4. Service Planning

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4. Service Planning

A key aspect of the Feasibility Reassessment process is the creation of service alternatives that align with the vision of the NSRL, ensuring robust service levels to effectively utilize the capacity of the NSRL tunnels. This chapter describes the process of designing, evaluating and selecting service plan alternatives for the NSRL project. The routings and frequencies chosen directly influence ridership, operational costs, fleet size, and base infrastructure requirements for the overall project.

4.1 Background and Previous Studies

Previous service planning efforts for the NSRL project explored a number of alternatives, all aiming for a 2025 build year. In addition to No Build and tunnel alternatives, the 2003 study examined two Transportation Systems Management (TSM) alternatives that focused on enhancements to existing transit systems. The two TSM alternatives were a dedicated shuttle bus service between North and South Stations and increased service on the MBTA Orange Line. This Feasibility Reassessment focuses on evaluating a No Build alternative, a surface improvements only alternative, and several tunnel alternatives.

Operational assumptions for the 2003 study were based on 2020 commuter rail schedules provided by the MBTA. Tunnel headways were set at 4-minute minimums, and frequencies for each line were 30 minutes or less at the peak and 60 minutes or less during off-peak periods. The 2003 study assumed that North Station surface terminal tracks would remain, even with a tunnel alternative. This Feasibility Reassessment makes North Station an underground station only in all the tunnel alternatives.

In the 2003 study, line pairings were developed for both two-track alternatives (one using the Back Bay Portal and the other using the South Bay Portal) and for the four-track alternative. Both two-track alternatives connected the Lowell Line with Amtrak services on the Providence Line (as in this Feasibility Reassessment), with Amtrak trains running up the Fairmount corridor in the South Bay Portal alternative to achieve this pairing. The four-track alternative created through-running pairs for every commuter rail line, including the Old Colony Lines. This Feasibility Reassessment does not route the Old Colony Lines through the tunnel in any alternative.

The 2003 study assumed that one-third of Amtrak intercity service (or up to eight trains per day for the two-track alternative and 18 trains per day for the four-track alternative) would continue through the tunnel, but the majority would still terminate at South Station. The proportion of Amtrak service assumed to be running through the tunnels is the same for this Feasibility Reassessment. In 2003, the trains continuing beyond the tunnel would terminate in Woburn, with a cross-platform transfer to the Downeaster services at this station.

A main takeaway of the 2003 study was a projection that the commuter rail lines coming into North and South Stations would continue to see an imbalance in passengers even with through-running service, which “presents challenges in operating the rail tunnel during peak periods.”

4.2 Service Plans Considered

The NSRL project team considered nine service alternatives as part of this Feasibility Reassessment, each providing a different level of service and infrastructure requirements. There are two surface alternatives and six tunnel alternatives (three two-track and three four-track), in addition to a No Build alternative, detailed in Table 8.

Alternative	Service Levels	Capital Assumptions	South Coast Rail Alignment
No Build	2017 schedules	No expansion of South Station. North Station programmed/committed improvements (including drawbridge)	Via Middleborough
South Station Expansion & Regular Service (No NSRL)	South Station Expansion (SSX) schedules (base year 2013)	New platforms available in SSX Alternative 3, Fairmount improvements, North Station programmed/committed improvements	Via Stoughton
South Station Expansion & All-Day Peak Service (No NSRL)	Use full capacity of expanded South Station. Peak levels of service all day, where possible (within infrastructure constraints).	As above	Via Stoughton
NSRL Minimum Service (two-track)	Maintain SSX level of service. Hourly off-peak service, where possible.	No expansion to South Station and no increase in fleet size. No surface North Station	Via Stoughton
NSRL Minimum Service (four-track)	As above	As above	Via Stoughton
NSRL Regular Service (two-track)	Double peak service levels from minimum tunnel. Hourly off-peak service, where possible.	No expansion to South Station. Increase in fleet size. No surface North Station	Via Stoughton
NSRL Regular Service (four-track)	As above	As above	Via Stoughton
NSRL All-Day Peak Service (two-track)	As much service as can be supported by the infrastructure. Continue max tunnel peak levels of service all day, where possible (within infrastructure constraints).	As above	Via Stoughton
NSRL All-Day Peak Service (four-track)	As above	As above	Via Stoughton

Table 8: Service Alternatives for Feasibility Reassessment

Caveats

The NSRL project team followed the service-planning process agreed to by MassDOT and the NSRL Working Group in developing the Feasibility Reassessment scope of work. As such, the analysis is 'supply-based' (based solely on the minimum service levels set for the alternatives) rather than 'demand-based' (based on evaluating the market to determine where service should be increased), although the four most promising service alternatives were subjected to a ridership assessment (along with the No Build alternative). The project team created detailed schedules to ensure that trains could feasibly run at the required service levels, but in some cases, headways on single-track sections are more frequent than those currently endorsed by MBTA. Additionally, some of the all-day peak service plans have such frequent headways that maintenance can be allowed only at night, as opposed to current MBTA practice, which services some vehicles and conducts track maintenance in between peak times.

Line Pairings

The line pairings within the new tunnel infrastructure will influence the benefits of the NSRL project, including ridership, mode shift, and reductions in VMT and travel time. To maximize the efficiency of a new link between the commuter lines currently running into North Station and those running into South Station, the Feasibility Reassessment has paired these lines according to several criteria, described in the next few paragraphs. The line pairings for the tunnel alternatives are illustrated in Table 9 and the figures on the following pages.

