NEC FUTURE
A Rail Investment Plan for the Northeast Corridor

Capital Costs Technical Memorandum

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Submitted by:

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A JOINT VENTURE

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1. Methodology

The cost estimating methodology used for NEC FUTURE has evolved during the alternatives development process, from initial concept planning and service development through concept design for the Tier 1 Draft Environmental Impact Statement (Tier 1 Draft EIS) No Action and Action Alternatives. This section presents the process used to refine the methodology to develop capital costs.

1.1 INITIAL ALTERNATIVES COST METHODOLOGY

Capital costs were not a factor for the screening of the Initial List of Alternatives. This effort focused on whether each Initial Alternative meets the Purpose and Need, which did not include any direct consideration of potential capital costs as a differentiator. (See the *Preliminary Alternatives Report*, available on the NEC FUTURE website, for more information.)

1.2 PRELIMINARY ALTERNATIVES COST METHODOLOGY

The Preliminary Alternatives broadly defined information related to infrastructure investments, with minimal location-specific infrastructure design details. Driven by service planning and operational approaches, these alternatives had only general station, alignment, and related infrastructure requirements and service goals. An initial estimate of each Preliminary Alternative's approximate capital costs was sufficient for the screening step. (See the *Preliminary Alternatives Evaluation Report* for a detailed description of the Preliminary Alternatives and the screening process.[1])

The Federal Railroad Administration (FRA) included the following cost components in each estimate:

- **Repair, upgrade and/or expansion of existing alignments** – Typical elements ranged from comprehensive state-of-good-repair projects for major infrastructure components, to upgrades of signals, catenary, track beds, or other systems for the existing Northeast Corridor (NEC), to improvement projects involving additional tracks, curve modifications, and other elements that would substantially improve performance, raise speeds, and increase capacity. Major infrastructure projects include large discrete infrastructure elements such as tunnels, bridges, large elevated embankments, and interlockings.
- **Development of new alignments, stations and major infrastructure** – These elements included entirely new alignment options, designed for high-speed train operations, often with new or expanded station areas, along with other major infrastructure elements (e.g., yards) that the Service Plans for the Action Alternatives require.

[1] *Preliminary Alternatives Report*. NEC FUTURE. April 2013. http://necfuture.com/pdfs/prelim_alts_report.pdf.

- **Rolling Stock** – An estimated cost for rolling stock was added to each alternative by multiplying an estimated unit cost per trainset by the estimated trainset count required to operate the Service Plan for that alternative.

The primary sources of cost information came from domestic and international experiences in each of the cost areas, focusing on projects that were in advanced design/development levels or were already completed and in operation. The FRA based approximate comparative cost estimates for the Preliminary Alternatives on tunnel, at-grade, aerial, and major bridge sections.

1.3 NO ACTION AND ACTION ALTERNATIVES COST METHODOLOGY

For the Tier 1 Draft EIS, the FRA advanced the No Action Alternative and Action Alternatives for analysis. The No Action Alternative cost methodology estimate was calculated by summing the total cost of the No Action Alternative Project List, as described in section 3.2.1. For the Action Alternatives, the FRA completed more detailed cost analyses for typical right-of-way cross sections (typical cross sections), station layouts, trackwork configurations, rolling stock requirements, and maintenance and operations costs. Cost estimates address all key 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.

The FRA increased the number of typical cross sections to reflect the more detailed analysis of likely construction configurations along the Representative Route of the Action Alternatives. Cost estimates were developed for each of the typical cross sections. Cost estimates for linear elements are based on applying the appropriate typical cross sections by the estimated quantity (i.e., length) of that typical cross section along the Representative Route. Costs for the various elements are expressed as cost-per-unit length for infrastructure.

The FRA developed lump-sum cost estimates for discrete items such as stations, railroad junctions, shops, and rolling stock purchases. These costs are drawn from standard cost libraries and derived costs for recently completed similar projects.

This section identifies the key data that have been incorporated and the general underlying assumptions that have been made across all alternatives.

1.3.1 Data Collected

The FRA collected data that included information regarding existing and proposed stations, parking facilities, existing track configuration and previously planned and proposed track improvements such as interlockings, new structures, signal and catenary improvements, and other improvements that could increase the capacity of the existing NEC. Additional data collected includes design standards for Amtrak and other railroads that own or operate on the corridor or that may control track options currently used by Intercity trains as they pass along the corridor. These options refer to the use of some tracks currently not suitable for high-performance trainsets in areas owned and operated by freight or commuter rail. Upgrading these tracks gives the high-speed rail operator the "option" to route more trains through certain chokepoints on tracks currently not acceptable for high-speed service.

