking at Urban Rail Termini
6) Full Transformation	15/15	Urban Rail trains make all local stops and use NSRL to connect both sides of system Regional express trains make all stops to Route 128 beltway, express to/from Boston	EMU	North-South Rail Link South Coast Rail Full-Build Grand Junction (Shuttle) Foxboro	High-Level Platforms Systemwide Unconstrained Parking at Most Stations

Note: Typical frequencies were systemwide targets, but may not apply at every station on every line.

Evaluation Approach and Assumptions

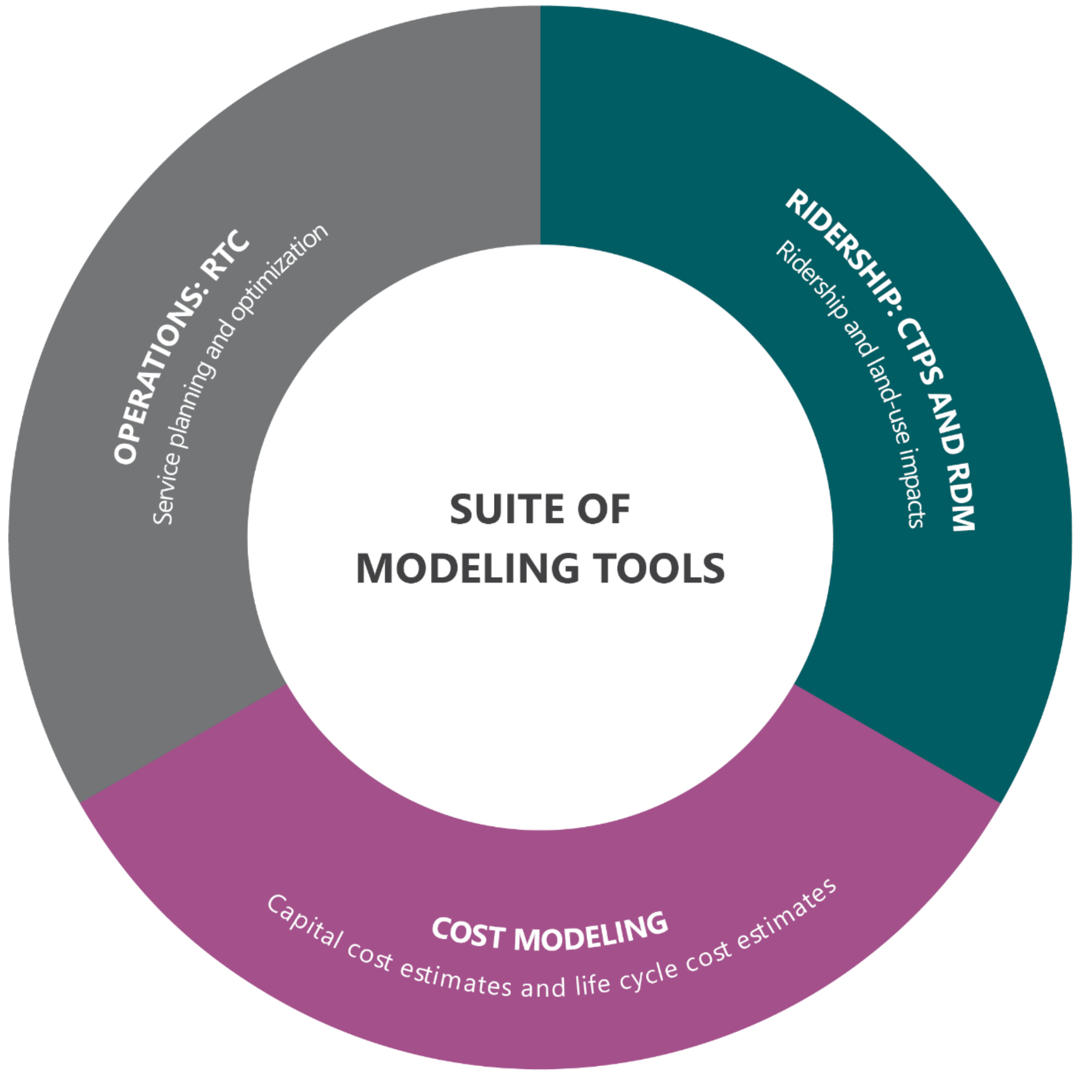
The Systemwide Alternatives Evaluation used several tools to assess operations, ridership, capital costs, and operating costs (see Figure 4-7). A description of the modeling approaches and assumptions follows.

Operations Modeling Approach

The Systemwide Alternatives Evaluation uses Rail Traffic Controller, a software developed by Berkeley Simulations, **to assess the operational feasibility of each alternative**. Rail Traffic Controller (RTC) is a simulation modeling software developed by Berkeley Simulations®. RTC simulates railroad operations at a detailed and realistic level to test and evaluate railroad operating plans, proposed capital improvements, and infrastructure alternatives. RTC provides a more detailed operations analysis of proposed train timetables and the impact on the rail infrastructure than ATTUne, which was used for the Line Level Evaluation.

RTC models include all track characteristics and infrastructure, such as interlockings and control points, track grades and speeds as well as civil speed restrictions. The RTC models used for this project emulate the signal system, to reflect realistic train interactions during dispatch.

Figure 4-7 Suite of Modeling Tools



In addition, the characteristics of locomotives and multiple units were coded to each vehicle's performance specification, including size and weight, acceleration and braking, and maximum possible speed. By combining these vehicle characteristics with the track and signal infrastructure, RTC simulates realistic train performance.

In each of the alternatives, timetables were designed to be **"clockface"** where possible, meaning that trains arrive and depart from each station at the same number of minutes after each hour. For example, if service on the Fairmount Line runs every 15 minutes, trains could depart at 2, 17, 32 and 47 minutes after each hour. Based on public input, all alternatives also included **bi-directional service** throughout the day, meaning that trains operate both to and from Boston during the morning peak, evening peak, and off-peak periods at consistent frequencies in both directions.

Part of the operations modeling approach included an iterative review of capital improvements by line, with potential adjustments based on different trade-offs. For example, without South Station Expansion, Alternative 2 could not achieve 15-minute peak frequencies on all south side lines due to the high frequency of trains and lack of terminal berthing space to accommodate them. Therefore, the analysis adjusted the Worcester, Needham, Franklin, Providence, and Old Colony lines to offer 30-minute peak frequencies, while all the north side lines could meet the 15-minute frequencies at key stations with fewer modifications to North Station to accommodate additional trains.

For each alternative, the project team, including MassDOT and MBTA staff, reviewed the infrastructure improvements required based on the RTC simulations to deliver different service patterns. The team agreed upon a set of infrastructure improvements to build into the RTC simulation, which fed the finalized service plans for each alternative.

Operations Modeling Assumptions

The MBTA's Railroad Operations department reviewed and approved all operations modeling assumptions used in the RTC simulations. Changes to any current operating practices, which may be limited by current technology but could become feasible in the future, were included if applicable.

Amtrak Service

Amtrak currently operates high-speed intercity Acela and Regional services to New York and Washington, D.C. on the Northeast Corridor (NEC) (shared operations with the MBTA Providence Line), long distance Lake Shore Limited service to Chicago via the Worcester Line, and the Maine Downeaster service from North Station on the Lowell and Haverhill Lines via the Wildcat Branch. Since Amtrak trains make fewer stops and operate at higher speeds than MBTA services, they use more track capacity than MBTA trains. Amtrak trains also create large signal wakes affecting trains operating behind them and overtake MBTA Commuter Rail trains at specific locations. Each alternative accounted for all Amtrak services in the operating plans and RTC modeling.

The modeling assumed that Amtrak trains operating on the NEC would have future service levels consistent with the South Station Expansion Project Assumptions.

The analysis included one Acela Express train per hour in each direction and one Northeast Regional train per hour in each direction. It assumed these Amtrak trains would stop at South Station, Back Bay, Route 128, and Providence.

The analysis maintained the existing daily Amtrak Lake Shore Limited round trip on the Worcester Line, with station stops at South Station, Back Bay, and Worcester. The analysis assumed that any additional future western route intercity service would operate in one of the identified express slots instead of in a slot for an MBTA Commuter Rail trip; these future services were therefore not provided an independent operating slot along the Worcester Line. On the north side of the system, the model assumed seven daily round trips for the Amtrak Downeaster on the existing route following the Lowell Line from North Station and continuing to New Hampshire and Maine via the Wildcat Branch to the Haverhill Line, with station stops at North Station, Anderson/Woburn, and Haverhill.

To facilitate clockface schedules, the operating model assumed that schedule adjustments were made uniformly to all Amtrak schedule times, creating consistent hourly arrival and departure times. Adjustments to Amtrak service were only made if MBTA adjustments could not be made first.

Freight Service

The RTC model did not include accommodations to simulate any freight service. The modeling assumed that freight trains would fit into non-Commuter Rail operating time windows and that all operating agreements with freight carriers would be renegotiated.

Span of Service

The operations analysis built all schedules with a span of service between 6 AM to 12 AM, based on the time trains arrive or depart Boston terminal stations (North Station and South Station), across all alternatives. The first inbound train would arrive and the first outbound train would depart the Boston terminal at approximately 6 AM, and the last train at approximately 12 AM. Today, some lines operate earlier or later depending on demand and scheduling, but, for comparison purposes, the analysis maintained this span of service across all lines.

Fleet Deceleration Rates

The RTC analysis assumed the following train consists to model deceleration rates:

- Diesel: 8 cars + 1 HSP-46 Locomotive for conventional Commuter Rail equipment
- Electric: 8 Metro-North Commuter Railroad M8s
- Urban Rail: 4 Car DMUs/EMUs

Table 4-2 shows how the analysis modeled braking rates in RTC, assuming PTC would be in place. PTC is a federally mandated safety requirement that enforces signal and civil speed restrictions, automatically stopping or reducing the speed of a train in an unsafe condition.

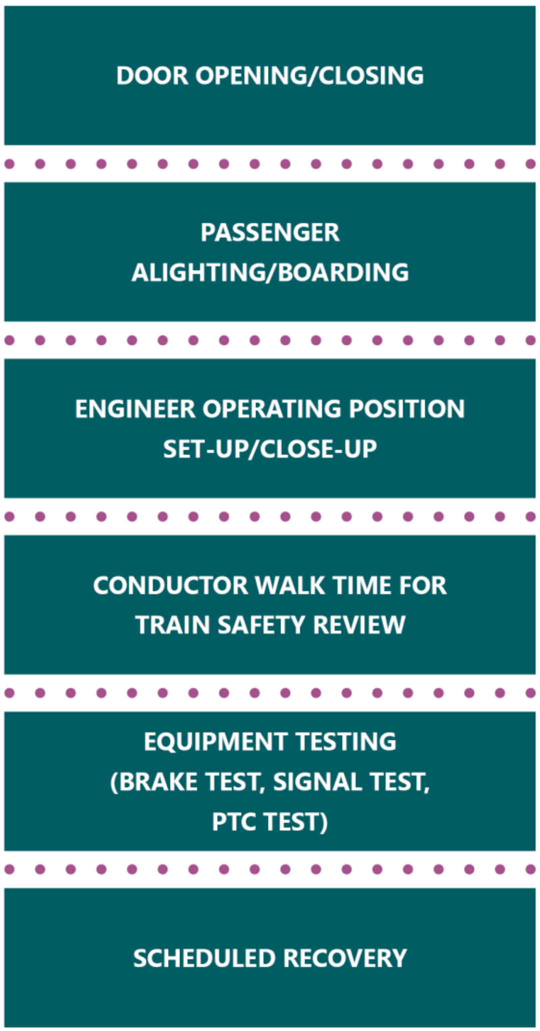
Table 4-2 RTC (or Simulation) Braking Rates in Miles per Hour per Second (mphps)

Vehicle Type	PTC Braking Rate	Service Braking Rate
Diesel (HSP-46)	1.168 mphps	1.6 mphps
Electric (Metro-North M8 EMU)	1.168 mphps	2.0 mphps
DMU (Nippon Sharyo)	1.168 mphps	2.0 mphps

New Vehicle Speed Assumptions

The operations modeling assumed the maximum speed for diesel-hauled, DMU, and EMU trains would be 80 miles per hour (mph). The one exception was for South Coast Rail Full Build, where the maximum speed was assumed to be up to 100 mph, consistent with the South Coast Rail Full Build operations.

Figure 4-8 Train Turn Time Components



Crew Staffing

The operations analysis assumed all trains would have a minimum of one engineer, one conductor, and one assistant conductor. High-ridership trains would have additional assistant conductors based on the current Commuter Rail practice.

Schedule Recovery Time

For all alternatives, the operations model scheduled up to 10% of the minimum required travel time for recovery, distributed across the route where best applicable on a line by line basis. Schedule recovery was typically allocated towards the end of a trip near terminal stations where trains are most prone to delay due to the high volume of trips converging in these areas.

Turn Times

For conventional diesel-hauled push-pull trains and 8-car EMU trains in revenue service, the operations modeling allotted 15 minutes for turnaround time, 10 minutes for active components and 5 minutes for schedule recovery (Figure 4-8).

For 4-car EMU trains, the operations modeling assumed 10 minutes for turnaround time, 7 minutes for active components and 3 minutes for schedule recovery.

These minimum turnaround times would require drop back crews ready to board and take over operations on arrival.

Dwell Times

The operations analysis specified dwell times for each station in each alternative based on platform height:

- 30 seconds for high-level platform with all power door boarding; and,
- 60 seconds for low-level platforms or low-level platforms with mini-high access.

Station Platforms

High-level platforms provide for shorter boarding and alighting times at stations. The analysis assumed that all platforms would be 850 feet long to accommodate all doors on trains of up to 10 locomotive and car units.

The assumptions were as follows:

- Alternative 1: Existing condition and currently programmed platform upgrades;
- Alternatives 2 and 3: High-level platforms at all key stations, as well as all stations assumed for Alternative 1;
- Alternatives 4 and 5: High-level platforms at all inner core stations, as well as all stations assumed for Alternative 1; and,
- Alternative 6: High-level platforms assumed at all stations systemwide.

Signaling

The operations analysis assumed all lines have ATC with cab signals as well as PTC as a baseline condition. ATC is a type of signal system that automatically enforces the signal speed in the event of an unsafe condition. ATC does not enforce civil speed restrictions, such as sharp curves, and is only limited by the current signal aspect displayed at any given location.

On the north side, the RTC model assumed that any existing signal block over 5,280 feet in length would be divided into smaller lengths to allow for an increase in capacity and frequency. The block lengths were determined by the number of trains passing over the segment in each alternative. The model maintained the existing interlockings and control points. Modifications were made on an alternative-by-alternative basis to minimize delay and conflicts where lines or services merge, or where new interlockings or control points would be required.

South Coast Rail

South Coast Rail Phase 1 was included as a No-Build service in the No-Build scenario, operating trains from South Station to New Bedford and Fall River via the Middleborough Line, Middleborough Secondary, New Bedford Main Line, and Fall River Secondary. Alternatives 1, 2, and 4 included the South Coast Rail Phase 1 schedules.

The Phase 1 schedules include the Greenbush and Kingston schedules, since South Coast Rail Phase 1 optimized the Old Colony Line schedules. These three alternatives maintained the Phase 1 infrastructure without the need for any additional capital improvements.

Systemwide Alternatives 3, 5, and 6 assumed the South Coast Rail Full Build and all associated infrastructure (although the capital cost estimates excluded costs associated with the Full Build). The South Coast Rail Full Build will operate via the Stoughton Line and on the NEC. The South Coast Rail Full Build assumes a maximum authorized speed (MAS) of 100 mph south of Stoughton where the alignment permitted 100 mph MAS. MAS represents the highest allowable speed that a train may operate on a given track.

Terminals

The operations analysis included a high-level terminal capacity evaluation to quantify terminal capacity limits on the approach tracks towards North Station and South Station, as well as the platform capacity for the number of trains which may berth per hour. This capacity evaluation measured whether a given alternative was oversubscribing the terminals operating capacity, triggering the requirement of terminal expansion or modifying service frequency.

Layover Facilities

While the operations modeling did not site specific locations for layover and maintenance of equipment facilities, it assumed that these facilities would be unconstrained where required for train storage capacity.

Ridership Projections Approach

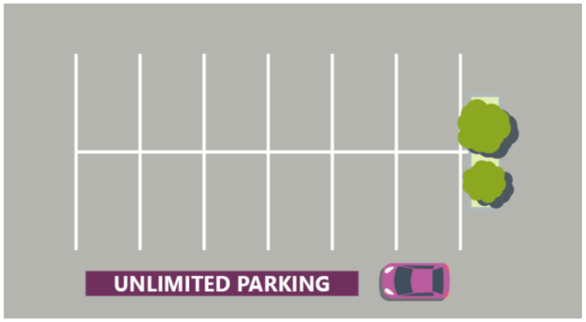
The Systemwide Alternatives Evaluation used the Massachusetts Statewide Travel Demand Model (TDM), developed by CTPS, to project ridership.

Developed in 2016, efforts to maintain and improve the model continue using current data and advanced modeling software. For the Systemwide Alternatives Evaluation, CTPS updated base data through 2018.

For each alternative, CTPS projected ridership by Commuter Rail line (in some cases, adjacent or connected lines are reported together) and provided several related systemwide outputs. All results are reported in comparison to the No-Build scenario (see Appendix D for more detail).

The CTPS model is a **four-step model**:

- *Trip generation* is estimated for each transportation analysis zone (TAZ) using land use, demographic, and socioeconomic data;
- *Trip distribution* determines how trips are distributed throughout the region based on travel times between TAZs and the relative attractiveness of each TAZ;
- *Mode choice* allocates trips to a mode of travel (walk, auto, and transit) based on travel times, number of transfers required, parking availability, and cost; and,
- *Trip assignment* estimates the number of trips on each route.