NSRL Regular & All-Day Peak Service (Two-Track)			NSRL All-Day Peak Service (Four-Track)		
Fairmount	to	South Station	Dedham*	to	South Station
Middleborough	to	South Station	Middleborough	to	South Station
Kingston/Plymouth	to	South Station	Kingston/Plymouth	to	South Station
Greenbush	to	South Station	Greenbush	to	South Station
Back Bay Portal					
Worcester	to	Newburyport/ Rockport	Worcester	to	Newburyport/ Rockport
Needham	to	Fitchburg	Worcester	to	Fitchburg
Franklin	to	Fitchburg	Needham	to	Haverhill
Dedham*	to	Fitchburg	Franklin	to	Haverhill
Providence/Stoughton	to	Lowell	Providence/Stoughton	to	Lowell
Providence/Stoughton	to	Haverhill			
			South Bay Portal		
			Fairmount	to	Newburyport/ Rockport
			Fairmount	to	Fitchburg

Table 9: Line Pairings for the Tunnel Alternatives

**'Dedham' indicates trains that originate and terminate at the Dedham Corp. Center station on the Franklin Line*

The line pairs in the two-track and four-track alternatives are similar, allowing for the maximum number of trains to be run on each individual line and maximizing the capacity of the tunnel(s). A challenge in pairing lines currently terminating at North and South Stations was balancing the smaller number of lines that currently run into North Station with the larger number of lines that currently run into South Station. This challenge was addressed by continuing to terminate the Old Colony Lines at the surface South Station, as they are today.

This Feasibility Reassessment of the NSRL differs from the 2003 study in that the current Feasibility Reassessment makes a technical and policy decision to assume reasonable constraints on the ability to deliver trains from branching lines into the NSRL. (This decision to avoid an unnecessary amount of additional infrastructure improvements to the wider commuter rail network was intended to limit the initial capital expenditure and reduce “scope creep”.) As a result, some service terminates at South Station in the two-track alternatives. In the four-track alternative, Fairmount service was prioritized to run through the tunnel to build on stakeholder aspirations for it to operate as more of a rapid transit-type service, leaving the Old Colony Lines to terminate at South Station, as they do presently.

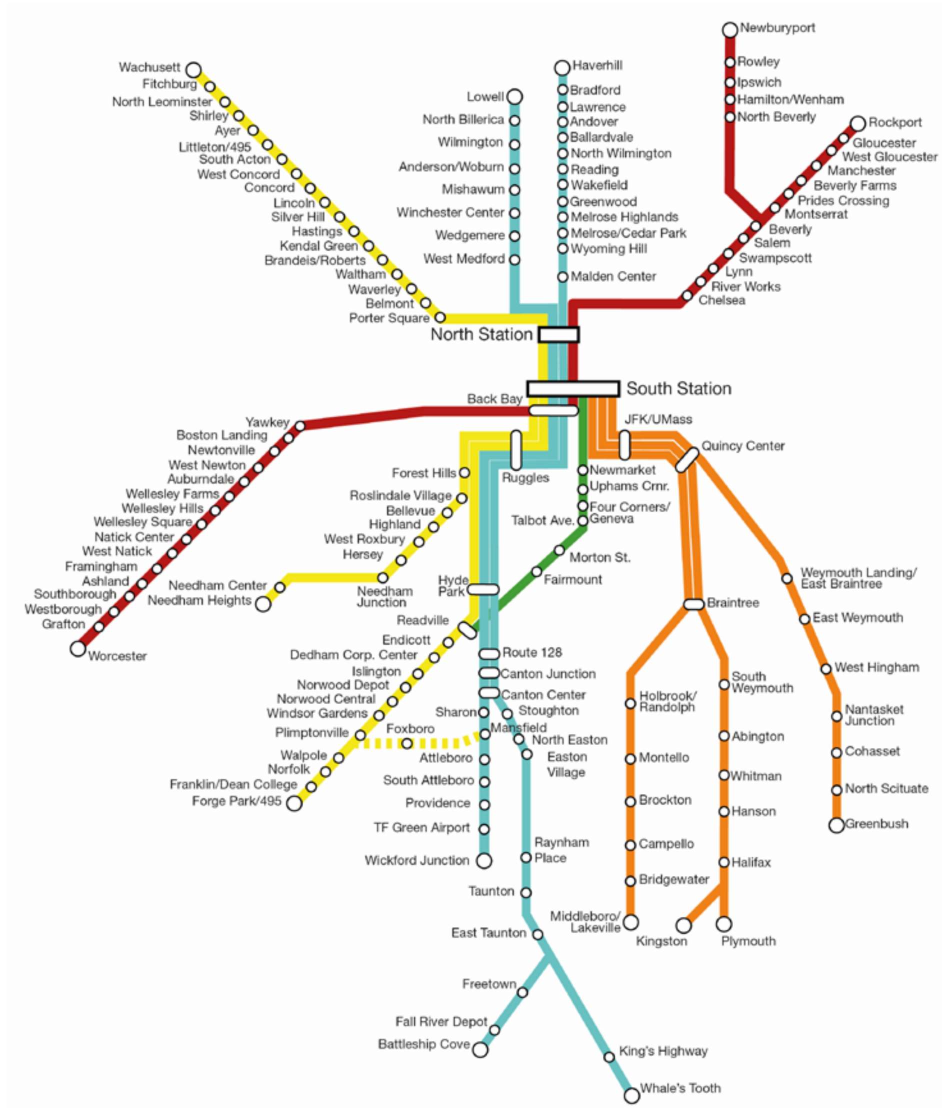

Figure 15: NSRL Regular and All-Day Peak Service (Two-Track) Tunnel Line Pairings

