NEC FUTURE

A Rail Investment Plan for the Northeast Corridor

Tier 1 EIS Alternatives Report

October 2015

Amended

U.S. Department of Transportation

Federal Railroad Administration

TABLE OF CONTENTS

TABLES

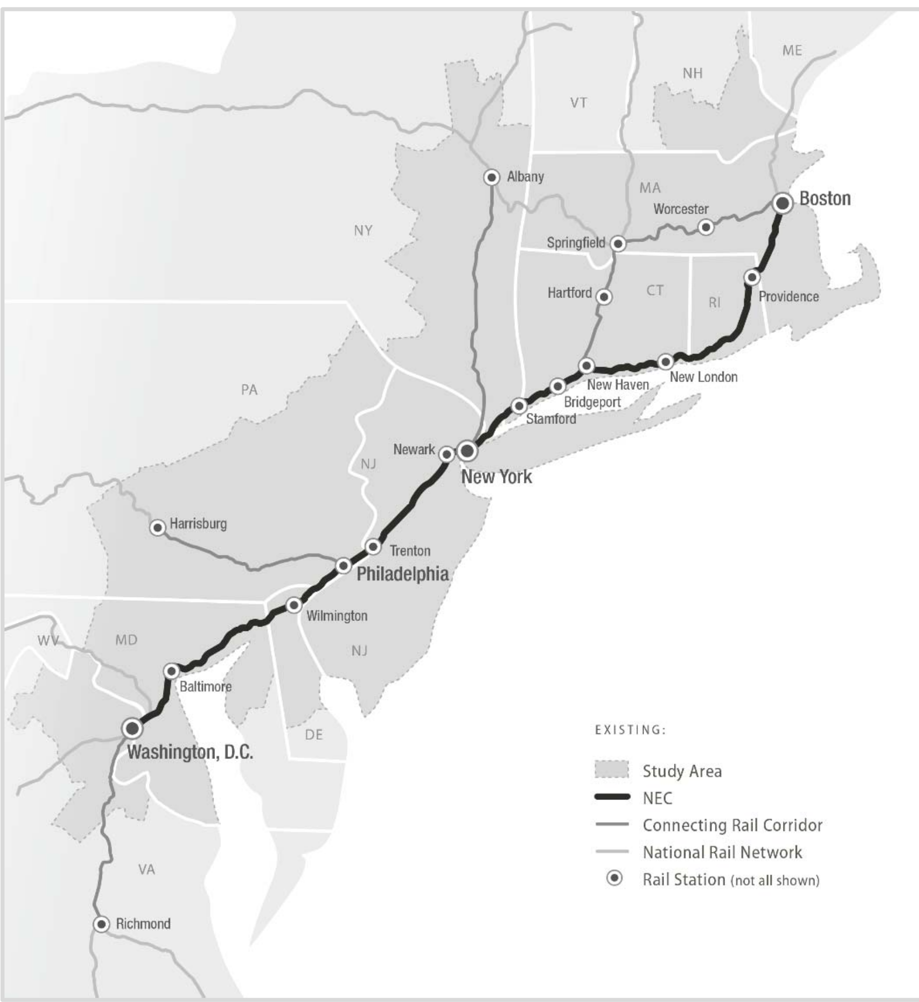
FIGURES

1. Introduction

NEC FUTURE is a comprehensive planning effort to consider the role of passenger rail service on the Northeast Corridor (NEC) within the regional multimodal transportation system and how it can meet current and future demand for Intercity and Regional rail service. As the lead federal agency for this planning effort, the Federal Railroad Administration (FRA) will determine a long-term vision and investment program, through the development of a Tier 1 Environmental Impact Statement (EIS) and Service Development Plan (SDP).

The NEC is the rail transportation spine in the Northeast of the United States and is a key component of the region's overall transportation system. It accommodates the operation of eight commuter-rail authorities and Amtrak—the Intercity rail service provider—as well as four freight railroads. The NEC FUTURE Study Area (Study Area) encompasses eight Northeast states and Washington, D.C., which are served directly by the NEC, plus those areas that can be reached directly by train or via a transfer from the NEC to connecting corridors. Figure 1 shows the Study Area, identifying the existing passenger rail network that comprises the NEC and connecting corridors.

Figure 1: Study Area



1.1 PURPOSE AND NEED

The 457-mile NEC and its connecting rail corridors[1] form the most heavily utilized rail network in the United States. The NEC ranks among the busiest rail corridors in the world, moving more than 750,000 passengers every day[2] on 2,200 trains.[3] Freight operators share the NEC with passenger railroads and move over 350,000 car loads of freight per year[4] on the NEC. This volume of traffic and diversity of service operate with capacity constraints that require scheduled and real-time trade-offs in passenger and freight service frequency, speed, and performance.

The congestion resulting from these capacity constraints, along with the NEC's aging infrastructure, further limit the opportunities to improve or expand passenger rail services. This infrastructure, in many cases built over 100 years ago, also does not provide the resiliency or redundancy necessary to respond to unanticipated natural disasters or other disruptive events. Additional details on the NEC's capacity constraints and aging assets are presented in the NEC FUTURE Scoping package (available on the NEC FUTURE website)[5] as well as the Northeast Corridor Infrastructure & Operations Advisory Commission (NEC Commission) *State of the NEC Region Transportation System* and *NEC Five-Year Capital Plan Fiscal Years 2016-2020*.[6]

An investment program to improve connectivity between passenger and freight rail markets and established and growing Northeast business centers is also critical to the economy. The Northeast is home to more than 51 million people[7] and includes four of the ten largest metropolitan areas in the United States. These major metropolitan areas, Washington, D.C., Philadelphia, New York City, and Boston, are among the top 25 largest metropolitan areas ranked by gross domestic product (GDP) in the world.[8] Approximately 20 percent of the nation's GDP comes from areas within the Study Area,[9] establishing the Northeast as an economic engine for the nation. In fact, if the Study Area were an independent country, it would represent the fifth-largest economy in the world.[10] The effectiveness and efficiency of that transportation system is critical to the continued economic growth and vitality of the Northeast.

As population and employment grow in the Northeast, however, even more demands are made on the existing transportation system. Traffic congestion and delays are routine across the transportation system

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[1] Connecting corridors are those rail corridors that connect directly to a station on the NEC. These include (1) corridor service south of Washington Union Station to markets in Virginia and North Carolina including Lynchburg, Richmond, Newport News, Norfolk, and Charlotte; (2) Keystone (connects to Philadelphia 30th Street Station); (3) Empire (to Penn Station New York); and (4) New Haven-Hartford-Springfield (to New Haven Union Station)

[2] Northeast Corridor Infrastructure and Operations Advisory Commission. (February 2014). *State of the Northeast Corridor Region Transportation System.* State of the Northeast Corridor Region Transportation System.

[3] Amtrak. (2014). *NEC Maps & Data: Growing Demand for Rail Services in the Northeast*. Retrieved January 2015, from Amtrak, The Northeast Corridor: *http://nec.amtrak.com/content/growing-demand-rail-services-northeast*

[4] Northeast Corridor Infrastructure and Operations Advisory Commission. (February 2014). *State of the Northeast Corridor Region Transportation System.*

[5] *www.necfuture.com*

[6] The referenced NEC Commission documents are available at *http://www.nec-commission.com*.

[7] U.S. Census Bureau. 2013. 1970–2012 Population Data. Washington, D.C.

[8] Brookings Institution. *Global MetroMonitor*. 2012. *http://www.brookings.edu/research/interactives/global-metro-monitor-3*

[9] United States Department of Commerce, Bureau of Economic Analysis. (2015). *Regional Economic Accounts*. Retrieved February 2015 from *http://www.bea.gov/regional/index.htm*

[10] Northeast Corridor Infrastructure and Operations Advisory Commission. (April 2014). *The Northeast Corridor and the American Economy.*

for highways and airports. By 2040, the Northeast is expected to add seven million new residents,[11] and no mode has sufficient new capacity to accommodate this growth. As growth continues and transportation demand exceeds the capacity of an already heavily used system, congestion will likely worsen.

Growth in population and employment in the Study Area combined with changes in travel preference will increasingly require a level-of-service and connectivity that is not supported by the existing NEC. Challenges to passenger rail travelers today include poorly coordinated transfers and inconvenient service frequencies, which make other travel choices and modes more attractive. A well-defined and coordinated investment program to support both preservation and enhancement of the NEC is essential to meet the needs of passenger and freight markets in the coming decades.

Moreover, there is national, regional, state, and local interest in how the transportation system, and in particular the rail network, can positively contribute to the overall environmental quality of the Northeast. It is, therefore, critical that improvements also consider environmental sustainability.

The ***purpose*** of the NEC FUTURE program is to upgrade aging infrastructure and to improve the reliability, capacity, connectivity, performance, and resiliency of future passenger rail service on the NEC for both Intercity and Regional rail trips, while promoting environmental sustainability and economic growth.

Overall ***needs*** addressed by the NEC FUTURE program include aging infrastructure, insufficient capacity, gaps in connectivity, compromised performance, lack of resiliency, environmental sustainability, and economic growth (Figure 2).

1.2 GUIDING PRINCIPLES

Given the unique complexities of alternatives development for the NEC, the FRA has drawn on international best practices, lessons learned in the development of the United States rail system, and stakeholder and public feedback to establish a set of "guiding principles" to help structure the planning process. These principles reflect agreed-upon policy objectives for the NEC FUTURE planning study to:

- Consider a Broad Range of Alternatives
- Develop Alternatives that Focus on Efficiency
- Structure Alternatives to Enable Incremental, Flexible Implementation

These principles and the related implications for the alternatives development process are described in the *Preliminary Alternatives Evaluation Report*, available on the NEC FUTURE website.

1.3 DOCUMENT PURPOSE

This Tier 1 EIS Alternatives Report presents the process for developing and refining the Tier 1 EIS Alternatives, which includes the No Action Alternative and Action Alternatives that will be analyzed in the Tier 1 Draft EIS. The alternatives development and refinement process, consists of service planning, ridership modeling, capital and operations and maintenance cost estimating, as well as stakeholder and

[11] Northeast Corridor Master Plan Working Group. (2010). *Northeast Corridor Infrastructure Master Plan*

public input. Furthermore, this document provides the complete definition and description of each alternative that will be presented in the Tier 1 Draft EIS.

Figure 2: NEC FUTURE Program Needs

State of Good Repair
Service quality currently falls short, due to the aging and obsolete infrastructure that has resulted from insufficient investment in maintaining a state of good repair on the existing NEC. Achieving and maintaining a state of good repair is needed to improve service.

Connectivity
The reach and effectiveness of the passenger rail network are limited by gaps in connectivity among transportation modes and between different rail services.

Capacity
Severe capacity constraints at critical infrastructure chokepoints limit service expansion and improvement, making it difficult to accommodate existing riders and growth in ridership.

Performance
In many markets, the trip times on passenger rail within the Study Area are not competitive with travel by air or highway. Improvements in travel times, frequency, or hours of service are needed to make passenger rail competitive with other modes.

Systemwide Resiliency
The NEC is vulnerable to the effect of severe storms. A more resilient and redundant passenger rail network is needed to enhance safety and the reliability of the region's transportation system.

Environmental Sustainability
Throughout the Study Area, energy use and emissions associated with transportation affect the built and natural environment. Passenger rail can help meet the region's mobility needs with fewer environmental impacts.

Economic Growth
A transportation system that provides options for reliable, efficient, and cost-effective movement of passengers and goods is needed for continued economic growth in the Northeast. The region's knowledge-based economic sector, including academic research and medical facilities, is especially reliant on access to convenient, reliable, and frequent rail service.

2. Alternatives Development Process Overview

There are many possible futures for the NEC. Some involve significant changes in the way passenger service is provided, while others focus on modifications to the existing system, keeping service much as it is today. Some options focus improvements only on the existing NEC, while others include service to new locations or different types of service. The FRA designed the NEC FUTURE alternatives development process to consider a broad array of distinct alternatives that address the program's Purpose and Need. With a set of guiding principles in mind (as listed in Section 1.2), the FRA progressively narrowed those alternatives to a smaller set that address the identified needs to varying degrees.

Because of the unique geographic, technical, and institutional complexity of the program, the FRA took an innovative approach developing the NEC FUTURE alternatives, organizing the process into three steps (Figure 3). The three-step process allowed for the preparation of corridor-wide service plans and infrastructure projects, and subsequent testing, refining, and optimizing of different service and geographic markets within the NEC. This process also provided the FRA with an understanding of how discrete elements perform relative to one another so that the strongest "package" of separate service, infrastructure, and route options could be crafted into different alternatives that meet the needs of various markets along the NEC.

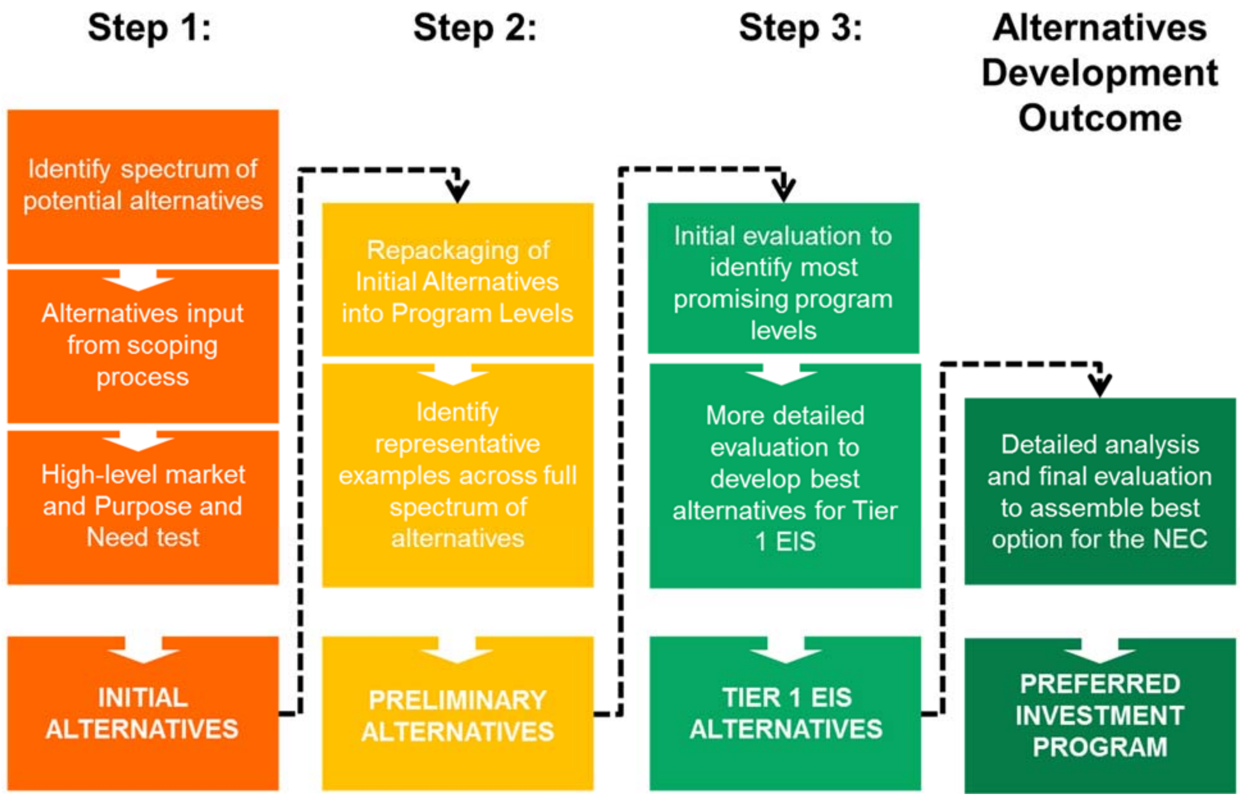
Decisions about the future of the NEC affect a wide range of stakeholders, from rail passengers, agencies, and service operators on the NEC to the residents, travelers, businesses, and communities potentially affected by the outcomes of NEC FUTURE. The FRA has been committed to an open and transparent engagement that involves these stakeholders in the alternatives development process. This engagement has entailed frequent coordination with state and railroad stakeholders, as well as federal and state environmental, transportation, and non-transportation officials. In addition, the FRA has conducted extensive public involvement and agency consultation activities including Scoping, consultation meetings, briefings, workshops, and presentations.

Each level of alternatives development is tied directly to the program's Purpose and Need and reflects the available level of detail from the supporting technical analysis. Similarly, alternatives and service concepts not meeting and addressing the Purpose and Need (Section 1.1) for NEC FUTURE were dismissed from further consideration.

In evaluating the alternatives, the FRA used a number of technical tools (as described in Section 4) to assess engineering feasibility, ridership, operational impacts, capital and operating costs, environmental impacts, and public benefits. The level of technical analysis and associated tools to develop applicable data becomes more detailed as the alternatives advance through the process. This approach was designed to allow for the refinement and the recombination of components of alternatives leading to FRA's identification of the Action Alternatives to be further analyzed and compared to a No Action Alternative in the Tier 1 Draft EIS.

The FRA defined and developed the Action Alternatives to a programmatic level, to focus on corridor-wide solutions within the Tier 1 Draft EIS. These alternatives establish a comprehensive, long-term vision for the corridor's future development and are defined by (1) a range of corridor-wide service options (Service Plans) required to meet varying degrees of projected growth and demand and (2) broad infrastructure needs to accommodate the service. Assumptions made at the Tier 1 level are representative and illustrative, to support analysis in both the alternatives development process and the Tier 1 Draft EIS. These service and infrastructure assumptions are not intended to be specific or prescriptive.

Figure 3: Alternatives Development Process



Source: NEC FUTURE team, 2015

The Action Alternatives provide the FRA and other stakeholders with a range of options and information over the No Action Alternative to determine the appropriate role of rail within the region's future transportation network. While focused on rail solutions (addressing the Purpose and Need), the alternatives have different implications for other transportation modes, including the region's airports, highways, and transit networks. In this way, they provide important information for policymakers to make decisions with this broader transportation system in mind.

The visions articulated by the Action Alternatives will take decades to fully implement. Additionally, improvements are likely to be implemented by multiple stakeholders across the NEC over many years, with specific timing dictated in part by availability of funding, local needs, and construction considerations.

As such, a key element of the NEC FUTURE planning process is to ensure improvements to the NEC are prioritized, integrated, and packaged for optimal service benefits across the entire rail network. The FRA developed the alternatives with the intent that they could be implemented in phases. Prioritization will be accomplished through phasing plans that define the necessary infrastructure and operational enhancements required to support various increments of new corridor-wide service. This phased implementation is described in Section 11.

2.1 INITIAL ALTERNATIVES

Developing a list of "Initial Alternatives" was the first step in the alternatives development process. To develop these alternatives, the FRA began with an analysis of Study Area travel demand and growth data to understand where people are traveling, where growth in population and employment is forecast to occur, and how travel patterns are likely to change in the coming decades. In addition, numerous route and service concepts were identified through input and data collected during Scoping. The FRA organized these ideas into a combination of "building blocks," including how trains will potentially access the markets (network/route), the amount of service to provide to each market (investment level), and the type of service to be provided (service). Mixing and matching these building blocks provided the basis for testing and comparing multiple market, investment, and service options. Table 1 describes these three building blocks.

Table 1: Initial Alternatives Building Blocks

Building Blocks	Variations
Network/Route ■ How can markets be accessed by rail?	■ Existing NEC ■ Potential second-spine ■ Potential new right-of-way segments ■ Potential connecting corridor links
Investment Level ■ How robust is the program? ■ How much service can be provided? ■ Which new markets can be served?	■ Low (A): 2040 growth on existing NEC serving existing markets ■ Medium-low (B): Additional capacity on existing NEC to add new types of express, regional, and connecting corridor services ■ Medium-high (C): Targeted expansion of the NEC to serve new off-corridor markets and expand service options to NEC and connecting corridor markets ■ High (D): Extensive end-to-end expansion of the NEC to serve new markets and high-speed rail service
Service ■ How can markets be best served?	■ Standard service mix (services similar to today) ■ Enhanced service mix (new types of service and operations)

Source: NEC FUTURE team, 2015

Using these three building blocks, the FRA identified approximately 100 Initial Alternatives to address a broad spectrum of opportunities to upgrade and expand the NEC, serve existing and new markets both on and off the corridor, provide better connectivity to other rail markets, transit, and airports, and develop new high-speed rail service.[12] Some of the initial ideas proposed, such as modifying the existing NEC to serve markets off of the existing spine when those markets could be better served through existing and/or future connecting corridors did not advance. The FRA also dismissed less efficient routing options, such as New York City to Boston via Albany. (See the *Preliminary Alternatives Report* available on the NEC FUTURE website for a full description of the process.)

In December 2012, the FRA hosted a set of regional workshops.[13] These December Dialogues presented the market-based approach underpinning the alternatives development process, the results of Scoping, and the framework used to generate the Initial Alternatives. The feedback from participants at the December Dialogues underscored the importance of providing a range of investment scenarios for the NEC, as well

[12] The definition of high-speed rail varies depending on context and purpose. For NEC FUTURE, high-speed rail consists of service provided by Intercity-Express trains operating at a range of speeds from 150 to 220 mph.
[13] A summary of this meeting is available on the NEC FUTURE website: *http://necfuture.com/get_involved/public_meetings.aspx*

as a flexible approach for the use of additional railroad capacity, allowing operators to respond to changing needs.

2.2 PRELIMINARY ALTERNATIVES

For the next step of the alternatives development process, the FRA organized the Initial Alternatives into four program levels to facilitate a comparison of the benefits and impacts of distinct levels of investment in the NEC. Some Initial Alternatives were not advanced into Preliminary Alternatives, particularly those alternatives that included specific engineering and alignment solutions not germane to a corridor-wide, Tier 1 NEPA planning process. These options can be appropriately considered in a project-level, Tier 2 NEPA process.

The four program levels (Table 2) differ by the level and types of rail service they provide to the region and support a broad range of options for the "role" that passenger rail can play on the NEC and in the Study Area, from upgrading the existing NEC to building a second-spine to support high-speed rail operations for existing and future markets. As program levels increase from A to D, larger investments in service and infrastructure are required.

Table 2: Preliminary Alternatives

Program Level	Alt.	Service Objective	Possible Service Option
A	1	Addresses state of good repair[14] and provides some increase in service and capacity along existing NEC	Standard (financially constrained)
	2		Standard
	3		Enhanced (mixture of services)
B	4	Substantially increases service to existing and connecting markets along existing NEC with high capacity operations	Standard
	5		Enhanced: Maximum frequency of trains
	6		Enhanced: Maximum trip time savings
	7		Enhanced: Maximum service to connecting corridors
C	8	Targeted expansion of existing NEC to serve new markets, reduce trip time, and introduce robust Regional rail service	Standard
	9		Enhanced: Maximum frequency of trains
	10		Enhanced: Maximum trip time savings
	11		Enhanced: Maximum service to connecting corridors
D	12	Achieves world-class high-speed rail potential through the addition of new spine	Second-spine generally parallel to existing NEC
	13		Second-spine via Danbury-Hartford-Providence
	14		Second-spine via Ronkonkoma-Hartford-Worcester
	15		Second-spine via Delmarva and Nassau County-Stamford-Danbury-Springfield

Source: NEC FUTURE team, 2015

[14] The condition in which the existing physical assets, both individually and as a system (a) are functioning as designed within their "useful lives," and (b) are sustained through regular maintenance and replacement programs; state of good repair represents just one element of a comprehensive capital investment program that also addresses system capacity and performance.

Within each program level, the FRA developed multiple alternatives to better understand and quantify key market and service dynamics, such as the trade-offs between frequency of service, trip time, and the convenience of one-seat end-to-end service. This allowed the FRA to test and compare different operating scenarios, or, in the case of the second-spine, different route options. In all, the FRA defined 15 Preliminary Alternatives (Table 2). Within Program Levels A, B, and C, the FRA developed two different service scenarios for testing and comparison:

- **Standard service** serves markets in much the same manner as they are served today, with Intercity trains stopping at major stations along the corridor and commuter trains taking passengers from suburban markets into urban centers.
- **Enhanced service** involves the evaluation and testing of new operating approaches and services that allow for more intensive use of existing or new infrastructure.

Because enhanced service, as defined, encompasses a broad range of potential new service options, the FRA developed separate alternatives in Program Levels B and C to focus on three different enhanced service objectives: maximizing the frequency of trains; providing the fastest express trip time; or maximizing service to connecting corridors. (Additional information about the Preliminary Alternatives can be found in the *Preliminary Alternatives Report* available on the NEC FUTURE website.)

In April 2013, the FRA hosted a second set of regional workshops to present the Preliminary Alternatives to the general public.[15] The feedback from participants at the April Dialogues confirmed the importance of preserving a range of program levels in the Tier 1 Draft EIS to reflect different visions for the future of the NEC. Participant feedback also highlighted the importance of evaluating multiple route options.

2.3 NO ACTION ALTERNATIVE AND ACTION ALTERNATIVES

In the final step of the alternatives development process, the FRA evaluated the 15 Preliminary Alternatives by comparing them to understand whether and how each met the Purpose and Need (Section 1.1), and analyzing their benefits in terms of ridership, travel time, and service quality. Similarly, among the different Program Level D second-spine route alternatives, the FRA compared performance (in terms of service and ridership) and environmental impacts.

To conduct the analyses of the 15 Preliminary Alternatives, the FRA developed evaluation criteria and associated performance measures derived from the Purpose and Need. This set of evaluation criteria are based on (i) best practices; (ii) results from models used in transportation investment programs of similar physical and programmatic magnitude, (iii) available data; and (iv) stakeholder input. Table 3 details the criteria and data used to evaluate the Preliminary Alternatives.

The FRA used the metrics and data for each criterion to compare Program Levels A through D, as well as to compare the separate alternatives within each program level. After evaluating the environmental impacts of the Preliminary Alternatives, the FRA determined that each was likely to result in environmental effects. Based on feedback received during the April Dialogues, the FRA dismissed the Delmarva routing in

[15] A summary of this meeting is available on the NEC FUTURE website: *http://necfuture.com/get_involved/public_meetings.aspx*

Preliminary Alternative 15, because of public concerns that the route was not viable for a variety of reasons, including the potential for environmental impacts as well as from a growth and market perspective.

Table 3: Preliminary Alternatives Evaluation Criteria

Evaluation Criteria	Metrics
Growth and Capacity Expansion	■ Annual trips ■ Annual passenger miles ■ Peak-hour passengers at major screenlines* ■ Peak-hour trains, Hudson River screenline
Aging Infrastructure	■ NEC in a state of good repair
Service Effectiveness and Performance	■ Express trip time savings ■ Maximum trains per hour ■ Peak-hour trains operating on NEC
Connectivity	■ Stations served by Intercity trains ■ Station-pairs served by Intercity trains ■ Airport stations
Environmental Consequences	■ Acres of environmental sensitivity

Source: NEC FUTURE team, 2015

* A screenline is an imaginary line used to count rail traffic at a specific location in the Study Area (e.g., the Hudson River, recognizing the capacity restrictions of the tunnels and/or to analyze certain defined types of service/markets).

The FRA's key findings during this stage of the alternatives development process were related to 1) defining service dynamics—evaluating passenger preferences for frequency of service, trip time, and one-seat-ride services; and 2) defining the role that rail can play in transporting travelers across the NEC region. Additional details on this process can be found in the *Preliminary Alternatives Evaluation Report* available on the NEC FUTURE website.

The FRA used this evaluation to repackage the Preliminary Alternatives into three distinct Action Alternatives that meet the Purpose and Need. The FRA also defined a No Action Alternative to establish a baseline for comparative purposes. Each alternative consists of 1) a set of geographic markets to be served by passenger rail; 2) a Representative Route (or footprint) that connects these markets; 3) assumptions about the level of passenger rail service that will be provided to these markets; and 4) infrastructure improvements that support this level-of-service.

The FRA further refined the No Action and Action Alternatives by adjusting and refining service and infrastructure needs based on input gained from over 200 meetings with stakeholders, including the NEC railroads; federal, state, and regional agencies; and other interested organizations and individuals. This refinement process is described in more detail in Section 0.

The following are brief descriptions of the No Action and Action Alternatives. A detailed definition for each alternative is provided in Sections 7, 8, 9, and 10.

- **No Action Alternative** is represented by the existing NEC[16] and maintains today's service levels, defined as the number of trains per hour by operator and existing types of service. It does not increase capacity, address gaps in connectivity, expand service to new markets, or achieve a state of good repair.

[16] Including initiatives currently under construction or funded (e.g., LIRR East Side Access).

- **Alternative 1** maintains the role of rail within the transportation system of the Northeast as it is today, keeping pace with the level of rail service and investment required to support proportional growth in population and employment. For this alternative, the FRA used the projected service plans of NEC service operators as a starting point, and made adjustments to meet projected increases in travel demand. To keep pace with demand, Alternative 1 includes new rail services and investment to expand capacity, add tracks, and relieve key chokepoints, particularly through New Jersey, New York, and Connecticut. Intercity service grows south of New York City through the addition of one Intercity-Express train and one Intercity-Corridor train during periods of peak demand. North of New York City, the Intercity schedule is expanded to include one Intercity-Express train and one Intercity-Corridor train operating hourly in each direction. The capacity of Regional rail service is increased by a combination of lengthening existing peak trains, and adding trains in the peak period where growth is strong and line capacity is limited, especially on the lines feeding New York City.
- **Alternative 2** grows the role of rail, expanding rail service at a faster pace than the proportional growth in regional population and employment. South of New Haven, CT, service and infrastructure improvements are focused generally on the existing NEC, and north of New Haven, a new supplemental two-track route is added between New Haven and Hartford, CT, and Providence, RI, to increase resiliency, serve new markets, reduce trip time, and address capacity constraints. The existing NEC expands in most areas to four tracks, with six tracks through portions of New Jersey and southwestern Connecticut. Alternative 2 includes a new rail route to serve Philadelphia International Airport, and some Regional rail run-through service in New York City and Washington, D.C., to increase terminal throughput.
- **Alternative 3** transforms the role of rail, positioning rail as a dominant mode for Intercity travelers and commuters. Service and infrastructure improvements include upgrades on the NEC and the addition of a two-track second-spine that operates adjacent to the NEC south of New York City and extends the reach of NEC rail to new markets north of New York City. This new spine supports high-speed rail services between major markets and provides additional capacity for Intercity and Regional rail services on both the existing NEC and new spine. Alternative 3 supports a wide variety of new Intercity and Regional rail services, tailored to the needs of specific markets, including non-stop express trains, high-speed zone express trains serving the long-distance commute market, and new service to markets off the existing NEC.

  Alternative 3 includes new high-speed service between Washington, D.C., and Boston. From Washington, D.C., to New York City, this service mostly runs on a route closely parallel to the existing NEC, but it deviates from the existing route to shorten trip times and serve new stations in downtown Baltimore, Philadelphia International Airport, and downtown Philadelphia. Between New York City and Boston, in addition to the existing NEC, Alternative 3 includes several new route options that provide shorter trip times than the existing NEC. Each route option serves different intermediate markets in central Connecticut and on Long Island. These north end route options are described in Section 5. The Service Plans developed to analyze Alternative 3 assume that some Intercity trains operate end-to-end over the new route between Washington, D.C. and Boston, while other Intercity trains, as well as Regional rail trains, operate interchangeably over portions of the new route and the existing NEC.

3. Technology

In defining a long-term vision for the role of passenger rail on the NEC, FRA has actively sought stakeholder and public input via an early and proactive outreach process. The overwhelming message received is that the users of the NEC are seeking reliable, integrated, and expanded train service to meet both Intercity and Regional rail travel needs. Considering that over 90 percent of the users of the NEC are Regional rail customers, it is clear that near-term investments that prioritize responding to the interconnected travel needs of existing rail passengers have great public and institutional support.

The FRA developed the NEC FUTURE Purpose and Need (Section 1.1) to reflect key deficiencies in today's NEC, and subsequently focused on Action Alternatives that best meet that Purpose and Need by improving steel-wheel passenger train technology that is used today by all the railroads sharing the NEC, including both Intercity and Regional rail operations, as well as freight service. The FRA considered proven technological advances, and, where appropriate, incorporated use of international best practices that are compatible with existing steel-wheel train technology for the following reasons:

- **Aging Infrastructure**: The quality of rail service on the NEC – reliability, travel time, and ride quality – currently falls short due to aging and obsolete infrastructure. This is the result of insufficient investment in the rail line to maintain its infrastructure in a state of good repair. Aging infrastructure also increases the cost and complexity of continuing railroad operations. Focusing first on the renewal of existing rail lines using steel wheel technology will yield a significant positive return on transportation investment by improving the reliability and overall quality of current Intercity and Regional rail service for the more than 700,000 daily users of the NEC.
- **Gaps in Connectivity**: Expanding travel connections across the NEC, and making those connections easier and more seamless for the hundreds of millions of people riding Intercity and Regional rail trains each year is fundamental to achieving the purpose of NEC FUTURE. The Northeast is steadily transforming from multiple separate markets to a single region. Essential to this transformation is an integrated network of passenger rail service that connects Intercity and Regional rail markets across the NEC, meets diverse trip origins and destinations of the traveling public, and accommodates projected growth in regional population and employment. Today's NEC passenger rail network is limited by gaps in connectivity among transportation modes and between different rail services. Even with compatible rail technology, today's rail service between stations often requires lengthy layovers or difficult transfers, limiting mobility options for passengers. Expansion of service that incorporates interoperable steel wheel rail technologies within the existing infrastructure will offer travelers a wider choice of city-pair combinations and travel options. It also offers better connectivity through shared station infrastructure and easier cross-platform transfers between Intercity and Regional rail trains.
- **Insufficient Capacity**: Severe capacity constraints at critical infrastructure chokepoints limit service expansion and compromise the ability to recover from service disruptions, making it difficult to offer reliable service and accommodate growth in ridership. Given the broad range of Intercity and Regional rail services provided on the NEC, and the significant cost for adding capacity, the NEC FUTURE Action Alternatives are intended to maximize the transportation benefits of investments in additional capacity, both on the existing NEC and for new routes connecting to or supplementing the existing NEC. The use of interoperable train technology in the Action Alternatives facilitates the incremental expansion of

service across the corridor to address immediate needs on the NEC, keeping up with underlying growth in transportation demand while leveraging individual projects on the NEC to maximize the regional benefits of investments in service and infrastructure.

Given the accelerating pace of change in consumer technology, business practices and transportation patterns, application of future emerging and new technologies may help to support rail service on the NEC and meet other transportation needs across the region. These might include new information systems and services, new train propulsion and guideway systems, fare collection innovations, and safety enhancements. The FRA plays an important role in bringing new rail transportation approaches and technologies to market and demonstrating their specific capabilities and role in the broader transportation system. For example, the FRA has sponsored development of next-generation propulsion systems for locomotives and has explored the potential for use of magnetic levitation train technology.

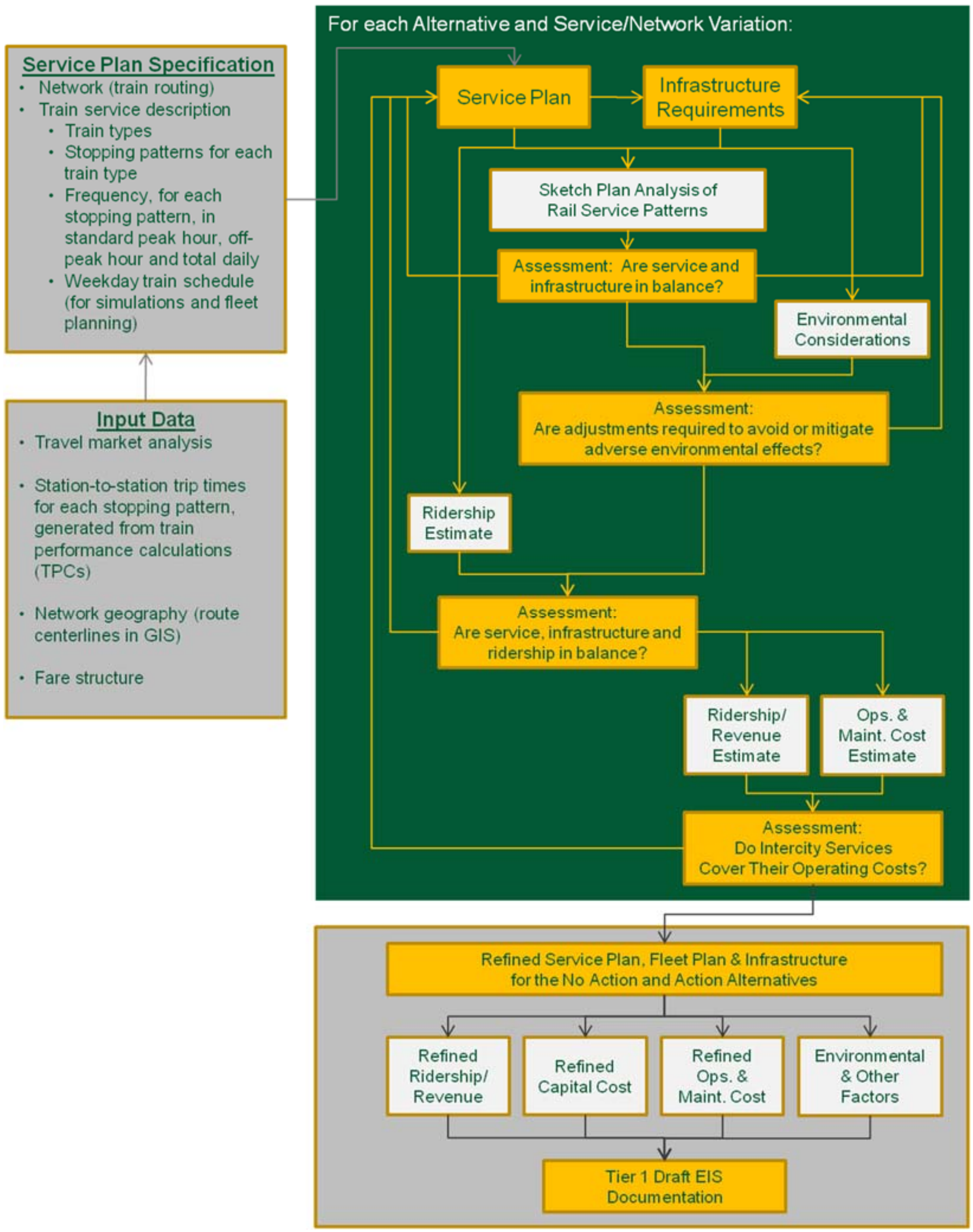
An advanced guideway system, such as magnetic levitation technology, could possibly be used to develop a second-spine or portions thereof as envisioned in Alternative 3. This would require separate stations, could not support run-through trains from connecting corridors, and does not offer proven integration efficiencies with today's NEC infrastructure and operators. However, because advanced guideway technologies remain under development they are not incorporated in the Action Alternatives.

Such technologies could be studied separately, and are not precluded as a future transformative investment in the regional transportation system. Other potential applications of new technology transportation systems could support the NEC passenger rail network by connecting off-corridor markets to the NEC, or a major market to the NEC. This might include a connection between a specific airport (such as JFK International Airport) or other activity center to a downtown center located on the NEC, or connecting the NEC to Pittsburgh, PA or Richmond, VA (e.g., Long Island or parts of northern Virginia).

4. Alternatives Refinement

The FRA refined the Action Alternatives through a phased and iterative process that drew from multiple sources and types of information and work products. Figure 4 summarizes this process in a flow diagram. The refinement of the No Action Alternative also followed this process; however, the process did not require multiple iterations.

Figure 4: Alternatives Refinement Process



Source: NEC FUTURE team, 2015

While the FRA was developing analytic models for estimating ridership, capital costs, and annual operations and maintenance costs, the FRA developed the specific elements of the representative Service Plans – service frequencies, stopping patterns, train routings, and rolling stock characteristics for each service type – to identify their ability to achieve efficient use of rail infrastructure capacity and serve the NEC's rail travel markets. The Service Plans are intended to be representational only, required for analysis of capacity, performance, and costs, as well as assessment of the environmental impacts associated with planned improvements. The Service Plans are not intended in any way to be prescriptive regarding how service should be operated in the future. In addition, the Service Plans are not intended to predict future operating patterns of the NEC operators. The FRA then refined the Service Plans in two broad steps as described below. Throughout this effort, the representative Service Plans remained consistent with the overall role of rail as defined for each of the Action Alternatives.

- The FRA modified the Service Plans to incorporate feedback and input from stakeholders and output from the initial ridership model. Additional refinements were made to balance the rail infrastructure associated with each Action Alternative and provide flexibility for the Regional rail operators, with an emphasis on the areas in and around major terminals.

- The FRA further refined the Service Plans using iterative work with the service planning, ridership, and cost modeling efforts. Interim conservative estimates of service levels were prepared and confirmed the reasonableness of the Representative Route[17] for each Action Alternative. The FRA compared results from the Interregional Model (Section 4.2) with the service levels, and subsequently adjusted the Service Plans to confirm that (1) capacity is reasonably in line with estimated ridership; and (2) the Intercity-Express and Metropolitan services, as defined in Section 4.1.2, generate revenues in excess of operations and maintenance costs in 2040.

For the No Action Alternative, the FRA developed a Service Plan identical to the existing service levels on the NEC, with one exception. The Long Island Rail Road East Side Access Project in New York City, which currently is under construction and therefore included within the No Action Alternative, will change the number of Regional rail trains and their service patterns crossing the East River between Manhattan and Queens, New York. As a result, the FRA incorporated future Regional rail service from Long Island to Manhattan identified in the East Side Access project's Record of Decision into the Service Plan for the No Action Alternative. Intercity service levels are assumed to remain the same as existing levels today.

4.1 SERVICE PLANNING

The FRA developed a sketch planning process for creating and analyzing the representative Service Plans to enable the efficient testing of multiple service scenarios, encompassing:

- Train types, routings, service levels and stopping patterns (peak and off-peak)

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[17] A Representative Route refers to a proposed route or potential alignment for an Action Alternative. It includes horizontal and vertical dimensions, which are based on prototypical cross sections and define its footprint. Prototypical cross sections identify construction methods (tunnel, viaduct, bridge, fly-over, bypass, track type, etc.) and right-of-way requirements for tracks, structures, ancillary facilities, and stations associated with each Action Alternative. (See Section 6.2.) The Representative Route is limited to the NEC Spine; and therefore, excludes connecting corridors and branch lines.

- Scenarios covering the range of service levels and types being considered for each of the Action Alternatives
- Service pattern analysis – balancing service needs and infrastructure requirements.

The FRA performed early rounds of analysis working with ranges of service levels. Service Plan scenarios were developed for the NEC network as a whole and also for key segments of the corridor. These scenarios were developed from a set of planning objectives directly related to the three visions (maintain, grow, transform) of the Action Alternatives.

In each representative Service Plan, the FRA considered:

- A mix of service types, including Intercity-Express, Intercity-Corridor (Metropolitan and Intercity-Corridor-Other), Long Distance, and Regional rail service (as defined in Section 4.1.2)
- Specific stopping patterns and rolling stock for each type of train service
- The calculation of trip times over the rail network for each train type and stopping pattern, based on train performance calculations, with reasoned assumptions about station dwell times, terminal layover time and overall schedule recovery time built into the scheduled trip times
- Future Regional rail frequency targets for each service type and stopping pattern:
  - Peak, at each station (e.g., provide slots for 2, 3, or 4 trains per hour [tph])
  - Off-Peak (e.g., provide slots for 1–2 tph)
- Infrastructure assumptions, including number of main tracks, location and configuration of rail junctions, track and platform configurations at stations, and the locations of train storage yards
- Assignment of trains (by type, stopping pattern and time of day) to available tracks in each segment of the corridor

Using stringline (time-distance) diagrams and train schedule information, the FRA aligned and overlaid a full set of train service patterns. The FRA adjusted train service patterns, schedule times, and track assignments interactively to eliminate operating conflicts. Adjustments to the rail infrastructure configuration were made, where necessary and appropriate to address conflicts that could not be resolved with operational and scheduling adjustments. The end result of this integrated process was a Service Plan and representative train timetable for each Action Alternative that is operationally feasible and fits within the available capacity of the rail infrastructure. This process is described in greater detail in Appendix A, *Service Plans and Train Equipment Options Technical Memorandum.* As noted, the Service Plans are intended to be representational only, required for analysis of capacity, performance, and costs, as well as assess environmental impacts, and are not intended in any way to be prescriptive regarding how service should be operated in the future. In addition, the Service Plans do not predict future operating patterns of the NEC operators.

4.1.1 SERVICE PLANS

The FRA developed Service Plans for the No Action and Action Alternatives to describe the types and levels of passenger train service operating on the NEC in 2040. These Service Plans are a representative train schedule for a typical future weekday, and include the train stops by station for both peak and non-peak periods. The Service Plans are operator-neutral and provide a technical basis that allows the FRA to estimate future ridership and capital investment needs and costs, as well as assess the environmental impacts associated with planned construction and future operations.

The FRA developed the Service Plans as a planning tool. They are not for purposes of actual implementation and are distinct from full detailed operating plans. The Service Plans do not include yarding and crewing assumptions, or specific track assignments at major stations and terminals. They are grounded in reasonable operational assumptions, driven by rigorous train performance calculations and informed by capacity analysis, supported by operations-related analysis at a level sufficient for the plan to be considered operationally feasible. Subsequent investment-grade simulation analyses generally will be required to support detailed decision-making and the development of actual operating plans and timetables.

4.1.2 SERVICE TYPES

For NEC FUTURE, the FRA organized the various types of passenger rail service into categories, based on travel distance, travel market, trip purpose, where and how the trains operate, and the service characteristics and amenities offered to passengers. The categories are used to represent the rail service that is provided in the No Action Alternative and Action Alternatives and correspond with the travel market definitions used for ridership estimating. These categories are aimed at best describing the full range of services provided in the Action Alternatives.

The top level categories are **Intercity** and **Regional rail.** Intercity service provides transportation between cities or metropolitan areas at speeds and distances greater than that of most Regional rail trips. Regional rail generally provides transportation within a single metropolitan region and serves more local markets. Regional rail service currently focuses largely, though not exclusively, on journey-to-work travel to the major central business districts within the Study Area. However, an increasing share of Regional rail trips are attributable to non-traditional commutes and non-work trip purposes. Moreover, reverse-peak and off-peak travel generally is growing at a faster rate than traditional commuting.

Intercity

For purposes of the travel demand analysis and ridership estimating, Intercity service is classified by market segment into two service types: **Intercity-Express** (serving the premium travel market composed largely of business travelers) and **Intercity-Corridor** (serving a broad market segment that includes a mix of business, personal, and leisure trips). Today's Amtrak's Acela Express and Northeast Regional services fit into these two service types, respectively. Ridership estimates were produced for these service types, as described in Section 4.1.2. These service types are described in greater detail in the *Service Plans and Train Equipment Options Technical Memorandum*.

- **Intercity-Express** – the future premium Intercity high-speed rail service offered on the NEC, making limited stops along the NEC and only serving the largest markets. Amtrak's Acela Express currently provides such service on the NEC between Washington, D.C. and Boston, MA. For the Action Alternatives, this category of service is envisioned as analogous to the state of the art high-speed rail services currently operating in Europe and Asia. Intercity-Express service offers the shortest travel times for Intercity trips, with a higher quality of on board amenities, at a premium price, using state of the art high-speed trainsets, with top speeds in the range of 160 mph to 220 mph.
- **Intercity-Corridor** – the Intercity services that operate *both* on the NEC and on connecting corridors that reach markets beyond the NEC. Whereas Intercity-Express service is aimed at the business travel

market, Intercity-Corridor trains serve the more price-sensitive end of the Intercity rail travel market, carrying both leisure and business travelers and stopping at a greater number of intermediate stations, compared with Intercity-Express trains.

- **Metropolitan** – the future primary Intercity rail service on the NEC, a subset of Intercity-Corridor service, and the successor to the existing Amtrak Northeast Regional Service. Whereas Intercity-Express service is aimed at the business travel market, Metropolitan trains serve both leisure and business travelers who are more price-sensitive. The FRA has chosen a new name for this service to emphasize its distinct characteristics and higher level of performance. Metropolitan trains use electric high-performance train equipment intended to operate at speeds up to 160 mph. They operate on regular schedules with high frequency (2-4 trains per hour) and are able to stop at more stations than the current Amtrak Northeast Regional service (including some stations that are only served today by Regional rail trains), due to faster speeds and high-performance operating characteristics. This allows Metropolitan trains to maintain competitive trip time while increasing the number of direct station-pair connections served by Intercity-Corridor trains. Metropolitan service also provides a travel choice for longer-distance commuters at stations served by both Metropolitan and Regional rail trains. In addition to providing service on the NEC Spine, Metropolitan trains provide service on the electrified Keystone Corridor in all three Action Alternatives and on the Hartford Line in the alternatives where this line is electrified (Alternatives 2 and 3).
- **Intercity-Corridor-Other** – Since Metropolitan service utilizes trainsets that can only operate in electrified territory, a separate Intercity-Corridor service is needed to provide connectivity and direct one-seat service between non-electrified connecting corridors and the large and mid-size markets on the NEC. These trains, along with the Metropolitans, are classified as Intercity-Corridor trains for purposes of ridership analysis, and they cater to similar market for Intercity service. These trains are assumed to have operating characteristics similar to today's Amtrak Northeast Regional trains, which will be dual-mode in the future – with top speeds of 125 mph on the NEC and up to 110 mph off of the NEC. The most prominent off-corridor routes served by these trains include Washington, D.C., to various points in Virginia and North Carolina, the Empire Corridor serving Upstate New York, the Knowledge Corridor serving central Massachusetts and Vermont, and the Inland Route corridor between Springfield, MA, and Boston.

- **Long Distance** – Intercity trains connecting the Study Area with other parts of the United States, generally entailing overnight travel with sleeping car and dining car service and handling checked baggage. This category includes existing Amtrak service to Florida, New Orleans, and Chicago. Since these trains operate over longer distances, they are subject to greater delays when operating off-corridor. As such, these trains are scheduled to operate on the NEC during off-peak periods. For NEC FUTURE, the FRA assumes that the level of long-distance train service on the NEC will remain constant through the 2040 horizon period—five round trips per day on the NEC between New York and Washington, D.C., and points south[18] plus the Capitol Limited and Lake Shore Limited, which connect with NEC services at Washington, D.C., New York City, and Boston.

[18] Represented by four existing overnight services (Silver Star, Silver Meteor, Crescent and Cardinal), plus the same-day Palmetto service to Savannah, GA.

Regional Rail

Regional rail encompasses all rail services that are concentrated within a single metropolitan region. Regional rail trains provide local and commuter-focused service characterized by relatively low fares and a high percentage of regular travelers. Regional rail includes the current services provided by Virginia Railway Express (VRE), Maryland Area Regional Commuter (MARC), Southeastern Pennsylvania Transportation Authority (SEPTA), NJ TRANSIT, Metropolitan Transportation Authority (MTA)-Long Island Rail Road (LIRR), MTA-Metro-North Railroad (MNR), Shore Line East, and Massachusetts Bay Transportation Authority (MBTA). None of these railroads, with the exception of Shore Line East, operates exclusively on the NEC. Most include relatively extensive networks of multiple branch lines, which feed one or more major terminal stations. As a result, the NEC does not operate in a vacuum, but rather as a key element within a complex and interconnected rail transportation system. Regional rail services have multiple stopping patterns, which vary by location and among the Action Alternatives: all-stop local service, zone express service (typically a weekday peak service that stops at a group of adjacent stations and then operates express to the main terminal), and limited-stop service focusing on selected key stations.

4.1.3 ROLLING STOCK

The FRA made assumptions in the Service Plans about combinations of various types and configurations of rolling stock and associated traction power. In the Action Alternatives, passenger trains on the NEC comprise both integrated trainsets and locomotive-hauled coaches. Integrated trainsets are represented by electric multiple-unit trains operated by some Regional rail providers, as well as the high-speed trainsets that are used for both Intercity-Express and Metropolitan service. On the NEC, integrated trainsets operate on electric power drawn from the overhead catenary system. Locomotive-hauled trains are categorized by the traction capabilities of the locomotive, which can either be electric (also drawing power from the catenary), diesel, or dual-mode (with the ability to operate under electric or diesel power). Locomotive-hauled trains are used for Intercity-Corridor-Other and Regional rail service.

The Service Plans for the Action Alternatives are based on the use of electric traction by all passenger trains operating on the NEC– using intact trainsets, electric locomotives or high-performance dual-mode locomotives – since these equipment types provide the most consistent top speeds and accelerating and braking performance, which allows for the highest utilization of available capacity. Specific assumptions regarding Regional rail service and rolling stock vary among the Action Alternatives. The ultimate decisions about rolling stock procurement, including the configuration and maximum speed of trainsets, will be made subsequent to the completion of the programmatic Tier 1 EIS.

4.1.4 ENHANCED SERVICE CONCEPTS

In addition to identifying requirements for rail infrastructure investments in capacity needed to accommodate increased levels of train service, FRA also examined the potential to improve passenger rail operations through the adoption of enhanced service and precision operations concepts to fully understand the dynamic operating environment in which passenger rail service on the NEC functions. These enhanced operating concepts represent national and international best practices, and are aimed at enhancing the attractiveness and convenience of train services, increasing the efficiency of operations, lowering the cost per capita of delivering rail service, and making the most efficient use of investments in new rail infrastructure. The FRA's focus in the development of the Action Alternatives was on concepts that take advantage of the elimination of chokepoints, the expansion of capacity and the standardization of rolling stock, so that the benefits of capital investment are maximized. Enhanced service concepts reach markets that are underserved or not served by existing service, while providing the rail operators the flexibility to deliver service that best meets the needs of the market in 2040. The new service concepts that the FRA applied and tested are discussed in the following sections, along with how and where these concepts are embedded within the representative Service Plans of the Action Alternatives.

Regular Clockface Headways

Service Plans for the three Action Alternatives provide for regular schedules for all train services operating on the NEC. Train schedules are headway-driven rather than load driven, as is the case today. In the Action Alternatives, virtually all NEC services operate at regular 15-, 30-, or 60-minute intervals, with local stations generally receiving 2 to 4 tph during peak periods and major stations often receiving more service. Peak shoulder hour, reverse-peak, and off-peak schedules retain the same operating patterns, but with a reduced number of trains per hour to match expected passenger demand. Individual service patterns repeat every hour (e.g., the local train stops each hour at 18 minutes and 48 minutes past the hour), though some patterns may only exist during peak periods.

An additional benefit of regular clockface headways is that they make it easy for passengers to make connections between rail and local transit services. For example, a bus route that runs on a regular clockface headway can be timed to meet connecting trains at a hub station[19]. This coordination increases ridership on both rail and other public transit services by reducing transfer time between modes. Additionally, a bus that is timed to meet the train can serve double duty – bringing passengers to the train as well as carrying passengers from the train on its onward journey. Transit agencies all along the NEC can choose to re-structure routes and schedules to take advantage of the regular clockface headway operation on the railroad.

Metropolitan Service

As described in Section 4.1.2, today's non-premium Intercity-Corridor service evolves into Metropolitan service, a new Intercity-Corridor service that provides frequent, regular service catering to the non-premium intercity market as well as the time-sensitive regional rail market. In all three Action Alternatives, Metropolitan service becomes the primary non-express Intercity service option for trips that begin and end on the NEC. A separate Intercity-Corridor-Other service remains to provide one-seat rides from NEC stations to markets beyond the NEC, including Virginia, North Carolina, and Vermont.

All of the Action Alternatives introduce Metropolitan service, although the level-of-service and the performance characteristics of the service varies among the alternatives. This variance is based on the railroad infrastructure and capacity that are provided in each alternative. In Alternative 1, Metropolitan trains share NEC slots with Intercity-Corridor-Other trains, operate mostly over existing NEC tracks, and service is limited to no more than two trains per hour in the peak periods. Metropolitan service is introduced to additional stations on the NEC, but the overall performance of Metropolitan and Intercity-Corridor-Other services is similar, and the principal travel benefits are derived from the improvement in the frequency of these combined services within the Intercity-Corridor category.

[19] Hub stations include smaller intermediate Intercity stations and key Regional rail stations, as well as new stations that have the potential to fill connectivity gaps, serve special trip generators, and/or provide important inter-modal connections. These stations are served by some Intercity service, although Intercity-Express service is more limited than the service levels offered at Major Hub stations. See Section 6.1.1.

In Alternative 2, Metropolitan service effectively replaces the existing Northeast Regional service for the low or economy end of the Intercity travel market for trips within the NEC territory. The service utilizes the high-speed tracks that are built at various locations along the NEC, and it provides four trains per hour, at regular 15-minute intervals at all locations and in all time periods on the NEC where there is demand to support the service. Intercity-Corridor-Other trains supplement the Metropolitans, further increasing the effective service frequency for travel within the NEC.

Alternative 3 provides two different sets of Metropolitan services, each operating with four trains per hour in peak travel periods. One service operates via downtown Philadelphia and the second-spine between New York City and Boston, and the other service operates on the existing NEC between Philadelphia and New Haven, with extensions of service to Harrisburg, PA via the Keystone Corridor, to Boston, MA via the Shore Line, and to Springfield, MA via the Hartford Line.

Run-Through Service at Major Stations/Terminals

In Boston, New York City, and Washington, D.C., the various Regional rail operators terminate service at the major rail stations in the central business district (CBD). Philadelphia is the exception on the NEC where Regional rail currently operates through Center City Philadelphia with branch lines on one side linked with different branch lines on the other side.

Regional rail run-through service, particularly applicable to Washington, D.C., and New York City, links branch lines from the different service operators and provides continuous revenue service on both sides of the metropolitan region through the CBD. For example, a peak-direction Regional rail train that originates in New Jersey operates into Penn Station New York, then continues eastward in revenue service and offers reverse-peak service to Long Island. Based on early market analysis performed during the alternative development process, demand for this through-service is modest relative to the demand for service to the CBD, and run-through demand is unlikely to be the driver for the investment in infrastructure required to support such operations. However, with considerable investment in the major terminals and coordinated improvements to train fleets, run-through service has the potential to provide operational efficiencies and reduce train interference conflicts, thereby unlocking additional capacity at these congested stations.

Alternative 1, which maintains the role of rail as it is today, retains the existing Regional rail operations with terminating services at Washington, D.C., New York City, and Boston, although the volume of train movement activity increases over existing and No Action Alternative levels. Intercity trains remain the principal through-running trains at Washington, D.C., and New York City.

Alternative 2 requires capital investment at Washington, D.C., and New York City to facilitate the through running of both Intercity and Regional rail trains, including the widening of station platforms and the creation of storage yard facilities on the far side of the terminal for originating and terminating Regional rail services. Through running is assumed to occur at both Washington, D.C., and New York City in this alternative – supporting frequent Metropolitan service as well as high-density Regional rail service. Through running capability and associated capacity projects permit Metropolitan service to be extended through Washington, D.C., to northern Virginia. Similarly, expanded Regional rail services at both Washington, D.C., and New York City are assumed to operate through the Major Hub stations, feeding yard facilities on the far side of the hub station and also enabling (but not requiring) revenue run-through service between suburban branch lines on opposite sides of the region.

Alternative 3 similarly supports through-running operations, which permit the most efficient use of platform and track capacity at the Major Hub stations and enable the dramatic increases in total train volumes that are possible in this alternative.

Intercity-Corridor and Regional Rail Express Service using New High-Speed Tracks

In Alternative 3, the new dedicated high-speed tracks for Intercity-Express and Metropolitan service provide an opportunity to increase the utilization of this infrastructure through urban areas with select Regional rail trains taking advantage of available slots not used by intercity trains. Intercity-Express and these select Regional rail trains operate with high-performance trainsets capable of operating in blended service with high-speed express trains. They supplement or replace the outer zone express service in the major metro regions, or could be used to extend Regional rail service beyond the existing service territories. For example, in New Jersey, this service could replace the current Trenton-Hamilton-Princeton Junction zone express trains, providing significant trip time improvement for these trips. This service could also be used to extend the service territory south to Philadelphia, providing high-quality express Regional rail service between Philadelphia and Bucks County to New York City.

This enhanced service concept is a significant feature of Alternative 3, offering substantially faster commute times for longer-distance commute trips from the outer suburbs. Maryland outer zone Regional rail trains can use the high-speed tracks between Baltimore and Washington, D.C. Similarly, outer zone Regional rail trains in New Jersey can use the high-speed tracks on final approach to New York City to reduce trip times and relieve congestion on the local tracks. Alternative 3 also provide opportunities for up to six or eight commuter express trains per hour from either Long Island or the Upper Harlem Line to Penn Station New York, depending upon the route option.

Simplified Operations

The simplified operations category encompasses a range of possible concepts for operating passenger service on a multi-track rail line. Service concepts include normalizing stopping patterns (with fewer but more regular and better coordinated patterns), as opposed to having a lot of unique individual patterns, less switching of trains between tracks in multi-track territory, fewer branch lines feeding the NEC Spine, timed transfers for branch line passengers at main line hub stations, and/or higher and more regular service frequencies for the stopping patterns that remain on the existing NEC. The primary benefit of a simplified Service Plan is that it brings more predictability to both train operators and passengers.

For train operators, simplifying the train schedule and adopting regular, repeating and well-integrated train stopping patterns can allow the railroad to be run more automatically, without the variability and potential human error introduced by a system that generates a wide range of unique conflicts that require frequent dispatcher decisions and unique solutions. The system remains too complex for completely automated operation, and train dispatchers are still needed to monitor and resolve conflicts and errors that do occur. However, simplified operations can reduce the number and type of train interference conflicts that arise for train dispatchers and allow them to better respond to conflicts when they occur, and respond in a way that is more predictable. Consequently, simplified options should improve the overall reliability of the railroad as well as minimize the amount of redundant and parallel rail infrastructure necessary to support a more complex Service Plan.

For passengers, the regularity of a simplified plan makes planning trips easier, increasing the attractiveness of rail versus other modes. More reliable service and better connections with other rail services and transit modes are benefits that attract additional ridership. Drawbacks of this type of plan may include serving fewer markets with one-seat-rides and increased trip times for express trains between major markets.

Both Intercity and Regional rail stopping patterns in all three Action Alternatives are simpler and more regular than in the current operating plans. These modifications, along with the elimination of chokepoints and the restoration of the railroad to a state of good repair, result in more reliable service and more efficient use of infrastructure. The most dramatic application of simplified operations occurs in Alternative 1 on the New Haven Line. A transit-style service with a simpler system of express and skip-stop local services replaces the current complex overlay of multiple stopping patterns. This service concept delivers greater throughput capacity without major additions of new track.

Coordinated Endpoint and Branch Line Connections

Coordinated scheduling of Regional rail trains on systems that have multiple branch lines or multiple terminals, or where the outer ends of two regional systems meet at a common station (defined as endpoints), can provide for convenient passenger connections, extending the reach of the existing systems, substituting for costly extensions for one-seat-ride service, and providing a much more convenient transfer experience for rail travelers. More precise schedule coordination becomes easier to accomplish with clockface scheduling, simplified operations, and elimination of the chokepoints that contribute to train delays—all of which are characteristics of the Action Alternatives. Convenient transfer connections depend on train schedules that allow enough, but not too much, time for passengers to change trains. Convenience also is enhanced with cross-platform or same-platform transfers, and the integration of timetable and real-time train information, particularly where more than one operating authority is involved. Trenton, NJ, is an example of a location where endpoint connections currently are provided between SEPTA and NJ TRANSIT Regional rail trains.

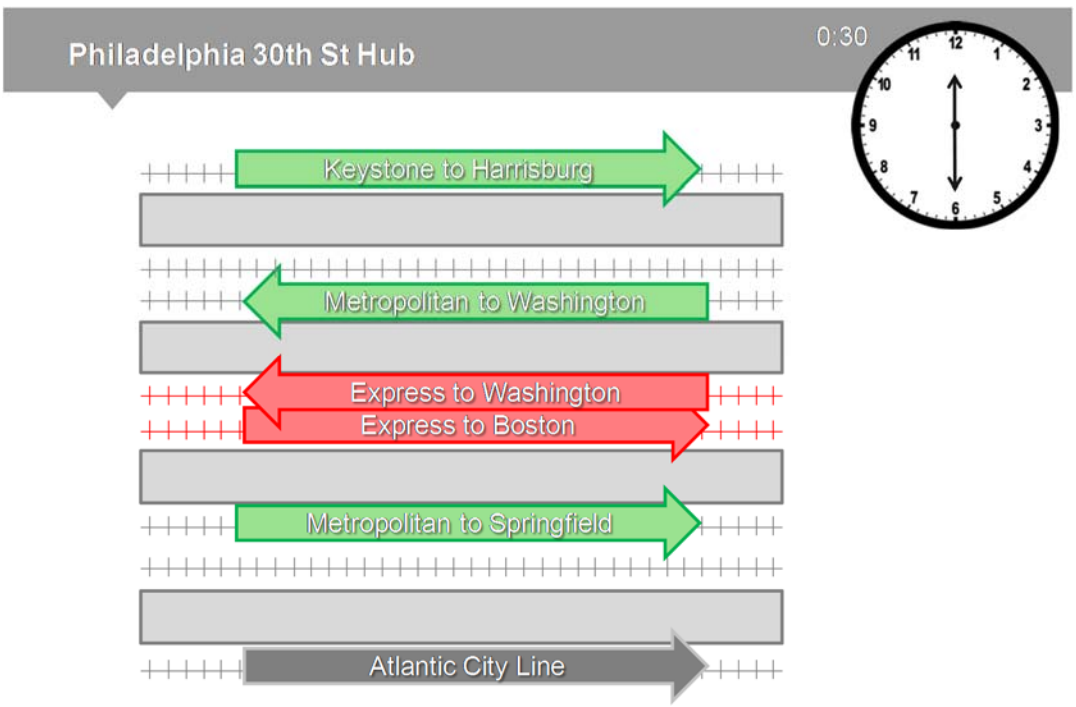
With clockface scheduling and regular, repeating service intervals, Alternatives 1, 2, and 3 take advantage of opportunities for better connected Regional rail service at several locations on the NEC, effectively closing the gaps that now exist in Regional rail connectivity from one system to another. As Maryland Regional rail service is extended to Newark, DE, schedules are coordinated with those of the Regional rail service to Philadelphia, enabling convenient passenger transfers. Modification of the track configuration near Trenton, NJ, allows timed cross-platform transfers between New Jersey and Philadelphia Regional rail trains in both directions. Also, the integration of Shore Line and Hartford Line Regional rail trains with New Haven Line service provides convenient cross-platform transfers at New Haven.

The Action Alternatives also improve connectivity between main line and branch line services at multiple locations. Intercity services can be better coordinated with Regional rail services at Philadelphia 30th Street with the normalization of train schedules. Similarly, NEC services can be better coordinated with train services to and from Hoboken, NJ, at the transfer station in Secaucus, NJ. The timing of Empire train arrivals and departures at Penn Station New York can be coordinated with Intercity-Express, Metropolitan, and Regional rail service on the NEC. And, in cases where simplified operations may reduce the number or frequency of direct train services from the NEC Spine to branch lines, shuttle services on the branch lines can be timed with convenient connections to and from NEC trains. This offers greater overall service frequency on the branch line, and a trip that remains convenient and time-competitive for the passenger making the transfer. The same principles apply to connecting transit services at hub stations. Regular clockface scheduling of rail services, coupled with reliable operating performance, allows local transit service providers to customize the arrival and departure timing connecting and feeder services to match the train schedules.

Pulse-Hub Operations

A pulse-hub is a special application of service coordination, where multiple trains converge on a single hub station concurrently or in close succession, dwell simultaneously for a period of time while passengers transfer from one service to another, and then depart toward their various destinations. A pulse-hub operation can be a key component in a simplified operation, but could also be featured in Service Plans with a wider variety of service offerings. Figure 5 illustrates one example of a pulse-hub operation at 30th Street Philadelphia. Several trains of different types and with various destinations have coordinated arrival and departure times, facilitating convenient transfers.

Figure 5: Philadelphia Pulse-Hub



Source: NEC FUTURE team, 2015

A pulse-hub operation offers opportunities to provide high-quality service to smaller markets that do not warrant one-seat-rides to a major market. For this system to work adequately, significant amounts of built infrastructure are needed at hub stations to facilitate the simultaneous movement of multiple trains through the station as well as the efficient movement of passengers between trains. Investment in station and rail infrastructure to enable easy passenger transfers is a prominent feature of pulse-hub operations. Investment in stations to facilitate high-quality passenger transfers, however, can also be a feature of Service Plans that do not rely exclusively on this type of operation, but selectively employ it at key stations on the network. Similarly, as with coordinated endpoint connections, this service enhancement works only if a transfer passenger can change trains without queuing and with the common practice of staging passengers on platforms.

The Service Plans for Alternatives 2 and 3 provide for pulse-hub operations on the lower level of Philadelphia 30th Street Station with Intercity-Express, Metropolitan, Keystone Corridor, and Atlantic City trains all connecting with universal transfer opportunities every 30 minutes during the peak periods. The Alternative 3 route option from Long Island through New Haven, CT, to Hartford, CT, also provides a timed pulse-hub at New Haven.