1.3.2 Capital Cost Benchmarking Data

The FRA collected data from other high-speed rail and passenger rail corridor investments as a means of benchmarking input into the capital cost model to estimate new high-speed rail infrastructure and to make improvements to the existing NEC. The FRA used the following U.S. examples: Amtrak NextGen HSR; California High-Speed Rail (CAHSR) Program; Chicago-St. Louis HSR Corridor Program (which is allowing for new 110 mph service); New Haven-Hartford-Springfield Rail Program; and the Amtrak Gateway Program. The FRA also included international HSR projects in England and Spain. In addition to the CAHSR cost data, which provided extensive design-level cost estimate inputs for common alternative elements, the FRA gathered costs from recently completed railroad projects to benchmark major infrastructure projects such as rehabilitation or construction of tunnels, significant bridges, and stations. (See Appendix A of this technical memorandum for a complete list of projects included in developing capital cost estimates.)

A key element of the benchmarking has been developing an understanding of the capital cost methodology and unit costs used for pricing the CAHSR Program, and aligning those estimates with the level of detail available for the Action Alternatives. The CAHSR Program has been particularly valuable because those estimates included extensive benchmarking to other domestic and international passenger rail projects, and recent contract awards have provided comparable construction costs that were then adjusted to reflect typical labor costs for infrastructure construction in the Northeastern United States.

The FRA benchmarked cost estimates of the No Action and Action Alternatives against cost estimates of the High Speed 2 (HS2) railway project in the United Kingdom. Appendix B of this technical memorandum includes the results of this analysis. Where applicable, the FRA compared specific line-item costs from the HS2 cost estimate to the No Action and Action Alternatives' costs.

1.3.3 General Assumptions

As part of its capital cost estimating methodology, the FRA developed numerous general assumptions that were applied consistently across the analysis. Among the most critical to the analysis were the following:

- Application of approximate right-of-way widths for typical infrastructure and station configurations are consistent with Representative Routes and station areas. Right-of-way acquisition requirements were identified based upon the Representative Routes and station areas, but site-specific property acquisition needs were not identified. The FRA based right-of-way acquisition costs on an analysis of land cover information collected by the FRA.
- Major conflicts with existing infrastructure such as overpasses, buildings, highway interchanges, and local roadways are identified and categorized. At the earlier stages of alternatives development, allowances were included for resolution of typical conflict categories (e.g., conflicts with existing under- or overpasses, roadways, rail lines).

- Development of typical station types are based on the station typology (Major Hub, Hub, and Local), surface grade (elevated, at-grade, below grade) and size (number of tracks/platforms, multimodal connectivity)—all with a consistent platform length that was based on service and operational characteristics.
- Alignments are grade separated in areas where operating speeds in excess of 110 mph are planned to preclude conflicts with other modes of transportation. All track related to dedicated high-speed alignments are designed for a minimum operating speed of 160 mph and a maximum operating speed of 220 mph.
- All main line track are equipped with Positive Train Control (PTC) systems.
- Intercity and high-performance trainsets are powered by overhead catenary systems (OCS).
- The base year of the analysis is 2014. Where needed, source data costs were escalated to 2014 dollars for use in this analysis. Results are presented in base year 2014 dollars and are not escalated to the expected year of expenditure or the midpoint of construction. This is due to the uncertainty and variability of funding availability, which will inform the overall programmatic development time frame and the design and construction schedule.
- Costs for railroad force account[2] construction crews required to perform removal or cut-ins[3] of the existing railroad infrastructure were not included in the cost estimate.
- Cost estimates are consistent with the infrastructure required to meet the Service Plans of each Action Alternative, as described in the *Service Plans and Train Equipment Options Technical Memorandum*, Appendix A of the *Tier 1 EIS Alternatives Report*.
- Estimated unallocated contingency costs were not included in the estimate. The FRA recognizes that all of the alternatives present unknown and indefinite cost risks of the types usually addressed by applying an unallocated contingency. However, a primary purpose of the Tier 1 Draft EIS capital cost estimate is to facilitate comparison between the No Action and Action Alternatives. The FRA believes that applying an unallocated contingency as a percentage of project costs would not provide useful insight into this comparative analysis, given the model and the level of analysis. Moreover, there is not a recognized industry-standard percentage that has reasonable precedence given the features of the NEC FUTURE capital cost model. Uncertainty about elements of project risks such as implementation timelines, project delivery methods, and funding sources also make it impractical to assign a discrete value to unallocated contingency at a corridor-wide level. Additional information about contingencies is provided in Section 2.10.
- Constructability access costs, which account for project costs for railroad flagging and protection, construction of laydown areas or track sidings in the work area, de-energizing of catenary adjacent to the work area, or other support costs that are exclusive of the cost

[2] Railroad force account typically describes work completed by the railroad's internal construction or maintenance employees within the railroad's right-of-way.