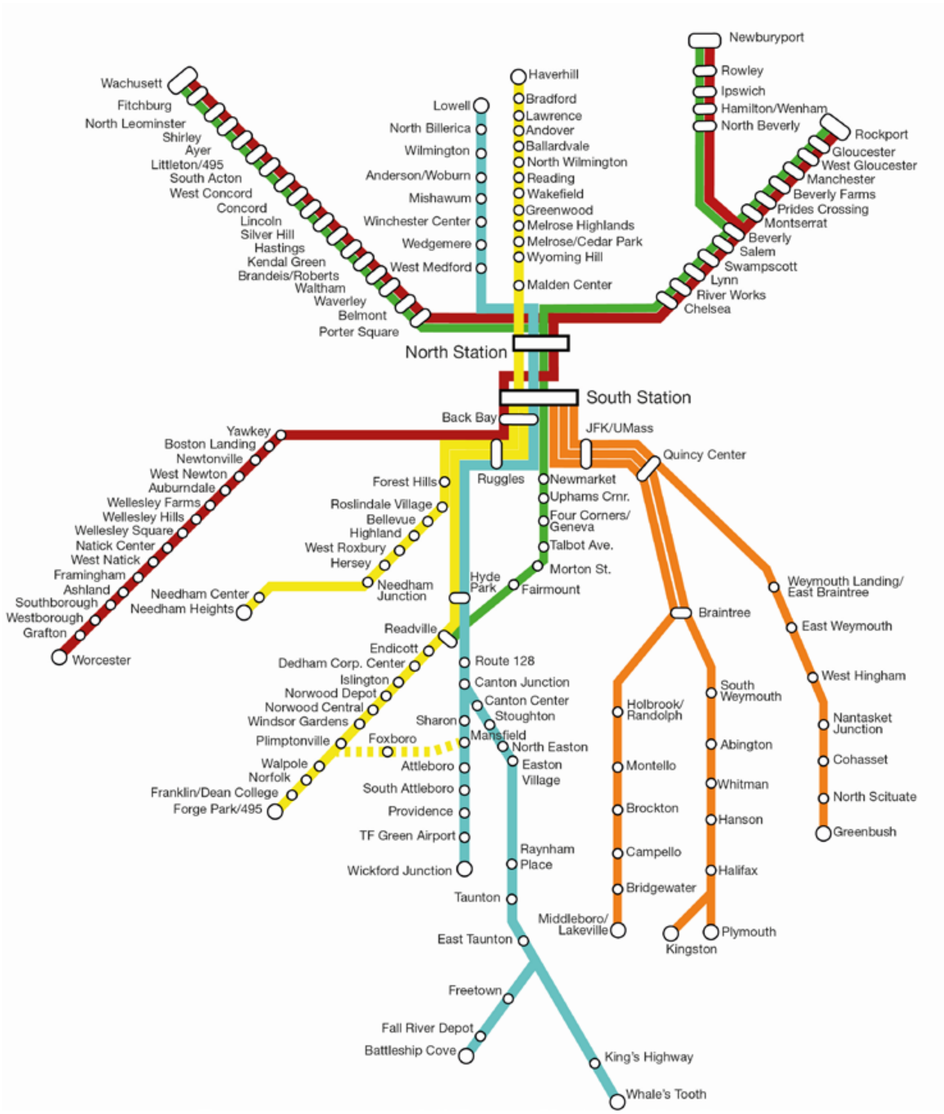

Figure 16: NSRL All-Day Peak Service (Four-Track) Tunnel Line Pairings

These line pairs have been determined by the following factors:

- Amtrak connections – linking services that currently terminate both north and south of the city to boost efficiency and create new connections
- All travel-to-work trips (both by transit and other modes — primarily auto) between north and south destinations – building on areas where there is already demand between destinations
- Connections to employment centers – linking more people to areas with a large number of jobs
- Capacity – pairing lines with similar frequencies, understanding the constraints of the entire network

In all of the alternatives, the Lowell Line is paired with the Providence/Stoughton Line to extend Amtrak's NEC to the northern suburbs and eventually allow electric service to as far north as Lowell. This pairing also assumes shared use of the Amtrak electrical overhead-contact system infrastructure from Providence to Boston and extending into the northern suburbs (allowing connections to Route 128 and potentially I-495). Using the NEC Future document (Federal Railroad Administration, 2017) as a guide, Amtrak express trains would continue to terminate at Boston South Station, but regional electric trains could use the tunnel and terminate at either Anderson or Lowell. Amtrak service from Springfield to Boston and from Boston to Maine could be combined into one dual-mode service, also operating through the NSRL. The intercity train routings are consistent with the line pairings and assumptions of the 2003 NSRL Study.