The CTPS travel demand model incorporated stopping patterns, travel times, and average peak and off-peak frequencies for each alternative, **based on the operating plan** developed for each alternative.

In addition, the ridership modeling assumed **specific fare structures for each alternative**. Since the model uses the trip cost as a decision factor, it responds to changes in fare. The ridership modeling assumed:

- The existing fare structure applied to the No-Build, and Alternatives 1-5;
- A modified Alternative 5 used the same operating plan but lowered the urban rail fare to $3.40 for all urban rail trips where the existing fare would exceed $3.40; and,
- Alternative 6 used a distance-based fare structure that reflected the fare structure used in the North South Rail Link Feasibility Study.

The modeling also **tested different parking limits**. Since the travel demand model incorporates passengers driving to transit stations (park and ride), modeling unlimited parking at those stations can test the potential demand where other solutions could be implemented (e.g., additional parking or improved first/last mile services). The assumptions were as follows:

- Alternative 1 reflected existing parking capacity limits at Commuter Rail stations;
- Alternatives 2 and 3 tested unlimited parking at key stations, which received high-frequency service all day;
- Alternatives 4 and 5 tested unlimited parking at the urban rail termini, which received high-frequency service all day; and,
- Alternative 6 tested unlimited parking at most Commuter Rail stations. Stations shared with rapid transit, and stations with fewer than 50 existing parking spaces, retained their existing parking capacity limits.

RDM/Land Use

Land development tends to intensify when transportation infrastructure investments are made, especially rail transit. To measure these land use and development dynamics, the Systemwide Alternatives Evaluation relies on the RDM. The RDM simulates how an urban area evolves over time, with emphasis on how transportation, land-use, population, and employment interact, addressing questions such as:

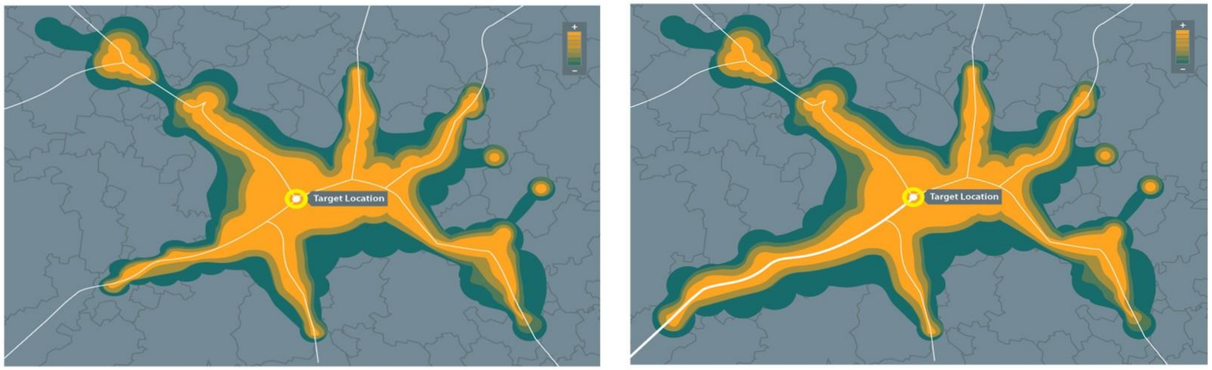
- How will people and employers respond to changes in conditions?
- How do transportation and land use operate together?
- What will the region look like under different scenarios?

The RDM outputs complement the ridership projections from the CTPS model. While the CTPS model forecasts ridership based on static 2040 projections about population and employment trends, the RDM results provide insight into the longer-term potential land use and development response to rail investments. The RDM results do not take into account zoning or other development parameters, but focus on the potential attractiveness of a location or area due to transportation infrastructure changes (**Figure 4-9**).

The RDM developed ridership estimates and land use impacts (reported as population and employment changes) for Alternatives 1, 5, and 6. For these alternatives, the RDM used inputs from the CTPS model, as well as operating plans, to estimate ridership with dynamic land use.

The RDM was calibrated and validated in a process that ensures the model can reasonably match travel-to-work patterns and checks transportation outputs against existing trip volumes. Testing against the CTPS model for the No-Build for 2040, the RDM forecast Commuter Rail riders that are within 2% of the CTPS forecast.

Figure 4-9 Example of Land Use Change with Transportation Investment



RDM tests the impact of transportation improvements on land use. The map on the left shows land use before an investment, while the map on the right shows how development extends on the corridor with investment (on the bottom left corner of the maps).

Environmental Justice Analysis

The EJ analysis, conducted by CTPS, assessed whether the Rail Vision alternatives would cause disproportionately high and adverse effects on minority or low-income populations in the study area compared to nonminority and non-low-income populations, respectively. Adverse effects may be either a delay or denial of benefits (disproportionate benefits) or an imposition of burdens (disproportionate burdens). The EJ analysis defines:

- A minority person is defined as someone who identifies as American Indian or Alaska Native; Asian; Native Hawaiian or other Pacific Islander; Black or African American; some other race other than White; and/or Hispanic or Latino/a/x; or
- The low-income population is defined as people in households for which the annual household income is less than or equal to 60% of the study area median income (i.e., less than or equal to $44,152).

For each alternative and nine metrics, the analysis defined when:

- Improvements **would likely cause disproportionate benefits or burdens for the EJ populations**; or
- Improvements **would likely not cause disproportionate benefits or burdens for the EJ populations.**

The analysis considered the following metrics:

- Access to jobs by transit;
- Access to retail opportunities by transit;
- Access to higher education by transit;
- Average transit travel times: trip attractions;
- Average transit travel times: trip productions;
- Average highway travel times: trip attractions;
- Average highway travel times: trip productions;
- Congested vehicle miles traveled; and,
- Carbon monoxide (CO) emissions.

Appendix E provides additional detail on the methodology and results of this analysis.

Capital Needs Assessment

Train service patterns drive the need for different capital improvements, including **infrastructure** (e.g., track and signals, structures, stations, electrification, land acquisition, and additional services) and **fleet and related needs** (e.g., new vehicles and layover or maintenance facilities). The Systemwide Alternatives Evaluation compiled a list of investments associated with each Alternative to develop the capital costs, described in the section following the capital needs methodology.

Infrastructure Assessment

The analysis identified infrastructure improvements for each alternative through the operations modeling. The operations modeling coded and dispatched the operating plans for each alternative. Through coding and dispatching the operating plans for each alternative, the simulation identified conflict areas where the infrastructure did not have capacity to deliver the service. The team first resolved these conflicts through scheduling adjustments and then built additional required infrastructure into the simulation where necessary.

This iterative process created a unique set of capital needs for each alternative to best optimize service and minimize delay. The analysis compared the improvements identified in RTC to aerial imagery to identify associated infrastructure needs, such as grade crossing and bridge improvements. The following sections provide more detail on the types of infrastructure needs identified.

Track and Signal

When the existing track in the RTC model was insufficient to provide for the service required by an alternative, **new or additional track** was added into the model. This additional track included double or triple track, allowing for higher capacity along a single route; passing sidings, allowing for precisely timed passing of trains running on a single track; and turn tracks, which allow trains to reverse their direction of travel along a route.

Where the addition of track occurred at existing **grade crossings**, the analysis accounted for the associated improvements. Additional track also required new **signal improvements**.

New and shifted trackwork also necessitated the addition of **end of siding interlockings, universal interlockings, and major junction interlockings,** depending on the complexity of track work. End of sidings allow two tracks to converge to a single track, or a single-track to split into two tracks. A universal interlocking provides universal access between two tracks, typically represented by two mirrored crossovers. More complex trackwork assumed a major junction, with three or more tracks included within the same interlocking or control point.

Structures

Where new track or station work interfered with an existing **undergrade railroad bridge** (rail passing over a roadway or body of water), an approximate measurement was taken using aerial imagery. If the measurement did not meet a predetermined allowable width, the analysis assumed that the alternative would require new track or elevated platforms in a separate span (i.e., if a bridge built for two tracks would need to carry a new third track, the analysis assumed a capital need for a bridge to carry a single track). Where new track or station work interfered with an existing **overhead highway bridge** (roadway passing over rail) the analysis assumed that the service would require rebuilding the entire bridge.

A planning level review of aerial imagery also identified where additional track might require **retaining walls,** in areas of potential wetlands impacts and high-grade differentials. The analysis did not consider retaining walls for stations, but instead assumed that any overall station improvements would cover these where needed.

Electrification

Alternatives 3, 5, and 6 include the overhead catenary and related power infrastructure required for **electrification**. The analysis accounts for these improvements on all revenue service tracks and storage tracks that use electric equipment.

Stations

To support improved service, the infrastructure needs assessment included **new stations**, **additional platforms**, and **station accessibility upgrades** (detailed earlier in this chapter). The modeling assumes that full-length, high-level platforms are needed wherever any work (e.g., an additional platform) is required.

Land Acquisition

Since infrastructure improvements may extend beyond the MBTA's right-of-way, the analysis considered potential land and building impacts. For improvements requiring additional track, the analysis included a land acquisition allowance based on the track mileage, to account for the acquisition of **slivers or portions of adjacent parcels** to accommodate the track. In addition, a planning level review of aerial imagery identified potential **building impacts** on a case-by-case basis, using a typical clearance based on the type of improvement.

Additional Services

Additional services were included as defined by the alternative. Additional services included both **terminal expansions** and/or service on **new corridors** within the MBTA service area, depending on the alternative.

Fleet Assessment

The increased service proposed by each alternative requires changes to the MBTA Commuter Rail fleet. **All alternatives require an increase in fleet size**, **and certain alternatives require new vehicle types.** The fleet estimates assume an incremental fleet acquisition to meet each alternative's needs (as opposed to a wholesale fleet replacement).

The analysis provided assumptions for both fleet sizing (the number of trainsets) and consist sizing (the length of trainsets). Further fleet and consist sizing would be required before implementation, but quantities are estimated for planning purposes. Additionally, the analysis included assumptions for layover and maintenance costs.

The fleet sizing process used the peak period revenue service demands to estimate the trainsets needed for daily servicing and inspection (S&I), as well as the spare trainsets needed to maintain maximum service requirements. Spare trainsets were calculated based on a Spare Ratio percentage that varies according to the size and type of fleet required.

The following assumptions accounted for refueling, S&I, and spare trainsets:

- For diesel vehicles, a minimum of one in four in-service trainsets must come out of service midday for fueling and S&I;
- For electric vehicles, peak period fleet required is sufficient since the vehicles will not need to be taken out of service for fueling, and S&I could happen at the beginning or end of service; and,
- Spare trainsets need to maintain maximum service requirements (a spare ratio percentage varying by size and type of fleet).

The analysis assumed a spare ratio of 20% for all fleets, with the exception of DMUs (which assumed 22% because of more complex equipment), and small fleets, which assumed a minimum of two spare sets of equipment.

The consist sizing process used peak period/ peak direction ridership and the total number of trips on each line to estimate the average number of passengers per trip, which then determined how many vehicles were needed in each trainset.

Consist sizing assumptions included:

- Consists with bi-level coaches would have a 4-coach minimum;
- DMU and EMU consists would operate in pairs (i.e., 2-car, 4-car, 6-car, 8-car);
- Bi-level EMUs and single-level DMUs;
- Seated capacity would reflect current vehicle design (five seats per row); and,
- Vehicle capacity would be 110% of seated capacity, consistent with MBTA policy.

Layover and maintenance assumptions included:

- Layover and Maintenance needs are identified only for incremental increases above current MBTA facilities' capacity;
- Specific site locations are not identified for new layover and maintenance facilities;
- All consists will require overnight layover;
- Layover would be primarily located at ends of lines, based on the operating plans;
- New two-track S&I maintenance facilities are assumed at more heavily utilized layover locations (as identified above);
- Maintenance and servicing would occur both overnight and during the daytime; and,
- This level of planning does not develop the details of a maintenance and layover program.

Capital Costs

The Systemwide Alternatives Evaluation uses an estimation workbook to assess **Order-of-Magnitude (OOM) capital costs**. These estimates include infrastructure costs (track and signals, structures, stations, electrification, land acquisition, and costs for additional services), as well as fleet costs (vehicles and layover/maintenance facilities). The capital cost estimates, developed in Excel, used the following parameters:

- Costs are presented in both current 2020 dollars and escalated to 2030 dollars to reflect an approximate horizon for construction;
- Estimates do not account for life cycle costs;
- Unit costs are based on recent MBTA and other peer agency projects;
- Contingencies and soft costs were applied, consistent with MBTA project controls; and
- Total capital costs for each alternative are rounded to the nearest $100 million.

Infrastructure Costs

As the infrastructure improvements were not designed, but only identified at a planning level, the approach to cost estimates relies on per-unit and other high-level assumptions.

Track costs were estimated on a per mile basis to include general civil and drainage elements. Grade crossing improvements include the civil and signal infrastructure that are required. Signal costs were estimated separately and include both the special trackwork and the signal components.

The analysis estimated retaining wall costs per linear foot and bridge costs per square foot. Undergrade railroad bridge upgrades carried the cost associated with adding a separate span for an additional track, while overhead roadway bridge upgrades carried the cost of a full bridge replacement.

The analysis built the electrification per mile cost based on the *North South Rail Link Feasibility Study,* with additional contingency to account for other impacts (i.e., to facilities, stations, bridges, and grade crossings). This cost is comparable to other projects (South Coast Rail, Caltrain, and Metrolink), identifying specific impacts and costs for each corridor would require further study.

Station improvements were divided into three different cost categories, based on recent MBTA station projects. Based on the operations modeling, some stations required two tracks (and therefore two platforms), while others only required only a single track and platform.

- The cost for a station with full-length, high-level platform access to two tracks (using up and over circulation) applied where an existing low-level station required an upgrade, either to a station with two high-level side platforms or a single, center island high-level platform.
- The cost for the addition of a second full-length, high-level side platform applied when a station with a single existing high-level platform added a station track, requiring the addition of another platform and up and over circulation.
- The cost for a station with full length, high-level side platform (no up and over circulation) applied mainly in Alternative 6, when existing low-level single platforms required accessibility upgrades but only served a single track.

The capital cost estimates also include a land acquisition allowance, based on a combination of a per-mile cost to reflect partial acquisitions and the cost associated with impacting buildings along the corridors.

The per mile cost reflects a systemwide average based on an analysis of three types of segments of additional track that varied in density and average land value. This per mile cost applied where track was added.

In addition, the land acquisition allowance also included costs associated with potential building impacts. This includes total parcel costs where parcels contained a single affected building. For parcels with multiple buildings, the analysis assumes a cost proportional to the percentage of affected buildings.

Wherever possible, the estimates based additional service costs on previous work rather than developing independent estimates. The cost estimates for all alternatives exclude costs associated with South Coast Rail (both Phase 1 and Full Build) and for any infrastructure associated with providing permanent service to Foxboro Station.

Fleet Costs

Fleet unit costs are based on current market conditions and industry comparisons, and include applicable ancillary costs, such as spare parts and training, soft costs, and a 15% contingency. The costs are conservative for planning purposes, as costs may vary widely depending on the procurement details.

Beyond what is currently programmed, the MBTA will need to make investment in bringing its locomotives to SOGR and replacing single-level coaches with bi-levels, regardless of any potential service changes associated with Rail Vision. These routine investments were not included in the fleet cost estimates. For Alternatives with all or partially diesel fleet, the costs solely reflect the additional needs beyond these routine updates. For Alternatives with fully electric fleets (Alternatives 3 and 6), the cost estimates incorporate a credit equal to the approximate cost of routine upgrades to the cost of purchasing the electric fleet, as it is assumed the MBTA would spend that investment regardless of the direction of fleet procurement.

Costs are also included for maintenance and layover facilities, even though the analysis did not specifically site facility locations. Layover facility costs are based on those developed for SCR. The maintenance facility cost assumes a two-track S&I facility.

O&M Costs

The OPEX model was used in both the Line Level and Systemwide Alternative Evaluations. It is based in Excel and estimates the **ongoing cost implications** of the various alternatives.

The model is grounded in existing cost data from the MBTA Commuter Rail. Cost sources include the MBTA's National Transit Database (NTD) report filing for 2016 and supplemental data from the MBTA's general ledger and Keolis. This level of disaggregation allows the outputs from the model to project future operating costs, including the ability to analyze the incremental impacts of service changes on each operating cost element.

Cost drivers include revenue miles and hours, track miles, vehicles available for maximum service, passengers, passenger miles, and fare revenue. The OPEX model multiplies the unit cost for each driver by the annualized forecasted operating statistics from the RTC and CTPS results for each proposed alternative to calculate the forecasted operating cost (Table 4-3).

Table 4-3 O&M Cost Model Input Annualized Operating Statistics per Alternative

Statistic	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Revenue (train) miles	6,922,540	11,235,481	14,388,096	9,541,090	10,544,106	16,199,449
Revenue (train) hours	258,674	449,428	430,815	380,504	398,936	540,223
Vehicle (car) revenue miles	33,481,088	57,761,723	70,564,081	54,658,956	57,273,895	98,667,953
Stations	203	182	188	221	229	233
Staffed stations	3	3	3	3	3	3
Track miles	987	1,011	1,051	1,017	1,032	1,032
Vehicles available in maximum service (VAMS)	651	855	733	1,007	859	964
Passenger trips	45,846,000	50,895,000	54,999,000	62,856,000	62,748,000	101,709,000
Passenger miles	837,775,287	731,170,260	930,560,130	1,115,762,040	963,152,640	1,549,253,790
Fare revenue	$325,904,850	$263,893,950	$293,687,100	$340,842,031	$308,712,788	$394,533,394

Note: The number of stations is higher than the physical number of stations, as stations that serve multiple rail lines are counted for each line served. For example, North Station is counted as four stations, as it serves the Newburyport/Rockport, Haverhill, Lowell, and Fitchburg Lines. Track mile numbers are higher than the physical miles of track, as track that is used by multiple rail lines is counted separately for each rail line. Passenger, passenger mile, and fare revenue used in the OPEX model were annualized from CTPS projections.