4.1.5 FREIGHT RAIL

While the purpose of NEC FUTURE focuses on passenger rail service, the NEC FUTURE Scoping process, along with input received from freight rail operators and state and regional stakeholders, identified the preservation of freight rail as an important objective. NEC FUTURE Service Plans for each of the Action Alternatives preserve freight access on the NEC and do not preclude future growth opportunities. The FRA relied on specific assumptions for the mixed operations of freight and passenger traffic on the same tracks and in the same right-of-way, consistent with the current FRA regulatory framework:

- Freight will not operate on high-speed tracks in mixed traffic with Intercity-Express passenger trains operating above 160 mph—this includes all new segments included in Alternative 3.
- Mixing of different types of passenger trains, including Intercity-Express and Metropolitan service using new high-performance equipment, are assumed to be permissible in the future on the existing NEC with passenger train speeds up to 160 mph—this applies mostly to the express tracks on the NEC where there are more than two main tracks, in all three Action Alternatives.
- New tracks generally will be built with sufficient separation from parallel tracks used by freight trains to permit simultaneous operation of freight and passenger traffic; however, temporal separation of freight traffic may be required for some portions of the NEC where existing express tracks are used by high-speed trainsets and are closely parallel to the existing local tracks, such as in Pennsylvania, New Jersey, and Massachusetts.[20]

4.2 RIDERSHIP

The NEC FUTURE ridership and revenue forecasting approach included two major components to address the most significant travel markets relevant to the NEC. These two components are listed below and described in the next sections:

- A new Interregional Model, which addressed travel between metropolitan market areas in the NEC, developed primarily from a new NEC household survey
- Existing regional models, which addressed travel within metropolitan market areas in the NEC (e.g., Washington, D.C., Baltimore, Philadelphia, New York City, Boston, etc.)

4.2.1 INTEGRATION OF THE INTERREGIONAL AND REGIONAL FORECASTS

The FRA estimated interregional and regional ridership forecasts in parallel processes using separate forecasting models. These forecasts were then combined to form overall ridership forecasts for the No

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[20] Railroad operating characteristics and limitations on permissible maximum speeds and the mixing of freight and passenger traffic are described more fully in Appendix A, *Service Plans and Train Equipment Options Technical Memorandum*.

Action Alternative and Action Alternatives. Combining the forecasts involved the identification and application of the appropriate "model of record" for each rail market. Table 4 summarizes the forecasting models used to evaluate the No Action Alternative and Action Alternatives for each region pair within the Study Area. Within the metropolitan regions (on the diagonal of the table), the appropriate regional models were used. Trips between regions were estimated using the new Interregional Model, for almost all pairs of regions. For the final rail results, there were very few interregional commuter-rail trips that were not captured using the regional models. Since the regional models were more robust in estimating commuter trips, as well as to avoid double-counting trips, the Regional rail ridership numbers were taken solely from the regional models as opposed to the Interregional Model commuter ridership.

Table 4: Models Used to Evaluate NEC FUTURE Rail Markets

From/ To	Market Area	Boundaries	A	B	C	D	E	F	G–L
A	Washington Metro	Northern Virginia to Pautuxent River	R1	IR	IR	IR	IR	IR	IR
B	Baltimore Metro	Susquehanna River to Pautuxent River	IR	R2	IR	IR	IR	IR	IR
C	Wilmington/ Philadelphia Metro	Susquehanna River to Trenton	IR	IR	R3	IR	IR	IR	IR
D	NY Metro, West of Hudson	Trenton to New York City	IR	IR	IR	R4	IR	IR	IR
E	NY Metro, East of Hudson	New York City, Long Island & Coastal Connecticut	IR	IR	IR	IR	R5	IR	IR
F	Providence/Boston Metro	Rhode Island to SE New Hampshire	IR	IR	IR	IR	IR	R6	IR
G	Empire Corridor	New York City to Albany	IR	IR	IR	IR	IR	IR	IR
H	Inland Connecticut, Massachusetts	New Haven to Springfield	IR	IR	IR	IR	IR	IR	IR
I	Virginia	Richmond to Washington D.C.	IR	IR	IR	IR	IR	IR	IR
J	Keystone	Philadelphia to Harrisburg	IR	IR	IR	IR	IR	IR	IR
K	Vermont	Vermont to Springfield	IR	IR	IR	IR	IR	IR	IR
L	Maine	Maine-New Hampshire	IR	IR	IR	IR	IR	IR	IR

Tools:

IR	NEC FUTURE Interregional Model
R1	Enhanced Washington Metropolitan Area Transit Authority Transit Post Processor of Metropolitan Washington Council of Governments Model
R2	Simplified Trips on Project Software (STOPS) Application for Baltimore Metropolitan Area
R3	Delaware Valley Regional Planning Commission Regional Forecasting Model
R4	NJ TRANSIT North Jersey Travel Demand Forecasting Model
R5	Metropolitan Transportation Authority Regional Transit Forecasting Model
R6	STOPS Application for Boston Metro/Rhode Island Area

Source: NEC FUTURE team, 2015

4.2.2 INTERREGIONAL MARKETS

The FRA's travel demand modeling and forecasting approach for interregional travel consisted of the development and application of a two-stage model system. The first stage modeled total interregional travel volume by origin-destination (OD) pair. The second stage predicted the share of intercity passengers expected to use each of the available intercity travel modes using a nested logit specification.

The two-stage model system was applied in reverse order (i.e., mode share before total travel demand) to allow mode share model results to be incorporated within the total demand model structure. This linkage provides the total travel model with sensitivity to changes in the level-of-service provided by all modes, allowing for the total number of trips to increase due to overall improvement in travel conditions.

Household Travel Survey

The development of the Interregional Model system was informed by the results of an extensive household survey conducted within the Study Area. Although existing survey data were available, the data were generally tied to specific existing models or forecasts focused exclusively on either interregional or certain regional sub-markets within the NEC. Moreover, these existing data sets and models did not provide a consistent integrated analysis and forecasting basis throughout the NEC. As such, the FRA conducted the NEC FUTURE Survey of Northeast Regional and Intercity Household Travel Attitudes and Behavior (Household Travel Survey) to provide data on travel patterns and mode choice within the Study Area for use in the mode choice models.

The new Household Travel Survey included only respondents who had made interregional trips between the respondent's home and eligible out-of-state locations were considered as qualifying trips. If a respondent took multiple qualifying trips, one was randomly selected to be the "reference trip" for the respondent. The actual mode chosen for the reference trip forms the basis for the revealed preference (RP) portion of the survey response. Respondents were then asked additional questions about this trip about attributes such as type of train service used, mode of access/egress, fare, estimated one-way travel time and cost, as well as trip purpose.

Six stated preference (SP) choice exercises represented the "core" of the survey and provided the primary basis for estimating the new mode-choice model. These SP questions asked respondents to think about the context of their reference trip and then choose from among three modes of travel with characteristics specified by the survey. These characteristics varied across the questions, according to an experimental design that minimized correlations among variables.

The specific SP trade-off questions reflected an experimental design to address an appropriate cross section of all the potential mode availability and service characteristic combinations. The detailed trip information obtained before the trade-off questions provided the context for the respondent's travel choices and a basis for defining trip-relevant service characteristics in the trade-off questions. The responses to the survey questions provided the basis for estimating key sensitivities to changes in the service characteristics, by market segment, for the new model. In addition to the SP questions, all qualifying respondents were asked demographic questions at the end of the survey.

Total Travel Demand Model

In the two-stage travel demand modeling approach, total travel demand models (one for each trip purpose) were required in conjunction with the mode share models (also one for each trip purpose). Total travel demand forecasts define the total market size to which the mode shares are applied to produce ridership forecasts by mode. In general, there are two major influences on the total travel demand between any two geographic areas; population and economic activity growth, and changes in the modal levels of service provided. The impact of population and economic activity contributes to organic growth, in that an increase in those measures will naturally generate more travel. The change of modal levels of service creates induced demand, as opposed to organic growth. Induced demand creates additional trips because overall travel between origins and destinations become more attractive, due to better travel conditions (such as reduced travel time or cost).

The FRA estimated total travel demand model using cross-sectional data that estimates the relationship between current levels of population, income, employment, and level-of-service and current observed demand. The modeling process then applies the observed relationships to forecasts of growth in population, income, employment, and changes in level-of-service.

Multimodal interregional passenger market data for the Study Area were assembled from a number of different sources. The sources are as follows:

- Auto market: NEC Automobile OD Study (2014), prepared by RSG for the NEC Commission
- Air market:
  - Air Carrier Statistics database (T-100 Domestic Market), 2012 Q3-Q4 and 2013 Q1-Q2, retrieved from *http://www.transtats.bts.gov/Fields.asp?Table_ID=258*
  - Airline Origin and Destination Survey (DB1B), 2012 Q3-Q4 and 2013 Q1-Q2, retrieved from *http://www.transtats.bts.gov/Fields.asp?Table_ID=247*
- Rail market: Amtrak Ridership and Ticket Revenue Data (FY 2013), provided by the Market Research and Analysis Department, Amtrak
- Bus market: Northeast Corridor Bus Schedule and Ridership Data (2014), prepared by RSG for the NEC Commission
- Demographic Data: Demographic Growth Forecasts provided by Moody's Economy.com (annual for years 2010 through 2040)

Using the data sources listed above, the FRA developed annual trip tables for each of the modes. Once the total trips were determined, the FRA then segmented them by purpose using the trip purpose percentage share calculated from the NEC FUTURE Household Travel Survey, segmented by mode and trip length. Table 5 presents the trips by mode and purpose, which shows that 70 percent of trips in the NEC market area are for non-business purpose. The final base trip table used in the Interregional Model was the total trips for each zone pair segmented by trip purpose.

Table 5: Summary of Existing (2013) Annual Person Intercity Trips by Mode and Purpose

Purpose	Auto	Air	Intercity-Express Rail	Intercity-Corridor Rail	Intercity Bus	Total
Business	63,195,000	8,717,000	1,725,000	2,698,000	1,031,000	77,366,000
Non-Business	274,272,000	7,951,000	1,423,000	7,126,000	6,991,000	297,763,000
Commute	47,150,000	0	192,000	1,598,000	1,562,000	50,502,000

Source: NEC FUTURE team, 2015

Mode-Choice Model

The mode share models estimate the share of total person travel by mode. This model component addressed travel by the following modes:

- Auto (passenger car/truck/van)
- Air
- Intercity bus
- Train, addressing the following types of train service separately:
  - Intercity-Express
  - Intercity-Corridor rail
  - Regional rail
  - Metropolitan

Model Structure

The new model estimated shares among these as a function of the following key independent variables describing the service characteristics:

- Travel time
- Travel cost or fare, taking account of the cost implications of travel by group and individuals and also including parking charges
- Schedule of service provided by air, rail, and bus
- Alternative-specific constants reflecting the differences between modes not directly measured by other independent variables in the model (factors and traveler perceptions such as the comfort and convenience provided by each mode would be reflected here)

The FRA estimated three separate mode share models, to reflect trip purpose market segmentation (business, non-business/non-work, and commute). To reflect the differential substitution that exists between different modes of travel, the FRA used a nested logit (NL) structure. Using the NL model structure allows the modes in a common nest to exhibit a higher degree of similarity and competitiveness than modes outside of the nest.

Models of modal travel choice can be based on RP or SP data. Each type of data provides certain advantages over the other. RP data reflect actual behavior and take account of the real world conditions that respondents face. SP data takes account of a wider range of potential choices and attributes. The SP data reflect an experimental design that provides for explanatory variables that have a larger range of variability within and between alternatives and break the correlation between explanatory variables within each alternative. While models can be estimated with each type of data separately, the most robust models combine RP and SP data in order to take advantage of the unique characteristics of each type. Combining the two sets of data to estimate a single model can produce a model that retains the advantages of both RP and SP models and eliminate or dramatically reduce the disadvantages of each. The NEC FUTURE

Household Travel Survey collected both types of data so for use in studying Intercity travel patterns and travel behavior along the NEC.

Modeling Metropolitan Trains

The SP questions in the Household Travel Survey presented four types of rail to respondents:

- High Speed Train (i.e., Intercity-Express)
- Regional Train (i.e., Intercity-Corridor)
- Commuter Train (i.e., Regional rail)
- Metropolitan Train (a new service)

At the time the survey was developed, Metropolitan service was envisioned as a mode that would be a level above the Regional rail services, but below the Intercity-Corridor rail, in terms of service quality. It would be moderately slower and cheaper than the Intercity-Corridor rail, while not having reserved seats (so potentially some riders may need to stand), and no amenities such as restrooms or food service. As the FRA developed the Service Plans for the No Action and Action Alternatives, Metropolitan service evolved to become similar to the Intercity-Corridor trains in terms of frequency and stopping patterns. In addition, the new equipment envisioned for use by the Metropolitan service allows for faster travel times for some Action Alternatives.

To include a new mode in a logit model, the modeler must assert that the new mode is independent from the other modes included in the model so that it does violate the independence from irrelevant alternatives (IIA) property of the model. While using an NL lessens the stringency of the IIA requirement, it does not eliminate it. Given that the more developed concept of Metropolitan service was similar to the existing Intercity-Corridor service in terms of speed, time, and cost parameters, the FRA decided to combine the Metropolitan with Intercity-Corridor for modeling purposes. The decision to estimate Metropolitan and Intercity-Corridor-Other service as a single rail mode does not mean that these services are identical, as there could be significant differences in on board amenities, reservations policy, and actual pricing. The combined service retained the label Intercity-Corridor. The daily frequencies for Metropolitan and Intercity-Corridor-Other were summed together and the travel times were averaged for each station-pair to account for any differences in the service.

As the naming convention of the rail modes differs across sections of the document, Table 6 provides a correspondence between the mode names.

Table 6: Intercity Rail Mode Naming Convention

Existing Name	Survey Name	Model Estimation Name	Model Application Name
Acela Express	High Speed Train	Intercity-Express Rail	Intercity-Express
Northeast Regional	Regional Train	Intercity-Corridor Rail	Intercity-Corridor
N.A.	Metropolitan Train	Metropolitan Rail	Intercity-Corridor

Source: NEC FUTURE team, 2015

Key Service Variable Sensitivities

The most important service variables in the mode-choice model include travel time, travel cost, and frequency of service. Travel time and travel cost typically have an inverse relationship, and can be used to calculate the Value of Time (VOT), or how much respondents are willing to pay to save additional travel time. The business and commute models had VOTs, which were similar to others seen in the corridor or for similar models, but the non-business model had much lower values of time, ranging from around $6 to around $20 (allowed to vary by total cost of the trip). These are lower values than have been seen in the Study Area in the past, and indicate that price is becoming a particularly important piece of the mode-choice decision, especially given that approximately 70 percent of travel in the Study Area is currently non-business. One reason for this shift in cost sensitivity could be the increased prevalence of low-cost intercity bus service that has occurred over the past several years, making travelers more aware of cheaper options in the interregional market. The market for Intercity-Express continues to appeal to business travelers who value time and are willing to pay for the service/time savings, but business travelers are only 18 percent of the total.

In all three mode choices of the Interregional Model (business, non-business, and commute), the FRA used a dampened function of frequency. This specification accounts for the expectation that additional departure options impact choice up until a certain saturation level, at which point travelers have enough options, and more frequency will not increase the utility of the mode. This saturation point in the models is around 50 trains per day, which indicates that once the trains are less than 30 minutes apart, the importance of frequency drops off.

4.2.3 REGIONAL MARKETS

The FRA conducted the regional forecasting process largely using existing ridership tools developed by the operators or the metropolitan planning organizations, with some modifications to accommodate the NEC FUTURE forecasting approach. Many of these tools have been used by Regional rail operators or other regional transit operators to plan Federal Transit Administration (FTA) New Starts investments and evaluate the implications of service and policy changes. By using existing tools to the maximum extent possible the NEC FUTURE team maintained consistency with local and future planning efforts, and ridership and growth estimates.

Shorter distance, regional travel markets that lie within a specific major region were addressed by the available regional models. Where local models were not available, the FRA used the FTA Simplified Trips on Project Software (STOPS)[21] module to estimate ridership demand.

The following lists the models used in the analysis of regional trip making:

- Washington: Metropolitan Washington Council of Governments/Washington Metropolitan Area Transit Authority Forecasting Model

[21] STOPS is the FTA's national forecasting model, which relies on a combination of national experience and local market-based information to estimate transit project ridership. STOPS is a series of programs designed to estimate transit project ridership using a streamlined set of procedures that bypass the time-consuming process of developing and applying a regional travel demand forecasting model. It is quite similar in structure to regional models and includes many of the same computations of transit level-of-service and market share found in model sets maintained by metropolitan planning organizations and transit agencies.

- Baltimore: FTA STOPS implemented for the Baltimore metropolitan region
- Philadelphia: Delaware Valley Regional Planning Commission Model
- New Jersey: NJ TRANSIT North Jersey Travel Demand Forecasting Model
- New York: LIRR/MNR/Shore Line East: MTA Regional Transit Forecasting Model
- Boston: FTA STOPS implemented for Boston metropolitan region

4.2.4 MODEL INPUTS AND ASSUMPTIONS

For analysis purposes, the FRA used a forecast year of 2040 for the No Action Alternative and Action Alternatives. Travel demand forecasts are driven by demographics and service levels.

Demographic Forecasts

The fundamental driver of growth in total trip making in the Study Area comes from forecasted growth in population, employment, and income. Forecasts used as the basis for growth were extracted from Moody's Analytics June 2013 "base" demographic forecasts. These forecasts were obtained on a county-level basis for the Study Area.

Table 7 and Table 8 present the population and employment projections, and percentage change for the major NEC metropolitan areas as contained in Moody's Analytics June 2013 forecasts. Three forecasts were supplied by Moody's. They include "low", "base" and "high" conditions. All of the forecasted results use the "base" (or most likely) condition.

Table 7: NEC Population Forecasts

Market	Population				Percentage Change vs 2013		
	2013	2040 (Low)	2040 (Base)	2040 (High)	2040 (Low)	2040 (Base)	2040 (High)
Washington, D.C.	5,930,000	7,127,000	7,655,000	8,238,000	21%	29%	39%
Baltimore	2,774,000	3,000,000	3,145,000	3,299,000	8%	13%	19%
Philadelphia	6,600,000	6,874,000	7,108,000	7,352,000	4%	8%	11%
New York City	22,210,000	23,276,000	24,306,000	25,393,000	5%	9%	14%
Providence	970,000	982,000	1,036,000	1,094,000	1%	7%	13%
Hartford/Springfield	1,794,000	1,876,000	1,905,000	1,935,000	5%	6%	8%
Boston	6,450,000	6,602,000	6,888,000	7,188,000	3%	7%	11%

Source: NEC FUTURE team, 2015

Table 8: NEC Employment Forecasts

Market	Employment				Percentage Change vs 2013		
	2013	2040 (Low)	2040 (Base)	2040 (High)	2040 (Low)	2040 (Base)	2040 (High)
Washington, D.C.	3,104,000	2,781,000	3,858,000	4,801,000	-3%	24%	62%
Baltimore	1,363,000	1,279,000	1,679,000	2,023,000	2%	23%	55%
Philadelphia	3,007,000	2,680,000	3,576,000	4,323,000	-4%	19%	50%
New York City	10,077,000	8,810,000	11,827,000	14,660,000	-6%	17%	51%
Providence	426,000	352,000	476,000	560,000	-10%	12%	39%
Hartford/Springfield	873,000	729,000	963,000	1,145,000	-10%	10%	37%
Boston	3,275,000	2,756,000	3,736,000	4,599,000	-9%	14%	48%

Source: NEC FUTURE team, 2015

Table 7 shows that the populations in the major metropolitan markets are projected to grow between 6.2 percent (Hartford) to 29 percent (Washington, D.C.). The low-high bounds are also fairly tightly bound to the "base" condition, generally plus or minus 5 percent points of the base forecast.

Table 8 presents the employment forecasts. While the "base" forecasts shows employment growing slightly faster than population, the low-high bounds are much wider for employment. This is an important element of the demographic forecasts, as Moody's forecast suggests larger uncertainty associated with future NEC employment. Their "low" scenario includes a contraction of the overall job market (as compared to today), while their "high" scenario includes a full boom in economic activity with large scale growth in employment. This suggests that one of the significant risks to the forecasts is the strength of the regional employment market, as Moody's has placed a wide band on these forecasts.

Service Characteristics

The primary mode-choice input for both the Interregional Model and regional models were the service characteristics of all available modes

For the Interregional Model, the relevant service characteristics included travel time (access/egress and line haul), cost, and frequency of service. For the non-rail modes (auto, air and intercity bus), the service characteristics were held constant across all alternatives and were based on existing service, with the exception of introducing highway congestion into the auto and intercity bus travel times. The rail service travel times and frequencies were determined from the service planning process. The non-rail modes were assumed to be unconstrained with respect to their capacity to accommodate future growth.

For the rail fares in the Interregional Model, the FRA initially assumed the current pricing. Later, as described in Section 4.3, the FRA evaluated the impact of lower fares on resulting rail demand to establish the model's sensitivity to pricing and understand the impacts on ridership demand and operating costs. The FRA found that the operating costs associated with the Action Alternatives were lower than the associated passenger fare revenues, which indicates the flexibility for an operator to discount fares and still cover operating expenses.

While there were six separate regional forecasting models applied to evaluate the No Action Alternative and Action Alternatives, the key attributes that drove the magnitude of the ridership results included travel time (line haul and access/egress), number of transfers, frequency, and total cost. For the Regional models, the service characteristics for the non-rail modes were dealt with in the same manner as for the Interregional Model, by holding them constant across the No Action and Action Alternatives. The rail frequencies and travel times were similarly calculated from the potential service plans developed as part of the alternatives development process. The FRA held Regional rail pricing constant through the analysis in real dollars, meaning Regional rail fares were assumed to grow with inflation.

4.2.5 MODEL OUTPUTS

As described earlier in Section 4, for the alternatives refinement process the FRA ran both the interregional and regional models with numerous intermediate Service Plans. The resulting ridership projections were then compared with the volume of service provided at key locations along the corridor to estimate the extent to which seats on board trains would be filled during peak periods. Service levels then were adjusted either upward or downward as necessary to balance the provided service with the forecasted demand. The Interregional model provided ridership information at screenlines north of Washington, D.C., at the Hudson River and East River, at approaching Boston South Station. The initial ridership results from the Regional model included daily and peak passenger volumes at screenlines in the following locations:

- Potomac River South of Washington Union Station
- North of Washington Union Station
- Susquehanna River
- Keystone West of Philadelphia 30th Street Station
- North of Philadelphia (between Cornwells Heights and Trenton)
- Hudson River
- East River
- Harlem River/Empire Corridor
- South of Boston South Station

The FRA utilized these screenlines by comparing the peak-hour, peak-direction ridership with the available capacity, and adjusting service where there were large discrepancies. The goal was to provide an adequate amount of service to allow for growth, but not to provide excessive capacity.

The primary output of the model was trips by mode for each zonal pair, which can be formatted in multiple ways to support alternatives evaluation. The FRA used the following model outputs (from both the interregional and regional models):

- Annual trips by mode for two levels of geographic aggregation:
  - Metropolitan statistical areas (collectively do not cover entire Study Area)
  - Greater metropolitan area (collectively covers the entire Study Area)
- Annual rail passenger miles
- Annual and average weekday passengers at two levels:

- Station boardings
- Station-to-station ridership

The year 2040 ridership forecasts were constrained to the available seated capacity where forecasted demand exceeded available seats. Specifically, the FRA applied capacity constraints at specific locations and to specific train services where demand was projected to exceed seating capacity. In the No Action Alternative, Intercity-Express, Intercity-Corridor, and New Jersey Regional rail service is capacity-constrained crossing the Trans-Hudson River screenline. In Alternative 1, New Jersey Regional rail crossing the Trans-Hudson screenline is capacity-constrained, but Intercity services have sufficient capacity to accommodate projected ridership. Alternatives 2 and 3 required no adjustments for capacity constraints, meaning that forecasted demand is accommodated by the amount of service offered by each alternative.

4.3 OPERATIONS AND MAINTENANCE COSTS

The FRA prepared operations and maintenance (O&M) cost estimates to provide representative estimates of the costs to operate and maintain the proposed Service Plans for the No Action and Action Alternatives. The methodology produced high-level, order-of-magnitude estimates for O&M costs appropriate for a Tier 1 EIS level of review. In conjunction with the capital cost estimates (Section 4.4), these O&M estimates facilitate comparative cost analysis between the No Action Alternative and each Action Alternative, and, for Intercity services, help the FRA to assess whether the Service Plans are likely to generate an operating surplus, where revenues exceed costs.

Where available, the FRA used data on recent actual Intercity and Regional rail O&M costs as a starting point for the analysis. The availability of this information varied across the service types and cost categories, and the FRA supplemented it with additional cost estimates where needed to provide a more comprehensive data set. The FRA combined these data, which were also generalized across the corridor, to facilitate consistent application of cost estimates across the Service Plans, based on key assumptions about the characteristics of the service types (Section 4.1.2). The FRA then applied these unit O&M costs to projected level-of-service and physical characteristics information to produce O&M cost forecasts for the alternatives for each of the service types.

The FRA calibrated the ridership model for 2013 base trips using current fares to accurately match existing ridership. For the Action Alternatives that include new markets, the FRA calculated distance-based fare equations based on current fares for three types of rail trips: trips entirely south of New York City, trips north of New York City, and trips through New York City, to reflect market-based differences in the pricing structures for these trips today. The O&M costs associated with these existing fare scenarios were substantially lower than the associated revenues. Therefore, the FRA tested multiple fare discounts for the Intercity-Corridor service, while keeping the Intercity-Express fares at the existing level. For each Action Alternative, the FRA reduced the Intercity-Corridor fares by 30 percent compared to today. This reduction is neither fare-maximizing nor ridership-maximizing analysis; rather, it is intended only to demonstrate that the Service Plans operate profitably over multiple fare structures.

4.4 **CAPITAL COSTS**

The FRA developed a capital cost model to provide conceptual cost estimates for each Action Alternative commensurate with the level of detail necessary to provide for an accurate, well-documented cost comparison between the No Action and Action Alternatives. The FRA calculated the No Action Alternative cost by summing the total cost of the No Action Alternative Project List (see *No Action Alternative Report*). While the goal of the model is to reflect a conceptual level of detail, the model is based on a validated methodology that relies on data from actual construction projects. The model is sufficient to reasonably estimate the costs for end-to-end Action Alternatives from Washington, D.C., to Boston, MA. The model is not intended to estimate the costs of specific smaller scale projects or programs separately from the end-to-end routes of the Action Alternatives, such as individual bridge replacements, individual tunnel construction projects, or individual station projects. These detailed project-level cost estimates would be developed in later planning, engineering, and design states as the NEC FUTURE program is implemented.

To develop the cost model, the FRA completed more detailed analysis for typical right-of-way sections, station configurations, track configurations, rolling stock requirements, and maintenance and operations costs. The estimates address all major capital cost elements such as station development, grade crossing eliminations, vehicle and maintenance shop needs, supporting systems, right-of-way acquisition, and costs of linear or area-based infrastructure elements such as tunnel or aerial sections or embankment or retained fill areas.

4.4.1 **LINEAR ELEMENTS**

Linear element costs represent those costs that are measured by linear attributes, such as route-feet or track-feet. The FRA calculated these costs by multiplying lengths by a unit cost per route-foot. There are three types of linear elements that describe capital investment in rail infrastructure and which translate into capital cost line items for the Action Alternatives:

- **Curve Modification**: a shift or straightening of existing NEC track alignments to improve speeds, including straightening a curve or eliminating the curve entirely. Curve modifications address the compromised performance of the existing NEC by reducing, or eliminating speed restrictions at certain locations along the NEC.
- **New Track**: improvements that increase capacity or improve trip times, generally contained within the right-of-way of the existing NEC; typical upgrade projects include:
  - Signal system upgrade
  - Catenary and electrification system upgrade
  - One or two new tracks constructed within existing right-of-way—includes new track as well as all associated construction to enable new tracks to be utilized, including new or modified catenary, signaling, interlockings and civil and structural work
- **New Segment:** New-track construction on new right-of-way that does not follow the existing NEC. New segments diverge from and reconnect to the existing NEC, which expand the capacity of the railroad and/or relieve chokepoints.

Linear elements are mapped along the Representative Route of each alternative. The FRA estimated the capital costs of linear improvements by developing a unit cost of construction per linear mile or foot, and multiplying this unit cost by the length of the route segment over which the given set of linear element improvements are expected. Contingencies and other cost factors were added to the individual line items or totals as appropriate.

Two sets of right-of-way characteristics, which also are mapped along the Representative Route of each alternative, are used to develop the unit cost of construction and to understand the magnitude of potential environmental impacts associated with construction. These right-of-way characteristics are referred to as the ***construction type*** and the ***typical cross section***.

- **Construction Type** identifies the vertical profile characteristics of the existing or proposed new right-of-way, which is a function of the terrain through which the route passes and the extent to which natural features, land development, or highway/waterway/railroad crossings drive the need to change the grade of the railroad. All existing and proposed route segments are assigned one of the following construction types:
  - ***Tunnel*** is typically applied where the Representative Route is beneath a large body of water, such as the Hudson River; the topography is too steep to meet high-speed performance criteria, as is the case in northern Connecticut; and in densely developed areas where there is no room for above ground segments, as is the case in Baltimore, New York City, and Providence.
  - ***Trench*** is generally applied prior to and following a tunnel, where a tunnel transitions to at-grade or embankment construction types, and where local conditions permit the construction of an open trench to provide grade separation of the railroad and crossing roadways.
  - ***At-grade*** is generally applied where local vertical grade changes permit construction at-grade and where existing highway/roadway rights-of-way are grade separated on aerial structures. At-grade segments are common south of New York City where the topography is relatively flat. It is less common north of New York City where changes in topography occur more frequently.
  - ***Embankment*** is generally applied following an aerial structure construction type, indicating where the aerial structure returns to grade, and where local vertical grade changes do not permit construction at-grade. Embankments are common south of New York City where the topography is relatively flat.
  - ***Aerial Structure*** is generally applied in heavily urbanized areas where land available at-grade is scarce and requires an aerial structure above existing rail or roadway rights-of-way, and at river crossings, wetland areas, valleys, or crossings over existing highways/roadways where vertical grade changes below top of rail vertical alignment and/or where potential for significant environmental impacts do not permit construction at-grade.
  - ***Major Bridge*** is generally applied at river crossings, wetland areas, valleys, or crossings over existing highways/roadways where vertical grade changes do not permit construction at-grade. The major bridge construction type generally is associated with long-span aerial structures and with movable bridges.
- **Typical Cross Section** for construction on new track and new segments, the FRA developed representative typical cross sections that identify construction methods and right-of-way configurations for track and track structures. The purpose of these typical cross sections is to aid in the development

and calculation of construction line-item quantities in the model. The typical cross sections define the requirements for major infrastructure components and provide for a quality control review of these quantities and a documentation source for how quantities were developed. The FRA developed quantities by calculating construction line items as they are depicted in the typical cross sections per route-foot. Each construction line item was assigned a unit cost, which was then multiplied by the quantity and summed to a total cost per route-foot for each typical cross section. There are 47 different typical cross sections, organized by interchangeability with the existing NEC, based on the number of total tracks in the right-of-way, the horizontal and vertical location of the new tracks relative to existing tracks, the maximum speed of the route segment, and the construction type. A unique unit cost of construction was developed for each typical cross section.

4.4.2 SUPPORTING INFRASTRUCTURE

In addition to the linear elements, there are several types of rail infrastructure that are location-specific and are best represented in the cost estimate by a single location or point along the Representative Route. These supporting infrastructure costs are generally applied as a single discrete cost per facility or bundle of track work. The discrete cost includes any route-foot or track-foot elements needed to construct the facility or track work.

For purposes of environmental impact assessment, every location-specific element has a defined area of potential impact associated with it. The size and shape of the polygon defining this area of potential impact varies according to the type of element. Construction costs were estimated for location-specific projects based on a unit cost per element and a count of the number of elements constructed at a given location or along a segment of the route. Supporting Infrastructure fall into the following categories:

- **Stations and Station Areas**: station buildings, waiting areas, parking, and ancillary buildings. Existing local stations that are not slated for expansion or upgrading were omitted from the list of location-specific line items, since there are no incremental capital costs associated with these locations.
- **Junctions:** the construction of major track connections or interlockings[22] at points where tracks converge or diverge allowing trains to switch from one set of tracks to another. Junctions are identified at every point where a new route segment connects with the existing NEC, and at locations where grade-separated track connections provide relief to existing chokepoints. This category also includes the additional railroad infrastructure to provide station sidings at new or upgraded stations where stopping trains need to use platform tracks separate from the through tracks used by non-stop express trains. The footprint for these junctions or major connections can extend beyond the existing NEC rights-of-way (but stay within the Representative Route) to accommodate grade-separated, conflict-free movement between tracks or between the NEC and connecting corridors, Regional rail branch lines, and storage yards.
- **Storage and Maintenance Facilities**: support fleet requirements of NEC FUTURE. Horizontal dimensions could extend beyond the limits of the footprint defined for new segments, new tracks, or curve modifications. Right-of-way requirements for these facilities would be evaluated as more details

[22] Interlockings are locations on multi-track rail lines where lines join together or where crossovers between tracks are placed to permit trains to change from one track to another. They are part of the signaling and train control system and are centrally controlled by train dispatchers on the NEC.

become available, during the planning, engineering, and design stages when NEC FUTURE is implemented.

4.5 STAKEHOLDER AND PUBLIC OUTREACH

Throughout NEC FUTURE, the FRA has engaged numerous agencies and operators within the Study Area. This engagement has occurred as part of a Council on Environmental Quality Pilot Program,[23] Scoping, Section 106 consultation, as well as various key program milestones in the alternatives development process (Section 2), to promote transparency and facilitate an informed, efficient, and compliant planning and environmental review process. The knowledge, data, and input these agencies and organizations provided have been valuable to the NEC FUTURE planning process.

- **Federal and State Departments of Transportation** includes administrations within the U.S. DOT and state agencies that plan for and provide transportation infrastructure and/or services within the Study Area. Coordination with federal and state departments of transportation, including with the NEC Commission, comprising voting members from each of the NEC state departments of transportation, Amtrak, and the U.S. DOT is necessary to keep them informed about FRA transportation planning efforts. The FTA is a cooperating agency on the Tier 1 Draft EIS.
- **Other State Agencies** includes other select state agencies within the Study Area, such as planning and economic development agencies, as well as bi-state or multi-state agencies.
- **Railroad and Transit Operators** includes agencies that operate railroad and transit services along the NEC and its connecting corridors, as well as freight rail operators.
- **Metropolitan Planning Organizations (MPO)** within the Study Area play a prominent role in transportation planning throughout their respective regions and serve as representatives of their member municipalities and counties.
- **Tribal Nations:** The FRA coordinating with tribal governments with lands and/or resources in the Study Area as part of the consultation process for Section 106 of the National Historic Preservation Act of 1966.
- **Local Agencies** includes select counties and local agencies within the Study Area.
- **Technical Working Groups (TWG)** were created by the FRA to provide technical guidance in the service planning and environmental review processes. The TWGs include Alternatives Development, Environmental, Engineering and Capital Cost, Operations, and Ridership and Revenue. The TWGs include FRA representatives, as well as members from the stakeholder community to leverage their considerable past work and expertise, as well as add to the general soundness and credibility of the analytical results.

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[23] In January 2012, CEQ and FRA announced the selection of the NEC FUTURE Tier 1 Environmental Impact Statement (EIS) as a pilot project to promote early collaboration with federal and state environmental agencies for efficient environmental decision-making. The pilot was designed to help avoid the conflicts and delays often found in complex, multi-state transportation projects by engaging environmental resource and regulatory agencies early in the environmental review and assessment process.

4.5.1 STATE TRANSPORTATION AGENCIES AND RAILROAD OPERATORS

Throughout refinement of the Action Alternatives, the FRA held a variety of meetings and briefings with state transportation agencies and railroad operators to provide a dialogue and timely exchange of information. The meetings created opportunities to share information on the No Action and Action Alternatives and obtain input and feedback toward improving the NEC FUTURE process and integrity of findings.

4.5.2 PUBLIC OPEN HOUSES

The FRA hosted a series of public open house meetings in November 2014. The purpose of these meetings was to introduce the No Action and Action Alternatives developed for evaluation in the Tier 1 Draft EIS, and provide an informal opportunity for the public to learn about NEC FUTURE, ask questions, and provide comments. A related objective was to provide participants with a better understanding of what to expect from a Tier 1 level of analysis.

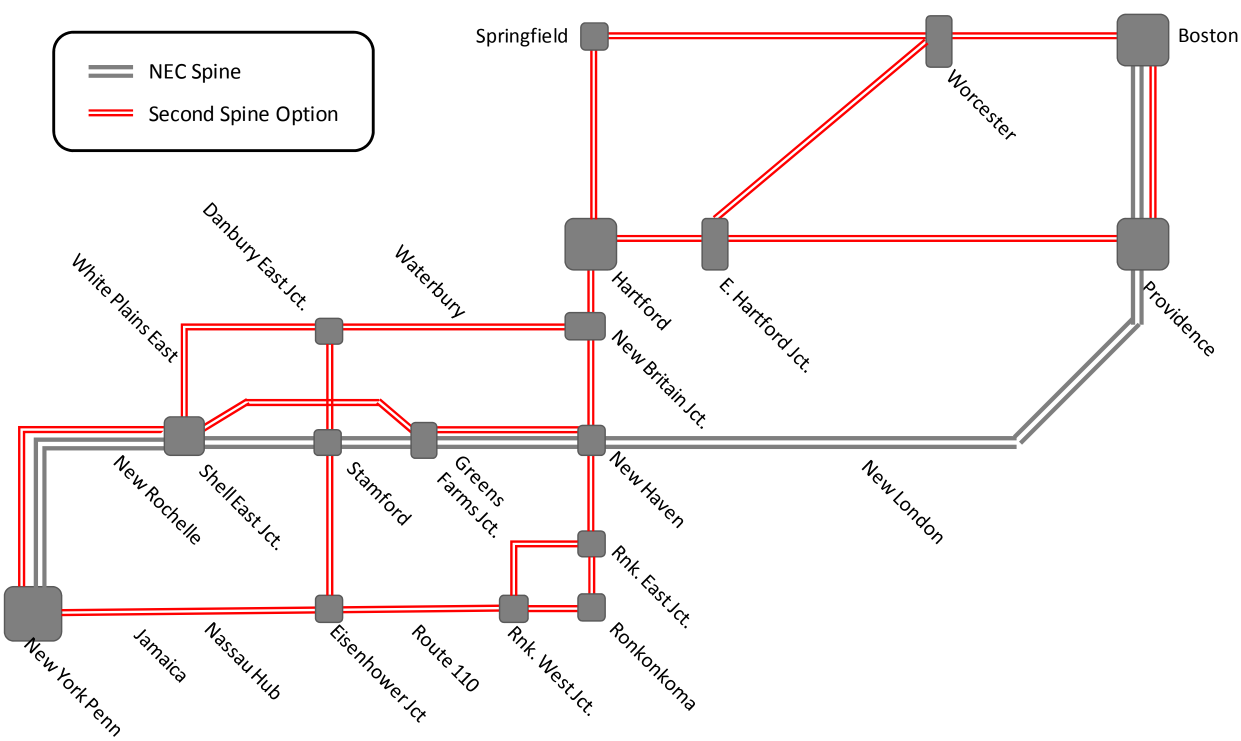
An open house meeting was held in each of the eight NEC states and Washington, D.C. A total of 377 participants attended the nine meetings. Discussion topics varied by location; however, some common themes included:

- The need to fix the existing NEC before expanding
- Importance of freight
- Questions about the feasibility of a Long Island route ("Could you really build it?")
- Relationship of NEC FUTURE to specific projects including Baltimore and Potomac (B&P) Tunnel, Gateway, New Haven-Hartford-Springfield Corridor; and overlap with plans for the Washington-Richmond corridor
- Cost of improvements
- Phasing – what improvements would be done when
- Continued questions about Tier 1 versus Tier 2
- Ability to mix and match alternatives
- Airport connections
- Fare prices, affordability compared to bus
- Climate change
- Importance to economy
- Potential for transit oriented development
- Importance of station areas and stations as destinations
- Seamless ticketing
- Need to accommodate bikes on board
- Millennials less likely to own cars; more will arrive to station by bike, walk, transit modes

5. North End Route Options Evaluation

The refinement of Alternative 3 included an examination of the range of potential options for establishing a new high-speed second-spine route to complement the existing NEC to provide rail service between New York City and Boston. The FRA identified several second-spine route options with potential to attract significant ridership and serve new markets – characteristics considered by the FRA to be essential for transforming the role of rail. Figure 6 shows diagrammatically the segments that comprise these route options. All of these route options deviate from the existing NEC at one or more points, providing direct Intercity service to new intermediate markets between New York City and Boston. Several of these route options touch the NEC only at the endpoints or for short distances. Other options run immediately parallel to or use portions of the existing NEC. Combining the various segments yields a total of 20 possible routing options between New York City and Boston. These options are arrayed in Table 9.

Figure 6: Segments Comprising the North End Route Options



Source: NEC FUTURE team, 2015

Table 9: Full Set of North End Route Options

<table>
<tr><th>No.</th><th colspan="6">North End Route Option</th></tr>
<tr><td>1</td><td rowspan="6">[NEC] New York City-New Rochelle-Stamford</td><td colspan="2" rowspan="3">[NEC] Stamford-New Haven</td><td rowspan="3">New Haven-Hartford</td><td>Hartford-Providence</td><td>[NEC] Providence-Boston</td></tr>
<tr><td>2</td><td>Hartford-Worcester</td><td rowspan="2">Worcester-Boston</td></tr>
<tr><td>3</td><td>Hartford-Springfield-Worcester</td></tr>
<tr><td>4</td><td colspan="2" rowspan="3">Stamford-Danbury</td><td rowspan="3">Danbury-Hartford</td><td>Hartford-Providence</td><td>[NEC] Providence-Boston</td></tr>
<tr><td>5</td><td>Hartford-Worcester</td><td rowspan="2">Worcester-Boston</td></tr>
<tr><td>6</td><td>Hartford-Springfield-Worcester</td></tr>
<tr><td>7</td><td rowspan="3">New York City-New Rochelle-Danbury</td><td colspan="3" rowspan="3">Danbury-Hartford</td><td>Hartford-Providence</td><td>[NEC] Providence-Boston</td></tr>
<tr><td>8</td><td>Hartford-Worcester</td><td rowspan="2">Worcester-Boston</td></tr>
<tr><td>9</td><td>Hartford-Springfield-Worcester</td></tr>
<tr><td>10</td><td rowspan="11">New York City-Nassau Hub</td><td colspan="2" rowspan="4">Nassau Hub-Ronkonkoma-New Haven</td><td colspan="2">[NEC] New Haven-Providence</td><td>[NEC] Providence-Boston</td></tr>
<tr><td>11</td><td rowspan="3">New Haven-Hartford</td><td>Hartford-Providence</td><td>[NEC] Providence-Boston</td></tr>
<tr><td>12</td><td>Hartford-Worcester</td><td rowspan="2">Worcester-Boston</td></tr>
<tr><td>13</td><td>Hartford-Springfield-Worcester</td></tr>
<tr><td>14</td><td rowspan="7">Nassau Hub-Stamford</td><td rowspan="4">[NEC] Stamford-New Haven</td><td colspan="2">[NEC] New Haven-Providence</td><td>[NEC] Providence-Boston</td></tr>
<tr><td>15</td><td rowspan="3">New Haven-Hartford</td><td>Hartford-Providence</td><td>[NEC] Providence-Boston</td></tr>
<tr><td>16</td><td>Hartford-Worcester</td><td rowspan="2">Worcester-Boston</td></tr>
<tr><td>17</td><td>Hartford-Springfield-Worcester</td></tr>
<tr><td>18</td><td rowspan="3">Stamford-Danbury</td><td rowspan="3">Danbury-Hartford</td><td>Hartford-Providence</td><td>[NEC] Providence-Boston</td></tr>
<tr><td>19</td><td>Hartford-Worcester</td><td rowspan="2">Worcester-Boston</td></tr>
<tr><td>20</td><td>Hartford-Springfield-Worcester</td></tr>
</table>

Source: NEC FUTURE team, 2015

Option number 1 in Table 9 was evaluated as Preliminary Alternative 12, which represented a second-spine parallel to the existing NEC from end-to-end. Following the development of the Preliminary Alternatives, the FRA dismissed Alternative 12 from further consideration for service, cost, constructability, and environmental sensitivity-related reasons, as follows:

- **Service**: the alternative provides no new markets north of New York City; and therefore, it performs the weakest in terms of ridership compared to other North End route options
- **Cost**: initial cost estimates indicated that this alternative accounts for the highest cost, as compared to the other second-spine route options
- **Constructability**: North of New York City, construction of a new two-track high-speed line adjacent to the existing NEC is challenging due to proximity to an operating railroad, dense populations, the existing capacity constraints, and bottlenecks across the numerous rivers in Connecticut
- **Environmental sensitivity**: the alternative has a greater proportion of the new right-of-way through environmentally-sensitive areas or through areas with greater environmental sensitivity, and through portions vulnerable to storm surge

In addition, Preliminary Alternative 12 largely overlaps with elements of other alternatives, including improvements between New York City and Hartford, new high-speed tracks between Old Saybrook and Kenyon, and new high-speed tracks between Providence and Boston.

The remaining combinations of route options all pass through Hartford CT. This provided the opportunity to split the analysis into two steps to first analyze and compare six route options for the territory between New York City and Hartford, and then analyze the three potential route options between Hartford and Boston. Figure 6 shows the six route options between New York City and Hartford and the three route options between Hartford and Boston.

5.1 METHODOLOGY

The FRA compared the service and ridership potential of sets of options north and south of Hartford. The objective of the analysis was to identify route options that best meet the NEC FUTURE Purpose and Need (Section 1.1) that can be further evaluated as Alternative 3.

In each step of the analytical process, the FRA prepared quantitative information about trip time, ridership, and capital cost, as well as information on distinguishing environmental factors, development and property impact, other local considerations, and the effects on transportation system connectivity. These characteristics were incorporated into evaluation matrices and used to compare the route options and identify those with greater potential to achieve the vision of Alternative 3.

The specific elements of the two-step process included:

- Step 1 – Assess New York City-Hartford route options [6 options]
  - Identify a limited number of representative New York City-to-Hartford route options with the potential to transform the role of rail, considering both New York City-to-Boston and intermediate markets, in terms of ridership potential, magnitude of expected capital cost, potential environmental effects, and extent of local support.

- Eliminate from further consideration those route options with lower ridership potential, higher cost, greater potential negative impacts, and/or less potential for transformational benefits.

- Step 2 – Assess Hartford-Boston route options [3 options]
  - Start with the selected representative New York City-to-Hartford route that offers the highest ridership potential.
  - Compare Providence, Worcester, and Springfield route options between Hartford and Boston.
  - Consider ridership effects of the full network, including dual spines (existing and a second-spine dedicated to high-speed rail) and connecting corridor service, as opposed to consideration of service on the second-spine route only.
    - Include Springfield, Knowledge Corridor, and Inland Route (Section 4.1.2)
    - Include Shore Line/Providence improvements in Worcester route options
  - Compare ridership potential, magnitude of expected capital cost, potential environmental effects and extent of local support, and identify representative New York City-to-Hartford route options with the greatest potential to transform the role of rail.
  - Eliminate from further consideration route options with lower ridership potential, higher cost, greater potential negative impacts, and/or less potential for transformational benefits.
  - Combine representative south-of-Hartford and north-of-Hartford route options, plus the Representative Route for a second-spine between Washington, D.C., and New York City, to create Representative Routes for Alternative 3 that span the full length of the NEC.

5.2 ROUTE OPTIONS BETWEEN NEW YORK CITY AND HARTFORD

The first step in the evaluation process considered the six route options between New York City and Hartford as follows:

- New York City-Nassau Hub-Ronkonkoma-New Haven-Hartford
- New York City-Nassau Hub-Stamford-Danbury-Hartford
- New York City-Nassau Hub-Stamford-New Haven-Hartford
- New York City-New Rochelle-Stamford-Danbury-Hartford
- New York City-New Rochelle-Stamford-New Haven-Hartford
- New York City-New Rochelle-White Plains-Danbury- Hartford

The FRA calculated trip times between New York City and various other stations for each of these route options, for both Intercity-Express and Intercity-Corridor service (Table 10 and Table 11). For comparative purposes in conducting this initial step of analysis, which analyzed the New York City-to-Hartford route options, all of these route options were assumed to reach Boston from Hartford via a new route through Providence. The best Intercity-Express trip times were achieved in options 1 and 6, the two options that build a dedicated new high-speed line all the way between New York City and Hartford and avoid the existing New Haven Line. Ridership potential (Table 12) is greatest for the routes via Long Island (route options 1, 2, and 3).

Table 10: Trip Times for Selected Intercity-Express Markets – New York City-to-Hartford

Trip Times by Option							
	Existing	Limited-stop Intercity-Express					
Penn Station New York	Acela	Run 1: PSNY>RNK> HFD>PVD> BOS	Run 2: PSNY>NAS> STM>DAN> HFD>PVD> BOS	Run 3: PSNY>NAS> STM>NHV> HFD>PVD> BOS	Run 4: PSNY>NRO> STM>DAN> HFD>PVD> BOS	Run 5: PSNY>NRO> STM>NHV> HFD>PVD> BOS	Run 6: PSNY>WHP > DAN>HFD> PVD>BOS
Boston South Station	3:40	1:37	1:46	1:52	1:55	2:00	1:32
Penn Station New York	**Existing**	**Express**					
Boston South Station	3:40	1:55	2:02	2:10	2:11	2:17	1:51
Providence Station	2:45	1:31	1:38	1:46	1:47	1:53	1:27
Hartford	--	1:04	1:11	1:19	1:20	1:27	1:00
New Haven Station	1:30	0:45	0:59	1:00	1:08	1:08	1:08
Stamford	0:45	0:38	0:29	0:29	0:38	0:38	0:38
Waterbury South	--	--	1:00	--	1:09	--	0:49
Danbury	--	--	0:51	--	1:00	--	0:41
Ronkonkoma	--	0:28	--	--	--	--	--
Nassau Hub	--	0:13	0:13	0:13	--	--	--
White Plains East	--	--	--	--	--	--	0:21

PSNY- New York Penn Station; NAS - Nassau Hub, RNK - Ronkonkoma; WHP - White Plains STM Stamford;
NHV - New Haven; NRO - New Rochelle; DAN - Danbury; HFD - Hartford; PVD - Providence; BOS - Boston

Source: NEC FUTURE team, 2015

Table 11: Trip Times for Selected Intercity-Corridor Markets – New York City-to-Hartford

Trip Times by Option							
	Existing	Metropolitan					
Penn Station New York	Regional	Run 1: PSNY>RNK> HFD>PVD> BOS	Run 2: PSNY>NAS> STM>DAN> HFD>PVD> BOS	Run 3: PSNY>NAS> STM>NHV> HFD>PVD> BOS	Run 4: PSNY>NRO> STM>DAN> HFD>PVD> BOS	Run 5: PSNY>NRO> STM>NHV> HFD>PVD> BOS	Run 6: PSNY>WHP > DAN>HFD> PVD>BOS
Boston South Station	4:10	2:13	2:18	2:28	2:27	2:35	2:10
Providence Station	3:20	1:46	1:51	2:01	2:00	2:08	1:43
Hartford	2:50	1:15	1:20	1:30	1:29	1:37	1:12
New Haven Station	1:40	0:52	1:12	1:07	1:21	1:14	1:14
Stamford	0:50	0:45	0:33	0:33	0:41	0:41	0:45
Waterbury South	--	--	1:07	--	1:16	--	0:59
Danbury	--	--	0:56	--	1:05	--	0:48
Ronkonkoma	--	0:34	--	--	--	--	--
Nassau Hub	--	0:15	0:15	0:15	--	--	--
White Plains East	--	--	--	--	--	--	0:23

PSNY - New York Penn Station; NAS - Nassau Hub, RNK - Ronkonkoma; WHP - White Plains STM Stamford;
NHV - New Haven; NRO - New Rochelle; DAN - Danbury; HFD - Hartford; PVD - Providence; BOS - Boston

Source: NEC FUTURE team, 2015

Table 12: Ridership for Intercity markets – New York City-to-Hartford, 2040

Route Option-->	1	2	3	4	5	6
	Nass Ronk NewHvn Hart Prov	Nass Stam Danb Hart Prov	Nass Stam NewHvn Hart Prov	NewRoc Stam Danb Hart Prov	NewRoc Stam NewHvn Hart Prov	NewRoc WhPlns Danb Hart Prov

Total Annual Intercity Trips (M)	1	2	3	4	5	6
Intercity-Express	2.4	2.4	2.4	1.7	1.7	1.9
Intercity-Corridor-Other/Metropolitan	4.2	3.9	3.6	2.7	2.4	3.0
Total Intercity	6.6	6.3	6.0	4.4	4.1	4.9

Common Station Pairs*	1	2	3	4	5	6
Intercity-Express	1.7	1.6	1.8	1.5	1.7	1.5
Intercity-Corridor-Other/Metropolitan	2.6	2.3	2.4	2.2	2.4	2.3
Total Intercity	4.3	3.9	4.2	3.7	4.1	3.8

Millions of annual intercity trips *BSS,RTE,PRV,HFD,NHV,STM,NYP,PHL,BAL,WAS

Top-performing options

Top-performing options not including LI Sound crossing

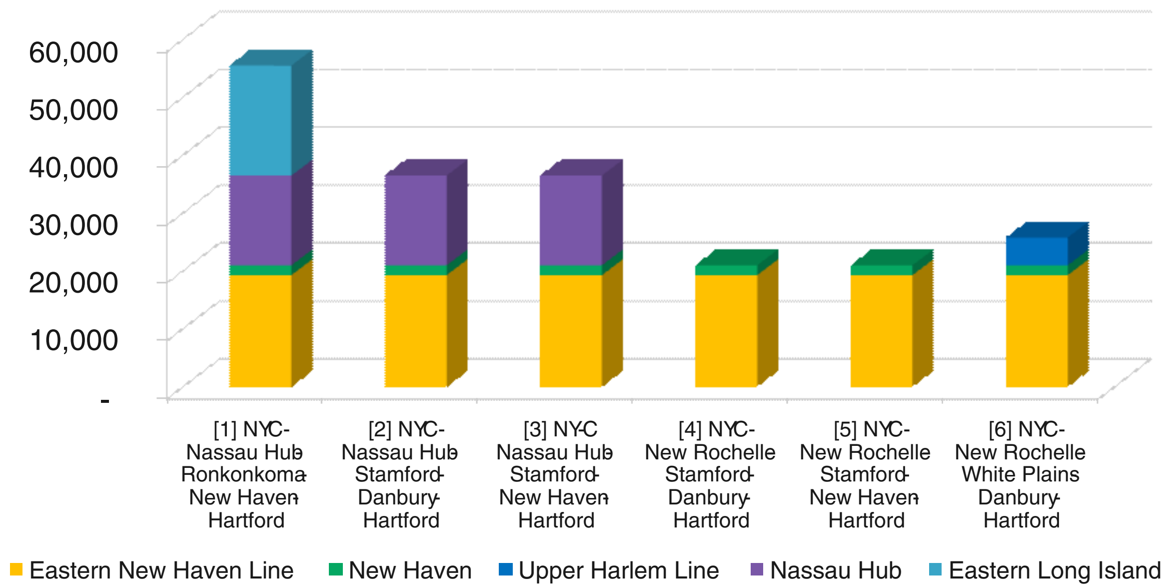
Source: NEC FUTURE team, 2015

A second measure of ridership potential exists in the New York City market. Construction of a new high-speed route via either Long Island, Central Connecticut, or parallel to the New Haven Line significantly decreases trip times for Regional rail services in the outer commuting zones of the New York City market, because these trains could utilize portions of the new high-speed route. Figure 7 presents the relative Regional rail ridership potential of the six New York City-to-Hartford route options. When both Intercity and Regional rail ridership potential are considered together, the New York City-Long Island-New Haven route emerges as the one with the best ridership potential. This is consistent with the Regional rail time savings for outer zone commuting to New York City (Table 13), which also shows the Long Island route to be superior.

Rough order-of-magnitude capital costs for new route construction were estimated for the six route options. Their relative cost and degree of construction difficulty were compared by estimating the extent of the various types of construction needed to create a new two-track right-of-way (Figure 8). The Long Island route is the most expensive, with a long tunnel crossing of Long Island Sound;[24] however, each of the route options have high costs because they require new right-of-way and entail significant amounts of tunneling.

[24] Tunnels were selected over bridges, where possible and appropriate, primarily, because they are easier to align for the straightest possible route (which supports top speeds) and generally because they generate fewer adverse impacts.

Figure 7: Regional Rail AM Peak Ridership for the New York City Market with Improvements to New Haven Line Capacity, 2040



Source: NEC FUTURE team, 2015

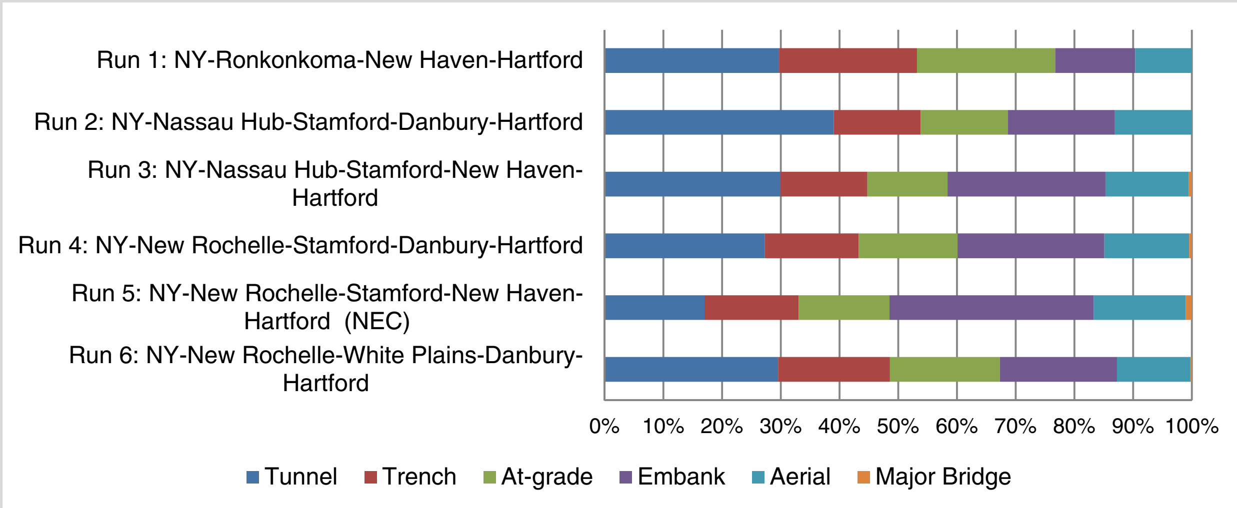
Table 13: Regional Rail AM Peak Period Minutes Saved per Trip for New York City Markets with Outer Zone Express Service Utilizing High-Speed Second-Spine Route –, with Improvements to New Haven Line Capacity, 2040

	New York City-Nassau Hub-Ronkonkoma-New Haven-Hartford	New York City-Nassau Hub-Stamford-Danbury-Hartford	New York City-Nassau Hub-Stamford-New Haven-Hartford	New York City-New Rochelle-Stamford-Danbury-Hartford	New York City-New Rochelle-Stamford-New Haven-Hartford	New York City-New Rochelle-White Plains-Danbury-Hartford
Eastern Long Island	30	—	—	—	—	—
Nassau Hub	25	25	25	—	—	—
Eastern New Haven Line	10	15	15	10	15	10
New Haven	50	25	30	20	25	10
Upper Harlem Line	—	—	—	—	—	20
TOTAL	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Source: NEC FUTURE team, 2015

Note: Column headers refer to the route options between New York City and Hartford, as listed in Table 9.

Figure 8: Relative Construction Type by Route Option, New York City-to-Hartford



Source: NEC FUTURE team, 2015

When all of these factors are considered together, the route options that utilize the relatively low-speed existing New Haven Line, as well as the route from Long Island to Danbury via Stamford, which has significant curvature and relatively lower speeds, do not perform as well as the other options and were eliminated from further consideration as routes for a second-spine. The New York City-Long Island-New Haven route shows the best ridership potential and was retained. Because of the high cost and the risks inherent in the proposed Long Island Sound tunnel crossing, the route option without a Long Island Sound crossing that had the best ridership potential was also retained – the Central Connecticut route via New Rochelle and Danbury.

5.3 ROUTE OPTIONS BETWEEN HARTFORD AND BOSTON

The second step in the evaluation looked at the three route options between Hartford and Boston:

- Hartford-Providence-Boston
- Hartford-Worcester-Boston
- Hartford-Springfield-Worcester-Boston

These route options are designated with letters rather than numbers to distinguish them from the New York City-to-Hartford route options. A complete New York City-to-Boston route option can be represented by the combination of a number and letter (e.g., option 1B for the route that links New York City, Ronkonkoma, New Haven, Hartford, Worcester, and Boston). The FRA compared trip times, ridership, and capital costs for the three route options between Hartford and Boston. Each of these comparisons used option 1 (the Long Island route via Ronkonkoma) as the assumed second-spine between New York City and Hartford, because this route option had the highest level of ridership in the Step 1 comparison, which served to amplify the differences among the Hartford-Boston route options. This was done to provide a basis for comparing the northern route options, and did not represent a preference.

Table 14 compares the relative Intercity-Express and Intercity-Corridor trip times for the resulting three Hartford-to-Boston route options. The Providence (1A) and Worcester (1B) route options produced very similar trip times; the route via Springfield was considerably longer in terms of both distance and time.

Table 14: Trip Times for Selected Intercity Markets – Hartford-to-Boston, 2040

Trip Times by Option	Existing	Super Express						
Penn Station New York	Acela	Run 1A: NYP>RNK> HFD>PVD> BOS	Run 1B: NYP>RNK> HFD>WOR> BOS	Run 1C: NYP>RNK> HFD>SPG> WOR>BOS				
Boston South Station	3:40	1:37	1:37	1:43				
	Existing	**Express**			**Existing**	**Metropolitan**		
Penn Station New York	Acela	**1A**	**1B**	**1C**	NE Regional	**1A**	**1B**	**1C**
Boston South Station	3:40	1:55	1:56	2:05	4:10	2:13	2:15	2:27
Providence Station	2:45	1:31	2:13	2:13	3:20	1:46	2:31	2:31
Hartford	--	1:04	1:04	1:04	2:50	1:15	1:15	1:15
New Haven Station	1:30	0:45	0:45	0:45	1:40	0:52	0:52	0:52
Stamford	0:45	0:38	0:38	0:38	0:50	0:41	0:41	0:41
Waterbury South					--	--	--	--
Danbury					--	--	--	--
Ronkonkoma					--	0:34	0:34	0:34
Nassau Hub					--	0:15	0:15	0:15
White Plains East					--	--	--	--

NYP - New York Penn Station; RNK - Ronkonkoma; HFD - Hartford; PVD - Providence; WOR - Worcester; SPG - Springfield; BOS - Boston

Source: NEC FUTURE team, 2015

The FRA compared the ridership potential of these three route options. The comparison yielded little difference in the magnitude of ridership potential (Table 15). The relative size of the Worcester and Providence markets, including the large swath of Boston suburbs lying to the west and south of Boston, is similar for Routes 1A and 1B. The Springfield market compensated for the loss in through ridership to and from Boston resulting from longer trip times. The Springfield route, however, by virtue of its extra length and the difficult topography to be traversed between Springfield and Worcester, requires extensive tunneling and was found to be considerably more costly than the two more direct routes, based on route-level cost estimates and the relative magnitude of the various types of required construction (Figure 9).

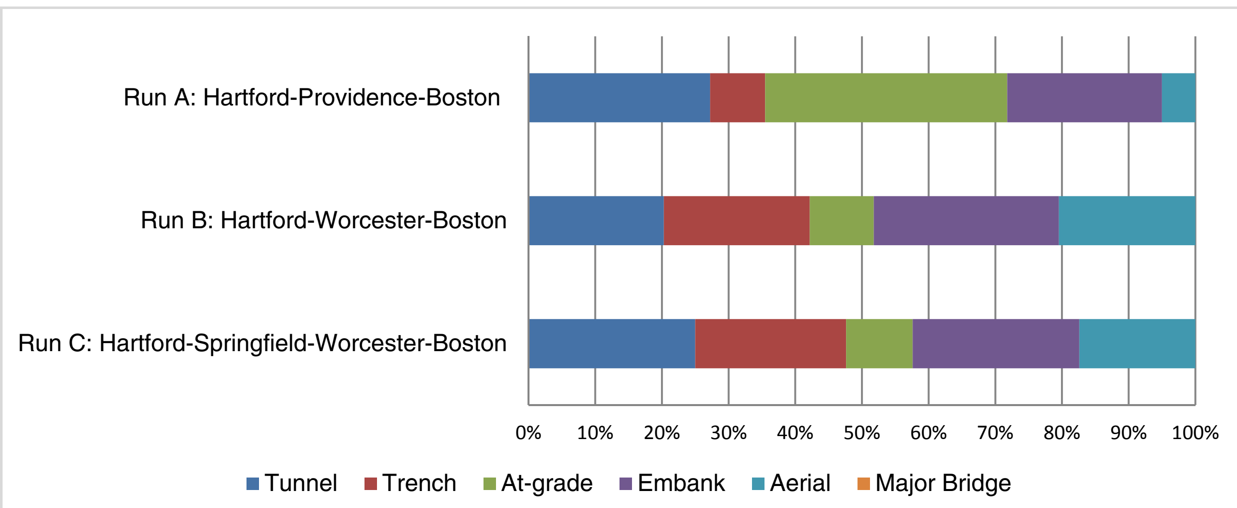
In addition to ridership potential and construction difficulty, the FRA considered the strength of potential connecting corridor service as a third factor to evaluate the route options. Springfield retains rail links to both New York City and Boston even in the options that do not provide direct high-speed service through Springfield – via connections at Hartford. The Hartford Line provides a 25-mile long connection from Springfield to Hartford, where a convenient transfer can be made to either Intercity-Express or Metropolitan trains running on the high-speed second-spine toward either New York City or Boston. The Inland Route, between Springfield, MA and Boston, MA, also offers a direct rail connection between Springfield and Boston that is not high-speed, but which is planned for improvements that offer reasonable service frequencies and trip times.

Table 15: Ridership for Intercity Markets – Hartford-to-Boston, 2040

Route Option-->	1A			1B			1C		
	Hartford-Providence-Boston			Hartford-Worcester-Boston			Hartford-Springfield-Worcester-Boston		
	Express	Corridor/ Metrop	Total	Express	Corridor/ Metrop	Total	Express	Corridor/ Metrop	Total
Total Annual Intercity Trips (M)									
Total North End Trips	3.0	4.2	**7.2**	2.8	4.4	**7.2**	2.9	4.4	**7.3**
Trips Between Common Station Pairs (NEC Spine plus Hartford)	2.5	3.5	**6.0**	2.0	3.4	**5.4**	2.0	3.4	**5.4**
Trips with end points in Greater Boston or New York & South	2.6	3.9	**6.5**	2.5	4.0	**6.5**	2.6	4.0	**6.6**
Percent of total north end trips			***89.7%***			***90.4%***			***90.1%***
Trips between Intermediate Markets	0.4	0.4	**0.8**	0.3	0.4	**0.7**	0.3	0.4	**0.7**
Percent of total north end trips			***10.3%***			***9.6%***			***9.9%***
Total Annual Intercity Trips (000)									
Trips between Greater Boston and New York & South	749	608	**1357**	701	697	**1397**	688	678	**1366**
Percent of total north end trips			***18.7%***			***19.3%***			***18.8%***

Source: NEC FUTURE team, 2015

Figure 9: Relative Construction Type by Route Option, Hartford-to-Boston



Source: NEC FUTURE team, 2015

On the other hand, the same cannot be said for Worcester or Providence, which must be on the high-speed second-spine in order to realize significant trip time and service frequency benefits relative to the No Action Alternative for travel to and through New York City. Without the high-speed second-spine, trip times from Worcester to New York City are significantly longer than via the existing Inland Route. Similarly, if the Providence route option is not selected, Providence retains Intercity-Express and Intercity-Corridor service, but the follows the existing NEC, and trip times to New York City are considerably longer. Moreover, through the various stakeholder and public meetings, the FRA received a greater amount of support for the Providence and Worcester route options, compared with Springfield.

In light of these considerations, the second-spine route option via Springfield was dropped from further consideration, but both of the other more direct route options (via Providence and via Worcester) were retained for further analysis. The service-related negative consequences of eliminating the direct route through Springfield are mitigated by the good connections that available at Hartford to both New York City and Boston with the two route options that are retained.

5.4 FINDINGS

Table 16 summarizes the disposition of the 20 unique north end route options with respect to documentation in the Tier 1 Draft EIS. Eight of the 20 routes are included among the Action Alternatives, either as the NEC or as connecting corridors. The FRA also retained the New Haven Line and Shore Line route as a route for through Intercity trains and Regional rail services in each of the Action Alternatives. In addition, the Stamford-Danbury corridor remains connected to the NEC as a Regional rail branch line. The further analysis and documentation of the Action Alternatives provides additional information on ridership, capital cost, environmental effects and other benefits, that will be used to inform identification of a Preferred Alternative.