Prior to formal alternative modeling, CTPS provided regional Journey-to-Work data. The CTPS dataset organized census travel data (classified by “auto”, “transit”, and “total” trips) into districts roughly surrounding the commuter rail lines. The most common origins and destinations between the different districts were identified by charting a large matrix of the trips to and from these districts. This helped to determine where there was the greatest demand for trips and whether the demand for these trips could be satisfied by pairing commuter rail lines.

Results from this analysis suggest the districts containing Back Bay and South Station attract many trips, a demand satisfied by all pairings in the two-track alternatives and most in the four-track alternative. Only the Fairmount Line pairings do not travel through Back Bay because they need to use a different portal, which cannot physically be connected to Back Bay. Additionally, the districts along the Worcester Line attract many trips from the other districts, particularly those along the Fitchburg Line. Districts along the Fairmount Line have the most current trips to destinations along the Fitchburg Line, causing them to be paired in the four-track alternative.

While new ridership is anticipated, existing high-ridership lines connect to lines containing one or more large employment centers. This drove the connection of the high-ridership Newburyport/Rockport Lines with the Worcester Line, which has the high-employment centers of Worcester and Framingham. Special consideration was paid to the large employment areas around Longwood Medical and Academic Area — encompassing about 45,000 employees and particularly accessible by lines paired with the Needham, Franklin, and Providence/Stoughton Lines — and advantaged by any line passing through Back Bay. As the Lowell Line is always paired with the Providence/Stoughton Line to connect Amtrak service, the next-highest ridership line, Fitchburg, is paired with Needham and Franklin in the two-track alternatives. Districts along the Haverhill Line also show a number of current trips to the Longwood area (determined from the origin–destination analysis), and are therefore paired with the Needham and Franklin Lines in the four-track alternative.

After the first three line pairing factors (as identified above) were considered, the line pairings were adjusted to maximize the efficiency of the tunnel(s), matching similar line capacities with one another. This step ensures each line is operating at or close to its maximum number of trains per hour. For example, the Fitchburg and Worcester Lines are paired in the four-track alternative because they have similar capacities and enable closer-in suburb-to-suburb trips. In some cases, this meant that line pairings with strong demand could not be considered because there was not available capacity on either the north or south portion of the line for them to be paired.

Screening Process

The original nine service alternatives described earlier in this section were screened down to five preferred alternatives using evaluation criteria and service plan metrics classified under the areas of Efficiency/Effectiveness, Equity, and Environment, as follows:

Efficiency/Effectiveness

- Peak-hour percentage of capacity (peak direction) – Measures peak-hour capacity utilization for North Station, South Station, and the tunnels in the two-track and four-track alternatives
- Peak-hour, peak-direction trips – All trips taken in the peak hour, and in the peak direction
- Number of hours the peak can be maintained
- Peak-hour vehicle requirements – Vehicle requirements for peak-hour trips, assuming a trainset ("consist") of eight traincars
- Cost – Qualitative assessment of cost, classified as low, medium, and high
- Relief of the rapid transit network – Qualitative assessment of the potential to relieve crowding on the Red, Orange, and Green Lines

Equity

- Travel market – Calculation (using train capacities for an eight-car trainset) of how much passenger capacity has access to South Station and Back Bay in each scenario
- Pairings of journey-to-work pairs – Quantity of origin-destination trips facilitated by line pairings
- North–south connections to areas of high job density for commuter-rail-adjacent households – Score measuring the improvement in car-free rail access to jobs in the study area

Environment

- Additional miles electrified
- Construction impacts – Qualitative assessment of the impacts of construction, divided into low, medium, and high levels

These evaluation criteria were arranged in a matrix to facilitate decision-making between the nine service alternatives. MassDOT reviewed this matrix and chose five alternatives for further analysis, which are discussed in more detail in the following section.

4.3 Service Plans Extensively Studied

The five service alternatives for further analysis — No Build, South Station Expansion & All-Day Peak Service (No NSRL), NSRL Regular Service (Two-Track), NSRL All-Day Peak Service (Two-Track), and NSRL All-Day Peak Service (Four-Track)— underwent more detailed assessment, most notably through the development of detailed schedules outlining train movements and identifying locations for upstream improvements to enhance capacity and address pinch-points (see Section 5.9 and Appendix B for more detail).

Table 10 provides an overview of the trains per hour for each commuter rail line under each service alternative. These frequencies have been influenced by the original service alternative requirements discussed in Section 4.2 and the capacity available on each line.

Systemwide Constraints

Both operating and physical infrastructure constraints on the MBTA Commuter Rail system limit the level of service that can be provided for each of the service alternatives. For example, the MBTA's maximum limits on headways, turnaround times, and junction margins can limit how closely trains can be run together. Physical constraints, like stretches of lines where only single tracks are provided, also limit total capacity. Additionally, it is difficult to provide regular, frequent headways while running variations on service, such as express and local trains.