[3] Cut-ins refer to locations where existing track has been replaced with new track components such as rail and ties, or where the entire trackbed (including subballast and ballast) have been replaced in discrete lengths typically less than 5 miles in length.

premium charged by railroad construction forces (see Section 2.4.4), do not include the following:

- Any penalties or fees associated with impacts to the operation of the host railroad that would result from the contractor's operations
- Railroad force account construction costs that exceed direct labor required for the work
- Costs for temporary access agreements with railroads

1.3.4 Derivation of Unit Costs for Typical Cross Sections

The FRA developed a cost-per-unit length for each typical cross section, which was derived from a buildup of assumed quantities and unit costs for standard items required to construct each of the typical cross sections. The FRA based the quantity and unit cost for each item on estimates of recent projects that were similar to each typical cross section configuration, and similar in complexity to the various elements included in NEC FUTURE. Those standard item costs that have a significant impact on total project capital cost, such as tunnel boring machine (TBM) costs, were evaluated in greater detail, with multiple options given the expected wide range in costs for different types of tunnels in different settings (e.g., a short rural tunnel to maintain grade through hilly terrain vs. a long urban area tunnel). The FRA normalized project costs from various sources to reflect the base year of the estimate and location of the project.

Where similar project references could not be identified, the FRA used a bottom-up estimate to develop the unit costs. This approach required analysis of production rates, labor and equipment rates, and material costs for each construction activity. The unit price analysis method was used to develop costs for complex construction elements including but not limited to viaducts, retained earth systems, tunneling and underground structures. This method allowed the FRA to develop unit prices based on current local construction and market conditions, such as changes that might affect productivity or the cost of labor or materials.

The FRA used the following sources to obtain basic cost data to develop any needed construction unit prices:

- Labor Rates – Federal Davis-Bacon Wage Determination
- Material Prices – material and supply prices for locally available material were obtained from local supplier quotes

2. Capital Cost Model

2.1 CONCEPTUAL LEVEL OF DETAIL

The NEC FUTURE capital cost model provides a conceptual cost estimate for each Action Alternative commensurate with the level of detail necessary to provide an accurate, documented, validated, and defensible cost comparison of the Action Alternatives. The conceptual level of detail was a function of deliberation, analysis, engineering assessment, and understanding of those components aggregated by the model. Actual costs could meaningfully differ after more refined engineering and design work is completed, selections of construction and staging methodologies are made, or price inflation/deflation occurs.

As described in Section 2.2, the level of detail and validity of the model was also a function of quality reviews at numerous development steps and of constructive critiques by both internal and external reviewers. These reviews reinforced the documentation process, the model's internal methodologies, and the inclusiveness of the model.

Even though the model reflects a conceptual level of detail, it is based on a validated methodology and documented references from actual construction projects. Construction specifications, construction plans, and detailed bid schedules were not available for the Action Alternatives; therefore, the FRA used and applied documented references from previously completed projects and construction programs to generate conceptual costs. Additionally, the FRA developed the cost estimates to generate conceptual costs for the end-to-end routes of the Action Alternatives from Washington, D.C., to Boston, MA. Therefore, the model is not intended to estimate the costs of specific smaller-scale projects separately (e.g., individual bridge replacements, tunnel construction projects, or station projects).

2.2 QUALITY CONTROL REVIEW PROCESS

Internal and external reviewers were instrumental in the review processes. The Capital Cost Estimating/Conceptual Engineering Technical Working Group (TWG) reviewed the methodology used for the cost estimate. In addition to representatives from the FRA, the TWG included representatives from railroad operators along the NEC, who are familiar with the planning and delivery of service changes and major infrastructure projects along the corridor. As such, the TWG members provided valuable feedback and insight into the development of the capital cost methodology. Workshops with the TWG included presentation and discussion of the following:

- Description of the Action Alternatives and the level of detail available
- Cost estimates developed, including all allowances
- Key risks considered in the analysis and how each was addressed in the cost estimate
- Relevant benchmarking data used and how it is relevant to the alternatives studied

In addition to the results of these workshops, the FRA incorporated discussion of the capital cost estimating methodology and benchmarking effort into the regularly planned TWG meetings for comment and input as work progressed.

In addition, the FRA conducted detailed quality assurance and quality control with CAHSR Program staff. The CAHSR reviews were conducted in late 2014. The FRA revised major unit costs as a result of the CAHSR reviews, which included aerial structure, station, and tunnel costs.

The FRA conducted detailed reviews of the functionality and cost components included in the model. The feedback resulted in improved unit price references and methodologies. Internal review processes considered all aspects of the capital cost estimate, and focused on reviewing sample cost estimates, unit cost sources, methodologies, and the organization and presentation of the cost estimates. As described in Section 2.12.2, the FRA completed map-based quality control reviews throughout late 2014 and early 2015.

2.3 UNIT COST LIBRARIES

2.3.1 Development

As described in Section 1.2, development of the unit cost libraries used in the model began with the preliminary cost model in 2013, which the FRA then reviewed and updated to 2014 dollars. Many unit prices were replaced with more accurate and validated unit prices where additional references and construction projects were identified.