The evaluation of the north end route options did not reveal a single superior route. Instead, the FRA identified two viable candidate routes between New York City and Hartford, and two between Hartford and Boston. Consequently, the FRA determined to carry forward the following four potential route options for the second-spine between New York City and Boston in Alternative 3 (Figure 10):

- Alternative 3.1 – Central Connecticut/Providence
- Alternative 3.2 – Long Island/Providence
- Alternative 3.3 – Long Island/Worcester
- Alternative 3.4 – Central Connecticut/Worcester

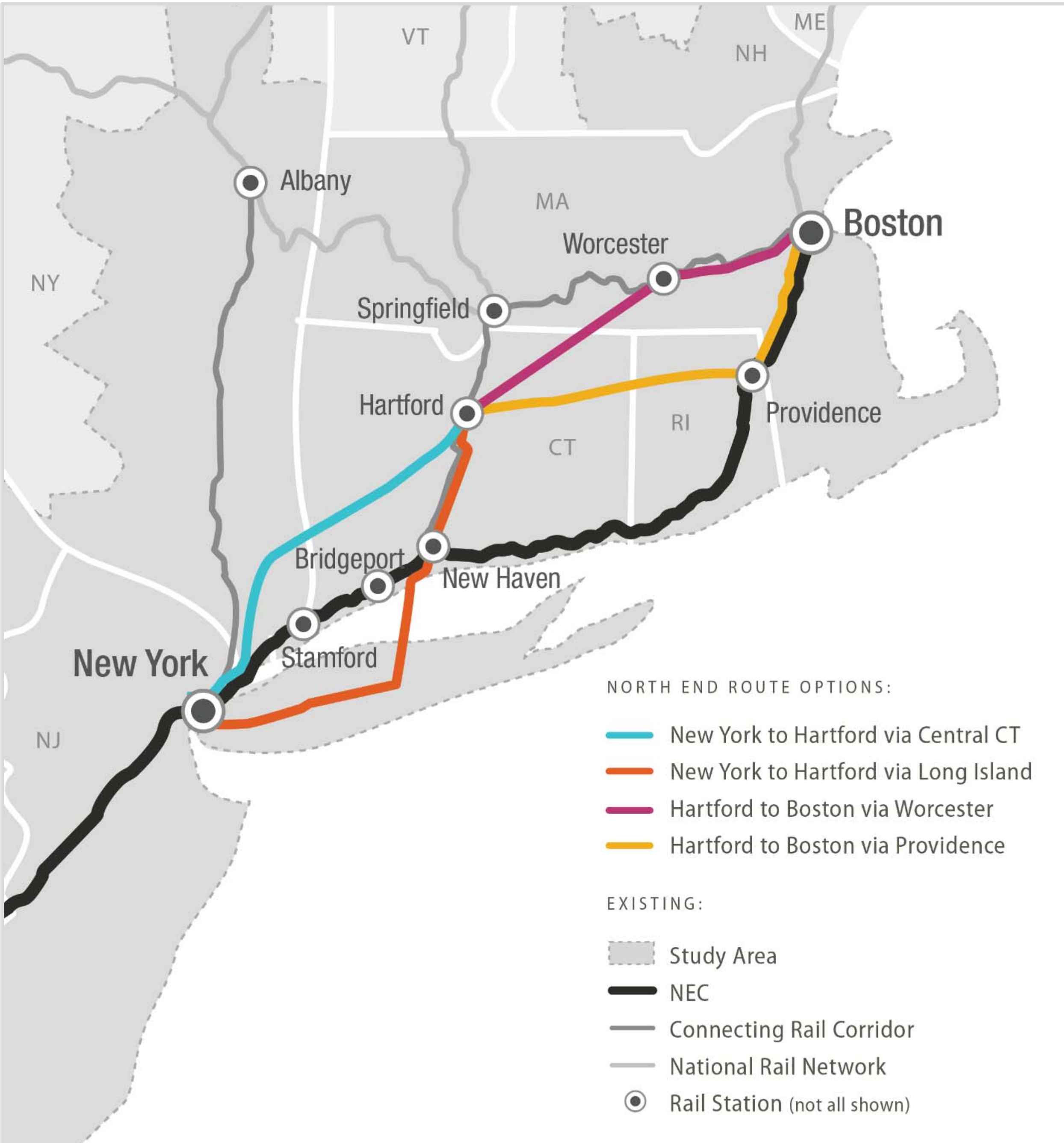
All four route options operate between Washington, D.C., and Boston, and join with common infrastructure improvements and rail services on the south end of the NEC, between Washington, D.C., and New York City. These route options are documented in the Tier 1 Draft EIS as part of Alternative 3.

Table 16: North End Routing Options Evaluation Summary, New York City to Boston

No.	North End Route Option						Disposition
1	[NEC] New York City-New Rochelle-Stamford	[NEC] Stamford-New Haven		New Haven-Hartford	Hartford-Providence	[NEC] Providence-Boston	Alt. 2
2					Hartford-Worcester	Worcester-Boston	X
3					Hartford-Springfield-Worcester		CC
4		Stamford-Danbury		Danbury-Hartford	Hartford-Providence	[NEC] Providence-Boston	X
5					Hartford-Worcester	Worcester-Boston	X
6					Hartford-Springfield-Worcester		X
7	New York City-New Rochelle-Danbury	Danbury-Hartford			Hartford-Providence	[NEC] Providence-Boston	Alt. 3.1
8					Hartford-Worcester	Worcester-Bos	Alt. 3.4
9					Hartford-Springfield-Worcester		CC
10	New York City-Nassau Hub	Nassau Hub-Ronkonkoma-New Haven		[NEC] New Haven-Providence		[NEC] Providence-Boston	X
11				New Haven-Hartford	Hartford-Providence	[NEC] Providence-Boston	Alt. 3.2
12					Hartford-Worcester	Worcester-Boston	Alt. 3.3
13					Hartford-Springfield-Worcester		CC
14		Nassau Hub-Stamford	[NEC] Stamford-New Haven	[NEC] New Haven-Providence		[NEC] Providence-Boston	X
15				New Haven-Hartford	Hartford-Providence	[NEC] Providence-Boston	X
16					Hartford-Worcester	Worcester-Boston	X
17					Hartford-Springfield-Worcester		X
18			Stamford-Danbury	Danbury-Hartford	Hartford-Providence	[NEC] Providence-Boston	X
19					Hartford-Worcester	Worcester-Boston	X
20					Hartford-Springfield-Worcester		X

X = This route was dropped from further consideration as a second-spine for the Action Alternatives.
CC = This route was included as connecting corridor service in various alternatives with second-spine via other route options.

Figure 10: Alternative 3 Route Options



6. Characteristics of the No Action and Action Alternatives

Each Action Alternative represents a unique long-term vision for improving passenger rail service that will enhance mobility options, improve performance, and better serve existing and new markets that support future population and employment growth in the Study Area. All three Action Alternatives provide substantially more and better rail service than the No Action Alternative, along the entire length of the NEC. While the three Action Alternatives are distinct in their service and physical characteristics, they include several common elements. Although the visions are unique, and despite differences in how they achieve that vision, each Action Alternative shares the following attributes:

- Maintains and improves service on the existing NEC.
- Brings the NEC to a state of good repair by replacing or renewing aging infrastructure on the existing NEC and eliminating the backlog of infrastructure requiring replacement, so that future capital upgrades are planned and implemented according to a regular replacement cycle.
- Addresses the most pressing capacity and service chokepoints that constrain capacity on the existing NEC.
- Protects freight rail access and the opportunity for future expansion.
- Incorporates appropriate passenger rail enhanced service concepts and operational “best practices” consistent with integrated service and infrastructure planning to address capacity constraints, broaden the mix of station-pairs served, improve performance, and generate operating cost efficiencies.

The FRA developed a range of Action Alternatives to help better understand and quantify key rail market and service dynamics, such as the trade-offs between frequencies of service, trip time, and the convenience of one-seat service between markets. The Action Alternatives provide the FRA, the region, and other stakeholders with a broad range of options and sufficient information to evaluate future visions and make reliable, long-term decisions about the appropriate role rail plays in the region’s multimodal transportation network. The investment program for each Action Alternative consists of 1) a set of geographic markets to be served by passenger rail; 2) a Representative Route (or footprint) that connects these markets; 3) assumptions about the level of passenger rail service that will be provided to these markets; and 4) infrastructure improvements that support this level-of-service. These characteristics, which are also used to describe the No Action Alternative, are all representative in nature.

6.1 MARKETS

The FRA took a market-based approach to develop Action Alternatives, first identifying current travel patterns, how they have changed over the past three to four decades, and potential new rail markets. The four primary geographic markets on the existing NEC are Washington, D.C., Philadelphia, Boston, and New York City. These four markets are distinguished by existing regional and state travel demand and population growth data, ridership projections made by Amtrak and the commuter-rail operators, data and discussions with states and planning organizations, and public and agency comments made during Scoping and other public meetings.

The data also show that there are other strong Northeast travel markets, both on and off the existing NEC. The Study Area includes a number of smaller intermediate cities and urbanized areas. Some of these are located directly on the NEC, such as Baltimore, Wilmington, and Providence. Others are located away from the NEC, such as Hartford, CT, or Worcester, MA. A significant number of interregional trips[25] include travel from these intermediate cities to the primary metro regions, or between two intermediate cities.

A third category of geographic markets within the NEC Study Area can be characterized as suburban areas, located within the general realm of one or more of the primary regions but without easy access to a large downtown train station. These areas are served by NEC stations with both intercity and commuter trains. For example, the Maryland suburbs of Washington, D.C., and Baltimore are served today by the New Carrollton and BWI Airport stations. A broad swath of New Jersey is linked by highway to the Metropark station. Westchester (NY) and Fairfield (CT) Counties are served today by multiple stations along the New Haven Line, and the southern and western suburbs of Boston have good highway access to the Route 128 station.

6.1.1 STATIONS

For NEC FUTURE, the FRA developed a hierarchy of station types, based on the size of the geographic market and type and quantity of rail service offered. This typology applies to existing stations and future stations included in the No Action and Action Alternatives. Stations are grouped based on similar characteristics into one of three categories:

- **Major Hub stations** serve the largest markets in the Study Area and have the full complement of rail services types. Major Hub stations serve the four primary markets: Washington, D.C., Philadelphia, New York City, and Boston, as well as other major markets within the Study Area, including but not limited to Baltimore, MD; Stamford, CT; and Providence, RI. Major Hub Stations are located in the most populous and densely developed metropolitan areas along the NEC, serving Intercity and Regional rail travel to these major population and employment centers.
- **Hub stations** offer some Intercity service, although the Intercity-Express service is more limited than the service levels offered at Major Hub stations. Hub stations include the existing smaller intermediate Amtrak stations, as well as selected key Regional rail stations and new stations that have the potential to fill connectivity gaps in the existing passenger rail network, serve special trip generators, and/or provide important inter-modal connections.
- **Local stations** are served almost exclusively by Regional rail trains, on the portions of the NEC where Regional rail service is offered. Examples of local stations include Halethorpe, MD; Claymont, DE; Torresdale, PA; Edison, NJ; Larchmont, NY; Westport, CT; Wickford Jct., RI; and Attleboro, MA. There are a limited number of locations on the NEC outside of Regional rail territory where the existing Amtrak stations are best classified as local stations (e.g., Mystic and Westerly stations). Similarly, smaller stations on connecting corridors beyond the NEC are considered local stations (e.g., Ashland, VA; Mt. Joy, PA; Rhinecliff, NY; Wallingford, CT).

[25] Trips that that start and end in different metropolitan areas.

6.2 REPRESENTATIVE ROUTE

The Representative Route refers to the physical path of a proposed Action Alternative, including horizontal and vertical dimensions. The Representative Route is defined by the broad physical limits (or footprint) of an alternative, and is used to assess the potential environmental effects of the Action Alternatives. At the Tier 1 level, the footprint is only representative of where the physical route might be located and are not a prediction of future preferences or decisions. For purposes of footprint-related environmental effects analysis, a relatively wide buffer is drawn around the Representative Route centerline to understand the resources and potential impacts in the general zone within which the actual right-of-way might be located. The width of the buffer area varies by type of construction and is larger for new segments than for new tracks that follow the existing NEC. Recognizing the uncertainty that exists at this early stage of planning, the Representative Routes provide a sound basis for programmatic evaluation of the environmental effects of each Action Alternative.

6.3 SERVICE PLAN

The utility of the current passenger rail network is limited by gaps in connectivity with other transportation modes and minimal coordination between different rail services. Railroads operating on the NEC today share fixed infrastructure but operate separate rail services with different equipment with different performance capabilities. Infrastructure (track configuration, power source) and equipment constraints (diesel, electric) further limit the ability to provide passengers with coordinated and direct service for many city pairs along the existing NEC and connecting corridors.

The representative Service Plans (Section 4.1.1) for the Action Alternatives incorporate operational improvements that better integrate train service across today's separate markets, and explore opportunities free from institutional and jurisdictional operating constraints. The Service Plans are intended to be representational only, required for analysis of capacity, performance, and costs, as well as assessment of environmental impacts, and are not intended in any way to be prescriptive regarding how service should be operated in the future. In addition, the Service Plans do not predict future operating patterns of the NEC operators. These representative improvements (Section 4.1.4) include "through-service" at major stations to provide operational efficiency and improved capacity utilization; clockface (service at regular intervals) train departures and standard stopping patterns to improve efficiency; integrated ticketing and fares across the NEC to improve passenger convenience; and decreased dwell time at stations to reduce travel time. In addition, some stations could be enhanced to accommodate multiple service types, and train schedules could be integrated across the NEC to provide easier transfers between trains, resulting in an increase in travel options and service frequencies to additional markets. Other operational improvements include:

- Development of Regional rail slot catalogues, in which schedule slots are assigned to services where and when demand is greatest and not assigned to a specific operator.
- Scheduling options for accommodating less reliable off-corridor operations to reduce their effect on NEC operations (e.g., extended dwells at NEC entry point, phantom slots, etc.).

6.4 INFRASTRUCTURE ELEMENTS

As described in the Purpose and Need, the Action Alternatives use existing and proposed infrastructure to support the operations necessary to meet market growth and the specific vision of that alternative. All of the Action Alternatives can accommodate different types of trains; however, some route segments in Alternatives 2 and 3 will be dedicated to high-performance trainsets. This integrated approach to operations and train schedules, requires a smaller infrastructure footprint compared to today's independently planned operations.

Individual infrastructure elements make up an Action Alternative's path and describe the type of the physical infrastructure improvement relative to the No Action Alternative. These discrete elements, including both linear elements and supporting infrastructure (Section 4.4), facilitate a modular approach to analyzing the alternatives. Infrastructure Elements that make up the Action Alternatives consist of the following:

- Curve Modification
- New Track
- New Segment
- Station Area
- Junction
- Storage and Maintenance Facility

7. No Action Alternative

The No Action Alternative represents future conditions if no rail investment program is advanced. It assumes planned and programmed improvements to highway, freight rail, transit, air, and maritime modes that will be completed by 2040. Interregional and regional travel demand is affected by the availability, price, and reliability of all transportation modes. Therefore, inclusion of improvements of these other modes is necessary to represent the reasonably foreseeable future transportation conditions in the NEC Study Area. The No Action Alternative serves as a baseline for the purpose of comparing the outcomes of the Action Alternatives in terms of ridership, revenue, cost, and train operations.[26]

The No Action Alternative represents a snapshot in time and has been developed using current information compiled from federal, state, and regional transportation planning documents. As the NEC FUTURE program progresses, assumptions regarding which projects are included as part of the No Action Alternative may be revised based upon available funding, urgency of needs, and changes or updates to the region's transportation plans.

Upon reviewing planning lists of projects across all transportation modes, the FRA used the following methodology for selecting projects for inclusion in the No Action Alternative:

- Funded projects or projects with approved funding plans (e.g., federal or state committed funding)
- Funded or unfunded mandates
- Unfunded projects necessary to keep the railroad running

The FRA assumes that sufficient funding will be made available to maintain current service levels with the No Action Alternative; however, if this is not available, the reliability, capacity, and service quality of the NEC will decline. In fact, historic funding levels are not sufficient to make the improvements and maintain service in the No Action Alternative. Because the implications of continuing current funding levels on service are hard to predict, it is assumed that sufficient funding will be made available for the No Action Alternative. Forecasting the implications of insufficient funding on the performance of the eight commuter railroads and Amtrak would be subjective given the uncertainty of what might or might not be funded and the resulting performance implications. Therefore, the FRA decided to separate evaluation of the No Action Alternative from the discussion of historic or future funding trends and the implications of insufficient funding.

The FRA assumes that the No Action Alternative projects necessary to maintain existing service levels along the NEC will be funded through 2040. However, the funding levels necessary for the No Action Alternative exceeds historic levels of capital funding from federal, state, and local sources made available to all of the owners/operators on the NEC. Historic funding levels have averaged $600 million per year over the last ten years.[27] If sufficient funding to meet the requirements of the No Action Alternative is not made available, the consequence of continuing past patterns of disinvestment in the NEC would be degradation of the reliability, capacity, and quality of service on the NEC with potential outcomes as summarized below.

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[26] For additional information on the No Action Alternative, please see the NEC FUTURE *No Action Alternative Report* on the NEC FUTURE website, *www.necfuture.com*.

[27] NEC Infrastructure and Operations Advisory Commission. *NEC Capital Needs Assessment FY15-19 (September 2014)*

- Reliability would decline, resulting in more frequent and longer delays, and reduced on-time performance of train service. This reduction in reliability would result from unscheduled delays, as well as "scheduled" delays required periodically (and randomly to allow engineering crews to access the railroad to make remedial repairs).
- Scheduled trip times would increase as the deteriorating condition of NEC infrastructure—particularly rail, bridge, and subgrade—would necessitate slow orders to reduce the impact of train operations on sensitive infrastructure and to ensure safety.
- Operating costs for infrastructure maintenance would rise in response to the need for more frequent maintenance and unscheduled and sometimes substantial repairs.
- Costs for train operations would increase as longer cycle times for equipment would require greater fleet sizes and more crew time and overtime.
- Ridership would decline in response to the reduced level and quality of service leading to declines in revenue such that current levels of operating profit for Intercity services would diminish and operating losses would occur.

However, as mentioned earlier, FRA has decided that, for the purposes of providing a baseline for comparison against the Action Alternatives, the FRA presumes sufficient funding to maintain current service levels are made available for the No Action Alternative.

7.1 MARKETS

The No Action Alternative serves existing geographic markets along the NEC. Table 17 identifies the stations served under the No Action Alternative.

7.2 REPRESENTATIVE ROUTE

The Representative Route of the No Action Alternative is the existing NEC between Washington Union Station and Boston South Station. It includes the MTA East Side Access Project currently under construction in New York City.

7.3 SERVICE PLAN

The representative Service Plan under the No Action Alternative is described by type and levels of passenger rail service at selected screenlines along the NEC (Table 18). Screenlines were used to measure the volume of passenger rail traffic at key locations along the NEC, particularly where capacity or utilization might change. Screenlines are drawn across a rail right-of-way usually associated with a particular geography in order to standardize the location at which the frequency and type of rail service are measured, evaluated, and compared. The volume of passenger rail traffic is expressed as trains per hour, per direction, by service type at the following points along the NEC: Washington, D.C.; Philadelphia, PA; the Hudson River and East River in the New York metropolitan region; New Rochelle, NY; and Boston, MA. For comparison purposes, existing (2012) service levels are compared to the No Action Alternative service levels for the peak-hour, peak direction.

Table 17: Existing Stations (excluding Connecting Corridors) Served Under the No Action Alternative

Geography	Total Stations	NEC Stations (excluding Connecting Corridors)
Washington, D.C.	1	Washington Union Station
Maryland	12	New Carrollton, Seabrook, Bowie State, Odenton, BWI Airport, Halethorpe, West Baltimore, Baltimore Penn Station, Martin Airport, Edgewood, Aberdeen, Perryville
Delaware	4	Newark, DE, Churchman's Crossing, Wilmington Station, Claymont
Pennsylvania	25	Marcus Hook, Highland Ave, Chester, Eddystone, Crum Lynne, Ridley Park, Prospect Park, Norwood, Glenolden, Folcroft, Sharon Hill, Curtis Park, Darby, Philadelphia 30th St, North Philadelphia, Bridesburg, Wissinoming, Tacony, Holmesburg Junction, Torresdale, Cornwells Heights, Eddington, Croydon, Bristol, Levittown
New Jersey	15	Trenton, Hamilton, Princeton Junction, Jersey Avenue, New Brunswick, Edison, Metuchen, Metropark, Rahway, Linden, Elizabeth, North Elizabeth, Newark Airport, Newark Penn Station, Secaucus
New York	7	Penn Station New York, New Rochelle, Larchmont, Mamaroneck, Harrison, Rye, Port Chester
Connecticut	29	Greenwich, Cos Cob, Riverside, Old Greenwich, Stamford, Noroton Heights, Darien, Rowayton, South Norwalk, East Norwalk, Westport, Green's Farms, Southport, Fairfield, Fairfield Metro, Bridgeport, Stratford, Milford, West Haven, New Haven Union Station, New Haven State Street, Branford, Guilford, Madison, Clinton, Westbrook, Old Saybrook, New London, Mystic
Rhode Island	5	Westerly, Kingston, Wickford Junction, TF Green, Providence Station
Massachusetts	12	South Attleboro, Attleboro, Mansfield, Sharon, Canton Junction, Route 128, Readville, Hyde Park, Forest Hills, Ruggles, Back Bay, Boston South Station

Source: NEC FUTURE team, 2014

Table 18: Standard Peak-Hour Trains, Peak Direction for the No Action Alternative, 2040

Screenline	No Action
Washington, D.C. Screenline *North of Washington at Anacostia River*	
Intercity-Express	1
Intercity-Corridor	1
Connecting corridor*	Included above as part of Intercity-Express and Intercity-Corridor
Regional rail	4
Philadelphia Screenline *Chester Pennsylvania*	
Intercity-Express	1
Intercity-Corridor	1
Connecting corridor*	0
Regional rail	3
Hudson River Screenline	
Intercity-Express	1
Intercity-Corridor	1
Connecting corridor*	1
Regional rail	21
East River Screenline	
Intercity-Express	1
Intercity-Corridor	1
Connecting corridor*	2
Regional rail**	36
New Rochelle Screenline *Between Shell Junction and New Rochelle Station*	
Intercity-Express	1
Intercity-Corridor	1
Connecting corridor*	Included above as part of Intercity-Express and Intercity-Corridor
Regional rail	21
Boston Screenline *South of Back Bay Station*	
Intercity-Express	1
Intercity-Corridor	1
Connecting corridor*	0
Regional rail	6

Source: NEC FUTURE team, 2015

* Connecting corridors include Springfield, Empire, Keystone and Virginia Service south of Washington Union Station.

** Excludes MTA-Long Island Rail Road access to Grand Central Terminal.

In the No Action Alternative, passenger rail service on the NEC operates similarly to and at the same approximate level as today's services. The No Action Alternative assumes the same types of Amtrak Intercity services, including Intercity-Express (Acela), Intercity-Corridor (Regional), and connecting corridors (i.e., Springfield, Keystone, and Empire). The No Action Alternative also assumes the same types of regional services offered by the eight commuter railroads operating on the NEC: MBTA, Connecticut DOT, MNR, LIRR, NJ TRANSIT, SEPTA, MARC, and VRE. East Side Access, currently under construction and thus part of the No Action Alternative, includes new LIRR service into Grand Central Terminal in New York City. While the types of service are assumed to be similar going forward, greater demand in the future could affect overall performance.

7.4 INFRASTRUCTURE ELEMENTS

The No Action Alternative represents the condition of the Northeast region's multimodal transportation system in 2040 assuming general continuation of infrastructure conditions. The No Action Alternative includes the completion of transportation projects already planned and programmed, or in-progress by 2040. Beyond specific named projects, the No Action Alternative assumes that right-of-way owners individual railroad operators will continue to maintain the NEC through their annual maintenance programs for key elements such as track, signals and communications, and structures, and that the individual railroad operators will continue to maintain their rolling stock and yard facilities. Capital replacement or upgrading of infrastructure assets is assumed be undertaken as necessary to maintain railroad operations at current levels, based on the condition of the assets. This includes some—but only a modest proportion—of the significant backlog of work associated with bringing the NEC to a state of good repair. The No Action Alternative does not bring the NEC to a state of good repair.

8. Alternative 1

Alternative 1 maintains the role of rail, with the level and capacity of rail service to keep pace with proportional growth in population and employment. For this alternative, the FRA used the projected service plans of NEC service operators as a starting point, and made adjustments to meet projected increases in travel demand. Alternative 1 includes new rail services and commensurate investment in the NEC to expand capacity, add tracks, and relieve key chokepoints, particularly through northern New Jersey, New York, and Connecticut (Figure 11). This includes a 60-mile bypass between Old Saybrook, CT, and Kenyon, RI, that adds capacity, improves travel time, and provides an alternative for most intercity trains to avoid five existing movable bridges along Long Island Sound and numerous sharp curves.

8.1 MARKETS

Alternative 1 primarily serves existing regional and interregional NEC travel markets. It also enables expanded service on some Regional rail lines that currently provide direct service to NEC markets. Alternative 1 provides the possibility, with additional investments, for Regional rail lines without such one-seat ride service to connect onto the NEC and offer one-seat ride service to those markets. This includes lines both in New Jersey and Connecticut. Where Metropolitan service is introduced, the accessibility of these areas to NEC Intercity service is significantly improved. The stations with Metropolitan service generally are those with significant local development and economic activity and/or excellent regional highway access.

8.2 REPRESENTATIVE ROUTE

The Representative Route of Alternative 1 closely follows the existing route of the NEC. In all but a few locations, the Representative Route is confined to the existing NEC. Exceptions include locations where infrastructure is added to provide chokepoint relief or add capacity, as described above.

8.3 SERVICE PLAN

The Service Plan for Alternative 1 offers a moderate expansion in service compared to the No Action Alternative, to accommodate underlying growth in both the Intercity and Regional rail markets by 2040. In the standard peak hour, Intercity-Express service increases to two trains per hour, on both the South End and North End. Intercity-Corridor service also increases. In the standard peak hour, two trains per hour operate between Washington, D.C., and New Haven, CT, providing a one-seat ride from the NEC to off-corridor markets on the connecting corridors. In addition to these trains, new Metropolitan service is introduced, with two trains in the standard peak hour running between Washington, D.C., and Boston, and an additional train serving the Keystone Corridor and running on the NEC between Philadelphia and New York City.

Major NEC cities see an increase in total trains per hour in the standard peak hour from combined service of Intercity-Express, Intercity-Corridor, and Metropolitan services:

- Washington, D.C.: 6 tph (2 Intercity-Express, 2 Intercity-Corridor-Other, and 2 Metropolitan)
- Philadelphia, PA: 7 tph (2 Intercity-Express, 2 Intercity-Corridor-Other, and 3 Metropolitan)

- Newark, NJ: 7 tph (2 Intercity-Express, 2 Intercity-Corridor-Other, and 3 Metropolitan)
- New Haven, CT: 6 tph (2 Intercity-Express, 2 Intercity-Corridor-Other, and 2 Metropolitan)
- Boston, MA: 4-5 tph (2 Intercity-Express, up to 1 Intercity-Corridor-Other[28], and 2 Metropolitan)

Expansion of trainset lengths, where possible, and increases in peak period service frequencies to provide more capacity, enables future Regional rail service to continue to carry its current share of journey-to-work trips to and from the major metropolitan CBDs, such as across the Hudson River screenline. Reverse-peak and off-peak service continues to be operated where it is provided today.

8.4 INFRASTRUCTURE ELEMENTS

Alternative 1 supports increases in Regional rail and Intercity services by bringing the existing NEC to a state of good repair, eliminating key chokepoints along the corridor, and increasing capacity at selected locations by adding additional track within the existing NEC and through new segments parallel to and outside the existing NEC right-of-way.

8.4.1 CHOKEPOINT RELIEF PROJECTS

Alternative 1 includes a set of location-specific capital projects to provide relief of train movement congestion and increase railroad capacity at several existing chokepoints. These projects are spread across the NEC, but are concentrated at locations that are currently congested and where train interference causes delays today—primarily south of New York City and on the New Haven Line in New York City and Connecticut. These chokepoint relief projects are located at stations, branch line junctions, and yard locations where trains lay over and change direction. Implementing these projects may, in some cases be challenging, given existing development and pending plans in project areas. Specific design solutions would be the focus of future Tier 2 studies. The chokepoint relief projects are listed below in geographic order from south to north, and their locations are identified in Figure 11:

- New Carrollton Station, 4 platform tracks, to permit express and local trains to operate on separate tracks
- Newark, DE, station relocation and track reconfiguration, to provide for smoother Intercity, Regional rail and freight train movements
- Holly Interlocking reconfiguration, DE, to separate local and express train traffic
- Philadelphia flyover, to facilitate regional rail local train movements
- Trenton Station and yard access, to facilitate Regional rail terminal operations
- Metropark Station platforms on express tracks, to permit Intercity-Express and Intercity-Corridor trains to stop at this station without switching to the local tracks
- Hunter flyover and Westbound Waterfront Connection, improving access to the NEC from the Raritan Valley Line and from Hoboken Terminal
- New Rochelle (Shell Junction) grade separation, to provide smoother train flows between the Hell Gate Line and New Haven Line
- South Norwalk and Devon junction improvements, to facilitate Danbury and Waterbury Regional rail branch line train movements
- East Bridgeport yard access and turnback track, to facilitate turning of local Regional rail services

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[28] The Intercity-Corridor-Other train at Boston would operate on the Inland Route (via Hartford, Springfield, and Worcester) and would operate at less than hourly service frequencies.

- Canton Jct.-Readville, MA track and junction improvements to facilitate smooth flow of trains

8.4.2 NEW TRACK

New-track projects are identified as linear elements along portions of the existing NEC that include associated junctions and interlockings required to access the new tracks. Six new-track projects are built in Alternative 1. Four are located south of New York City, two of which are in Maryland, which is currently a two- and three-track right-of-way. There are two new-track projects north of New York City. Two tracks are added to the Hell Gate Line in Queens and the Bronx, NYand one or two tracks are added near Route 128 station in Massachusetts. New-track projects are shown on the map in Figure 11 and include the following locations:

- Odenton, MD, to Halethorpe, MD, 4th track
- Bayview, MD, to Newark, DE, additional track(s)
- Elizabeth, NJ, to Newark Airport, NJ, additional track(s)
- Hell Gate Line, Queens and the Bronx, NY, expanded to 4 tracks
- East Greenwich, RI-Warwick, RI, additional track(s)
- Canton Jct., MA, to Westwood/Route 128, MA, additional track(s)

8.4.3 NEW SEGMENT

Alternative 1 adds three new segments,[29] parallel to and outside of the existing NEC right-of-way. Two new segments are located south of New York City: a new tunnel near Baltimore Penn Station and a third and fourth tunnel under the Hudson River between New Jersey and New York. These new segments are listed below (with their approximate length in parentheses) and are also identified on the map in Figure 11:

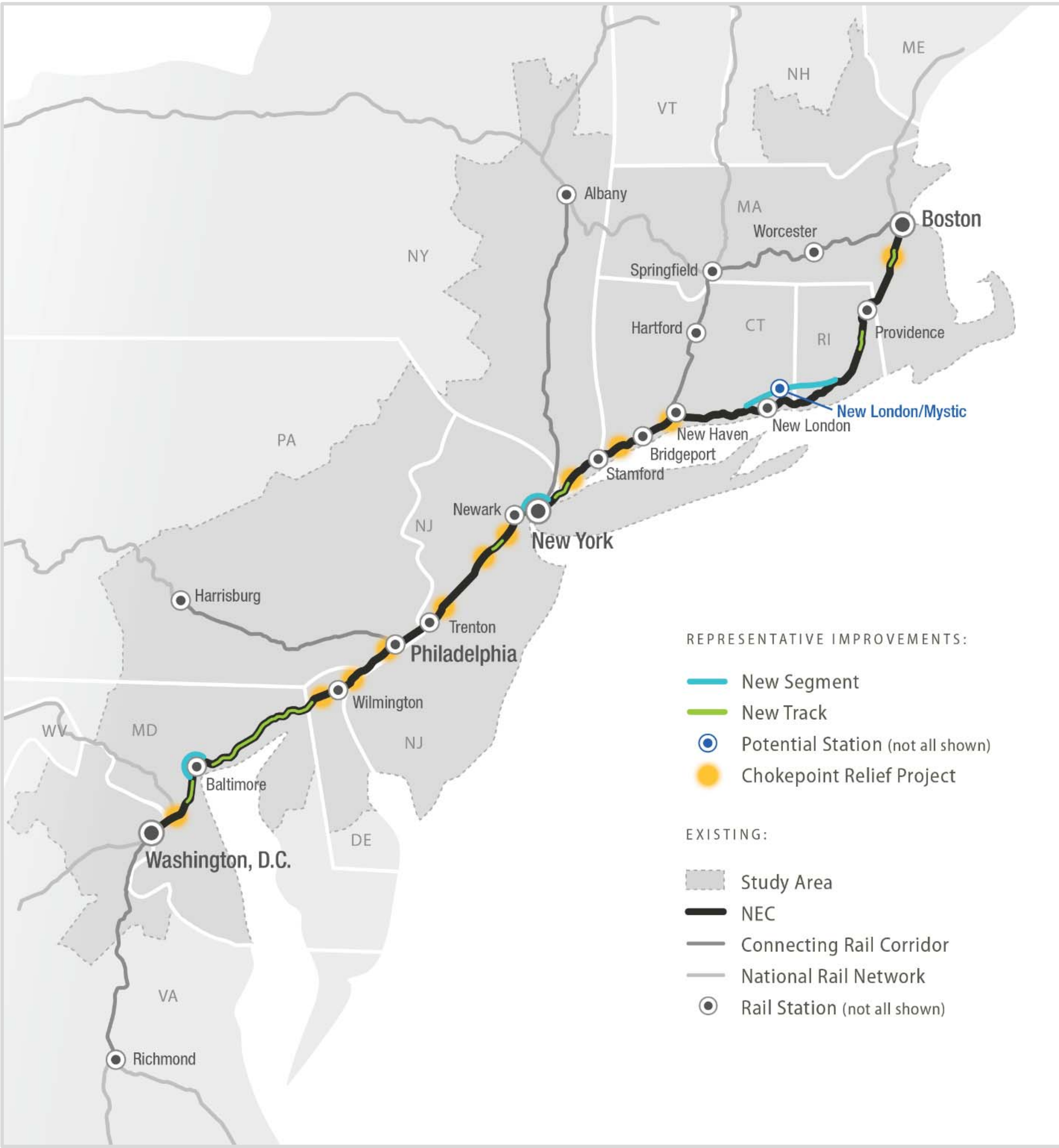
- Baltimore Tunnel (~2 miles)
- Hudson River third and fourth tunnels and expanded Penn Station New York (~3 miles)
- Old Saybrook, CT-Kenyon, RI (~50 miles)

All of these are locations for new segments are where the railroad is capacity-constrained, where expanding capacity within the existing right-of-way is difficult or impractical, or, in the case of the Baltimore Great Circle Tunnel, where existing facilities require life-cycle replacement.

This alternative also includes one long parallel new segment in southeastern Connecticut, the Saybrook-Kenyon bypass. This new route, approximately 50 miles long, provides a more direct and faster route than the circuitous existing Shore Line, and it circumvents the existing movable bridges over navigable waterways connected to Long Island Sound, over which daily train movements are capped by current agreements and where approval for significant increases in future train traffic will be difficult to obtain. Operating Intercity-Express and Metropolitan service on this bypass route saves approximately 30 minutes of travel time compared with the existing Shore Line route and frees up capacity on the existing route for anticipated growth in Regional rail and freight service. A new station for Intercity-Express and/or Metropolitan services could be built on the bypass route in the New London-Mystic area. The existing stations serving the downtown areas of New London, Mystic and Westerly continue to be served by trains running on the existing Shore Line.

[29] New segments contribute to the Representative Route of an alternative, as described in Section 8.1

Figure 11: Alternative 1



Source: NEC FUTURE team, 2015

9. Alternative 2

Alternative 2 grows the role of rail, expanding rail service at a faster pace than the proportional growth in regional population and employment. During the business travel peak periods, very frequent Intercity-Express service is provided along the entire NEC, with Intercity-Express trains operating at 4 tph. Metropolitan service also is operated on the NEC at a frequency of a train every 15 minutes, providing a level-of-service resembling that of transit. In all regions of the NEC, Regional rail service frequencies also are increased significantly above No Action Alternative levels. As shown in Figure 12, south of New Haven, CT, infrastructure improvements focus on the existing NEC right-of-way with some variations in the route to improve train speeds in areas with speed-limiting curves, address capacity constraints, and serve selected new markets. North of New Haven, Alternative 2 provides a new route segment between New Haven, Hartford, and Providence, improving performance for express trains operating between Boston and New York City while providing better connections for markets in the Connecticut River Valley. Alternative 2 also brings the existing NEC to a state of good repair and implements operational best practices to obtain the highest practical utilization of the infrastructure capacity that is created.

9.1 MARKETS

Alternative 2 greatly improves the level-of-service available to all of the existing NEC markets and selectively taps potential new travel markets that are not served currently or are not well served by the NEC. This includes the New Haven-Hartford-Springfield corridor, now known as the Hartford Line. Hartford becomes a market on the NEC Spine rather than part of a connecting corridor. Other locations along this line have improved trip times and service offerings by virtue of the new high-speed line between New Haven and Hartford featured in this alternative, and the greatly improved accessibility of Providence and Boston by rail.

A second market that receives greatly improved rail service is Philadelphia International Airport, which has a station directly on the NEC in this alternative, with frequent Intercity-Express, Metropolitan, and Regional rail service up and down the NEC as well as to the Keystone Corridor and the rest of the SEPTA Regional rail network.

A third market with significantly increased NEC rail service is located on the south side of Washington, D.C. Improvements to the Long Bridge corridor between Washington, D.C., and Alexandria, VA, coupled with improvements at Washington Union Station, permits Metropolitan service and selected Regional rail trains to run through Union Station, effectively extending the reach of the NEC to this heavily populated part of greater Washington, D.C., and to Ronald Reagan Washington National Airport.

Figure 12: Alternative 2

Source: NEC FUTURE team, 2015

9.2 REPRESENTATIVE ROUTE

Much of the Representative Route of Alternative 2 follows the existing NEC between Washington, D.C., and New Haven, CT, with some exceptions where infrastructure is added or modified to provide chokepoint relief or improve capacity and performance. These infrastructure elements are described Section 9.4. North of New Haven, a new route is provided for Intercity-Express and Metropolitan trains running between New York City and Boston. The new route runs on new tracks between New Haven and Meriden, CT, shares the existing Hartford Line between Newington, CT and Hartford, CT, and runs on new tracks between Hartford, CT and Providence, RI.

9.3 SERVICE PLAN

Alternative 2 significantly grows Intercity service on the NEC through improved service to all existing markets and additional service to selected new markets. In the standard peak-hour, Intercity-Express service increases to four trains per hour compared to the No Action Alternative, where there is never more than one train per hour operating on any segment of the NEC. Intercity-Corridor-Other service increases to 2 tph between Washington, D.C., and New Haven. Metropolitan service provides 4 tph, during peak travel periods, between Washington, D.C. and New Haven.

Major NEC cities see an increase in the total number of Intercity trains in the standard peak hour:

- Washington, D.C.: 10 tph (4 Intercity-Express, 2 Intercity-Corridor-Other, and 4 Metropolitan)
- Philadelphia, PA: 10 tph (4 Intercity-Express, 2 Intercity-Corridor-Other, and 4 Metropolitan[30])
- Newark, NJ: 10 tph (4 Intercity-Express, 2 Intercity-Corridor-Other, and 4 Metropolitan)
- New Haven, CT: 10 tph (4 Intercity-Express, 2 Intercity-Corridor-Other[31], and 4 Metropolitan[32])
- Boston, MA: 8–9 tph (4 Intercity-Express, up to 1 Intercity-Corridor-Other[33], and 4 Metropolitan)

Regional rail service on the NEC is provided with peak service frequencies at most NEC stations based on 15-mintue headways, which represents an increase in service at a majority of stations, compared with the No Action Alternative. In areas with heavy Regional rail demand, additional service zones are created to increase peak zone express service and reduce average trip times. In addition, service to branch lines is increased where sufficient capacity exists.

9.4 INFRASTRUCTURE ELEMENTS

Alternative 2 maximizes the capacity of the existing NEC, focusing on where future demand is greatest. Alternative 2 includes chokepoint relief projects necessary to provide for smooth-flowing operations, and

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[30] Service at 4 tph is provided in the direction of both New York City and Washington, D.C. Metropolitan service in the standard peak hour at Philadelphia consists of 2 trains running between Washington, D.C., and Boston, 2 trains running between Harrisburg and Boston, and 2 trains running between Philadelphia and Washington, D.C.

[31] The Intercity-Corridor-Other trains operate via the Hartford Line to Springfield, with selected trains extended to Vermont via the Knowledge Corridor and to Boston via the Inland Route.

[32] Metropolitan services at 4 tph from New York City splits at New Haven, with 2 tph continuing on the Shore Line to Boston, and 2 tph operating via the new route segment to Boston via Hartford and Providence.

[33] The Intercity-Corridor-Other train at Boston operates on the Inland Route (via Hartford, Springfield and Worcester) and at less than hourly service frequencies.

new-track projects and new segments improve trip times through increases in allowable speeds or bypassing the slowest-speed portions of the existing NEC in and around the major urban areas, on antiquated bridges, and in southeast Connecticut.

9.4.1 CHOKEPOINT RELIEF PROJECTS

Alternative 2 includes capital projects at specific locations to relieve chokepoints on the existing NEC. Most of the chokepoint projects in Alternative 2 are the same as those identified for Alternative 1, addressing chokepoints near stations, at railroad junctions, and at yard locations where trains lay over and change direction. The inclusion of new segments or new tracks at certain locations obviates the need for a separate chokepoint project. The Philadelphia Flyover is one such project, where the new segment via Philadelphia International Airport reduces the severity of train movement conflicts at the location of the potential flyover. As noted, implementing these projects may, in some cases be challenging, given existing development and pending plans in project areas. Specific design would be the focus of future Tier 2 studies. The chokepoint projects identified in Alternative 2 include:

- New Carrollton Station, 4 platform tracks, to permit express and local trains to operate on separate tracks
- Newark, DE, station relocation and track reconfiguration, to provide for smoother intercity, regional rail and freight train movements
- Philadelphia 30th Street – Penn Interlocking – 4-track approaches, to enable the station to operate as a pulse-hub with coordinated transfers between train services at timed intervals
- Trenton Station and yard access, to facilitate regional rail terminal operations
- Metropark Station platforms on express tracks, to enable Intercity-Express and Intercity-Corridor trains, including Metropolitan trains, to stop at this station on the express tracks
- Hunter Flyover and Westbound Waterfront Connection, improving access to the NEC from the Raritan Valley Line and from Hoboken Terminal
- New Rochelle (Shell Junction) grade separation, to provide smoother train flows between the Hell Gate Line and New Haven Line
- New Haven Station, to facilitate the smooth movement of Intercity and Regional rail trains into and out of the station
- Canton Jct.-Readville, MA track and junction improvements to facilitate smooth flow of trains

9.4.2 NEW TRACK

Alternative 2 includes the construction of several new-track projects. Three are located in Maryland where the existing NEC is currently a two- and three-track railroad. Two are located north of New York City, including adding two tracks to the Hell Gate Line in Queens and the Bronx, NY.

- Washington, D.C., to New Carrollton, MD, 3rd Track
- New Carrollton, MD to Halethorpe, MD, 4th Track
- Bayview, MD to Perryville, MD, 4-track railroad
- Hell Gate Line, Queens and the Bronx, NY, expanded to 4 tracks
- Providence, RI to Hyde Park, MA, 4 tracks

9.4.3 NEW SEGMENT

Alternative 2 includes 10 new segments parallel to and outside of the existing NEC right-of-way at the following locations (with the approximate length of the new segments shown in parentheses):

- Baltimore Tunnel (~2 miles)
- Aberdeen, MD, to Newark, DE (~23 miles)
- Wilmington, DE Bypass (~8 miles)
- Baldwin, PA, to Philadelphia 30th Street Station via Philadelphia International Airport (~10 miles)
- Philadelphia 30th Street Station to Bridesburg, PA through North Philadelphia, PA (~8 miles)
- North Brunswick, NJ, to Colonia, NJ (~16 miles)
- Elizabeth, NJ, to Secaucus, NJ (~12 miles)
- Secaucus, NJ, to Hell Gate Viaduct, Queens, NY, via new Hudson and East River Tunnels and expanded Penn Station New York (~8 miles)
- New Rochelle, NY, to Westport, CT (~29 miles)
- Sharon, MA to Canton Jct., MA (~3 miles)

The biggest change in the Representative Route between Alternatives 1 and 2 is in the New Haven-to-Providence territory. Alternative 2 provides new route segment that runs all the way from New Haven to Providence via Hartford. This new route via Hartford is estimated to save an additional 15-20 minutes of run time, compared with service via the New Haven-Saybrook-Kenyon-Providence route in Alternative 1. It removes Intercity-Express trains from 120 miles of the Shore Line route between New Haven (Mill River, CT) and Providence (Hebronville, MA), a route that includes capacity-limited, movable bridges and over which Providence and Worcester freight trains operate in addition to Shore Line East and MBTA Regional rail services.

10. Alternative 3

Alternative 3 is intended to enable transformation of the role of rail within the transportation network, positioning rail as the dominant mode for intercity travel within the NEC and a more competitive mode for all types of tripmaking within the metropolitan regions of the NEC. This alternative provides a major increase in the capacity of the NEC compared with the No Action Alternative and, consequently, offers the potential for considerably more rail service and the introduction of new types of service – both to existing and new markets within the Study Area. Infrastructure improvements include upgrades on the NEC and the addition of a two-track second-spine that operates adjacent to the existing NEC south of New York City and expands the reach of the NEC to new markets north of New York City (Figure 13). This new spine supports high-speed rail services between major NEC markets and provides additional capacity for Intercity and Regional rail services on both the existing NEC and the new spine. The FRA identified several potential routes for the new spine between New York City and Boston (Figure 13).

10.1 MARKETS

The additional NEC rail capacity, coupled with the faster trip times that are possible between the major NEC cities, can be used in this alternative to expand the physical reach of the NEC. The routes that are created parallel to the existing corridor improve the rail system's coverage within the NEC Study Area. Several new geographic markets become part of the NEC and are provided with direct and frequent NEC rail service – including Intercity-Express, Metropolitan and, in some cases, express Regional rail trains:

- Downtown Baltimore
- Downtown Philadelphia
- Central Connecticut Corridor, including White Plains, NY, and Danbury and Waterbury, CT, (Alternatives 3.1 and 3.4 route options)
- Long Island (Nassau and Suffolk Counties) and Jamaica, Queens (Alternatives 3.2 and 3.3 route options)
- Hartford, CT, and Springfield, MA
- The Hartford-Providence Corridor (Alternatives 3.1 and 3.2 route options)
- The Hartford-Worcester-Boston Corridor (Alternatives 3.1 and 3.4 route options)

Figure 13: Alternative 3

Source: NEC FUTURE team, 2015

Alternative 3 provides sufficient capacity to enable Intercity service from connecting corridors onto the NEC to be offered at a volume of up to four trains per hour. This enables an increase in service on existing connecting corridors, as well as the introduction of one-seat ride service onto the NEC from new connecting corridor markets. Capital investment, as well as new railroad access agreements, would be required to implement such connecting service in the future. Opportunities include:

- Washington-Richmond corridor and the Southeast High-Speed Rail corridor (to Richmond, Newport News, Norfolk and Charlotte, NC)
- Washington-Charlottesville-Lynchburg-Roanoke, VA
- Keystone Corridor extended (Philadelphia-Harrisburg-Pittsburgh)
- Empire Corridor extended (New York City-Albany-Buffalo-Cleveland, plus potential links with faster trip times from New York City to Montreal and Toronto)
- Delmarva Peninsula (Newark, DE-Dover-Ocean City, MD)
- Atlantic City (New York City-Atlantic City, Philadelphia-Atlantic City, NJ)
- Lehigh Valley (New York City-Raritan, NJ-Easton-Allentown, PA)
- Scranton (Port Morris, NJ-Scranton, PA)
- Eastern Long Island (New York City-Montauk)
- Knowledge Corridor extended (Springfield-Burlington, VT-Montreal)
- Cape Cod (Attleboro-Fall River-New Bedford-Cape Cod)
- Boston-Concord, NH-Burlington-Montreal
- Downeaster Corridor (Boston-Portland-Brunswick, ME).

Additional capacity exists in this alternative to offer new or improved service to combinations of the above markets while also providing superior service to existing Intercity and Regional rail markets on the NEC. There is not sufficient capacity on the railroad to provide new or greatly improved service to all of these markets simultaneously, even in Alternative 3, requiring trade-off analysis subsequent to NEC FUTURE, to identify which of these corridors, if any, warrant direct service based on their cost-effectiveness or economic benefits. However, slots are provided in Alternative 3 for Intercity-Express and/or Intercity-Corridor trains to operate along portions of the NEC to connect these markets to Boston, New York City, Philadelphia, and/or Washington, D.C. The FRA did not include any particular combination of the above services in the Alternative 3 Service Plan. Rather, the Service Plan provides extra or “phantom” Intercity-Corridor slots on the existing NEC at regular 15-minute intervals. These could be filled by trains serving any combination of these off-corridor markets.

Alternative 3 also provides additional capacity that can be used to offer Regional rail service in new corridors or to offer one-seat ride service to NEC destinations on Regional rail lines that do not currently offer direct service or have only limited direct service. However, considerable investment in railroad infrastructure, stations, fleet and/or yard facilities are required in locations outside the NEC to take advantage of this new service. The scope of NEC FUTURE does not encompass these potential branch line initiatives – either the required investments or their environmental consequences – although the potential benefits of expanding Regional rail network connections to the NEC will be assessed qualitatively. In Alternative 3, the future sponsors and operators of Regional rail and Intercity-Corridor service have great discretion to develop and implement service concepts that meet market demands for rail travel as they emerge. Potential Regional rail concepts are summarized below, without any judgment as to their efficacy or practicality, but as examples of the types of service improvements that could be possible.

There are a number of proposals in New Jersey to extend rail service beyond the current service limits. There are challenges to extending these services, which are not yet resolved, including capital and operating funding. Some of these proposals could advance in the future and support a one-seat ride to Midtown Manhattan.

In Maryland, Alternative 3 presents the potential opportunity for shifting MARC service on the NEC to the new high-speed line along the CSX corridor north of Baltimore, offering station opportunities at Rosedale, White Marsh, and Joppatowne, which are closer to the population centers of Baltimore and Harford Counties than the existing Amtrak line.

In Massachusetts, new rail capacity is needed to meet a level of Intercity service greater than the expanded Boston South Station can accommodate. This might entail the construction of new rail lines and/or new station and rail terminal facilities. There are multiple possibilities for the locations of and connections between these facilities, and some of these options present opportunities for expanding the coverage and connectivity of the Regional rail network serving the greater Boston region.

Finally in Alternative 3, the re-routing of most of the Intercity-Express service to new rail routes through Baltimore, Philadelphia, and New York City presents an opportunity to utilize the capacity freed up on the existing routes within these metropolitan regions to provide short-headway local rail service—effectively creating new rail transit lines. This concept is analogous to the Overground and Thameslink services in London, the RER service in Paris, and the various S-Bahn networks throughout Germany and Switzerland. The NEC route through Baltimore was identified as a potential future transit line in the 2000 Baltimore Region Rail Plan. Offering transit-style service in Hudson and Essex Counties in New Jersey could supplement the capacity provided in Alternative 3 and be complementary to both the Regional rail and rail transit networks.

10.2 REPRESENTATIVE ROUTE

The Representative Route of Alternative 3 approximately parallels the existing NEC between Washington, D.C., and New York City. The new high-speed route is closely parallel to the NEC in many locations, but it deviates from the existing corridor in several locations to shorten trip times or service additional travel markets, such as the more direct routes through downtown Baltimore and Philadelphia. North of New York City, the four route options are considered, as described in Section 10.4. In addition, the existing NEC remains as a route for Intercity and Regional rail trains.

10.3 SERVICE PLAN

Alternative 3 offers dramatically more Intercity service on the NEC through the construction of dedicated high-speed rail tracks as well as providing new service to new markets within the NEC Study Area. In the standard peak hour, Intercity-Express service increases to six trains per hour compared to the No Action Alternative and includes limited-stop Intercity-Express trains that run between Washington, D.C., and New York City and between New York City and Boston in under 100 minutes. The new Metropolitan service provides four trains between Washington, D.C., and Philadelphia and eight trains between Philadelphia and New York City in the peak hour. North of New York City, four trains per hour Metropolitan service is offered on two different routes – the existing NEC and the new high-speed spine route. An additional four train slots per hour is provided for Intercity-Corridor-Other and Long Distance trains between Washington, D.C., and New Haven. These slots could be filled by new connecting corridor rail services.

Major NEC cities see an increase in the total number of Intercity trains in the standard peak hour:

- Washington, D.C.: 12–14 tph (6 Intercity–Express, 2–4 Intercity–Corridor–Other, and 4 Metropolitan)
- Philadelphia, PA: 16–18 tph[34] (6 Intercity–Express, 2–4 Intercity–Corridor–Other, and 8 Metropolitan)
- Newark, NJ: 16–18 tph (6 Intercity–Express, 2–4 Intercity–Corridor–Other, and 8 Metropolitan)
- New Haven, CT: 8–18 tph[35] (2–6 Intercity–Express, 2–4 Intercity–Corridor–Other, and 4–8 Metropolitan)
- Boston, MA: 12–13 tph (6 Intercity–Express, up to 1 Intercity–Corridor–Other,[36] and 6 Metropolitan)

Regional rail service is increased to fill the capacity made available in this alternative. This includes increasing the quantity of zone express service on NEC Regional rail lines, increasing service to existing branch lines, introducing service on new Regional rail branch lines or existing lines that currently only offer transfer connections to the NEC. In addition, this alternative includes introduction of express Regional rail services that operate from the outer Regional rail service zones and share portions of the new high-speed tracks with intercity trains, offering significantly reduced trip times for long-distance regional commuters.

10.4 INFRASTRUCTURE ELEMENTS

Alternative 3 provides major new rail capacity throughout the entire NEC with two new high-speed tracks between Washington, D.C., and Boston, as well as upgrades to the existing NEC similar to Alternative 1, which brings the existing NEC to a state of good repair and provides capacity and chokepoint relief along the corridor. Alternative 3 provides a new route through New York City with six tunnel tracks beneath the Hudson and East Rivers, along with station facilities for all service types, addressing the most critical capacity issues within the Study Area. Additional infrastructure improvements in Alternative 3 include downtown routing in Baltimore and Philadelphia and terminal capacity expansion in Washington, D.C., New York City, and Boston. New Stations could be built in locations such as downtown Baltimore, Philadelphia International Airport, and Danbury, Connecticut.

Six-track sections, locations where there is a new segment adjacent to the four-track NEC, increase considerably on the south end. Six-track sections extend from Washington, D.C., to Baltimore, and Philadelphia to New York City. Six-track sections are also located in coastal Fairfield County.

10.4.1 CHOKEPOINT RELIEF PROJECTS

Alternative 3 includes capital projects at specific locations to relieve chokepoints on the existing NEC. Most of the chokepoint projects in Alternative 3 are the same as those identified for Alternatives 1 and 2, addressing chokepoints near stations, at railroad junctions, and at yard locations where trains lay over and

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[34] These services are split between 30th Street Station and a new NEC station on the second-spine route at Market East. The six Intercity-Express and four Metropolitan trains serve Market East. The two Intercity-Corridor-Other trains and the other four Metropolitan trains serve 30th Street Station.

[35] The lower totals for Intercity-Express and Metropolitan correspond to the route options via Central Connecticut, which bypass New Haven. The higher totals correspond to the route options via Long Island, which converge with the existing NEC at New Haven.

[36] The Intercity-Corridor-Other train at Boston operates on the Inland Route (via Hartford, Springfield and Worcester) at less than hourly service frequencies.

change direction. The inclusion of new segments or new tracks at certain locations obviates the need for a separate chokepoint project. As noted, implementing these projects may, in some cases be challenging, given existing development and pending plans in project areas. Specific design solutions would be the focus of future Tier 2 studies. Chokepoint relief projects identified in Alternative 3 include:

- New Carrollton Station, 4 platform tracks, to permit express and local trains to operate on separate tracks
- Odenton Station island platforms, to enable Metropolitan trains to stop at this station on the express tracks
- Newark, DE, station relocation and track reconfiguration, to provide for smoother intercity, regional rail and freight train movements
- Philadelphia flyover, to facilitate regional rail local train movements
- Trenton Station and yard access, to facilitate regional rail terminal operations
- Metropark Station platforms on express tracks, to enable Intercity-Express and Intercity-Corridor trains, including Metropolitan trains, to stop at this station on the express tracks
- Hunter Flyover and Westbound Waterfront Connection, improving access to the NEC from the Raritan Valley Line and from Hoboken Terminal
- New Rochelle (Shell Junction) grade separation, to provide smoother train flows between the Hell Gate Line and New Haven Line
- Canton Jct.-Readville, MA track and junction improvements to facilitate smooth flow of trains

10.4.2 NEW TRACK

Alternative 3 includes the construction of fewer new-track projects on the existing NEC, because the need for additional tracks is reduced with the construction of new high-speed tracks along the entire corridor. The locations of the most prominent new-track projects are the following:

- Odenton, MD, to Halethorpe, MD (4th track)
- Bayview, MD, to Perryville, MD (4-track railroad)
- Hell Gate Line, Queens and the Bronx, NY (expanded to 4 tracks)
- Providence, RI, to Hyde Park, MA (4 tracks)

10.4.3 NEW SEGMENT

As shown on Figure 13, Alternative 3 includes multiple new segments parallel to and outside of the existing NEC right-of-way, providing a second-spine route between Washington, D.C. and Boston, MA. This alternative also increases the capacity of the existing NEC with the Baltimore Tunnel and new segments of two track line parallel to the New Haven Line between New Rochelle and Stamford.

11. Phased Implementation

To ensure that incremental capital investment in the NEC will result in benefits for the entire corridor, the FRA anticipates that the Action Alternatives will be implemented in phases consisting of integrated, complementary projects. Such phased implementation of the expanded service envisioned in the Action Alternatives is inevitable due to many factors, including funding, environmental approvals, market growth, and practical constraints relating to construction on a very busy rail corridor. Even as NEC FUTURE uses the year 2040 as a horizon year for planning purposes, the time frame for implementing corridor improvements is likely to extend beyond 2040.

As such, the FRA believes it is important to identify an initial phase of the long-term NEC FUTURE vision that addresses the NEC's most critical near-term needs, provides tangible transportation benefits, and provides a "down-payment" on achieving the long-term vision articulated by each of the alternatives. A Universal First Phase would address the most pressing capacity, chokepoint, and state of good repair needs of the NEC by implementing a set of projects that address these common needs across all the Action Alternatives. In some cases, the specific scope and design of a project in this Universal First Phase may vary across the Action Alternatives to allow for subsequent implementation of the unique characteristics of a specific alternative.

Implementation of this first phase would create a level starting point for further advancing any of the three Action Alternatives. Importantly, implementation of this first phase would enable NEC stakeholders to more quickly realize the benefits of investment in the NEC—increased service, improved reliability and advancing state-of-good-repair priorities—as well as build the stakeholder partnerships required to successfully implement a highly complex, integrated and complementary program of service and infrastructure improvements. Subsequent incremental phases can be developed that build upon the initial investment and ultimately achieve the full long-term vision.

Many factors will ultimately influence the scope of an initial phase of service for each alternative. These include the following:

- Political and governance support for investment to offer enhanced services
- Growth in passenger rail ridership demand
- Availability of public and private funding for capital investment and operating expenses
- Environmental and other regulatory clearances, approvals, and permits
- Workforce and construction industry capacity to undertake and sustain the scope of work
- Impacts on, and constraints imposed, to protect ongoing NEC rail service

The Universal First Phase will be fully described in the Tier 1 Draft EIS. A full phasing plan, including a set of prioritized service objectives and necessary improvements that achieve important regional benefits, for the Selected Alternative will be detailed in the SDP.

12. Next Steps

The Tier 1 Draft EIS will analyze and compare the Action Alternatives outlined in this document to the No Action Alternative. The framework for this evaluation ties directly to the NEC FUTURE Purpose and Need; as such, the FRA identified evaluation metrics to measure, both quantitatively and qualitatively, how well the No Action and Action Alternatives address Study Area needs. The evaluation factors developed for the early screening of Initial and Preliminary Alternatives form the basis for this more detailed evaluation of alternatives. The evaluation framework also considers other factors such as ridership, cost, and constructability.

The FRA established specific metrics to evaluate how the No Action and Action Alternatives address these factors and to compare alternatives. Table 19 presents the evaluation factors and the specific metrics to evaluate them. The transition from an earlier set of less detailed metrics used to screen Initial and Preliminary Alternatives is also presented to show how the metrics have evolved toward increasingly detailed and quantitative analysis.

Table 19: Evaluation Factors and Metrics

Factors	Early Metrics for Screening	Metrics for Evaluation of Alternatives
NEC FUTURE NEEDS		
Aging Infrastructure	▪ NEC in a state of good repair	▪ NEC in a state of good repair ▪ Passenger trips shifted to safer mode of travel
Capacity	▪ Peak-hour trains ▪ Peak-hour seats/ passengers at major screenlines annual trips ▪ Annual passenger miles	▪ Peak trains per hour ▪ Capacity utilization/available capacity (residual capacity) – train slots/passenger seats ▪ Annual trips
Connectivity	▪ Stations served by Intercity trains ▪ Station-pairs served by Intercity trains ▪ Airport stations	▪ Service frequency – train volume for key city pairs and key stations ▪ Service frequency – train volume for connecting corridors ▪ Ridership changes at airport stations (new, existing) ▪ Ridership within 10-mile buffer of Representative Route ▪ Qualitative assessment of transfers/connections/access at key stations
Performance	▪ Express trip time savings ▪ Maximum trains per hour ▪ Peak-hour trains operating on NEC	▪ Travel-time savings (key city-pairs) ▪ Average speed (key city-pairs) ▪ Top speed by segment ▪ Qualitative assessment of on-time-performance/reliability
Resiliency	▪ N/A	▪ Redundancy for key network links ▪ Route miles/passenger miles within or outside areas vulnerable to weather-related events
Environment	▪ Areas of environmental sensitivity	▪ Rating of magnitude of effects on water resources, ecologically sensitive habitats, air quality/GHG emissions, EJ populations, Section 4(f)/cultural resources and conversion of land cover by type, noise/vibration effects and indirect and cumulative effects
Economic Growth	▪ N/A	▪ Jobs resulting from construction and/or operations ▪ Value of travel-time or cost savings, change in emissions ▪ Land premium or agglomeration potential
BENEFITS, COSTS, AND OTHER FACTORS		
Ridership – Interregional and Regional	▪ Annual Passengers	▪ Annual Passengers ▪ Annual Passenger Miles ▪ Peak-hour Passengers
Capital/O&M Costs	▪ N/A	▪ Total capital cost ▪ Total O&M cost
Constructability/ Phasing	▪ N/A	▪ Ridership and service benefits of Initial Phase

Service Plans and Train Equipment Options Technical Memorandum

October 5, 2015
Amended Version

Submitted by:

Table of Contents

Figures

Tables

1 Introduction

The Federal Railroad Administration (FRA) created this technical memorandum to document the process undertaken to determine Service Plans and train equipment options for the alternatives developed for the Tier 1 Draft Environmental Impact Statement (Tier 1 Draft EIS). The technical data, methodology, and assumptions assembled in this memorandum provide background information and insight into the service planning process for readers of the Tier 1 EIS Alternatives Report.

The NEC FUTURE Service Plans provided a technical basis used in estimating ridership and capital investment needs and costs, and in assessing environmental impacts associated with planned construction and future operations. The operational and maintenance costs of improved service and potential capital improvements to the network were also tested against anticipated ridership increases and revenue streams to validate their usefulness and provide quantitative comparisons between the No Action and Action Alternatives. Service Plans were the mechanisms that made these assessments possible, and thus have been integral to the development and evaluation of the performance of rail scenarios and alternatives.

The creation of Service Plans is a process that uses planning tools, distinct from the development of full-detailed operating plans. The Service Plans are intended to be representational only, required for analysis of capacity, performance and costs, as well as assessment of environmental impacts associated with planned improvements. The Service Plans are not intended in any way to be prescriptive regarding how service should be operated in the future. The Service Plans also are not intended to predict future operating patterns of the railroad operators within the NEC. The FRA grounded the Service Plans with reasonable operational assumptions, and utilized train performance calculations, capacity thresholds, and operations-related analyses with levels of detail sufficient for the resulting Service Plan to be considered operationally feasible. Additional future analyses will be required to support the development of operating plans, timetables, yarding or crewing assumptions, or specific track assignments at major stations or terminals, which are not addressed in the NEC FUTURE Service Plans.

The information in this technical memorandum is organized as follows:

- Section 2 identifies and discusses the key factors—ridership markets, service types, and time periods—that influenced the development of the NEC FUTURE Service Plans.
- Section 3 documents the service planning methodology that was developed specifically by the FRA for NEC FUTURE. The methodology involved a sketch planning approach to approximate various capacity and demand scenarios (which are not prescriptive nor do they represent predict future operations of the railroads on the NEC) followed by a two-step balancing process: (1) to balance the service and the rail infrastructure provided in each alternative; and (2) to balance the service with the estimated level of ridership and to assure that projected Intercity service revenues will exceed costs of operations and maintenance.

- Section 4 describes the results and effects by alternative of the two-step balancing process described in Section 3.
- Section 5 describes relevant operational and service-related best practices of the world-wide rail industry and discusses the assumptions made regarding their application in the Service Plans of the Action Alternatives.
- Section 6 discusses the train-equipment options available to the operators of the Northeast Corridor (NEC) and details the rolling stock assumptions for the No Action and Action Alternatives.
- Section 7 presents the Service Plans and includes tables and diagrams that illustrate the Service Plan attributes and components of the No Action and Action Alternatives.

The appendix to this technical memorandum provides additional background and technical information. Additional information regarding tables and diagrams in support of the NEC FUTURE service planning process will also be included in the Tier 1 Draft EIS.

2 Service Plan Factors and Drivers

Service Plans, while not prescriptive, were developed specifically in response to the travel demand needs of the markets. Service Plans helped to define the investment needed to meet demand within and beyond the current capacity. The definitions of relevant ridership markets, service types, and time periods were all essential to the development of Service Plans for each Action Alternative and are outlined below.

2.1 RIDERSHIP MARKETS

The FRA defines four regions within the NEC Study Area:

- Washington-Baltimore
- Philadelphia-Wilmington
- New York (includes portions of New Jersey and Connecticut)
- Boston

The regions are characterized by the following:

- They have major central business districts (CBD). These CBDs have rail stations or terminals that are hubs for Regional rail service that carry a significant share of work trips from suburban areas to the CBD.
- They include other significant cities within the reach of the Regional rail network.
- They have metropolitan planning organizations (MPO) and extensive travel demand data and models available for travel demand analysis (but not limited to one MPO or data set and model per region).
- They have major air carrier airports with international service.

To improve the analysis of ridership markets, the FRA created two categories of ridership within the Study Area: ***interregional*** and ***regional markets.*** The two categories are differentiated by their geographical zone pairs (origins and destinations of trips). The zone pairs associated with a regional market lie within the same metropolitan area or region. For an interregional market the zone pairs extend beyond the boundaries of a single region.

2.1.1 Interregional Market

The ***interregional*** travel market encompasses travel that extends beyond the boundaries of a single metropolitan region. Most, but not all, trips on Amtrak trains today are interregional trips. NEC FUTURE developed a new interregional travel model to estimate future demand for interregional trip-making. The model[1] is trip-based, similar in structure to other existing models, including Amtrak's NEC model. It estimates the future total travel demand, based on existing and estimated growth from (1) changes in population and economic activity; and (2) changes in the modal levels of service provided. It estimates mode shares among rail, air, intercity bus, and highway auto. Data for the new model are drawn from a new, detailed survey of households in the Study Area. In addition, surveys of automobile travelers and intercity bus riders—sponsored by the Northeast Corridor Infrastructure and Operations Advisory Commission (NEC Commission)—provided data on auto and bus trips. Ticket data from the Federal Aviation Administration were used to provide information on air travel, and rail ridership data were furnished by Amtrak and the Regional rail operators.[2]

The interregional travel model distinguishes among business, non-business, and commuter trip purposes. The model estimates ridership for all varieties of rail service that are available for each zone pair market, including premium rail service (represented by Intercity-Express), non-premium rail service (represented by the Intercity-Corridor services, including both Metropolitan and Intercity-Corridor-Other trains), and Regional rail (represented by commuter rail services if available to serve the zone pair). The riders of the premium service tend to be drawn from the business travel segment and tend to be more responsive to trip time and less sensitive to price, whereas the riders of the non-premium and Regional rail modes tend to be more price-sensitive and include business, non-business, and commuter travel segments.

2.1.2 Regional Market

The ***regional*** markets comprise trip-making that occurs within a metropolitan area. The Study Area contains four major metropolitan areas: Washington-Baltimore, Philadelphia-Wilmington, New York (including portions of New Jersey and Connecticut), and Boston. Each of these metropolitan regions is served by its own network of Regional rail lines and includes one or more major stations on the NEC. A large majority of the Regional rail trips on the NEC have one of these four major markets as one or both endpoints of the trip.

The analysis of the regional markets builds off of existing urban area travel data sets and models from the various MPO and railroad operators in these regions, which are commonly used for urban area travel demand analysis, including the evaluation of Federal Transit Administration (FTA) New Starts program's rail projects. In some cases, the model geography is adjusted to cover the territory served by Regional or commuter rail service, including combining contiguous areas within the same or adjacent regions where needed. The focus of the intraregional data and models remains mostly on journey-to-work commuting—both traditional commuting to the regional CBDs, as well as other more dispersed work trip patterns—but also encompass other trip purposes, which represent a growing share of metropolitan area train travel. By leveraging the existing locally developed forecasting tools, where available, the FRA can avoid costly new model development and provide

[1] The ridership model is documented in the Ridership Technical Memorandum, which will be included as an appendix of the Tier 1 Draft EIS, along with the sources of data, including the methodology and survey of households and travelers within the NEC.