The analysis annualized the weekday service day statistics from RTC and CTPS using two approaches, varying by the input source:

- For CTPS inputs, multiply the weekday value provided by CTPS (passengers, passenger miles, and fare revenue) by CTPS' Commuter Rail annualization factor of 270.
- For RTC inputs, multiply the weekday value by the number of weekday service days in a year (254 days), and add the estimated value for weekend service days.

Since the analysis did not develop specific train schedules for weekend service, annual weekend statistics were calculated by taking those for the baseline service and multiplying them by the percent difference between the weekday baseline and weekday alternative statistics. The O&M cost modeling used this method to calculate train revenue hours, train revenue miles, and train vehicle (car and locomotive) miles. The number of stations, track miles, or vehicles available for maximum service did not require annualization, as these values represent counts of physical assets so remain constant regardless of the service day.

Note that the nature of this approach assumes a continuation of much of the MBTA's current Commuter Rail operating practices, methods, and procedures. The OPEX model aggregates costs into the following five categories:

- Staff
- Vehicle operations
- Vehicle maintenance
- Non-vehicle maintenance
- General administration

Where the MBTA does not have direct operating cost experience, the OPEX model based costs on those of relevant U.S. peer group Commuter Railroads. These costs include the following:

- EMU vehicle maintenance
- Electric locomotive vehicle maintenance
- Electric traction (propulsion) power
- Electric power distribution system maintenance
- DMU vehicle maintenance

The Systemwide Alternatives Evaluation presents all operating costs in 2020 dollars. Appendix G provides additional detail on the approach and assumptions behind the operating cost model.

Life Cycle Cost Estimates

To better understand the full cost exposure to the MBTA of each of the Systemwide Alternatives, life cycle costs were calculated at a high-level by **adding capital costs to a total of 30 years of incremental operating and maintenance (O&M) costs**. The time period was selected based on the Federal Transit Administration's (FTA) accepted 30-year useful life of Commuter Rail revenue rolling stock. The estimates are in both 2020 constant dollars, and in nominal (inflated) dollars.

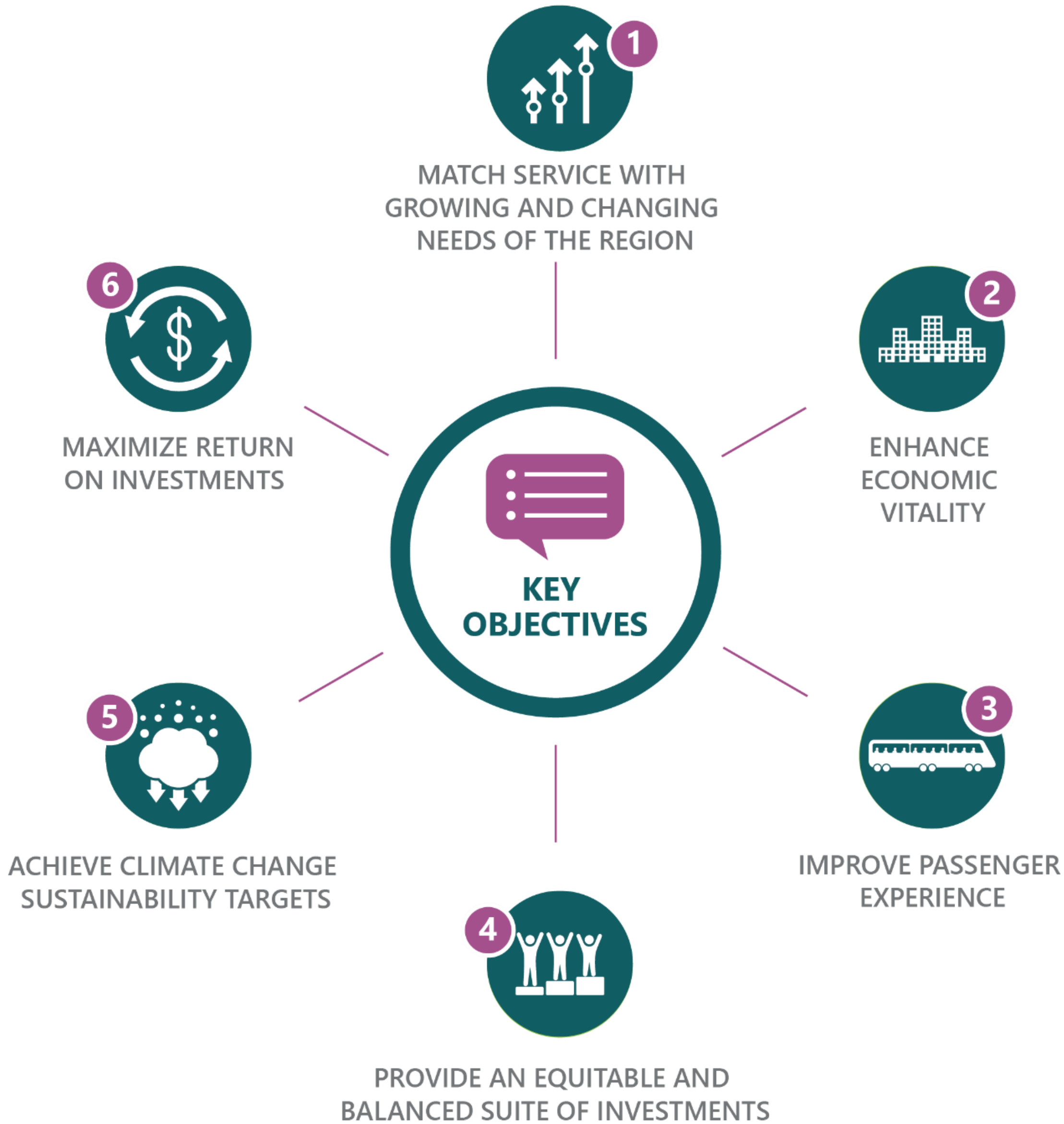
To calculate the O&M cost portion in constant dollars, the life cycle cost estimates multiply the annual O&M cost of each of the alternatives by 30 years, and subtract the 30-year No-Build cost to provide the incremental 30-year O&M cost. For the total constant-dollar life cycle cost, the O&M cost was added to the estimated capital costs in 2030 dollars.

The O&M cost portion in nominal dollars is calculated in a manner similar to that of the constant dollars, except that the costs are inflated annually by 2% from 2020 through 2049. For the total nominal-dollar life cycle cost, the O&M cost was added to the estimated capital costs in 2030 dollars.

Systemwide Alternatives Evaluation Criteria

The Systemwide Evaluation used a variety of metrics to measure how well each alternative met the project objectives as compared to the No-Build scenario (see Figure 4-10). The following sections define each metric. All metrics related to ridership use 2040 forecasts as a point of comparison based on the No-Build horizon year.

Figure 4-10 Project Objectives



Objective 1: Match Service with the Growing and Changing Needs

Metric 1.1: Change in Daily Commuter Rail Boardings

The CTPS model measures the change in the number of passenger trips boarding Commuter Rail trains on a daily basis to measure the effectiveness of each alternative in generating ridership.

Metric 1.2: Change in Off-Peak Commuter Rail Boardings

The CTPS model measures the change in passengers boarding Commuter Rail trains during the non-rush hour, or off-peak, periods of the weekday service day. Weekday off-peak periods include the mid-day (9 AM to 3 PM) and evening/night (6 PM to 6 AM) periods. The ridership levels associated with off-peak Commuter Rail service demonstrate the utility of providing all-day service outside of peak periods.

Metric 1.3: Change in Reverse Peak Commuter Rail Boardings

The CTPS model estimates the change in passengers boarding Commuter Rail trains during the peak periods of the weekday service day in the reverse, or non-peak, direction (outbound from Boston in the morning peak and inbound to Boston in the afternoon peak). The level of ridership associated with reverse peak Commuter Rail service demonstrates the utility of providing bi-directional service during peak periods.

Metric 1.4: Change in Daily Commuter Rail Passenger Miles

The CTPS model measures the change in the distance (in miles) that all passengers travel on the Commuter Rail system. As an example, if two people board a train and then exit at a station two miles later, these people travel a total of four passenger miles. This provides an alternative way to measure the total change in passenger use of the system.

Metric 1.5: Change in Daily MBTA Systemwide Boardings

The CTPS model measures the change in ridership in terms of average weekday boardings across the entire MBTA transit system. This metric includes boardings on the rapid transit, bus, and ferry services in addition to Commuter Rail, reflecting projected changes in how many new Commuter Rail passengers are shifting from other MBTA modes (as opposed to shifting from auto use).

Objective 2: Enhance Economic Vitality

Metric 2.1: Change in Number of Jobs Accessible Within 1 Hour of Using Commuter Rail

CTPS estimated the change in the number of jobs accessible within a one-hour Commuter Rail train ride, including in-vehicle travel time, wait time, and any time associated with getting to or from the stations. This metric helps assess how the improvements to the rail network would impact access to employment in the region.

Metric 2.2: Change in Population Accessible within 1 Hour of North Station/South Station/Back Bay

The RDM measures the change in population that can travel to North Station, South Station, or Back Bay station within one hour using Commuter Rail. This includes the time required to access a Commuter Rail station, wait for the arrival of the next Commuter Rail train, travel on a Commuter Rail train, and any additional transfer time required. This metric helps assess how the improvements to the rail network could make certain areas more attractive for population and employment growth.

Objective 3: Improve the Passenger Experience

Metric 3.1: Average Change in Trip Time

This metric estimates end-to-end trip time by averaging the in-vehicle travel time between select station pairs across the system using the schedules developed in RTC. The analysis selected two to three station origins per line and one destination station on each side of the system for each station origin. This metric demonstrates which alternatives provide the most travel time savings on average systemwide.

Metric 3.2: Change in the Number of Daily Commuter Rail Train Trips

RTC measures the number of one-way train trips operated across the network to assess systemwide frequency.

Metric 3.3: Change in the Number of Daily Commuter Rail Train Miles

RTC measures the change in the average weekday Commuter Rail train miles. This metric reflects the level of service, but differs from Metric 3.2 by accounting for the length of each trip.

Metric 3.4: Change in Daily Passenger Trips on the MBTA Bus and Rapid Transit Network

The CTPS model measures the change in the number of boardings on the MBTA bus and rapid transit network. This metric reflects how each Alternative affects the passenger experience on other modes – a reduction in passenger trips on the MBTA bus and rapid transit services would result in lower levels of crowding and improved passenger experience.

Objective 4: Provide an Equitable and Balanced Suite of Investments

Metric 4.1: Change in Accessibility to Employment for EJ Compared to non-EJ Populations

The CTPS model estimated the change in accessibility to employment for EJ populations compared to non-EJ populations (see Appendix E for more detail). This metric compares the projected change in the number of jobs located within a one-hour travel time from EJ populations to the change in the number of jobs located within a one-hour travel time from non-EJ populations. Due to the uncertainty inherent in forecasting future conditions, the analysis reports the changes as one of the following:

- Change less than the forecasting error
- Disproportionate benefit (change is greater than the forecasting error and provides a greater increase in benefits to EJ populations than to non-EJ populations)
- Disproportionate burden (change is greater than the forecasting error and provides a greater decrease in benefits to EJ populations than to non-EJ populations)

Metric 4.2: Change in Average Travel Time - Transit Serving EJ Populations

The CTPS model estimated change in the average travel times from EJ populations to their destinations, to the change in the average travel times from non-EJ populations to their destinations. This measure assesses potential inequities in which populations gain benefits from proposed improvements. Due to the uncertainty inherent in forecasting, the analysis reports the changes as one of the following:

- Change less than the forecasting error
- Disproportionate benefit (change is greater than the forecasting error and provides a greater increase in benefits to EJ populations than to non-EJ populations)
- Disproportionate burden (change is greater than the forecasting error and provides a greater decrease in benefits to EJ populations than to non-EJ populations)

Metric 4.3: Does not Adversely Burden EJ Population (Accessibility to Employment)

The CTPS model examined the benefits and burdens of each Alternative on EJ populations in the MBTA Commuter Rail service area for a number of metrics. Metric 4.3 identifies whether each alternative adversely affects the EJ populations. Disproportionate benefits or burdens would occur when the EJ population would receive less of an increase or a greater decrease in access to jobs than the non-EJ population.

Each Alternative was evaluated for impacts to EJ populations, defined as populations meeting either of:

1. A person who identifies as American Indian or Alaska Native; Asian; Native Hawaiian or other Pacific Islander; Black or African American; some other race other than White; and/or Hispanic or Latino/a/x

2. People in households for which the annual household income is less than or equal to 60% of the study area median

Objective 5: Help the Commonwealth Achieve its Climate Change Resiliency Targets

Metric 5.1: Change in Daily Kilograms of Greenhouse Gas Emissions

This metric uses the CTPS model in combination with RTC outputs and train emissions factors to estimate the change (reduction or increase) in kilograms of greenhouse gas emissions due to a reduction in driving associated with increased ridership and operations of trains (diesel or electric). This measures the environmental benefits or impacts of each alternative.

Metric 5.2: Change in Commuter Rail Mode Share

The CTPS model estimated the change in Commuter Rail mode share, defined as the percentage share of person trips made by Commuter Rail out of the total number of person trips across transit, automobile, and non-motorized modes. This demonstrates how effectively each Alternative grows the share of people using Commuter Rail in the region.

Metric 5.3: Number of Daily Auto Diversions

The CTPS model estimated the number of auto trips diverted onto Commuter Rail. Auto diversions can reduce roadway congestion and greenhouse gas emissions.

Metric 5.4: Change in Average Daily Vehicle Miles Traveled for Personal Vehicles

The CTPS model measures the number of miles driven by personal vehicles (vehicles excluding TNCs, taxis, and transit vehicles). As an example, if two cars each drive three miles, these cars travel a total of six vehicle miles traveled (VMT). Reducing VMT can reduce roadway congestion and greenhouse gas emissions.

Metric 5.5: Change in Average Daily Vehicle Hours Traveled for Personal Vehicles

The CTPS model measures the number of hours spent driving personal vehicles. As an example, if two cars each drive 30 minutes, these cars travel a total of one hour of vehicle hours traveled (VHT). Reducing VHT can reduce roadway congestion and emissions.

Objective 6: Maximize Return on Investment (Financial Stewardship)

Metric 6.1: Estimated Order-of-Magnitude Capital Costs

As described earlier in this chapter, estimated capital costs include everything necessary to implement the proposed alternative, including infrastructure (e.g., track, station) and vehicle procurement.

Metric 6.2: Order-of-Magnitude Change in Annual O&M Cost

The O&M model estimates the change in annual O&M cost (described earlier in this chapter). The O&M cost includes all costs associated with operating Commuter Rail train service as well as maintaining the infrastructure and vehicles.

Metric 6.3: Order-of-Magnitude Change in Annual Revenue (MBTA Systemwide Fares)

The CTPS model estimated the change in revenue generated from fares on all MBTA services, including bus, rapid transit, and ferry in addition to Commuter Rail. It measures revenue across all services to account for trips shifting from one MBTA mode to another. Increases in revenues can help to partially offset additional costs.

Metric 6.4: Change in Operating Subsidy per Passenger

This metric combines the outputs from the CTPS model and O&M model to measure the change in the operating subsidy per passenger for each alternative. The operating subsidy per passenger is defined as the shortfall in revenue required to cover the O&M costs, divided by the total number of boardings to assess the efficiency of the service provided.

5 Findings and Feedback

Evaluation of the Systemwide Alternatives

This chapter summarizes the evaluation of each of the alternatives against the six project objectives, identifying key takeaways about system-level performance. While the objectives all reflect specific regional goals, the process did not assign weights or comparative values to each. The metrics used are not translated into comparable values (e.g. quantified into equivalent dollar values). Assessing the performance of the Alternatives across the objectives as a whole can inform a regional conversation about how the Commonwealth should value each objective, as well as how investments in Commuter Rail fit into larger efforts to meet the associated goals.

The end of the chapter describes the feedback from stakeholders to supplement and provide additional context for the quantitative results.

Alternative 1	Higher Frequency
Alternative 2	Regional Rail to Key Stations (Diesel)
Alternative 3	Regional Rail to Key Stations (Electric)
Alternative 4	Urban Rail (Diesel)
Alternative 5	Urban Rail (Electric)
Alternative 6	Full Transformation

Table 5-1 summarizes key results by alternative. For results for all metrics by alternative, please refer to Appendix C.