Risks in Implementing Service Plans

The following represent some of the biggest concerns MBTA Operations has with the study's assumptions:

- Service disruptions on one or two tracks in the tunnel will cause ripple effects throughout the entire commuter rail system
- Assumptions about train loading/unloading time are much more aggressive than current experience
- Depth of stations is a concern during evacuation (and possible negative impact on customer experience due to longer time to exit stations)
- Rapid transit stations were not designed to accommodate transfers from commuter rail in the way they would happen now and may lack platform capacity to adequately do so
- Locations for additional layover and maintenance capacity have not been identified and are challenging to site

Service Alternative	Trains per hour									
	Newburyport / Rockport	Haverhill	Lowell	Fitchburg	Worcester	Needham	Franklin	Providence/ Stoughton	Fairmount	Old Colony (each line)
No Build	3-4 (P) 1-2 (OP)	2 (P) 1 (OP)	2-3(P) 1 (OP)	2 (P) 1 (OP)	3-4 (P) 1 (OP)	2 (P) 1 (OP)	2 (P) 1 (OP)	3-4 (P) 1-2 (OP)	1-2 (P) 1 (OP)	1-2 (P) <1 (OP)
South Station Expansion & All-Day Peak Service (No NSRL)	4 (AD)	3 (AD)	3 (AD)	3 (AD)	6 (AD)	2 (AD)	2 (AD)	4 (AD)	4 (AD)	2 (P) 1 (OP)
NSRL Regular Service (Two-Track)	4 (P) 1 (OP)	3 (P) 1 (OP)	3 (P) 1 (OP)	4 (P) 2 (OP)	4 (P) 1 (OP)	2 (P) 1 (OP)	2 (P) 1 (OP)	6 (P) 2 (OP)	4 (P) 2 (OP)	2 (P) >1 (OP)
NSRL All-Day Peak Service (Two-Track)	4 (AD)	3 (AD)	4 (AD)	6 (AD)	4 (AD)	2 (AD)	4 (AD)	7 (AD)	4 (AD)	2 (P) 1 (OP)
NSRL All-Day Peak Service (Four-Track)	4 (AD)	4 (AD)	6 (AD)	6 (AD)	6 (AD)	2 (AD)	4 (AD)	6 (AD)	4 (AD)	2 (P) 1 (OP)

(P) – Peak

(OP) – Off-peak

(AD) – All-day

All designations exclude late-night frequencies

Table 10: Overview of Service Alternatives

4.4 Capacity Assumptions

Rolling stock and infrastructure capacities play a significant role in determining the level of service that can be provided and how proposed investments can be efficiently utilized.

Train Capacity

MBTA currently operates a mix of single- and double-deck coaches into North and South Stations, with a mix of train types and sizes (services into South Station have both more and larger trains than those going into North Station). Currently operated trainsets (or consists) vary from five to nine cars.

This Feasibility Reassessment incorporates the MBTA Commuter Rail Fleet Plan, which anticipates the replacement of the system's current single-deck cars with 180-passenger double-deck cars. The plan identifies replacing 203 single-deck cars with 190 double-deck cars.

Coach type	Capacity (seated passengers)*
Amtrak standard train (with expected 2040 capacity increase)	400
MBTA single-deck coach	114
MBTA double-deck coach	180

Table 11: Coach Capacity Assumptions

**The capacity above records the seated capacity for an entire Amtrak train (6 cars), while the MBTA measures are per coach (MBTA Commuter Rail train lengths vary)*

Tunnel Capacity

This Feasibility Reassessment bases its calculations on a tunnel capacity of 22 trains per hour (tph) in each direction. This metric is based on the operating environment in comparable projects currently constructed or underway, including the existing Amtrak and NJ Transit Hudson Tunnel into Penn Station New York (24 trains per hour) and the future London Crossrail. However, upstream constraints limit the maximum throughput of the tunnels and their efficient use. This is especially true for the four-track alternatives, which are limited in the number of trains that can run in the second tunnel because the South Bay Portal can only accommodate the Fairmount and Old Colony Lines, which run a maximum of four or six tph, respectively.

These challenges mean that, absent significant upstream investment beyond the scope of the NSRL Feasibility Reassessment, the most realistic assumption is to operate 16 to 17 trains through the tunnel in each direction per hour (for context, this is more frequent service than currently provided on the Red Line).

Based on an entire fleet of double deck cars seating 182 passengers each and eight to nine coaches per train, No Build system capacity will be about 44,000 total peak hour seats.

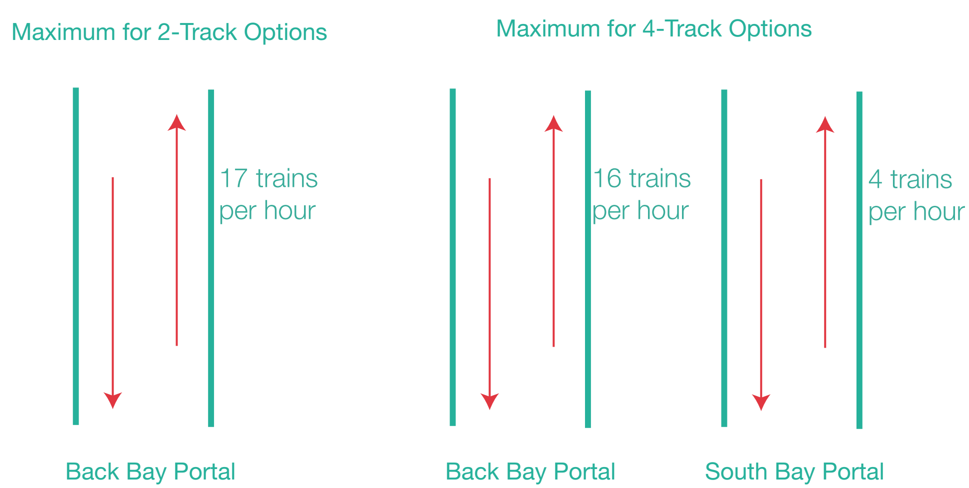

Figure 17: Tunnel Maximum Throughput (Trains Per Hour)