Unit costs indexed in the model were named according to infrastructure construction line items (such as catenary, track, etc.). The development of these unit costs included both materials and all contractor labor leading up to and including final installation. The unit costs include an industry-standard assumption that approximately 50 percent of costs are attributed to material and approximately 50 percent are attributed to labor. Because labor costs can vary widely throughout the NEC, all unit prices were normalized to an average labor rate. Labor costs for the Philadelphia, PA, metropolitan area were determined to be a good average labor rate for the region. As such, notations in the unit cost library refer to an adjustment to Philadelphia labor rates. Where unit costs reference construction projects located outside the Study Area, the FRA adjusted the labor component of these costs consistent with the RS-Means 2013 edition to Philadelphia labor rates. (See Appendix A of this technical memorandum for a complete list of unit prices used in the model.)

2.3.2 Standard Cost Categories

As capital costs were developed for the typical infrastructure configurations throughout the existing NEC, the FRA organized and reported capital cost estimates using the following Standard Cost Categories (SCC) as used throughout its passenger rail development programs:

- 10 Track Structures and Track
- 20 Stations, Terminals, Intermodal
- 30 Support Facilities: Yards, Shops, Administration Buildings

- 40 Site work, Right of Way, Land, Existing Improvements
- 50 Communications & Signaling
- 60 Electric Traction
- 70 Vehicles
- 80 Professional Services

2.4 LINEAR ELEMENT COSTS

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.

2.4.1 New Segments

New segments are sections of new track that may be constructed in new railroad right-of-way outside the existing NEC right-of-way. At the conceptual level, new segments are envisioned as being constructed according to one of the 46 typical cross sections. (See Appendix C of this technical memorandum for full details of the 46 typical cross sections.)

Typical Cross Sections

The typical cross sections are a further refinement of the following six construction types identified in the Representative Route for the Action Alternatives: tunnel, trench, at-grade, embankment, aerial structure, and major bridge. The purpose of 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. Typical cross sections also 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.

In a few cases, typical cross section costs were modified to reflect design parameters specific to an Action Alternative. As an example, Alternative 2 is designed for a top operating speed of 160 mph. Some typical cross sections used for Alternative 2 are also used by Alternative 3, where the top design speed is 220 mph. In these cases, specific section costs that apply only to ≥160 mph operation (e.g., additional safety requirements such as crash walls for adjacent tracks) were therefore not needed for Alternative 2, and were omitted from the typical cross section costs for that alternative.

Tunnel construction is represented by two typical cross sections: tunnel (applied to all tunnel lengths less than or equal to 10 miles) and long tunnel (applied to any tunnels greater than 10 miles in length). Given the conceptual nature of the capital cost model, tunneling costs for both tunnel and long tunnel typical cross sections use TBM unit costs. The FRA revised tunnel costs from the preliminary cost model to match the latest material provided by the CAHSR Program team in early

2015. Long-tunnel unit prices reflect unit prices extrapolated from Channel Tunnel (Chunnel/U.K.) prices inflated to 2014 dollars.

2.4.2 New Tracks

New tracks represent additional track or systems improvements along the existing NEC. These upgrades are defined as the addition of one or two tracks to the existing NEC by construction type (tunnel, trench, at-grade, embankment, aerial structure, and major bridge), or an upgrade to the catenary or signal systems. The FRA estimated the cost of these upgrades by calculating the unit price of construction line items, similar to those identified for new segments.

2.4.3 Curve Modifications

Curve modifications represent sections of existing track that would be modified to increase operating speeds. The overall intent is to increase speeds and reduce travel times. The FRA developed the costs of this construction by multiplying the appropriate typical cross section cost against the length of each curve modification. An additional track factor was multiplied against the length if the existing track configuration included more than two tracks.

2.4.4 Constructability Access

The cost methodology of the Preliminary Alternatives included complexity factors as a means of capturing construction access costs and costs associated with the complexities of constructing infrastructure in between or adjacent to existing and live operating railroad tracks. During this initial phase, these complexity factors were percentage increases applied to the quantity of the construction line items for each typical cross section. These factors reflected professional judgment and were appropriate for the high-level analysis done during the Preliminary Alternatives stage.

However, for the cost estimate for the Tier I EIS Alternatives, the FRA replaced the complexity factors with a methodology designed to assess specific representative costs for construction access and staging for activities within or adjacent to in-service tracks on the existing NEC. The FRA determined that additional costs were likely where construction would occur between or within 30 feet of existing operating railroad tracks. In these locations, this methodology assumes additional costs for railroad safety protection, access/egress to the construction site, and other items such as adding run-around tracks, or fitting staging and laydown areas into constrained site locations. The FRA did not assess these constructability access costs for typical cross sections where new tracks are more than 30 feet from existing tracks, or where tracks are constructed in a new right-of-way outside the existing NEC right-of-way.

Construction access costs mitigate the contractor's impact to existing railroad operations. These costs do not represent penalties or fees associated with construction impacts to existing operations, railroad force account construction costs that exceed direct labor required for the work, or temporary construction access agreements with the operating railroads. (See Appendix A of this technical memorandum for complete details of the unit prices used in calculating constructability access costs.)