[2] Regional rail ridership data were furnished by Maryland Transit Administration , Southeastern Pennsylvania Transportation Authority, NJ TRANSIT, Metropolitan Transportation Authority (New York), ConnDOT, and Massachusetts Bay Transportation Authority.

analysis results that were consistent with those undertaken by local agencies to develop long-range plans and support programmed projects. Where existing regional models were unavailable, the FTA's Simplified Trips on Project System (STOPS) model and data sets were utilized.

2.2 SERVICE TYPES

The markets described in Section 2.2 can be served by a variety of rail services types. An important step in the development of the visions for the NEC was for the FRA to identify the types of services that best satisfy rail travel demand by offering attractive service characteristics and amenities. The FRA did not limit choices about the types of rail service to be offered and their characteristics to the services that are currently operated on the NEC.

For NEC FUTURE, the FRA organized the various types of NEC passenger rail service into categories, based on travel distance, the travel markets and trip purposes served, where and how the trains operate, and the service characteristics and amenities offered to passengers. The categories are used to represent the rail service that is provided in the No Action Alternative and each of the Action Alternatives and correspond with the travel market definitions used for ridership estimating. These categories describe the full-range future service that is provided in the Action Alternatives, but they also relate to the existing services offered by Amtrak and the Regional rail operators. These rail service types are summarized in the Tier 1 EIS Alternatives Report (Section 4) and are described in greater detail below.

Intercity rail service provides transportation between cities or metropolitan areas at speeds and distances greater than that of most commuter trips. **Regional rail**, by definition, operates within a single metropolitan region and serves more local markets. Regional rail service currently focuses largely though not exclusively on journey-to-work travel to the major central business districts within the NEC study area. However, an increasing share of trips on the regional railroads are attributable to non-traditional commutes and non-work trip purposes, and reverse-peak and off-peak travel generally is growing at a faster rate than traditional commuting. The FRA identified several types of potential rail service within each of these categories. The various service types are described in Sections 2.3.1 and 2.3.2, followed by a table in Section 2.3.3 that relates service types to travel markets and the models used to analyze them.

2.2.1 Intercity

Intercity passenger service on the NEC falls into three basic categories, each having fundamentally different characteristics and targeting different travel markets and trip purposes. The existing services offered by Amtrak fit into these categories. Future service concepts—some of which differ significantly from current service offerings—also fit within these same categories. The primary distinguishing features of these service categories, and their applicability to existing NEC Amtrak service and potential future service, are as follows:

- Intercity-Express
  - Premium high-speed rail service

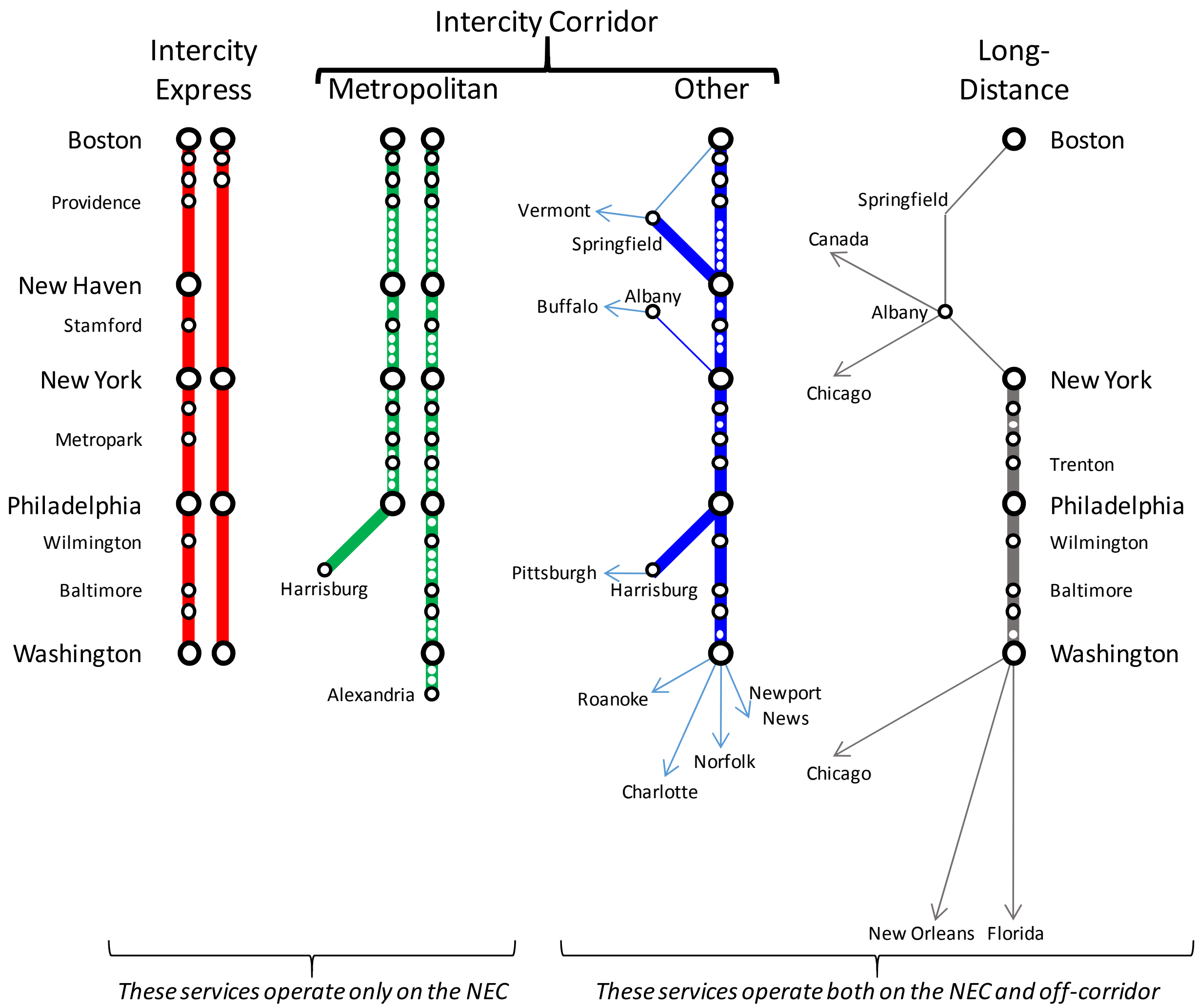
   - Aimed at business travel markets where trips are relatively time-sensitive and price-insensitive
   - Serves major cities and Major Hub stations[3]
   - Includes existing Amtrak Acela Express service
- Intercity-Corridor
   - Regular Intercity passenger service on the NEC
   - Aimed at non-business and price-sensitive travel markets
   - Serves major cities and Major Hub stations, and also serves intermediate travel markets at hub stations not served by Intercity-Express trains
   - Includes trains that operate exclusively within the NEC, as well as trains that operate both on- and off-corridor, serving connecting corridors to the NEC
   - Includes existing Amtrak Northeast Regional service[4]
   - Includes connecting corridor trains from Virginia, North Carolina, Keystone Corridor from central and western Pennsylvania, Vermont, and Empire Service from Upstate New York.
- Long Distance
   - Includes trains that operate overnight with sleeping and dining car service, or to locations remote from the NEC Study Area, which do not carry passengers locally within the NEC
   - Includes international trains to and from Toronto and Montreal
   - Includes existing Amtrak trains to Florida, Georgia, New Orleans, Chicago, and Canada

For purposes of travel demand analysis and ridership estimating, Intercity rail service is classified by market segment into **Intercity-Express** (serving the premium travel market composed largely of business travelers) and **Intercity-Corridor** (serving the regular or "economy" end of the Intercity travel market, serving mostly travelers with non-business trip purposes). Ridership estimates are produced for these two categories of service. Figure 1 depicts schematically the extent of service and NEC station stopping patterns for the various types of Intercity service.

[3] Major Hub stations serve the four primary markets (Washington, D.C., Philadelphia, New York, and Boston), as well as other major markets within the Study Area, and have the full complement of services types. See *Tier 1 Alternatives Report*, Section 6.1.1 (stations).

[4] Northeast Regional service is Amtrak's regular Intercity service currently operating on the NEC Spine and on the connecting corridors feeding the NEC Spine. Some Northeast Regional trains operate exclusively on the NEC Spine between Washington, D.C., and Boston, or Washington, D.C., and New York. Selected Northeast Regional trains continue beyond the NEC Spine. Trains operate with conventional passengers coaches (the "Amfleet"), hauled by either electric or diesel locomotives. For those trains that operate beyond the electrified NEC, there is an engine change required at the points at which these trains enter or leave the NEC Spine.

Figure 1: Intercity Service Types



Source: NEC FUTURE team, 2015
Note: This graphic is intended for illustrative purposes only.

The following summary descriptions of these four intercity service types are organized around the operational and fleet characteristics of the service:

- **Intercity-Express** is the future premium Intercity high-speed rail service offered on the NEC, making limited stops along the NEC and serving only the largest markets. For Action Alternatives, this category of service is envisioned as analogous to the state-of-the-art high-speed rail services currently operating in Europe and Asia. Intercity-Express service offers the shortest travel times for Intercity trips, with a higher quality of onboard amenities, at a premium price, using state-of-the-art high-speed trainsets, with top speeds in the range of 160 mph to 220 mph. In general, these trains make the same station stops as today's Amtrak Acela Express service. In alternatives and time periods where Express service is provided at a level of at least four trains per hour, selected trains are able to operate with fewer stops, improving trip times for the major travel markets. Where new high-speed routes are provided, Express trains stop at Major Hub stations along the new routes.

- **Metropolitan** service utilizes high-speed equipment similar to the trainsets that provide Intercity-Express service. Consequently, these trains operate exclusively on the NEC and in electrified territory connected to the NEC. Metropolitan service is the future primary Intercity rail service on the NEC, a subset of Intercity-Corridor service, and the successor to the existing Amtrak Northeast Regional service. Whereas Intercity-Express service is aimed at the business travel market, Metropolitan trains serve both leisure and business travelers who are more price-sensitive. The FRA has chosen a new name for this service to emphasize its distinct characteristics and higher level of performance. Metropolitan trains operate on regular schedules with high frequency (2-4 trains per hour) and stop at more stations than the current Amtrak Northeast Regional service (including some stations that are only served today by Regional rail trains), thereby increasing the number of direct station-pair connections served by Intercity trains. Metropolitan service also provides a travel choice for longer-distance commuters at stations served by both Metropolitan and Regional rail trains. In addition to providing service on the NEC Spine, Metropolitan trains provide service on electrified Keystone Corridor in all three Action Alternatives and on the Hartford Line in alternatives where this line is electrified (Alternatives 2 and 3).
- **Intercity-Corridor-Other**–Since Metropolitan service utilizes trainsets that can operate only in electrified territory, a separate Intercity-Corridor service provides connectivity and direct one-seat service between non-electrified connecting corridors and the large and mid-size markets on the NEC. These trains, along with the Metropolitan trains, are classified as Intercity-Corridor trains for purposes of ridership analysis, and they cater to the same market for regular Intercity service. They generally stop at the NEC stations currently served by Amtrak Northeast Regional trains. These trains are versatile, operating on the electrified high-speed NEC Spine and on the non-electrified national railroad network on tracks owned by and shared with freight railroads. Off-corridor trains are made up of rail cars pulled by locomotives, as opposed to the specialized trainsets that provide NEC-only service. Intercity-Corridor-Other trains operate at top speeds of 125 mph on the NEC and up to 110 mph off of the NEC. The FRA assumes that by 2040 dual-mode locomotive technology will allow movement along electrified and non-electrified corridors without engine changes for Intercity-Corridor-Other services.[5] The most prominent off-corridor routes served by these trains include the several Virginia corridors south of Washington, D.C.,[6] the Empire Corridor serving Upstate New York,[7] the Knowledge Corridor

[5] Dual mode locomotive technology does not currently exist that meets the top speed and other performance requirements for operations on both the NEC spine and off-corridor on the U.S. freight rail network. Should such technology not become available, the Service Plans for the Action Alternatives remain feasible if engine changes continue to be made at Washington, D.C. and New Haven, CT or Springfield, MA.

[6] Off-Corridor service to and from Virginia covers four different routes: three routes via Richmond, VA, plus a route serving Charlottesville, Lynchburg and Roanoke. The three Washington-to-Richmond routes diverge south of Richmond and include the corridor to Williamsburg and Newport News, the corridor to Norfolk, and the corridor to Raleigh and Charlotte, NC. All services that are part of the Southeast High-Speed Rail (SEHSR) initiative are included within this definition of the Virginia Off-Corridor routes.

serving central Massachusetts and Vermont, and the Inland Route corridor between Springfield, MA, and Boston, MA. This category includes named trains that operate partially on the NEC but also over longer distances on rail lines owned and dispatched by freight railroads, including the Carolinian, Pennsylvanian and Vermonter services.

- **Long-Distance Services** are Intercity trains connecting the Northeast with other parts of the United States that generally entail overnight travel with sleeping car and dining car service and handling checked baggage; this category includes existing Amtrak service to Florida, New Orleans, and Chicago. Generally, these trains are scheduled to operate on the NEC during off-peak periods; since these trains operate over longer distances, they are subject to greater delays when operating off-corridor. They are assumed to operate with electric locomotives on the NEC but with diesel locomotives for the off-corridor portion of the trip, requiring a change of engines at the points at which these trains enter and leave the NEC Spine. For this analysis the FRA assumes that the level of Long-Distance train service on the NEC will remain constant through the 2040 horizon period. Five round trips per day operate over the full length of the NEC between New York and Washington, D.C., on their way to and from and points south.[8] Several other Long-Distance trains serve stations on the NEC and offer connections to other NEC trains, but the trains only operate on short sections of the NEC in proximity to these stations.[9]

2.2.2 Regional Rail

Regional rail encompasses rail services within a single metropolitan region. Regional rail trains provide local and commuter-focused service characterized by relatively low fares and a high percentage of regular travelers. Regional rail includes the current services provided by Virginia Railway Express (VRE), Maryland Area Regional Commuter (MARC), Southeastern Pennsylvania Transportation Authority (SEPTA), NJ TRANSIT, MTA-Long Island Rail Road (LIRR), MTA-Metro-North Railroad (MNR), Shore Line East, and Massachusetts Bay Transportation Authority (MBTA). These railroads, with the exception of Shore Line East, do not operate exclusively on the NEC. Most regional railroads in the Study Area operate relatively extensive networks of multiple branch lines, which feed one or more major terminal stations. The NEC does not operate independently, but rather is the backbone of an extensive and interconnected rail network.

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[7] The Empire Corridor connects New York City with Albany, NY, and extends westward to Buffalo and Niagara Falls, NY. Intercity rail service in the Empire Corridor as envisioned in the Action Alternatives remains independent of NEC Spine service. Empire trains operating within New York State utilize push-pull trainsets powered by dual-mode locomotives, which will be stored and maintained at the Amtrak facility in Rensselaer, NY. Trains using the Empire Corridor to and from Canada and Chicago will continue to operate with conventional equipment outside of the peak periods and as non-revenue trains on the segment between Penn Station New York and Sunnyside Yard in Queens, NY.

[8] Represented by four existing overnight services (Silver Star, Silver Meteor, Crescent, and Cardinal), plus the same-day Palmetto service to Savannah, GA.

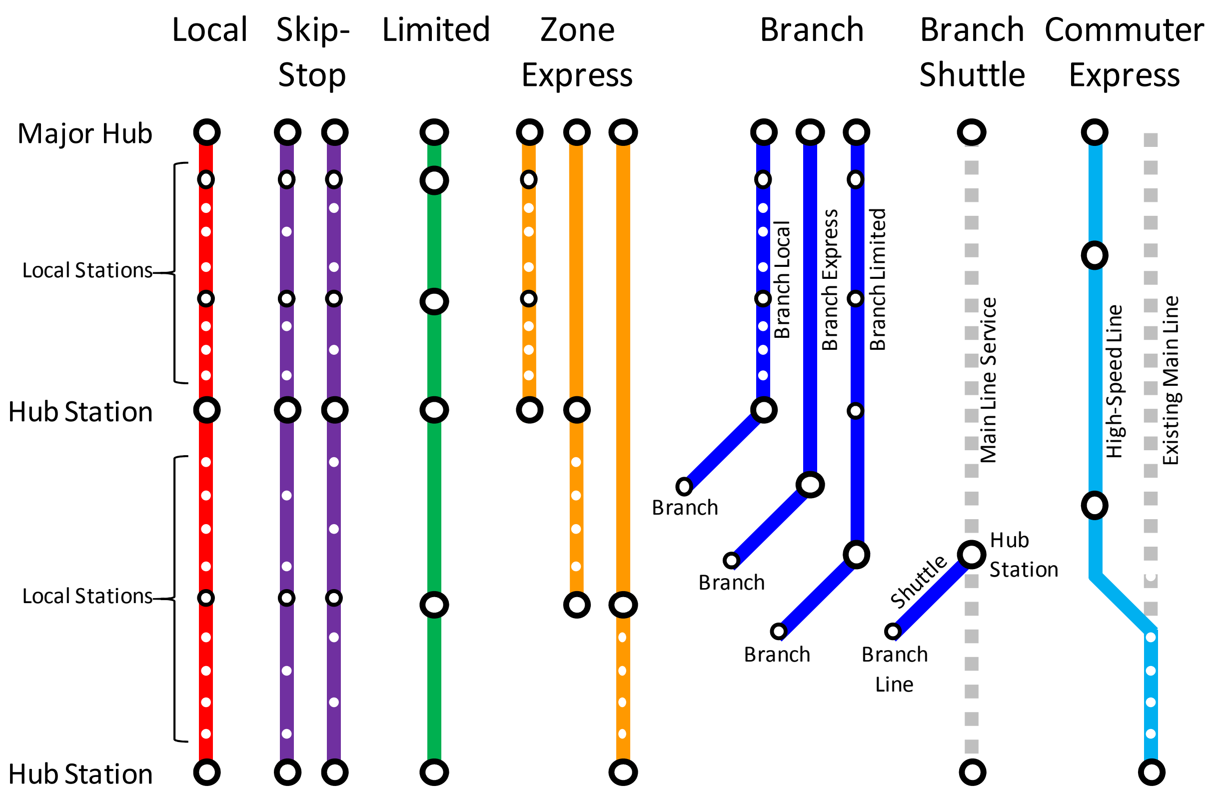
[9] Includes two existing overnight services, the Capitol Limited between Washington and Chicago, and Lake Shore Limited from both New York and Boston to Chicago via the Empire Corridor. Also includes two international trains that operate same-day service on the Empire Corridor from New York to Montreal (Adirondack) and Toronto (Maple Leaf).

The Service Plans for each of the eight Regional railroads have evolved over the last few decades. Faced with the constraints imposed by existing physical assets and jurisdictional boundaries, the railroads have finely tuned their train schedules and stopping patterns to maximize the utilization of scarce capacity during the weekday peak periods. Train schedules and patterns are designed to fill up the trains and can vary considerably throughout the peak period. This has allowed Regional rail operators working within existing capacity constraints to maximize their ridership volumes during the peak periods; but this practice results in uneven headways and makes the establishment of timed multimodal and rail-to-rail connections, especially between different rail providers, difficult. For purposes of NEC FUTURE analysis, the wide array of potential Regional rail stopping patterns on the NEC is organized into the following categories, which are illustrated schematically Figure 2:

- ***Local*** service makes all stops in the territory in which it operates. A local train can operate for the entire length of the service territory or within the "inner zone"—the closest group of stations nearest to the major terminal.
- ***Skip-Stop Local*** service is a variation on local service that operates more than one pattern of service on the local tracks at close headways. Local trains stop at every second or third local station, skipping the other stations. Subsequent trains serve the stations skipped by the initial train. This increases the average speed of local trains by reducing the number of station stops. This type of service is most commonly seen on rail transit lines but is applicable to Regional rail service plans that seek to simplify operations by running independent local and express services. An example of this type of service is described in Section 4.3.6.3 for the New Haven Line in Alternative 1.
- ***Limited*** service stops at select stations only. This train generally operates over the full service territory and serves major stations in that territory. Metropolitan service is a good example of a limited-service pattern, as are the Regional rail trains operating on the express tracks on the New Haven Line in the simplified operations scenario described in Section 4.3.6.3.
- ***Zone express*** service stops at a group of stations in succession within a zone on the NEC Spine and then operates as a non-stop express train the rest of the way to its major city destination. These trains usually run only in the weekday peak periods in the major direction of travel—inbound in the morning and outbound in the evening. The number of zones offering zone-express service within a region depends upon the length of the service territory and the volume of passenger demand.
- ***Branch*** service describes a train that operates on the NEC for a portion of its run and on a branch line for the remainder of the run. On the NEC, these trains can operate as non-stop zone-express trains, as limited trains, or as locals.
- ***Shuttle*** service describes a branch line train that operates exclusively on the branch line, but not on the NEC Spine, or only over a very short distance on the Spine. Shuttle service allows trains on the branch line to be operated independently of the NEC, providing greater scheduling flexibility and the opportunity for increased service frequency in locations where the main line capacity is limited. All passengers on shuttle services must transfer at Hub stations where the branch line meets the NEC to access origins or destinations elsewhere on the NEC.
- ***Commuter Express*** is a new type of service that takes advantage of available capacity on new high-speed tracks. It is a variation on zone-express service, with trains serving the outer zones

on existing Regional rail lines and then switching to the high-speed tracks for the remainder of the trip to the CBD. By utilizing rolling stock with higher top speeds, major trip time savings are possible from these service zones.

Figure 2: Regional Rail Service Types



Note: This graphic is intended for illustrative purposes only.

2.2.3 Correspondence between Markets and Service Types

Generally, ridership for Intercity rail services is drawn from interregional markets and estimated using the interregional model, while ridership for Regional rail trains is drawn from the intraregional markets and estimated from the various MPO regional travel demand models. However, the somewhat artificial geographic boundaries of the regional travel demand models are limiting factors, and these models are unable to estimate the full extent of commuting and travel for other purposes crossing the boundaries of metropolitan regions. As a result, the interregional model is used to estimate commuter travel between adjacent regions by all modes, including commute trips on Intercity trains. In addition, Regional rail provides service for some interregional markets as they are defined for this project. In those instances the interregional model provides an additional source of estimated ridership.

Table 1 indicates the markets served by the various rail services and lists the various rail service types in the first column. The remaining table columns represent the ridership markets as they are analyzed in the travel demand models. The top level breakdown is between the interregional and regional markets. Within the interregional model, trips are defined and then spread among the available rail service types in three categories related to the predominant trip purpose: 1) the market for premium service (which primarily serves business travelers who tend to be more time-sensitive); 2) the market for regular Intercity service (which primarily serves non-business travelers who tend to be more price-sensitive); and 3) the market for journey-to-work trips that happen to cross regional boundaries and are therefore captured in the interregional model data. The table highlights the overlaps between markets and service types, such as the potential for Metropolitan trains to serve both the interregional and regional markets, and the contribution of cross-boundary commute trips from the interregional model to ridership on Regional rail services.

Table 1: Correspondence Between Ridership Markets and Service Types

	Ridership Markets			
	Interregional Markets (by *Trip Purpose Categories)*			
Service Types	***Premium***	***Regular/ Economy***	***Commute Trips Across Regional Boundaries***	**Regional**
Intercity-Express	✓ [IR]			
Intercity-Corridor ▪ Metropolitan ▪ Intercity-Corridor-Other*		✓ [IR] ✓ [IR]**	✓ [IR]	✓ [Reg]
Long-Distance	(Travel market assumed to remain constant and not analyzed explicitly)			
Regional rail			✓ [IR]	✓ [Reg]

Source: NEC FUTURE team, 2015
Notes: Travel Demand Model(s) used to generate ridership estimates:
[IR] New interregional ridership model
[Reg] Regional ridership models based on existing MPO models and regional travel data.
* Includes connecting corridor service that remains mostly or entirely off-corridor but connects with NEC services, such as Empire Service and Hartford Line shuttle service.
** Interregional model is used to estimate ridership for station pairs that are entirely in the NEC FUTURE market area. For any off-corridor city pairs that are not fully within the market area, ridership estimates at a coarse sketch plan level of precision can be obtained by utilizing the FRA's CONNECT model.

2.3 PEAK PERIODS

The unit of analysis for the development of the Service Plans was the ***standard peak hour***. Because the temporal patterns of Intercity and Regional rail service on the NEC do not align perfectly, it was necessary to define a reasonable worst-case condition that simultaneously imposes a maximum level of demand for both service types, in each of the primary markets that comprise the NEC. This condition is not one that exists simultaneously everywhere on the NEC, but it is most representative of conditions in the weekday evening peak period, when Intercity service generally is operating in both directions of travel at maximum levels, at the same time as the evening peak commuter rush hour. In most locations, the morning commuter peak is not as heavily subscribed with Intercity trains, and the Regional rail operators take advantage of the available capacity to run slightly more concentrated service in the morning than in the afternoon, which generally matches the sharper commuter demand peaks in the morning rush. This is expected to continue to be the case in the future; however, the analysis remained conservative by basing estimates of ridership on and developing Service Plans for the standard peak hour.

In support of the daily ridership analysis, the FRA made assumptions in the Service Plans regarding off-peak service levels and patterns, and the peaking of service within peak periods. Full-day Service Plans were developed for selected scenarios and for the No Action Alternative and each Action Alternative in order to develop requirements for fleet and yard facilities, and for the purposes of estimating annual operations and maintenance costs. Infrastructure requirements and capital costs were driven by the capacity needed to serve the weekday peak periods.

Service Plans for the Action Alternatives provide information on train service, by type of train within each service territory, for a typical weekday in the year 2040. ***Intercity service*** specifications include the number of trains per hour in the standard peak hour and the total number of daily trains in each direction, for each type of Intercity service. Regular Intercity service is assumed to operate throughout the day on a repeating clockface schedule, with train departures at evenly spaced intervals for each type of service.[10] Standard peak-hour service includes additional trains needed to satisfy peak demand during the business travel peaks, typically over a three-hour period in morning and again for three hours in the afternoon and evening. Selected trains originate/terminate at intermediate points in the peak shoulder hours and at the beginning and end of the service day.

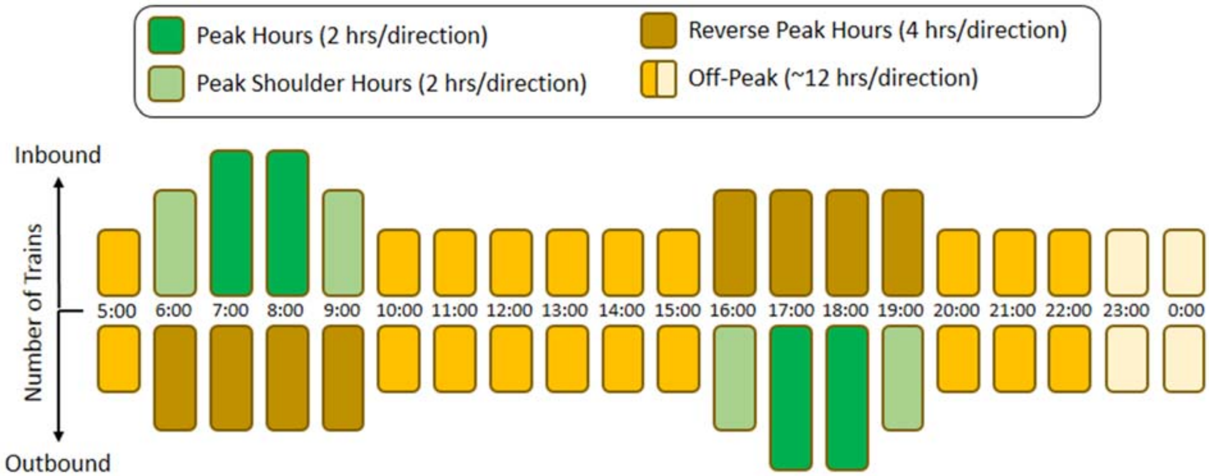
Regional rail service specifications for each NEC region include total daily trains on a typical weekday, broken out into the number of trains per hour for each service pattern in each of four standard time periods:

- Peak hour, peak direction – defined as the *Standard Peak Hour* (assumed to comprise two hours in the morning in the inbound direction of travel and two hours in the evening in the outbound direction)
- Peak shoulder hour, peak direction (the one-hour periods immediately preceding and following the standard peak hour)
- Reverse-peak hour (travel in the direction opposite the peak flow, over the entire four-hour periods – outbound in the morning and inbound in the evening)
- Typical off-peak hour, representing all other hours of the day (the larger Regional rail operators generally provide off-peak service over 12 hours of the day, including midday and late evening/nighttime service; the smaller all-day operations typically provide 10 hours of off-peak service; some operators, and some branch line services, provide peak-only service or have only limited reverse-peak and off-peak service.)

Figure 3 illustrates how the level of Regional rail service is assumed to fluctuate within these hourly time intervals through the course of a typical weekday. This represents an idealized picture of peaking on the Regional railroads, but one that generally reflects observed peaking patterns and is representative of expected future conditions.

[10] The concept of clockface schedules and regular repeating service patterns is described in Section 5.1, which highlights operational best practices that are incorporated into the Action Alternatives.

Figure 3: Standard Temporal Distribution of Regional Rail Service by Time of Day

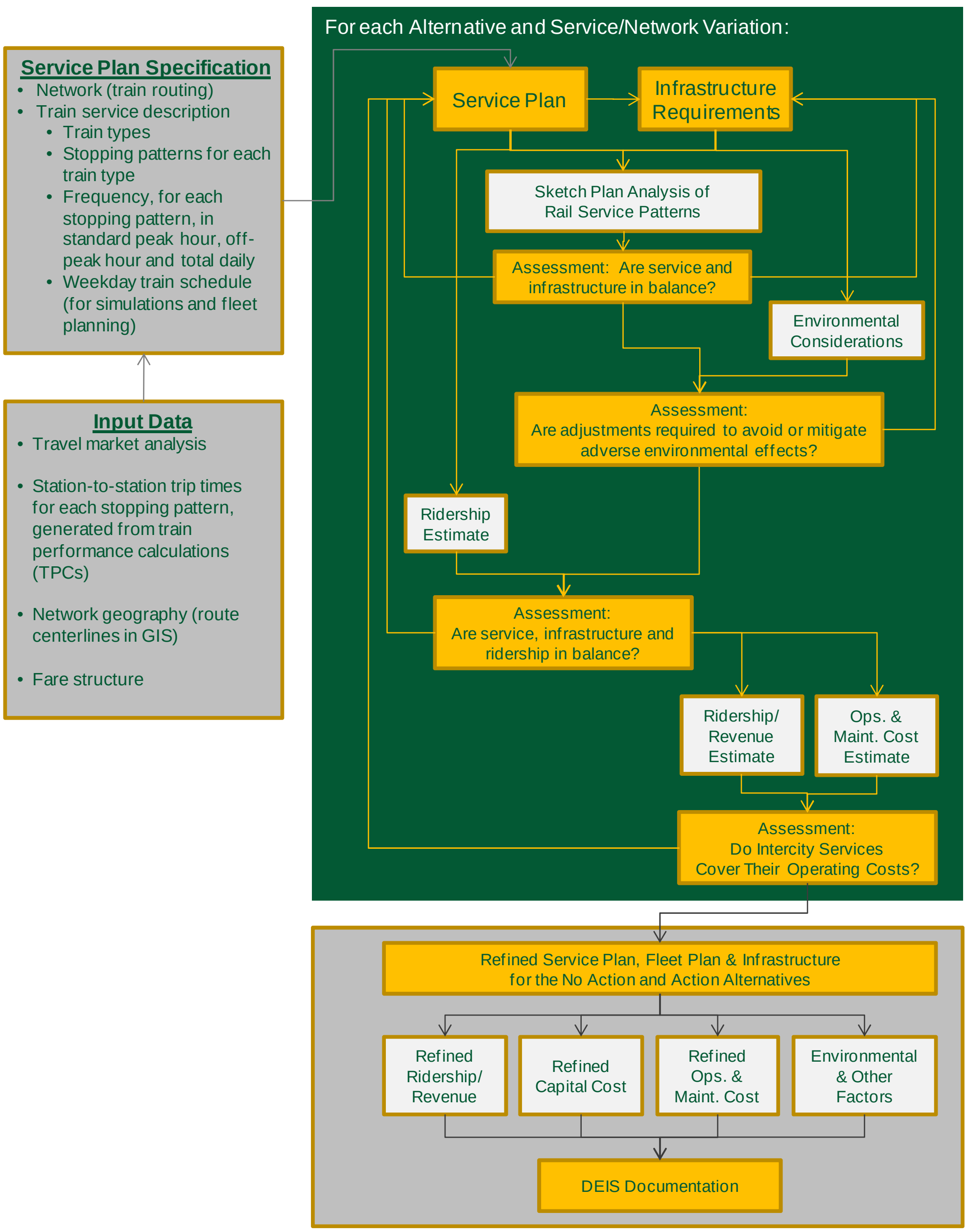


Note: Figure depicts relative volume of train movements in both directions of travel by time period. In every weekday, for Regional rail travel, there are four standard peak hours, four peak shoulder hours, eight reverse-peak hours, and 20-24 off-peak hours (counting both directions of travel).

3 Service Planning Methodology

This section summarizes the various components of a rail service plan and outlines the methodology and interdependent tools used to create Service Plans to assist in the development and the assessment of the Action Alternatives. As shown in Figure 4, the sketch plan analysis of rail service patterns provides an understanding of practical line capacity and terminal capacity at critical locations—measured in trains per hour typically for the standard peak hour.

Figure 4: Alternatives Refinement Process



Source: NEC FUTURE team, 2015

The FRA developed an early series of hypothetical and non-prescriptive Service Plans for each of the Action Alternatives. Based on existing information and projected growth rates, a mix of Intercity-Express, Metropolitan, Intercity-Corridor-Other, and Regional rail services was posited for each ridership market. Plans were developed with regular headways such that each market received two, four, or more trains per hour. These early Service Plans were used to test infrastructure requirements and market response with the detailed cost and ridership models that were being developed in parallel with service planning. After the detailed ridership forecasts were completed and validated, the Service Plans were adjusted to improve the supply-demand balance.. In Alternative 3, for example, the ridership models suggest that reducing the Intercity-Express service and adding Metropolitan trains to serve the low end of the interregional ridership market yields higher ridership and better service utilization. The final Service Plans reflect this adjustment. Across all Action Alternatives, early morning, midday, and late evening services were reduced to better tailor service around travel peaks and reduce unnecessary train miles**.** As noted, the Service Plans are intended to be representational only, required for analysis of capacity, performance, and costs, as well as assessment of environmental impacts, and are not intended in any way to be a prediction of future conditions or prescriptive regarding how service should be operated in the future.

3.1 EARLY ANALYSIS STAGES

The FRA set up the early stages of analysis to encompass a wide range of service levels, ensuring that the objectives of the three visions for rail in the NEC are met. Scenarios were developed for the NEC network and for key segments of the corridor. Service scenarios followed planning guidelines directly related to the overarching vision for each Action Alternative, as summarized in Section 3.4. Each service scenario considered the following:

- A mix of service types, including Intercity-Express, Intercity-Corridor, Intercity off-corridor and Regional rail service
- Specific stopping patterns and rolling stock for each type of train service
- Trip times over the rail network calculated for each train type and stopping pattern, based on train performance calculations, with reasoned assumptions about station dwell times, terminal layover time and overall schedule recovery time built into the scheduled trip times
- Future Intercity and Regional rail frequency targets for each service type and stopping pattern:
  - Peak, at each station – e.g., provide slots[11] for 2, 3, or 4 trains per hour (tph)
  - Off-Peak – e.g., provide slots for 1–2 tph

[11] A slot, for purposes of rail service planning, is defined to be a scheduled opportunity for a train to run. It represents a time window within which a train can run at a specific geographic location, and it also represents a path through the railroad network over a period of time. Slots are defined to be free of train interference conflicts along the route, so any train operating within its slot can operate without delays caused by other trains. A slot can be filled with an actual train, or it can remain empty. The slot is based on specific assumptions about train speeds, equipment performance, station stops and dwell times, so the slot may be usable by only certain types of trains.

- Infrastructure assumptions, including number of main tracks, location and configuration of rail junctions, track and platform configurations at stations, and the locations of train storage yards
- Assignment of trains (by type, stopping pattern and time of day) to available tracks in each segment of the corridor.

3.2 SKETCH PLANNING

For NEC FUTURE, a sketch planning process for creating and analyzing Service Plans was used to facilitate the relatively efficient testing of multiple service scenarios, including:

- Train types, routings, service levels and stopping patterns (peak and off-peak)
- Scenarios covering the range of service levels and types being considered for the Action Alternatives
- Service pattern analysis – balancing service needs and infrastructure requirements

Using stringline (time-distance) diagrams and train schedule information, as described further in Section 3.3, the FRA introduced and aligned individual train service patterns with each other to identify potential train operating conflicts. The train service patterns, schedule times, and track assignments were adjusted interactively to eliminate operating conflicts. Adjustments to the rail infrastructure configuration were made where necessary and appropriate to address conflicts that cannot be resolved with operational and scheduling adjustments. The end result of this process was a hypothetical Service Plan and train timetable that was shown to be operationally feasible and which fit within the available capacity of the rail infrastructure.

The sketch service planning framework for NEC FUTURE was developed at two different scales. Corresponding to the breadth of the NEC, the Service Plans are intended to inform the Tier 1 Draft EIS and support public review and comment on the alternatives, as well as policy discussions and decisions by stakeholders. This broad scale defines the overall vision but does not claim to represent specific physical or operational conditions with accuracy and does not purport to impart information sufficient for final implementation decisions or funding commitments. The service and infrastructure assumptions are representative and illustrative of potential future conditions, not prescriptive, absolute or a prediction of future operating plans for the NEC railroad operators.

At a smaller scale, the Service Plans are a basis for discussions with the railroad operators and transportation agencies. These discussions are more technical in nature and examine the corridor at a more granular level, looking at infrastructure and service on specific line segments or at individual stations and interlockings. This more detailed scale provides for "proof of concept" or confirmation of the operational and physical feasibility of the proposed plans. It also furnishes the data on train movements and operating characteristics that were required for the quantitative analyses that support the Tier 1 Draft EIS, including projections of ridership and revenue, estimates of capital and operating and maintenance costs, operations simulations, and analysis of the environmental effects associated with the volume and type of train movements, such as noise, vibration, air quality and energy consumption. The Service Plans also enabled an equitable comparative evaluation of the performance of train service patterns and infrastructure and for determining the extent to which service and infrastructure were balanced in any given scenario for the Action Alternatives.

3.3 ANALYTIC TOOLKIT

3.3.1 Rail Planning Tools

The service planning effort for NEC FUTURE used a combination of spreadsheet-based tools, a detailed simulation model using the Rail Traffic Controller[12] (RTC) software, and several planning-level models developed using the Viriato[13] software package. Viriato aids in the development of railroad Service Plans and associated outputs, including timetables, stringline charts (time-distance diagrams) and cumulative train operating data, at a sketch planning level of detail appropriate to a Tier 1 Draft EIS level of alternatives development and analysis. Viriato, a conceptual planning tool, allows for a rapid assessment of multiple alternatives, providing the rail planner with direct control of the service planning process. Unlike a dynamic simulation tool such as RTC, Viriato is a static planning tool that operates with a customized user interface accessing a database of infrastructure, train performance, and service data. The static nature of this tool allows the user to work with varying levels of specificity in infrastructure and service information, and facilitates the development and assessment of multiple scenarios.

The FRA used RTC to calibrate and validate the train performance calculations (TPC) the FRA developed with Viriato. The FRA coded the rail alignments associated with each of the Representative Routes[14] into Viriato and the RTC model for the production of TPC travel times and speed profiles.

Figure 5 provides an example of the tools available within Viriato including a stringline chart, a speed profile, and a train window. The train window contains all the critical service information to describe a "train family." A train family is a group of trains that operate on regular headways and share a consistent set of service characteristics such as route, stopping pattern, speed between stations and dwell time at stations. The train window also contains the departure time for the first and last train in the train family and the equipment used to operate that service. The service planning process for NEC FUTURE, including specifications of trains and conflict resolution was performed primarily using the train window and the stringline chart tools in Viriato.

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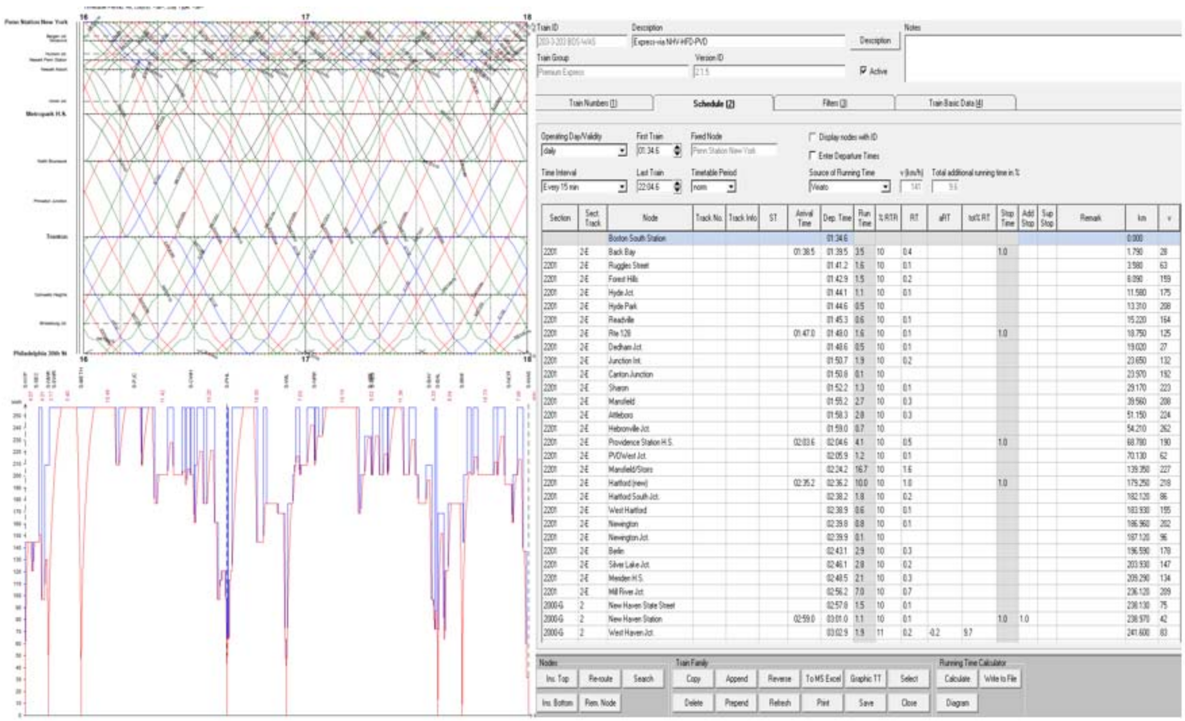
[12] Rail Traffic Controller is a product of Berkeley Simulation Software, Inc.
[13] Viriato is a product of SMA+Partner.
[14] The Representative Route refers to a proposed route or potential alignment for an Action Alternative, including horizontal and vertical dimensions. The Representative Route defines the physical limits or representative footprint for each Action Alternative, and is used to assess the potential effects of the Action Alternatives.

Figure 5: Sample Viriato Stringline, Speed Profile, and Train Window



3.3.2 Initial Train Performance Calculations

The first service planning step was to code single-track alignments for the Action Alternatives into the RTC model to simulate trip times for stopping patterns of selected prototypical trains. These trip times were developed using the following six trainsets that cover the reasonable spectrum of performance on the NEC:

- A high-speed train, capable of 220 mph, similar to the French TGV
- A consist similar in performance to Amtrak's Acela equipment
- A conventional, electric, Intercity locomotive with 8 coaches
- A conventional, electric, commuter locomotive with 10 coaches
- A 10-car Electric Multiple-Unit (EMU) train
- A diesel locomotive with 4 coaches

The FRA used the calibrated, validated performance characteristics of these six trainsets to create a conservative representation of train that could feasibly operate on the NEC. The alignment attributes included the location of proposed stations, the location and speed limit of curves, and the location of concepts for junction points associated with connections to other alignments.

The FRA coded train sets with similar performance characteristics into Viriato for the production of trip times using the TPC in that software platform. The trip times produced by Viriato were calibrated using the simulated trip time results produced from the RTC model, so that the onboard TPC in Viriato could be used "on the fly" as train stopping patterns were changed to resolve conflicts or to test alternative scenarios. This calibration of train performance between the two software platforms provided the confidence to use the trip times from either platform when developing Service Plans.

3.3.3 Schedule Margin

The simulated trip time results produced from RTC and Viriato represent an optimal theoretical trip time. A uniform 10 percent "schedule margin" was added to the pure simulated time for all trains in the network to account for factors that may cause train performance to deviate from ideal conditions, including uncertainty of future alignments, braking and acceleration rates that take into account passenger comfort and energy use, and interactions with other trains in the network. This is common practice among railroad operators in the development of train schedules.

While all train schedules include some schedule margin, there is not a single correct way to apply it, and it can be specific to operating conditions. Schedule margin can be added at the beginning or end of a run, included in the dwell time at major terminals, or spread evenly over the run. The 10 percent schedule margin added for all Action Alternatives was applied evenly across the run of the train to the segment times between every operational node through which the train passes, including stations and junctions (but not to station dwell times). Schedule margin as defined for this analysis is made up of three components: network interaction allowance, civil speed allowance, and alignment uncertainty allowance.

Network Interaction Allowance – This is the additional time in train schedules that accounts for the variability in actual train performance due to day-to-day variability and interactions of trains on the network. It adds a percentage of time to the best possible running times to account for minor delays caused by train interference and other factors, including those caused by conflicting train movements at junctions, yards, terminals and train turning locations. In order to preserve reasonable on-time performance, this allowance needs to increase as the density of traffic approaches the practical capacity of the line and as the complexity of the overall network increases, as measured by the number of branch lines and the number of different equipment types and train stopping patterns served. On actual railroads, this allowance is built into the train timetables and typically is increased in response to network congestion.

Civil Speed Allowance – This factor accounts for the differences between actual train performance and how train performance is simulated in the models used to generate train running times. It helps calibrate the modeled train performance to actual performance and is not an allowance that is built into actual timetables. Civil speed limits are established for a rail line based on the physical characteristics of the line, such as curvature and grade, and are normalized along a line to ensure passenger comfort and avoid unnecessary accelerations and deceleration in territories with frequent curves and changes in physical characteristics. These speed limits are lower than the maximum possible speed in some locations, and this allowance is used to adjust the simulated train performance to match typical operating conditions.

Alignment Uncertainty Allowance – Train speeds and associated trip times on new route segments in the Action Alternatives were developed based on the Representative Routes, which identified railroad alignments only at a highly conceptual level. Once detailed engineering design and environmental analysis is performed for any prospective new route, the actual alignment is likely to be different and might greater curvature and slower speeds to save cost or reduce potential impact. To ensure appropriately conservative train running times for purposes of service planning and ridership analysis, additional trip time was added to the ideal running times to account for this uncertainty with respect to future new route alignments. This alignment uncertainty allowance also is not applicable to existing train timetables.

The No Action Alternative, which is based on existing train schedules, includes only the network interaction allowance, assumed to be four percent for Acela Express and nine percent for Northeast Regional trains. All three allowances were included in the assumed 10 percent schedule margin for each of the Action Alternatives. Each alternative included a civil speed allowance of 2.5 percent. However, the composition of the remaining schedule margin varied from alternative to alternative. The network interaction allowance was 6.5 percent for Alternative 1, 5.5 percent for Alternative 2, and 3.5 percent for Alternative 3. With increasing investment in railroad capacity, redundancy and parallel movement capability, and as train movement conflicts are eliminated and as trains with differing performance characteristics are able to operate on separate tracks, the amount of extra network interaction time built into train schedules to protect against train interference conflicts is expected to decrease. On the other hand, the alignment uncertainty allowance increases as the proportion of total route-miles utilizing new route segments increases. This allowance was set at one percent for Alternative 1, which mostly follows the existing NEC, two percent for Alternative 2, and four percent for Alternative 3, where Express and Metropolitan trains operate mostly on new route segments. The differences in the latter two factors tend to cancel each other out, resulting in the uniform 10 percent schedule margin applied to all trains in the analysis.

3.3.4 Dwell Time

Dwell time is the elapsed time that a train is stopped in the station at a scheduled station stop. Dwell time comprises the entire stopped time of the train, including time required for passenger flow (passenger alighting and boarding) and time in a station before and after the passenger doors open. Dwell times may also include time to service the train at major terminals and may differ based on station configuration and passenger loads. In addition, these times are greater at a major terminal with larger passenger loads.

Dwell times at specific stations on the corridor varied based on conditions such as platform height, platform width, consist composition and passenger loads. Assumptions for dwell times were based on the size and use of stations on the corridor and represented an approximation of “typical” conditions for similar stations.

For most stations the FRA assumed a 1-minute dwell time for Intercity service. This is typical of intermediate station stops for Amtrak Northeast Regional trains, such as New Carrolton, Trenton, and Bridgeport. For the larger intermediate stations and stations where the FRA planned for transfers between services, the FRA assumed a minimum of 2-minute dwells. These stations typically have larger passenger loads that require additional time for alighting and boarding of passengers. Examples included Philadelphia and New Haven. The FRA assumed 30-second to 1-minute dwell times for Regional Service at non-terminal stations.

Dwell time assumptions at Penn Station New York for Intercity trains were assumed to be 8-12 minutes in Alternative 1, which does not require platform widening, and 8 minutes in Alternatives 2 and 3, where platforms are assumed to be widened, providing for more efficient passenger handling.

3.3.5 Practical Line Headways

The FRA developed prototypical trains using a reasonable set of potential stopping patterns within each service type and incorporating the schedule margin and dwell assumptions described above. Once the prototypical trains were specified, they were organized into a service plan. Further assumptions regarding appropriate train spacing governed how these trains were compiled into a coherent and feasible plan. The practical following headway for passenger trains for the Action Alternatives was assumed to be the following:

- 220 mph top speed: 4 minutes
- 160 mph top speed: 3 minutes
- Slower-speed territory, including station approaches with merging and diverging movements: 2 minutes.

These assumptions are consistent with a fixed block (cab, no wayside) signal system and an overlay Positive Train Control system. Shorter block lengths were assumed to provide for higher-density operation at shorter headways than the existing signal system. Moving block technology was *not* assumed for the NEC or connecting corridors in the NEC FUTURE analysis.

3.3.6 Scheduling Trains

The development of Service Plans followed a logical pattern based on priority sequencing of trains into the plan. Service type governed the order in which a train was added to the plan. Intercity-Express trains had the highest priority and thus the FRA added them to the plan first. These trains were routed on the optimal route through the network, operating on express tracks and maintaining the minimum dwell and schedule margin for the entirety of their run.

Intercity-Corridor service (both Metropolitan and Intercity-Corridor-Other trains) received the next highest priority. To the extent possible, these trains were scheduled on the express tracks into slots between the Intercity-Express trains. Where conflicts arose between the faster moving Intercity-Express trains and the slower Intercity-Corridor and Metropolitan trains, the FRA either shifted the Intercity-Corridor trains onto the local or intermediate tracks or extended their station dwell at select stations to facilitate an overtake. In some instances, the FRA added schedule margin to these trains (above the minimum 10 percent) to resolve conflicts.

At key Hub stations along the network, primarily at New Haven and Philadelphia, “scheduled meets” were planned. These meets occur when an Intercity-Express train and Intercity-Corridor train traveling in the same direction are scheduled for a simultaneous stop at a given station. These meets serve two purposes. They provide connectivity between the service types allowing for easy, cross-platform transfers between trains. They also facilitate Intercity-Express trains “overtaking” or passing the slower Intercity-Corridor trains at these stations, allowing for efficient operations of the Intercity-Express trains with minimal added time to the stopping Intercity-Corridor train.

The FRA added Regional rail trains to the schedule after the Intercity pattern was fully planned. Zone Express trains were added first, operating on the local tracks at the extremities of the network, and then shifting to the intermediate or express tracks for the express portion of their run, filling the remaining slots on these tracks into the major terminals. The local train patterns were then added and operated exclusively on the local tracks.

The development of the Service Plans at this stage focused on meeting the peak-hour service levels. Trains were added to the plan using the peak service specification. Only after the all trains in the peak hour were added and fully integrated into the plan with no remaining conflicts, did the FRA adapt the plans for the full-day service. For Regional rail trains, the service levels for the reverse-peak, off-peak and shoulder hours represent a subset of peak service. The FRA adjusted each train pattern or train family to meet the full-day service specification.

For Intercity service, the transition from peak-hour to full-day operations is not achieved by merely adjusting the service frequency or train count for non-peak periods to represent a subset of the peak. Because of their long travel distances and times, most Intercity trains do not fit comfortably into a single time slot along the entire run. A train leaving Washington, D.C., at the height of the evening peak hour, for instance, does not arrive in Boston until late evening. So, the volume of Intercity service was tailored to the business travel peak periods in Washington, D.C., New York, and Boston by originating and terminating selected trains at key intermediate stations. Specifically, this tapering of service was accomplished for both the morning and afternoon service peaks by taking every second train in the peak pattern and introducing it (at the start of the peak period) or cutting it off (toward the end of the peak period) at an intermediate station.

For Intercity-Express service, selected trains were designated to originate in New York in both directions at the start of the business peak periods, as the frequency of service ramped up to its maximum level north and south of New York in the morning and evening peaks. As the service tapered at the ends of the peak periods, selected trains were terminated at New York as well as the endpoints of the NEC. This peaking pattern approximately matched the ridership peaks that currently exist on the NEC. For example, a 6:00 a.m. southbound Intercity-Express train serving the morning business peak between New York and Washington, D.C., needs to originate in Boston before 4:00 a.m. Instead, these trains were designated to originate in New York with the first Boston trains originating after 5:00 a.m. Similar tapering at the end of the service day occurred with late evening southbound trains from Boston, and northbound trains from Washington, D.C., terminating in New York. Similar service breaks were also planned for the beginning and end of the day for Intercity-Corridor trains in New York, and for Metropolitan trains in New Haven, New York, and Philadelphia.

4 Alternatives Refinement

The FRA developed initial Service Plans for each Action Alternative, building from the successful elements of the Preliminary Alternatives that were advanced from the evaluation of the Preliminary Alternatives. As the analytic models for estimating ridership, capital costs and annual operations and maintenance costs were being developed, the specific elements of the Service Plans—service frequencies, stopping patterns, train routings and rolling stock characteristics for each service type—were tested and evaluated for their ability to achieve efficient use of rail infrastructure capacity while meeting the varying service needs of each type of rail service. Service Plans were iteratively refined in two broad steps—first to balance the service and the rail infrastructure provided in each alternative, and second to balance the service with the estimated level of ridership and the ability of Intercity services to cover their projected cost of operations and maintenance. The Service Plans are intended to be representational only, required for analysis of capacity, performance, and costs, as well as assessment of environmental impacts, and are not intended in any way to be prescriptive regarding how service should be operated in the future. In addition, the Service Plans are not intended to be a prediction of future operating patterns of the NEC railroad operators.

The FRA developed a Service Plan for the No Action Alternative, in the same format as for the Action Alternatives, to permit direct comparison. Throughout the NEC, the FRA assumed that service levels for the No Action Alternative are identical to existing service levels, with the exception of the East Side Access project to bring LIRR trains to Grand Central Terminal.[15] Service levels in the No Action Alternative Service Plan were calibrated to existing peak hour and total daily train movements. Within these control totals, the patterns and levels of service during peak-period, peak-shoulder, reverse-peak and off-peak hours were adjusted to fit the NEC FUTURE Service Plan format.

The work effort to refine the Action Alternatives was undertaken 1) based on work that was possible prior to completion of the new ridership models and 2) with work that relied on the initial ridership model results. The service and operating plans were refined to clearly distinguish the characteristics of each of the Action Alternatives. The work effort prior to obtaining initial ridership estimates included the following:

- Analysis of the Action Alternatives
  - Refine Service Plans consistent with the distinct nature of each alternative.
  - Develop service and infrastructure assumptions.

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[15] East Side Access is one of the largest transportation infrastructure projects currently underway in the United States. The project encompasses work in multiple locations in the New York City boroughs of Manhattan and Queens and includes more than 11 miles of tunneling. When completed, East Side Access will provide a faster and easier commute from Long Island and Queens to the east side of Manhattan in a new 8-track terminal and concourse below Grand Central Terminal.

  - Perform capacity analysis using sketch operations planning tools to confirm the practical capacity of various critical segments of the corridor.
  - Estimate trip times and relative order-of-magnitude capital costs.
  - Prepare service plan specifications that respond to the objectives of each alternative and fit within the limits of the practical capacity of each segment of the railroad.
  - Test alternative service patterns to determine which patterns best utilize available infrastructure capacity.
  - Identify infrastructure configurations that can support multiple ways of delivering the same level of rail service.
  - Adjust service and/or infrastructure as needed to achieve high levels of capacity utilization during peak periods and balance the supply of and demand for train operating slots on the NEC.
- Conceptual Engineering Analysis
  - Complete development of typical cross-sections and construction types by segment, junction configurations, and station configurations.
- Test enhanced service and precision operations concepts and identify best practices to be applied to the Action Alternatives.
- Develop analytic tools and models, including interregional and intraregional ridership models, capital cost model, operations and maintenance cost model and rail operations simulation model.[16]

Following the receipt of initial Intercity and Regional rail ridership results, the FRA reviewed and refined the Action Alternatives including the performance of the following analyses:

- Refined Service Plans and rail infrastructure configurations based on balancing capacity and demand in:
  - Portions of NEC with four main tracks but demand for additional track capacity
    - Northern New Jersey
    - New Haven Line
  - Portions of NEC with less than four main tracks
    - Maryland and Delaware
    - Hell Gate Line
    - Southeast Connecticut

[16] These tools were developed in parallel with the alternatives refinement process. They were not available at the start of the process and became available for use interactively with servicing planning by the end of the refinement process.

  - Massachusetts
- Validated service pattern assumptions
- Confirmed minimum Regional rail service level assumptions for Alternatives 1, 2, and 3 for visions of the NEC that maintain, grow, or transform the role of rail
- Quantified relative effects of changing frequency, trip time/reliability and fare on Intercity and intraregional ridership
- Quantified ridership performance of Metropolitan service
- Estimated the potential effect on ridership of coordinated/improved rail-rail and multimodal transfers
- Evaluated the range of North End Route Options for a second spine in Alternative 3
- Evaluated 220 mph vs. 160 mph as the top speed for Intercity-Express trains
- Evaluated the relative market and ridership benefits of alternative service patterns for Alternative 3
- Estimated the relative magnitude of connecting corridor ridership markets
- Prepared preliminary estimates of rolling stock fleet and yard facility requirements

4.1 GENERAL SERVICE CHARACTERISTICS

The FRA developed Service Plans following the method outlined in Section 3. The Service Plans and scenarios that the FRA analyzed, accounted for the full mix of Intercity and Regional rail passenger trains operating on the NEC. The FRA first developed Service Plans for the standard peak hour, as defined in the previous section. The operational feasibility of the Service Plans—their ability to fit within the infrastructure provided and operate free of conflicts between train movements of different types—was established for the standard peak hour, which included the maximum number of Intercity and Regional rail trains operating on all portions of the NEC. Service during all other hours of the day was defined as a subset of the standard peak hour and, therefore, was considered to be operationally feasible.

Intercity services were planned so that trains of the same type (and with the same stopping patterns) operate at intervals of exactly 30 minutes, or in some cases 15 minutes. Similarly, Regional rail trains, whether they are all-stop locals, zone-expresses, limited-stop services or branch line trains, were scheduled at regular intervals. For service zones and branch lines with relatively heavy demand or relatively close to the regional central cities, the service objective for 2040 was to operate trains at regular 15-minute intervals at each station. The overall headway at stations served by more than one stopping pattern (e.g., both a local train and a zone-express train) in many cases was less than 15 minutes. Where projected demand was lighter, typically on branch lines or in outer zones on the NEC farthest from the urban centers (such as the MARC outer zone between Perryville and Newark, DE, or the Gladstone Branch in New Jersey or the Waterbury Branch in Connecticut), peak service at regular 30-minute headways was provided.

4.2 INTERCITY SERVICE LEVELS AND PATTERNS

4.2.1 Intercity-Express Service

At the conclusion of the evaluation of the Preliminary Alternatives, the initial service specifications for the three Action Alternatives called for increases in Intercity-Express service from the No Action Alternative and existing levels of service (which are equivalent, with 1 tph south of New York and approximately 1 tph every two hours north of New York) to 2 tph in Alternative 1, 4 tph in Alternative 2, and 8 tph in Alternative 3 during the standard peak hour. This level of service was selected based on the ridership estimates that were prepared for the Preliminary Alternatives, where the market for Intercity-Express service, comprising primarily business travelers, was analyzed separately from other Intercity travel markets.

The new interregional travel demand model considered all interregional travel together and assigned trips by mode and among the service types within the rail mode based on relative cost, frequency and trip time. As ridership numbers became available for the Action Alternatives, it became clear that the increase in demand for Intercity-Express service between Alternatives 2 and 3, and to a lesser extent between Alternatives 1 and 2, was less than originally envisioned. This was due to multiple factors, including the greater sensitivity of the new Intercity model to fares and relatively lower sensitivity to frequency of service and trip time in the selection of mode and service type as compared with previous models. The resulting competitive strength of Metropolitan service, and the estimated ability of the air mode to continue to offer service in the longer-distance NEC travel markets at prices superior to Intercity-Express rail, tended to dampen projected Intercity-Express ridership. As a result of these early findings, the volume of Intercity-Express service in the standard peak hour was reduced from 8 trains to 6 trains in Alternative 3.

With the overall level of Intercity-Express service established for the Action Alternatives, the remainder of the analysis focused on analyzing alternative stopping patterns, which focused on the level of service provided at each station served by Intercity-Express trains, and on the trip times between stations on the NEC. Trip time is relatively more important in the interregional express market, which is largely made up of business travel, than in other Intercity travel markets. Trip time savings can be achieved through a combination of the following:

- Service changes (i.e., reducing the number of intermediate stops and the time spent dwelling at stations)
- Infrastructure improvements (i.e., modifying curves on the existing alignment or constructing new route segments that are more direct and permit higher speeds)
- New rolling stock (capable of higher maximum speeds and with improved acceleration and braking performance)

The options that were considered with respect to infrastructure configuration and rolling stock are addressed in subsequent sections of this technical memorandum. Regarding service, tradeoffs had to be made between the number of markets and stations served by Intercity-Express trains and the trip times offered between the major stations with the largest ridership markets. These tradeoffs, and the resulting decisions made about the types of service that represent each of the Action Alternatives, are described below in the remainder of this section.

4.2.1.1 Intercity-Express Stopping Patterns

Several Service Plan scenarios were analyzed to test the merits of introducing an Intercity-Express service that stop only at the stations serving the major markets: Washington Union Station, Philadelphia, Penn Station New York, Boston Back Bay Station, and Boston South Station. These limited-stop Intercity-Express trains supplement rather than replace the regular Intercity-Express service that continues to serve key intermediate markets such as Baltimore, MD, Wilmington, DE, Stamford, CT and Providence, RI.

Alternative 2 provided a useful framework for analyzing the operational, infrastructure and ridership effects of various Intercity-Express stopping patterns. Four Intercity-Express trains operate in each direction in the standard peak hour in Alternative 2. Many different combinations of stopping patterns for these four Intercity-Express trains are possible, but two scenarios offered a good illustration of the tradeoffs and issues. The analysis started with the most difficult scenario to develop in terms of fitting peak trains onto the railroad without schedule conflicts: the scenario with two different Intercity-Express service patterns, plus Metropolitan service, on top of the Regional Rail rush hour service patterns. Then, a second scenario with four similar Intercity-Express patterns on regular 15-minute headways was developed, with a simpler set of express patterns and similar Metropolitan and Intercity-Corridor-Other patterns.

Intercity-Express Scenario with Two Different Express Patterns

This scenario provided a limited-stop Intercity-Express and a regular Intercity-Express service, each operating with 2 tph spaced 30 minutes apart in the standard peak hour. This scenario prioritized the Intercity-Express and Metropolitan trains by developing the schedules for these trains first and creating the best spacing and interaction between these two services. Then in decreasing priority, the Intercity-Corridor and Regional rail trains were scheduled into patterns around these services. This priority order was limited to the pattern development and not the level of service. Both scenarios provided similar levels of service corridor-wide for all types of Intercity and Regional rail trains.

This scenario offered Intercity-Express service among the four major markets with all 4 tph, with two of these trains being the limited-stop Intercity-Express stopping only at Boston, New York, Philadelphia, and Washington, D.C. The remaining intermediate stations were served with the two regular Intercity-Express trains with an “Acela-like” stopping pattern. The total travel time difference between the Intercity-Express and limited-stop Intercity-Express[17] between Boston and Washington, D.C., was 30 minutes – approximately 15 minutes between Boston and New York and 15 minutes between New York and Washington, D.C.

The benefit of the limited-stop Intercity-Express service was that it provided fast, regular service between the four primary markets, which dominate premium express ridership. The tradeoff

[17] A rail service pattern where trains make stops only in primary markets.

introducing this type of service was that it created irregularity in the Service Plan, adding to the complexity of train movements throughout the network and compromising capacity.

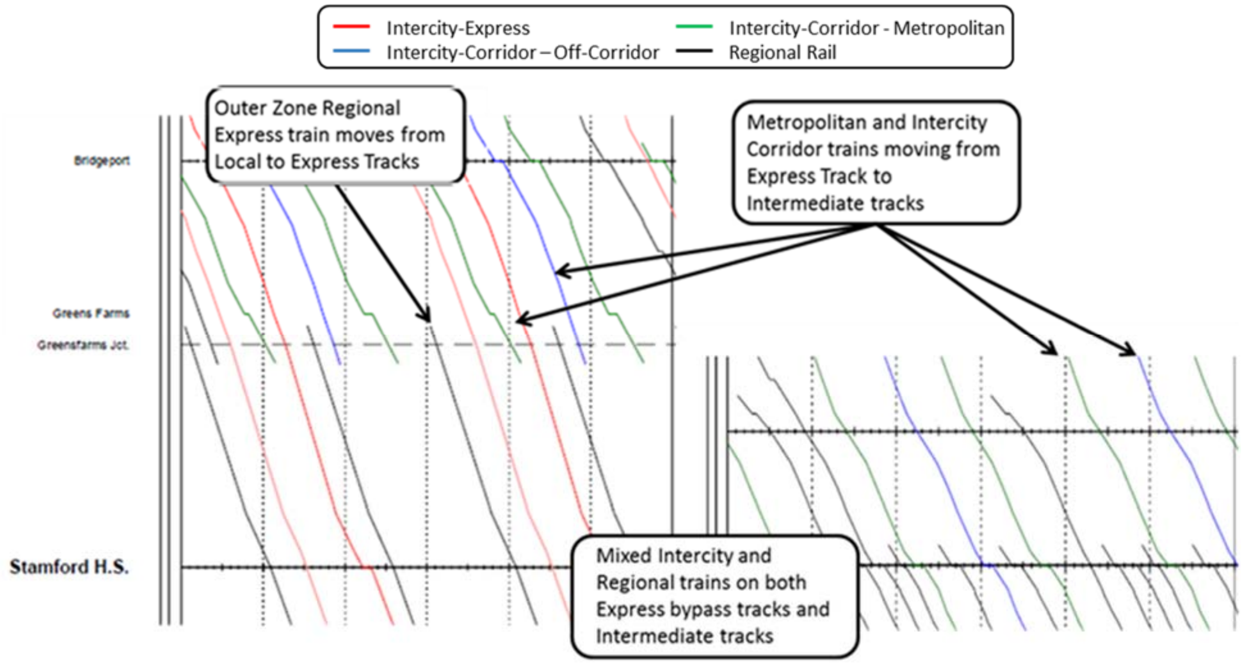
Metropolitan service was offered on the corridor at regular 15-minute headways in the standard peak hour, to provide frequent regular service to intercity markets as well as serve the major regional markets in the large metropolitan regions. In addition, two slots per hour for Intercity-Corridor-Other trains between Washington, D.C., and Boston were provided on 30-minute headways. A good illustration of how this scenario works is provided by the territory in Connecticut on the New Haven Line between Stamford and Bridgeport – looking at Alternative 2 service levels in the standard peak hour and including the construction of two new express tracks parallel to the NEC between Stamford and Westport, CT. In Alternative 2, the express bypass between New Rochelle and the Saugatuck River in Westport, CT results in six tracks in this territory. The existing inside express tracks are referred to as the intermediate tracks as the new bypass becomes the express tracks. North of the Saugatuck River, there are four tracks, with only express and local.

Figure 6 shows the graphic timetables (stringline charts) for the express and intermediate tracks between Bridgeport and Stamford, CT, for this scenario with two different Intercity-Express patterns. North of Westport, CT, only express tracks are shown because no intermediate tracks exist; south of Greens Farms, express tracks are shown on the left, intermediate tracks on the right. Each line represents a single train and is color coded by train type:

- Red = Intercity-Express (limited-Stop Intercity-Express in pink)
- Blue = Intercity-Corridor-Other (Intercity-Off-Corridor)
- Green = Metropolitan
- Black = Regional rail

A one-hour time period is shown in Figure 6, with Intercity and Regional rail service running in mixed service on both the express and intermediate tracks. At Greens Farms Junction, the Intercity-Corridor and Metropolitan trains move from the express tracks to the intermediate tracks to avoid conflicts with the express trains. At the same junction, Regional rail trains (outer zone New Haven express trains) move from the local tracks (not shown) to the express tracks.