In the build options, capacity increases with both additional trains and additional coaches. In the South Station Expansion & All-Day Peak Service (No NSRL) alternative, the peak hour capacity approaches 48,000 seats (a 9% increase), while in the tunnel alternatives, capacity further increases into the double digits. In the NSRL Regular Service (Two-Track) alternative, the peak hour capacity totals about 56,000 seats (an increase of about 27%), and in the NSRL All-Day Peak Service (Two-Track) alternative, capacity increases to about 59,000 peak hour seats (a 34% increase). In the NSRL All-Day Peak Service (Four-Track) alternative, about 67,000 peak hour seats are provided, an increase of about 50%. Details are in Figure 18.

The tunnel has additional theoretical capacity beyond this; however, increasing the number of trains requires additional upstream improvements beyond those considered in this study and additional investment in rolling stock, including coaches and locomotives.

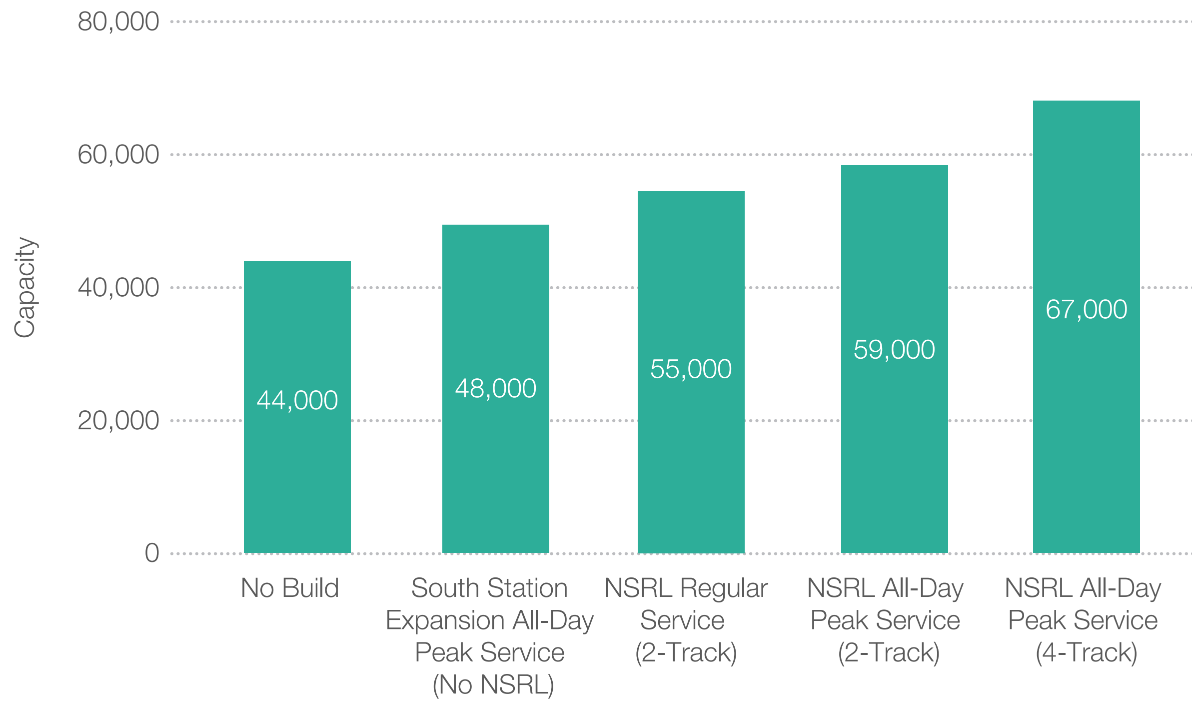

Figure 18: Peak-Hour Project Capacity

4.5 Ridership and Operating Costs

CTPS modeled the five service alternatives (including the No Build alternative) to forecast the differences in travel for each alternative. These forecasts facilitate the assessment of impacts and benefits for each alternative (the benefit-cost analysis is discussed in more detail in Chapter 7 of this report). Using the regional travel model described in Section 3.2 and assuming a 2040 build year, CTPS generated outputs based on all travel in the region and how it would be affected by the various build alternatives (in addition to the No Build alternative). For ease of analysis, the area served by commuter rail was divided into 39 regions.

The CTPS model estimates daily transit ridership and highway traffic volume based on changes to the transportation system — in this case, the build alternatives. The model set takes into consideration data on service frequency, routing, travel time, and cost for all services.

Key outputs for each alternative include quantified impacts to the transit and highway systems, as well as region-wide changes in the way people travel. Outputs specifically related to transit include ridership (the total number of commuter rail trips) and travel time (in-vehicle and total, which includes transfers). Outputs specifically related to the highway system include vehicle miles and hours traveled. Both the transit and highway outputs include data on trip purpose. The model outputs identify district-to-district and regional total flows, which show the details of travel broken down by the mode chosen (transit or highway) and the distance traveled (transit segments or entire lines). These outputs can highlight the differences in travel between two districts for the alternatives when they are connected by commuter rail and when they are not.

For the purpose of the ridership estimates, it was assumed that parking at stations would be unconstrained (i.e., drive access trips would not be limited by current parking lot capacity) to allow for future transportation changes, including more use of ride share for pick-ups and drop-offs.