2.5 SUPPORTING INFRASTRUCTURE COSTS

Supporting infrastructure costs represent those costs that are not measured by route-foot or track-foot. Although there may be route-foot or track-foot elements included in the construction line items, the supporting infrastructure components of stations, junctions, and yards are identified at points along the Representative Route by stationing.

2.5.1 Stations

The FRA estimated station costs by calculating the cost of building a new station or upgrading an existing station. Elements included the surface grade of the station, the number of new, rebuilt or modified platforms, and other capacity or pedestrian circulation improvements.

For both new stations and upgraded existing stations, the FRA identified a station service type based on the types of rail service provided at the station now, and in the future. The station types are Major Hub, Hub, and Local. These three station types were refined into five sub-station types for cost estimation purposes as described below:

- **Gold** serves the largest markets in the Study Area and includes a full complement of passenger rail services.
- **Red** serves the major markets in the Study Area and includes regular Intercity-Express service.
- **Blue** serves the smaller intermediate Amtrak stations in the Study Area, as well as key Regional rail stations. Blue stations fill connectivity gaps in the existing passenger rail network. These stations include regular Intercity-Corridor trains and limited Intercity-Express service.
- **Green** serves the smaller intermediate Amtrak stations in the Study Area, as well as key Regional rail stations. Green stations include special trip generators and/or important intermodal connections. These stations include regular Intercity-Corridor trains and limited Intercity-Express service.
- **Purple** only offers Regional rail service in Regional rail service areas.

The five sub-station types above fit into the station types as follows: Gold and Red stations are Major Hubs, Blue and Green stations are Hubs, and Purple stations are Local. (See the *Station Identification and Location Analysis Technical Memorandum* for additional station details.)

The FRA also identified the surface grade: below grade, at-grade, or aerial. As such, the unit price library for stations includes 30 unique station descriptions: five station types at three surface grades, for both new and upgrade stations.

For each of the station descriptions, the unit price library included a construction cost based on actual construction costs of completed station projects, or bids for station construction. Where a completed project or bid reference could not be found, the cost of the station was calculated as a percentage increase or decrease of the cost of a referenced station. Of the 30 unique station descriptions, 23 references are provided, accounting for approximately 94 percent of all stations identified in the Action Alternatives. In all cases, the track and platform construction line items were excluded from the station description unit prices. Track costs of stations were included within the new segments, curve modifications, new tracks (Section 2.4) or junctions (Section 2.5.3).

For existing stations where an expansion was identified, the FRA calculated the cost of platforms by identifying the number of island or side platforms at the stations in each Action Alternative. For existing stations, the unit price of existing island and side platforms was subtracted from the cost estimate to represent the salvage value or reuse of existing platforms before including the unit price of island and side platforms in the Action Alternative. Therefore, the estimated cost for platforms at new stations is greater than the estimated cost at existing stations. For existing stations where an expansion was identified and the configuration of platforms in the Action Alternative would not change from the existing condition, the cost of a rebuilding or modifying a platform was added to the cost estimate. (See the *Stations Identification and Location Analysis Technical Memorandum* for stations in the Action Alternatives.)

2.5.2 Yards

Yard costs were estimated by calculating the unit price of construction line items at different types of yards and facilities. There are six different types of yards: Major Service and Inspection Facility, Service and Inspection Facility, Heavy Maintenance Facility, Maintenance-of-Way Facility, Storage Yard and Minor Service and Inspection Facility, and a Storage Yard. The FRA calculated the total cost of each yard type identified throughout the corridor. However, the cost estimates include yards and facilities used by Intercity operations and do not include yards and facilities used by Regional rail operators. The costs for these yards are non-site specific, and do not include acquisition costs for yard right-of-way. See the *Service Plans and Train Equipment Options Technical Memorandum* for additional information on the FRA's consideration of yards and facilities.

2.5.3 Junctions

Junction costs were estimated by calculating the unit price of construction line items, including different types of junctions, interchanges, or connections, referred to collectively as junctions. The FRA provided configurations for each of the 50 types of junctions. The FRA used these configurations to estimate the cost of each type identified throughout the corridor.

2.6 PROFESSIONAL SERVICES

Professional services represent programmatic (non-construction) costs of the project. For the Tier I EIS analysis, professional services costs used in the cost methodology of the Preliminary Alternatives were further refined and/or validated against additional sources. Financing for construction bonds (typically two percent of the direct costs) were not included in the cost model because programmatic funding sources and mechanisms for NEC FUTURE financing have not been identified, even at a conceptual level. Alternative means of financing could be pursued, which may negate the need to pay for construction bonds.

The professional service cost factors were applied to each alternative's total direct costs with allocated contingency included.