Figure 6: Graphic Timetable of Intercity-Express and Intermediate Track between Bridgeport and Stamford – Two-Pattern Scenario



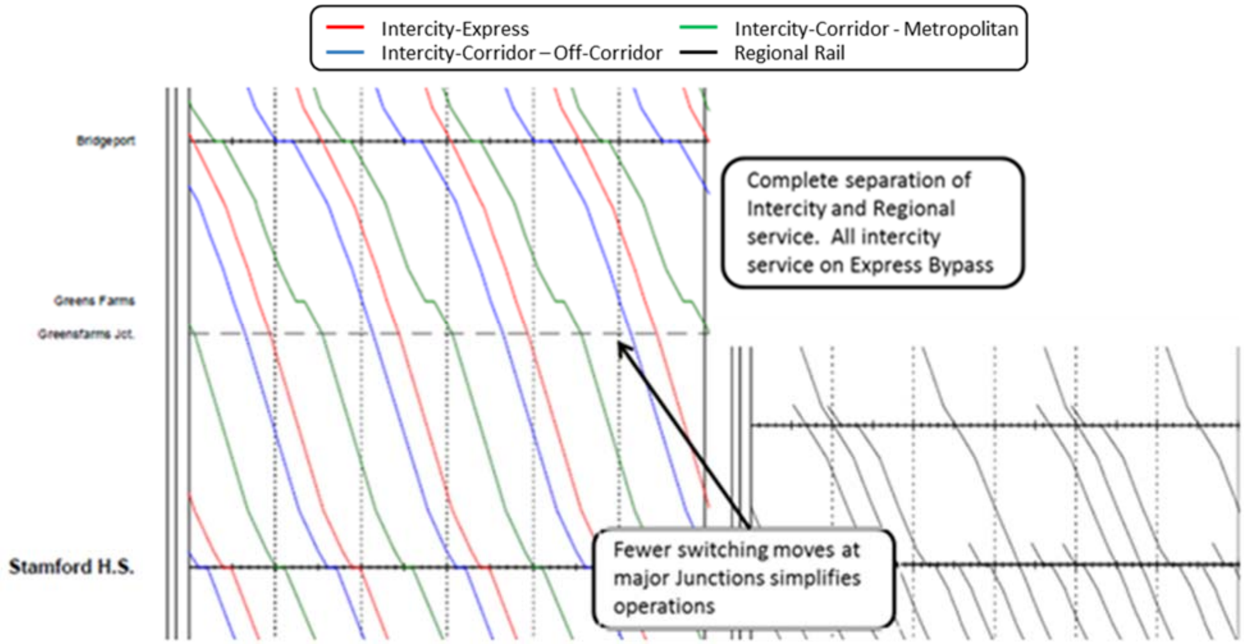
Source: NEC FUTURE team, 2015

This two-pattern Intercity-Express scenario provided an increase in service on the New Haven Line to Grand Central from 21 to 24 tph and introduced Regional rail service to Penn Station New York with 8 tph during the peak period. A mix of outer-zone Intercity-Express trains and inner-zone local trains were scheduled to both terminals, with a similar zone structure as operates today on the New Haven Line.

Express Scenario with Repeating 15-Minute Express Pattern

This scenario provided the same number of Intercity trains as the previous scenario, but included a more regular service plan to maximize slot capacity. To accomplish this, the limited-stop Intercity-Express trains were removed from the Service Plan and replaced with two regular Intercity-Express trains, resulting in a single express pattern that operated at 15-minute headways between Boston and Washington, D.C., during the standard peak hour. Figure 7 shows the graphic timetables (stringline charts) for the express and intermediate tracks in Connecticut for this scenario.

Figure 7: Graphic Timetable of Express and Intermediate Track between Bridgeport and Stamford – Single Pattern Scenario



Source: NEC FUTURE team, 2015

Scenario Comparison

While the two scenarios achieved a similar level of overall service, there were some key differences in terms of complexity of the operations and available capacity in particular parts of the corridor. On the New Haven Line, both scenarios achieved the same level of capacity, but the two-pattern scenario with limited-stop Intercity-Express service resulted in more complex operations with a greater number of instances of trains having to change tracks to enable or avoid being overtaken by other trains. The train movements through Greens Farms Junction, where the railroad expands from four to six tracks, are streamlined in the single-pattern scenario. All Intercity service (Intercity-Express, Intercity-Corridor-Other, and Metropolitan) remain on the express tracks all the way through Stamford to New Rochelle. The Regional rail service is segregated and is left to occupy the intermediate and local tracks. As a result, the only train movement at this junction is a sorting of the Regional rail trains from local tracks north of the junction to local and intermediate tracks south on this junction.

Figure 5 shows that with all three Intercity services operating at regular repeating 15-minute intervals in the single-pattern scenario, there is capacity to accommodate all Intercity trains on the express tracks, avoiding any track switching in this territory and freeing up both the local tracks and intermediate tracks for Regional rail service. This scenario also provides four slots per hour for Intercity-Corridor-Other service instead of the two slots shown in the previous scenario.

In the two-pattern scenario, the difference in run times between the two express patterns did not allow for these four Intercity-Express trains to run in 15-minute intervals everywhere on the corridor. The territory between New York and Philadelphia was prioritized for even headway spacing between these trains to maximize the capacity and plan the Regional rail service in this territory. As a result, the Intercity-Express trains were more closely spaced in the Wilmington-Washington, D.C., territory and the Boston-Stamford territory. Because of this, the New Jersey to New York Regional rail service is essentially the same in both scenarios, and because the Boston and Philadelphia Regional rail service operating on the local tracks was more fully segregated from the express services, these Regional rail services were also essentially the same between the two scenarios. Where these patterns impacted the Regional rail Service was on the New Haven Line and in the Washington, D.C., region.

Table 2 compares the number of standard peak-hour train slots provided at the north-of-Washington screenline under both Intercity-Express service scenarios. It shows the differences in available slots for both Intercity-Corridor-Other and Regional rail service on the NEC at Washington, D.C.

Table 2: Comparison of Intercity-Express Service Scenarios – Alternative 2 – Train Slots in the Standard Peak Hour, Peak Direction at Washington, D.C. Screenline

TRAIN MOVEMENTS IN STANDARD PEAK HOUR, PEAK DIRECTION

	North of Washington, D.C.	
	W/ Limited EXP Stop	15-MIN EXP Pattern
Intercity-Express		
Limited-Stop Express	2	-
Express	2	4
Intercity-Corridor – Metropolitan	4	4
Intercity-Corridor – Other	2	4
Regional Rail	8	12
Total	**18**	**24**

Source: NEC FUTURE team, 2015

In the single-pattern scenario, Intercity-Corridor-Other service is provided with four slots, which is useful for enabling late trains reaching the NEC from the Virginia or Vermont connecting corridors to access an available slot. In addition, the single-pattern scenario allowed for four additional Regional rail train slots in the peak hour from the NEC to Washington, D.C. (12 as opposed to 8). These slots can be used by any type of train, but the specific stopping patterns on which these slots are based are most appropriate for Regional rail. The resulting level of service, with all slots utilized, was more than adequate to meet the capacity necessary to serve the market in this region as indicated by the 2040 demographic forecasts, but the level of service also provided the Regional rail operator with additional operational recovery ability and flexibility for to fill a wider array of slots with trains.

The single-pattern scenario offers two more slots for Intercity trains than the two-pattern scenario, and four more slots for Regional rail service. This is due to the more regular patterns that exist in the single-pattern scenario at Washington, D.C., the southern end of the NEC.

Table 3 compares the two Intercity-Express service scenarios for a set of criteria. Both scenarios are operationally feasible On the basis of most of the criteria, the single-pattern scenario performs better. The principal benefit of the two-pattern scenario is improved trip times on the limited-stop Intercity-Express trains between the major cities on the NEC. Marginally faster trip times increased ridership in the major markets, but the reduction in service frequency at the intermediate Intercity-Express stations had a dampening effect on ridership in the intermediate markets. Absent a strong ridership response to faster express trip times in the premium interregional market, FRA selected the single-pattern scenario with its benefits as the basis for the representative Alternative 2 Service Plan.

Table 3: Comparison of Intercity-Express Service Scenarios – Alternative 2

Criteria	Two Pattern Scenario (Intercity-Express at 2 tph limited-stop Intercity-Express at 2 tph)	Single Pattern Scenario Intercity-Express at 4 tph
Service frequency in standard peak hour	4 tph	4 tph
Service frequency in off-peak hours	2 tph (no limited-stop)	2 tph
Service frequency at intermediate stations (e.g., BWI Airport, Baltimore, Stamford, Providence)	2 tph	4 tph
Trip time between major stations	Limited-stop Intercity-Express offers fastest trip times	All trains have the same trip times
Available capacity for other services on express tracks	Lower capacity – Variable slots at 30-min intervals	Higher capacity – Regular 15-min slots
Operational feasibility – meets service objectives for Alternative 2	Yes	Yes
Operational simplicity – relative number of times non-express trains need to change tracks	More complex – Lower reliability	Simpler – Higher reliability
Ability to support alternative train stops at lower volume intermediate stations (e.g., Metropark and Trenton)	No	Yes
Impact on intermediate overtakes	High	Low
Ridership potential	TBD Better for major markets	TBD Better for intermediate markets
Required infrastructure investment	Potential additional capacity needed to accommodate complex service patterns	Efficient use of railroad capacity

Source: NEC FUTURE team, 2015

Note: Cells with green shading indicate better performance, and cells with red shading indicate worse performance in a relative comparison. No shading indicates lack of a clear preference between the scenarios.

Train Routing

In Alternatives 1 and 2, the Intercity-Express service always follows the fastest NEC route between Washington, D.C., and Boston, to achieve the best possible trip times with the infrastructure available in each alternative. In Alternative 3, Intercity-Express service follows multiple routes. With the increased capacity and routing choices in Alternative 3, many possible combinations of stopping patterns and routes for Intercity-Express were tested, with the intent of finding a representative mix of Intercity-Express service patterns that serves multiple markets and achieve the highest ridership potential. North of New York, Intercity-Express service at a minimum level of 2 tph was provided on the existing NEC between New York and New Haven, ensuring improved Intercity-Express service at Stamford and New Haven; the highest ridership was achieved in Alternative 3 by having all remaining Intercity-Express services follow the fastest route between New York and Boston along the new second spine route. South of New York, in scenarios that included peak Intercity-Express service at 8 tph, the analysis indicated opportunities for splitting the service between existing and new downtown Baltimore and Philadelphia stations to potentially improve access to premium rail service in these cities by offering it at multiple stations. However, at 6 tph, which was the level of traffic supported by the ridership estimates, all trains were routed on the fastest route, through the new downtown stations, to offer the best potential combination of service frequency and fast trip times.

Maximum Speeds

In Alternatives 1 and 2, the top speed for Intercity trains is 160 mph. In Alternative 3, the FRA developed and tested service scenarios with two different maximum speeds for Intercity-Express and Metropolitan trains: 160 mph and 220 mph. Trip times for Alternatives 1 and 2, and for the 160 mph variation of Alternative 3, were estimated based on non-tilting equipment. The impact of reducing the top speed on trip times can be mitigated by utilizing rolling stock with tilting capability, which allows trains to operate around speed-limited curves at higher speeds than is possible with non-tilting equipment.[18]

According to the model, time savings for Intercity-Express services associated with the higher top speed were relatively modest (single-digit minutes between major markets). Limiting top speed to 160 mph reduces the capital cost of new route segments by reducing the amount of tunneling required. The preliminary ridership analysis showed a relatively limited response in the premium and regular intercity markets to improved trip times resulting from increasing the top speed of Intercity-Express and Metropolitan trains from 160 mph to 220 mph. The limited time savings, coupled with modeling assumptions that gave a relatively low benefit to rail time savings relative to trips by other modes, resulted in modest incremental ridership associated with the higher top speed.

However, the FRA determined that the initial results of the ridership and cost analysis were not sufficiently conclusive given the relatively coarse nature of the analysis, which was not able to take into account all of the factors involved in predicting future travel times and costs for all modes of

[18] The decision on the specific type of rolling stock to be used for Intercity-Express service will be made as part of a Tier 2 process subsequent to NEC FUTURE.

Intercity transportation. The FRA decided that the cost-effectiveness of limiting the top speed of Intercity-Express services to 160 mph was not sufficiently proven, and therefore decided to carry both operating speeds forward into the Tier 1 Draft EIS with variations by alternative. The Action Alternatives that maintain or grow the role of rail in the NEC (Alternatives 1 and 2) have the top speed of high-speed passenger trains on the NEC capped at 160 mph. A 220 mph top speed was retained for the second spine routes in Alternative 3, enabling consideration in the Tier 1 Draft EIS of the transformative potential of state-of-the-art high-speed rail to attract ridership by reducing trip times by rail to their practical minimums given current technology and the physical constraints of the corridor.

Full-Day Service Plans

Existing Acela Express service on the NEC is provided at the same level throughout the day. This even or flat level of service is carried forward in the No Action Alternative. With the increases in service included in the Action Alternatives, the opportunity exists to match the supply of service to the variations in demand through the course of the day. Full service (i.e., the level of service specified for the standard peak hour) is provided during weekday morning and afternoon hours when business travel demand is greatest. Service tapers on the shoulders of the peak (i.e., during the hours immediately preceding and following the peak hours). As Intercity ridership results became available from the new Intercity model, the levels of peak service and full-day service and the available train seating capacity provided were compared with ridership, and an exercise was undertaken to balance service with projected 2040 ridership.

Table 4 compares the volume of daily train movements for Intercity-Express service in the No Action and Action Alternatives, for the standard peak hour and for an average weekday. The increases in the magnitude of Intercity-Express service are substantial in the Action Alternatives, compared to the No Action Alternative. For traffic south of New York, the frequency of Intercity-Express service in Alternative 1 is 50 percent higher than in the No Action Alternative, increases by a factor of 2.5 in Alternative 2, and increases almost five-fold in Alternative 3. North of New York, where there is a lower base of existing service, the growth is even more pronounced, with the volume of daily Intercity-Express trains approximately doubling in Alternative 1, quadrupling in Alternative 2, and growing by a factor of 8 in Alternative 3, compared with the No Action Alternative.

Table 4: Intercity-Express Service Specifications

Alternative	Standard Peak Hour Trains/Hour		Average Weekday One Way Trips	
	South of NY	North of NY	South of NY	North of NY
Existing	1	<1	32	18
No Action Alternative	1	<1	32	18
Alternative 1	2	2	48	38
Alternative 2	4	4	82	82
Alternative 3	6	6	146	150

4.2.2 Intercity-Corridor and Intercity-Long Distance Service

For purposes of analysis in NEC FUTURE, all Intercity passenger rail service that is not classified as Intercity-Express falls into the general category of Intercity-Corridor service. Each of the three Action Alternatives includes two different sets of service patterns on the NEC for Intercity-Corridor trains:

- Metropolitan service operates solely within the electrified territory of the NEC (i.e., north of Washington, D.C., south of Boston, and on the Keystone Corridor between Philadelphia and Harrisburg)
- Intercity-Corridor-Other service operates both on and off the NEC, including off-corridor trains that serve connecting corridors as well as Long-Distance trains to and from Florida, New Orleans, Chicago and Canada

The former set of trains is "captive" to the NEC and can take advantage of improved infrastructure and high-performance rolling stock to greatly improve the level and quality of service offered to non-Intercity-Express markets within the corridor. The latter set of trains needs to operate in the Class 1 freight rail environment as well as on the NEC and utilizes traditional trainsets of locomotive-hauled coaches. Different schedule slots were created for these two types of trains, because of their different performance characteristics. However, these two service types serve essentially the same markets within the NEC.

Based on the results of the analysis of the Preliminary Alternatives, where all off-corridor markets generated significantly higher estimated ridership when provided with direct one-seat ride service to New York, it was decided to continue to expand the ability to offer direct service from connecting corridors to New York via the NEC to the extent feasible. As a result, most Keystone Corridor and Hartford Line Intercity trains continue onto the NEC as Intercity-Corridor trains. Since the Keystone Corridor is electrified, this service is operated as a Metropolitan service in all three Action Alternatives. Intercity service between New Haven, CT and Springfield, MA is also operated as Metropolitan service in Alternatives 2 and 3, since the route is electrified. Alternative 1 does not assume electrification of the existing Hartford Line, and, therefore, Intercity-Corridor-Other trains with dual mode locomotives are assumed to provide the intercity service in this corridor.[19]

Each of the Action Alternatives provides slots on the NEC for trains coming from off-corridor. Alternative 1 provides two slots in each direction per hour for these trains. Alternative 2 provides four slots per hour in each direction. Not all of these slots are occupied by trains in the Service Plan. The unused or "phantom" slots are available for the use of Intercity-Corridor-Other trains that may arrive at their entry point to the NEC later than scheduled. Alternative 3 provides for up to four trains per hour in each direction, with the ability to accommodate late trains in additional phantom slots.

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[19] Electrification of the Hartford Line between New Haven and Springfield is included in the long-range plan for the New Haven-Hartford-Springfield corridor but is not currently funded or part of the near-term implementation plan.

Trains from Virginia and North Carolina[20] are assumed to operate through Washington, D.C., onto the NEC and utilize these Intercity-Corridor-Other train slots at up to 2 tph. At the other end of the NEC, trains from the Knowledge Corridor, from Montreal via Vermont, and from the Inland Route from Boston via Worcester, all operate via the Hartford Line from Springfield to New Haven and join the NEC at New Haven. As on the south end, these trains utilize slots at up to 2 tph.

These trains continue northward and provide off-NEC connections to the north and east of Springfield, including the Knowledge Corridor and Montreal service via Vermont, and the Inland Route to Boston via Worcester. The slots in the Service Plan run continuously between Virginia and the northern connecting corridors. Actual train schedules may have Montreal trains and Virginia trains that do not occupy these slots from end to end. Empire Service operates to and from Penn Station New York in each of the Action Alternatives, with New York being by far the largest ridership market for Empire Service. All Action Alternatives provide well-coordinated transfer connections to NEC trains in both directions.

Ridership-service balancing was undertaken once ridership results from the new interregional travel demand model became available, similar to the balancing performed for Intercity-Express service. As with Express service, the off-peak service was tapered to a greater extent than originally envisioned, resulting in fewer daily Intercity-Corridor-Other and Metropolitan trains than were in the original service specification.

All three Action Alternatives were developed and analyzed with the same level of service on the connecting corridors – combining to generate Intercity-Corridor-Other service on the NEC Spine at up to two trains per hour in each direction. Initial ridership analysis indicated that this level of service was consistent with the estimated magnitude of demand for rail travel between the connecting corridors and the NEC, which in most cases is most heavily concentrated on the New York region as the primary destination for trips coming from off-corridor markets. Higher than anticipated growth in demand for connecting corridor service is accommodated by increasing the frequency of Intercity-Corridor-Other service. In Alternatives 1 and 2, this additional service comes at the expense of either Metropolitan or Regional rail service, because capacity on all of the NEC main line tracks feeding New York is heavily utilized in these alternatives. With the full second spine in Alternative 3, there is sufficient main line capacity to support an increase in the number of off-corridor trains coming onto the NEC. Therefore, the potential is greatest in Alternative 3 for accommodating either an increase in the volume of service from the existing connecting corridors or the introduction of service to potential new connecting corridors. Conceptual Service Plans for Alternative 3 were identified that provided for increased numbers of Intercity-Corridor-Other trains and potential service to new connecting corridors, but these plans were not analyzed in detail because they entail making assumptions about infrastructure investment and rights of way beyond the limits of the NEC as defined for purposes of this analysis.

Long-distance service was assumed to remain the same in the future as it is today. These trains operate on the NEC generally outside of the business travel peaks and utilize slots allocated to

[20] These trains including Long-Distance trains, Virginia-sponsored Intercity-Corridor trains, and Southeast High Speed Rail corridor trains from Charlotte, NC, and Norfolk, VA.

Intercity-Corridor-Other service. The train equipment used for Long-Distance service, including both locomotives and rail cars, was assumed to be upgraded as needed to be able to perform equivalently to Intercity-Corridor trains in terms of top speed (125 mph on the NEC) and acceleration and braking performance. Extra unused or "phantom" slots were provided in the Service Plans for Alternatives 2 and 3 as a way to mitigate late train arrivals from off-corridor, allowing late Intercity-Corridor-Other or Long-Distance trains to fall back into an available phantom slot for the remainder of its trip on the NEC.

4.2.3 Metropolitan Service

The concept of Metropolitan Service as a new NEC rail service bridging a gap in current service between Intercity and Regional rail, serving both interregional and regional markets, was tested extensively in the development of Service Plans for the Action Alternatives. Metropolitan service emerged from the analysis of Preliminary Alternatives as a service type with strong ridership potential. Multiple service patterns and scenarios were developed and analyzed to better understand how this service operates, and how it can be scheduled on the railroad along with other service types. The best fit with other services was achieved with Metropolitan service utilizing trainsets with the same performance characteristics as the Intercity-Express trainsets, since this allowed these trains to operate at relatively close headways either directly ahead of or behind Intercity-Express trains.

Among the scenarios analyzed were various service frequencies and combinations of stations and stopping patterns. Service frequencies in the standard peak hour of 2, 4, 6, and 8 tph were tested. Ridership as measured in the interregional model increased significantly up to the level of 4 tph on a given route but exhibited diminishing returns as frequency increased above that level. The number of station stops for the Metropolitan service ended up as a combination of three factors: ridership demand, the geography of the NEC network, and the average speed of the trains relative to other train types in the Service Plan. Metropolitan service performed well in terms of ridership demand with stations positioned within the gaps in-between existing Intercity stations and at locations with local employment or activity centers and good highway access. The number and location of station stops also was a factor of how well trains of different types fit together on the same tracks, particularly with respect to Metropolitan and Intercity-Corridor-Other service. This tends to limit the number of stops on Intercity-Corridor-Other trains to the existing Intercity stations with frequent Amtrak service, and provides opportunities to add a reasonable number of Metropolitan stops at logical locations where the average speed of Metropolitan service is matched with that of Intercity-Corridor-Other service, or to facilitate the overtaking of Metropolitan trains by Intercity-Express trains at convenient locations such as Philadelphia 30th Street, Trenton, NJ, or Bridgeport, CT.

Service plan scenarios were developed for Alternatives 1 and 2 both with and without Metropolitan service. In scenarios without Metropolitan service, the non-premium intercity market is served by regular Intercity-Corridor trains with characteristics and stopping patterns similar to current Amtrak Northeast Regional service. In selected other scenarios, Metropolitan service was introduced, catering to both the Regional rail and Intercity markets, and the assumption was made in these cases that the future service targets are met in the major commute markets by substituting four Metropolitan trains for two Regional rail trains in the peak hour, enabling a commensurate reduction in the number of peak hour Regional rail trains, as well as a reduction in allowances for Intercity-Corridor train slots in the standard peak hour.

The initial estimates of ridership with Metropolitan service as a brand distinct from Intercity-Express and Intercity-Corridor-Other service yielded model results that generated substantial swings in ridership based on relatively small changes in frequency, speed and stopping patterns. The analysis results became more stable when Metropolitan and Intercity-Corridor-Other services were considered together as a single service type in the ridership model, so subsequent ridership analyses were based on having two types of Intercity service. Similarly, Metropolitan service was tested as an Intercity-only service and as a service that carries passengers in both the interregional and regional markets. The latter scenarios allow Metropolitan service to achieve higher levels of demand, but remain at levels that were estimated to be within the capacity of trainsets. To a large degree, the extent to which capacity on these trains is allocated among interregional and regional travelers is a function of rail fares, which can be adjusted as needed to regulate demand and distribute passengers between the two train types in a way that balances demand with available seating capacity.

The analysis of these various service scenarios, with initial results from the ridership models, confirmed the effectiveness of Metropolitan service and its potential ability to supplement or replace traditional Intercity-Corridor rail service for trips within the NEC. Initial ridership and service planning analyses also confirmed the success and basic operational feasibility of Metropolitan as a type of service that participates in both travel markets and productively fills the current service gaps that exist at the boundaries between these markets. Consequently, Metropolitan service is featured in all three Action Alternatives. It shares slots with Intercity-Corridor-Other trains in Alternative 1, achieves 15-minute peak headways in Alternative 2 on the NEC, and is deployed on both the existing and new spine routes in Alternative 3.

Metropolitan service, as presented in the Action Alternatives, is illustrative and representative. There are several variables that can be adjusted in the definition of the service, including the specific stations served, the frequency of peak and off-peak service, reservations policy, rolling stock configuration, extent of onboard food service, and fare policy. More information on the characteristics of Metropolitan service and the reasons for its inclusion in the Action Alternatives is provided in the discussion of enhanced service concepts in Section 5.2.

4.3 REGIONAL RAIL SERVICE LEVELS AND PATTERNS

The general guidance that the FRA used to develop NEC FUTURE Regional rail Service Plans related to the visions for the role of rail in each of the three Action Alternatives. For **Alternative 1**, which *maintains* the current role of rail, the FRA increased the level and capacity of Regional rail service in response to projected growth in travel resulting from increasing population and employment, although the FRA did not fundamentally change current Regional rail service patterns. Where projected growth can be accommodated by adding cars to existing peak trains, the FRA avoided or limited increases in service frequencies. Conversely, in areas where existing trains are crowded, where average train lengths cannot be easily increased, and where future growth is projected to be strong, the FRA provided additional train service frequencies to increase peak seating capacity commensurate with projected demand growth, including the introduction of Metropolitan trains serving hub stations. The FRA also identified the infrastructure capacity improvements that are required to support the Service Plan.[21] A focus of the interactive analysis of service options for Alternative 1 was the testing of different mixes of service types, levels of service, and service patterns on segments of railroad and at locations that have constrained capacity and where considerable investment is required to increase capacity.

For **Alternative 2**, which *grows* the role of rail in urban area travel relative to highway and other transit modes, a broader array of improvements were identified, including increasing the frequency of service, extending the duration of the peak periods and operating windows for off-peak service, and reducing trip times through the introduction or expansion of zone-express service. A set of general service standards at Regional rail stations was used to guide the development of future service targets for the *Grow* vision:

- Peak-hour service on lines with relatively heavy ridership demand at 4 tph
- Peak-hour service on lines with relatively less ridership demand, including lighter density branch lines and the portions of the NEC at the extremities of regional commuting territory, at 2 tph, tapering to 1 tph during peak shoulder hours
- Reverse-peak service on all NEC services and branch lines at 2 tph
- Off-peak service at 2 tph on heavily utilized lines and 1 tph on light density lines, coupled with weekend service where practical and appropriate

Where Regional rail service currently is provided only as all-stop local service, service zones comprising groups of adjacent stations were created to enable the introduction of zone-express service at peak periods. Where zone-express service already exists, consideration was given to increasing the number of zones, in order to improve trip times for stations in the outer zones.

Metropolitan service also is introduced along the NEC in Alternative 2 at 4 tph, providing an additional option for limited-stop service at existing and potential Hub stations. Service Plans were tested and ridership estimates obtained for scenarios that both included and excluded Metropolitan service in the regional travel markets. Metropolitan service helps to distribute passenger loads in certain Regional rail markets.

In **Alternative 3**, which seeks to *transform* the role of rail within the NEC Study Area, determining those characteristics of a future Regional Rail service that might be transformative is challenging, since Regional rail service patterns for Alternative 3 bear a strong resemblance to those developed for Alternative 2. Providing service that is frequent, highly reliable and available at all times of day is a prerequisite. Additional benefits offered in Alternative 3 are extensions of Regional rail service territories, expansion of non-journey-to-work trip opportunities, and faster trip times for longer commutes where Regional rail trains can share the new high-speed tracks with Intercity trains.

[21] This memorandum focuses on passenger rail Service Plans. Associated infrastructure requirements are summarized in the *Tier 1 Alternatives Report*.

Some concepts that were tested in Alternative 3 that push the envelope of what Regional rail can do to influence trip-making include:

- Operation of transit-style service on the portions of the railroad network through city centers (i.e., close headways, all-stop local service, and fares comparable to local transit fares), to expand the reach and capacity of urban transit networks and relieve crowding on congested parallel transit lines
- Through-running service at major regional stations/terminals to better connect regional sub-centers
- Operating new Regional rail express services from outer suburban areas to regional centers, using the inner portions of new high-speed rail routes to dramatically shorten commute times for longer-distance work trips
- Significant expansion of off-peak and weekend service to open up rail travel and capture a wider array of trip purposes

Specific issues that were considered and addressed in each of the Regional rail service territories of the NEC as Service Plans were developed and refined are summarized below.

4.3.1 Greater Washington, D.C., and Maryland

MARC and the Virginia Railway Express (VRE) provide Regional rail service to Washington Union Station from five branch lines serving suburban Maryland and northern Virginia. Current service is concentrated during the weekday morning and evening peak periods, with two to three trains per hour serving each branch line. The MARC Penn Line, which operates over the NEC in Maryland, provides hourly service during weekday off-peak hours, and weekend service was initiated on the line in 2014. The No Action Alternative retains the current level of service through 2040.

VRE and the MARC Brunswick and Camden Lines are the only Regional rail services touching the NEC that currently operate with very limited reverse-peak and off-peak service. With high growth in Regional rail travel in the greater Washington, D.C., region projected through 2020, all of the Action Alternatives increase the quantity of service and expand these Regional rail systems to bi-directional rather than peak-focused service and extend service into off-peak periods beyond the commuter rush hours.

Two sources were tapped containing information on potential future Regional rail service in Maryland: the MARC Growth and Investment Plan, with projections of service for 2030 and 2050, and the Washington Union Terminal Master Plan, which included service growth assumptions for 2020, 2025, and 2030. These plans provided a range of Regional rail service levels, which were tested for their ridership potential.

4.3.1.1 Penn Line (NEC Spine)

The No Action Alternative retains the existing Penn Line train schedule. Some peak-period Penn Line trains are at their maximum length given station platform lengths and the hauling capabilities of the MARC diesel locomotives. Other trains can be lengthened to provide capacity for growth, but these opportunities are limited and cannot keep up with the pace of expected demand given projected population and employment growth in the region.

With construction of a fourth main track on the NEC between Odenton and West Baltimore in Alternative 1, MARC is able to run Regional rail service at more regular headways between Baltimore and Washington, D.C. than in the No Action Alternative, where southbound Regional rail trains must be scheduled around Intercity services on a single main track. The fourth track increases the number of slots available for Regional rail trains and provides the Regional rail operator with greater scheduling flexibility. All of the Action Alternatives include the planned extension of MARC service to Elkton and Newark, DE (2 tph during peak period, with a zone-express stopping pattern).

Alternative Service Plans were tested for Maryland Regional rail service on the Penn Line that provide 8, 10, or 12 trains in the weekday peak hour and peak direction. Each plan divides the line into either two or three service zones. In all three scenarios, Regional rail stations between Martin Airport and Washington, D.C., receive peak service with at least 4 tph, and an outer zone-express service operates at 2 tph. Options for the core Baltimore-to-Washington, D.C., service in Alternative 1 includes a Martin Airport-to-Washington, D.C., local train at 4 tph, or a pattern with two inner zones comprising a Baltimore-to-Washington, D.C., local service and a Martin Airport-to-BWI Airport zone-express service each operating at 2 tph. Initial ridership estimates favored the latter scenario, with 6 tph in the peak hour, which was selected by the FRA to represent Alternative 1.

Given the relatively robust growth in Regional rail demand, the Service Plan with three service zones and a total of 10 tph in the peak hour and peak direction at the screenline north of Washington, D.C. was selected by the FRA to represent Alternative 2. In addition, Metropolitan trains provide additional capacity for commuters from Newark, DE and Aberdeen, MD to Baltimore, BWI Airport and Washington, D.C. The relatively fast trip times make these Metropolitan trains attractive for longer-distance commuters. Also, more robust reverse-peak service to both serve the reverse-commute market to strong employment centers near Odenton, BWI Airport, Baltimore and Aberdeen, and to enable cycling of equipment to make additional peak period trips is provided. Off-peak service is increased to 2 tph between Washington, D.C., and Martin Airport, with an outer zone-express train provided at 1 tph serving stations between Baltimore and Newark, DE.

For Alternative 3, the FRA selected a Service Plan providing full Regional rail service on the Penn Line, with three service zones each operating at 15-minute headways (4 tph) in the peak hour and peak direction. This level of service through Baltimore at 5-minute headways during the peak hour effectively provides a new rail transit line through Baltimore[22] on the route of the NEC. Alternative 3 introduces transfers between the Penn Line and the existing Baltimore (MTA Maryland) METRO line[23] and other proposed rail transit lines at multiple locations.

[22] The full ridership effects of transit operations within Baltimore were not modeled. Incremental ridership benefits of such service are assessed qualitatively.
[23] Requires construction of one or two new transfer stations at the point(s) where the METRO and rail lines cross. These new stations are not precluded by Alternative 3, but they are not explicitly included in the definition of

4.3.1.2 Camden and Brunswick Lines

These two MARC Lines operate principally on CSX-owned rail lines and join with the NEC within the limits of Washington Union Terminal. These lines share station platforms and facilities at Washington Union Station with the Penn Line, as well as with Amtrak and VRE.

Alternative 1 includes modest increases in peak and reverse-peak frequency. Off-peak service remains limited, given the difficulty and cost associated with obtaining access to the freight rail lines on which these services operate (1-2 midday roundtrips on each line).

In Alternative 2, Camden Line service increases to 3 tph in the peak hour, 2 tph for reverse-peak and peak shoulder hour service, and bi-hourly off-peak service. Brunswick Line service increases to 6 tph in the peak hour (three services at 2 tph each: Martinsburg zone-express, Brunswick local, and a Frederick limited-stop service – which together provide peak service at 4 tph at all major stations between Brunswick and Silver Spring), with reverse-peak service and bi-hourly off-peak service to Frederick.

Alternative 3 retained the same peak service as in Alternative 2, with reverse-peak service at 2 tph and hourly off-peak service.

4.3.1.3 Virginia Regional Rail

Virginia Railway Express (VRE) currently operates on two lines that converge at Alexandria, VA, and run to Washington, D.C., via the Long Bridge across the Potomac River and the First Street Tunnel, into the lower level platform tracks on the east side of Washington Union Station. The VRE System Plan, updated in 2014, was the principal source of information about future VRE levels of service at Washington Union Station. The System Plan included both medium-term (c.2030) and long-range (c. 2040) Service Plans. The medium-term plan operates 3 tph from each line in the peak hour and peak direction (6 tph total). An extension off the Manassas Line to Gainesville and Haymarket in western Prince William County, VA is included, with relatively limited service. The medium-term plan also includes limited reverse-peak service (bi-hourly), with no off-peak service. A slightly more robust version of this plan included hourly reverse-peak service and bi-hourly off-peak service on each line.

The VRE long-range plan, with a horizon year of 2040, increases peak hour service to 4 tph in the peak direction on each line (8 tph total), include full peak-direction service on the Manassas Line (2 tph from both of the Haymarket and Broad Run branches, with 4 tph at primary stations inboard of Manassas). The long-range plan includes reverse-peak service at 2 tph to both Fredericksburg and Haymarket, as well as off-peak service at 2 tph on both lines.

The No Action Alternative retains the existing VRE train schedule. Alternative 1 is based on the medium-term plan for VRE (6 tph in the peak hour, peak direction at Washington), with the more limited reverse-peak service and no significant off-peak service. Alternatives 2 and 3 include the full

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Alternative 3 and will be the subject of subsequent comprehensive local transit planning studies to determine the potential effectiveness of regional transit service on the railroad and associated multimodal network connections.

long-range plan for 8 tph in the peak hour, peak direction. Alternative 2 assumes limited reverse-peak and off-peak service. Alternative 3 assumes the full long-range plan with robust reverse-peak and off-peak service (2 tph on each line) and the introduction of weekend service.[24]

4.3.1.4 Greater Washington, D.C. and Regional Rail Rolling Stock

The FRA based all three Action Alternatives on the same assumptions with respect to train equipment. All services operate with locomotives and coaches in a push-pull configuration (i.e., the trains can be operated with the locomotive at either the front or the rear of the train, with the engineer positioned either in the locomotive or in a cab control car at the opposite end). The Service Plans for Penn Line service on the NEC, selected by the FRA to represent the Action Alternatives, were based on Regional rail trainsets made up of coaches hauled by electric locomotives. The Camden, Brunswick, Fredericksburg and Manassas Lines were assumed to continue to operate with diesel locomotives. Since NEC FUTURE does not prescribe the extent or type of service to be provided by regional operators, the FRA analyzed alternative service plan scenarios for the Penn Line based on the use of diesel locomotive-hauled trains for Regional rail trains, but with the same infrastructure configuration. Because trains with diesel locomotives generally accelerate more slowly than those with electric locomotives, the Regional rail stopping patterns required adjustments to avoid train movement conflicts, particularly during the standard peak hour. In these cases, peak service can be provided at levels that meet the demand for rail service in 2040, but with less regular service patterns and less scheduling flexibility for Regional rail service.

4.3.2 Delaware and Pennsylvania South of Philadelphia

4.3.2.1 Wilmington-Newark Line

The Wilmington-Newark Line of SEPTA currently provides service to Center City Philadelphia from two *de facto* zones, marked by the Delaware-Pennsylvania state line: local service to and from Marcus Hook, the last station in Pennsylvania; and service to Delaware, with some trains turning at Wilmington and others turning at Newark, DE. The latter service is financially supported by the State of Delaware. Most trains operate as all-stop locals, though selected Newark trains in the peak periods make limited stops in Pennsylvania. Ridership demand growth through 2040 is projected to be smaller on this line than in other locations, such as New York or Washington, D.C. The greatest growth is projected from the Delaware markets, and Delaware intends to increase the frequency of service and reduce the number of intermediate stops to improve trip times.

The No Action Alternative retains the existing SEPTA train schedule. Three service concepts were analyzed for this line to represent the Action Alternatives, all of which provide for increased service and improved trip times from the Delaware stations to Philadelphia. The first concept retains the Marcus Hook and Wilmington local services and increases the frequency and expand the time

[24] NEC FUTURE Service Plans were developed for an average weekday. Regional rail ridership also was estimated for an average weekday in 2040. Weekend service was not modeled explicitly. Assumptions about the level of weekend service were embedded in the factors used to convert average weekday ridership into estimated annual ridership, which were based on the historical factors for Regional rail systems in the NEC study area that currently operate weekend service.

windows of the Newark-Philadelphia zone-express service. The second concept creates a clear distinction between the Pennsylvania and Delaware services, creating a grade-separated turnback facility at Marcus Hook for inner zone services, and overlaying Delaware zone-express services from Newark and Wilmington. A third concept was examined that creates three service zones. While not driven by high ridership demand, these zones take maximum advantage of rail infrastructure planned as part of Alternatives 2 and 3 to minimize train operating conflicts at the capacity-constrained Wilmington Station and at locations where inner zone trains lay over and change direction. In this concept, the inner zone for local service ends at a new Regional rail station at Baldwin. A middle zone is created between Baldwin and a planned new station at Edgemoor, DE, just short of the Wilmington Station. Turning Regional rail trains at this location, where the local tracks are side-by-side, reduces the number of trains on the single local track at Wilmington Station and avoid crossing conflicts with trains on the express tracks. The third zone serves the stations between Wilmington and Newark, and provides express service between Wilmington and Philadelphia (including the potential to directly serve the Philadelphia International Airport in Alternative 2).

The capacity for additional service on the Wilmington-Newark Line is available to accommodate long-term growth in the demand for rail service. It also will help mitigate impacts associated with future lane closures on Interstate 95 (I-95) in Delaware County, PA, when it is reconstructed at some point in the future.

4.3.2.2 MARC and SEPTA Service in Delaware

NEC FUTURE considered the potential for integration of MARC and SEPTA Delaware service, creating a single through-running Regional rail line in lieu of two separate services that both terminate at Newark, DE. Service integration is operationally efficient and reduces the physical footprint of the station at Newark and any train storage facilities at Newark. Integration of service, however, raises issues associated with rolling stock compatibility (electric equipment is necessary for operations through the tunnels in Center City Philadelphia), train consists (MARC trains typically have more coaches than SEPTA trains), institutional and contractual requirements, and the inherent reliability of a single Regional rail service that operates over such a long route. The size of the ridership markets in this area are small relative to other service zones along the NEC, so the benefits of integrated operations are marginal from a ridership standpoint. Therefore, the NEC FUTURE Action Alternatives are based on continuation of separate Washington, D.C., and Philadelphia-oriented Regional rail operations and provide for the required terminal facilities at Newark, though there is nothing in the NEC FUTURE service or infrastructure plans that precludes integrated operations, should they be deemed warranted. Metropolitan service provides an additional 2–4 tph, stopping at several stations between Philadelphia and Washington, D.C., to stations that are only served by Regional rail today.

4.3.3 Pennsylvania North of Philadelphia

SEPTA service along the NEC on the north side of Philadelphia includes two branch lines: the Trenton Line, which operates entirely along the NEC, and the Chestnut Hill West line, which branches off the NEC at North Philadelphia. Ridership demand growth is projected to be smaller on these Regional rail lines than in other locations, such as New York or Washington, D.C. Existing trains also are relatively short, and additional cars can be added relatively easily to increase available seating capacity. Nevertheless, NEC FUTURE allows for increases in service frequency on these lines, which can be accommodated on the local tracks of the existing four-track corridor without constraining the projected growth in Intercity service operating on the express tracks. In addition to providing for future demand growth, increased service on the Trenton Line will help mitigate impacts associated with I-95 reconstructions over the next two decades.

The Trenton Line currently operates with all local service, at frequencies of up to 4 tph in the peak hour, with half-hourly reverse-peak and hourly off-peak service. This level of service is retained in the No Action Alternative and in Alternative 1. In Alternatives 2 and 3, consideration was given to introducing inner and outer service zones, to shorten trip times from the outer zone to Philadelphia. This introduces the need to create a grade-separated intermediate turnback location, since one does not currently exist. A better option results in the introduction of a limited-stop train that operate on the local tracks in the slots between the all-stop locals and serve the stations on the line with the highest ridership and greatest parking capacity. Slots were available to run these trains at 4 tph, but demand was estimated to support service at 2 tph, which became the level of service carried forward for Alternatives 2 and 3. These limited-stop slots turned out to have two useful functions. In the peak direction, for Philadelphia commuting (south in the morning, north in the afternoon), these trains run between Trenton and Philadelphia. In the peak direction for New York commuting, these trains originate in Philadelphia in the morning and run through Trenton to serve the outer zone for Regional rail in New Jersey (Trenton through North Brunswick) and then operate express to Penn Station New York. They return to Philadelphia in the evening, providing a one-seat ride Regional rail option for commuters to New York from all of the Regional rail stations on the line in Philadelphia and Bucks County, PA. – not just the two stations served by Metropolitan trains (North Philadelphia and Cornwells Heights). These trains also are needed for the regional travel market in New Jersey, to supplement Regional rail zone-express service to New York stations from the outer zone on the Northeast Corridor Line in New Jersey.

Chestnut Hill West service currently operates at 2 tph in the peak hours. This level of service was retained in the No Action Alternative and Alternative 1, and peak service was increased to 4 tph in Alternatives 2 and 3.

4.3.4 New Jersey and Hudson River Crossing

The capacity of the existing Hudson River tunnels is effectively fully utilized during the weekday peak hours in the peak direction of travel. There is no room to add significant numbers of new trains, and most trains are at or close to their maximum lengths given constraints on station platform lengths, yard space and locomotive hauling capacity. The No Action Alternative, therefore, which retains the existing train schedule, is severely constrained in terms of ridership growth potential, and this alternative is unable to maintain rail’s share of trans-Hudson travel in the face of the projected 30- to 40-percent increase in trans-Hudson travel demand projected by 2040.

The Action Alternatives add new tunnel capacity across the Hudson River. Two new tunnel tracks are added in Alternatives 1 and 2, effectively doubling current capacity. Alternative 3 provides an additional pair of rail tunnels from New Jersey to Midtown Manhattan for a total of six. In each of these Action Alternatives, ridership estimates have demonstrated that there is sufficient ridership demand in 2040 to fill all of the peak Regional rail trains that fit within available capacity – and the trans-Hudson bus and PATH services remain oversubscribed. Consequently, service planning for New Jersey Regional rail focused on enabling maximum utilization of the available rail infrastructure capacity, in combination with the growth in Intercity passenger service specified for each alternative. The Alternative 1 Service Plan provides 30 tph in the standard peak hour crossing the Hudson River, an increase of slightly more than 40 percent over the current level of 21 tph. Alternative 2 provides 42 tph at the Hudson River screenline, fully utilizing the two pairs of tunnels and representing a doubling of peak-hour service compared with the No Action Alternative. Alternative 3 provides Regional rail service at up to 54 tph in the standard peak hour and peak direction across the Hudson River, supplemented by Metropolitan service at 8 tph, fully utilizing the three pairs of tunnel tracks from New Jersey to Manhattan that are included in this alternative and allowing for growth in Intercity service. The ridership estimates indicated a high level of utilization of these Regional rail services in the peak periods in all alternatives, along with continued growth in trans-Hudson travel by other modes, reinforcing the decision by FRA to develop Service Plans for Regional rail in Alternatives 2 and 3 that fully utilize the available tunnel and New York terminal capacity.

4.3.4.1 Standard Slots for Local and Express Services

With three distinct Regional rail service zones on the NEC in New Jersey, plus multiple Regional rail branch lines potentially feeding the NEC at various locations, there are many possible service patterns and concepts that can be developed to fit within the available Hudson River tunnel capacity. NJ TRANSIT identified potential future service levels by branch line, and initial travel demand estimates provided a sense of the projected magnitude of travel growth within the catchment areas of the NEC service zones and branch line service territories. These inputs provided guidance for the development by the FRA of representative Regional rail Service Plans for the Action Alternatives. The FRA tested several concepts for operating Intercity and Regional rail service together on the NEC, to find those that were able to use rail infrastructure most efficiently and provide the greatest ridership potential. The most productive concepts utilized regular Regional rail stopping patterns aligned on repeating 15- and 30-minute intervals in the standard peak hour, which can be synchronized with the Intercity patterns that also followed the same repeating intervals. This led to the development of Service Plans that identified an array or catalogue of standard slots on the express and local tracks of the NEC that encompassed all of the stopping patterns necessary to meet the service standards for each service zone or branch, while not dictating the precise mix of patterns and level of service for each of the branch lines. These standard slots repeated at either 15- or 30-minute intervals. Actual trains can occupy either an entire slot or a portion of the slot by joining/leaving the line at an intermediate point. Benefits of developing a service plan based on a standard slot catalogue include the following:

- Scheduling flexibility for the Regional rail operator in the development of branch-specific train schedules
- Maximizes practical capacity by standardizing stopping patterns and operating speeds
- Demonstrates operational feasibility without prescribing a particular configuration and level of branch line service.

The service planning objective was to develop standard slots or train paths over as long a portion of the corridor as practical. After some initial evaluation, it was found that the zone between Newark Liberty Airport and Penn Station New York was the most appropriate territory over which to provide the standard slot catalogue. Specific Service Plans and stopping patterns were developed for the remainder of the NEC in New Jersey, between Newark Liberty Airport and Trenton.

To better understand the impact on capacity through use of a standard slot catalogue, the FRA developed an illustrative Service Plan for the four-track NEC main line in northern New Jersey connecting to the four Hudson River tunnels that are provided in Alternatives 1 and 2. In this example, the express tracks between Newark Airport and the Hudson River connect into the existing Hudson River tunnels, and the local tracks connect into the new third and fourth Hudson River tunnels. [25] This example is not intended to be prescriptive, and other service plans could prove equally or more efficient or offer a better mix of services to the regional travel markets.

For this example, the standard slots on the local tracks followed an identical pattern of stops and were spaced to deliver 28 tph to the new tunnels, which was estimated to be the practical capacity of the tunnel and associated station complex in New York configured for through-running service (as in Alternative 2). Figure 8 shows the catalogue of available slots. All trains in these slots on the local tracks stopped at Newark Airport, Newark Penn Station and Secaucus, enabling trains to be operated at two-minute headways. Figure 9 presents an example of how the local track slots might be utilized in the evening peak service plan for Alternative 2. This is only one of many possible ways in which the standard slots can be utilized, and is presented here for the purpose of explaining the concept of a standard slot catalogue, not to imply any particular preference with respect to actual service patterns. In this sample case, southbound trains were deployed as follows:

- 2 tph – Trenton locals from Penn Station New York
- 4 tph – North Jersey Coast Line locals from Penn Station New York (exiting at Union Junction)
- 6 tph – North Jersey Coast Line zone-expresses from Penn Station New York (2 exiting at Union Junction and 2 shifting to the express tracks at Newark Airport)
- 16 tph – "Standard" local slots for inner branch line services – these can be deployed in multiple ways; one possible allocation is as follows (shown in Figure 8 for purposes of illustration):
  - 5 tph – Main, Bergen and Pascack Valley Line trains from Penn Station New York (exiting the local tracks at Secaucus via the Bergen Loop connection)
  - 8 tph – Morris and Essex Line and Montclair-Boonton Line trains from Penn Station New York (exiting the local tracks at Swift Junction west of Secaucus)

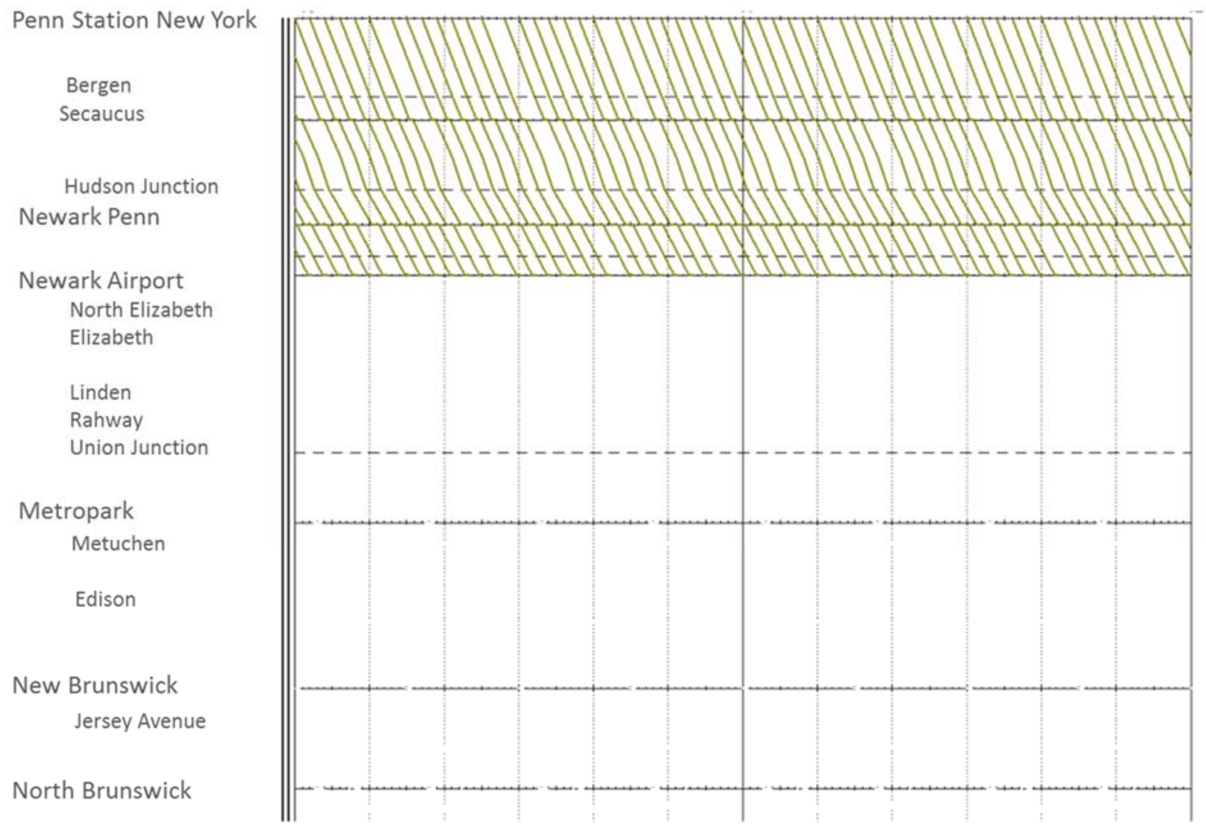
[25] Other feasible scenarios could route Intercity-Express and Metropolitan trains to new tunnel tracks and use the existing tunnels to accommodate Regional rail service growth. NEC FUTURE is not prescriptive with respect to future operating plans for rail traffic through New York, and Tier 2 studies subsequent to NEC FUTURE will determine the specific configuration of tunnels, tracks, station facilities and yard facilities to be provided in the New York area – and how they will be operated.

- 3 tph – Raritan Valley Line trains from Penn Station New York (exiting the local tracks at Hunter Junction west of Newark)
- 3 tph – Raritan Valley Line trains from Hoboken (entering at Hudson Junction in Kearny, NJ and exiting at Hunter Junction – these trains occupy the same slots as Main-Bergen-Pascack or Morris & Essex trains, which vacate the slots prior to Hudson Junction)
- 2 tph – North Jersey Coast Line Bay Head trains from Hoboken (entering the local tracks at Hudson Junction in Kearny, NJ and shifting to the express tracks at Newark Airport – these trains occupy the same slots as two Main-Bergen-Pascack trains, which vacate the slots at Secaucus)

The standard slot patterns for the local trains do not include any extra or ’phantom’ slots to protect late Regional rail trains. However, the hourly throughput of 28 tph represents a conservative estimate of practical capacity. The signal system design accommodates train movements at up to 31–32 tph, with all trains retaining the same standard stopping pattern. As a result, headways can be reduced to accommodate denser train movements when necessary to recover from train delay conditions. This ability to recover from delays, and to operate trains in any sequence with a standard stopping pattern, is a significant benefit associated with the concept of standardized stopping patterns. The provision of phantom slots is a more appropriate concept where stopping patterns are varied.

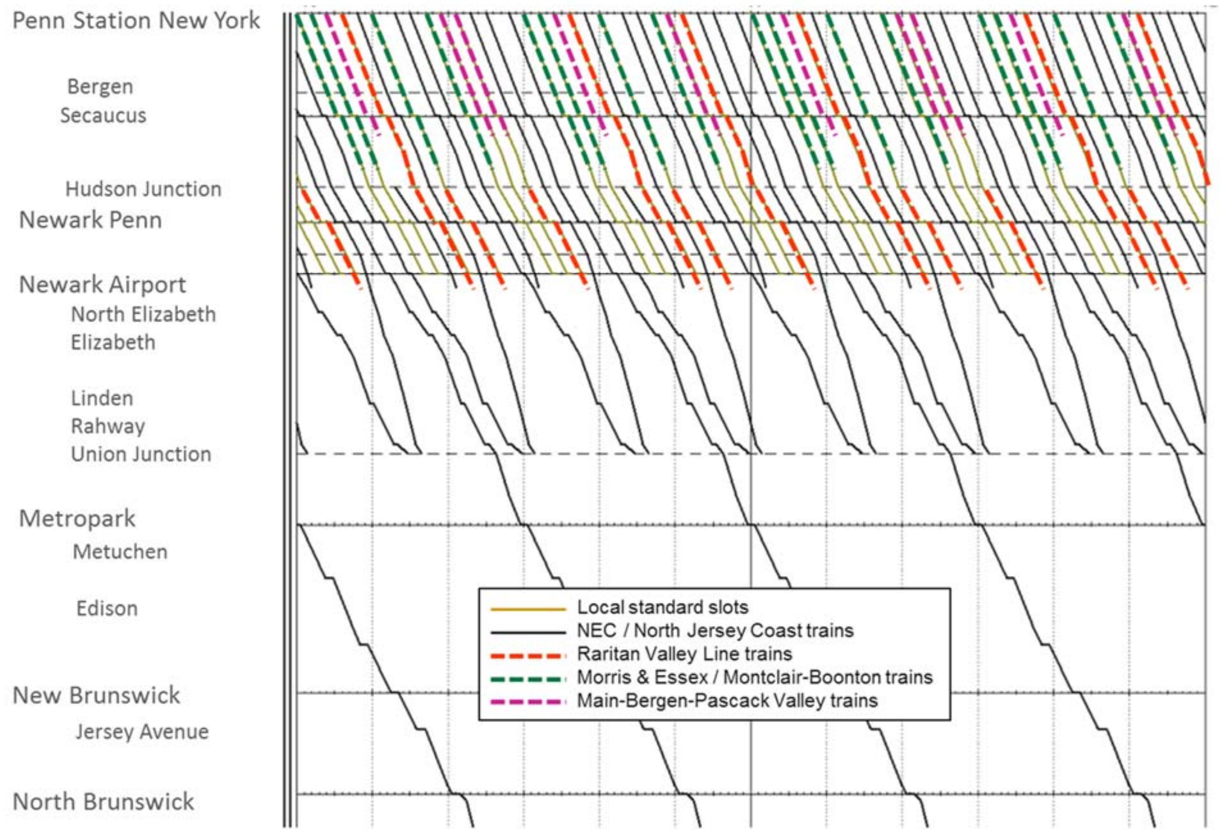
While the example described above illustrates how standard slots can be used in practice, the value of the standard slot catalogue lies in its inherent flexibility—its ability to support any combination of trains using the standard slots that are supported by the railroad infrastructure.

Figure 8: Illustrative Standard Slots on Local Track (New Jersey and Hudson River Crossing)



Source: NEC FUTURE team, 2015

Figure 9: Illustrative Utilization of Local Track Slots (New Jersey and Hudson River Crossing)



Source: NEC FUTURE team, 2015

The standard slots on the express tracks provided three different stopping patterns that were overlaid with each other in an overall pattern that repeated every 15 minutes and provided a total level of service of 26 tph, close to the estimated practical capacity of the existing Hudson River tunnels. Shown in Figure 10, these included the following pattern categories:

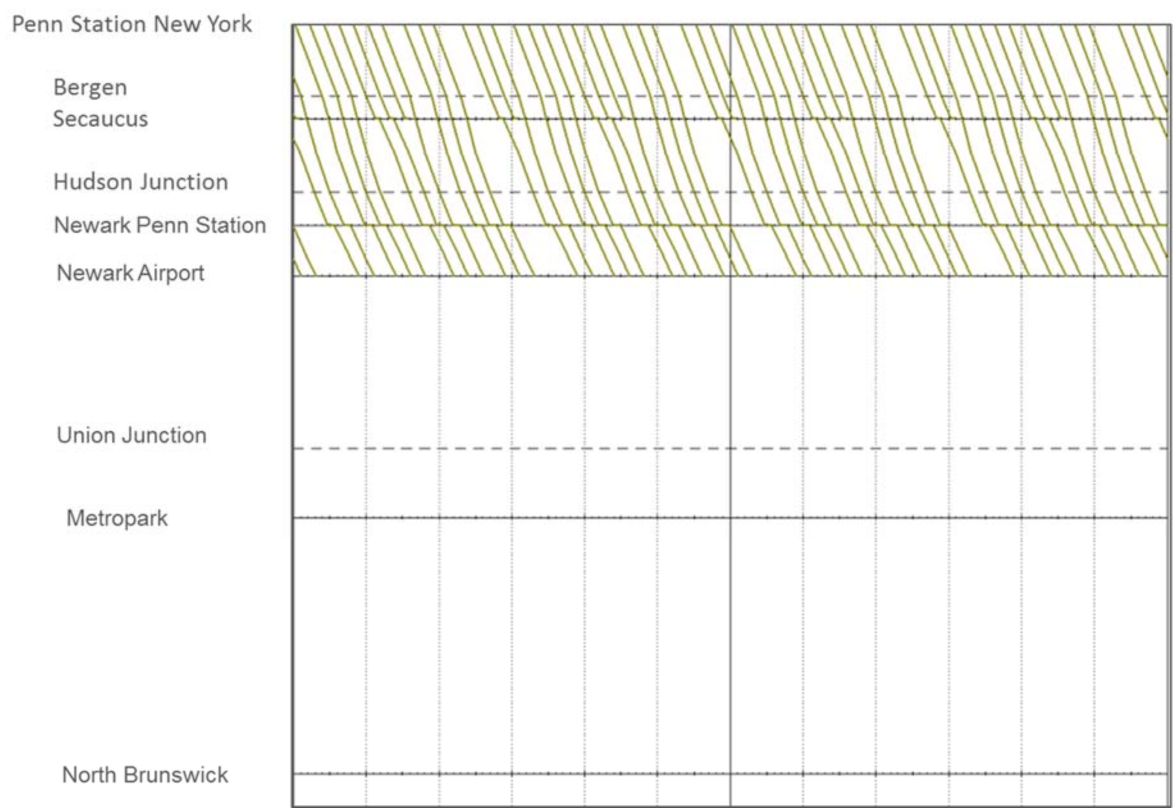
- 12 slots with patterns that stopped only at Newark Penn Station
- 8 slots that included stops at both Secaucus and Newark Penn Station
- 4 slots that existed only between Penn Station New York and Secaucus

Figure 11 illustrates how these slots were deployed for southbound trains in an evening peak-hour service plan for Alternative 2:

- 4 tph, Pattern #1 – Intercity-Express
- 4 tph, Pattern #1 – Metropolitan service

- 4 tph, Pattern #1 – Intercity-Corridor slots for off-corridor trains (two of which are filled with trains, and two of which are "phantom" slots reserved for accommodating late Intercity-Corridor-Other or Long-Distance trains)[26]
- 6 tph (4 tph in Pattern #1, 2 tph in Pattern #2) – Trenton outer zone-expresses
- 4 tph, Pattern #2 – North Brunswick middle zone-expresses
- 4 tph, Pattern #3 – Main, Bergen and Pascack Valley Line to Penn Station New York (exiting at Secaucus)

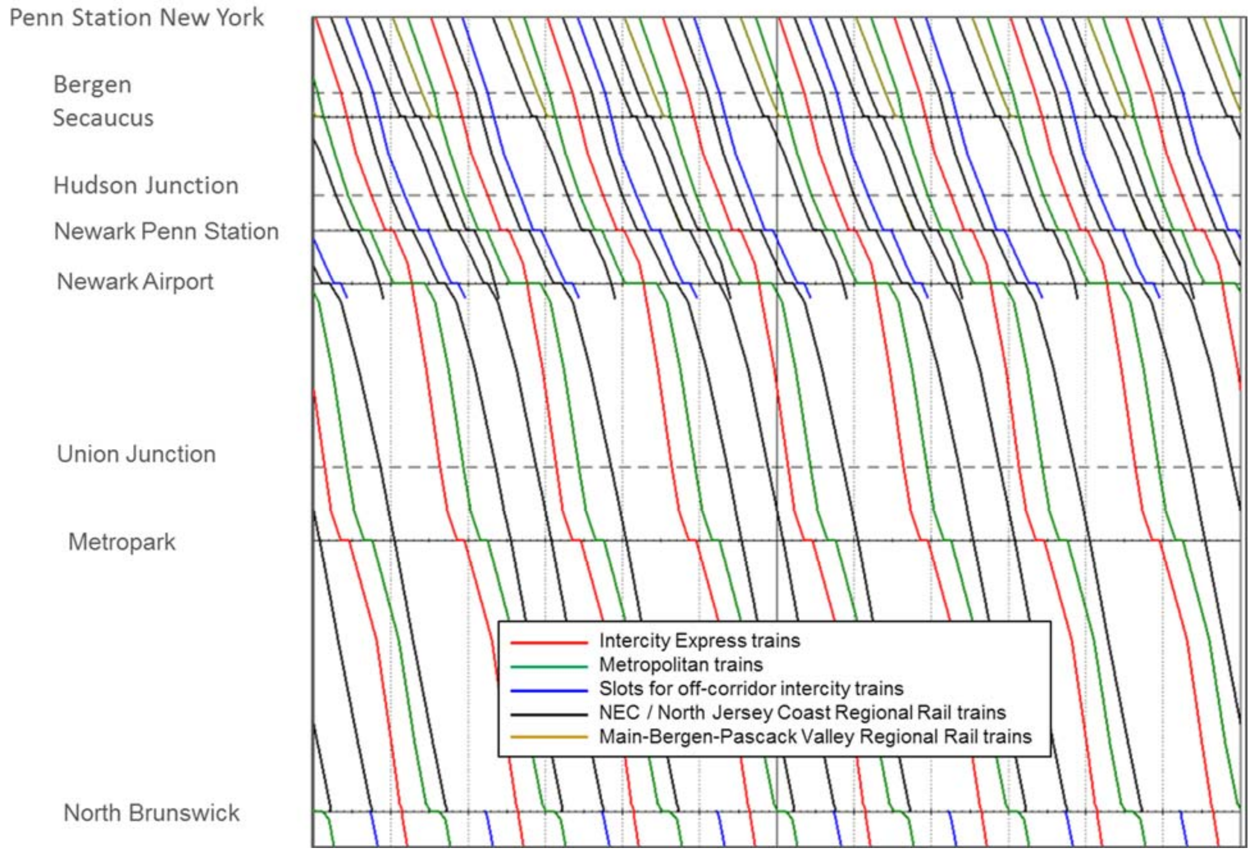
Figure 10: Illustrative Standard Slots on Intercity-Express Tracks (New Jersey and Hudson River Crossing)



Source: NEC FUTURE team, 2015

[26] These trains disappear from the express track stringline diagram south of Newark Airport, because they move to the intermediate tracks on the six-track section of railroad between Elizabeth and Rahway, NJ.

Figure 11: Illustrative Utilization of Intercity-Express Track Slots (New Jersey and Hudson River Crossing)



Source: NEC FUTURE team, 2015

4.3.4.2 Hoboken Service

NEC FUTURE does not explicitly involve developing Service Plans or train schedules for New Jersey Regional rail services to and from Hoboken Terminal that do not travel along any portion of the NEC. For purposes of developing ridership estimates, these Hoboken-oriented services—which operate on the Morris and Essex, Montclair-Boonton, Main, Bergen and Pascack Valley Lines—were assumed to remain similar to current levels of service.

The Service Plans for the No Action and Action Alternatives do include Bay Head trains from the North Jersey Coast Line that serve Hoboken. The Action Alternatives also include trains from the Raritan Valley Line serving Hoboken, taking advantage of the conflict-free track connections at both Hunter and Hudson Interlockings that are provided in all Action Alternatives.

4.3.4.3 Metropark, North Brunswick, Trenton and Philadelphia Service

Early regional travel demand model results indicated very high existing ridership demand and projected growth from this territory, particularly the middle and outer zones between Metropark and Trenton. This is the only territory on the NEC where inherent ridership demand is projected to exceed what can be carried on four full-length trains per hour, with the current configuration of service zones. The Service Plans for each of the Action Alternatives, therefore, provide extra trains in the standard peak hour serving this territory, including middle zone (Metropark-North Brunswick) and outer zone (North Brunswick-Trenton) service at a minimum of 4 tph, an all-stop Trenton local service at 2 tph, and an additional outer-zone express service at 2 tph that originate in Trenton in Alternative 1 or in Philadelphia in Alternatives 2 and 3 to provide a one-seat ride to New York from the relatively small but growing commuter market to New York from Philadelphia and Bucks County, PA. This increased level of traffic depends upon chokepoint relief projects at both North Brunswick (Mid-Line Loop) and Trenton to keep trains running smoothly at higher densities.

4.3.4.4 Bergen and Passaic Service

A strong ridership market has been identified for trans-Hudson trips to Manhattan from Bergen and Passaic Counties in northeastern New Jersey and the New York west-of-Hudson counties of Rockland and Orange. The Bergen Loop project is designed to provide one-seat-ride access to Penn Station New York from the Main, Bergen and Pascack Valley Lines of NJ TRANSIT and the Port Jervis Line (operated by NJ TRANSIT on behalf of the MTA), which serve these growing suburban counties, via a direct track connection at Secaucus. Passengers currently can transfer to Penn Station-bound trains at the Secaucus Junction Station. In Alternative 1, which maintains the current role of rail in the region, the ability to transfer to a wider selection of Penn Station trains is retained, but the direct track connection is not provided. Direct rail service from the northern New Jersey lines via the Bergen Loop is assumed in Alternatives 2 and 3. The capital project to construct the loop connection is identified as a Related Project in the No Action Alternative Report[27] and is not included in the capital cost of rail improvements to the NEC, since it exclusively serves Regional rail branch lines.

4.3.5 Long Island, Queens, Bronx and East River Crossing

The East River screenline is the one location on the NEC that sees a significant increase in service in the No Action Alternative, as compared with existing conditions. This is due to completion of the LIRR East Side Access project, which will open a new tunnel connection from the LIRR to Grand Central Terminal with capacity for an additional 24 tph in the peak hour and peak direction of service. This allows 60 tph in the peak direction for Regional rail service across the East River to or from Penn Station and Grand Central Terminal. As described in the *No Action Alternative Report*, the No Action Alternative does not include the introduction of train service from the New Haven Line and East Bronx to Penn Station. Such service, however, for planning purposes, was incorporated into the operations modeling in each of the Action Alternatives.

4.3.5.1 Standard Slots in the East River Tunnels

The Action Alternatives identify a number of train slots available for Regional rail services in the standard peak hour crossing the East River to and from Penn Station. These include slots for LIRR main line and Port Washington Branch trains serving Penn Station. The MTA has programmed funding for Penn Station Access in its 2015-19 budget, and the Governor of New York State has set aside funding for new stations on the Hell Gate Line as part of the Penn Station Access program.

[27] [Add correct citation for No Action Alternative report]

With these improvements, standard slots could also be provided for Regional rail trains from the Bronx, Westchester, and Connecticut. Slots for non-revenue trains operating without passengers (sometimes referred to as deadhead trains) between Penn Station New York and Sunnyside Yard also are accounted for in the screenline capacity analysis, ensuring that train service remains within available practical capacity. However, tables summarizing the train movements associated with the Service Plans do not include deadhead (non-revenue) trains unless explicitly identified.