Projected Ridership

Table 12 shows the projected 2040 ridership for each of the alternatives and the percent change versus the No Build alternative.

Service Alternative	Projected Ridership* (2040)	Percent Increase from No Build
No Build	150,000	
South Station Expansion & All-Day Peak Service (No NSRL)	195,000	30%
NSRL Regular Service (Two-Track)	195,000	30%
NSRL All-Day Peak Service (Two-Track)	225,000	50%
NSRL All-Day Peak Service (Four-Track)	250,000	67%

**daily weekday trips*

Table 12: Projected Ridership (2040) per Service Alternative

CTPS's ridership forecasts for all five service options can be summarized as follows:

- 2040 No Build commuter rail ridership totals about 150,000 boardings per day, an 18% growth over the 2016 base year. This roughly 1.5% growth per year is consistent with past trends on MBTA Commuter Rail.
- The South Station Expansion & All-Day Peak Service (No NSRL) alternative shows an increase to about 195,000 daily boardings, a 30% increase over the 2040 No Build. This ridership increase is spread across the system, as this alternative increases frequency for many trips. Overall, the south side sees a greater increase (34%) than the north side (24%), with a significantly higher total number of trips on the south side.
- The NSRL Regular Service (Two-Track) alternative has a daily ridership of about 195,000, the same percentage increase over the 2040 No Build. Despite the presence of a tunnel to enable through-running trains, less midday service than the all-day peak alternatives causes the results of this alternative to be the same as those of the South Station Expansion & All-Day Peak Service (No NSRL).
- The NSRL All-Day Peak Service (Two-Track) ridership increases to about 225,000 daily boardings, a 50% increase over the 2040 No Build. Compared to the South Station Expansion & All-Day Peak Service (No NSRL) alternative, almost all the increase is from boardings on the north side of the system – with north side boardings increasing by 75%. This is likely attributed to the ability for north side commuters to connect directly to areas south of North Station, as large increases are seen at South Station, Back Bay, Ruggles and others, while North Station sees declines in boardings.
- The NSRL All-Day Peak Service (Four-Track) ridership increases to about 250,000 daily boardings, a 67% increase over the 2040 No Build and an 11% increase compared to the NSRL All-Day Peak Service (Two-Track) service.

Across each 2040 alternative – whether surface or tunnel – certain lines perform better than others. Worcester and Providence services do not grow as strongly as others, and Franklin shows a decrease. This is perhaps due to the model putting greater emphasis on travel time relative to increases in frequency; however, it is likely that in actual practice ridership will increase on these lines. On this basis, the model results can be considered slightly conservative.

Forecasting Commuter Rail Ridership in Metro Boston

Who produces the forecasts: The Central Transportation Planning Staff (CTPS) maintains and uses a computerized travel model set to predict how many trips will occur. CTPS acts as staff to the Boston Region Metropolitan Planning Organization (MPO). CTPS was created in 1974 to provide continuing expertise in comprehensive, multimodal transportation planning and analysis. About 50 professionals work at CTPS.

What is the travel demand model and what does it do: Travel models predict how many trips will be made by people in a given region on a typical day, where those trips will go, and what modes and routes those trips will use. Travel models provide information about projects, programs, and policies for decision makers. Travel models are used in project development to predict how many vehicles will use a new or modified roadway, or how many people will board a new or modified transit line or link, such as the North South Rail Link.

How does the travel model work: Travel models are based on people´s observed behavior, usually obtained from household travel surveys. Statistical analysis of the survey data yields the models that describe this behavior. The models then forecast future travel as population and employment patterns, costs of the different travel modes, and the transportation system changes are considered.

The CTPS travel model encompasses all of Massachusetts, all of Rhode Island, and a portion of southern New Hampshire; it represents weekday travel only, and is an “aggregate model set” that represents and forecasts travel for groups of travelers, rather than for individual travelers. The model is a planning-level tool, offering a 10,000-foot view and using trips between analysis zones (of which there are more than 5,700).

The model uses regional demographic inputs (as described in Section 3.2). The travel demand forecasts used in this Feasibility Reassessment are based on regionally adopted demographic forecasts. The MAPC develops socioeconomic forecasts for use by the Boston Region MPO, which are, in turn, used in the MPO’s Long-Range Transportation Plan (LRTP). The current LRTP, *Charting Progress to 2040*, was adopted in July 2015. This demographic information is summarized in the MPO’s Needs Assessment document (July 2015).[21]

Table C1 in Appendix C details the employment and population changes forecast for the Boston region, which are the basis for the travel demand forecasts. It should be noted that these forecasts were developed several years ago; however, they represent the current regionally adopted forecasts and are therefore used for all transportation analysis in the region. In these forecasts, employment grows by about 160,000 jobs between 2015 and 2040 (about 6%, or about 0.25% annually), and population is forecast to increase by about 510,000 (about 9%, or about 0.35% annually). More employment growth is forecast in the area within Route 128 than the area outside (55%/45%), while the population increases in both areas are about equal. The southern suburbs have about 15-20% more jobs and residents than the northern suburbs.