The professional service factors in the model are as follows:

Service Development Plan/Service Environmental	0.00%[4]
Preliminary Engineering/Project Environmental	2.00%
Final Design	6.00%
Project management for design and construction	3.00%
Construction administration and management	4.00%
Professional liability and other non-construction insurance	0.50%
Legal, permits, and review fees by other agencies/cities, etc.	0.40%
Survey, testing and investigation	0.20%
Engineering inspection	0.20%
Start-up	6.00% of SCC 50/60

2.7 ENVIRONMENTAL MITIGATION

Environmental mitigation costs include an allowance to account for the cost of environmental mitigation that relates to the following: hydrologic/water resources (which includes wetlands), hazardous waste and contaminated materials sites, cultural resources and historic properties, safety and security, noise and vibration, and air quality during construction.

The FRA subtracted tunnels from the construction line items for environmental mitigation since tunnels would have negligible environmental mitigation costs along and above their alignment with potential impacts only at their portal sites and only a few limited locations where ventilation structures would be needed at the surface.

Environmental mitigation was applied as 7.5 percent multiplied against the sum of an alternative's direct costs plus the allocated contingency. Environmental mitigation was grouped by construction line item and was assigned an FRA SCC of 40.

2.8 RIGHT-OF-WAY ACQUISITION COSTS

Land cover unit costs in a dollar-per-acre format were derived from prior technical studies of real estate requirements within the NEC, including Amtrak NextGen HSR, Technical Report (2011); Amtrak Vision for the NEC (2012 update); and data sets comprising CoStar, Property Shark, and Loopnet average sales transaction by land use category. These dollar-per-acre unit costs were multiplied by the number of acres within the Representative Route for each land cover type, as defined by the National Land Cover Database (NLCD).

[4] For the NEC, service development and environmental planning are being completed by the NEC FUTURE process.

Rural and natural undeveloped lands in the Northeast range from approximately $4,000 to $30,000 per acre. This high end cost of $30,000 per acre equates to approximately $0.69 per square foot, which was entered into the model for natural undeveloped land (Appendix A of this technical memorandum).

The FRA identified right-of-way acquisitions costs for those locations where the Representative Route does not represent the existing NEC right-of-way. Where the construction type is identified as tunnel or major bridge, right-of-way acquisition costs were reduced 95 percent to reflect 5 percent of the calculated value. In the case of tunnels, this reduction assumes that tunnels would be constructed 40 feet to 45 feet below surface grade, with right-of-way acquisition for intermittent ventilation shafts and other permanent surface features. In the case of major bridges, this reflects the right-of-way acquisition associated with air-rights.

Right-of-way acquisition costs for yards and stations were not included in the model since it is unknown which entity would pay for certain land assets. Furthermore, much of the potential right-of-way acquisition requirements for stations were already included within the Representative Route.

2.9 VEHICLES COSTS

Vehicles costs refer to the vehicles used on a railroad, also known as rolling stock. Rolling stock costs reflect the cost to acquire additional high-performance trainsets required to operate the Service Plans for each Action Alternative. The FRA specified (at a conceptual level) the rolling stock fleet size for each Action Alternative, including operational and spare equipment. These counts are based upon service planning data. The unit cost is $50 million per trainset, as per the Amtrak NextGen HSR Study.

2.10 CONTINGENCIES

Both allocated and unallocated contingencies are a means of addressing unknown project risks that can possibly increase the cost of a project.

2.10.1 Allocated

The FRA applied allocated contingency to each construction line item of the cost estimate in different percentages since each construction line item would face varying degrees of risk/unforeseen circumstances based upon its own nature. The cost model included both low and high allocated contingency percentages. The low percentages were based upon typical historical project values and were referenced from the Amtrak NextGen HSR Study. The high Allocated Contingency rates were 50 percent greater than the low allocated contingency rates to reflect unknown risk. The low and high allocated contingencies were the only difference between the low and high cost estimates.

2.10.2 Unallocated

Unallocated contingency identifies a reserve of project funds that are designated for use in the event the project encounters any of a wide range of unpredictable circumstances that impact project development and delivery. These potential project risks include, but are not limited to, unforeseen design or engineering impediments (e.g., geologic conditions, hidden or undocumented utilities or environmental resources), shifts in market or economic conditions (e.g., changes to construction material or labor costs or availability), changes in legal, political, or financial circumstances, unpredictable project delivery issues (e.g., construction site vandalism or obstruction, construction accidents, material defects, or construction errors), or external events outside the project's control (e.g., severe weather or other natural disasters). Even though each item is unlikely on its own, any combination of these items could impact a project through schedule delays, damages, or other increases in cost.

Estimates of the appropriate unallocated contingency for project planning purposes usually rely on comparing the current project to previous successful projects of a similar scope and scale. The contingency value is usually applied as a single percentage value, multiplied as a factor against the overall project cost. Contingency values often are adjusted as project planning evolves from the earliest conceptual diagrams through to detailed construction-level engineering and budgeting documents.