Alternatives 2 and 3 include additional rail tunnels beneath the East River and, for planning purposes, provide sufficient capacity to accommodate up to 50 Regional rail trains per hour at Penn Station New York from Long Island and potentially from the New Haven Line and East Bronx.

Alternative 1 is limited to the existing four East River Tunnels, plus the LIRR East Side Access project. The peak-hour, peak-direction capacity of the East River Tunnels in this alternative is assumed to be approximately 48 tph,[28] accommodating Intercity and Regional rail service to Penn Station New York. For planning purposes, six slots per hour are allocated to Intercity trains in the standard peak hour, leaving 42 slots for the regional rail markets.

Alternative 2 adds a fifth and sixth East River tunnel and avoids the need to substantially increase the capacity of the existing tunnels. Overall, East River crossing capacity increases to approximately 68 tph in the peak direction for both Intercity and Regional rail services. For planning purposes, with 10 slots allocated to Intercity services, the remaining 58 slots are sufficient to meet the maximum planned service for Regional rail service, with eight excess slots remaining available for additional new services, if warranted by demand.

Alternative 3 includes the same number of East River tunnel tracks as Alternative 2, but the second spine route north of New York increases the number of Intercity trains to as many as 18 tph in each direction during peak hours. With the same capital improvements to the signal system and interlocking on the existing tunnel routes, total East River crossing capacity to and from Penn Station New York increases to 76 tph, including the same East River tunnel capacity improvements that are included in Alternative 1, and the same overall peak capacity of 58 tph remains available for Regional rail services to Penn Station. As in Alternative 2, for planning purposes up to eight slots per hour are available for additional Regional rail service. In Alternative 3, this additional capacity was allocated to Regional rail service from the outer service zones of the LIRR, but could also be utilized for trains from Metro-North's upper Hudson Line if the New York-Danbury-Hartford route option were selected; these trains fill available capacity on the high-speed second spine into Manhattan and offers substantially reduced trip times to Penn Station New York (Table 5).

[28] This represents an increase in peak capacity through the existing tunnels from the 40 tph that corresponds to existing service and the 2040 No Action Alternative. The increase in capacity is assumed to be achieved through a combination of signaling, track alignment and interlocking improvements within the tunnels, at Penn Station New York and in western Queens.

Table 5: Trip Times for Outer Zone Regional Rail Express Services (existing routes versus new service via high-speed second spine routes (Alt. 3))

Selected Stations	Route	Minimum Trip Time (Hrs:Min)
Ronkonkoma	Existing LIRR to Penn Station New York Via High-Speed Tracks to Penn Station New York	1:09 :56 (zone exp.) :45 (express)
Pt. Jefferson	Existing LIRR to Penn Station New York Via High-Speed Tracks to Penn Station New York	1:36 1:00
Patchogue	Existing LIRR to Penn Station New York Via High-Speed Tracks to Penn Station New York	1:32 1:01
Babylon	Existing LIRR to Penn Station New York Via High-Speed Tracks to Penn Station New York	1:02 :31
Brewster Southeast	Existing MNR to Grand Central Illustrative via High-Speed Tracks to Penn Station New York	1:18 :53*
Wassaic	Existing MNR to Grand Central Illustrative via High-Speed Tracks to Penn Station New York	1:59 1:27*

Source: NEC FUTURE team, 2015
* The trip time shown for the route shown from Brewster Southeast via high-speed tracks to Penn Station New York is illustrative only and intended for planning purposes to identify possibilities. This example is not intended to be prescriptive.

4.3.6 New Haven Line

The No Action Alternative continues current service levels on the New Haven Line and introduces the planned new Barnum station at East Bridgeport. There are limited opportunities to increase the lengths of some peak trains on the New Haven Line, but existing service levels lack the ability to accommodate projected growth in demand.

Service Plans for the Action Alternatives initially were developed based on the assumed rail infrastructure configuration in each alternative. Alternative 1 eliminates the chokepoints at New Rochelle, Harrison and Stamford with new tracks to grade separate Intercity-Express and Regional rail zone-express trains from local Regional rail service. To meet estimated travel demand growth in the corridor, the level of Regional rail service in Alternative 1 was set at 26 tph in the peak direction in the standard peak hour, an increase of 24 percent over the current level of 21 tph in the peak hour. Alternative 2 expands the existing NEC from four to six tracks from New Rochelle to east of Westport, CT. Alternative 3 was developed with the same infrastructure as Alternative 1 on the New Haven Line but rerouted most, but not all, Intercity-Express service to a new second spine route. Intercity-Express service on the New Haven Line was retained at 2 tph in the standard peak hour in Alternative 3, in order to continue to provide Intercity-Express service to Washington, D.C., New York, and Boston from Stamford.

4.3.6.1 Standard Slots on New Haven Line

All Action Alternatives provide slots that could be used for Regional rail trains from the New Haven Line through to Penn Station New York via the Hell Gate Line. Additional track capacity is required on the Hell Gate Line, as are capital improvements to relieve chokepoints at the rail junctions in New Rochelle and in western Queens. Table 6 presents the number of trains operating on the New Haven Line in the weekday peak hour and peak direction of travel at New Rochelle. These trains could be distributed between Grand Central Terminal and Penn Station New York, with the actual split of service to be determined at a future date based on additional analysis and planning.

Table 6: Capacity Slots Available for Regional Rail Trains in the Standard Peak Hour, Peak Direction

Alternative (2040)	New Haven Line at New Rochelle		
No Action	21		
1	26		
2	32		
3	34 + 8*		

* The additional eight slots are on the high-speed second spine route to Penn Station New York, in the variations of Alternative 3 that provide the second spine route via Central Connecticut.

The use of a standard slot catalogue for New Haven Line Regional rail service would have several benefits:

- Provides future scheduling flexibility for New Haven Line service
- Maximizes practical capacity by standardizing stopping patterns and operating speeds
- Demonstrates the operational feasibility of the service plan concepts without specifying a particular level of service to Penn Station New York and Grand Central Terminal.

4.3.6.2 East Bronx Service

For planning purposes, all three Action Alternatives assume the construction of four new stations on the Hell Gate Line in the East Bronx, at Hunt's Point, Parkchester, Morris Park, and Co-Op City, and that these stations are served in the standard peak hour by four local trains in each direction. Bi-directional service could operate between Penn Station New York and points on the New Haven Line. High-Density Transit-Style Service

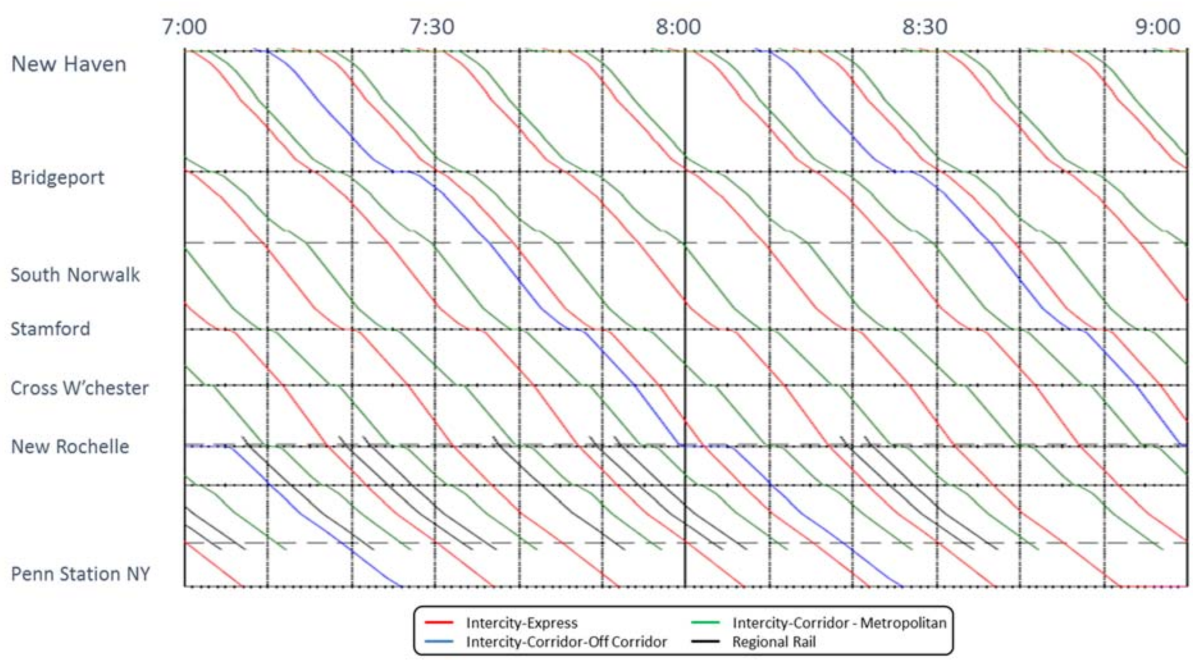
Based on stakeholder feedback and in recognition of the difficulty and high capital cost associated with six-tracking the western half of the New Haven Line, consideration was given to Regional rail service concepts that make more intensive use of existing track capacity and potentially avoid or significantly reduce the need for six-tracking of the line. This approach for more intensive track use is illustrative only and has not been endorsed by the rail operator, nor has it been thoroughly evaluated by the FRA. It was developed to enable a comparison of two very different concepts for operating rail service on the New Haven Line and to illustrate the range of solutions that are possible for accommodating anticipated future growth in demand for rail service. These are based on two different approaches for potentially delivering Regional rail service:

- Traditional zone-express service, where peak trains operate on the outside local track to serve a group of local stations then shift to an inside express track and operate non-stop the rest of the way to the downtown terminal
- Transit-style service, with largely separate limited-stop express services on the inside tracks and local service with skip-stop patterns on the outside tracks

These concepts, as originally analyzed, are independent of the overall vision for rail in the NEC and are potentially applicable to any of the Action Alternatives. The traditional zone-express service concept requires considerable additional rail infrastructure on the New Haven Line as the level of traffic begins to exceed the available capacity, including grade-separated junctions at New Rochelle and locations where branch lines join the corridor, removal of intermediate chokepoints where trains turn or access yards, such as at Harrison and Stamford, and two additional main line tracks (for a total of six) from New Rochelle to east of the Saugatuck River to accommodate the volume of trains and varieties of stopping patterns.

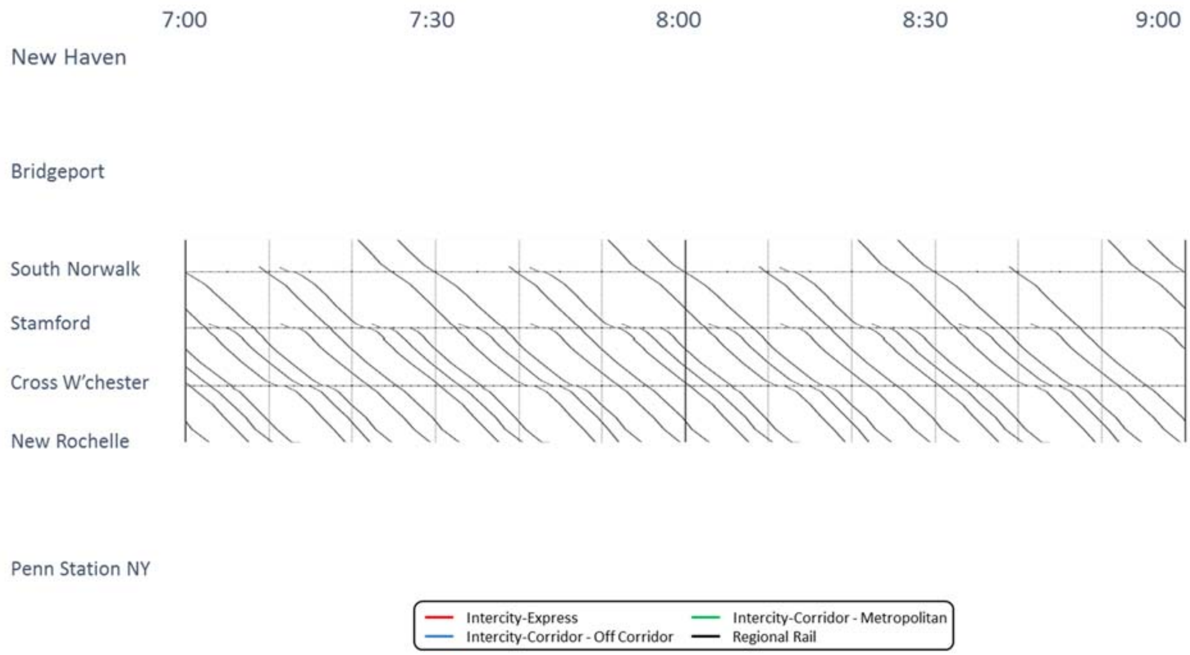
Service characteristics for the traditional concept resemble current service patterns, with zone-express trains operating on local tracks when stopping and on the express tracks the rest of the way to or from Grand Central Terminal and potentially Penn Station New York. The assignment of trains between Grand Central Terminal and Penn Station New York are flexible within available slot capacity. Figure 12 through Figure 14 show in stringline or time-distance diagram format the standard peak hour service patterns for a traditional service plan corresponding to Alternative 2 levels of service—on the express, intermediate and local tracks. Between New Rochelle and the Saugatuck River, the intermediate tracks correspond to the existing inside tracks on the New Haven Line, and the express tracks become the new fifth and sixth main tracks in this territory.

Figure 12: Traditional Zone-Express Service – Alternative 2 – New Haven Line Express Tracks



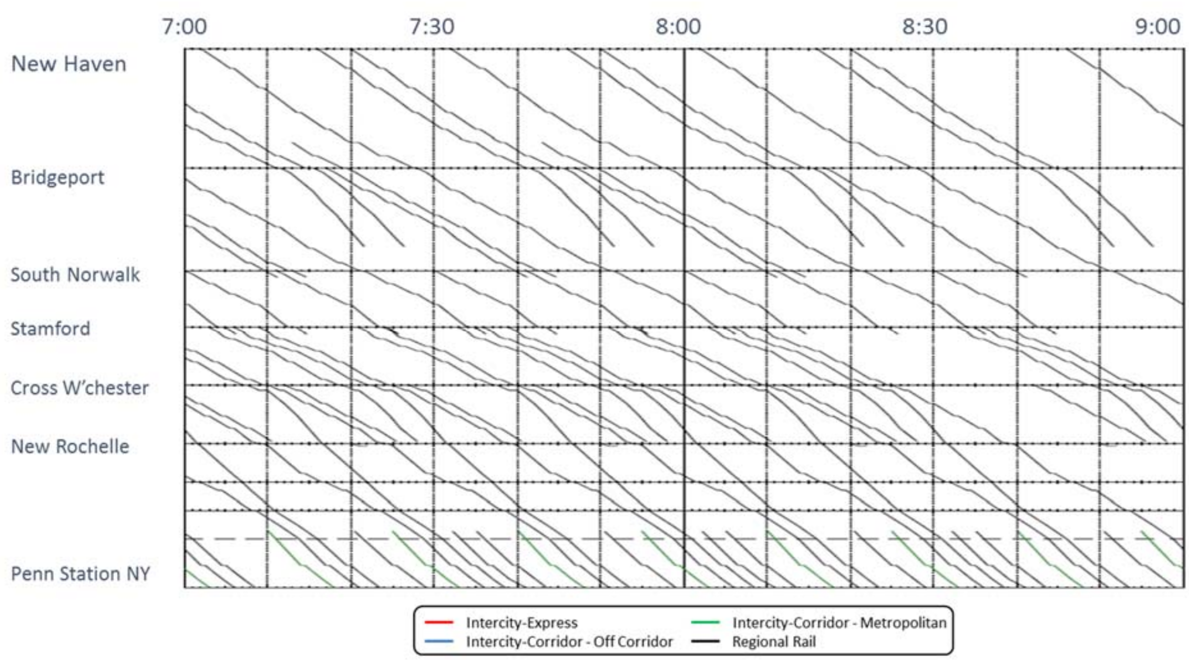
Source: NEC FUTURE team, 2015

Figure 13: Traditional Zone Express Service – Alternative 2 – New Haven Line Intermediate Tracks



Source: NEC FUTURE team, 2015

Figure 14: Traditional Zone Express Service – Alternative 2 – New Haven Line Local Tracks



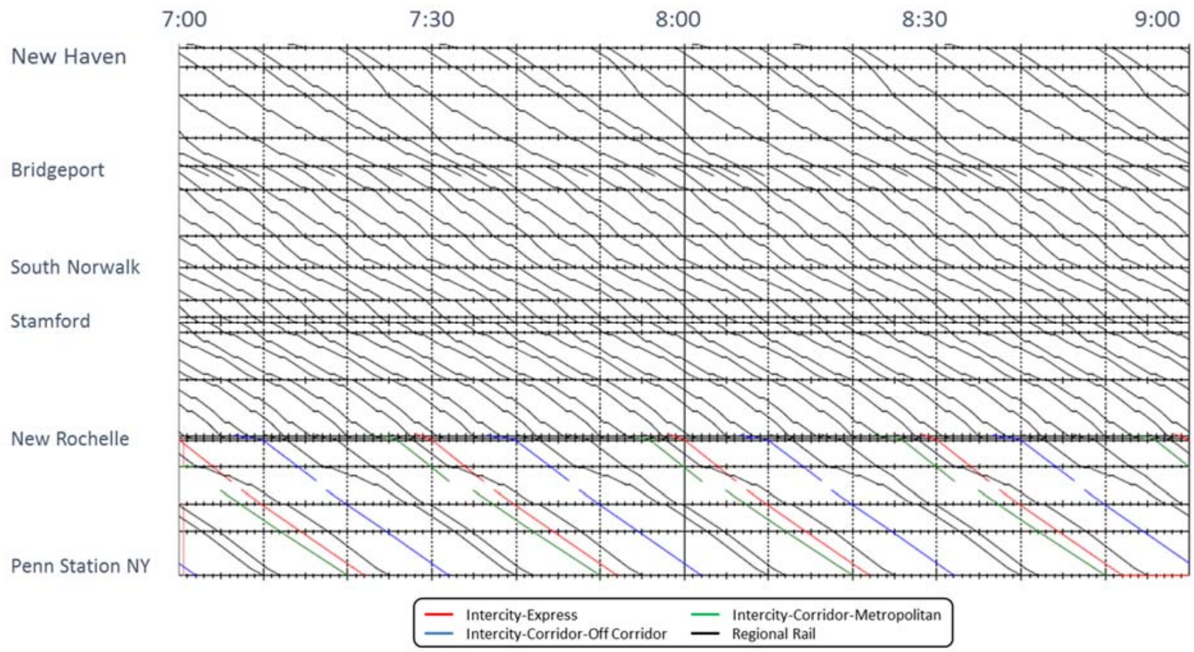
Source: NEC FUTURE team, 2015

Transit-style service offers a simpler array of service patterns, dedicated to and optimized for each main track in the right-of-way. Local trains remain on the local tracks. Because of the high number of local stations on the line, running all-stop locals seriously degrades trip times to New York from stations at the outer end of the line. As a result, the service concept for the local tracks employs a “skip-stop” service concept, which operates trains in groups of two or three, enabling each train to serve selected stops while all operating at approximately the same average speed to preserve relatively short headways. This style of service exists or has been operated in the past on various rail transit lines, notably in Chicago, New York, and Philadelphia.

Trip times to Grand Central Terminal from stations on the New Haven Line, on average, are similar to existing trip times, with some stations seeing slightly higher time and others slightly lower. Even though the skip-stop trains make more total station stops than the traditional zone-expresses, the overall simplicity of the operation and reduced number of train movement conflicts allows for a reduction in the extra time included in train schedules to account for anticipated train delays. These two factors tend to offset each other, resulting in trip times that are not significantly worse than those in a traditional service plan. Some direct service between local intermediate stations is lost in the skip-stop concept, but all local trains stop at the stations that have significant employment or activity centers, and overall connectivity and service is improved to the major destination stations. Service headways also are relatively short and can be sustained over an extended peak period in this concept. The transit-style concept requires an increase in the size of the rolling stock fleet, because all local trains operate over longer distances, with the elimination of “short” inner zones on the line.

Two examples of this type of service are illustrated in the following figures that depict stringlines for the New Haven Line. In the first example, which is consistent with the level of train service in Alternative 1, service on the local tracks operates with an A-B skip-stop pattern with trains operating at 4-minute headways, as shown in Figure 15. Local stations that serve predominantly residential suburbs, designated as either “A” or “B” stations, is served by alternate trains, stopping every eight minutes. More important stations, including those designated as express stations or local stations that also significant employment centers (such as Greenwich and Fairfield, CT) are designated as “A-B” stations, with every local train stopping, providing four minute headways in the peak periods. The local trains in this example operate from an eastern terminal at East Bridgeport yard to Grand Central.

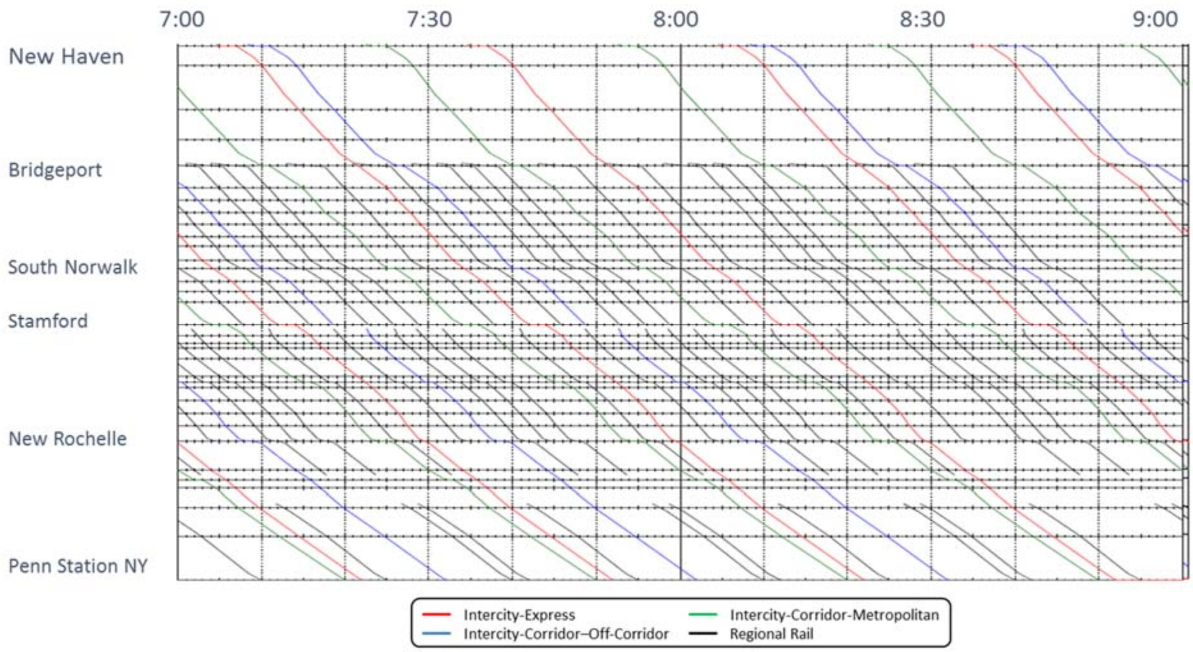
Figure 15: Transit-Style Service – Alternative 1 "A-B" Pattern – New Haven Line Local Tracks



Source: NEC FUTURE team, 2015

Figure 16 shows the services that operate on the express tracks in the same territory. For planning purposes, to slots are designated for two Intercity-Express trains per hour, four Intercity-Corridor (Metropolitan or Intercity-Corridor-Other) trains per hour, and up to 10 Regional rail express trains per hour. All of the Regional rail and Intercity-Corridor trains stop at the express stations, which include East Bridgeport, Bridgeport, South Norwalk, Stamford, Cross-Westchester, and New Rochelle. The existing stations that become express stations, but which only have side platforms on the outside tracks, are reconfigured with two island platforms serving all four main tracks, which entails major construction at these locations. This concept can be implemented with a different mix of express stations based on more detailed subsequent studies. The Intercity-Express trains stop only at the New Haven and Stamford stations in Connecticut. These trains occupy two consecutive slots on the express tracks, enabling these trains to achieve a shorter trip time than the other trains using the express tracks.

Figure 16: Transit-Style Service – Alternative 1 – New Haven Line Express Tracks



Source: NEC FUTURE team, 2015

A second example of transit-style service operates with greater density of traffic and is consistent with the service levels provided in Alternative 2.

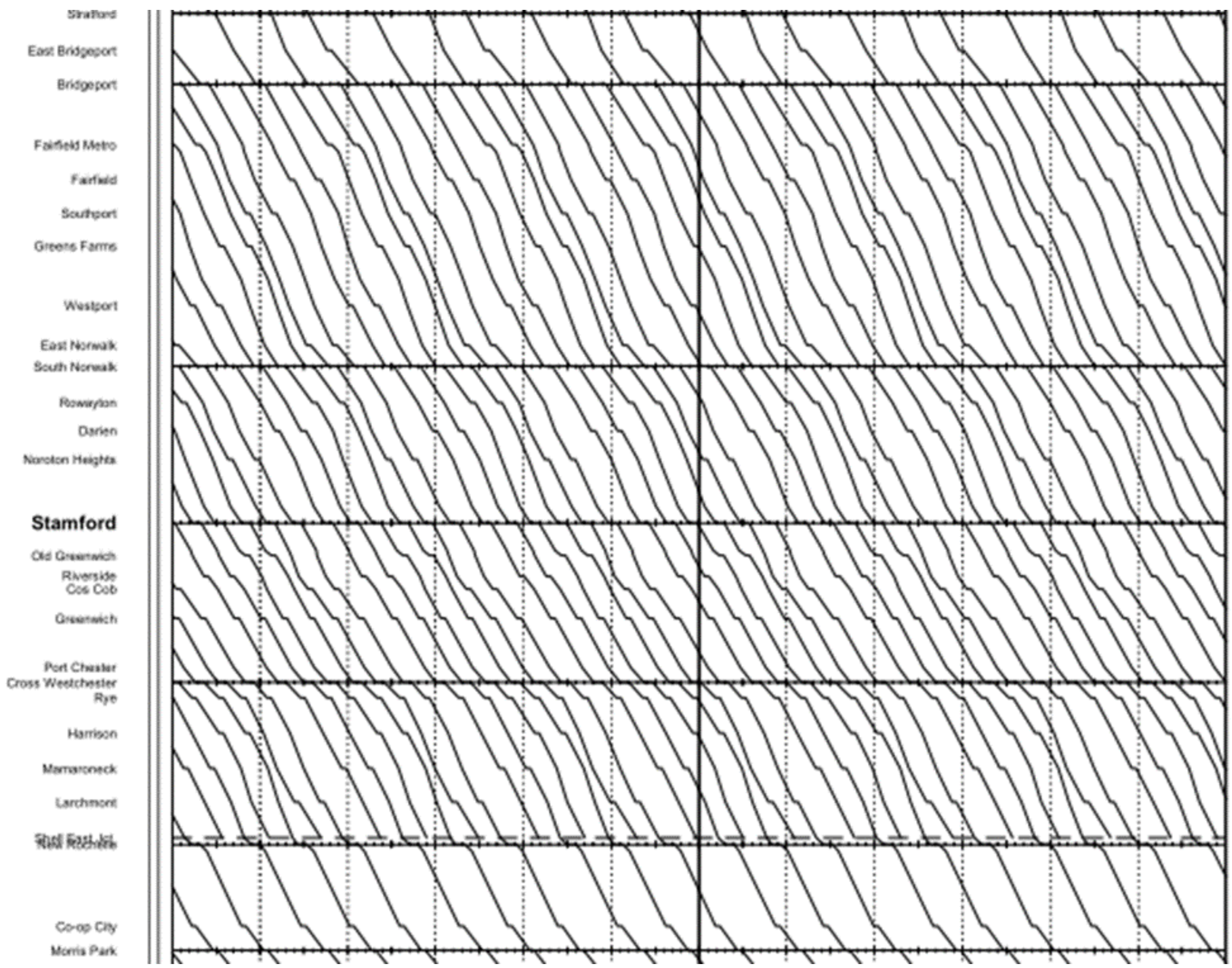
Under this example, local service is provided in an A-B-C skip-stop pattern (Figure 17). Each local pattern operates every 9 minutes. Alternating trains could run to Penn Station New York and Grand Central Terminal, providing local service at 18-minute intervals to each of these two terminals. Overall, local service operates at 3-minute headways on average during the peak periods, and the A-B-C stations are served by local trains every 3 minutes, with Grand Central and Penn Station New York each receiving 10 tph.

Intercity and Regional rail trains could operate on the express tracks at up to 20 tph (an average headway of 3 minutes) under this example. Half of these trains are Regional rail trains, destined for Grand Central Terminal or potentially split between Penn Station New York and Grand Central Terminal. Four Metropolitan trains and four Intercity-Express trains run via Penn Station New York. Essential characteristics of the transit-style A-B-C pattern include the following:

- Efficient use of track capacity and rail infrastructure, with all elements of both existing and new infrastructure highly utilized, major investment limited to chokepoint elimination, island platforms at express stations, and an expanded yard at East Bridgeport, CT
- Service at transit-like headways within the New Haven Line service territory
- Balanced operations in both directions, providing very high-quality reverse-commute service in addition to peak direction service to serve the growing intrastate demand within southwest Connecticut

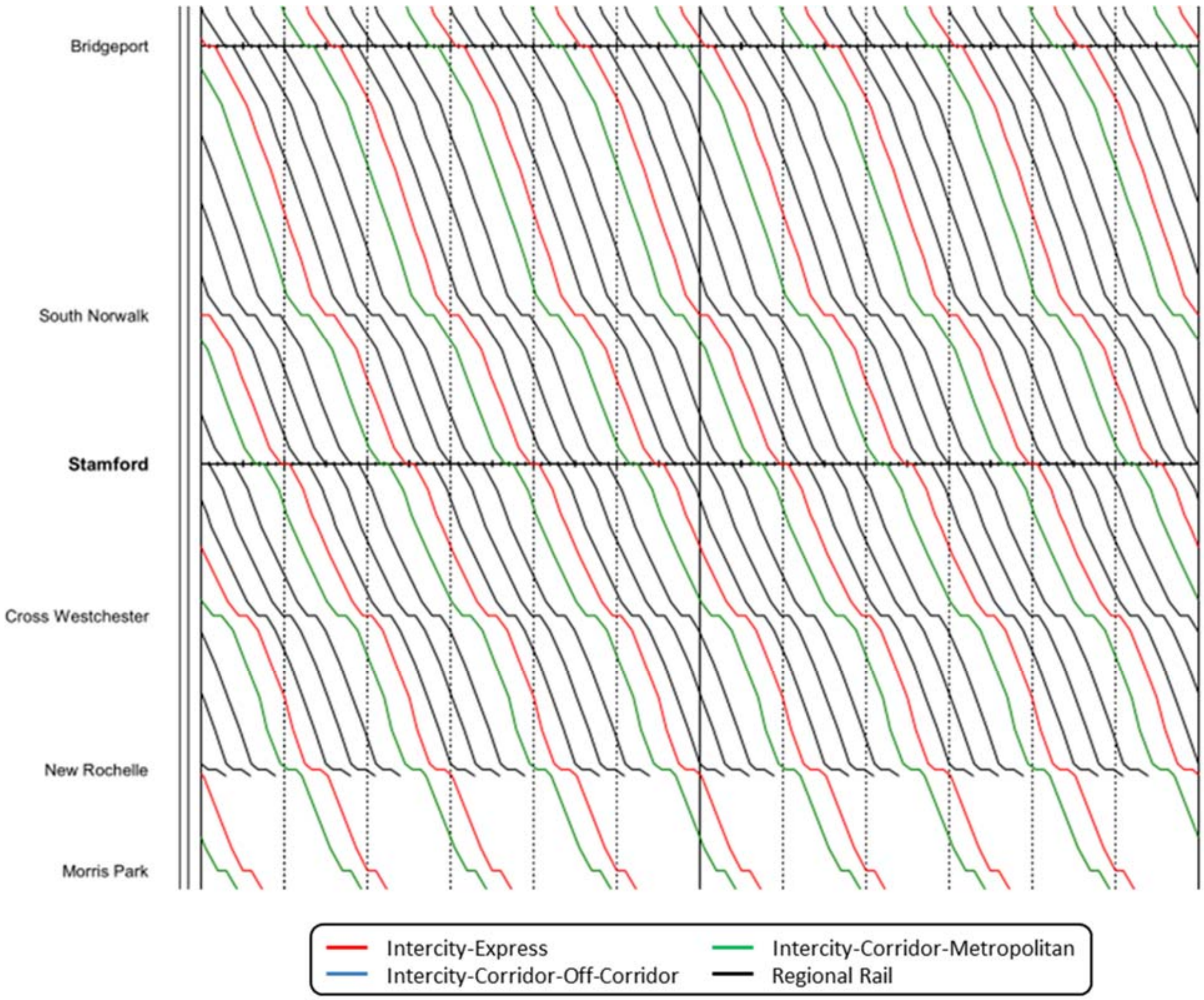
- Operations that can be sustained at peak levels over an extended period of time – the trains keep moving and are not constrained by limited yard capacity at terminals or limited reverse-direction capacity
- Service that tapers during peak shoulder hours and off-peak hours.

Figure 17: Transit-Style Service – Alternative 2 "A-B-C" Pattern – New Haven Line Local Tracks



Source: NEC FUTURE team, 2015

Figure 18: Transit-Style Service – Alternative 2 – New Haven Line Express Tracks



Source: NEC FUTURE team, 2015

Both of these examples of transit-style service are operationally feasible. The first example, with the A-B local pattern and 25 Regional rail trains per hour in the peak hours, was selected to represent Alternative 1 on the New Haven Line, because it meets the service objectives of this alternative at a significantly lower capital cost than a concept that provides the same level of service with traditional zone-express service patterns.

Traditional zone-express service patterns were retained for Alternatives 2 and 3, which have essentially the same service plan for Regional rail. These Action Alternatives increase the capacity of the inner portion of the New Haven Line by expanding it to six tracks. The service concepts in these Action Alternatives deliver the best express trip times and greater scheduling flexibility.

4.3.7 Shore Line East and Hartford Line

The No Action Alternative includes funded and committed service improvements, including the initial phase of service improvements included in the New Haven-Hartford-Springfield corridor plan.

All of the Action Alternatives provide for Regional rail service in the peak hour and peak direction at 15-minute headways on Shore Line East and 30-minute headways on the Hartford Line. This level of service provides ample capacity to accommodate projected 2040 Regional rail ridership to the north and east of New Haven, so the same service levels are provided in all three Action Alternatives.

Hartford Line Regional rail trains are assumed to terminate at New Haven with a transfer to NEC trains. In all three Action Alternatives, this is a coordinated timed transfer, intended to minimize wait times at New Haven and improve the predictability and convenience of rail travel.

As with the existing service, selected Shore Line East trains are extended to Stamford in the No Action Alternative and in Alternatives 2 and 3, to offer one-seat rides between Shore Line East stations and Stamford. Commuters to New York City are able to transfer to New Haven Line Regional rail trains at New Haven or Stamford. With transit-style service, Stamford becomes an inconvenient place to turn trains because of the higher volume of through-train service. Therefore, the Alternative 1 Service Plan terminates all Shore Line East service at New Haven, with coordinated timed transfers to both Intercity-Express and local Regional rail services.

The potential exists to integrate the Shore Line East and Hartford Line into the New Haven Line, and this was considered as a possible service plan variation. There are some concerns, however, that make full integration problematic, even assuming removal of institutional barriers. Issues include differences in train consists (driven by the significantly lighter ridership demand east and north of New Haven compared with the New Haven Line, and affecting station platform lengths and operating costs) and the potential need for electrification of the Hartford Line. The possibility of splitting New Haven Line trains at New Haven was considered, breaking up a single long New Haven train and running separate shorter sections to and from the Hartford-Springfield and Shore Line East routes. This approach requires high-precision operations, which are a basic assumption in Alternatives 2 and 3. It also leads to higher operating costs and has a potential impact on reliability. As a result, the Action Alternatives assume independent operation of these Regional rail services, with coordinated connections at New Haven. Tier 2 studies could examine the potential for more closely integrated Regional rail services within Connecticut, which is not precluded in any of the Action Alternatives.

4.3.8 Rhode Island and Massachusetts South and West of Boston Back Bay Station

The No Action Alternative includes funded and committed service improvements, including those planned for service and stations on the Fairmount Line between Readville and Boston South Station. Otherwise, the No Action Alternative assumes retention of existing levels of Regional rail service. The Action Alternatives include planned service improvements by 2040, including introduction of South Coast service to Fall River and New Bedford via the Stoughton Branch, plus increases in peak period service on all lines feeding Boston South Station.

Alternative 1 accommodates modest growth to these planned increases in service and minimizes the investment in new rail infrastructure capacity within Massachusetts. Schedule patterns are regularized to fit within the regular schedule patterns of the planned Intercity services. Needham Branch service operates at 2 tph in both directions exclusively on the third main track between Forest Hills and South Station so as not to conflict with main line train movements. Franklin Branch trains also operate at 30-minute intervals, sharing the third track with Needham trains in the peak direction, and running over the Dorchester Branch in the reverse-peak direction between Boston and Readville, to avoid the need to construct a fourth main track on the NEC main line inboard of Readville. This represents a slight reduction in Franklin Branch service frequency during the peak hour versus the existing condition and No Action Alternative, but the 30-minute headway service is sustained over a longer period, resulting in an increase in the total number of peak period trains.

Alternative 2 increases service frequencies in the standard peak hour on the NEC and branch lines feeding the NEC. This includes four Providence trains (two of which are extended to Westerly, RI), four Stoughton Line trains (two of which are extended to Fall River and New Bedford), and four Franklin Line trains. The Needham Branch continues to operate as in Alternative 1, with 30-minute headways in both directions. The cumulative total of Regional rail trains on the 3-track NEC between the Forest Hills and Back Bay stations increases to 12 tph in the peak direction of travel. In addition, Metropolitan service is available at Providence, Route 128, Back Bay, and South Station.

Alternative 3 provides Regional rail service on the Providence, Stoughton, Franklin and Needham branches that are equivalent to what is provided in Alternative 2. The variations of Alternative 3 that include two new high-speed tracks parallel to the existing NEC between Providence and Boston support the reduction in trip times from the Providence-Westerly outer zone by operating the zone-express trains on the high-speed tracks for the express portion of their trip. In the variations of Alternative 3 that provide a new high-speed second spine via Worcester, commuter express service can be offered on the Worcester Line.

4.4 CONNECTING CORRIDOR SERVICE

The following connecting corridors currently have train service onto or connecting with the NEC:

- Washington, D.C.-Richmond corridor, with extensions beyond Richmond to Newport News, Norfolk and Charlotte, NC, encompassing the Southeast High-Speed Rail (SEHSR) corridor
- Washington, D.C.-Charlottesville-Lynchburg-Roanoke, VA
- Keystone Corridor extended (Philadelphia-Harrisburg-Pittsburgh)
- Empire Corridor extended (New York-Albany-Buffalo-Cleveland, plus potential links with faster trip times from New York to Montreal and Toronto)
- Knowledge Corridor (Springfield-Burlington, VT), with an extension to Montreal, Quebec
- Inland Route – Springfield-Worcester-Boston
- Downeaster Corridor (Boston-Portland-Brunswick, ME), though serving a different station in Boston than NEC service.

Based on the service and ridership analysis undertaken by the FRA for the Preliminary Alternatives, the FRA determined that demand for direct service to the NEC from the connecting corridors can be accommodated in the standard peak hour on two trains operating in both directions. The FRA also reviewed the most recent plans by the states and railroad operators for service growth on the existing NEC connecting corridors and confirmed that these plans are not expected to generate demand for rail service onto the NEC in excess of 2 tph in any given hour. Therefore, the Action Alternatives reserve a minimum of two slots per hour, spaced 30 minutes apart, along the NEC between Washington, D.C., and New Haven. The two slots continue north of New Haven to both Boston (via the Shore Line) and Springfield. Trains can be routed either way, depending upon demand. The Keystone Corridor is provided with two additional train slots on the NEC between Philadelphia and New York, separate from the slots provided from Washington, D.C., to New Haven. These slots can be configured either for Metropolitan trainsets or traditional Intercity-Corridor-Other trains. Because the Keystone Corridor is electrified to Harrisburg and has physical and operating characteristics similar to the NEC, Metropolitan equipment is planned for in Alternatives 2 and 3. Alternative 1 retains the use of traditional locomotive-hauled coaches, to enable a comparison of relative performance. Empire Corridor service is assumed to continue to originate and terminate at New York, so these trains are not assumed to operate in revenue service on the NEC, although the trains themselves operate at Penn Station New York. The Action Alternatives include two Empire Corridor trains in each direction in the standard peak hour. Empire trains requiring servicing or storage at New York also operate through the East River Tunnels to and from Sunnyside Yard in Queens.

The slots for Intercity-Corridor-Other trains are provided in the service plan throughout the day. However, the service itself is expected to exhibit peaking characteristics similar to other Intercity services. Interregional business and non-business travel, somewhat like commuter travel, has morning and afternoon peaks that occur over about a three-hour period in both mornings and afternoons. However, given the longer trip distances involved in interregional travel, these peaks will not all occur at the same time in all locations on the NEC, so the Intercity service peaking patterns will not be as sharply defined as was shown in Figure 1 in Section 2.4 for Regional rail service. Intercity-Corridor-Other service from the connecting corridors will fill the allotted two slots per hour at certain times of day. At other times of day, fewer trains are operated. As a result, not all slots for Intercity-Corridor-Other trains are filled at non-peak times of day. The initial Service Plans had relatively robust daily services in each of the existing connecting corridors, allowing for peak demand that occurs in different parts of the NEC at different times. Upon review of initial ridership results and Intercity-Corridor-Other plans being prepared by the states and railroad operators, the FRA reduced the level of Intercity-Corridor-Other service outside of the business peak hours for Intercity-Express travel, to reflect an appropriate balance between estimated passenger-miles and the available seat-miles on these Intercity-Corridor-Other trains provided by the Service Plans. With the provision in the Service Plans of regular Intercity-Corridor-Other slots throughout the day, the Action Alternatives all provide the flexibility to grow connecting corridor service in line with passenger demand and investment in these corridors, up to the limit of 2 tph in any given hour. Table 7 summarizes the level of existing service and the range of service levels considered for the Action Alternatives, for the existing connecting corridors that feed the NEC.

Table 7: Connecting Corridor Service Levels

Connecting Corridor	Standard Peak Hour		Daily Round Trips	
	Existing/ No Action	All Action Alts	Existing/ No Action	All Action Alts
Keystone Corridor				
▪ Philadelphia-Harrisburg	1	2	16	16-24
▪ Harrisburg-Pittsburgh			1	1
Hartford Line				
▪ New Haven-Springfield	1	2	6	16-24
▪ Springfield-Boston (Inland Route)			-	12
▪ Springfield-Vermont (Knowledge Corr.)			1	2
Virginia and North Carolina Corridors				
▪ Washington-Richmond	1	2	9	21
▪ Richmond-Newport News			2	3
▪ Richmond-Norfolk			1	6
▪ Richmond-Charlotte			1	5
▪ Washington-Charlottesville			3	6
Empire Corridor				
▪ New York-Albany	1	2	13	23
▪ Albany-Buffalo			4	9
▪ Niagara Falls-Toronto			1	1
▪ Albany-Montreal			1	1
▪ Albany-Rutland			1	1

Note: Includes Long-Distance services and excludes Amtrak Auto Train. Train counts for the individual line items are not additive; they represent total daily Intercity round trips operating in each segment.

The service analysis also considered the introduction of service onto the NEC from potential new connecting corridors, which were identified as part of the Scoping process. Capital investment, as well as new railroad access agreements, would be required to implement such connecting service in the future. Opportunities include the following:

- Delmarva Peninsula and Ocean City, MD
- Atlantic City, NJ
- Lehigh Valley (Allentown and Bethlehem, PA)
- Scranton, PA and Binghamton, NY
- Eastern Long Island
- Montreal, QC [Canada] via several potential new high-speed routes
- Cape Cod, MA
- Providence, RI-Worcester, MA
- Direct linkage from NEC to Downeaster Corridor serving Portland and Brunswick, ME

Capacity is available off-peak to fill unused Intercity-Corridor slots with trains from other corridors. However, new markets are assumed to demand service during peak periods, so it was not considered reasonable to plan additional connecting corridor service that operate only outside of the peak travel periods. Alternatives 1 and 2 concentrate on markets within the NEC and existing connecting corridors. New service only becomes feasible within Alternative 3; therefore, Intercity service in new connecting corridors was considered in the context of Alternative 3 and the transformative vision for the future of the NEC. All of the Action Alternatives support the provision of convenient passenger transfers between new or expanded Intercity-Corridor-Other services and NEC Spine services at the Hub stations where connecting corridors meet the NEC. The ridership potential of these new corridors was not directly estimated, nor was a comparative evaluation or ranking of new connecting corridor services or further enhancements to existing connecting corridor service undertaken as part of NEC FUTURE.

4.5 RAIL INFRASTRUCTURE CONFIGURATION

The configuration of tracks, junctions, station platforms and yards is integrally tied to the rail service plan for each alternative. As was the case with Service Plans, an initial set of assumptions about the configuration of NEC rail infrastructure was made for each Action Alternative. As the FRA tested various hypothetical service concepts and refined the Service Plans, the FRA made corresponding adjustments to the rail infrastructure configurations to ensure that new infrastructure meets the needs of the various rail services and that, in turn, the Service Plans make productive use of the proposed rail infrastructure. This iterative process of refining both the Service Plans and the associated infrastructure configurations maintained an appropriate service and infrastructure balance in each of the Action Alternatives.

Additional infrastructure-related work performed in parallel with the testing of service plan concepts included:

- Confirmation of the location, configuration, and scope of chokepoint relief and bypass projects
- Extent of bypasses and 6-track railroad required for capacity, especially in the territory surrounding New York City
- Identification of opportunities to decrease trip times and increase average speed

4.6 MAJOR STATIONS, TERMINALS AND YARDS

4.6.1 Washington, D.C.

The physical and operational characteristics of the Action Alternatives within the Washington, D.C., terminal area address the needs and requirements identified in the 2012 Washington Union Terminal Master Plan[29] prepared by Amtrak (WUTMP). The levels of rail service in the Action

[29] The Washington Union Terminal Master Plan was completed by Amtrak in 2012. Amtrak and its partners at Washington Union Station are continuing to develop master plan concepts and a phased implementation plan for station and yard improvements at Washington, building upon the 2012 Master Plan. The specific elements of the

Alternatives correspond closely with the major implementation phases established for the WTUMP. Implementation of Phases 1, 2 and 3 of the WUTMP results in the reconfiguration of the track and platform area of Union Station to create a facility that meets modern train movement and passenger handling standards for a high-performing rail terminal. The station includes 12 stub-end platform tracks and eight run-through platform tracks feeding the tunnel leading to the Potomac River and Virginia. This configuration supports the peak and daily traffic levels for Intercity and Regional rail traffic included in Action Alternatives 1 and 2. A fourth phase of the WUTMP further increases the capacity of the Union Station complex by constructing a new lower level of tracks and platforms, connected by new tunnels to the NEC main line and to terminal yard facilities. These facilities are included in Alternative 3. The new lower level station supports future high-density Intercity-Express operations, freeing up capacity on the upper levels for expansion of Regional Rail, through-running Metropolitan service, and Intercity-Corridor-Other traffic.

4.6.1.1 Train Movements

Table 8 presents the standard peak-hour train volumes, by type of service and location within Union Station, for the Action Alternatives. The levels of traffic are comparable to those analyzed in the WUTMP. A significant exception is Metropolitan service (described in Section 2.3), which is a new type of service identified as part of NEC FUTURE and essentially takes the place of the existing Northeast Regional service, on which the WUMTP was based.

Table 8: Washington Union Station – Standard Peak Hour-Peak Direction Revenue Train Movements in 2040

Service Type	Alternative 1	Alternative 2	Alternative 3
Intercity-Express	2	4	6
▪ Originate/Terminate (via West Side stub tracks)	*2*	*4*	—
▪ Originate/Terminate (via new lower level tracks)	—	—	*6*
Intercity-Corridor			
Virginia off-corridor ▪ All trains via East Side	2	2	2–4
Metropolitan	2	4	4
▪ Run-Through (via East Side)	—	*4*	*4*
▪ Originate/Terminate (via West Side stub tracks)	2	—	—
MD Regional rail/Commuter (MARC Penn Line)	6	10	12
▪ Run-Through (via East Side)	—	*4*	*4*
▪ Originate/Terminate (via West Side stub tracks)	*6*	*6*	*8*
VA Regional rail/Commuter (VRE)	6	8	8
▪ All trains via East Side			

Source: NEC FUTURE team, 2015

Table 9 provides a breakdown of the volume and mix of trains projected to be operating on the east side of Union Station in the 2040 horizon year under NEC FUTURE Alternatives 2 and 3, where this

master plan may be revised as a part of this work, which is proceeding in parallel with NEC FUTURE and is being coordinated by the FRA in concert with Amtrak and other stakeholders.

portion of the station complex is estimated to operate at the maximum practical level of capacity utilization :

Table 9: First Street Tunnel – PM Peak Hour Train Movements – Alternatives 2 and 3

Service	PM Peak Hour Southbound	PM Peak Hour Northbound
Intercity-Corridor	2–4	2–4
Metropolitan	4	4
VRE Peak Direction	8	—
VRE Reverse Peak	—	4
MARC Run-Thru	—	4
Total	**14–16**	**14–16**

4.6.1.2 East Side Track and Platform Configuration

The most critical area of the station is the east side, with the tracks that run through to and from Northern Virginia. This is the part of the station that is most physically constrained, in terms of both horizontal and vertical alignment, and it is the part of the station that is expected to see the greatest proportional growth in traffic, especially over the next decade. Consequently, the long-range configuration aims to maximize the capacity of the East Side zone, and to enable smooth through-running operations with dwell times that are as short as practically possible. The WUTMP proposes widening this zone and expanding from six to eight platform tracks. Wider platforms and ample vertical circulation capacity are provided to permit trainloads of boarding passengers to be positioned on the platforms before a through train arrives. Three low platform edges are provided to support VRE operations with low-level boarding Gallery equipment. In addition, there are six platform edges (three island platforms) that permit high-level boarding.

Reconfiguration of this zone was identified in the WUTMP as the highest priority for major investment, which commences in Phase 2 of the WUTMP. Phase 2 also provides space below the track and platform level for future program requirements of vehicle parking, taxis and potentially the bus terminal, so that the existing parking garage structure can be taken down at the start of Phase 3.

The east side tracks are configured to facilitate the continuation of engine changes for Intercity-Corridor and Long-Distance trains that operate through Washington, D.C. The strong preference is to eliminate engine changes altogether with the advent of high-performance dual-mode locomotives that can operate at 125 mph on the NEC and also at up to 100 mph on the Class I freight network – or with the electrification of the main line to the south of Union Station. However, the WUMTP protects the ability to continue engine changes in the short to medium term with shorter station dwells, by configuring the interlocking north and south of the east side platforms to permit engines to be staged and moved in parallel with normal revenue train movements. Full flexibility to simultaneously continue engine changes while increasing the frequency of train movements require reconstruction of the northern portion of the First Street Tunnel (generally in the zone beneath Massachusetts Avenue) to provide an engine pocket track and parallel through-running capability. With either electrification or introduction of dual-mode locomotives, however, the need for this costly tunnel reconfiguration is avoided.

4.6.1.3 Yards and Equipment Maintenance

Requirements, initial options and concepts for increasing train storage and maintenance capacity at Washington, D.C., developed as part of the Washington Union Terminal Master Plan, have been the basis of NEC FUTURE's planning. Amtrak's subsequent Washington Terminal Yard Master Plan, however, represents the most recent and comprehensive source of information and findings from this work effort should supersede the earlier work. There are some key conclusions that still hold and which should guide future planning.

VRE midday storage is most effective if located on the east side of NEC right-of-way, with dedicated track access from the Union Station east side platform tracks, so the VRE trains going to and from the yard are not required to cross the path of NEC trains going to and from the stub-end platform tracks.

Potential run-through service for Maryland Regional rail trains (MARC) and/or Metropolitan trains, with a storage and maintenance facility in Northern Virginia, reduces the requirement for yard expansion on the north side of Washington, D.C., assuming that sufficient capacity is provided for these trains in the Long Bridge corridor.

4.6.2 Philadelphia

30th Street Station retains its track and platform configuration in each of the Action Alternatives. The lower level of 30th Street station, which serves Intercity and NJ TRANSIT Atlantic City trains, has ample capacity and is well configured to accommodate planned growth in service. Alternative 1 requires no significant changes to the infrastructure configuration. Alternative 2 utilizes the existing platform and track configuration at the station, but reconfigures the terminal interlocking and expand the approaches on both the north and south sides of the station from two tracks to four tracks, to facilitate the operation of 30th Street as a hub for convenient transfers between rail services. Alternative 3 provides a new route via downtown Philadelphia for Intercity-Express and selected Metropolitan trains. The Alternative 3 Service Plan, however, is intended to preserve and enhance Intercity service at 30th Street Station, even with the development of a new downtown station at Market East. Metropolitan service at 4 tph operates via 30th Street, along with Intercity-Corridor-Other services and Long-Distance trains. Virtually all Philadelphia Regional rail trains are routed through Center City Philadelphia and serves both 30th Street Station (on the upper level) and Market East. Table 10 summarizes standard peak-hour train movements, by train type, on the NEC north and south of Philadelphia for the No Action and Action Alternatives.

Table 10: Philadelphia Area – Standard Peak Hour-Peak Direction Service in 2040

South Screenline	Existing	No Action	Alt. 1 Maintain	Alt. 2 Grow	Alt. 3 Transform
Number of Tracks	4	4	4	6	6
Standard Peak Hour (Trains/Hour)	7	7	14	20	28-30
Intercity-Express	1	1	2	4	6
Intercity-Corridor	1	1			
Metropolitan			2	4	4
Intercity-Corridor-Other			2	2	2-4
Regional rail Lines					
Wilmington-Newark	3	3	6	8	12
Philadelphia Int'l. Airport	2	2	2	2	8
North Screenline					
Number of Tracks	4	4	4	4	6
Standard Peak Hour (Trains/Hour)	10	10	15	22	28-30
Intercity-Express	1	1	2	4	6
Intercity-Corridor	2	2			
Metropolitan			3	4	8
Intercity-Corridor-Other			2	2	2-4
Regional rail Lines					
Trenton Line	4	4	4	6	6
Chestnut Hill West Line	2	2	2	4	4
Atlantic City	1	1	2	2	2

Source: NEC FUTURE team, 2015

Intercity rail services on the NEC generally operate through Philadelphia, especially in the peak hours. As service builds in the hours prior to the morning and afternoon peak hours, selected Intercity-Express and Metropolitan trains originate at Philadelphia, heading northward toward New York. Similarly, as service tapers in the hours following the peak hours, selected trains from the north terminate at Philadelphia. These originating and terminating trains require yard storage at Philadelphia, assumed to be provided at or in the vicinity of the Coach Yard adjacent to 30th Street Station. Yard storage requirements are a function of the extent of the service tapering.

Keystone Corridor service comprises a combination of trains that continue onto the NEC in the direction of New York, and trains that originate, terminate or turn at Philadelphia 30th Street Station. Keystone service requires yard space for both overnight and midday storage of trains.

In Alternative 2, there are three sets of Metropolitan services at 30th Street Station, each with 2 tph offset at 30-minute intervals. One set operates between Boston and Washington, D.C., on the NEC. A second set operates from Boston and New York on the NEC and serves the Keystone Corridor, with trains changing direction at the lower level platforms as is done today. A third set operates between Philadelphia and Washington, D.C., filling the gaps in the 15-minute Metropolitan headways left by the Keystone trains; this third set of Metropolitan trains, in this alternative, require yard space at Philadelphia for equipment turns and for overnight and midday storage.

4.6.3 New York

Multiple planning initiatives are underway in and around the New York rail terminal, comprising Penn Station New York, the Hudson and East River tunnels and approaches, the New Jersey Meadowlands and western Queens, NY.[30] Since these initiatives are running in parallel with NEC FUTURE, the NEC FUTURE service and infrastructure plans remain generalized so as avoid conflict with more detailed plans that are under development. Service Plans were developed and infrastructure investments identified, based on appropriate assumptions representative of potential future conditions in the New York terminal area, in order to confirm the operational feasibility of Service Plans and estimate potential ridership and the order-of-magnitude capital cost of capacity-related improvements.[31]

4.6.3.1 New York Area Capacity Assumptions

The segment of the NEC which serves the New York region, between northern New Jersey and the New Haven Line in Connecticut, has the heaviest Intercity and Regional rail demand and the greatest densities of train service. Current demand fills the existing available line and terminal capacity to the maximum during the weekday peak periods. Future demand for Regional rail also was estimated to fully utilize the service provided in each of the Action Alternatives. As a result, the FRA confirmed reasonable assumptions for the practical capacity of these portions of the NEC. The FRA used available simulation modeling tools and assumptions about future signal system capabilities and trainset performance to perform a signal wake analysis[32] and determine the maximum practical headways for trains operating on the existing and planned future NEC tracks. The FRA then combined these headways with the stopping patterns for each of the three Alternatives to determine the practical capacity of the line.

In addition, the FRA reviewed prior studies and analyses of the capacity of the Penn Station New York complex to generate reasonable estimates of the incremental station capacity improvements that is accomplished with station expansion. The FRA assumed that minimum practical station dwell times for originating, terminating, turning and through train movements and considered configurations with the existing narrow station platforms and configurations with reconstruction and/or expansion of the station with wider platforms. All of these analyses, taken together, helped the FRA understand the maximum practical capacity of the systems feeding Penn Station New York across both the Hudson and East River screenlines for the No Action Alternative (including completion of the LIRR East Side Access project) and for each of the Action Alternatives. Figure 19

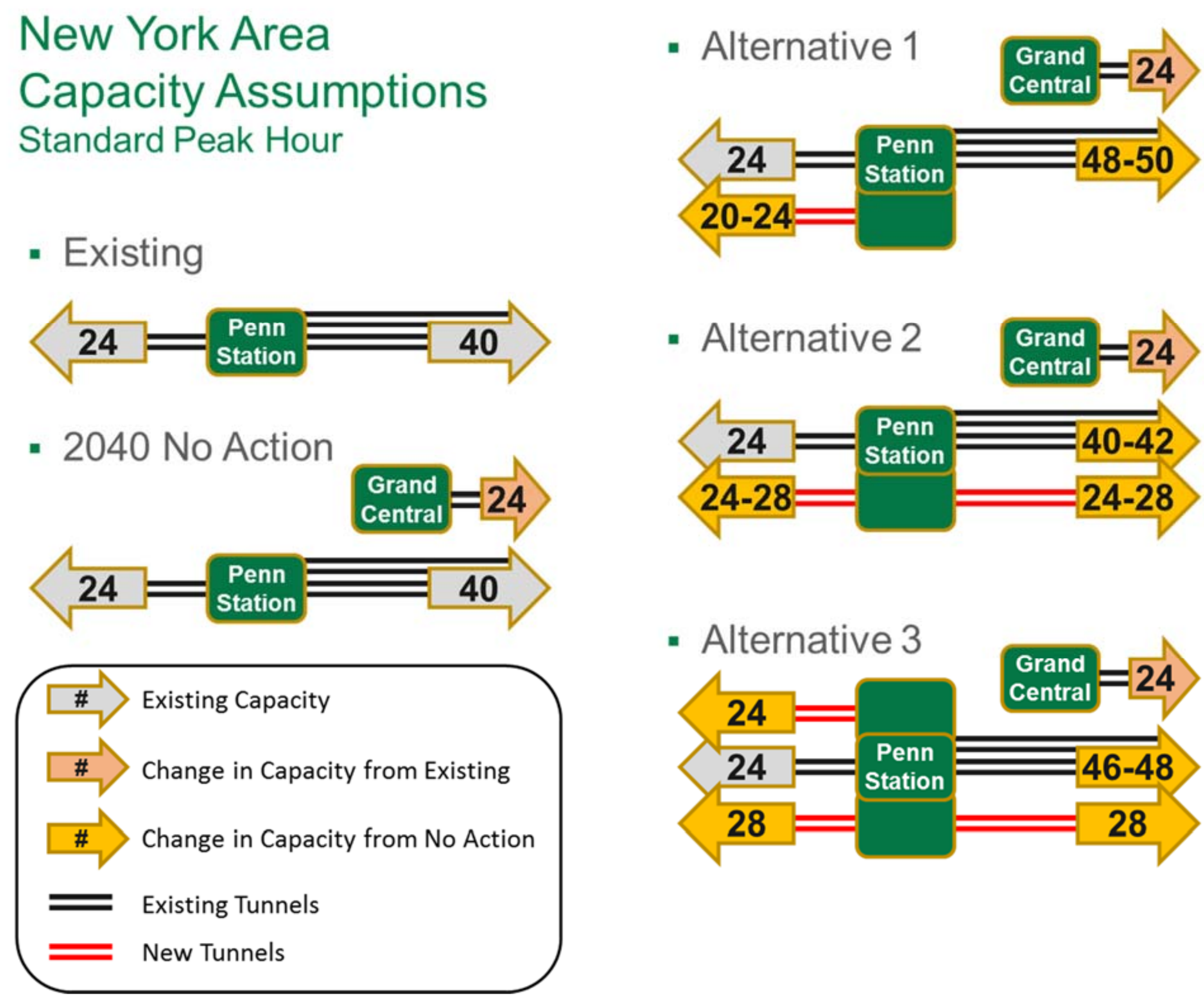
[30] These initiatives include the Moynihan Station redevelopment, vision planning for existing Penn Station New York on the part of the railroads that operate at Penn Station New York, a Master Plan for Sunnyside Yard in Queens, the Metro-North Penn Station Access plan, and the Amtrak Gateway initiative to construct new Hudson River tunnels, expand Penn Station New York and Secaucus Station and replace the Portal movable bridge across the Hackensack River.

[31] NEC FUTURE is not prescriptive with respect to future operating plans for rail traffic through New York, and Tier 2 studies subsequent to NEC FUTURE will determine the specific configuration of tunnels, tracks, station facilities and yard facilities to be provided in the New York area—and how they will be operated.

[32] Signal Wake Analysis is a quantification of line capacity, based on simulated signal clearing time for capacity-critical segments of a rail line, using a computer simulation model of the line's physical characteristics, including the signaling and train control system, and the rail traffic operating over the line.

presents the assumed practical capacities for each alternative. All service plan scenarios tested kept standard peak hour traffic within these limits of practical capacity.

Figure 19: Standard Peak-Hour Practical Capacity at Hudson River and East River Screenlines



Source: NEC FUTURE team, 2015

4.6.3.2 Service Plan Characteristics

Table 11 and Table 12 present the Standard peak-hour train movements in the year 2040 at the Hudson River and East River screenlines, by train type for the No Action and Action Alternatives.

Table 11: Hudson River Screenline – Standard Peak Hour-Peak Direction Service in 2040

	Existing	No Action	Alt. 1 Maintain	Alt. 2 Grow	Alt. 3 Transform
Number of Tracks	2	2	4	4	6
Capacity (Trains/Hour)	24	24	44–48	48–52	76
Standard Peak Hour (Trains/Hour)	24	24	37	52	70
Intercity-Express	1	1	2	4	6
Intercity-Corridor (includes Metropolitan and Intercity-Corridor-Other trains)	2	2	5	6	10
NEC and North Jersey Coast Line	15	15	20	22	24
Other Regional Branch Lines	6	6	10	20	30

Table 12: East River Screenline – Standard Peak Hour-Peak Direction Service in 2040 (Penn Station New York Trains Only)

	Existing	No Action	Alt. 1 Maintain	Alt. 2 Grow	Alt. 3 Transform
Number of Tracks	4	4	4	6	6
Capacity (Trains/Hour)	40	40	48–50	68–70	74–76*
Standard Peak Hour (Trains/Hour)	40	40	48	60	66–74
Intercity-Express	1	1	2	4	6
Intercity-Corridor (includes Metropolitan and Intercity-Corridor-Other trains)	3	3	4	6	10
Regional rail Trains	36	36	42	50	50–58

* The increase in overall peak hour capacity indicated for Alternative 3 reflects capital investment in the capacity of the existing East River Tunnels and Penn Station New York complex, to increase capacity. This work is included in Alternatives 1 and 3. It is not needed to support service levels in Alternative 2 and therefore this capital work and its associated capacity are not included in the plan for Alternative 2.

Current Intercity service on the NEC is heavier to the south of New York than to the north. With improvements in both capacity and trip time on the north end of the NEC, future operations are expected to be more balanced. During peak hours, Intercity trains of all types operate through New York. In Alternative 1, these trains utilize existing tracks and platforms at Penn Station New York, and dwell times of at least 12 minutes are required to ensure that alighting and boarding passenger volumes can be handled safely and that there is sufficient time for train servicing activities and crew changes. In Alternatives 2 and 3, Service Plans are based on Intercity trains utilizing station facilities with platforms and passenger and service circulation facilities that are sufficiently sized to efficiently handle through trains, with minimum dwell times on the order of eight minutes.

Even though Penn Station New York is configured mostly as a through station, current Regional rail operations of the LIRR and NJ TRANSIT use the facility exclusively as a terminal.[33] Both railroads

[33] Metro-North Railroad and NJ TRANSIT currently cooperate to provide a Metro-North service that operates through Penn Station New York from the New Haven Line to Secaucus, NJ, on selected weekends, to carry

utilize yards on the far side of Penn Station New York for storage and equipment turning, which allows for through-running train movements at Penn Station New York, but not run-through revenue operations. These yards, however, have limited capacity and are not easily accessed from all station tracks, so many trains of both railroads turn at the station platforms and often occupy those platforms for extended periods of time. Alternative 1 continues to use Penn Station New York primarily as a terminal station for Regional rail, similar to today's operations. The expanded Penn Station New York, accessible to the new Hudson River tunnel tracks, functions as a stub-end terminal. Alternatives 2 and 3are based on maximizing through-running operations to and from expanded far-side storage yards,[34] also providing connections between Regional rail lines on both sides of New York. Linking Regional rail branch lines with run-through revenue service is possible in these Service Plans, and reduces the number of required train movements, which is important during the commuter peak periods. However, it is not a prerequisite for these Service Plans to be feasible. Although new travel patterns from one side of a metropolitan region to the other benefit from run-through service, ridership potential for trips from one side of the region to the other is estimated to be relatively low, compared with rail ridership to and from the Manhattan CBD. This reflects the relatively low volume of total trips more than any shortcomings related to the level and quality of rail service. Consequently, the principal reasons for through-running operations at Penn Station New York are not market-related but instead derive from the ability to reduce operational conflicts and efficiently utilize the available railroad infrastructure.

Deterministic service planning analyses were undertaken to test a number of potential operating patterns through and at Penn Station New York, based on available data and prior simulation and capacity analyses that have been performed at the station. Additional detailed operations analysis was not undertaken as part of this Tier 1 Draft EIS.

4.6.3.3 Yards and Equipment Maintenance

During the shoulders of the peak periods and at the beginning and end of the service day, selected Intercity trains operating in both directions originate or terminate at New York and require access to storage yard and maintenance facilities, which continues to be concentrated at Sunnyside Yards in Queens.

Expansion of existing yards and/or new facilities in the Meadowlands area of New Jersey and in western Queens are provided as part of the Action Alternatives. Regional rail midday storage requirements increase as the level of peak rail service increases among the Action Alternatives.

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passengers attending sporting events at the Meadowlands sports complex. This is the only example of through-running Regional rail service in New York City. Such service is not provided at present during weekday peak periods.

[34] Sunnyside Yard in Queens, NY, is an example of a far-side yard for NJ TRANSIT. Some morning peak New Jersey Regional rail trains, after discharging passengers at Penn Station New York, continue onward as non-revenue trains (i.e., without passengers) through the East River tunnels to Sunnyside, where they are stored until it is time for their return trip to New Jersey. This mode of operation allows for relatively short dwell times at Penn Station New York and minimizes train interference delays. Alternative 2 expands this concept for New Jersey, Long Island, and New Haven Line Regional rail services, entailing either expansion of existing yards or the construction of new yard facilities in both Queens and on the New Jersey side of the Hudson River tunnels.

4.6.4 Boston Area Capacity Assumptions

Action Alternatives rely on the completion of the Boston South Station Expansion Project being advanced by MassDOT with the support of the FRA, which will expand the platform track capacity at South Station and reconfigure the terminal interlockings, providing space to accommodate a greater number of peak train movements to and from South Station. In Alternatives 1 and 2, the planned South Station expansion is estimated to be sufficient to accommodate the level of Intercity and Regional rail train movements and passenger traffic estimated for 2040. Service specifications for Intercity and Regional rail service on the NEC approach to South Station were shared with MassDOT, and it was agreed that these levels of service were consistent with the level of rail traffic that can be accommodated by the planned expansion project.

In Alternative 3, however, the total level of traffic in the standard peak hour is estimated to exceed the capacity of the South Station complex, even with the planned expansion. New rail terminal facilities, therefore, are assumed to be constructed at some point subsequent to the South Station expansion but prior to 2040, in this alternative. NEC FUTURE does not specify the precise location of these new facilities, the associated changes to the rail network that is needed to take advantage of the increased capacity, or the extent to which improved rail service and access within the greater Boston region affects travel choices and patterns within the region. Additional Boston area capacity takes several forms, including further expanding the capacity of the Boston South Station complex, terminating some service within the Boston region but short of South Station (with transfers to Regional rail or rail transit services), or re-routing some service to other locations within the Boston region. Decisions about the specific future rail network configuration are beyond the scope of NEC FUTURE and will be part of subsequent Tier 2 analyses.