Table 5-1 Comparison of Results for Alternatives 1-6

	Alternative 1: Higher Frequency Commuter Rail	**Alternative 2:** Regional Rail to Key Stations (Diesel)	**Alternative 3:** Regional Rail to Key Stations (Electric)	**Alternative 4:** Urban Rail (Diesel)	**Alternative 5:** Urban Rail (Electric)	**Alternative 5:** Urban Rail (Electric) with Modified Fares	**Alternative 6:** Full Transformation
2040 Ridership (compared to No-Build)	+**19,000** daily CR boardings **(+13%)** *+5,300 drive access* *+13,700 walk access* +**9,200** new linked transit trips in system	+**36,200** daily CR boardings **(+24%)** *+10,200 drive access* *+26,000 walk access* +**21,200** new linked transit trips in system	+**52,900** daily CR boardings **(+35%)** *+19,400 drive access* *+33,500 walk access* +**35,800** new linked transit trips in system	+**80,400** daily CR boardings **(+53%)** *+12,600 drive access* *+67,800 walk access* +**47,500** new transit trips in system	+**81,600** daily CR boardings **(+54%)** *+10,300 drive access* *+71,300 walk access* +**47,500** new transit trips in system	+**99,000** daily CR boardings **(+66%)** *+20,000 drive access* *+79,000 walk access* +**59,100** new transit trips in system	+**225,900** daily CR boardings **(+150%)** *+94,400 drive access* *+131,500 walk access* +**122,400** new transit trips in system
Assumptions: *-Fare Structure*	*-Current fares*	*-Current fares*	*-Current fares*	*-Current fares*	*-Current fares*	***-Urban rail fares***	***-Urban rail fares and distance-based fares***
-Parking	*-Parking constrained*	***-Parking unconstrained at most key stations***	***-Parking unconstrained at most key stations***	***-Parking unconstrained at urban rail termini***	***-Parking unconstrained at urban rail termini***	***-Parking unconstrained at urban rail termini***	***-Parking unconstrained at all stations (excluding rapid transit & limited parking stations)***
Fleet Needs	Diesel Locomotives Bi-Level Cab Cars/Coaches	Locomotives Bi-Level Cab Cars/Coaches	Bi-level EMUs	Diesel Locomotives Bi-Level Cab Cars/Coaches Single-Level DMUs	Locomotives Bi-Level Cab Cars/Coaches Bi-Level EMUs	Locomotives Bi-Level Cab Cars/Coaches Bi-Level EMUs	Bi-Level EMUs
Preliminary Capital Costs (2020$/ 2030$)	**$1.7B** (2020$)/ **$2.3B** (2030$)	**$4.5B** (2020$)/ **$6.3B** (2030$)	**$17.9B** (2020$)/ **$25.2B** (2030$)	**$8.9B** (2020$)/ **$12.6B** (2030$)	**$10.6B** (2020$)/ **$14.9B** (2030$)	**$10.6B** (2020$)/ **$14.9B** (2030$)	**$28.9B** (2020$)/ **$40.7B** (2030$)
Incremental MBTA Systemwide Revenues (2020$)	**$29M**/Year	**$52M**/Year	**$52M**/Year	**$58M**/Year	**$48M**/Year	**$15M**/Year	**$80M**/Year
Incremental MBTA Commuter Rail O&M Costs (2020$)	**$130M**/Year	**$379M**/Year	**$439M**/Year	**$333M**/year	**$304M**/year	**$304M**/year	**$643M**/year

Objective 1: Match Service with the Growing and Changing Needs

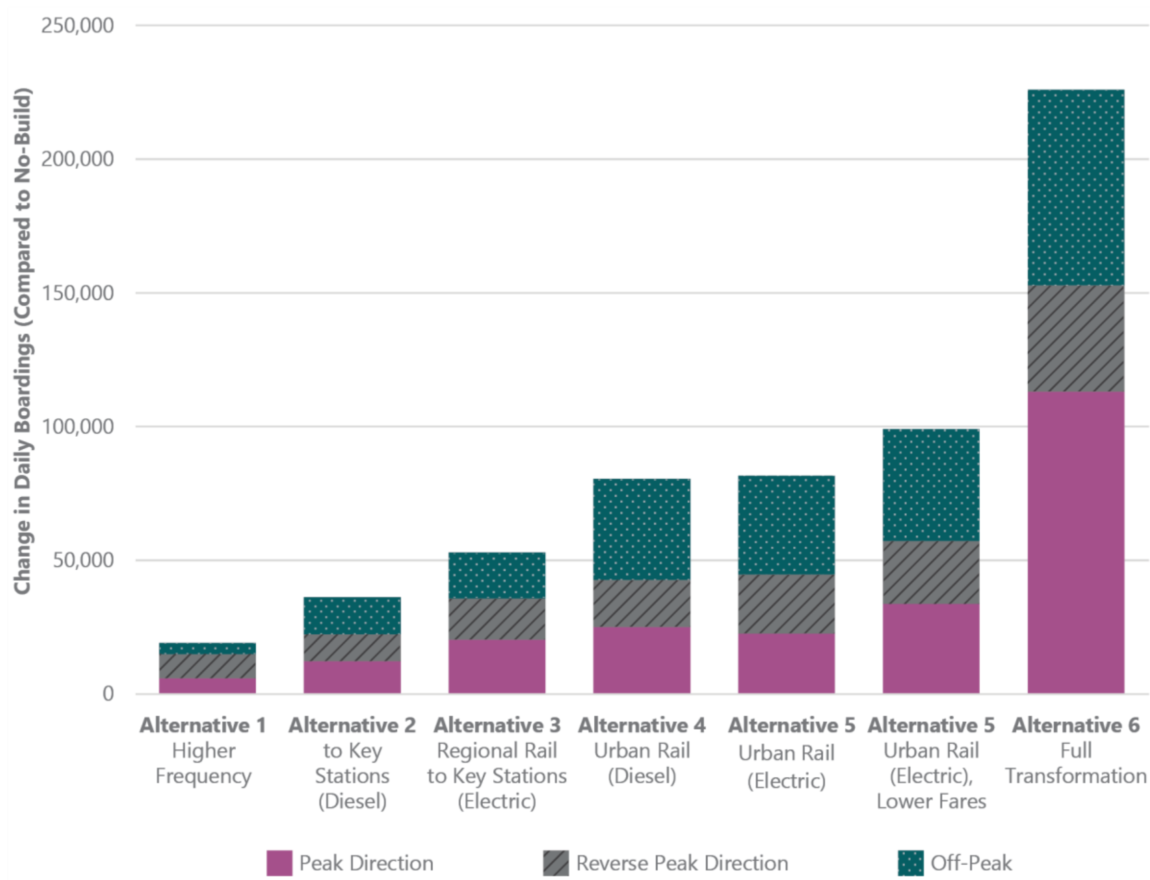
The Objective 1 metrics evaluated growth in ridership. The analysis found that the following factors increased ridership:

- *Urban rail* generated more ridership than regional rail, demonstrating that the land use surrounding the inner core is more responsive to *high-frequency, all-day, bi-directional service*.
- *Faster travel times* due to frequent express service increased projected ridership at key stations in Alternatives 2, 3, and 6.
- *Unlimited parking* increased projected ridership and is a large reason for the major increase in ridership in Alternative 6. Walk/non-drive access accounted for a larger portion of ridership gains in the urban rail alternatives than the key station alternatives. Ridership growth attributed to unlimited parking may be more challenging to generate in implementation, due to challenges and costs associated with expanding station parking.
- *Lower fares* for urban rail service increased the projected ridership in a variation of Alternative 5 and accounted for a portion of the ridership growth in Alternative 6.

The ridership increase in the lower fare variation of Alternative 5 would also affect the value of other metrics that incorporate ridership (e.g. change in number of jobs accessible within one hour), but those results are not reported separately in this analysis.

The trends in Figure 5-1 also largely apply to projected MBTA systemwide ridership growth and growth in commuter rail passenger miles (i.e., alternatives with higher projected commuter rail ridership growth also had greater projected systemwide ridership growth and passengers traveled more miles on the system).

Figure 5-1 Change in Ridership Demand (Compared to No-Build) for Alternatives 1-6

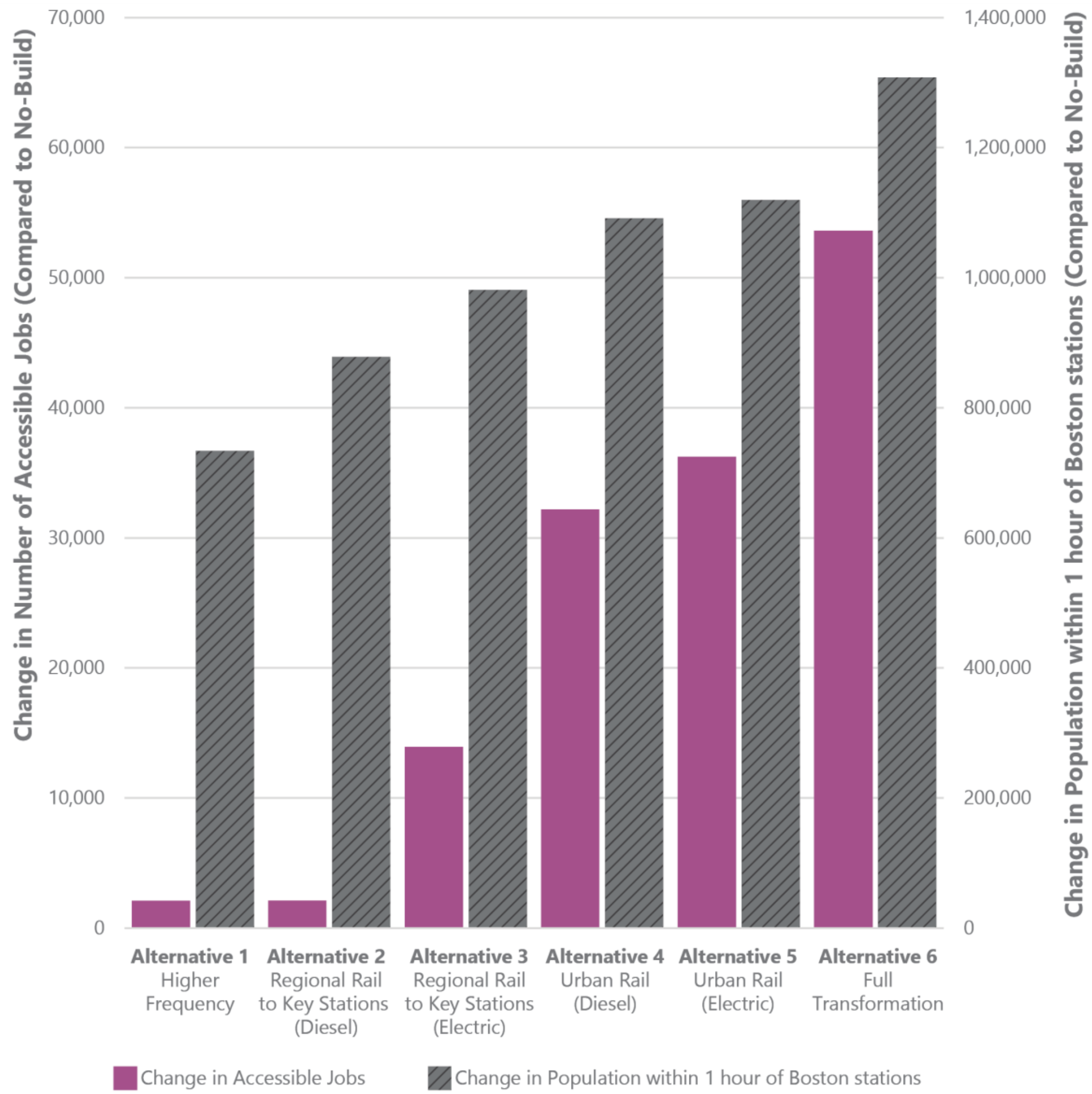


Objective 2: Enhance Economic Vitality

The metrics for Objective 2 evaluated economic vitality by measuring access to jobs and population growth. The analysis found that the following factors improved economic vitality:

- Creating a *repeating schedule with higher frequency service* throughout the day resulted in a considerable increase in the population accessible to Boston across all alternatives, with more growth from the No-Build to Alternative 1 than from Alternative 1 to Alternative 6.
- *High frequency service in the inner core* resulted in significant increases in both accessible jobs and population growth (in Alternatives 4-6).
- Providing *faster service to key stations* resulted in more limited increases in job accessibility than providing high frequency service in the inner core.
- *Improving frequency on the south side* resulted in considerable growth in accessible jobs between Alternatives 2 and 3.

Figure 5-2 Changes in Access to Jobs and Population for Alternatives 1-6



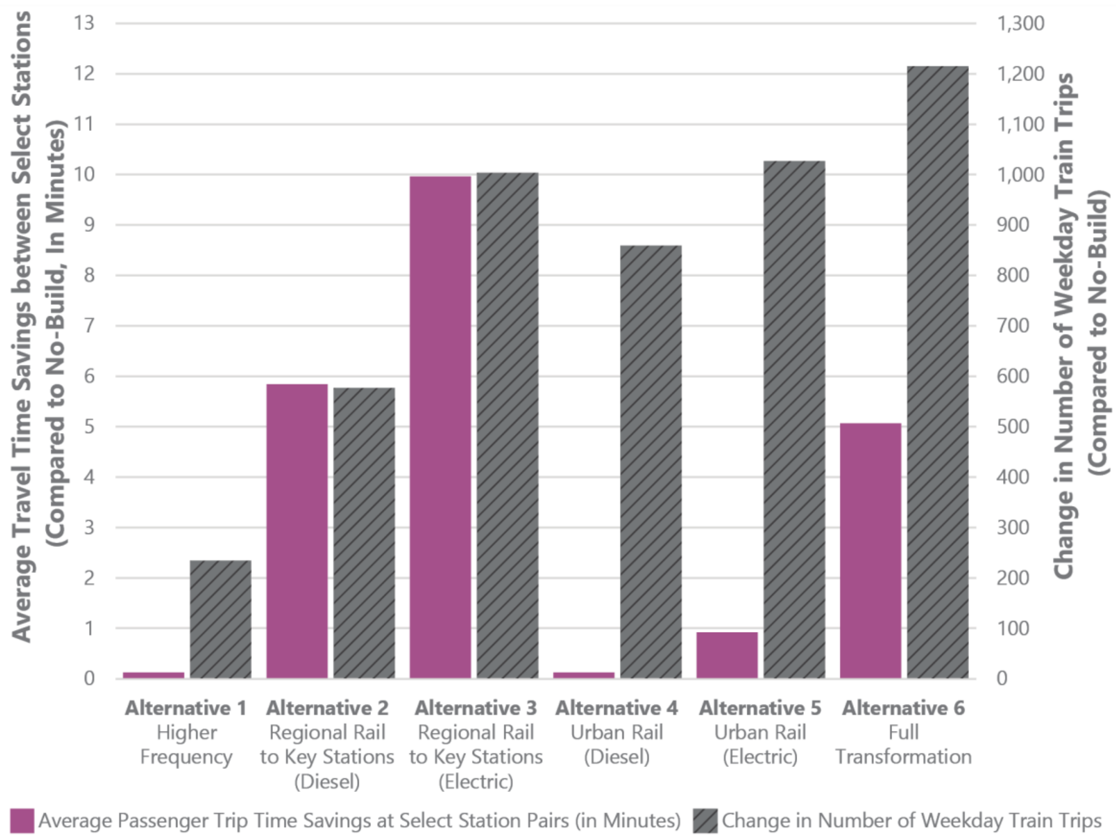
Objective 3: Improve the Passenger Experience

The Objective 3 metrics assessed passenger experience by measuring the travel time savings and increased frequency offered by each alternative, finding:

- *Higher frequency commuter rail, urban rail service, and the full transformation* provide significant increases in the number of train trips. These services focused on bi-directional local stopping patterns, providing increased frequency for a large number of stations, and therefore did not provide as much travel time savings.
- *Regional rail* resulted in the greatest average passenger trip time savings, although not the highest number of train trips. The travel time savings came from the number of trips that only stopped at key stations, meaning that other parts of the system saw more limited increases in frequency.
- *Electrification* resulted in faster travel times compared to using diesel equipment, particularly due to acceleration benefits from making frequent stops (e.g., on local trips).

How passengers value travel time and frequency varies and depends on their circumstances and how they are using the system. Passengers traveling shorter distances on commuter rail may value frequency, and the flexibility it brings, whereas long distance travelers may value travel time more. In addition, this analysis focused on service patterns and did not detail other factors that affect passenger experience, like amenities.