The FRA recognizes that all of the Action Alternatives present unknown and indefinite cost risks of the types usually addressed by applying an unallocated contingency. However, for a number of reasons the FRA decided not to estimate unallocated contingency for the Tier 1 Draft EIS. First, a primary purpose of the Tier 1 Draft EIS capital cost estimate is to facilitate comparison between the No Action and Action Alternatives. The capital cost model was designed to serve this primary purpose through its focus on estimating the costs of specific infrastructure elements required for each of the alternatives. The FRA believes that at this corridor-wide, conceptual level of analysis, applying an unallocated contingency as a percentage of total costs would not provide value for this comparative analysis.

Furthermore, few comparable investment programs in scale and scope to the Action Alternatives exist to inform an empirical estimate of the appropriate level of contingency at this point of project development. Lastly, uncertainty about several elements that drive project risks, such as implementation timelines, project delivery methods, and funding sources, also make it impractical to assign a discrete value to unallocated contingency at a corridor-wide level. The FRA expects that many of these issues will be resolved as NEC FUTURE advances. Thus, applying unallocated contingency may be revisited in these later stages, as appropriate.

2.11 EXCLUSIONS

The level of analysis performed at this stage of NEC FUTURE does not allow for the development of some costs. These items currently excluded from the model include the following:

- State of good repair: The cost of the No Action Alternative Projects List includes those projects that are funded or included within approved funding plans, those projects that are funded or unfunded mandates, and those projects that are unfunded but necessary to keep the railroad running.

- Unallocated contingency (see Section 2.10.2).
- Finance charges (see Section 2.6).
- Property acquisition for yards and stations (see Section 2.8).
- Railroad force account construction costs (see Section 2.4.4).
- Penalties or fees associated with construction impacts to existing operations (see Section 2.4.4).
- Temporary construction access agreements with the operating railroads (see Section 2.4.4).

2.11.1 Levels of Uncertainty

The model currently accounts for some level of uncertainty through assumptions regarding various construction line items and components, including efficiencies of construction, types of contract execution, and the construction schedule. These uncertainties may have implications for the allocated contingency percentages and for the professional services should these uncertainties be better defined in the future. As a result, the FRA will continue to reevaluate the cost estimate in future iterations, which may reduce allocated contingencies or professional service percentages. These possible uncertainties may be associated with, but are not limited to the following:

- Efficiencies of construction or new methods of construction
- Railroad owners or operators
- Bonding requirements or ability to bond
- Contract execution types for construction or design (e.g., Design-Bid-Build versus Design-Build versus Design-Build-Operate-Maintain packaging)
- The construction schedule, or identification of a date of midpoint of construction for inflation
- How the various Action Alternatives may be split up into different projects based on size, limits, location and scope

2.12 ADDITIONAL QUALITY CONTROL REVIEW PROCEDURES

As described in Section 1.3.2 Capital Cost Benchmarking Data, the FRA completed numerous reviews to ensure quality control of the capital cost model.

2.12.1 Reviews with California HSR

The FRA completed numerous reviews with the CAHSR Program team. These reviews resulted in changes to aerial structure, station, and tunnel costs. In addition, the following revisions resulted from the quality control reviews with the CAHSR Program team and the FRA:

- Omission of sound walls since they were already included in environmental costs
- Revisions to unit costs to reflect the average labor rates of the Northeast

- Development of additional cost details for junction and yard costs developed from the bottom up including more detailed systems and high-speed turnout cost references
- Revisions to professional service percentages to be in line with Transit Cooperative Research Program (TCRP) documented percentages and percentages from the CAHSR Program
- Revisions to unit costs for earthwork, walkways, ductbanks, and landscaping to apply to validated real-world project examples
- Modification of how ventilation costs are applied to tunnels through a more detailed mechanism including unit prices for fan plants, tunnel vents and ventilation shafts
- Revision of the "Long Tunnel" threshold to be a minimum of 10 miles in length
- Revision of the "Tunnel" unit price to correspond to data provided by the CAHSR Program.

2.12.2 Quality Control Review of Input Data – GIS Graphical Display

Following receipt of input data, a graphical database of all inputs received was developed. The FRA reviewed this graphical input to confirm that the data in the capital cost model accurately reflected the definition of the Action Alternatives and the Service Plans for the Action Alternatives. This review was valuable in refining and validating capital cost estimates of the Action Alternatives, including refinements to stationing of new segments, new tracks NEC, and curve modifications.

2.12.3 Quality Control Review of Excel Functions

In addition to internal reviews and external reviews with the CAHSR Program team and TWG members, two professionals (not working directly on NEC FUTURE) reviewed the functionality of the capital cost model in Microsoft Excel. These professionals possessed a working knowledge of the functions within Microsoft Excel, and an understanding of the logic and intent of the model to calculate incremental costs of the components of the Action Alternatives. These reviews resulted in minor corrections and refinement of capital cost calculations that had a negligible effect on the total cost estimates.