For purposes of ridership estimation, all Intercity rail services are assumed to originate and terminate at Boston South Station in all of the Action Alternatives. Similarly, all Regional rail services on the south side of Boston are assumed to continue to operate to and from South Station. Table 13 presents standard peak-hour train movements, by train type, for trains operating on the NEC to and from Boston, for the No Action and Action Alternatives.

Table 13: Boston South Screenline (South of Back Bay Station) – Standard Peak Hour-Peak Direction Service in 2040

	Existing	No Action	Alt. 1 Maintain	Alt. 2 Grow	Alt. 3 Transform
Number of Tracks	3	3	3	3	5
Standard Peak Hour (Trains/Hour)	10	10	17	22	24–32
Intercity-Express	<1	<1	2	4	2–6
Intercity-Corridor / Metropolitan	<1	<1	3	4	2–6
Regional rail Trains	9	9	12	14	20

Source: NEC FUTURE team, 2015

4.7 FREIGHT RAIL

- The NEC FUTURE Scoping process, along with input received from freight rail operators and state and regional stakeholders identified the preservation and enhancement of freight rail as an important concern, and the identification of opportunities to facilitate improved freight rail service as an important objective of NEC FUTURE. NEC FUTURE Service Plans for each of the Action Alternatives preserve freight access on the NEC and do not preclude future growth opportunities. Specific assumptions were developed for the mixed operations of freight and passenger traffic on the same tracks and in the same right-of-way, consistent with the current FRA regulatory framework: Freight will not operate on high-speed tracks in mixed traffic with Intercity-Express passenger trains operating above 160 mph – this includes all new route segments included in Alternative 3
- Mixing of different types of passenger trains, including Intercity-Express and Metropolitan service using new high-performance equipment, are assumed to be permissible in the future on the existing NEC with passenger train speeds up to 160 mph – this applies mostly to the express tracks on the NEC where there are more than two main tracks, in all three Action Alternatives[35]
- New tracks generally will be built with sufficient separation from parallel tracks used by freight trains to permit simultaneous operation of freight and passenger traffic; however, temporal separation of freight traffic may be required for some portions of the NEC where existing express tracks are used by high-speed trainsets and are closely parallel to the existing local tracks, such as in Pennsylvania, New Jersey and Massachusetts.

As part of NEC FUTURE, locations were identified where freight traffic operates on the NEC. Future freight rail traffic is difficult to forecast, and the freight railroads adjust their business plans year to year as a result of changing market conditions. The FRA, therefore, in lieu of preparing long-range freight forecasts, identified opportunities in all three Action Alternatives to facilitate or allow for increased freight service at selected locations where future demand likely increases. As an example, the portions of the NEC that have overhead[36] freight traffic today that is restricted to nighttime access includes investment in additional track capacity that permits daytime overhead freight operations on the local tracks, while Intercity-Express service is operated on separate express tracks.

In addition to preserving freight rail access to local industries along the NEC and not precluding future expansion of freight rail service, the Action Alternatives were reviewed with respect to their potential effects on four specific potential freight traffic growth opportunities:

- Freight access to Port of Baltimore, Port of Wilmington and Delmarva Peninsula
- Freight access along the NEC in Southeastern Connecticut and Rhode Island

[35] Railroad operating characteristics and limitations on permissible maximum speeds and the mixing of freight and passenger traffic are described more fully in Section 8.1.

[36] Overhead freight trains are defined to be through trains that operate from one end of a segment of railroad to the other, without stopping at intermediate locations. This is distinct from local freight trains, which serve industrial customers or call at yards located within the segment.

- Potential high-capacity, double-stack clearance freight line parallel to NEC between Washington, D.C., and northern New Jersey
- Freight rail access to Long Island and New England

In the Baltimore to Wilmington segment, all Action Alternatives expand the existing NEC to four tracks, replace or expand the two-track Gunpowder, Bush and Susquehanna River crossings to provide four tracks, and provide daytime slots for through-freight trains. Norfolk Southern uses the NEC to access the ports of Baltimore and Wilmington and to serve the Delmarva Peninsula. With a four-track main line, Intercity-Express and Metropolitan services operate on tracks that are separate from Regional rail and freight traffic, and crossings of the express and local tracks are grade-separated to permit access to freight branch lines and port and yard facilities that exist on both side of the right-of-way. Freight trains and Regional rail trains operate in mixed traffic on the local tracks, with commuter traffic dominating during weekday peak periods and freight rail having priority during overnight hours. Regional rail stations will have high platform edges that meet the requirements for level boarding under the Americans with Disabilities Act and enable rapid passenger boarding and alighting. Freight trains need to be dimensioned to be compatible with high platforms, or additional infrastructure will need to be built at stations, such as gauntlet tracks or freight bypass tracks. The formal wide clearance freight route remains on existing NEC express tracks, but will be used only during overnight hours or on a contingency basis.

Similar issues and opportunities exist in the territory where the P&W railroad operates in Southeast Connecticut and Rhode Island:

- All Action Alternatives envision operation of Tier III passenger equipment along the existing Shore Line route.
- Temporal separation of freight traffic on the NEC may be required in certain locations where investment in parallel track capacity is not economically warranted.
- Expansion of track capacity for increased passenger service will need to consider grade separation of key freight moves where warranted (e.g., Quonset, RI).

Conditions vary among the Action Alternatives in this territory:

- Alternative 1 and Alternative 3 variations with the second spine route via Worcester
  - Express service continues to be operated via the Shore Line, at frequencies greater than today.
  - Mixed Tier IIII operations are possible at New Haven-Old Saybrook at speeds less than 125 mph.
  - The Old Saybrook-Kenyon bypass allows for Intercity passenger trains to operate separately from freight trains.
  - Kenyon-Providence: a parallel freight track is provided to permit Tier III passenger operations on express tracks at up to 160 mph.

  - Grade-separated access for freight trains to the Narragansett Bay port facilities at Davisville is provided.

- Alternative 2 and Alternative 3 variations with Intercity-Express service in the Hartford-Providence corridor
  - Express service is provided via the New Haven-Hartford-Providence new route, enabling increased freight use of the Shore Line.
  - Passenger/freight trains are able to operate on the Shore Line route in a Tier I operating environment at passenger speeds up to 125 mph.

Each of the Action Alternatives preserves the future opportunity to create a dedicated north-south high-clearance, high-density freight line, which remains a long-term goal of Northeast transportation planners. Alternative 3 does the most in terms of providing new rail infrastructure that can be used by freight trains in portions of the corridor in Maryland, and freeing up the existing NEC for increased freight service in southeastern Connecticut and Rhode Island. Also, the Action Alternatives remove Intercity-Express trains from local tracks in many areas, creating potential opportunities for increased sharing of these tracks by Regional rail and freight trains during non-peak periods. Freight rail operations are generally incompatible with high-speed passenger operations utilizing Tier III equipment. Therefore, new separate infrastructure for freight will need to be built in most areas to provide a truly independent through-freight line.

Freight access to Long Island and New England is an issue that is beyond the scope of NEC FUTURE to address and resolve. NEC FUTURE will not draw any definitive conclusions about the ability to support significant opportunities for freight rail access as a consequence of the NEC FUTURE investments in and around New York. However, subsequent Tier 2 actions could address the potential for new Hudson River and East River tunnels to carry freight rail during overnight hours and identify the physical and operational requirements, life safety and security issues, and cost impacts.

5 Operations and Service Best Practices

The adoption of enhanced service and precision operations concepts on the NEC becomes possible with investment in the corridor to bring the railroad into a state of good repair, eliminate chokepoints, and expand capacity, which occurs with the Action Alternatives. These enhanced operating concepts represent national and international best practices and are aimed at increasing the efficiency of operations, lowering the cost per capita of delivering rail service, and making the most efficient use of investments in new rail infrastructure by maximizing the utilization of practical system capacity. These enhanced service concepts reach markets that are underserved or not served at all by existing service, while providing the rail operators the flexibility within which to deliver service that best meets the needs of the market in 2040. A discussion of several enhanced service concepts follows, along with a description of how these concepts were applied and tested as the Service Plans for the Action Alternatives were refined.

The analysis of alternatives focused on train operations and service patterns. However, a number of concepts in the customer service realm also are considered best practices that should be applied to future rail service improvements to maximize the benefits of those improvements to rail passengers. Additional features of improved rail service, not explicitly captured in the Service Plans for the Action Alternatives, potentially include the following:

- Fare collection system integration among Regional rail systems and with regional transit systems and Intercity rail
- Multimodal coordination, including improved opportunities for enhanced “first and last mile” links between rail stations and the places where people live and work
- Improved real-time travel information for rail and connecting travel modes.

5.1 REGULAR CLOCKFACE HEADWAYS

The Service Plans developed for the Action Alternatives are based on regular, repeating service patterns, which allow for the efficient scheduling of trains and use of infrastructure. Also, where new capacity infrastructure is needed at junctions and at locations where faster or non-stop trains need to overtake slower or stopping trains, regular repeating patterns tend to result in the most efficient and effective use of this additional infrastructure. Analysis of a wide range of potential service patterns has led to a set of common assumptions among the Action Alternatives to base schedule patterns for virtually all NEC services on trains operating at regular 15-, 30-, or 60-minute intervals, with local stations generally receiving 2-4 tph during peak periods and major stations often receiving more service. Peak shoulder hour, reverse-peak, and off-peak schedules typically can be developed by keeping the same operating patterns and reducing the headways or number of trains per hour associated with each service type and pattern.

An additional benefit of regular clockface headways is that they enable improved connections between rail and local transit services. For example, a bus route that runs on a regular clockface headway can be timed to meet connecting trains at a Hub station. This coordination increases ridership on both transit and rail by reducing transfer time between the modes. Additionally, a bus that is timed to meet the train can serve double duty—bringing passengers to the train as well as carrying passengers from the train on its onward journey. Transit agencies all along the NEC can choose to re-structure routes and schedules to take advantage of the regular clockface headway operation on the railroad.

Figure 20 provides an example of a regular headway pattern from the Alternative 2 service plan. In this example, Intercity-Express trains depart Boston South Station every 15 minutes at regular intervals throughout the AM peak period.

Figure 20: Sample Regular Interval Service – AM Peak Intercity-Express

Boston South Station	6:04	6:19	6:34	6:49	7:04	7:19	7:34	7:49	8:04
Back Bay	6:09	6:24	6:39	6:54	7:09	7:24	7:39	7:54	8:09
RTE 128	6:17	6:32	6:47	7:02	7:17	7:32	7:47	8:02	8:17
Providence Station	6:34	6:49	7:04	7:19	7:34	7:49	8:04	8:19	8:34

Source: NEC FUTURE team, 2015

Train schedules for the Action Alternatives are headway-driven rather than being load driven,[37] as is the case today. Virtually all NEC services operate at regular 15-, 30-, or 60-minute intervals, with local stations generally receiving 2-4 tph during peak periods and major stations often receiving more service. Peak shoulder hour, reverse-peak, and off-peak schedules retain the same operating patterns but reduce the headways or number of trains per hour in line with expected demand. Benefits of regular clockface scheduling include predictability, improved rail-to-rail and multimodal connection possibilities, simplified and therefore more reliable operations, improved convenience for rail travelers, and, as a consequence, increased ridership potential.

The use of standard hour and regular, repeating service patterns somewhat oversimplifies the factors that go into development of actual railroad operating plans and train schedules. However, clockface scheduling facilitates the implementation of pulse hubs and endpoint transfers (described elsewhere in this section), and it allows for more regular service intervals, which are desirable as service-related best practices.

5.2 METROPOLITAN SERVICE

As described in Section 2.3, Metropolitan service is a new Intercity-Corridor service that provides frequent, regular service on the NEC. By catering to the non-premium intercity market and the time-sensitive regional rail market, and offering service to a large set of stations that include both the Major Hubs as well as smaller hubs serving intermediate markets, this service becomes the

[37] Headway-driven schedules provide trains at regular time intervals. Load-driven schedules seek to maximize the number of passengers on trains in response to observed ridership peaking. The time intervals between trains are variable and tend to be shorter for lines or service zones with higher or more highly peaked ridership, and longer for more lightly patronized lines or zones. Load-based schedules are highly customized to the specific ridership markets being served and tend to be employed where overall capacity is severely constrained.

backbone of the NEC and the primary non-express Intercity rail option for trips that begin and end on the NEC.

Currently Amtrak Intercity-Corridor service (Northeast Regional) is not offered uniformly across the corridor, essentially using the same station stops since Amtrak's inception in the 1970s. Some stations are served infrequently, and other relatively important regional stations do not have Intercity service. Regional rail service, on the other hand, is geographically limited to single metropolitan areas and is focused largely on serving CBD commuters. In addition to a service gap, there is a price gap, with large differences between current Intercity and Regional rail fares.

The proposed Metropolitan service covers the entire NEC and includes more stations than currently served by Amtrak trains, providing service to markets that are underserved or not served by Intercity trains today. Stations providing Metropolitan service, in addition to where the existing Intercity-Corridor service stops today, are located at population, employment, and activity centers or at locations with good highway access, parking capacity and local transportation system connections. Examples include the following:

- Odenton, MD, which is adjacent to the major military base and employment center at Fort Meade and offers highway and potential connecting transit access to Annapolis and Columbia, MD
- Aberdeen, MD, adjacent to the military base and employment center at the Aberdeen Proving Ground
- Newark, DE, adjacent to the University of Delaware and at a station site with major development potential
- North Brunswick, NJ, at a potential station location with good highway access and major development potential, strategically located midway between the educational, research and employment centers of Princeton, NJ and New Brunswick, NJ

Despite adding station stops, Metropolitan service remains competitive with the trip times offered by current Amtrak Northeast Regional service, because it uses high-performance trainsets similar to those used for Intercity-Express service, and because it takes advantage of trip time improvements that are possible with the faster routes and improved infrastructure that are provided, to varying degrees, in the Action Alternatives.

While Metropolitan service functions as the future replacement for current corridor service, a separate Intercity-Corridor-Other service is also operated, providing one-seat rides to markets beyond the NEC, including Virginia, North Carolina, and Vermont. These two Intercity-Corridor services combine to provide service frequencies and passenger-carrying capacity on the NEC that are significantly higher in each of the Action Alternatives than is offered in the No Action Alternative. The travel demand analysis using the ridership models developed by the FRA for NEC FUTURE showed the combined Intercity-Corridor service to be successful in capturing a high level of ridership. Metropolitan service, therefore, is introduced in all of the Action Alternatives.

In Alternative 1, Metropolitan trains share NEC slots with Intercity-Corridor-Other trains, and service is limited to no more than 2 tph in the peak periods. As a result, the impact of adding this service is incremental. In Alternative 1, Metropolitan and Intercity-Corridor-Other services follow the same route, trip time performance is similar between the two service offerings, and they combine to offer a frequent and time-competitive service for interregional travelers.

In Alternative 2, Metropolitan service at 4 tph (15-minute regular headways) effectively replaces the existing Amtrak Northeast Regional service for the low or economy end of the Intercity travel market for trips within the NEC territory. The service utilizes the high-speed tracks that are built at various locations along the NEC. Metropolitan service between Washington, D.C., and Boston is operated at regular 30-minute intervals. The Keystone and Hartford Line connecting corridors are served by additional Metropolitan trains, also operated at 30-minute headways. These two sets of trains together provide a regular 15-minute headway between Philadelphia and New Haven. At the Washington, D.C., and Boston ends of the NEC, the headway gaps during peak periods are filled by shorter-haul Metropolitan trains (such as between Washington, D.C. and Wilmington, DE, or between Boston, MA and Providence, RI), as warranted by demand.

In Alternative 3, the Metropolitan service operates over extended distances on the high-speed infrastructure and outperforms the Intercity-Corridor trains for most station-to-station markets, in terms of both trip times and frequency of service. Alternative 3 operates the equivalent level of Metropolitan service as Alternative 2 on the existing NEC and on the Keystone and Hartford Lines. A second set of Metropolitan trains also operating at 15-minute headways is introduced on the second spine route north of New York (via White Plains, NY and Danbury, CT, or via Long Island, depending upon which new route segments are constructed to serve the New York-to-Boston Intercity-Express market). This doubles the number of Metropolitan trains running through New York to as many as 8 tph. In addition, the main line capacity included in this alternative presents the opportunity to introduce new connecting corridor services that have service characteristics similar to Metropolitan service, such as between the Empire Corridor and Long Island, even though different rolling stock is required to operate in non-electrified territory.

5.3 RUN-THROUGH SERVICE AT MAJOR STATIONS/TERMINALS

In Boston, New York, and Washington, D.C., the various Regional rail operators terminate service at the major rail stations in the CBD. Philadelphia is the exception on the NEC where Regional rail currently operates through the CBD with northern branch lines linked with those to the south.

Regional rail run-through service, particularly applicable to Washington, D.C., and New York, links branch lines from the different service carriers and provide continuous revenue service on both sides of the particular metro region through the CBD. For example, a peak-direction Regional rail train that originates in New Jersey operates into Penn Station New York, and then continues in revenue service and offer reverse-peak service on Long Island. Run-through service can provide operational efficiencies and unlock additional station capacity, which can help contain the need for considerable additional investment in the major terminals.

Alternative 1, which is based on retaining current operational environments as much as possible, retains the existing Regional rail terminal operations at Washington, D.C., New York and Boston, although the volume of train movement activity increases over existing and No Action Alternative levels. Alternative 1 intentionally avoids reliance on through-running operations where they do not currently exist to illustrate the limits of current terminal operations. Intercity trains remain the principal through-running trains at Washington, D.C., and New York.

To meet the service scenarios developed for Alternatives 2 and 3 with higher volumes of peak train traffic, run-through Regional rail operations are introduced to illustrate how they can free capacity and support highly reliable operations and maximize the utilization of new railroad infrastructure.

Alternative 2 expands the terminals at Washington, D.C., and New York to facilitate the through-running of both Intercity and Regional rail trains, including the widening of station platforms and the creation of storage yard facilities on the far side of the terminal for originating and terminating regional services. Efficiencies gained with through-running at both Washington, D.C., and New York are assumed in this alternative—supporting frequent Metropolitan service as well as high-density Regional rail service. Through-running capability and associated capacity projects permit Metropolitan service to be extended through Washington, D.C., to Northern Virginia. Similarly, expanded Regional rail services at both Washington, D.C., and New York are assumed to operate through the Major Hub stations, feeding yard facilities on the far side of the Hub station and also enabling (but not requiring) revenue run-through service between suburban branch lines on opposite sides of the region. This concept is not predicated on any particular assumptions with respect to the entity or entities that operate the various services.

Alternative 3 similarly supports through-running operations, which permit the most efficient use of scarce platform and track capacity at the Major Hub stations and enables the dramatic increases in total train volumes that are possible in this alternative.

5.4 REGIONAL RAIL EXPRESS SERVICE USING HIGH-SPEED TRACKS

In Alternative 3, in which new dedicated high-speed tracks are provided for Intercity-Express service, there is an opportunity to use this infrastructure through urban areas for select Regional rail trains by taking advantage of available slots not used by the Intercity-Express service. These select Regional rail trains are operated with high-performance trainsets with top speeds and acceleration and braking rates similar to Intercity-Express and Metropolitan trainsets, making them capable of operating in blended service with high-speed express trains without unduly constraining the capacity of the high-speed tracks. These select Regional rail express trains supplement or replace the outer zone-express service in the major metro regions, or can be used to extend Regional rail service beyond the existing service territories.

There is insufficient capacity in Alternatives 1 and 2 to offer regional express service on the high-speed tracks. However, this is a significant feature of Alternative 3, offering substantially faster commute times for longer-distance commute trips from the outer suburbs.

For example, Maryland outer-zone Regional rail trains can use the high-speed tracks between Baltimore and Washington, D.C. Similarly, this service improves trip times to New York from the outer–zone service serving New Jersey and Bucks County, PA, while relieving congestion on the local tracks. Other opportunities to provide high-speed Regional rail service in Alterative 3 exist in

Long Island and Westchester County, in which Regional rail providers can take advantage of portions of the new high-speed line feeding New York and Boston to dramatically reduce trip times to the outer zone markets. Opportunities exist for 6 to 8 commuter express trains in the peak hour from either Long Island or the Upper Harlem Line to Penn Station New York, if new high-speed lines were built from New York either via the Long Island or Central Connecticut second spine routes.

5.5 SIMPLIFIED OPERATIONS

Simplified operations encompass a range of possible concepts for operating passenger service on a multi-track rail line. All of these concepts share the objectives of maximizing the utilization of infrastructure capacity, increasing the reliability of rail service and the ability of the system to recover when delays occur, and providing customers with a high level of convenience. Service concepts that fall under the heading of simplified operations include the following:

- Normalizing stopping patterns (with fewer but more regular and better coordinated patterns), as opposed to having a lot of unique individual patterns
- Less switching of trains between tracks in multi-track territory
- Fewer branch lines feeding the NEC
- Timed transfers for branch line passengers at main line Hub stations
- Higher and more regular service frequencies for the stopping patterns that remain on the NEC

The primary benefit of a simplified service plan is that it brings more predictability to both train operators and passengers.

For train operators, simplification of the train schedule and adoption of regular, repeating and well-integrated train stopping patterns can allow the railroad to be run more automatically, without the variability and potential human error introduced by a system that generates a wide range of unique conflicts that require frequent dispatcher decisions and unique solutions. The system remains too complex for completely automated operation, and train dispatchers are still needed to monitor and resolve conflicts and errors that do occur. However, simplified operations can reduce the number and type of train interference conflicts that arise for train dispatchers and allow them to better respond to conflicts when they occur, and respond in a way that is more predictable. Consequently, simplified options should improve the overall reliability of the railroad as well as minimize the amount of redundant and parallel rail infrastructure necessary to support a more complex service plan.

For passengers, the regularity of a simplified plan makes planning trips easier, increasing the attractiveness of rail versus other modes. More reliable service and better connections with other rail services and transit modes are benefits that attract additional ridership. Drawbacks of this type of plan may include serving fewer markets with one-seat rides and increased trip times for express trains between major markets.

Several of the scenarios developed for Alternative 2 provide a clear illustration of the differences between a complex and a simplified set of service patterns. Both schemes have advantages and drawbacks relative to the other, and the analysis demonstrates that the rail infrastructure configuration assumed for Alternative 2 accommodates either set of patterns, which enables the specific development of Service Plans and train schedules to be made at a later date as market demands and the needs and priorities of the railroad operators are better known. These scenarios differed in the variations in stopping patterns among the Intercity services and the extent to which Intercity and Regional rail services were segregated onto separate tracks.

Both Intercity and Regional rail stopping patterns for the Action Alternatives are simpler and more regular than in the current operating plans, which, when coupled with the elimination of chokepoints and the restoration of the railroad to a state of good repair, results in highly reliable service and efficient use of infrastructure. The Action Alternatives generally retain the relatively complex network configuration that feed multiple branch lines onto the NEC at various points along the corridor.

The most dramatic application of simplified operations occurs in Alternative 1 on the New Haven Line, where a transit-style service is implemented that replaces the current complex overlay of multiple stopping patterns with a simpler system of express and skip-stop local services that can deliver greater throughput capacity without major new track capacity. Comparison of this alternative with the more conventional zone-express service patterns in Alternatives 2 and 3 enabled the relative merits and challenges of implementing a simplified operating pattern to be better understood.

5.6 COORDINATED ENDPOINT CONNECTIONS

Coordinated scheduling of Regional rail trains—on systems that have multiple branch lines or multiple terminals, or where the outer ends of two regional systems meet at a common station—can provide for convenient passenger connections, extending the reach of the existing systems, substituting for costly extensions one-seat-ride service, and providing a much more convenient transfer experience for rail travelers. More precise schedule coordination becomes easier to accomplish with clockface scheduling, simplified operations and elimination of the chokepoints that contribute to train delays—all of which are characteristics of the Action Alternatives. Convenient transfer connections depend on train schedules that allow enough, but not too much, time for passengers to change trains at the Hub or endpoint station. Convenience also is enhanced with cross-platform or same-platform transfers, and the integration of timetable and real-time train information, particularly where more than one operating authority is involved. Trenton, NJ, is an example of a location where endpoint connections currently are provided between SEPTA and NJ TRANSIT Regional rail trains.

For coordinated endpoint connections to work well, physical and operational barriers to transferring must be reduced. The reduction in physical barriers includes investing in station and line infrastructure to accommodate cross-platform transfers and providing clear and intuitive pathways between platforms. The reduction in operational barriers also includes an integrated ticketing system so that a trip that includes multiple legs across multiple rail operators is easily booked and fully transparent to the passenger and allowing passengers free flowing access to platforms.

With clockface scheduling and regular, repeating service intervals, Alternatives 1, 2, and 3 take advantage of opportunities for better connected Regional rail service at several locations on the NEC, effectively closing the gaps that now exist in Regional rail connectivity from one regional system to another. As Maryland Regional rail service is extended to Newark, DE, schedules are coordinated with those of the Regional rail service to Philadelphia, enabling convenient passenger transfers. Modification of the track configuration in the vicinity of Trenton (or potentially at some other future location in New Jersey) allows timed cross-platform transfers between New Jersey and Philadelphia Regional rail trains in both directions. Also, the integration of Shore Line and Hartford Line Regional rail trains with New Haven Line service provides convenient cross-platform transfers at New Haven.

In the Action Alternatives, opportunities for better connected service are provided at locations such as Newark, DE, New London, CT, Westerly, RI, and Springfield, MA. The full-build plan for a new multimodal Hub station at Newark, DE, facilitates cross-platform transfers between Washington-based (MARC) and Philadelphia-based (SEPTA) Regional rail services, as well as potential new passenger service on the Delmarva Peninsula. Existing stations need to be improved or reconfigured to enable closing of the Regional rail service gap between Shore Line East service to New Haven and MBTA service to Providence and Boston. And at Springfield, convenient timed transfers can be provided between NEC Metropolitan and Intercity-Corridor-Other trains serving the Knowledge Corridor and Inland Route.

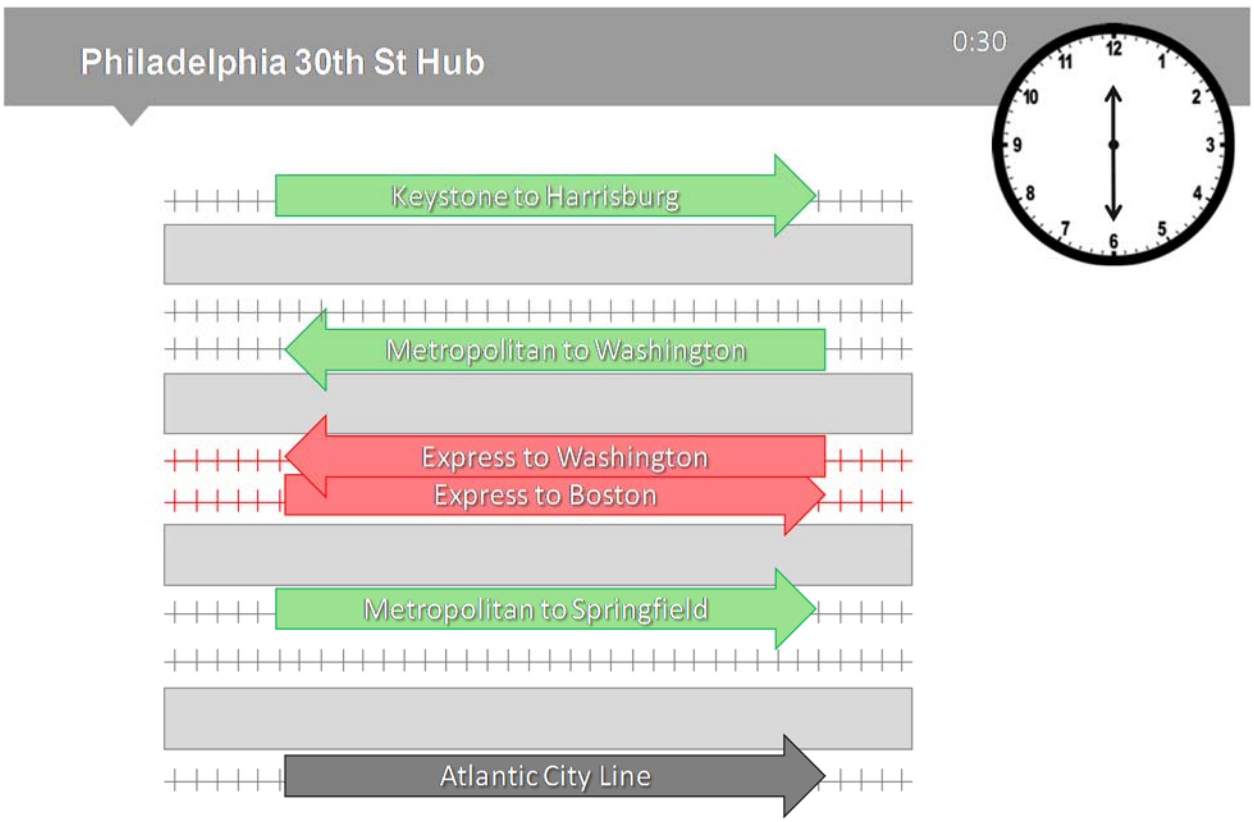
The Action Alternatives also improve connectivity between main line and branch line services at multiple locations. Intercity services can be better coordinated with regional services at Philadelphia 30th Street with the normalization of train schedules. The timing of Empire train arrivals and departures at Penn Station New York can be coordinated with Intercity-Express, Metropolitan, and Regional rail service on the NEC. And in cases where simplified operations may reduce the number or frequency of direct train services from the NEC main line to regional branch lines, shuttle services on the branch lines can be timed with convenient connections to and from NEC trains, offering greater overall service frequency on the branch line and a trip that remains convenient and time-competitive for the passenger making the transfer. The same principles apply to connecting transit services at Hub stations. Regular clockface scheduling of rail services, coupled with reliable operating performance, allows local transit service providers to customize the arrival and departure timing connecting and feeder services to match the train schedules.

5.7 PULSE-HUB OPERATIONS

A pulse-hub operation plays a prominent role in a simplified operation, but can also be a feature of Service Plans with a wider variety of service offerings. In pulse-hub operations, trains from different lines and service tiers arrive at a Hub station concurrently or in close succession. Passengers can then transfer to a range of services during the simultaneous dwell of these multiple trains. Trains then leave the station in close intervals. Figures 20 and 21 illustrate one example of a pulse-hub, at 30th Street Philadelphia, where several trains of different types and with different destinations have coordinated arrival and departure times, facilitating convenient transfers.

A pulse-hub operation offers opportunities to provide high-quality service to smaller markets that do not warrant one-seat-ride to major markets. For this system to work appropriately, significant amounts of infrastructure may be needed at Hub stations to facilitate the simultaneous movement of multiple trains through the station as well as the efficient movement of passengers between trains. Investment in station and rail infrastructure to enable high-quality passenger transfers and elimination of operational barriers including segregated ticketing and limited passenger access to platforms are prominent features of pulse-hub operations. Providing high-quality passenger transfers can also be a feature of Service Plans that do not rely exclusively on this type of operation, but selectively employs it at key stations on the network.

Figure 21: Philadelphia Pulse Hub



Source: NEC FUTURE team, 2015

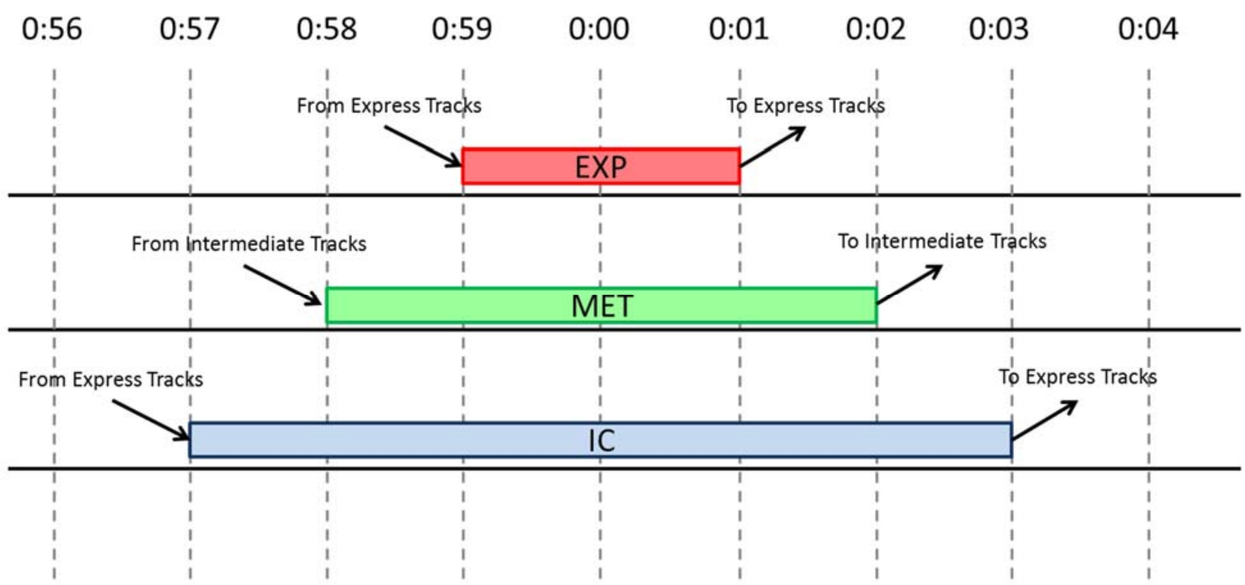
The service scenarios that were developed for Alternative 2 provide a good example of pulse-hub operations at the lower level of Philadelphia 30th Street Station and at New Haven Union Station – both locations where Intercity connecting corridors and multiple Regional rail services come together at a single location. The Service Plans for Alternatives 2 and 3 provide for pulse-hub operations on the lower level of 30th Street Station every 30 minutes, with Intercity-Express, Metropolitan, Keystone and Atlantic City trains all connecting with universal transfer opportunities every 30 minutes during the peak periods. The versions of Alternative 3 that provide for a new route from Long Island through New Haven to Hartford also provide for a timed pulse-hub at New Haven.

Figure 21 shows a simplified schematic of the lower level of track and platforms at 30th Street station in Philadelphia during a pulse in service at the tops of the hour when northbound and southbound Metropolitan and Intercity-Express trains and an Atlantic City-bound train are all in the station simultaneously. In this example, the Intercity-Express trains will depart first, followed closely by the Metropolitan trains and then finally the Atlantic City train.

Two Metropolitan trains are scheduled on 30-minute headways the entire length of the corridor providing the basic all-day Intercity service to markets on the NEC and operate over the express route between Providence and New Haven via Hartford.

These trains re coordinated with the express trains in Philadelphia providing convenient transfers between the Metropolitan and Intercity-Express service twice per hour, allowing the Metropolitan to act as feeder/distributer service for Intercity-Express trains broadening the market reach of express service. This timed transfer opportunity in Philadelphia is also timed to coincide with Intercity-Corridor trains allowing for transfer between all three services. This allows passengers on the Intercity-Corridor trains, particularly those beginning their journey from off-corridor markets south of Washington, D.C. and traveling to Harrisburg, convenient same-platform transfers to both the Intercity-Express and Metropolitan trains, allowing access to more on-corridor markets than are served directly by the Intercity-Corridor train. Figure 22 depicts this Philadelphia concept.

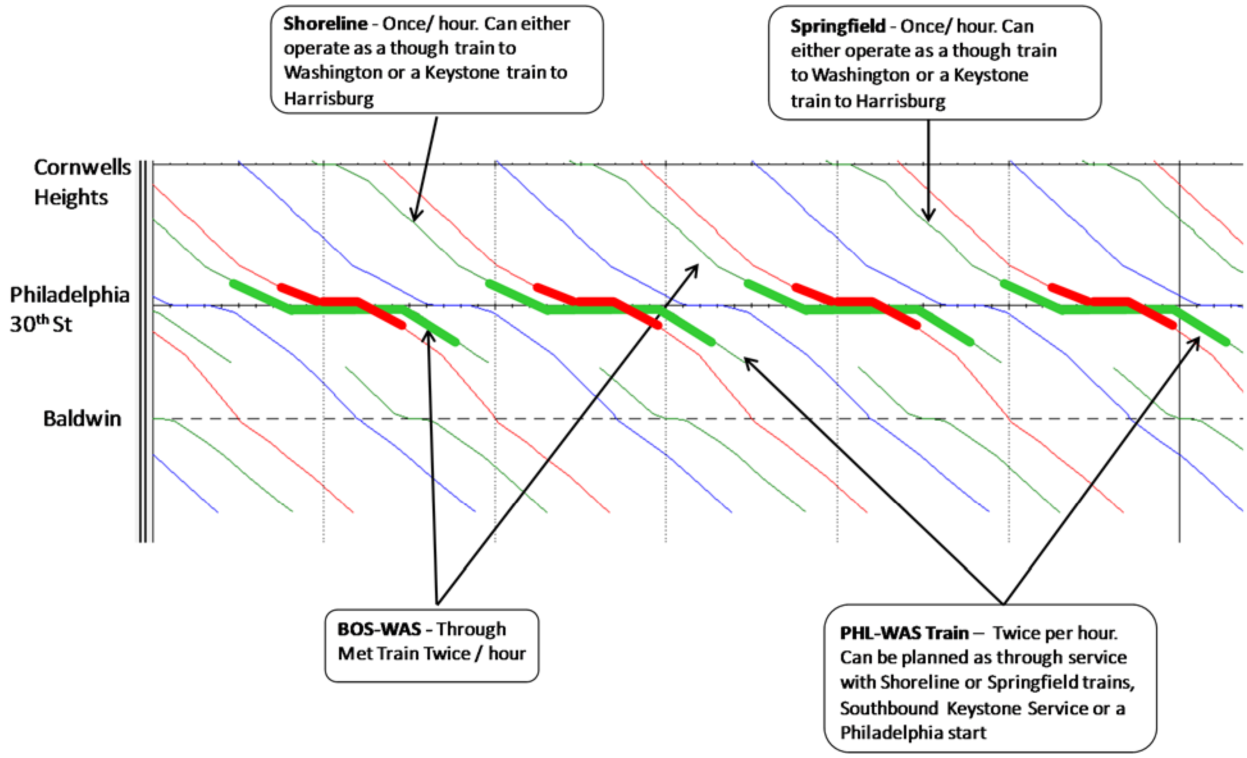
Figure 22: Philadelphia Pulse-Hub Concept



Source: NEC FUTURE team, 2015

A potential Philadelphia pulse-hub with a 15-minute cycle, which can be implemented in Alternative 2 to provide an even greater degree of rail-to-rail connectivity, is shown in the stringline diagram format in Figure 23.

Figure 23: Philadelphia Hub with Intercity-Express and Metropolitan Transfers Every 15 Minutes

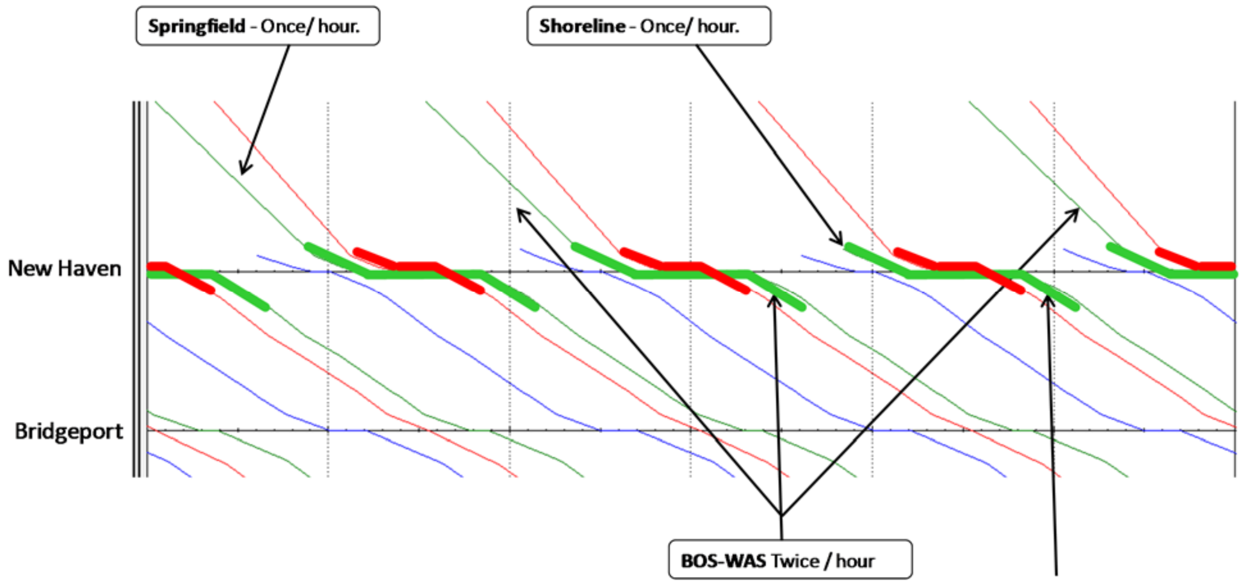


Source: NEC FUTURE team, 2015

A similar pulse-hub operation can be implemented in New Haven in Alternative 2 or 3. The following example illustrates how the pulse-hub concept works in Alternative 2. In New Haven, express trains arrive at the station at 0:59, 0:14, 0:29, and 0:44 past the hour. These trains dwell at the station for two minutes and leave New Haven at 0:01, 0:16, 0:31, and 0:46 past the hour. At the top and bottom of the hour, the Boston to Washington, D.C., Metropolitan trains arrive two minutes before and leaves two minutes after the Intercity-Express train facilitating a cross-platform transfer and providing an opportunity for the Intercity-Express train to overtake or pass the Metropolitan train in the station, as opposed to out on the main line. This happens simultaneously in both directions.

At 15 minutes after the hour, this transfer/overtake occurs between the southbound Shoreline Metropolitan and the northbound Springfield Metropolitan and Intercity-Express in both directions. At 45 minutes after the hour this transfer/overtake occurs between the northbound Shoreline Metropolitan, and the southbound Springfield Metropolitan and Intercity-Express in both directions. Figure 24 shows a diagram of this operation.

Figure 24: New Haven Hub with Intercity-Express and Metropolitan Transfers Every 15 Minutes



Elements of the pulse-hub concept can be adopted at Washington Union Station to coordinate the schedules of Regional rail trains with Intercity train arrivals and departures in both directions of travel. This concept also can be used to enable Intercity passengers from origins south of Washington to have convenient transfers to Intercity-Express trains for faster trip times to points on the NEC such as New York or Boston.

6 Rolling Stock

6.1 TRAIN EQUIPMENT OPTIONS

The FRA considered a range of potential rolling stock types for passenger rail service on the NEC for analysis purposes. Table 14 presents the menu of rolling stock options. The objective of FRA's service planning for NEC FUTURE is to establish a long-term vision and investment plan for the NEC and is not to make decisions about fleet composition and equipment procurement for NEC rail services. Planning goals are to achieve operational efficiencies, maximize capacity utilization, and make the best use of infrastructure investment dollars by making train performance more uniform. These goals are best achieved through the standardization of rolling stock types on the NEC to enable delivery of a consistent and high level of performance. The Action Alternatives, therefore, are based on the use of the same high-speed trainset technology for both Intercity-Express and Metropolitan service, and the use of all-electric equipment for Regional rail service. Ultimate decisions about rolling stock procurement, including the configuration and maximum speed of high-speed trainsets, will be made over time after completion of the Tier 1 EIS. Specific assumptions regarding Regional rail service and rolling stock vary among the Action Alternatives, and consideration is given, particularly in Alternative 1, to continued use of diesel-hauled trains, where a level of service sufficient to meet the objectives of the alternative can be achieved, although some reduction in Regional rail service frequency and scheduling flexibility result, compared with what is possible using all-electric equipment.

6.2 BASIS OF ANALYSIS FOR NO ACTION AND ACTION ALTERNATIVES

This section summarizes the rolling stock characteristics of the No Action Alternative and Action Alternatives for each service type.

6.2.1.1 No Action Alternative

The size of the Intercity-Express fleet is augmented through the procurement of a new fleet of high-speed trainsets, which increases train seating capacity from 305 to 450 and allows for limited expansion of Intercity-Express service on the NEC. Normal life-cycle replacement of the Amfleet Intercity-Corridor equipment occurs over the period through 2040, but the configuration of these trains with electric locomotives and trailer coaches remains the same.

Regional rail service is operated with the future fleet that currently is planned for each of the eight Regional rail systems:

- Boston: diesel locomotives and bi-level coaches
- Shore Line East: EMU trainsets
- Metro-North New Haven Line: EMU trainsets and dual-mode locomotives in a push-pull configuration.
- LIRR: EMU trainsets on electrified lines and dual-mode locomotives and bi-level coaches in a push-pull configuration on trains to Penn Station New York serving non-electrified territory
- NJ TRANSIT: EMU trainsets

- SEPTA: EMU trainsets or electric locomotives and coaches
- MARC: electric or diesel locomotives and bi-level coaches in a push-pull configuration
- VRE: diesel locomotives and Gallery-style coaches (low platform boarding only) in a push-pull configuration

Table 14: Rolling Stock Options for Service Planning Purposes

Equipment Type	Tier	Length [1]	Locomotives	Loco Type / Traction Power Type	Train Length[2] (ft)	Seats/Car	Seats/Train	Operates Off-Corridor	Max. Speed on NEC (mph)	Boarding Platform Level	Remarks
Intercity-Express High-Speed Trainset	III	7–14	0	Concentrated or distributed power w/ Catenary	595–1,190	50–60	350–840	No	220	High only	
Metropolitan or Intercity-Corridor High-Speed Trainset	III	7–14	0	Concentrated or distributed power w/ Catenary	595–1,190	60–70	420–980	No	220	High only	On NEC Spine and branches w/ catenary electrification
	III	12	0	Dual Power/Cat. + 3rd Rail	1,020	60–70	720–840	Yes	160–220[5]	High only	NEC-Long Island run-through services
	III	12	0	High–Performance Dual Mode[3]	1,020	60–70	720–840	Yes	160–220[6]	High or Hi-Lo	Other off-corridor extensions
	III	12	0	Dual Mode/3rd Rail + Diesel	1,020	60–70	720–840	Yes	160–220[6]	High or Hi-Lo	Long Island-Empire run-through services
Intercity-Corridor Train	I	10	1–2	High–Performance Dual Mode[3]	1,000	60–70	600–700	Yes	125	Hi-Lo	New loco type[3]
	I	12	1–2	Diesel loco	1,170	60–70	720–840	Yes	(110)	Hi-Lo	Operates off-corridor only
	I	12	1–2	Electric loco/Catenary	1,170	60–70	720–840	Yes	125	Hi-Lo	On NEC w/ engine change
Regional rail Electric Multiple-Unit (EMU)[4]	I	12	0	EMU/Catenary or 3rd Rail	1,020	105	1,260	Yes	100–125	High or Hi-Lo	Single level fleet, similar to M7, M8, Silverliner V
	I	12	0	EMU/Catenary or 3rd Rail	1,020	135	1,620	Yes	100–125	High or Hi-Lo	New fleet type – Bi-Level or multi-level EMU
Regional rail Push-Pull, Single level or Bi-level[4]	I	10–12	1–2	Electric, Diesel or Dual–Mode loco	1,000	135	1,350–1,620	Yes	125/100	High or Hi-Lo	Includes run-through services
	I	8	1	Electric, Diesel or Dual–Mode loco	755	135	1,080	Yes	125/100	High or Hi-Lo	Includes run-through services
Intercity-Long Distance Train	I	10–12	1–2	Same locomotive options as Intercity–Corridor trains	1,170	n.a.	400	Yes	125	Hi-Lo	Operates on NEC during off-peak hours only

[1] Measured in equivalent 85-foot car lengths. Also can be operated in smaller consists as warranted by demand. High-speed equipment assumed to comprise one or two intact trainset modules.
[2] Based on 85 ft. long passenger cars and 75 ft. long locomotives, or the equivalent length of intact trainset modules.
[3] Assumptions re future high-performance dual-mode locomotive or multiple-unit trainset (technology assumed to exist prior to 2040 horizon year): Catenary on existing NEC; Diesel off-corridor; Top speed off-corridor: 110 mph; Braking rate: 1.6 mph/second; Acceleration: similar to AEM7 (placeholder with middle-of-the-road performance).
[4] Includes through-running services, assuming compatibility with traction power system (if any) on all lines served.
[5] There is currently no high-speed trainset 220 mph-capable that has both overhead electrification and third rail equipment. This trainset will need to be compatible with the three types of AC power present on the existing NEC.
[6] There is currently no trainset 220 mph-capable that is powered by overhead electrification and diesel.

6.2.1.2 Alternative 1

Intercity-Express service operates with Tier III high-speed trainsets, with a top operating speed of 160 mph. The high-speed trainsets may have tilting capability, to permit these trains to operate around existing curves on the existing NEC at a higher speed than currently is permitted for conventional trains. Tilting technology affects vehicle weight and cost and requires minimum track center spacing greater than what exists in some portions of the existing corridor. Tilting capability therefore is not a prerequisite.

Intercity-Corridor service, as well as Intercity-Long Distance service, is operated with trains composed of locomotive-hauled coaches. Metropolitan service is assumed to be operated with Tier III high-speed trainsets with performance characteristics similar to Intercity-Express trains, but with an interior configuration with greater seating capacity and larger vestibule areas to facilitate rapid boarding and alighting at stations.

Service Plans for Regional rail service on the NEC are based on locomotive or trainset performance equivalent to push-pull trains with high-performance electric locomotives. Those systems that operate with lower-performing equipment, such as the diesel locomotives currently operating on the NEC in Maryland, southeastern Connecticut and Massachusetts, upgrade to electric locomotives or equivalent-performing equipment. In this alternative, Regional rail operators are able to operate with lesser-performing equipment—albeit with reduced scheduling flexibility, fewer peak trains, and/or less reliability.

6.2.1.3 Alternative 2

Alternative 2 is based on the same rolling stock performance assumptions as Alternative 1. Intercity-express service is assumed to be operated with Tier III high-speed trainsets, with a top operating speed capped at 160 mph.

Metropolitan service is operated with Tier III high-speed trainsets, with the same performance characteristics as the Intercity-Express trains, allowing them to operate on the high-speed tracks between express trains at minimum headways, in order to maximize the utilization of the line’s practical capacity. The interior configuration of the Metropolitan trainsets are different from the express trainsets, since these trains are expected to carry higher passenger loads including both Intercity travelers and commuters, with higher seating capacities, larger vestibules and a greater number of doors to facilitate passenger boarding and alighting.

Intercity-Corridor service, as well as Intercity-Long Distance service is operated with trains composed of electric or dual-mode locomotive-hauled coaches.

Service Plans for Regional rail are based on use of high-performance equipment to maximize capacity utilization. Regional rail operators are able to operate with lesser-performing equipment—albeit with reduced scheduling flexibility, fewer peak trains, and/or less reliability.

6.2.1.4 Alternative 3

Alternative 3, which entails the construction of a second spine on new right-of-way along most of the corridor between Washington, D.C., and Boston, offers the opportunity to develop a dedicated high-speed rail service with top speeds higher than what can be practically achieved on the existing NEC and with significantly improved trip times for both Intercity-Express and Metropolitan services. Compared with Alternative 2, Intercity-Express trains following the second spine route in Alternative 3 makes the trip between Washington, D.C., and New York approximately 48 minutes faster and saves over 60 minutes on the northern portion of the trip between New York and Boston. The analysis was based on the use of a Tier III high-speed trainset with a top speed of 220 mph, equivalent to the current state of the art of European and Asian high-speed rail systems. These trains do not have tilting capability, and therefore, need to operate at lower speeds around existing curves on the NEC and any curves on the new alignment. The same high-speed trainset technology is assumed for all Intercity-Corridor and Metropolitan services operating on the NEC. The trip time performance of these 220 mph trainsets was compared with the performance of the Tier III equipment assumed in Alternatives 1 and 2 (160 mph top speed with tilting capability). The 160 mph tilting equipment generated trip times approximately 8 minutes longer between Washington, D.C., and New York and 13 minutes longer between New York and Boston compared with the use of equipment with a top speed of 220 mph, over the same Alternative 3 second spine route for a typical Intercity-Express train.

Intercity-Corridor rolling stock assumptions are the same in Alternative 3 as in the other Action Alternatives. All Regional rail services are assumed to operate with high-performance equipment on the NEC (i.e., either EMU trainsets or coaches pulled by high-performance electric locomotives in a push-pull configuration).

A new type of Regional rail service also is investigated in this Action Alternative—commuter express service, which operates partly on the existing Regional rail network and partly on the new high-speed lines, taking advantage of available capacity on these lines close to the major regional business districts. These trains must match the performance of the Intercity-Express and Metropolitan trains and, therefore, are assumed to utilize the same trainset technology, with an interior configuration and door spacing similar to the Metropolitan trainset.

7 Service Plans for the No Action and Action Alternatives

This section provides final service plan information for the No Action Alternative and Action Alternatives analyzed in the Tier 1 Draft EIS. For each alternative, the level of peak and daily train service is described, by type of service, with the required capital investments in capacity-related rail infrastructure also identified. The service specifications used to drive the ridership and operations and maintenance cost models, and on which the analysis of service-related environmental effects was based, will be presented in Appendix B of the Tier 1 Draft EIS. The Service Plans are intended to be representational only, required for analysis of capacity, performance, and costs, as well as assessment of environmental impacts, and are not intended in any way to be prescriptive regarding how service should be operated in the future. In addition, they are not intended to predict the future operating patterns of the NEC railroad.

7.1 NO ACTION ALTERNATIVE

The No Action Alternative serves existing markets along the NEC using the existing mix of trains and level of train service. South of New York, there are three Intercity services, each operating with 1 tph in the standard peak hour: an Intercity-Express (Acela Express) train, an Intercity-Corridor (Northeast Regional) train, and a Keystone Corridor train. Intercity-Express and Intercity-Corridor service is operated north of New York to Boston and/or Springfield, at frequencies of approximately one train every two hours each. Empire service operates approximately hourly in the standard peak hour in each direction. Table 15 presents the level of Regional rail service in 2040 included in the No Action Alternative. The only substantive change from existing service levels is the introduction of LIRR service to Grand Central Terminal, which becomes possible with completion of the East Side Access project. A fuller description of the No Action Alternative is contained within the *No Action Alternative Report*[38].

[38] Available on the NEC FUTURE website at www.necfuture.com.

Table 15: 2040 No Action Alternative – Regional Rail Service

REGIONAL TRAINS PER HOUR	Existing / No Action			
	Peak	Shoulder	Reverse Peak	Off Peak
WASHINGTON REGION				
MD Regional Rail (Penn Line)	3	2.5	1.5	1.3
VA Regional Rail	5.5	1	0.2	0.1
PHILADELPHIA REGION				
North Side Regional Rail	7	4	4	2.5
South Side Regional Rail	5	4	3.5	3
NEW YORK REGION				
NJ - NEC / NJCL Trans Hudson	15	8	7	3
NJ - Other Regional Rail Trans Hudson	6	3	3	2
NJ - Standard Inner Branch Slots	-	-	-	-
CT - New Haven Line (PS & GCT)	22	16	12	3
BOSTON REGION				
NEC Regional Rail	9	4	4	2.6
Worcester / Framingham Lines	3	2	1	1

Source: NEC FUTURE team, 2015

Note: Table excludes Long Island Rail Road services. Fractional values represent services that do not operate the same number of trains each hour during the four major time periods. For existing service, these values were derived so that the total daily number of trains in the service specification approximately matches the number of trains actually operated.

7.2 ALTERNATIVE 1

Alternative 1 maintains the role of rail as it is today, with the level and capacity of rail service keeping pace with the projected population and employment within the Study Area. Alternative 1 builds off Service Plans developed by the NEC rail operators to meet the projected organic increase in travel demand. Alternative 1 includes new rail services and commensurate investment in the NEC to bring the railroad to a state of good repair, expand capacity, add tracks, and relieve key chokepoints, particularly through northern New Jersey, New York, and Connecticut.

Alternative 1 is focused on meeting the growth needs of existing NEC rail markets, rather than providing service to new markets. Projected increases in population and employment within the Study Area through 2040 will increase demand for rail in the corridor, requiring commensurate increases in Intercity and Regional rail service on the NEC. Intercity service nearly doubles compared with the No Action Alternative, which alleviates the existing constraints on ridership and accommodates future population and employment growth. Alternative 1 increases available Regional rail capacity by lengthening trains in some locations, mostly outside the New York area, but these opportunities are limited and are not sustainable through 2040 corridor-wide. As a result, Alternative 1 adds train service over and above what is provided in the No Action Alternative, to allow more riders to be carried at peak periods. This, in turn, requires targeted investment in railroad capacity beyond No Action Alternative levels where constraints currently exist—such as at the Hudson River crossing, in Maryland south of Baltimore, on the New Haven Line, and at the major terminals in Washington, D.C., New York and Boston. Taken together, lengthening trains and increasing service frequency enables future Regional rail service to continue to carry its current share of journey-to-work trips to and from the major metropolitan central business districts. Reverse-peak and off-peak service continues to be operated where it is provided today.

In general, Alternative 1:

- Includes the infrastructure investment necessary to meet 2040 Regional rail ridership and service targets, along with moderate expansion of Intercity service
- Focuses investment on eliminating chokepoints and getting the highest practical capacity out of the existing railroad
- Assumes the current institutional structure of rail operators is maintained
- Resembles the future Service Plans proposed by the rail service providers as much as possible
- Incorporates a potential new service concept—Metropolitan service—to the extent possible within available capacity.

Table 16 and Table 17 present the service plan specifications for Intercity and Regional rail service, respectively, showing the levels of rail service provided in Alternative 1.

Table 16: Alternative 1 – Intercity Service in Standard Peak Hour

	Existing	No Action	Alt 1
South End			
Intercity Express	1	1	2
Intercity Corridor			
Wash-Phila	1	1	2
Phila-NY	2	2	2
Metropolitan			
Wash-Phila	--	--	2
Phila-NY	--	--	3
North End			
Intercity Express	<1	<1	2
Intercity Corridor			
NY-New Haven	<1	<1	2
New Haven-Boston (Shore Line)	<1	<1	1
New Haven-Springfield	--	--	1
Metropolitan			
NY-New Haven	--	--	2
New Haven-Boston (OSB-KEN Bypass)	--	--	2
New Haven-Boston (Shore Line)	--	--	--
New Route	--	--	--
Connecting Corridors			
Virginia	<1	<1	2
Empire	1	1	2
Keystone	1	1	1
Springfield	<1	<1	1
Knowledge Corridor	1 tpd	1 tpd	<1
Inland Route	--	<1	<1
Other	--	--	--

Source: NEC FUTURE team, 2015

Table 17: Alternative 1 – Regional Rail Service

REGIONAL TRAINS PER HOUR	Existing / No Action					Alternative 1			
	Peak	Shoulder	Reverse Peak	Off Peak		Peak	Shoulder	Reverse Peak	Off Peak
WASHINGTON REGION									
MD Regional Rail (Penn Line)	3	2.5	1.5	1.3		6	5	3	2
VA Regional Rail	5.5	1	0.2	0.1		6	4	2	0.4
PHILADELPHIA REGION									
North Side Regional Rail	7	4	4	2.5		8	5	5	3
South Side Regional Rail	5	4	3.5	3		6	6	6	3
NEW YORK REGION									
NJ - NEC / NJCL Trans Hudson	15	8	7	3		20	10	7	3
NJ - Other Regional Rail Trans Hudson	6	3	3	2		-	-	-	-
NJ - Standard Inner Branch Slots	-	-	-	-		10	8	6	6
CT - New Haven Line	22	16	12	3		26	20	16	8
BOSTON REGION									
NEC Regional Rail	9	4	4	2.6		12	10	10	4
Worcester / Framingham Lines	3	2	1	1		4	3	1	1

Source: NEC FUTURE team, 2015

Note: Fractional values represent services that do not operate the same number of trains each hour during the four major time periods. For existing service, these values were derived so that the total daily number of trains in the service specification approximately matches the number of trains actually operated.

Alternative 1 invests in capacity sufficient to keep pace with demographic growth, but does not provide additional capacity to support growth beyond 2040 or to meet changing market needs.

Growth in Regional rail service differs by region along the corridor. In the slower growth regions of Boston and Philadelphia, Regional rail frequencies will increase 15 to 20 percent in the peak period with expanded train consists providing additional capacity in both regions. More robust population growth in the Washington, D.C., metro area is expected and Regional rail from both the north and the south will expand at a higher rate—50 percent growth in frequencies from the north and a more than doubling of service from the west/south. With additional trans-Hudson capacity, Regional rail from New Jersey increases 70 percent in the peak hour.

7.2.1 Markets Served

Alternative 1 serves existing NEC travel markets. There are several suburban corridors that potentially could include one-seat ride service to Manhattan in this alternative, such as the Raritan Valley Line corridor in northern New Jersey.. Where Metropolitan service is introduced, the accessibility of these areas to NEC Intercity service is greatly improved. This is due to the criteria that define the Hub stations at which Metropolitan trains stop, which include the presence of substantial local development and economic activity and/or available regional highway access.

7.2.2 Service Levels

Intercity service in Alternative 1 approximately doubles in the standard peak hour, compared with the No Action Alternative. The level of peak hour Intercity service is as follows:

- Intercity-Express: 2 tph, operating between Washington, D.C., and Boston
- Intercity-Corridor-Other: 2 tph, with one Washington, D.C.-Boston train and one Washington, D.C.-Springfield train
- Keystone Corridor: 1 tph, operating Philadelphia to New York
- Empire Corridor: 2 tph to Penn Station New York (remaining separate from NEC)

Selected Intercity-Corridor trains are assumed to extend beyond the NEC (e.g. to Virginia, North Carolina, Vermont and central Massachusetts via Springfield and the Inland Route to Boston). These trains are considered to be Intercity-Corridor-Other trains, utilizing upgraded conventional trainsets of coaches hauled by high-performance dual-mode locomotives. Outside of the standard peak hour, some of these Intercity-Corridor-Other slots are assumed to be available for Long-Distance trains. The remainder of the Intercity-Corridor service (i.e., those trains that operate wholly on the NEC Spine) is assumed to be Metropolitan service, operated with high-performance trainsets, stopping at additional stations designated as hub stations.

One Intercity-Express train per hour will operate between Boston and Washington, D.C., supplemented by a second hourly frequency between New York and Washington, D.C. This service expansion, along with lengthening the trainsets, will more than double the available Intercity-Express seats in the peak hour. Two Intercity-Corridor-Other trains per hour will provide one-seat rides from the markets south of Washington, D.C., (Newport News, Norfolk, Richmond, Lynchburg, and Charlotte) to markets along the NEC. These trains will also provide Intercity service between intermediate markets along the NEC.

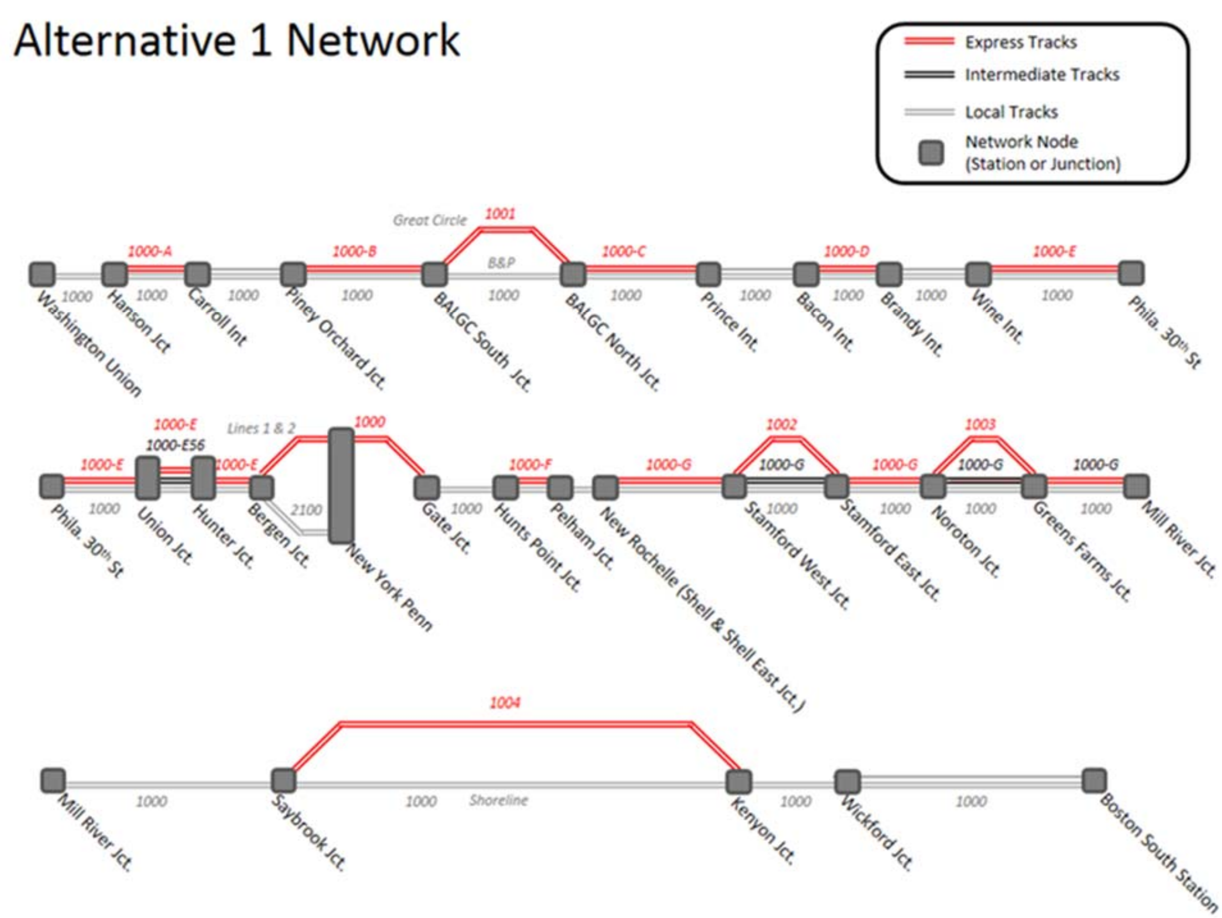
Even with the major expansion in capacity in the New York City region, rail access through New York City remains constrained. Metropolitan service helps to meet the increased demand, by serving both regional and Intercity travelers on the same train. It effectively increases the number of trains in the peak hours available for both interregional and regional riders, since the Metropolitan trains can be counted in each category. Though the physical capacity and total number of slots is the same, the scarce capacity can be more flexibly utilized by rail passengers, since the pricing of Metropolitan service can be used to regulate the level of regional ridership on these trains. One of the Metropolitan trains runs the entire corridor from Boston to New York, serving both Intercity and Regional rail passengers. The other train operates from Boston or New York to Philadelphia and serves the Keystone Corridor to Harrisburg, PA. The combination of Metropolitan and Intercity-Corridor-Other service provides regular service during peak hours at 4 tph in the busiest portion of the NEC between Philadelphia and New Haven, serving all current Intercity stations. The two Metropolitan trains also serve major Regional rail stations in these markets, such as Odenton, MD and North Brunswick, NJ.

7.2.3 Network

The Representative Route for Alternative 1 includes the entire existing NEC main line between Washington, D.C., and Boston. (This is also the case for Alternatives 2 and 3.)

A schematic diagram of the Representative Route for Alternative 1 is shown in Figure 25. This diagram, and the others that depict the available routes for the other Action Alternatives, were developed to help build the analytic model used to analyze and reconcile train movement and station stopping patterns, and show major stations and junctions and the network links that connect them. The horizontal close parallel lines represent the number of NEC main tracks. The other lines that in places deviate from the main horizontal line represent new segments that generally are constructed off the existing NEC right-of-way, either to obtain better speeds and trip times or because of right-of-way constraints on the existing corridor.

Figure 25: Representative Route Schematic – Alternative 1



Source: NEC FUTURE team, 2015

7.3 ALTERNATIVE 2

Alternative 2 is intended to grow the role of rail within the Study Area, expanding rail service at a faster pace than the proportional growth in regional population and employment. As shown in Figure 26, south of New Haven, CT, service and infrastructure improvements are focused generally within the existing NEC; however, north of New Haven, a new supplemental route is added between New Haven, Hartford, and Providence to increase resiliency, serve new markets, reduce trip times, and address capacity constraints. The existing NEC generally expands to four tracks, with six tracks through portions of New Jersey and southwestern Connecticut. Alternative 2 includes new service to Philadelphia International Airport, and some Regional rail run-through service in New York City and Washington, D.C., to increase terminal throughput.

Alternative 2 provides a significant increase in the volume of Intercity service on the NEC compared to the No Action Alternative. With major investment in new railroad capacity between central New Jersey and southwestern Connecticut, this alternative also provides the opportunity for increasing the volume of peak Regional rail service, though the increases in Regional rail are more marginal, as these increases build on the very high base of service specified in the minimum 2040 targets. Alternative 2 can simultaneously accommodate the program for Intercity train service, meet or exceed the 2040 targets for Regional rail service, and provide for 15-minute headway limited-stop Metropolitan service along the entire NEC if it is developed to the high end of the range of capacity. In addition, the infrastructure in Alternative 2 provides reasonable scheduling flexibility for both the Intercity and Regional rail operators, permitting a relatively wide range of possible future schedule and service patterns.