Figure 5-3 Travel Time Savings and Frequency of Trips for Alternatives 1-6

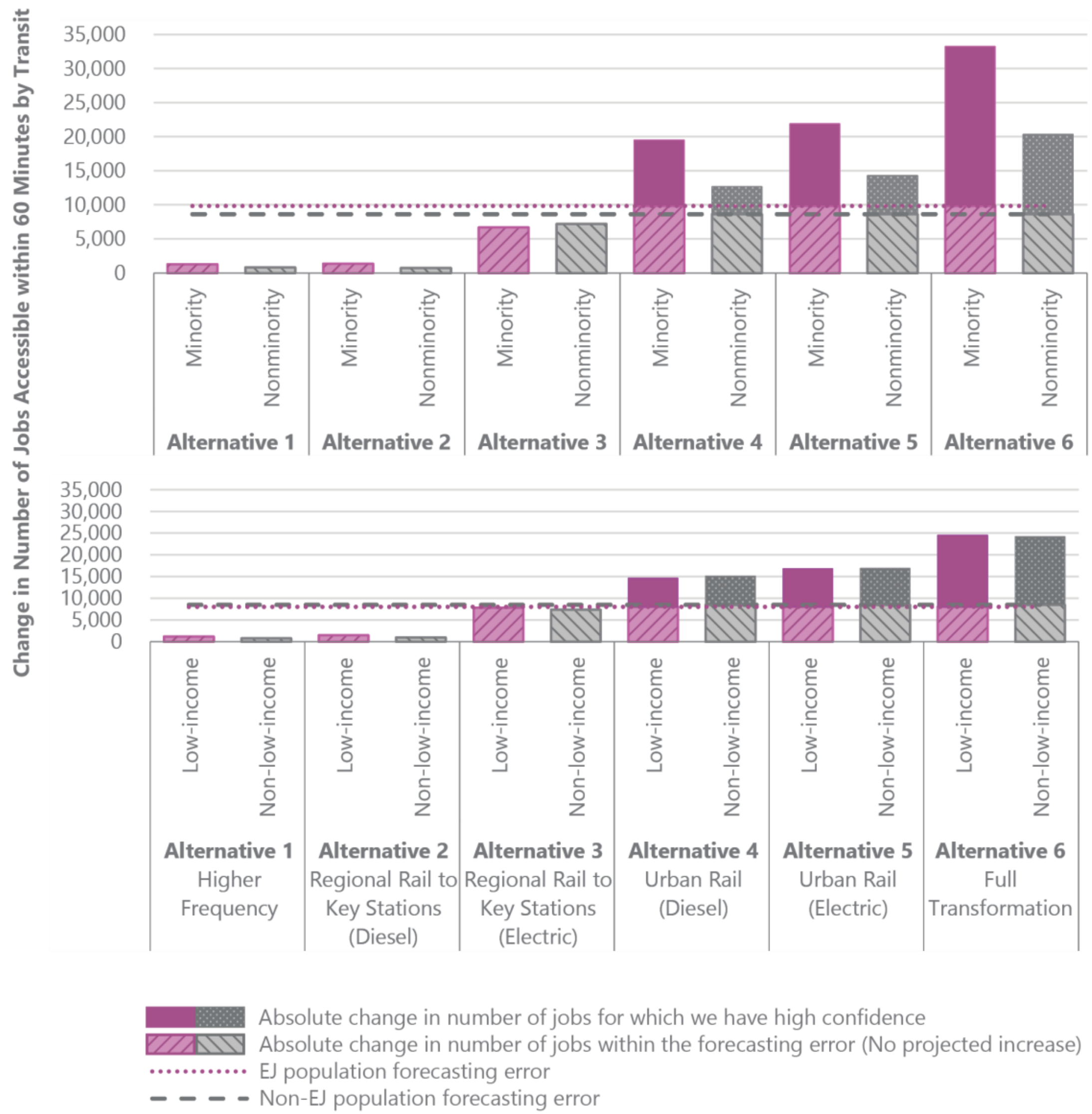


Objective 4: Provide an Equitable and Balanced Suite of Investments

The metrics for Objective 4 evaluated equity by comparing how the alternatives benefitted EJ and non-EJ populations. The evaluation found the following:

- *Higher frequency service within the inner core* benefits minority and low-income communities. In Alternatives 4-6, the analysis forecasted that minority communities would have a greater increase in jobs accessible within 60 minutes by transit than non-minority communities, while Alternatives 1-3 resulted in no impacts to either the minority or nonminority populations because the projected changes were less than the forecasting error.
- *Electrified services' quicker travel times* improve job access, shown in the results for Alternatives 5 and 6.
- *Growth in job accessibility for low-income populations* was comparable in magnitude to the growth for non-low-income populations where the projected impact was greater than the forecasting error.

Figure 5-4 Change in Number of Jobs for Alternatives 1-6 for EJ and Non-EJ Populations

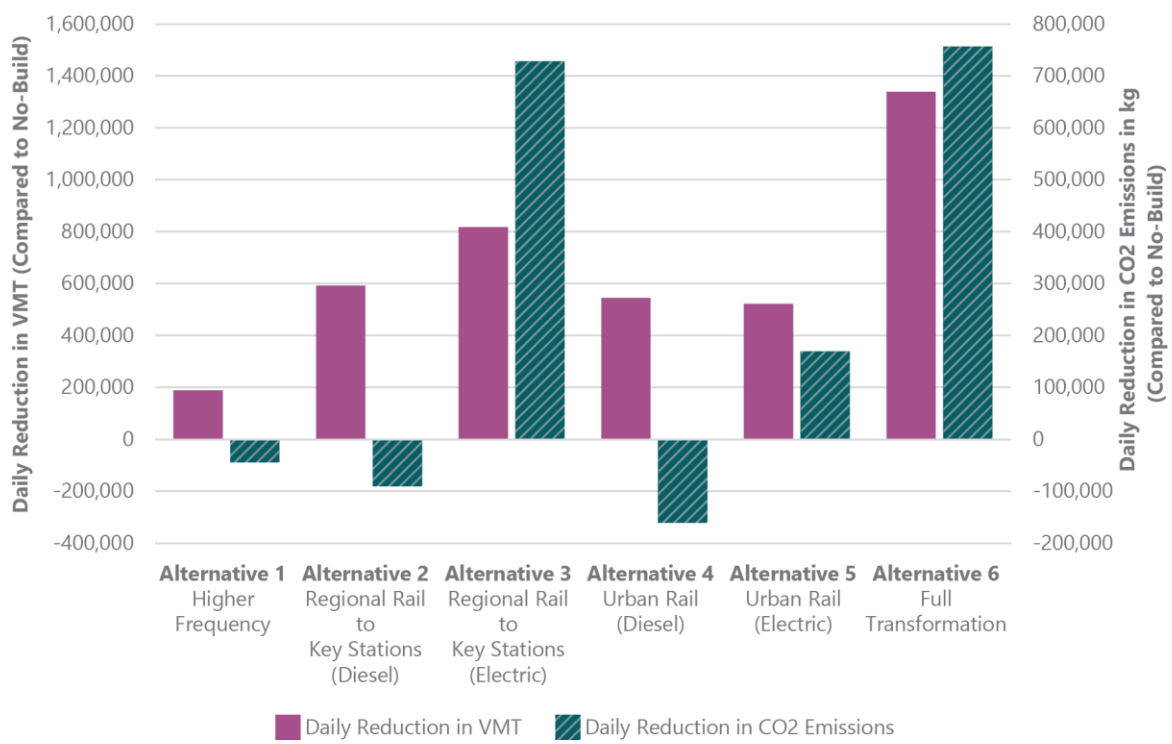


Objective 5: Help the Commonwealth Achieve its Climate Change Resiliency Targets

The Objective 5 metrics assessed the impacts of each alternative on climate change and related metrics. Based on the evaluation:

- *Electrification* results in the highest reductions of greenhouse gases. Alternatives with urban rail or full system electrification had projected net reductions in carbon dioxide (CO_2) and nitrogen oxide (NOx) emissions, while diesel-powered alternatives increased these emissions because the increase in diesel-powered train miles. Essentially, running diesel-powered trains at high frequencies all-day did not generate enough ridership (and associated mode shift) to outweigh the emissions associated with the service.
- All alternatives result in *VMT and VHT reductions* (with VHT reductions trending in a similar pattern as VMT reductions).
- *Alternatives with urban rail* had the highest number of auto diversions and largest transit mode share, but lower VMT reductions than regional rail. The *longer trip lengths associated with regional rail* drove the VMT and VHT reductions.

Figure 5-5 Reduction in VMT and CO_2 Emissions for Alternatives 1-6

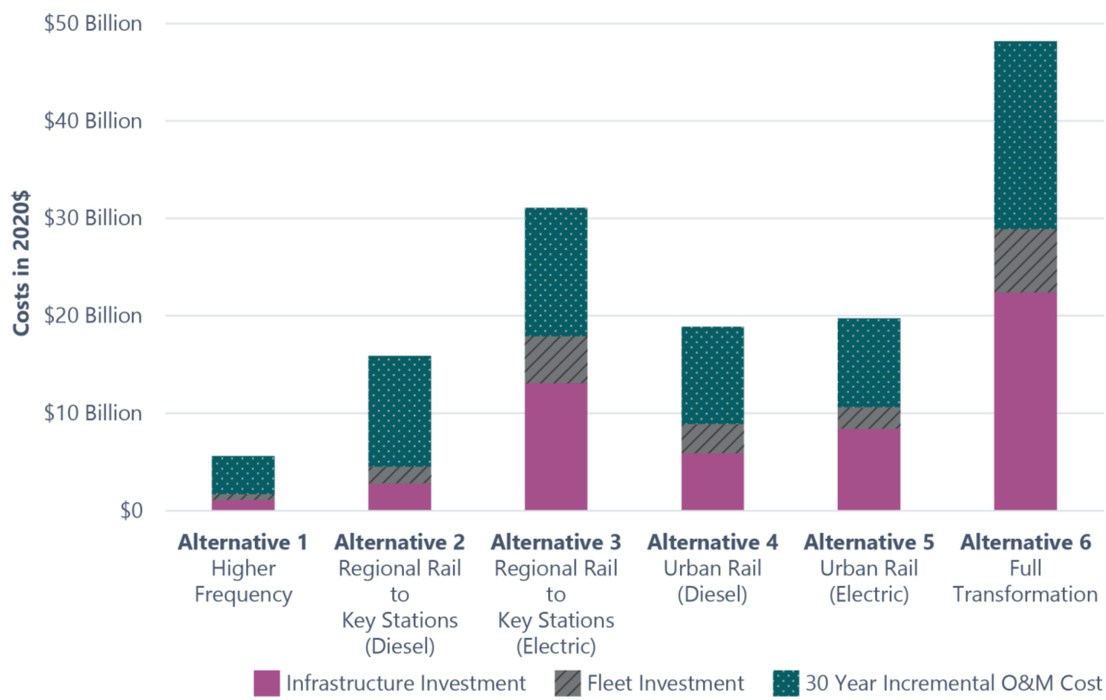


Objective 6: Maximize Return on Investment (Financial Stewardship)

The analysis for Objective 6 evaluated financial metrics. The evaluation found the following:

- The *range of costs* reflects the service and capital intensity of the alternatives.
- *Electrification* increases capital costs due to the infrastructure investment, but reduces O&M costs compared to diesel alternatives.
- *The full transformation* had the greatest financial impact, with a capital investment of $28.9 billion and an O&M cost increase of $643 million annually.
- *All alternatives would increase the per passenger operating subsidy*. Increased revenues would not offset increased O&M costs. Alternatives 1 and 6 had the smallest increases at $0.56 and $0.61 per passenger, respectively. Since parking assumptions (e.g., unlimited parking at most stations in Alternative 6) impact ridership and fare revenue, the subsidy may increase without improvements to access.

Figure 5-6 Life Cycle Costs for Alternatives 1-6 (in 2020$)



Feedback - Stakeholder and Public Input

As discussed in Chapter 1, the process engaged stakeholders in a variety of ways. One key method was the non-rider survey, to which there were nearly 3,000 non-rider respondents. The non-rider perspective is important since meeting the first objective of Rail Vision requires reaching markets not currently using Commuter Rail. The survey confirmed that non-riders weigh convenience and travel time more heavily than cost when deciding whether to ride the Commuter Rail. This indicates the current service is not convenient or fast enough to meet their needs. A high-level review of the responses showed that **non-riders had a breadth of needs and preferences for using the system** (e.g., when to use the system, whether more express or local service would be more valuable), and it is challenging to simultaneously meet those needs.[15]

Other key takeaways emerged from the Advisory Committee meetings, legislative and community briefings, and public meetings, including:

- Frequent service (i.e., trains every 15 minutes) is important, especially in the core;
- Expanded station parking, especially at the outer stations, would support more ridership;
- Minimizing the environmental impact and combating climate change is important, and electrification is viewed as a means to achieve this goal;
- Reliability is critical for passengers as even small delays ripple through the service;
- Fare policy should be equitable and designed to maximize ridership, and within the urban core, fares should parallel those of other MBTA transit options;
- Removing barriers to access by providing high-level platforms throughout the system should be a priority;
- Adding regular off-peak service will support mode shift for both work and non-work trips; and,
- An external Advisory Panel should be included as part of the implementation.

Many of these points complement the quantitative findings and provide a context for the potential prioritization of projects for implementation. **In general, the project revealed a deep interest in transforming the system consistent with the project objectives.**

Key Takeaways

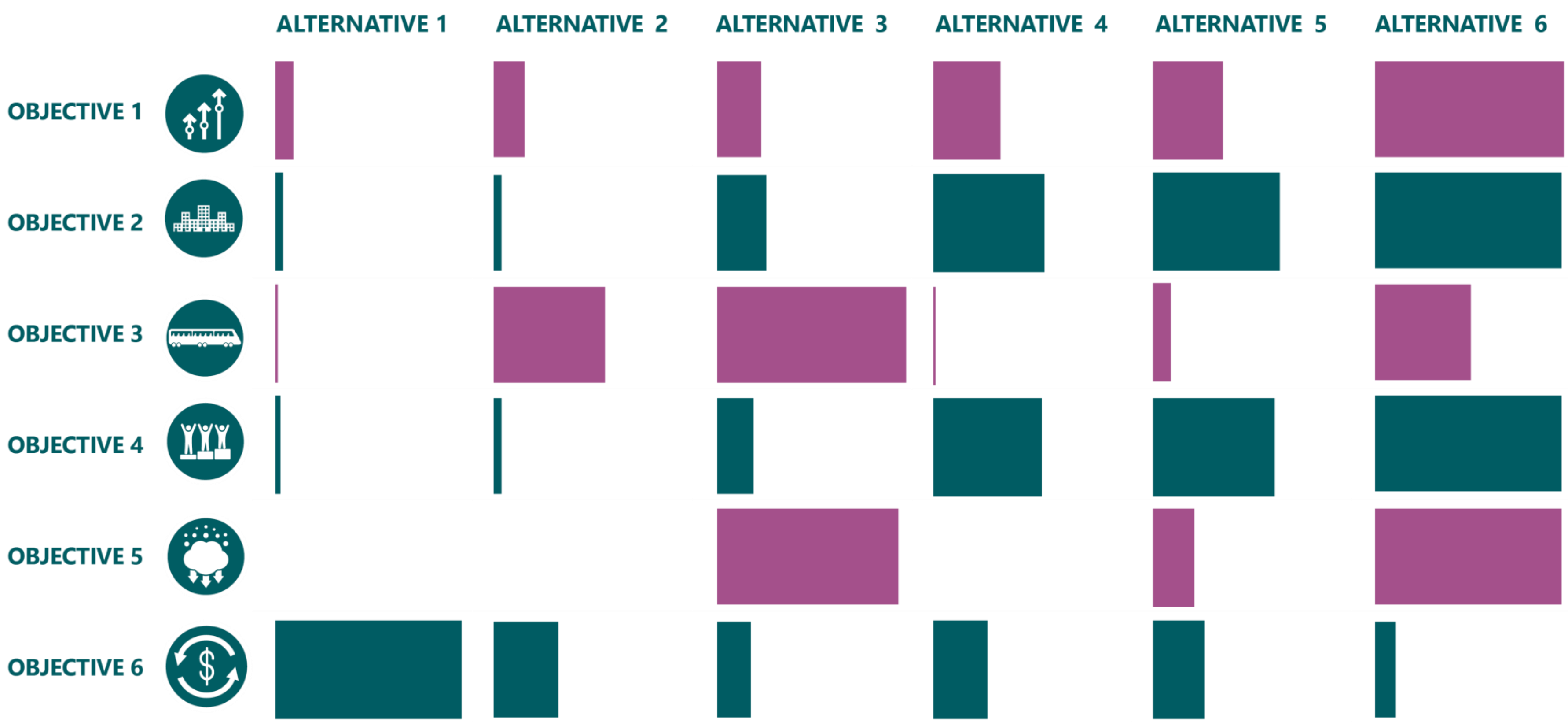
Comparison of the Alternatives across all six objectives reveals the following (Figure 5-7):

- *Frequency drives ridership* (particularly in the inner core and for minority and low-income communities), *lower fares* result in additional ridership, and most trips still occur in the *peak period/direction* even with all-day bi-directional service,
- *Generating ridership results in auto diversions*, which reduces VMT, VHT, and emissions, but does not outweigh the emissions associated with running frequent all-day diesel-powered service;
- *Electrification enables faster travel times and reduces emissions*, but has a more limited impact on ridership;
- *Service increases in the inner core generate more walk-up service* than in the outer parts of the region, where the construction of *additional parking* may be required to see ridership gains; and
- *Improvements present a range of costs and benefits*. Alternative 1 provides benefits for a fraction of the cost of other alternatives. Alternative 5 shows that urban rail could provide many of the full transformation benefits at a portion of the cost. Alternative 6 provides the most benefit at the highest cost.

[15] The survey is available on the project website at: https://cdn.mbta.com/sites/default/files/projects/commuter-rail-vision/downloads/2019-05-03-non-rider-survey-final-results-accessible.pdf.

Figure 5-7 Key Takeaways from the Systemwide Alternatives Evaluation

Although the Systemwide Alternatives evaluation tested six alternatives, the final Rail Vision could include components from a mix of the alternatives. This figure summarizes the relative results of the Systemwide Alternatives in terms of each of the six Rail Vision objectives. The alternatives are listed across the top, and the objectives are listed down the left side. The shaded bars represent the relative advantage of each alternative for each of the objectives. If the column for one alternative is mostly shaded from top to bottom, then that alternative offers the most positive impact across the six objectives



The graphic includes the following metric for each objective to represent the relative advantages. Including different metrics for each objective would affect the results shown

Objective 1: Change in Commuter Rail Boardings
Objective 2: Change in Number of Accessible Jobs
Objective 3: Average Passenger Trip Time Savings at Select Station Pairs
Objective 4: Change in Accessibility to Employment for Minority Populations
Objective 5: Daily Reduction in CO_2 Emissions. Note this is left blank where there is a projected increase in CO_2 emissions.
Objective 6: Life Cycle Costs (in 2020$). Note this shows the lowest cost alternative as the most shaded bar and the highest cost alternative as the least shaded bar.

1050
1050
T
DANGER 480 Volts
r Protection Required At This Level
While Locomotives Are Running.