The four major steps in the travel-modeling process are as follows:

- Trip Generation. This step predicts how many trips, for each of several trip purposes, a household will make on a typical day.
- Trip Distribution. This step links trips from one place to another. Trips produced by households in one analysis zone are attracted to other analysis zones in direct proportion to the relative sizes of those other zones. Trip distribution forecasts the volume of trips from one place to another.
- Mode Choice. This step assigns the trips from every analysis zone to analysis zone by mode of travel, based on the relative times and costs associated with each available mode. Mode choice forecasts the way the trips identified in trip distribution are actually made (bus, car, walk).
- Route Assignment. This step routes trips on the cheapest and fastest links (compared to other available routes) for both roadway and transit trips. Trip assignment estimates the traffic and passenger flows on a transportation network.

Within each step are many other tasks that inform the process and play a role in how people choose to travel. A more detailed description of the model is available in Appendix C.

Train Miles/Hours

Train miles and hours allow for the estimation of operating costs, including maintenance. The calculations for train miles and hours are based on the following principles:

- Distances are derived from the current MBTA Commuter Rail track network
- Journey times are based on current schedule timings
- Non-revenue mileage and train hours are based on assumed trainyard locations. (A high-level assessment of yard capacity has been undertaken to identify indicative locations for overnight storage and staging, including some locations not currently in use.) The calculations do not allow for non-revenue moves between lines during operating hours or any additional movements required for rolling stock maintenance or refueling.
- Mileage and hours are based on the whole consist rather than per coach.

Table 13 shows weekday revenue and non-revenue train miles and hours for each of the five service alternatives.

Unsurprisingly, the NSRL All-Day Peak Service (Four-Track) tunnel alternative has the greatest number of revenue and non-revenue miles and hours, closely followed by the NSRL All-Day Peak Service (Two-Track) tunnel alternative. The NSRL Regular Service (Two-Track) tunnel alternative has the smallest increase in revenue miles/hours from the No Build alternative but has the third-highest increase in non-revenue miles/hours, reflecting the need to reposition trains in the off-peak periods.

	Weekday Daily Totals			
Service Alternative	**Revenue Miles**	**Revenue Hours**	**Non-revenue Miles**	**Non-revenue Hours**
No Build	16,420	530	800	30
South Station Expansion & All-Day Peak Service (No NSRL)	41,550	1,370	1,630	60
NSRL Regular Service (Two-Track)	28,290	950	2,300	80
NSRL All-Day Peak Service (Two-Track)	51,470	1,690	2,480	80
NSRL All-Day Peak Service (Four-Track)	55,230	1,780	2,800	90

Table 13: Weekday Train Revenue and Non-revenue Miles and Hours per Service Alternative

In order to allow for a consistent comparison across all service options, the No Build figures in Tables 13 and 14 are from Arup's estimates, which are within about 6% of operating numbers received from Keolis, the MBTA Commuter Rail operator.

Trains Required for Service

The identification of weekday revenue and non-revenue miles and hours allows for the calculations of train requirements for each service alternative, as detailed in Table 14. As described in Section 4.4, the assumption is that all new train cars required for service will be double-decker cars.

MBTA's schedules (as of 2017) require 67 consists (individual trains) using 364 coaches. The MBTA Fleet Plan calls for replacing the current single-level traincars with double-decker cars. This reduces the number of scheduled traincars to 316 and increases capacity adequately to serve the forecasted increase in No Build ridership.

Table 14 shows the rolling stock requirements for each of the five service alternatives. All of the build alternatives require an increase in overall fleet size, and Table 14 only illustrates coaches and locomotives in scheduled service. MBTA uses a spare ratio of about 11% for coaches and about 35% for locomotives, which increases the overall fleet requirements. In future planning stages, train storage and marshalling yards and tracks will need to be included in the analysis, as they have not been incorporated in this Feasibility Reassessment.

All of the build alternatives require significant increases in fleet size. These increases require both additional capital expenditure (for the cost of the additional yards, coaches, and locomotives, assuming the existing base fleet is regularly renewed) and additional operating costs.

Finally, as service increases, and the currently scheduled weekday consists increase to more than 100, additional train crews and maintenance personnel will be required. This Feasibility Reassessment did not look at this in depth, so this should also be included in future planning stages.

For the purposes of the NSRL Feasibility Reassessment, one capital cost is utilized for the two-track alternatives pursuant to the study's scope. The capital cost differences between the NSRL Regular Service (Two-Track) and the NSRL All-Day Peak Service (Two-Track) is not significant, as the infrastructure requirements are identical and the fleet requirement – which is driven by the peak hour of train service – is almost the same. The combined fleet size is informed by the peak period requirement and a reasonable assumption of "short turns" and other operational practices that can reduce overall fleet requirements.

Unit Operating Costs

MBTA Commuter Rail operating costs for 2016 were $17 per car mile and $515 per car hour for the all-diesel fleet. In contrast, Philadelphia's SEPTA operating costs for 2016 were $13.85 per mile and $292 per hour for the all-electric fleet. Since there will be some combination of electric and diesel service, a range of costs is used as part of the financial impacts provided in the Feasibility Reassessment.

Service Alternative	Consists	Coaches (Bi-Level Equivalents/ Scheduled)
No Build	67	316
South Station Expansion & All-Day Peak Service (No NSRL)	116	524
NSRL Regular Service (Two-Track)	104	514
NSRL All-Day Peak Service (Two-Track)	121	527
NSRL All-Day Peak Service (Four-Track)	143	550

Table 14: Weekday Train Requirements per Service Alternative