7.3.1 Markets Served

Alternative 2 improves the level of service available to all of the markets served by the No Action Alternative. It also selectively taps a set of potential new travel markets that currently are not served or not well served by the NEC. This includes the New Haven-Hartford-Springfield corridor, now known as the Hartford Line. Hartford becomes a market on the NEC rather than a connecting corridor, and other locations along this line have improved trip times and service offerings by virtue of the new high-speed line between New Haven and Hartford that is part of this alternative, as well as the greatly improved accessibility of Providence and Boston by rail.

A second market that sees greatly improved rail service is Philadelphia International Airport, which also has a station directly on the NEC in this alternative, with frequent Intercity-Express, Metropolitan and Regional rail service up and down the NEC as well as to the Keystone Corridor and the rest of the SEPTA Regional rail network.

A third market with the opportunity for significantly increased NEC rail service in Alternative 2 is located on the south side of Washington, D.C., Improvements to the Long Bridge corridor between Washington, D.C., and Alexandria, VA, coupled with improvements at Washington Union Station, permit Metropolitan service and selected Regional rail trains to run through Union Station, effectively extending the reach of the NEC to this heavily populated part of greater Washington, D.C., as well as to Reagan National Airport.

7.3.2 Service Levels

Intercity service is increased to four Intercity-Express trains per hour in the standard peak hour between Washington and Boston, which represents a four-fold increase in service on the south end and an even greater proportional increase on the north end, compared with the No Action Alternative. This Alternative also seeks to increase the number of train slots reserved for Intercity-Intercity-Corridor-Other trains, including Long-Distance services, to 4 tph in each direction, provided there is sufficient available capacity to accommodate these unoccupied train slots in the peak period.

The levels of Intercity rail service in Alternative 2 in the standard peak hour are as follows:

- Intercity-express: 4 tph, operating between Washington, D.C., and Boston
- Metropolitan service: 4 routes offering 4 tph at all major stations along the spine, with…
  - 2 tph operating between Washington, D.C., and Boston on the express route (via New Haven-Hartford-Providence on the north end and via Philadelphia Airport on the south end)
  - 1 tph operating from the Keystone Corridor to New York, and thence to Boston via the Shore Line
  - 1 tph operating from the Keystone Corridor to Hartford via the express route, and thence to Springfield via the Hartford-Springfield Line
  - 2 tph operating from Washington, D.C., to Philadelphia via Philadelphia Airport, with one or both trains extended westward on the Keystone Corridor as warranted by demand
- Intercity-Corridor-Other service: 2-4 slots per hour, to accommodate up to 2 tph, with one Washington, D.C.-Boston train and one Washington, D.C.-Springfield train
- Empire Corridor: 2 tph to Penn Station New York (remaining separate from NEC), with improved transfers at Penn Station New York.

The level of Intercity-Corridor service running off-corridor remains the same in each of the Action Alternatives, representing an increase in service consistent with the most recent plans developed for this corridor. Alternative 2 provides for 2 tph following the existing NEC route (one Virginia-Washington, D.C.-Boston train via the Shore Line and one Virginia-Washington, D.C.-New Haven-Springfield train heading to either the Knowledge Corridor or Inland Route). These Intercity-Corridor-Other trains serve the Virginia corridors, the SEHSR corridor, the Knowledge Corridor in Massachusetts and Vermont, and the Inland Route between Springfield and Boston. However, the Service Plans in this alternative seek to provide four slots, particularly in the scenarios that represent the high end of the possible range of tunnel capacities into Manhattan. Two of these are empty or “phantom” slots, available for the use of Intercity-Corridor-Other or Long-Distance trains arriving late from off-corridor at their NEC entry point, such as Washington, D.C., or Springfield. These slots also provide an extra margin of reliability and recovery capacity at those times when delays occur on the NEC.

With Metropolitan service provided at 4 tph between New Haven and Philadelphia, Keystone Corridor and Hartford Line service can be provided by Metropolitan trains, and a richer mix of train services becomes available to Intercity travelers in the central portion of the NEC through New York.

Alternative 2 assumes half-hourly pulse-hub operations at the lower level of 30th Street station, with regularly repeating opportunities for coordinated timed transfers among various rail services at repeating 30-minute intervals. In the assumed service plan, Intercity-Express trains overtake Metropolitan trains at 30th Street, with cross-platform transfers between the two trains while dwelling at the platform in Philadelphia. In this same scenario, both Keystone Metropolitan trains and inbound Atlantic City Line trains are timed to arrive just ahead of the Intercity-Express and Metropolitan trains, providing convenient transfers for passengers from these services to northbound Intercity-Express trains, southbound Intercity-Express, and Metropolitan trains.

Regional rail service expands above the minimum levels needed to preserve existing regional rail market share, with increased frequencies of service and increased capacity that enable Regional rail ridership to grow at a greater pace than underlying demographic growth within the regions of the NEC. The largest increase in Regional rail service results from the two new tunnels under the East River on approach to Penn Station New York, which enables an increase in Regional rail service from Connecticut, Long Island and New Jersey to and through New York City.

Further increases in Regional rail service are also planned for in the Philadelphia, Baltimore, and Washington, D.C., regions. Table 18 and Table 19 present the service plan specifications for Intercity and Regional rail service, respectively, showing the levels of rail service provided in Alternative 2.

Table 18: Alternative 2 – Intercity Service in Standard Peak Hour

NEC FUTURE EIS ALTERNATIVES
Standard Peak Hour Trains per Hour

	Existing	No Action	Alt 2
South End			
Intercity Express	1	1	4
Intercity Corridor			
Wash-Phila	1	1	2
Phila-NY	2	2	2
Metropolitan			
Wash-Phila	--	--	4
Phila-NY	--	--	4
North End			
Intercity Express	<1	<1	4
Intercity Corridor			
NY-New Haven	<1	<1	2
New Haven-Boston (Shore Line)	<1	<1	-
New Haven-Springfield	--	--	2
Metropolitan			
NY-New Haven	--	--	4
New Haven-Boston (OSB-KEN Bypass)	--	--	--
New Haven-Boston (Shore Line)	--	--	1
New Route	--	--	4
Connecting Corridors			
Virginia	<1	<1	2
Empire	1	1	2
Keystone	1	1	2
Springfield	<1	<1	2
Knowledge Corridor	1 tpd	1 tpd	1
Inland Route	--	<1	1
Other	--	--	--

Source: NEC FUTURE team, 2015

Table 19: Alternative 2 – Regional Rail Service

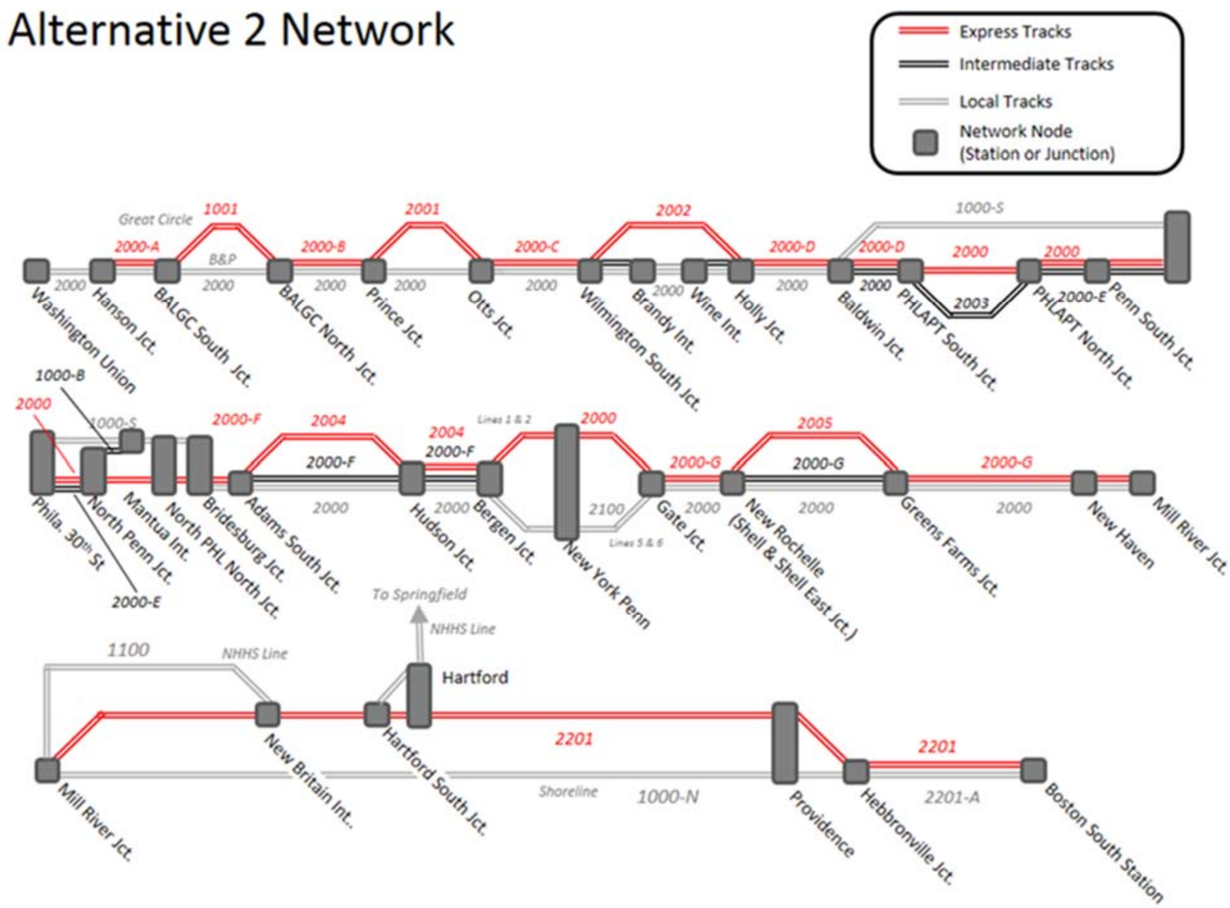
REGIONAL TRAINS PER HOUR	Existing / No Action				Alternative 2			
	Peak	Shoulder	Reverse Peak	Off Peak	Peak	Shoulder	Reverse Peak	Off Peak
WASHINGTON REGION								
MD Regional Rail (Penn Line)	3	2.5	1.5	1.3	10	6	5	3
VA Regional Rail	5.5	1	0.2	0.1	8	5	3	3
PHILADELPHIA REGION								
North Side Regional Rail	7	4	4	2.5	12	6	5	4
South Side Regional Rail*	5	4	3.5	3	10	10	12	7
NEW YORK REGION								
NJ - NEC / NJCL Trans Hudson	15	8	7	3	22	14	10	4
NJ - Other Regional Rail Trans Hudson	6	3	3	2	-	-	-	-
NJ - Standard Inner Branch Slots	-	-	-	-	20	14	10	8
CT - New Haven Line	22	16	12	3	32	19	15	6
BOSTON REGION								
NEC Regional Rail	9	4	4	2.6	14	10	10	5
Worcester / Framingham Lines	3	2	1	1	4	3	1	1

Source: NEC FUTURE team, 2015
Note: Fractional values represent services that do not operate the same number of trains each hour during the four major time periods. For existing service, these values were derived so that the total daily number of trains in the service specification approximately matches the number of trains actually operated.
* Service Plan includes four additional inner-zone Regional rail trains in the peak hour on the Wilmington Line that are not reflected in the Alternative 2 peak counts.

7.3.3 Network

A schematic diagram of the Representative Route for Alternative 2 is shown in Figure 26.

Figure 26: Representative Route Schematic – Alternative 2



Source: NEC FUTURE team, 2015

7.4 ALTERNATIVE 3

Alternative 3 provides a rail network with much greater capacity and the ability to offer a full array of rail services. Alternative 3 transforms the role of rail within the Study Area, positioning rail as the dominant mode for Intercity travel within the NEC and for journey-to-work travel to the major CBDs of the NEC. This alternative features construction of a new 2-track high-speed rail line for the entire length of the route between Washington, D.C., and Boston. It also includes infrastructure upgrades and service improvements along the existing NEC route.

Service and infrastructure improvements include upgrades on the NEC and the addition of a two-track second spine that operate adjacent to the NEC south of New York and expand the reach of the NEC to new markets north of New York. This new spine supports high-speed rail services between major NEC markets and provides additional capacity for Intercity and Regional rail services on both the existing NEC and new spine.

7.4.1 Routing and Service Options

The two ends of the rail corridor on either side of New York City have different roles and characteristics in Alternative 3. South of New York the route approximately parallels the existing NEC, serving roughly the same travel markets but providing much better service and offering greater service frequency and more service choices at NEC stations, including introducing Intercity service at selected major Regional rail stations. North of New York, Alternative 3 provides a new, second route for high-speed train service, opening up the NEC to new travel markets and creating an expanded network of rail services. Four variations of Alternative 3 are analyzed as Action Alternatives, corresponding to the four North End Route Options that emerged from the comparative evaluation of North End options:

Alternative 3 – North End Route Options for Second Spine Between New York and Boston

- 3.1 – New York-White Plains East-Danbury-Hartford-Providence-Boston
- 3.2 – New York-Long Island-New Haven-Hartford-Providence-Boston
- 3.3 – New York- Long Island-New Haven-Hartford-Worcester-Boston
- 3.4 – New York-White Plains East-Danbury-Hartford-Worcester-Boston

All four of these variations are identical in terms of both service and infrastructure between Washington, D.C., and New York. All four variations include upgrading of the existing NEC Spine and improvements in service on the existing New Haven Line and Shore Line, irrespective of the location of the second spine route. Between New York and Boston, the level of service and mix of rail service types remains constant across the four route variations, although the specific stopping patterns and trip times for services utilizing the second spine route vary somewhat.

The Service Plans for Alternative 3 are intended to provide a quantity of train service significantly higher than the other Action Alternatives, filling the capacity created by the construction of two new high-speed express tracks for the full length of the existing NEC between Washington, D.C., and Boston.

7.4.2 Markets Served

The additional NEC rail capacity, coupled with the faster trip times that are possible to the major NEC cities, can be used in this alternative to expand the physical reach of the NEC. At the same time, the new routes that are created parallel to the existing corridor improve the rail system’s coverage within the Study Area. Several new geographic markets become part of the NEC and are provided with direct and frequent NEC rail service – including Intercity-Express, Metropolitan and, in some cases, express commuter trains:

- Downtown Baltimore
- Center City Philadelphia
- Central Connecticut corridor, including White Plains, NY and Danbury and Waterbury, CT (Route Options 3.1 and 3.4 only)

- Long Island (Nassau & Suffolk Counties) and Jamaica, Queens (Route Options 3.2 and 3.3 only), as documented in Section 6 of this memorandum
- Hartford, CT
- The Hartford-Providence corridor (Route Options 3.1 and 3.2 only)
- The Hartford-Worcester-Boston corridor (Route Options 3.1 and 3.4 only)

Potential connecting corridor markets that can be served on an extended NEC or connecting high-speed line, also have the opportunity for new direct Intercity service to the NEC or receive significantly improved service to the NEC where some service now exists.

The coverage of the Regional rail network also can be expanded significantly in Alternative 3. Alternative 3 is expected to generate capacity beyond what will be needed to serve the existing markets. This additional capacity can be used to offer Regional rail service in new corridors or to offer one-seat ride service to NEC destinations on Regional rail lines that do not currently offer direct service or have only limited direct service. In virtually all these examples, considerable investment in railroad infrastructure, stations, fleet and yard facilities are required in locations other than on the NEC. The scope of NEC FUTURE does not encompass these potential branch line initiatives – either the required investments or their environmental consequences – although the potential benefits of expanding Regional rail network connections to the NEC will be assessed qualitatively and taken into consideration in the evaluation of the Action Alternatives. In Alternative 3, the future sponsors and operators of Regional rail and Intercity-Corridor service have great discretion to develop and implement service concepts that meet market demands for rail travel as they emerge.

Finally, the re-routing of most of the Intercity-Express service to new rail routes through Baltimore, Philadelphia and New York in Alternative 3 presents the potential opportunity to utilize the capacity freed up on the existing routes to provide short-headway local rail service within these metropolitan regions – effectively creating new rail transit lines for these cities. This concept is analogous to the Overground and Thames link services in London, the RER service in Paris and the various S-Bahn networks throughout Germany and Switzerland. The NEC route through Baltimore was identified as a potential future transit line in the 2000 Baltimore Region Rail Plan. In the New York area, offering transit-style service on the inner portions of the LIRR network in Queens and in Hudson and Essex Counties in New Jersey is possible with the capacity provided in Alternative 3 and can be complementary to both the Regional rail and rail transit networks.

7.4.3 Service Levels

The Alternative 3 Service Plans provide for more than six times the quantity of Intercity-Express and Metropolitan service compared with the No Action Alternative, in the standard peak hour. It provides for Intercity-Express service at 6 tph in the future standard peak hour, with some operating the full length of the corridor between Boston and Washington, D.C., on the express tracks, others diverging to serve groups of stations along portions of the existing NEC, and still others introducing direct premium service to connecting corridors such as the Keystone and Springfield lines.

The high number of express trains that are possible in this alternative allows for relatively wide variations in stopping patterns, providing dramatic reductions in trip times (90 minutes between Boston and New York and between New York and Washington, D.C., on the Boston-New York-Philadelphia-Washington, D.C., service) while also providing direct premium service to more stations on the NEC. Many stations that currently receive only Regional rail or Amtrak's Northeast Regional Intercity service today, receive regular premium service in Alternative 3. This is one aspect of Alternative 3 that potentially can be transformative in its effect on rail travel within the Northeast U.S.

Metropolitan service is also expanded significantly, since it operates at 4 tph over two separate routes to the north of New York and covers dual routes through Philadelphia and Baltimore. Four to 6 tph operate the full length of the corridor between Washington, D.C., and Boston with additional service supplementing these frequencies with 2 tph between New Haven and Philadelphia. This results in 8 Metropolitan trains per hour through New York. North of New York, four of these trains operate on the existing NEC between New York and New Haven; four operate via the new high-speed route - either Central Connecticut or Long Island. Service through Philadelphia is split between the two stations with 4 tph serving 30th Street Station and 4 tph serving the new Center City station. Two of the four trains that serve 30th Street provide service to Harrisburg on the Keystone Branch, the other six trains (two from 30th Street, four from Center City) continue to Washington, D.C.

Excess capacity on the new high-speed route provides an opportunity to deliver express commuter service operated with high-performance trainsets. This service reduces trip time from outer zone commuter territories, improve the quality of the passenger experience, and potentially expand the existing Regional rail territories beyond their current boundaries.

Two corridor trains per hour will provide one-seat rides from the markets south of Washington (Newport News, Norfolk, Richmond, Lynchburg, and Charlotte) to markets along the NEC. These trains, along with the Intercity-Express and Metropolitan trains will also provide Intercity service between markets along the NEC. An additional two Intercity-Corridor slots is available on the NEC to accommodate various combinations of connecting corridor service from other off-corridor markets.

Table 20 presents the assumed level of Intercity rail service in Alternative 3 for the standard peak hour. The level of Regional rail service is expanded to both respond to identified demand and to fill available capacity on the railroad. Table 21 shows the assumed service levels.

Table 20: Alternative 3 – Intercity Service in Standard Peak Hour

	Existing	No Action	Alt 3
South End			
Intercity Express	1	1	6
Intercity Corridor			
Wash-Phila	1	1	2
Phila-NY	2	2	2
Metropolitan			
Wash-Phila	--	--	4
Phila-NY	--	--	8
North End			
Intercity Express	<1	<1	6
Intercity Corridor			
NY-New Haven	<1	<1	2
New Haven-Boston (Shore Line)	<1	<1	-
New Haven-Springfield	--	--	2
Metropolitan			
NY-New Haven	--	--	4
New Haven-Boston (OSB-KEN Bypass)	--	--	--
New Haven-Boston (Shore Line)	--	--	2
New Route	--	--	4
Connecting Corridors			
Virginia	<1	<1	4
Empire	1	1	2
Keystone	1	1	2
Springfield	<1	<1	2
Knowledge Corridor	1 tpd	1 tpd	1
Inland Route	--	<1	1
Other	--	--	2

Source: NEC FUTURE team, 2015

Table 21: Alternative 3 – Regional Rail Service

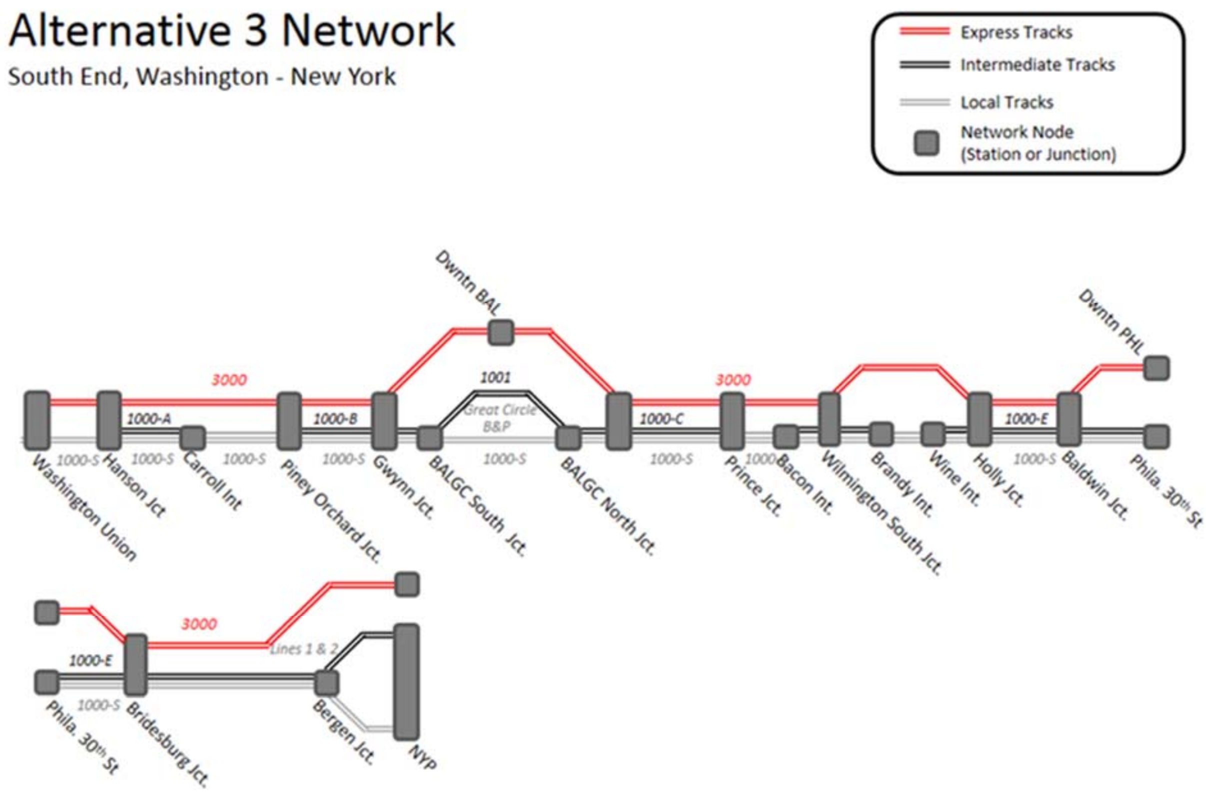
REGIONAL TRAINS PER HOUR	Existing / No Action				Alternative 3			
	Peak	Shoulder	Reverse Peak	Off Peak	Peak	Shoulder	Reverse Peak	Off Peak
WASHINGTON REGION								
MD Regional Rail (Penn Line)	3	2.5	1.5	1.3	12	8	6	3
VA Regional Rail	5.5	1	0.2	0.1	8	6	4	4
PHILADELPHIA REGION								
North Side Regional Rail	7	4	4	2.5	12	7	6	4
South Side Regional Rail*	5	4	3.5	3	16	14	16	11
NEW YORK REGION								
NJ - NEC / NJCL Trans Hudson	15	8	7	3	24	14	10	4
NJ - Other Regional Rail Trans Hudson	6	3	3	2	-	-	-	-
NJ - Standard Inner Branch Slots	-	-	-	-	30	24	20	12
CT - New Haven Line	22	16	12	3	36	19	15	6
BOSTON REGION								
NEC Regional Rail	9	4	4	2.6	20	14	12	9
Worcester / Framingham Lines	3	2	1	1	8	4	2	2

Source: NEC FUTURE team, 2015
Note: Fractional values represent services that do not operate the same number of trains each hour during the four major time periods. For existing service, these values were derived so that the total daily number of trains in the service specification approximately matches the number of trains actually operated.
* Service Plan includes four additional inner-zone Regional rail trains in the peak hour on the Wilmington Line that are not reflected in the Alternative 3 peak counts.

7.4.4 Network

The Representative Route for Alternative 3 generally parallels the existing NEC and serves the same metropolitan regions and markets as the existing corridor on the south end between Washington, D.C., and New York. A new 2-track high-speed line is constructed on new route segments. In most locations, the route is adjacent to the existing NEC. In several places, however, the high-speed line deviates from the existing corridor, most prominently taking more direct routes through downtown Baltimore and Philadelphia. The south end Representative Route, common to all four variations of Alternative 3, is shown schematically in Figure 27.

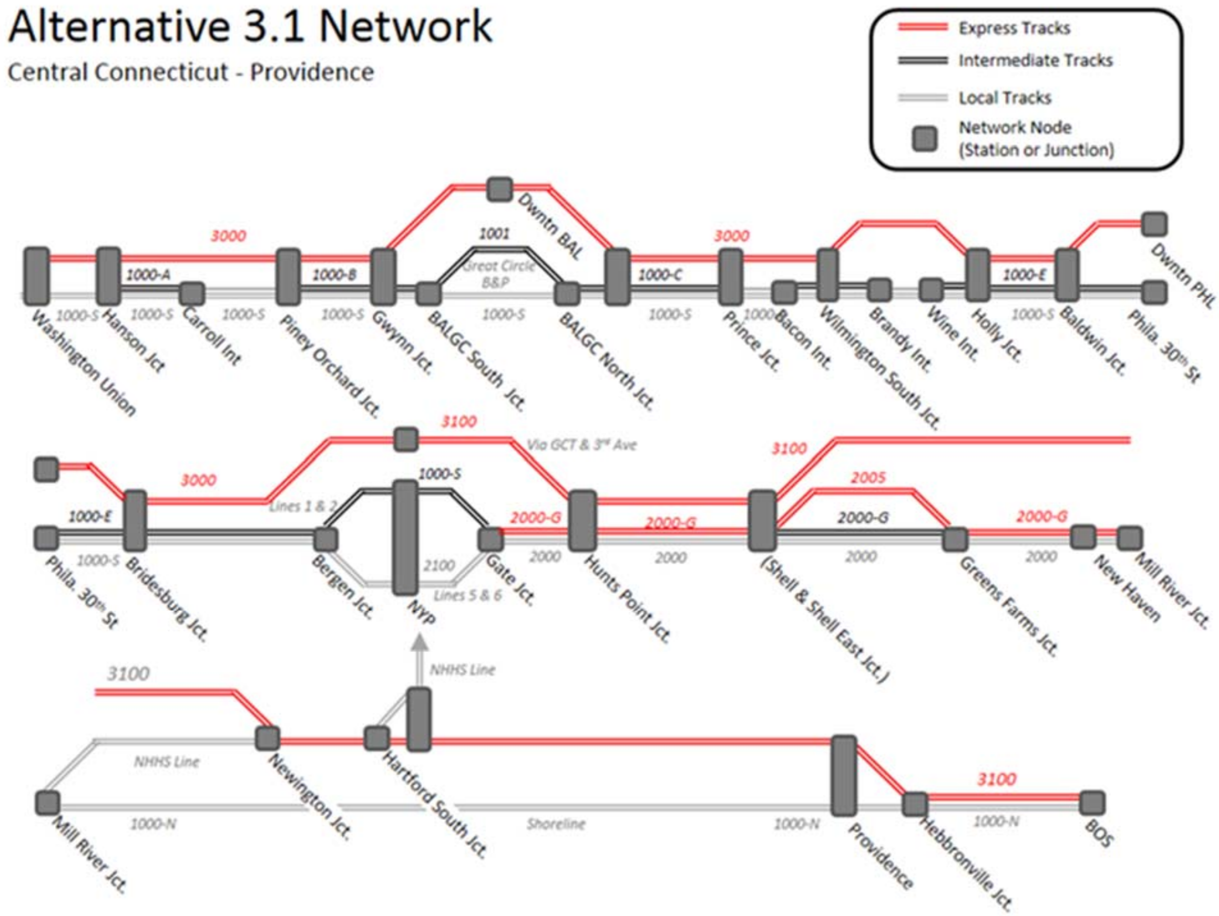
Figure 27: Representative Route Schematic – Alternative 3, All Route Options (Washington-to-New York)



Source: NEC FUTURE team, 2015

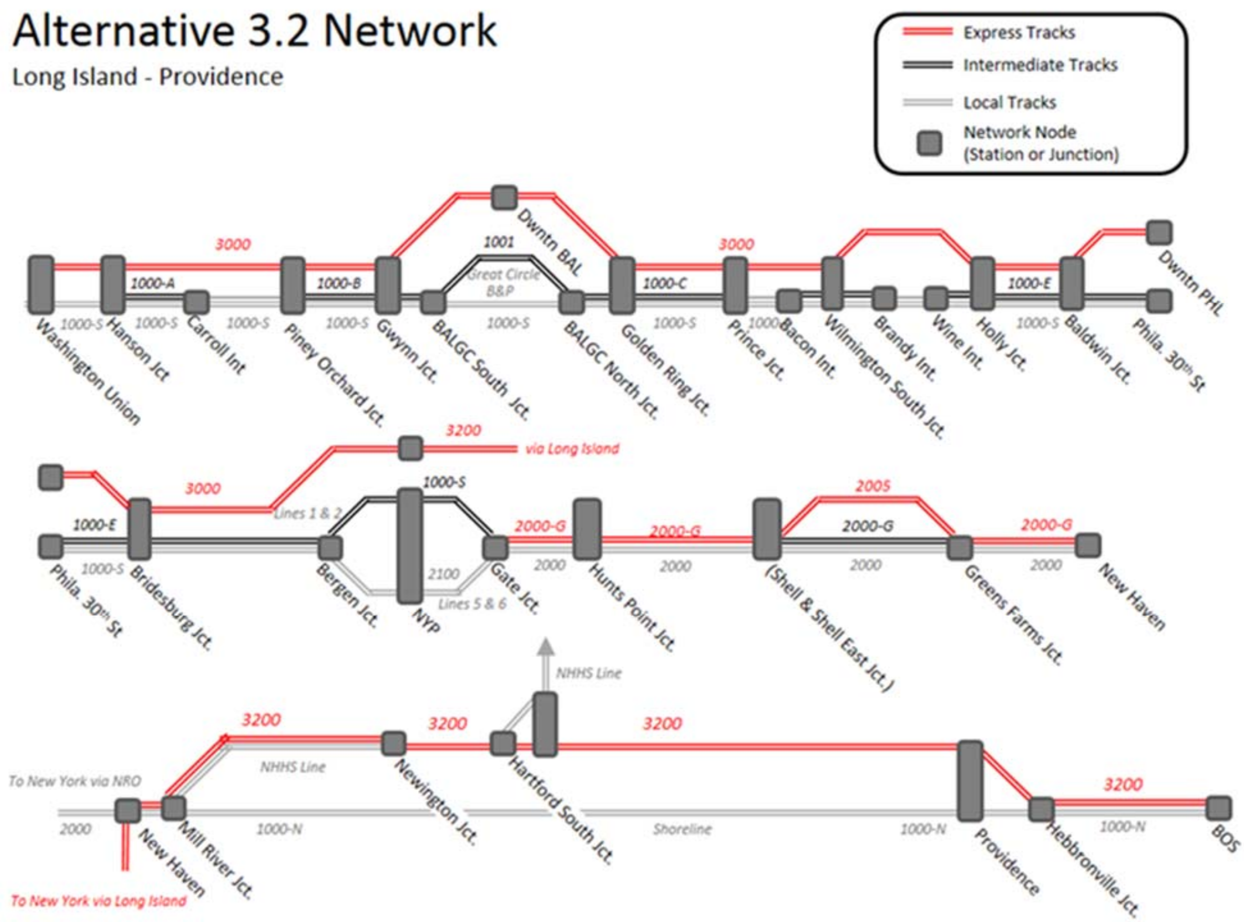
Figure 28 through Figure 31 depict the four north end routing variations for the second spine between New York and Boston. Alternative 3.1 provides the new high-speed route via Central Connecticut and Providence (New York-Danbury-Hartford-Providence-Boston). In Alternative 3.2, the north end route for the second spine goes via Long Island and Providence (New York-Long Island-New Haven-Hartford-Providence-Boston). Alternatives 3.3 and 3.4 include the routes via Worcester instead of Providence.

Figure 28: Representative Route Schematic – Alternative 3, Variation 3.1 (Central Connecticut-Providence Route)



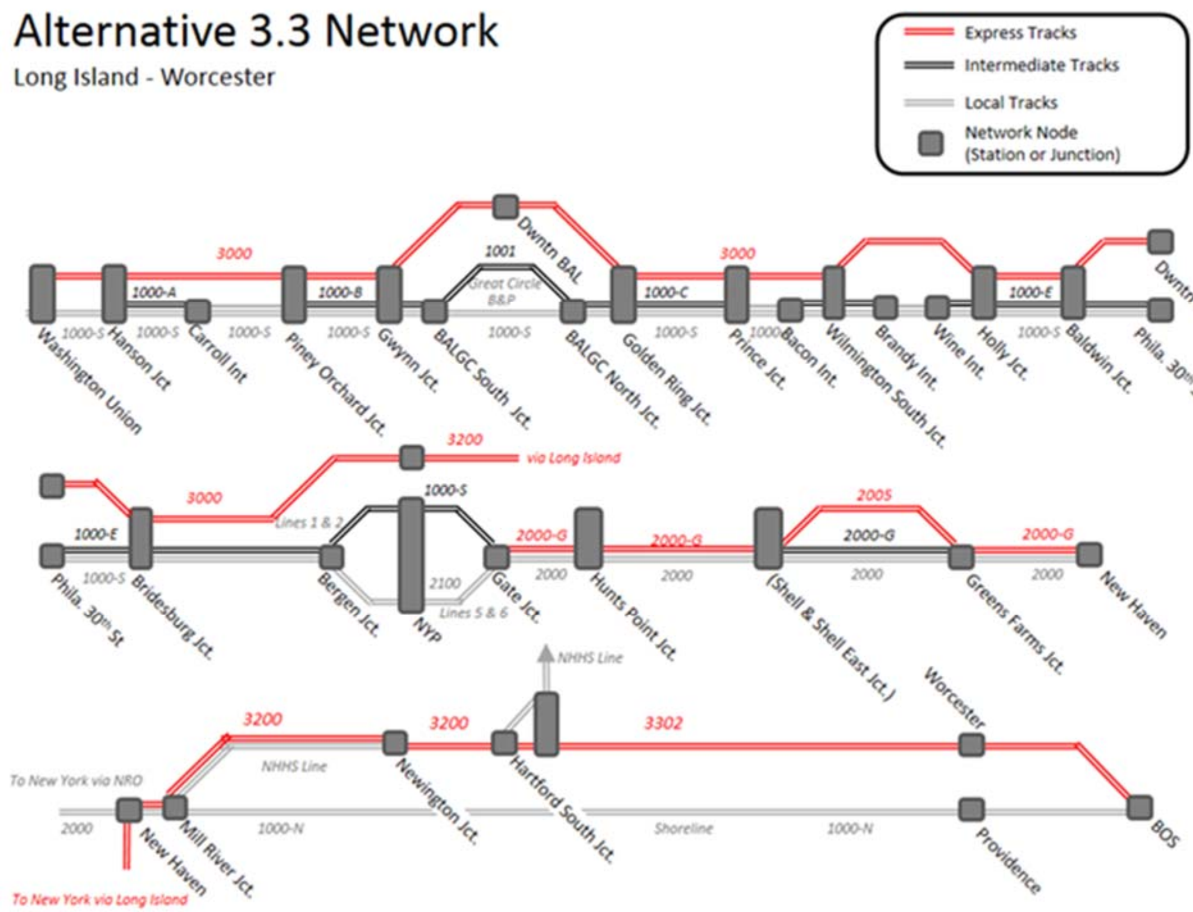
Source: NEC FUTURE team, 2015

Figure 29: Representative Route Schematic – Alternative 3, Variation 3.2 (Long Island-New Haven-Hartford-Providence Route)



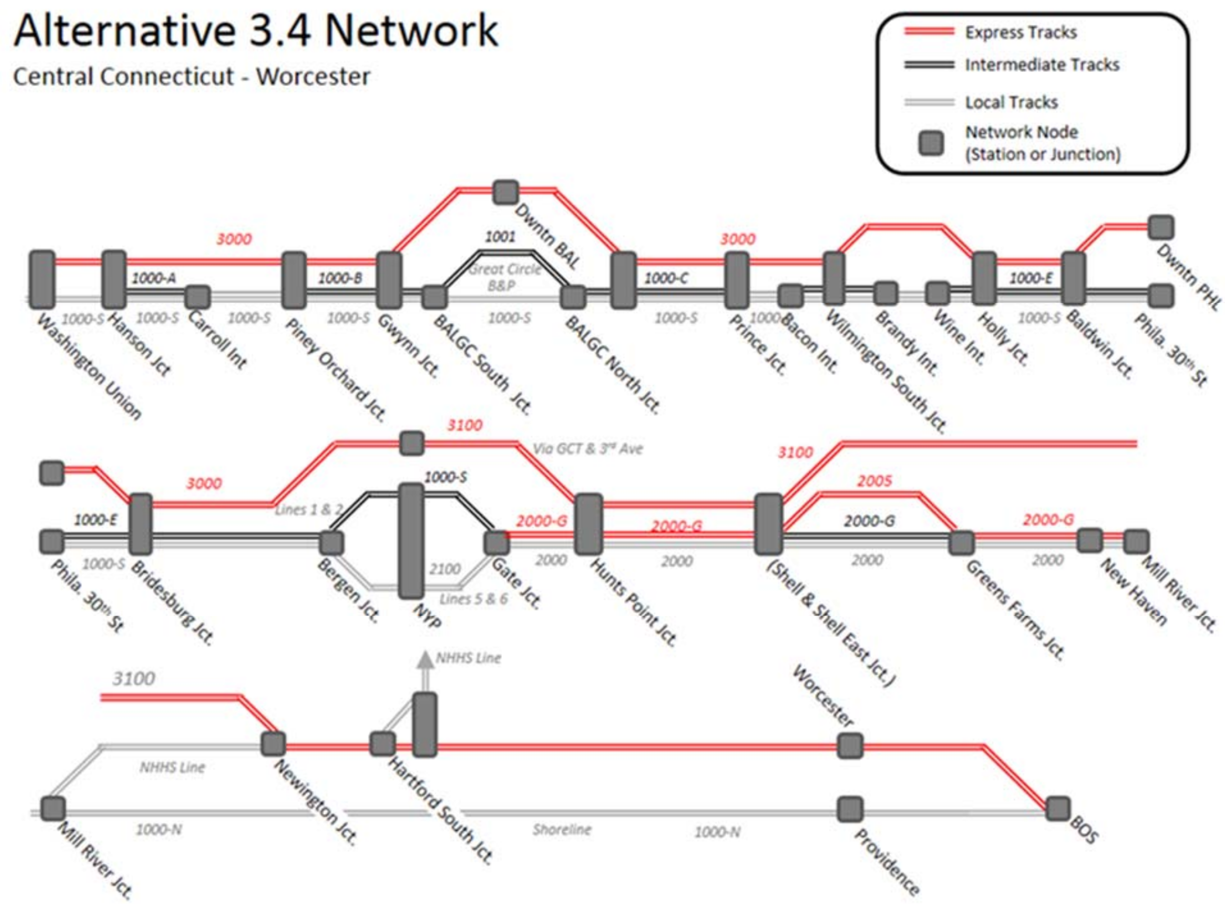
Source: NEC FUTURE team, 2015

Figure 30: Representative Route Schematic – Alternative 3, Variation 3.3 (Long Island-New Haven-Hartford-Worcester Route)



Source: NEC FUTURE team, 2015

Figure 31: Representative Route Schematic – Alternative 3, Variation 3.4 (Central Connecticut-Worcester Route)



Source: NEC FUTURE team, 2015

8 Appendix

8.1 TECHNICAL ASSUMPTIONS

This appendix summarizes assumptions for the analysis of the Tier 1 EIS Alternatives (Action Alternatives) with respect to selected operational and physical characteristics of the railroad, particularly segments of new track envisioned in the alternatives. The draft assumptions listed in this memorandum are for planning purposes only and are subject to change. Use of these assumptions for NEC FUTURE does not imply or indicate their future approval or adoption as standards by the FRA or any of the operating railroads.

This memorandum is intended to supplement rather than replace the methodology technical memoranda covering operations analysis and engineering. A separate memorandum, included in the Tier 1 Draft Environmental Impact Statement, describes the construction types and typical right-of-way cross-sections that define the representative routes for each of the Action Alternatives. The full range of relevant technical issues is addressed in these other documents.

8.1.1 Operating Environment and Equipment Tiers

The Northeast Corridor (NEC) is a complex operating environment, in which many different kinds of passenger and freight trains operate. It is unique in the U.S. in its functioning simultaneously as a high-speed rail line, a conventional-speed main line for regular intercity and commuter passenger trains, and in various locations as a line serving both through and local freight trains.

The FRA's passenger equipment safety standards currently govern the crashworthiness standards and emergency egress/rescue access systems of Tier I and Tier II passenger equipment (not to be confused with the National Environmental Policy Act (NEPA) Tier 1 and Tier 2 environmental review processes). Tier I equipment operates at speeds not exceeding 125 mph, Tier II equipment operates at speeds between 125 mph and 150 mph, and the standards require regulatory approval for the operation of Tier II passenger equipment that has not been previously used in revenue service in the U.S. The FRA track regulations also set the maximum allowable speed for different classes of track, and regulatory approval is required for equipment operating at speeds above 125 mph

Because the FRA has authorized the operation of Amtrak's Acela Express at speeds up to 150 mph, the existing NEC has trains operating in both a Tier I and Tier II environment. Because of this unique mix of services on the NEC, waivers to the FRA regulations in certain cases are granted by the FRA to permit operating characteristics that fall outside of the limits prescribed in the regulations. NEC Tier I operations are constrained by the maximum operational speed for passenger trains of 125 mph, but there are currently no Tier 1 restrictions regarding shared use or right-of-way with freight operations. The connecting corridors (e.g., New Haven-Hartford-Springfield) off of the NEC also operate in the Tier I environment.

Tier II standards govern operations along the portions of the NEC where maximum authorized speeds for passenger trains range between 125 mph and 150 mph Amtrak Acela Express trains are the only Tier II train equipment permitted to operate at these speeds. With a waiver, the Acela equipment can operate intermixed with other Tier I passenger and freight operations and operate above 125 mph, so long as there is temporal separation with any freight operations. Intermixed operations currently include Amtrak Intercity Corridor and Long Distance trains. Amtrak has petitioned the FRA for increasing the top speed of its Tier II operations to 160 mph in certain locations, which would require modification to its current waiver.

The FRA is currently developing Tier III passenger equipment safety standards. The Tier III standards would represent a relatively new national standard for high-speed rail operations and equipment, which will apply to the California high-speed system, and are assumed for future NEC operations in all of the Action Alternatives being considered for NEC FUTURE. In conjunction with the FRA track standards and other regulations, the Tier III standards will establish the crashworthiness standards for equipment that can operate on shared tracks or on separate tracks within a shared right-of-way and the infrastructure and systems required for safe operations.

It is assumed that Tier III passenger equipment safety standards (along with the FRA's track safety standards), would permit higher-performance high-speed rail operations, with maximum authorized speeds above 125 mph, up to 220 mph. The Tier III environment would require exclusive right-of-way for high-speed trains operating above 125 mph and prohibit other equipment types from sharing the exclusive high-speed tracks. There would be no intermixing of high-speed operations with freight or non-Tier III passenger operations (Tier I or Tier II) at speeds above 125 mph. Tier III equipment could operate, however, in a Tier I shared use environment on tracks used by conventional passenger and freight equipment, at speeds at or below 125 mph.

It is assumed that the FRA could waive Tier III standards to permit Tier III operations at speeds up to 160 mph in a shared use environment, allowing these trains to match the performance of the Tier II Acela Express when operating on the existing NEC. Otherwise, the FRA regulations would restrict the Tier III equipment operating in a shared use environment to a top speed of 125 mph, which would result in much slower average speeds and longer trip times than existing Acela equipment when operating on the existing corridor – which would tend to offset the benefits of high-speed operations in alternatives (or interim phases of implementation) that use both new high-speed lines and portions of the existing NEC.

Table 1 summarizes the above key elements of the current Tier I and Tier II operating environments on the existing NEC and the associated characteristics of the types of equipment operating on the corridor. Table 2 summarizes the same key elements for the Tier I and Tier III operating environments that are assumed to be in place on the NEC in the future, once Amtrak completes its planned replacement of the Acela Express fleet with new Tier III equipment.

The FRA's track safety standards also govern other factors, such as grade crossings. No grade crossings are permitted when operating speeds exceed 125 mph (Class 8 and Class 9 track). This is generally not an issue on the NEC, where there are no grade crossings except on portions of the Shore Line in southeastern Connecticut and Rhode Island where track curvature limits speeds to below 125 mph. Any new rail right-of-way included in the Action Alternatives will be completely grade-separated.

As noted previously, Tier III passenger equipment is assumed to be able to operate with a waiver above 125 mph, up to 160 mph (Class 8 track), on tracks that are also used by freight trains, as long as the freight trains operate with temporal separation (i.e., the operation of freight trains is strictly limited to times of day during which passenger service with Tier III equipment is not operating).

The requirement for exclusive use, along with track maintainability issues, will preclude operation of freight trains on Class 9 track with speeds up to 220 mph. The Action Alternatives will seek to provide for freight operations on separate conventional (non-high-speed) tracks. Where operation of freight trains on high-speed or express tracks (at Class 8 or below) is unavoidable and can be accommodated, either for normal or contingency operations, restrictions may be placed on the type, weight or maximum speed of freight trains operating on the high-speed tracks, with possible requirements for signaling, dragging equipment, overheated bearing and high impact wheel detectors in place at entry points to such tracks. Additional study is required to determine the most appropriate rail freight requirements and solutions for each Action Alternative.

The requirements for and costs of additional infrastructure to provide for safe operations in a mixed traffic environment remain to be determined. The FRA will make reasonable assumptions about infrastructure requirements and costs based on the latest information available for NEC FUTURE.

Intercity Long-Distance trains, and Intercity Corridor trains that operate for a portion of their route off-corridor on tracks owned by freight railroads, are assumed to operate with performance characteristics on the NEC that are similar to or better than existing Tier I Northeast Regional trains (i.e., 125 mph maximum speed, similar or better braking and acceleration rates).

Table 1. Operating Environments and Equipment Classification – Existing

Operating Environment	Characteristic	Rolling Stock			
		Tier III	Tier II	Tier I	Freight
Tier I	Max. Authorized Speed	Not Allowed	125 mph	125 mph	--
	Shared Track Use		Allowed	Allowed	Allowed
	Shared Right-of-Way		Allowed	Allowed	Allowed
Tier I and II with waiver	Max. Authorized Speed	Not Allowed	160 mph**	125 mph	--
	Shared Track Use		Allowed	Allowed	Not Allowed*
	Shared Right-of-Way		Allowed	Allowed	Allowed, with appropriate physical separation

*Except with temporal separation
**Speeds of 160 mph would only be permitted with modification of existing waiver permitting Amtrak's Acela Express to operate at speeds up to 150 mph.

Table 2. Operating Environments and Equipment Classification – Future Assumption

Operating Environment	Characteristic	Rolling Stock		
		Tier III	Tier I	Freight
Tier I	Max. Authorized Speed	125 mph	125 mph	--
	Shared Track Use	Allowed	Allowed	Allowed
	Shared Right-of-Way	Allowed	Allowed	Allowed
Tier III	Max. Authorized Speed	220 mph	n.a.	
	Track Use and Right-of-Way	Exclusive Use Only	Not Allowed	
Tier III with waiver	Max. Authorized Speed	220 mph	Separate tracks within right-of-way, in Tier 1 operating environment	
	Track Use	Exclusive Use Only		
	Right-of-Way	Shared right-of-way allowed with appropriate offset distance, barrier separation and intrusion detection and protection; requires waiver		
Tier I and III with waiver	Max. Authorized Speed	160 mph	125 mph	--
	Shared Track Use	Allowed	Allowed	Not Allowed*
	Shared Right-of-Way	Allowed	Allowed	Allowed, with appropriate physical separation

* Except with temporal separation

8.1.2 Maximum Authorized Speed on New High-Speed Lines

Assumptions regarding the maximum authorized speed (MAS) for trains operating on new tracks on the NEC or new connecting routes are presented in Table 3. Existing Tier II (Acela Express) rolling stock is assumed to be retired prior to the 2040 year of analysis. The replacement fleet is assumed to be composed of Tier III equipment.

Table 3. Assumed Maximum Operating Speeds on New Tracks

Case	Track Class	Equipment mix	Maximum Authorized Speed (MAS)		
			Tier III	Tier I	Freight
1	9	Tier III passenger equipment only	220 mph	n.a.	n.a.
2	8	Tier III and Tier I passenger equipment in mixed traffic operations; freight operating with temporal separation	160 mph*	125 mph	50 mph**
3	7	Tier III and Tier I passenger equipment and freight trains in mixed traffic operations	125 mph	125 mph	50 mph**

*Waiver required for operation of Tier III trainsets above 125 mph in shared use environment.
**Maximum values – Subject to further restrictions on speed or limitations on freight access imposed by signal system design, weight limitations, access windows, track maintenance requirements and other factors.

The maximum allowable speed will be reduced in locations with more restrictive civil speed limits, which may occur on account of track curvature, tunnels, adjacent tracks, stations, reduced clearances or other right-of-way conditions. Top speeds for passenger trains on off-corridor routes may be further limited by class of track, availability of cab signals or requirements of the host railroad (e.g., Class 6—110 mph; Class 5—90 mph; Class 4—80 mph).

As part of NEC FUTURE, the FRA is examining alternatives that have a maximum authorized speed for high-speed intercity trains of 220 mph, as well as alternatives that cap the maximum speed at 160 mph. The performance, cost and capacity tradeoffs of these two alternative configurations will be evaluated as Action Alternatives are developed and analyzed. In its assessment of procurement options for NEC high-speed equipment, Amtrak sought information on the performance and cost characteristics of potential trainsets with the capability of operating up to a continuous operating speed of 186 mph or 220 mph. Based on the results of the initial comparison of 220 mph and 160 mph top speeds, FRA may choose to examine in a later phase of analysis of NEC FUTURE a potential high-speed equipment type with an intermediate top speed (e.g., 186 mph).

8.1.3 Right-of-Way Infrastructure

NEC FUTURE will assume that intrusion detection and protection is required for new track on new right-of-way or new track parallel to existing rail lines with operating speeds greater than 125 mph – but is not required when speeds are at or below 125 mph. Currently, Class 8 and Class 9 track owners are required to submit a "right-of-way" barrier plan for the FRA approval that contains provisions designed to prevent vandalism, launching of objects from overhead bridges or structures into the path of trains, and intrusion of vehicles from adjacent rights of way. Train operations on existing NEC tracks with maximum authorized speeds greater than 125 mph are assumed to be able to continue, accommodating the equipment planned for the Action Alternatives, with the infrastructure and systems currently in place or planned for these portions of the NEC. Requirements for additional investment to provide for intrusion detection and protection will be determined on a location-specific basis. Full fencing of the right-of-way perimeter is assumed for all ROW with speeds above 125 mph. Underpasses or bridges for wildlife are assumed to be provided where necessary.

Inter-track barriers (crash walls) will be assumed where new Class 8 or 9 high-speed tracks are constructed parallel to the existing NEC or other existing rail lines, and where the track center spacing between adjacent existing and new tracks is less than 100 feet. Where high-speed tracks are provided in the center of the existing NEC and where the top speed for passenger trains is 160 mph or less, inter-track barriers will not be assumed. Design of inter-track barriers will be based on concepts developed for the California High Speed Train Project (CHSTP). The barrier system is assumed to provide breaks in the barrier wall at one-mile intervals to permit cross access for emergency and maintenance access.

8.1.4 Station Platform Geometry

Platform length assumptions for NEC FUTURE are shown in Table 4. These apply to new stations and to improvements to existing stations, based on the type of train services that will be using the stations. All station platforms on the NEC and new or upgraded connecting routes are assumed to have high-level platforms that facilitate efficient boarding for passengers and comply with the standards of the Americans with Disabilities Act (ADA).

New Intercity Express trains, other Intercity Corridor trains and Regional trains will be assumed to be interoperable at existing station platforms along the NEC. Even in alternatives that provide new dedicated high-speed rights-of-way, there may be locations where trains of various types will share tracks and station platforms, and interim phases of implementation will likely require shared operations over portions of the NEC. Therefore, new high-level platforms at both new and existing stations will be assumed to meet current NEC standards with a platform height 48 inches above the top of rail. New rolling stock operating on the NEC will be assumed to also meet ADA requirements, be compatible with the existing NEC standard for high-level station platforms, and be interoperable with other types of rolling stock at NEC station platforms.

Platforms will be located on tangent (i.e., straight) track wherever possible, to meet the ADA standard for a maximum 3-inch gap between train door sill and platform edge. Where curvature is unavoidable, platform tracks can have a horizontal curvature of no more than 1 degree, 40 minutes. Vertical curves are not allowed on station platform tracks. Platform tracks should be level wherever possible. Where platform tracks must be on a grade, they will be on a constant grade and should be as level as possible, with a maximum gradient of 0.5 percent. NEC FUTURE will assume that island platforms are at least 30 feet wide between platform edges. Side platforms should be 20 feet wide, and vertical circulation elements to and from side platforms should be located outboard of the passenger circulation and waiting zones on the platforms. At locations with physical constraints or low passenger volumes, narrower platforms can be considered, with minimum widths of 26 feet for island platforms and 15 feet for side platforms (with additional width required at points where vertical circulation is provided). Subsequent planning and design, at a Tier 2 level of project development, will confirm the most appropriate dimensions for station platforms.

The assumed station platform lengths shown in Table 4 are initial assumptions for purposes of developing and analyzing the Action Alternatives. Ideally, plans would protect the ability to utilize 400 meter long trainsets on the NEC, which is the current international standard. However, retrofitting existing NEC stations is a major challenge, especially since many existing station platforms are shorter, and their lengthening may be precluded or made very expensive by physical constraints. These planning standards are consistent with the plans for Washington Union Station developed in 2012 as part of the terminal master plan by Amtrak. These assumptions will be revisited as the project progresses and are subject to change based on ongoing NEC system planning that is occurring. Ultimate decisions about the scope of station improvements and new station construction will be made as part of Tier 2 projects that will follow the completion of the NEC FUTURE Tier 1 EIS.

Table 4. Station Platform Lengths

Train Service Type	Criteria	Minimum Platform Length
Express and Metropolitan Services	Planning standard, based on existing constrained platform length conditions at locations such as Boston, New York and Washington (equivalent in length to a 14-car conventional train)	1,200 ft.
	Planning goal, where space permits (accommodates two international-standard 200 meter trainsets coupled together)	1,350 ft.
Intercity Corridor and Long-Distance Services	Planning standard, based on 12 85-ft. coaches plus 2 locomotives	1,200 ft
Regional Rail Services	Planning standard for major stations, based on 12-car EMU trainsets, or 10 coaches plus 2 locomotives	1,050 ft.
	Local regional rail stations can be designed for shorter trains, based on passenger demand and train consists	As required

8.1.5 Rolling Stock

NEC FUTURE service plans for the Action Alternatives will be developed assuming combinations of the types and configurations of rolling stock shown in Table 5, for service on the NEC and in connecting corridors feeding the NEC. There is considerable potential variability in the characteristics of rolling stock that could serve the NEC, and more detailed planning subsequent to the NEC FUTURE process will inform the ultimate decisions about fleet standards and procurement. These planning assumptions will serve as initial guidance for system planning and sizing purposes, as the Action Alternatives are developed and analyzed.

These represent initial working assumptions, for purposes of alternatives development and analysis, which will be updated as the NEC FUTURE analysis progresses. The ultimate decisions about rolling stock procurement, including the configuration and maximum speed of high-speed trainsets, will be made subsequent to the completion of the NEC FUTURE process.

Table 5. Initial Menu of Rolling Stock Choices for Service Planning Purposes

Equipment Type	Tier	Length [1]	Locomotives	Loco Type / Traction Power Type	Train Length [2] (ft)	Seats/Car	Seats/Train	Operates Off-Corridor	Max. Speed on NEC (mph)	Boarding Platform Level	Remarks
Premium Express High-Speed Trainset	III	7-14	0	Concentrated or distributed power w/ Catenary	595-1190	50-60	350-840	No	220	High only	
Metropolitan or Intercity Corridor High-Speed Trainset	III	7-14	0	Concentrated or distributed power w/ Catenary	595-1190	60-70	420-980	No	220	High only	On NEC Spine and branches w/ catenary electrification
	III	12	0	Dual Power / Cat. + 3rd Rail	1020	60-70	720-840	Yes	160-220[5]	High only	NEC-Long Island run-through services
	III	12	0	High-Performance Dual Mode[3]	1020	60-70	720-840	Yes	160-220[6]	High or Hi-Lo	Other off-corridor extensions
	III	12	0	Dual Mode / 3rd Rail + Diesel	1020	60-70	720-840	Yes	160-220[6]	High or Hi-Lo	Long Island-Empire run-through services
Intercity Corridor Train	I	10	2	High-Performance Dual Mode[3]	1000	60-70	600-700	Yes	125	Hi-Lo	New loco type[3]
	I	12	2	Diesel loco	1170	60-70	720-840	Yes	(110)	Hi-Lo	Operates off-corridor only
	I	12	2	Electric loco / Catenary	1170	60-70	720-840	Yes	125	Hi-Lo	On NEC Spine w/ engine change
Regional Rail Electric Multiple-Unit (EMU) [4]	I	12	0	EMU / Catenary or 3rd Rail	1020	105	1260	Yes	100-125	High or Hi-Lo	Single level fleet, similar to M7, M8, Silverliner V
	I	12	0	EMU / Catenary or 3rd Rail	1020	135	1620	Yes	100-125	High or Hi-Lo	New fleet type – Bi-Level or Duplex EMU
Regional Rail Push-Pull, Single level or Bi-level[4]	I	10-12	2	Electric, Diesel or Dual-Mode loco	1000	135	1350-1620	Yes	125/100	High or Hi-Lo	Includes run-through services
	I	8	1	Electric, Diesel or Dual-Mode loco	755	135	1080	Yes	125/100	High or Hi-Lo	Includes run-through services
Intercity Long-Distance Train	I	10-12	2	Same locomotive options as Intercity Corridor trains	1170	n.a.	400	Yes	125	Hi-Lo	Operates on NEC Spine during off-peak hours only

[1] Measured in equivalent 85-foot car lengths. Also can be operated in smaller consists as warranted by demand. High-speed equipment assumed to comprise one or two intact trainset modules.
[2] Based on 85 ft. long passenger cars and 75 ft. long locomotives, or the equivalent length of intact trainset modules.
[3] Assumptions about future high performance dual mode locomotive or multiple-unit trainset (technology assumed to exist prior to 2040 horizon year): Catenary on NEC Spine; Diesel off-corridor; Top speed off-corridor: 110 mph; Braking rate: 1.6 mph/second; Acceleration: similar to AEM7 (placeholder with middle-of-the-road performance).
[4] Includes through-running services, assuming compatibility with traction power system (if any) on all lines served.
[5] There is currently no high speed trainset 220 mph-capable that has both overhead electrification and third rail equipment. Also of note, this trainset would need to be compatible with the three types of AC power present on the existing NEC.
[6] There is currently no trainset 220 mph-capable that is powered by overhead electrification and diesel.

8.1.6 Signaling and Train Control Systems

The future NEC is assumed to be equipped with a fixed block (cab, no wayside) signal system and an overlay Positive Train Control (PTC) system. PTC, based on the Amtrak Advanced Civil Speed Enforcement System (ACSES), provides four critical functions in addition to the cab signal-based Automatic Train Control functions:

- Permanent civil speed enforcement,
- Temporary civil speed enforcement,
- Positive stop enforcement,

- Roadway worker safety protection, including prevention of incursions into work zones and provision for enforced temporary speed restrictions while passing work zones on adjacent tracks.

The cab, no wayside system is assumed to be based on shorter block lengths where needed to provide for higher-density operation at shorter headways than the existing signal system. In these high-density locations, the signal system architecture assumes all passenger equipment is capable of braking speeds of 1.6 miles per hour per second (mphps) at the low end of the speed range and is assumed to support freight trains operating at reduced speed.[39]40 The Action Alternatives will be developed to *not preclude* reasonable future investment in signaling systems or other infrastructure along the existing NEC to enable freight trains to operate at higher speeds.

In the following locations, where overhead (i.e., through-running) freight trains operate on the NEC, the signal system is assumed to permit mixed traffic operation of freight and passenger trains and support operation of freight trains at normal operating speeds (up to 50 mph) on the non-high-speed tracks:

- Bayview (Baltimore), MD to Wilmington, DE
- New Haven, CT to Pawtucket, RI
- Other portions of the NEC where high-density signaling is not required for capacity purposes

For purposes of developing service plans prior to full network simulation analyses, given the signal system architecture described above, the assumed practical following headway for passenger trains is assumed to be:

- 220 mph top speed: 4 minutes
- 160 mph top speed: 3 minutes
- Slower-speed territory, including station approaches with merging and diverging movements: 2 minutes

These planning headways will be confirmed or modified as appropriate based on the results of the full network simulations.

Moving block technology is *not* assumed for the NEC or connecting corridors in the NEC FUTURE analysis. The European Train Control System Level 3 (ETCS-3) technology currently is under development and may be a potential option for the future of the NEC. This would provide continuous data transmission to and from the train, but train location and train integrity supervision would no longer need to rely on trackside equipment such as track circuits or axle counters.

[39] The maximum allowable speed of a freight train is assumed to be limited to the speed at which the engineer is able to control the movement of the train to permit stopping within half the range of vision, looking out for broken rail and misaligned track, and not exceeding the speed prescribed by Timetable Special Instructions and other directives, not exceeding 20 mph outside interlocking limits and 15 mph within interlocking limits.

However, since ETCS-3 is not yet fully implemented in Europe, and there are no high-speed rail systems currently in operation internationally that employ moving block technology, NEC FUTURE will make the conservative assumption (with respect to line capacity) that the NEC will continue to employ a fixed-block signaling system. The existing system will be assumed to be upgraded and reconfigured to provide the highest density of traffic that is practical given the projected future mix of traffic.

8.1.7 Other

8.1.7.1 Turnout Geometry and Interlockings

NEC FUTURE will assume the following geometry and maximum diverging speeds for turnouts on the existing NEC and new high-speed tracks:

- New very high-speed turnout: 160 mph*
- New high-speed turnout: 100 mph*
- #32.7 turnout: 80 mph
- #26.5 turnout: 60 mph
- #20 turnout (tangential): 45 mph

* These are placeholders for purposes of initial analysis and developing conceptual layouts and capital cost estimates. The performance and cost tradeoffs associated with potential higher-speed turnouts will be investigated. Assumptions regarding turnout dimensions and costs for high-speed turnouts will be derived based on experience with the California High-Speed Train Project and internationally, taking into account the characteristics of the NEC, including the available cab signal speeds.

Diverging speeds at interlockings will, to the greatest extent practicable, match the NEC cab signal speeds of 160 mph, 125 mph, 100 mph or 80 mph. The basis of these interlocking concepts will be planning and design concepts developed for the CHSTP and the Amtrak Next Generation plan for the NEC.

8.1.7.2 Grade Crossings

All new right-of-way will be free of grade crossings. Existing grade crossings will be eliminated where maximum authorized speeds are increased above 125 mph.

8.1.7.3 Maximum Speed on Tracks Adjacent to Station Platforms

In general, NEC FUTURE will plan for new stations and improvements to existing stations on the NEC that permit non-stopping express trains to pass through stations on tracks without platform edges. At locations without dedicated station bypass tracks, additional side tracks may be provided to accommodate station platforms. However, where space is constrained, or where the volume and speed of non-stopping trains does not warrant the construction of additional side platform tracks, non-stopping trains may need to operate on station tracks that have high-level platforms. In all cases where the speed of non-stopping trains will be greater than 160 mph, dedicated bypass tracks will be provided separately from the station platform tracks.

Passenger trains are assumed to be able to operate non-stop through stations on tracks with platforms at speeds up to 135 mph, provided that the station platforms are equipped with ADA-compliant signage and public address announcements to warn passengers of an approaching train. Passenger trains are assumed to be able to operate non-stop through stations on tracks with platforms at speeds up to 160 mph, provided that the station platforms are equipped with platform doors or screens that provide a physical barrier between the platform and the trackway.

8.1.7.4 Wide-Clearance Freight Traffic Routes

Equipment normally operating on the NEC will be assumed to comply with the Amtrak clearance diagram, designated as Drawing D-05-1355 Rev. E. However, there are occasions when trains with horizontal dimensions exceeding the normal standards operate on the NEC, and these operations need to be protected in the future NEC track configuration.

The Strategic Rail Corridor Network (STRACNET) consists of 38,800 miles of rail lines important to national defense and provides service to 193 defense installations whose mission requires rail service. The Railroads for National Defense Program (RND), in conjunction with the Federal Railroad Administration (FRA), established STRACNET to ensure that the minimum railroad access needs of the Department of Defense (DOD) are identified and coordinated with appropriate transportation authorities. STRACNET enables the deployment of heavy and tracked military vehicles via the railroad network among DOD installations and US seaports. A critical characteristic of STRACNET is the ability of these lines to accommodate oversize (high/wide) loads. Significant portions of the NEC are included in STRACNET. Provision for high and wide-load train movements along portions of the NEC designated as STRACNET routes will be preserved in all Action Alternatives.

On portions of the NEC where overhead (i.e., through-running) freight trains are operating, including the Bayview (Baltimore) to Wilmington and New Haven to Pawtucket segments, freight trains are assumed to operate on the local (non-high-speed) tracks, through stations that have high-level platforms. In these areas, freight bypass tracks are to be provided where space permits. Where space is constrained, gauntlet tracks are assumed to be provided in station areas on the local tracks with high-level platforms.

Local freight trains are assumed to be capable of operating on station tracks with high-level platforms without gauntlet tracks.

The above planning assumptions notwithstanding, Action Alternatives will be developed to not preclude reasonable future investment in infrastructure to enable freight trains to operate with greater clearances.

8.1.7.5 Topics for Further Research and Discussion

Recognizing the programmatic and conceptual nature of the infrastructure, equipment and service elements of the alternatives at this early stage of planning, all of the technical criteria and standards that would be necessary for the design and implementation of the rail system improvements are not available and are not required in order to initiate planning and develop the alternatives for environmental assessment purposes. Additional research and analysis will need to be undertaken to further define the requirements.

Topics and issues that may be appropriate for further research and discussion include, but are not necessarily limited to, the following:

1. Barrier design criteria; range of designs for various speeds and offset differences; specific assumptions related to the physical and operational characteristics of parallel freight trains
2. Functional criteria for intrusion detection and protection for adjacent transportation systems (passenger, freight, highway)
3. Tunnel cross-sections, associated with various design speeds (160 mph up to 220 mph)
4. High-speed turnout design criteria and length required for crossovers and turnouts
    a. Very high-speed turnout design criteria (e.g., between 160 and 220 mph) – investigate recent developments in Europe and Asia
    b. New turnout designs being developed by Amtrak (60 and 80 mph diverging moves in limited footprint)
5. Interlocking configurations, including at junctions and stations
6. Standard schematic plans and cross-sections for stations
7. Update rolling stock physical and operational characteristics
8. Freight train characteristics, including maximum speeds, horizontal and vertical clearances and maximum axle loads
9. Signal and train control system assumptions (e.g., build on existing nine-aspect cab signal system, increase the “super clear” speed to 160 mph, add one more aspect for 220 mph or 186 mph)
10. Electric traction power system assumptions (e.g., retention of existing three voltage/phase combinations plus 25 kV 60 Hz for anything of substantial length that is new, versus upgrading of existing system to 25 kV)
11. Criteria for maximum speed of non-stopping trains past station platforms, and separation of station platforms from high speed tracks (and associated side track geometry) with MAS greater than 135 mph
12. Confirm ADA and safety standards for stations, including assumptions concerning the speed of trains operating non-stop on tracks with station platforms
13. Confirm or define maximum speeds where grade crossings remain (Connecticut, Rhode Island)
14. Life safety criteria and requirements (e.g., NFPA 130 Fire Life Safety issues as they relate to train separation in tunnels, including criteria for 30 minute floor fire test and emergency evacuation of passengers and train crews)
15. Potential configuration and performance specifications of future dual-mode trainsets providing intercity service both on the NEC (with electric traction) and off-corridor (under diesel power), particularly with respect to the ability of the equipment to operate on the high-speed tracks on the NEC in mixed traffic with electric-only high-speed trainsets at acceptable levels of performance (i.e., top speed, acceleration and braking)
16. Passenger comfort standards (horizontal and vertical acceleration and jerk)
17. Traction power facility footprint size and interval frequency
18. Control of access/grade separations, possibly as it relates to speed
19. Maintenance access and access intervals
20. Open versus closed drainage systems

21. Integrated criteria for rolling stock performance and track design, with parameters including a range of maximum speeds, superelevation, unbalance, activation of tilt capability and track centerline spacing, for each rolling stock type and service territory on the NEC.