6 Moving Towards the Future

Based on the results of the evaluation and feedback from key stakeholders, the MBTA's FMCB voted on November 4, 2019 to direct the MBTA to **"transform the current commuter rail line into a significantly more productive, equitable, and decarbonized enterprise."**

The FMCB voted on four resolutions related to the Commuter Rail system (Figure 6-1), with an additional resolution related to the bus network. The resolutions:

- Endorsed electrification, higher frequency service, accessibility improvements, and lower fares;
- Identified priority lines and elements of Phase 1 of the transformation effort;
- Proposed the establishment of a Commuter Rail Transformation Office, with the single mission of advancing Rail Vision; and,
- Advocated for new contract mechanisms and new labor practices, and a formal request of the Legislature to enact the reform proposals in Governor Baker's transportation bond bill.

The Rail Vision team has already built up an understanding of the current rail network and its limitations. The Rail Vision Systemwide Alternatives Evaluation provides initial insight into the potential investments needed to achieve the future system the FMCB resolutions describe. Implementing such a transformation requires defining the scope, costs, and timeframes of the specific changes needed.

As a next step, the MBTA would have to develop an effective plan to refine and implement Phase 1 and future improvements building upon initial investments. The following chapters describe this in more detail.

Figure 6-1 FMCB Resolutions

As part of this transformation, the FMCB made the following additional recommendations:

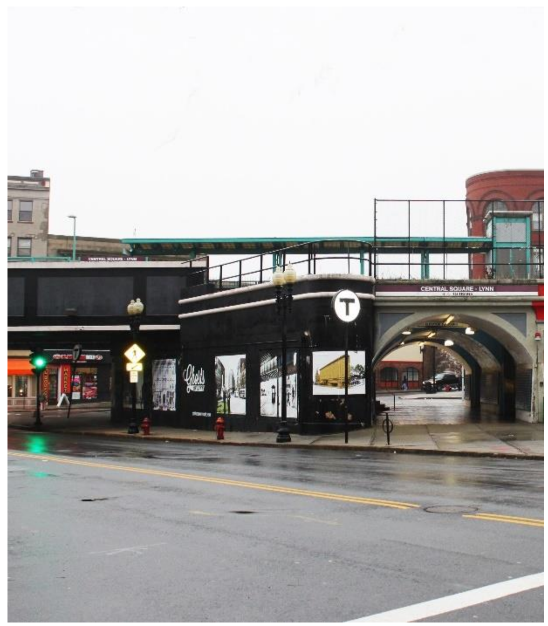
Transforming the current commuter rail into a significantly more productive, equitable, and decarbonized enterprise would:

- Provide service similar to rapid transit, **all day service on its most dense corridors at 15-20 minutes headways,** and appropriately scheduled additional service on all of its lines;
- Be largely **electrified;**
- Fully **integrate** rail service with the rest of the MBTA system; and,
- Implement **first mile/last mile** and **increased parking access** as part of this program.

1. Create a set of options to **maximize ridership returns on investment** over the next 10 years
2. Support a pathway to more improvement over the long term with **particular emphasis on lines that are most likely to be well used**
3. Develop a **program of high-level platform implementation** in a sequence that is consistent with the Program for Accessible Transportation Investment (PATI) and optimizes impacts for the customer

Immediately take steps to prepare for implementation for **Phase 1** of the transformation:

1. EMU powered service along the **Providence/ Stoughton Line**
2. EMU powered service with rapid transit headways at fare levels akin to the fare structure of the rapid transit system along the **Fairmount Line and Newburyport/Rockport Line** through Lynn (covering Boston, Everett, Chelsea, and Revere)



Immediately establish a **Commuter Rail Transformation Office,** which shall:

1. Contain responsibility for all short-, medium- and long-term elements of transformation including developing and maintaining the business case to support the investments needed
2. Develop and implement environmental, financial, procurement, current commuter rail operating agreementre-bid and operational strategies as well as others as needed
3. Be responsible for developing and implementing a stakeholder engagement plan
4. Have no responsibilities outside the transformation mission

Consider **new contract mechanisms** and **new labor practices.**

1. The Board requests the Legislature support the statutory authorization for a public-private partnership and reform proposals in Governor Baker's transportation bond bill proposal.
2. Greater use of the talent and innovation in the private sector is critical and tools that provide the Authority with greater leverage over long term performance of the private sector is essential.


PRUDENTIAL
EXIT
EXIT

7 Translating the Vision into a Delivery Plan

Rail Vision contemplates more than an adjustment to Commuter Rail schedules and operations; realizing such transformative change would require a complete change in thinking about the system. It would require an innovative approach across all aspects of developing, constructing, and delivering rail projects and services.

This chapter sets out a process for turning Rail Vision into a delivery plan. This process begins by defining the desired outcome, and scoping and prioritizing the delivery plan. It then identifies options for financing and funding the improvements. Finally, this chapter describes deliverability elements and challenges to implementation, highlights some dependencies and constraints, and outlines potential risk factors and mitigation.

Defining the Desired Outcome

The first step towards a rail transformation is to clearly define the desired outcome, or end state, for the system and prioritization criteria to support a pathway forward.

While the FMCB resolutions provide a foundation, to move forward, the MBTA and MassDOT would need to clarify the goals of a rail transformation program. Rail Vision outlined six evaluation criteria that work both in concert or in conflict. For example, maximizing ridership and customer experience with high frequency service had varying effects on climate resiliency and sustainability goals, depending on the technology used. Services focused on travel time reductions could reduce connectivity for local communities without express service. An approach that prioritizes economic development may roll out differently than one that prioritizes ridership. All the service approaches require significant investment, but the mechanisms for securing funding may differ depending on the desired outcome.

A clearly defined set of goals would ensure the Commonwealth can develop an effective delivery plan and more accurately measure the success of the program. It would also help bring stakeholders across the region together in support of the proposed future system.

The desired outcome should specify both the end state as defined by user experience – including service availability, access, fares, and ease of use – as well as consider how the system will balance the costs and potential revenue implications. For example, changes to the fare policy to meet certain goals or policy priorities in support of a transformation would have ongoing revenue implications (that may change over time, pending ridership response). Essentially, this transformation would involve more than changing service operations – its success relies on developing a cohesive approach to all factors that affect a rider's decision to use the system. The definition of the desired end state should incorporate all these factors.

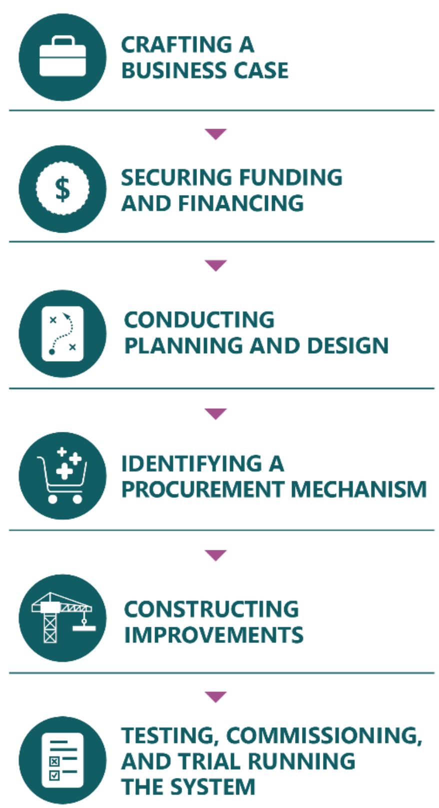
Once the Commonwealth agrees upon a clear desired outcome, the MBTA and MassDOT can use the goals within it to help shape the path toward implementation and the broad prioritization of short-, medium-, and long-term investments.

Scoping and Prioritizing a Delivery Plan

No matter the details of the desired end state, transforming the operations of 14 rail lines across nearly 400 miles is not a simple, straightforward task. Delivery of a program of this magnitude requires a multi-stage process, each step of which contains challenges. The MBTA would need to employ a framework for scoping all of the specific components of this type of capital program to ensure each deliverable and project works in concert towards the end goal. At a high-level, a delivery plan would consist of the following elements (Figure 7-1):

- *Crafting a Business Case:* The Commonwealth has an unprecedented opportunity to improve mobility options for people in the Boston metropolitan area, strengthening the region's economy and addressing equity and climate goals. Quantifying the key benefits of these changes would support the case for investment. A business case would be a living document. As planning and design progresses, the level of detail would increase and the MBTA would refresh and re-confirm it, particularly as technological improvements may affect the scope over time.
- *Securing Funding and Financing:* The ability to deliver the investments required for a system transformation would depend in large part on securing additional funding, likely from a number of sources. In other regions, funding has included state, municipal, and private sources as well as federal grants.
- *Conducting Planning and Design*: This would include stakeholder engagement and potentially securing planning authorizations; ensuring compliance with environmental standards (e.g., noise, vibration, waste and ground water, air pollution, waste management); and securing temporary or permanent restrictions (e.g., closures and diversions affecting highways and pedestrians).
- *Identifying a Procurement Mechanism*: The MBTA could source contracts for construction, commissioning, and operation either individually or as a bundle with potential options for risk transfer, including performance.
- *Constructing Improvements:* As part of the delivery plan, the MBTA would need to consider how to undertake construction with minimal disruption to Commuter Rail operations, and assuring safety throughout. It may be difficult to carry out work during the hours of service operation; however, modern methods involving partial assembly of equipment and structures off-site and efficient installation processes could help to minimize the duration and extent of service interruption.
- *Testing, Commissioning, and Trial Running the System:* Introducing new equipment, signaling, and/or electrification would require extensive testing to ensure the integrity of system safety and reliability of operation. This critical activity would require fully testing the vehicles or technology prior to introducing it into revenue service.

Figure 7-1 Key Stages in Work Package



Funding and Financing

The magnitude of the transformation presents unique opportunities and challenges in identifying potential funding sources. Evaluating the available **federal, state, regional, local, and private funding opportunities** would entail understanding the requirements, approval processes, legal authority, and potential revenue generation associated with each. Participation by other key agencies and partners would be essential to securing the necessary buy-in to move forward.

Any future path would need to ensure effective financial stewardship. From the outset, a successful program would need to focus on achieving financial sustainability.

The early stages of implementation would require high-level cost estimates for interventions of different scales, natures, and complexities. However, the long-term nature of the program means there is a significant degree of uncertainty in the projections for ridership and revenues. Therefore, the process should provide a reasonable and realistic allowance for variation above and below the central financial projections. This approach would recognize that value for money refinements of the program would inevitably result in adjustments to the specifications and the timing of delivery.

Cost estimates should reflect the whole-life and whole-system impacts of the proposed investments. This would require an understanding of asset performance and life expectancy in order to forecast the costs of operations, maintenance, and renewals. It would also require accounting for the regular maintenance and upgrades the MBTA would pursue, regardless of the program's direction, as the Rail Vision alternatives did in the fleet cost estimates. A well-designed investment and delivery plan would better control some upfront costs and minimize longer-term O&M costs.

Other key considerations in developing cost projections include:

- Understanding the relationship between costs and program schedule, including the scale of program risks; and,
- Considering the true cost of the disruptive impacts of intervention works, not only to the rail system, but also the potential effects on users of other modes, residents, and businesses.

Ensuring effective cost control during project development and implementation requires a robust project governance structure with appropriate risk allocation, clearing of program interdependencies, and mitigation plans for project delays. Meanwhile, calculating the net full costs should incorporate revenues from fares and other sources, such as commercial retailing and property development.

As the transformation progresses, the MBTA would need to update and refine ridership and revenue forecasts to reflect adjustments to scope (endogenous effects) and external factors (exogenous effects, e.g., demographic and economic changes) that affect ridership. Ridership and revenues are sensitive to fare levels, and the MBTA could test potential alternative fares strategies to assess how best to ensure the financial sustainability.

Once the MBTA identifies the total financial needs to transform the Commuter Rail, it may require a significant increase in rail investment funding. An overall **financing plan** would then need to include a cash flow analysis for the duration of the capital improvements and close the funding gap between the total capital and operating costs and existing revenue sources.

MassDOT and the MBTA could draw on a number of potential **traditional funding options** with federal, state, or municipal government sources. Table 7-1 identifies some of these sources. The eligibility requirements for many of the existing funding sources are extensive and vary depending on the final project scope.

Funding the investments may require a blend of programs through various Federal Railroad Administration (FRA), FTA, and other U.S. Department of Transportation (U.S. DOT) competitive and formula funds. For example, the FTA's Capital Investment Grant Program (CIG) applied to a New Starts or Core Capacity Project could provide funding given the mix of rail services that the Boston's Commuter Rail provides. Commuter Rail improvements could also be eligible for flexible highway funding programs if they can demonstrate a substantial reduction in traffic congestion on key highway corridors through modal shift. It is also important to consider the use of various types of federal financing assistance under Transportation Infrastructure Finance and Innovation Act (TIFIA), Railroad Rehabilitation and Improvement Financing (RRIF), and Private Activity Bonds (PAB) as well as to incorporate opportunities for private sector participation.

Several of the traditional funding sources require a project-specific benefit-cost analysis. As some benefits could only be achieved through the full delivery of the transformation program, it may be difficult to secure these types of grants on a project-by-project basis.

MassDOT and the MBTA could also develop other more **innovative funding streams** to pay for the capital improvements (Table 7-2), particularly as transforming the system would likely drive significant change to the economic, commercial, and environmental well-being of the region.

Table 7-1 Potential Traditional Funding Sources

Traditional Funding Options
FRA Consolidated Rail Infrastructure and Safety Improvements Program (CRISI) and Federal-State Partnership for SOGR
FTA Capital Investment Grants: New Starts or Core Capacity
U.S. DOT Better Utilizing Investments to Leverage Development grant program (BUILD) and Federal Highway Administration (FHWA) Surface Transportation Program (STP) and Congestion Mitigation and Air Quality (CMAQ) Programs
U.S. DOT TIFIA and RRIF loans, and PABs
Commonwealth of Massachusetts funding (sales tax)
Dedicated local assessments

Table 7-2 Potential Alternative Funding Options

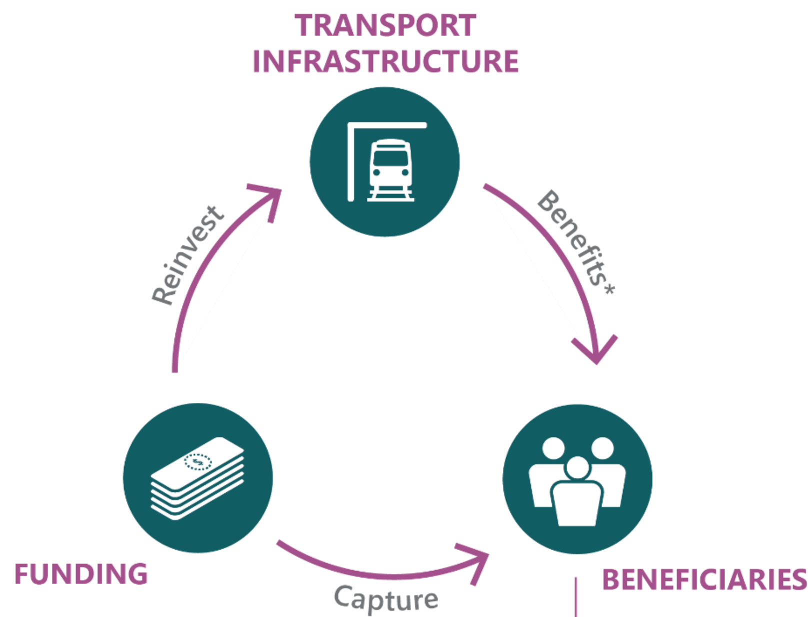
Alternative Funding Options	Examples of Application
Transit-Oriented Development policy lever	NYC Hudson Yards, Vancouver (and other cities)
Joint Development	Washington DC Metro (Ballston, Bethesda, etc.); BART (Fruitvale, Richmond, etc.)
Commuter Tax	Paris, France (and in the past, NYC)
Business Taxes	Crossrail, London, UK; UK generally; France
Highway Tolls	NYC (cross-subsidy of PANYNJ revenues for PATH)
Passenger Facility Charge	Numerous airport transit links across U.S.
Cap-and-Trade/Carbon Fee	California High Speed Rail (and Vancouver Translink)

These innovative funding streams could range from land value capture schemes or transit-oriented development at or near rail stations, as well as other user or regional transportation fees. Demonstrating that regional value exceeds income captured from the beneficiaries of Rail Vision (Figure 7-2) would help justify these measures. In addition, construction of housing, retail, and commercial spaces near Commuter Rail service could support ridership increases.

While alternative streams can provide a useful means of supporting the funding of major transformational rail projects, these sources do not operate in isolation. Typically, such projects involve complex delivery programs over long timeframes where there will always be significant uncertainty. Only the government has the capacity to shoulder the risks associated with such uncertainty.

In addition to funding capital improvements, the MBTA would also need to fund ongoing operations. This would include maintenance and renewal of the rail infrastructure and equipment assets, and meeting any gap between operating costs and revenue. The operation of any public transportation system rarely, if ever, can generate enough income to offset costs, so it is critical to identify the appropriate mechanism for supporting operations.

Figure 7-2 Virtuous Cycle in Infrastructure Investment



BENEFICIARIES

DEVELOPERS

Benefit from land value increase as more businesses and/or residents look to relocate. This can result in higher density, increased rental values and/or sale incomes

BUSINESSES

Benefit through agglomeration as greater productivity and lower cost arise from the concentration of economic activity alongside access to a wider labor pool

TRANSPORT USERS

Benefit from improved provision of public transport and reduced highway congestion

LAND OWNERS

Benefit through an increase in land values that result from an increase in demand of businesses and/or residents to relocate nearby

RESIDENTS

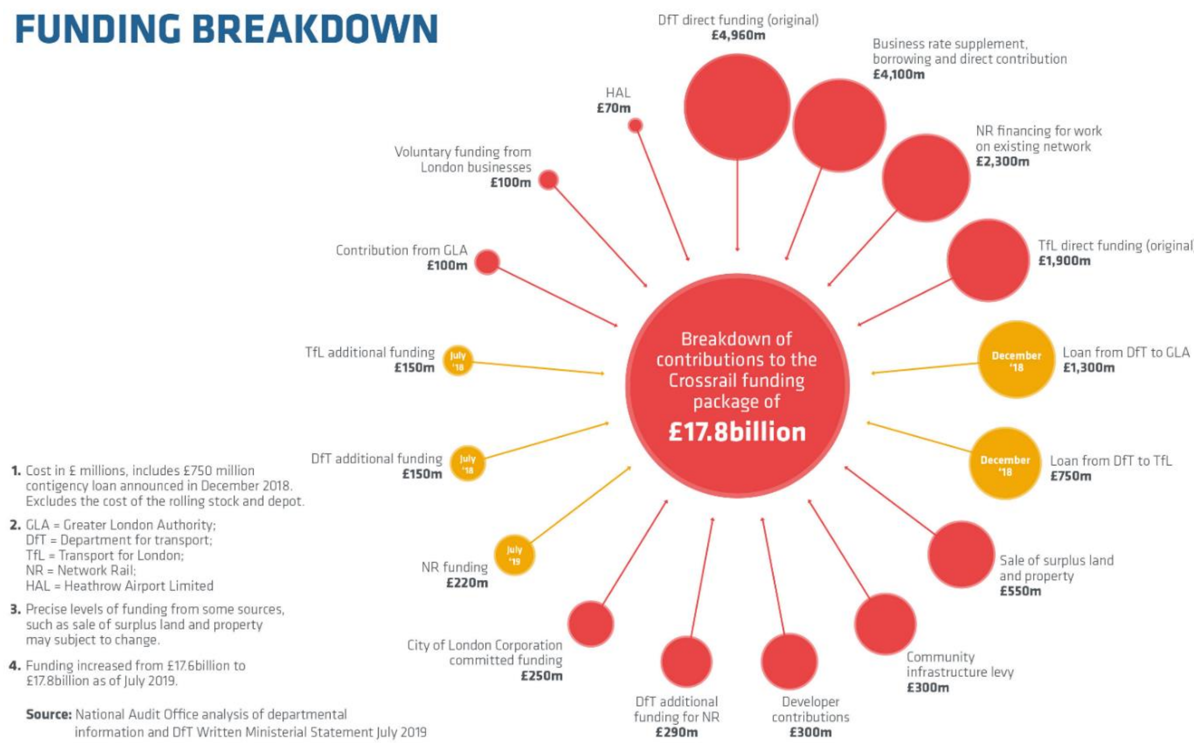
Benefit from access to more jobs

*(e.g. land value appreciation)

Other major metropolitan areas globally have faced similar challenges in funding major changes to passenger rail. Some have sought to reduce the reliance on government funding by seeking alternative funding streams. For example, in London, the £17.8 billion (US $23.5 billion) Crossrail Commuter Rail project has sought funding from a wide range of sources that have included the sale of land and property, developer contributions, and Heathrow Airport Ltd, a key stakeholder in the project. As is illustrated in Figure 7-3, nearly 60% of the total funding was raised by alternative means, though less than 5% was raised through land value capture mechanisms.

In Toronto, Metrolinx is seeking to engage private sector investors to help deliver its Regional Express Rail (RER) program. As of Winter 2020, a procurement is underway to seek a delivery partner for this proposed Design Build Finance Operate Maintain project, which would transform the transportation network in the Greater Toronto and Hamilton Area. The project seeks to modernize and expand the GO Transit rail network into a system that delivers two-way, all-day services every 15 minutes over core segments of the network. Systemwide infrastructure upgrades include adding tracks, expanding stations, electrification of the rail network, and procuring new locomotives and train control systems to enable more frequent service.

Figure 7-3 Breakdown of Funding Sources for Crossrail



Other projects in the U.S. and internationally have tapped into locally and regionally generated sources for funding that seek to capture a proportion of the generated benefits. Los Angeles voters approved Measure M in November 2016 with over 70 percent approval. Measure M authorized a new one-half cent sales tax to help fund 40 major highway and transit projects, generating over $100 Billion by 2039. Other regions which have embraced similar, if smaller, alternative funding streams include Atlanta, the San Francisco Bay Area and Seattle. In Europe, agencies have funded large scale capital projects through business, employer, and land value capture mechanisms.

The extension of the New York City number 7 subway line to Hudson Yards used some non-traditional funding techniques. The Hudson Yards redevelopment included over $3 billion of infrastructure improvements, including the subway extension and road and public space enhancements. While delays in development have resulted in changes to how the financing of the infrastructure works, the project received much of its funding from developer contributions and an increase in property taxes generated by the development and surrounding properties. This future property tax income stream is anticipated to help pay off the initial debt raised to construct the subway and other public works.

Deliverability Elements and Challenges

With ever increasing demands on public expenditure, ensuring value for money and good financial stewardship of public funds is essential. The MBTA would need to demonstrate that the transformation and the elements within it would deliver a positive return in benefit to cost terms. The MBTA would need to **scale the scope and timing of improvements to the amount of funds available.**

A rail transformation and the associated delivery plan would need to consider the elements and potential challenges subsequently described.

Phasing and Integration

To transform the Commuter Rail, the MBTA would need to **establish a coherent integrated master program** that enables realization of passenger benefits at the earliest opportunity, while **phasing the major work packages** in a way that is realistic and affordable. It would be particularly important to make the case for investment throughout the stages. This would require clear definition of roles and responsibilities to "own" each subset of work or project, including clarity on scope and funding, and ensuring that contracts set out how to appropriately interact with existing operations. In terms of schedule, achieving short-term benefits is important for rider support, but should not come at the expense of allowing sufficient contingency to absorb project delays.

Major transformation programs take many years to implement, with the construction of improvements staged over intervals. Rehabilitation or renewal of structures, track, or signaling systems can require temporary stoppage of services or closure of sections of the network. The MBTA would need to plan and program such work so as to minimize their disruptive impacts (including temporary interruption of train services, highway closures, and disturbance to neighborhoods) while maximizing efficiency. This includes the need to establish effective and well communicated plans for alternative transportation arrangements during planned service interruptions.

Phasing would also include tackling the backlog of work required to ensure that the rail system assets are in a SOGR. This will be an essential precursor to delivering a safe and reliable Commuter Rail system. In setting out the program for delivering a rail transformation, there would be trade-offs between implementing enhancements and reducing the SOGR backlog. There may also be opportunities to realize efficiencies where the renewal or enhancement of assets can be scheduled to avoid abortive SOGR works.

The MBTA would need to logically sequence activities to account for critical interdependencies. It would be important to develop strategies for mitigating risks arising from interdependencies between asset upgrades. For example:

- Operating new electric equipment requires route electrification, which would also require new power distribution systems to supply electricity to Commuter Rail; and,
- Modern signaling and control systems use technologies that typically interface with equipment on-board systems, requiring a whole-system approach in the planning and delivery of rail modernization programs.

Successfully delivering a transformation would be dependent on the functional capability and capacity of the railroad infrastructure and fleet.

The MBTA would need to develop a set of **incremental interventions** to adjust service patterns in an iterative process. The relationship between incremental steps in increasing service frequency and reducing travel times, and the interventions to achieve them is not linear. Overcoming critical constraints, such as bi-directional single tracks, would be subject to value assessments. Planning and design efforts could identify ways to optimize service patterns or make slight adjustments to service plans to significantly reduce the capital investment required.

Similarly, technical solutions for other critical path interventions (such as expanding stations with extra platforms to accommodate higher frequencies or platform extensions to allow longer higher capacity trains), accessibility improvements (such as platform height changes), and new stations would all require specification and value assessment. The MBTA would need to align any improvements to station accessibility with the agency's Plan for Accessible Transit Infrastructure (PATI). This would not only enable travelers with accessibility needs to access the service, but would also enhance the passenger experience by reducing dwell times at stations to offer faster travel times.

Project Resources

To transform the system, the MBTA would need to ensure that there are sufficient resources **to manage the delivery program.** The scale of ambition is unprecedented in the region, and inevitably resources would need to be drawn in from elsewhere. The MBTA and MassDOT would need a recruitment strategy to onboard staff and initiate consultant contracts dedicated to this program with a variety of skills including: project management, commercial expertise including contract negotiations, business and economic analysis to ensure any works support the business case, and stakeholder engagement capabilities.

Similarly the MBTA would need to consider the supply chain and its capacity to draw on critical specialist resources (e.g., railroad signaling and electrification system engineers), which could slow progress if not carefully planned. For example, procuring new vehicles is a lengthy process because of the time required to design and build the vehicles, but also because the limited number of suppliers might have other orders already in process.

Fleet and Layover Strategy

The MBTA Commuter Rail system is extensive and comprises distinct north and south networks. To deliver additional service and types of service, the MBTA would need to procure new equipment, which may include a mix of locomotives, bi-level coaches and cab cars, and EMUs. For each fleet, the MBTA would need to develop specifications to define attributes such as:

- Performance capability to meet train service plan requirements;
- System interface compatibility, including signal, control, and communications systems;
- Safety and legislative standards;
- Inter-operability with existing train fleets (if mixed fleets are proposed); and,
- Minimum reliability thresholds.

Procurement of new fleet would require the MBTA to **create an equipment strategy** that sets out the requirements for each delivery phase. This strategy would need to reflect the introduction of successive new fleets and how they would be transitioned into service, taking into account the supporting infrastructure required for maintenance, servicing, and parking at strategic locations across the network.

An expanded fleet with new equipment technologies would likely require associated new layover storage, service and inspection, and maintenance facilities. These could require working with municipalities to site new facilities and acquire land, which can be a challenging and costly endeavor. The location of these facilities would ideally support efficient operation of the train service plan and therefore would be an important part of the fleet strategy.

Performance and Reliability

Providing a punctual and reliable Commuter Rail service is critical to the passenger experience. Achieving this would require **embedding operational performance and reliability requirements in system design**, including for equipment and infrastructure. Any future plan would need to design resilience into the system to withstand adverse weather conditions, and redundancy to enable sustained service operations during partial planned or unplanned outages. The MBTA may need planned outages to enable critical activities, including asset maintenance, renewals, or enhancements. Unplanned outages could arise as a result of asset faults (e.g., power failure), weather related events (e.g., fallen trees, flooding, landslides) or external events (e.g., vandalism, trespass). The threats of extreme weather events occurring with increasing frequency and intensity are testing many rail transport authorities around the world. There is a recognition that systems need to be designed with greater robustness and resilience to mitigate these threats, and agencies need to have effective contingency plans for when they do occur.

Technology Strategy

Modern equipment brings with it updated or new technology. Introducing new technologies into a live operational Commuter Rail system presents a number of challenges. In transforming the system, the MBTA would need to **develop an integrated technology strategy** that encompasses rolling stock, signaling, control and communications, and electric traction systems. This strategy could include transition plans to minimize temporary degradation or stoppage of train services as new systems and equipment are commissioned.

Dependencies and Constraints

A system transformation would be subject to dependencies, some of which may be controllable while others, less so. Examples of potential **controllable dependencies** include:

- *Interfaces with other railroads*: The MBTA Commuter Rail network shares infrastructure with Amtrak, CSX, and Pan Am. To implement major service changes, the MBTA would need jointly agreed solutions with these stakeholders to manage system design interfaces and any associated infrastructure enhancements, as well as negotiate new access arrangements.
- *Coordination with other transit and highway programs*: Major enhancements to the Commuter Rail network would inevitably require periods of temporary disruption to services. At these times, passengers would be dependent on capacity on other modes. Therefore, the temporary closures or capacity reductions on the Commuter Rail system should be coordinated to avoid coinciding with other transit or highway programs so as to minimize the impact on transportation system capacity and capability as a whole. It also requires consideration for major construction efforts affecting other modes, such as closures on rapid transit lines or at stations. At a broader level, coordination is also critical to ensure that multimodal improvements are complementary to enhance overall systemwide efficiencies.
- *Capacity to accommodate growth*: the ability for a system to realize its full potential for ridership growth depends on the capacity of connecting transit systems.

Physical constraints can present challenges to the design and planning processes that are less within direct control of the MBTA and MassDOT. For example, the scope and location of equipment storage and maintenance facilities would be subject to the availability of suitable land; the feasibility of extending platform lengths or adding track capacity could be affected by the presence of structures such as highway bridges. Mitigation could require compromised solutions if additional capital budget cannot be justified.

Another critical constraint over which the MBTA has some, but limited control, is station access. The demand forecasts produced for Rail Vision included unlimited parking availability in some cases. MassDOT and the MBTA are examining ways to improve access to stations. Parking alone cannot meet demand across the Boston region. To reach the growth potential, MassDOT and the MBTA would also need to use other strategies, such as enhanced first/last mile connections, bicycle and pedestrian connectivity, and transit-oriented development near stations. Successful improvements in access would require support from municipal governments across the region.

Status of Other Projects

A key dependency in the success of transforming the rail system would be coordination with other committed or planned transportation projects in the Boston region. These projects could have a direct impact on enabling the MBTA to deliver better Commuter Rail service or support the benefits generated by Commuter Rail improvements (for example, distributing Commuter Rail passengers to parts of downtown Boston not directly served by Commuter Rail).

A number of other ongoing individual projects could impact any transformation efforts. These include, but are not limited to:

- Green Line Extension and Transformation projects;
- Red and Orange Line Transformation projects;
- South Coast Rail;
- Implementation of systemwide PTC;
- Fleet (locomotive and coach) procurement and overhauls;
- Corridor improvements (e.g., Franklin Line Double Track, Worcester Triple Track);
- Station improvements (e.g., Chelsea, Newton stations, Forest Hills, Natick Center, Back Bay, Quincy Center, Worcester Union Station, Ruggles); and,
- Structure improvements (e.g., High Line Bridge, Gloucester Drawbridge, and others).

Risks and Mitigation

As with any project or policy initiative, implementation would depend on the successful navigation of a number of risks that can complicate or even undermine project and program delivery. This section identifies some of these risks, with a particular emphasis on **institutional or policy risks** and **wider national and regional factors**, and describes potential mitigation techniques. Figure 7-4 summarizes these risks and risk management strategies.

Figure 7-4 Risk and Risk Management Strategies

Institutional Risks

Institutional risks can deviate a program from achieving its strategic objectives and generating value. The MBTA would need to develop efficient approaches to managing uncertainty, allowing the program to accommodate negative events and take advantage of favorable opportunities.

A key, fundamental risk is delivering a program with a higher degree of private participation than other MBTA capital investments, as this would be the first time such an approach was employed for an effort of this magnitude. An important part of mitigating that risk is taking the time, before proceeding with a procurement, to understand how interests align and differ, as well as the limitations of risk transfer.

Risk management and transfer is a key element of P3, and a common mistake that public agencies make is seeking to transfer too much risk, which can result in either the lack of interest from the private sector or a higher cost to the public. For example, unaccounted delays can result in additional negotiated costs.

Wider Risks

A number of external risks could impact the ultimate success. These risks can be grouped as follows:

- Wider economic or demographic factors such as price inflation and changes in population and employment trends in the Boston region;
- More specific, but indirect factors that can influence the cost of operating services and improve or reduce rail's attractiveness compared to car or other transportation modes, such as fuel prices;
- Future technological changes that may impact planned scope, by making certain approaches obsolete or affecting the prices of different options; and,
- Risks associated with developing a robust set of projects that are both deliverable by the MBTA and acceptable to stakeholders and strategic delivery partners.

While the MBTA and other public agencies could manage some of these wider risks, a number of these are outside of their control. In particular, while a system transformation could play a role in making the Boston region more attractive for people and businesses, other factors such as availability of skills, tax policy, and wider economic trends would ultimately drive these factors.

The MBTA would need to develop robust management plans that consider how to identify, scale, and ultimately implement risk mitigation strategies. Assessing the sensitivity in the business case to a change in outcomes, such as lower population growth, is a useful tool to scale the impact of any key risk.

As with any risks, there are a number of approaches or strategies to effectively manage them, including:

- Reducing risks by taking some measures to either limit MBTA's exposure or eliminate them;
- Transferring risks to those better placed to manage them such as through effective outsourcing or P3 contracts and management practices;
- Avoiding risks by identifying whether elements of the Rail Vision project are inherently risky (e.g., new technology) or whether alternative approaches can remove them;
- Accepting risks which are not controllable (such as wider demand risk due to econometric factors) or where the cost to mitigate them is assessed as high (for example future price inflation.

Figure 7-5 Case Study Example of Bundled Risk Transfer

SOUTH WALES METRO TRANSFORMATION PROGRAM, UK

Transport for Wales (TfW) recently competitively procured an Operations and Development Partner (ODP) to implement its transformative $6 billion Wales and Borders and South Wales Metro program. The ODP, a joint venture between Keolis and Amey, was appointed under a DBMO (design, build, maintain and operate) contract, where it is responsible for implementing and operating an entire system transformation. The ODP will be remunerated against a pre-agreed payment schedule with the performance of ongoing operations subject to a penalty/reward incentive mechanism linked to a range of operational and customer service output metrics.

While TfW had a clear vision for the future modern rail and metro system that it wanted to achieve by the transformation of the current, somewhat antiquated network, it wanted to draw on the expertise and innovation of the private sector to develop the technical solution and deliver a high quality and reliable service. TfW employed a competitive dialogue process to procure the ODP. The process enabled TfW to set out its key objectives and then invite bidders to respond with their initial outline solutions. TfW was then able to engage with each bidder through a dialogue process in which it could clarify its requirements and receive feedback on how requirements and the commercial structure could be refined to allow the market to offer improved, better value solutions. Following the dialogue process, detailed proposals were prepared by bidders against a common specification and the contract awarded following a defined bid evaluation process.

While TfW took great care to set out its key minimum requirements for the ODP (including objectives for service frequency, journey connectivity and quality standards, such as customer satisfaction and accessibility), it also took equal care not to be over prescriptive. Bidders were free to determine their preferred technology solution, including whether to adopt a light rail or heavy rail system and choice in traction system, where they could choose to combine partial electrification with on-board storage or bi-mode operation or adopt full system electrification.

The MBTA could identify the key risks by establishing a risk register and working with stakeholders and strategic delivery partners to develop strategies to actively manage risks. Encouraging input from across the MBTA, other public bodies, and stakeholders could help shape these risks and identify priorities to focus attention.

A key opportunity in managing these risks is to regularly review the risk register and prioritize strategies that best meet the customer service proposition. For example, the attractiveness of Boston's Commuter Rail system is its ability to deliver people to the key employment centers and cultural, commercial, and education destinations quicker and more reliably than car or other competing modes at a similar or lower price. Any risk mitigation strategies that protect the Commuter Rail system's attractiveness would therefore be prioritized. Likewise, risks could be assessed against the business case as this can also focus attention on those risks that would most impact benefits or increase costs.

Any strategy or set of strategies would include taking a modular approach to de-couple safety-critical assets from those that are not safety critical. It would also maintain a flexible and a proactive approach to anticipating new risks and opportunities, as technology, work practices, commuting patterns, and other factors change.

8 Governance and Procurement Considerations

To transform the Commuter Rail, the MBTA would need to change how it plans, procures, and operates the system. This chapter describes these changes as well as other governance and procurement issues to consider.

Governance

The level of investment and the complexity of the challenge the rail transformation presents would raise the need for important organizational adjustments. New contracting mechanisms and labor practices would need to be considered to transform the system in a timely manner. Involving the talent and innovation of the private sector has the potential to leverage the MBTA's deliverability.

Fundamental changes to the current approach to delivering projects could include:

- Acquiring the knowledge and expertise to handle significantly different contracts;
- Transferring risk and control of certain aspects of the program to the private sector;
- Establishing longer-term relationships with the private sector in comparison to the shorter-term, transactional nature of the current MBTA procurement approaches;
- Developing a level of comfort with relational contracting norms and incomplete contracts common with higher degrees of private participation;
- Considering changes from a life-cycle perspective, where services are bundled to different degrees, which can provide important benefits, but prior planning is essential to avoid unintended consequences;
- Changing the contracting mentality, from separately hiring the design and construction of an asset to contracting the provision of a service where operations and maintenance may be included with design and construction;
- Strengthening the MBTA's oversight capacity and focusing on the outcomes, rather than components of a program, based on key performance indicators; and,
- Using private finance to lower the immediate, short-term impact on government revenue streams while accounting for potential risks for repayment.

Alternative Procurement Models

The MBTA has a unique opportunity to consider **alternative delivery models**. The scale and complexity of the potential transformation make it challenging to deliver using traditional contracting models.

With a myriad of alternative delivery options available, a successful process would adequately reflect the institutional capabilities, specific funding sources, and legislative atmosphere in which the MBTA performs. Of course, project decisions should not depend solely on value-for-money analysis. It is also important not to forget the realization of benefits linked to Rail Vision's goals and objectives, which would be at the heart of the case for investment.

Successful innovative financing arrangements find an optimal balance between public and private risk allocation, trading off costs of the arrangement with incentives for financiers to add project value. Importantly, risk transfer needs to consider whether the private sector can control the risk – for example, future trends in terms of inflation or wider economic factors typically represent poor value for money if transferred to the private sector.

It is important to understand the total life cycle costs associated with any proposed solution for a project. The private sector can drive initial costs down, but without the right outcomes-based criteria, costs over the lifespan of an asset could exceed the costs of using a more traditional route. The private sector can reduce construction times through innovative construction techniques; however, some approaches can work against the needs of the service users and surrounding neighborhoods. Any contract or agreement with the private sector to deliver improvements would need to set criteria not only for the outcomes, but for expectations and impacts during the construction and implementation phase.

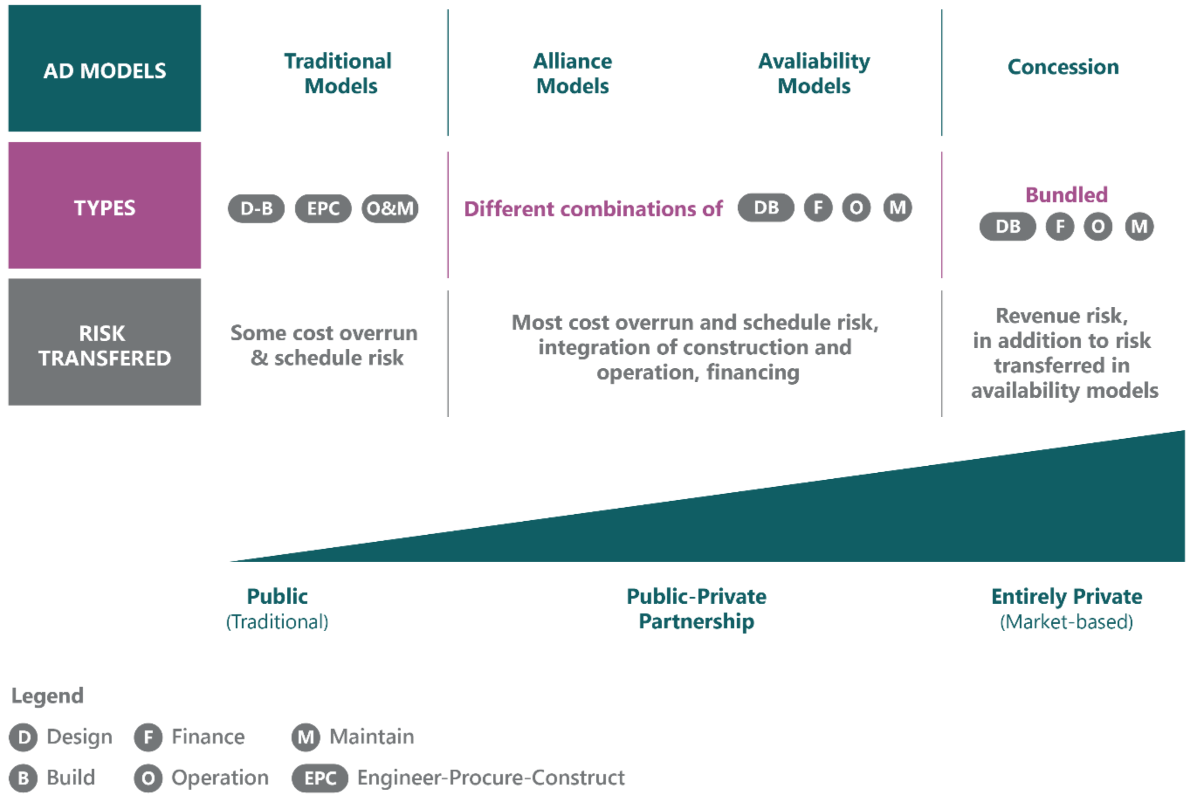
A key challenge is to **identify which delivery models** would improve outcomes in comparison to current or traditional delivery approaches. This would require an effective screening assessment combined with robust models that would help identify the financial implications of the different delivery models.

A detailed **feasibility assessment** would allow the MBTA to determine how different alternative delivery methods fit particular aspects of the transformation program. Developing a *long-list* of models is essential to understanding how to address the different challenges of various projects. For the MBTA to transform the Commuter Rail, any focus on alternative delivery models would likely include the options presented in Figure 8-1, which presents the level of risk transfer and private participation for the most common models.

A feasibility assessment would compare modes of delivery for specific projects or bundles of projects as part of a larger transformation. In it, it would be essential to:

- Determine full project life cycle costs;
- Model costs associated with key project risks and impacts associated with risk transfer;
- Assess the optimal value for money attainable within the Alternative Delivery models;
- Guide discussions and decisions around accounting treatment;
- Set affordability limits for the MBTA and its government partners; and,
- Validate project budgets and cash flow impacts under the shortlisted delivery scenarios.

Figure 8-1 Alternative Delivery Models Applicable for Individual Rail Vision Projects



The results from the feasibility assessment could inform the development of a business model and financial structure for the program that would address:

- Risk allocation structure;
- Payments and financial obligations and their timelines;
- Optimal contract length; and,
- Level and timeline of private sector financing required (i.e., debt and equity).

The MBTA would need to **examine key trade-offs** associated with the preferred business models and financing strategies in order to attain an effective risk transfer while maintaining control and flexibility to meet future needs. An important tension arises between risk transfer and control retention, as an effective transfer of risk implies a transfer of control. When transferring control of a project to a third party, flexibility to shape its evolution is relinquished. This tension is especially relevant in long-term arrangements.

Bundling elements, such as station infrastructure, separately from electrification or other rail infrastructure could help maximize cost and delivery effectiveness, but minimize other risks, such as scope uncertainty. Contract length can also be an effective incentive mechanism (e.g., through longer-term operational or maintenance responsibilities), though not in every case.

The MBTA would also need to devise a strategy for engaging with market participants to gather information and maximize future competition. The market strategy could include a series of industry outreach meetings that would allow the MBTA to test the business model and financial structure with market players, including developers and contractors, equity providers, lenders, and guarantors. The MBTA could then refine elements of the business model and financial structure for different projects to reflect market observations and better align public sector and market interests.

Public-Private Partnerships - P3

Even though there is no internationally accepted definition of a P3, and different jurisdictions use similar names to describe dissimilar structures, universal elements exist among P3 interpretations. The FTA defines a P3 as a "contractual agreement formed between a public agency and a private sector entity that is characterized by private sector investment and risk-sharing in the delivery, financing and operation of a project."[16] In practice, the term P3 encompasses as many different definitions as there are projects, and generalizations must be handled with care. In this document, a **P3 describes a long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility, and payment is linked to performance.** Some key advantages of P3s stem from this definition:

- Under a P3, the public sector pays for the provision of a service and not the delivery of an asset, which implies that the profile of payments is substantially different (spread over the long-term rather than concentrated in the short-term);
- A P3 contract focuses on outputs (such as railroad quality) and not on inputs (such as railroad materials and design); and,
- As the private sector's payment is defined by the quality of the service it provides, innovation and a life-cycle approach are encouraged.

The duration of P3 arrangements implies that many components and risks can arise from a long-term contractual relationship and change dynamically over the P3's life-cycle. By nature, P3 contracts are incomplete given the impossibility of redacting a contractual consequence for any and every event that might occur in the duration of the partnership. Therefore, the risk distribution in a P3 is essential to guarantee the economic equilibrium of the contract and define responsibilities according to which party is in best condition to manage, absorb, or mitigate the risk.

Usually, P3s involve the bundling of the design, construction, management, and operating phases of an infrastructure project with the purpose of aligning the best practices in each phase and reducing life-cycle costs. It is common that the public sector relinquishes some control over the infrastructure by assigning these tasks to the private sector as a way of levering on the latter's efficiencies.

P3s can be more expensive than public procurement; the Special Purpose Vehicle (SPV) created for the project usually has access to higher financing rates than local governments, as the collateral is the project and not any real asset, and the probability of default for a government is much lower. Risk bearing by the private party comes with a price usually reflected in the discount rate used and the amount of revenues required to repay the initial outlays. Additionally, a weak framework can lead to unjustified private gains due to possible opportunistic bidding and renegotiations. Poor planning and performance can lead to an unexpected increase in the contingent liabilities to the public sector.

Nevertheless, if the process and the project are structured in the correct way, the efficiency gains of involving the private sector will more than offset the additional costs. The transfer and sharing of responsibilities and risks to the private party means that the government must develop a regulatory framework to:

1. Bring confidence to the private sector that the rules under which the contract was drafted will be maintained; and
2. Assure that there will be effective supervision and oversight of the project to guarantee that the social and economic benefits of it are delivered.

To deliver a transformation of the commuter rail system using a P3, the MBTA would need to ensure relevant policies, laws, regulations, and institutions promote arrangements that allow for the full benefits of private investment.

16 49 CFR Part 650.5

9 Conclusion and Next Steps

Rail Vision sought to fulfill six key objectives for the MBTA Commuter Rail system:

1. Match Service with the Growing and Changing Needs
2. Improve Access to Jobs and Opportunities
3. Improve the Passenger Experience
4. Provide an Equitable and Balanced Suite of Investments
5. Help the Commonwealth Achieve its Climate Change Resiliency Targets
6. Maximize Return on Investment (Financial Stewardship)

Using an iterative service design process, the study considered a number of different concepts to meet these objectives. This then informed development of six Systemwide Alternatives.

The Systemwide Alternatives Evaluation tested different service models systemwide to assess where they excel and where trade-offs occur.

Based on the evaluation, key takeaways include:

- Frequency drives ridership, especially in the inner core;
- Generating ridership results in auto diversions;
- Electrification enables faster travel times and reduces emissions, but does not bring significant ridership gains alone;
- Service increases in the inner core generate walk-up ridership, while service increases in the outer parts of the region may require construction of additional parking to see ridership gains;
- While the full transformation would generate the greatest benefits, electrified urban rail would generate many of the benefits at a portion of the cost, and higher frequency commuter rail would provide benefits over the No-Build at a fraction of the cost.

The Rail Vision evaluation provides policymakers a tool to understand the trade-offs the different levels of investment each of the alternatives requires compared to the benefits they would provide.

Short-Term Next Steps

Rail Vision serves as an initial step of the comprehensive and detailed planning needed to support a transformation of the commuter rail system. The analysis provides insight into which types of services and improvements perform better against varying objectives and the costs associated with delivering different outcomes. The FMCB resolutions outline the general direction for a commuter rail transformation and the previous two chapters identify specific considerations for delivering this future.

Based upon the results of the Rail Vision analysis and the direction provided by the FMCB, immediate next steps include more thorough assessment of:

- Desired outcome and business case for change
- Electrification
- Operations, including non-revenue moves
- Fleet
- Layover and maintenance facilities
- Parking and access

Moving forward requires clearly defining the **desired outcome** and crafting a **business case for change**, as described in Chapter 7. This critical next step would include effectively communicating future plans to MBTA employees, suppliers, riders, stakeholders, and the public at large.

Full system or partial electrification would require more extensive study prior to implementation. This would include study of existing clearances to determine where it is feasible to construct new catenary, where clearances are not sufficient, and where modifications or replacement structures are needed. It would also cover the feasibility of new and emerging techniques to implement electrified services. In addition, coordination is necessary with multiple electric utilities to ensure existing infrastructure could deliver enough electricity to the new electrified Commuter Rail lines.

For example, while providing electric service on the Providence Line may appear to be straightforward as the majority of the track has overhead catenary already for Amtrak's intercity trains, more electric power would be required to operate the MBTA's commuter trains. This would require upgrades and expansions to the power transmission and distribution system. In addition, the MBTA would need to expand the catenary to cover third and fourth track segments on the Providence Line.

The MBTA would need to conduct additional **operations modeling and planning** to define a desired service plan for an initial phase and develop schedules that include both revenue and non-revenue moves. These refinements would further inform any infrastructure improvements required to operate the desired service, as well as help identify opportunities for near term service improvements.

A new **fleet transition plan** could consider how to phase in new vehicles (e.g., EMUs) while shifting existing diesel-hauled equipment to other rail lines to enhance frequency and expand passenger capacity. EMUs in particular would require new or re-built maintenance and layover facilities that include overhead catenary for traction power. These requirements would be above and beyond the need for **new train layover storage, service, inspection, and maintenance capacity**. The MBTA would also need to evaluate the existing equipment **maintenance program** to determine the changes in labor practices and technology needed to maintain both diesel and electric equipment, and where to perform the new added maintenance functions. As new trains are among the most visible assets to the public, these planning efforts must ensure that the new rolling stock specifications effectively deliver Rail Vision, both practically within the MBTA's unique operating environment but also in the image the public expects for the customer experience.

Planning for improvements would require further consideration of **station access**. Improving Commuter Rail service would result in additional demand, and it is critical that potential passengers can access the service. This could require coordination with a number of stakeholders, including municipalities and other local and regional organizations.

These efforts would be iterative as they are co-dependent. For example, with electrification, both the catenary design and the rolling stock specifications would drive the amount of electricity needed from the utilities. Where the electric trains would layover and have maintenance would also drive electric power needs, potentially from different utility companies. The EMU specifications would drive the power distribution specifications, or vice versa.

The next step activities described here would be initial steps in a transformation of the Commuter Rail. These activities would take place within the larger context of the vision for the system, setting the foundation for the investments required to deliver that change.

Moving Towards Implementation

The Rail Vision process revealed considerable public interest in transforming the system consistent with the project objectives. Looking ahead, the outcomes from this effort can shape a regional conversation about how the Commuter Rail fits into the future vision for mobility in the Commonwealth. It can help inform priorities and focus areas for improvement, based on the potential for ridership, density and land-use changes, and equity benefits.

This conversation is critical as the region's population and economy continue to grow while traffic congestion worsens. The MBTA Commuter Rail can reinforce this growth and help transform regional mobility to provide improved service to a range of users. The Commuter Rail has an opportunity to unlock broad social, economic, and environmental benefits throughout the region.

Technical Appendices