2.13 RELATED PROJECTS

There are several ongoing rail projects located within the Study Area that are not included in the No Action Alternative Project List. These projects are included as Related Projects since they fall within one of the following three categories as described in the *No Action Alternative Report*:[5]

- Fully or partially funded projects located in a connecting corridor and not on the NEC
- Unfunded projects along the NEC with ongoing or completed National Environmental Policy Act/Preliminary Engineering (NEPA/PE)
- Fully or partially funded transit (e.g., NJ TRANSIT, MTA-Long Island Rail Road) or freight projects located off but connecting to the NEC

[5] *No Action Alternative Report*. NEC FUTURE. April 2015. http://necfuture.com/pdfs/2015_04alternatives_report.pdf.

These Related Projects have independent utility, and many are currently undergoing their own separate NEPA processes, such as the Southeast High-Speed Rail Corridor – Washington, D.C., to Richmond, VA. Others are intended to address some of the NEC's most pressing reliability, safety and capacity needs, such as Boston South Station expansion, Portal Bridge replacement, and the Baltimore and Potomac (B&P) Tunnel replacement. The full-scale rehabilitation and/or replacement of bridges and tunnels identified as Major Backlog assets (e.g., New Haven Line Bridges and Hudson River Tunnels), are also included in this category of Related Projects since their construction is currently unfunded. See the *No Action Alternative Report* for a complete list of Related Projects included in the cost estimates for the Action Alternatives.

The following methodology was employed for inclusion of Related Projects:

- The cost model projected costs for Related Projects by utilizing unit costs multiplied by established lengths. In some instances (e.g., stations), point unit costs were employed to emulate the Related Project costs. These were high-level conceptual placeholders and the methodology employed to emulate Related Projects was consistent across all Action Alternatives.
- No gaps existed in the input data; each Related Project on the NEC mainline intended for inclusion was included in the input coding. This was confirmed during internal reviews (Section 2.12.2).
- At a later date, costs received by external sources will be checked against costs generated by the input coding.

3. Model Application and Cost Estimates

3.1 MODEL TESTING

The capital cost model was tested with inputs from a draft of Alternative 2.[6] The first comprehensive estimate was completed and presented internally in late 2014. The model was refined to address the comments and concerns raised in internal review, including revisions to several unit price references and calculations; both the allocated and unallocated contingencies; labor location adjustment factors; sound walls; professional services; tunnel costs; and the addition of constructability access. These refinements are reflected in the descriptions of the cost estimate in Section 2. The refined model was tested with inputs for another draft Alternative 2 and presented internally in early 2015. As shown in Table 1, the draft Alternative 2 cost estimate included both a high and low estimate by FRA SCC.

Table 1: DRAFT, Alternative 2 Cost Estimate (Used for Model Testing Only)

FRA SCC	DESCRIPTION	LOW (millions)	HIGH (millions)
10	Track Structures and Track	$83,748	$87,651
20	Stations, Terminals, Intermodal	$5,182	$5,417
30	Support Facilities	$192	$204
40	Site work, Right-of-Way, Land, Existing Improvements	$24,027	$24,721
50	Communications & Signaling	$2,192	$2,291
60	Electric Traction	$2,897	$3,029
70	Vehicles	$6,600	$6,600
80	Professional Services	$29,086	$30,528
90	Unallocated Contingency	$0	$0
100	Finance Charges	$1,972	$2,070
	TOTAL	**$155,900**	**$162,600**
	Cost per Route Mile	$222	$231

Source: NEC FUTURE team, 2015

In addition to the project-wide benchmarking with HS2 (Section 1.3.2), and the model testing of draft Alternative 2, a small-scale validation of the cost model with the NJ High-Speed Rail Improvement Project, also known as "Raceway," was conducted. The trackwork, improvements, communications, and signaling, and electric traction associated with the narrative scope of the actual Raceway project, as described in the *No Action Alternative Report*, were modeled. This small-scale validation resulted in a low and high cost of $421 million and $442 million, respectively. The average of these two numbers is $432 million, which is within 5 percent of the $450 million budget for the Raceway project, which is currently under construction.

[6] This draft Alternative 2 is not the same as the Alternative 2 carried into the Tier 1 Draft EIS, which has a different operating plan and infrastructure requirement.

3.2 COST ESTIMATES FOR THE TIER 1 DRAFT EIS NO ACTION AND ACTION ALTERNATIVES

The FRA completed the cost estimates generated by the capital cost model for the No Action and Action Alternatives in early 2015 and are presented in Table 2 through Table 18.

3.2.1 No Action Alternative

The No Action Alternative cost estimate was calculated by summing the total cost of the No Action Alternative Project List.

Table 2: No Action Alternative Cost Estimate

FRA SCC	DESCRIPTION	LOW (millions)	HIGH (millions)
10	Track Structures and Track	$0	$0
20	Stations, Terminals, Intermodal	$0	$0
30	Support Facilities	$0	$0
40	Site work, Right-of-Way, Land, Existing Improvements	$0	$0
50	Communications & Signaling	$0	$0
60	Electric Traction	$0	$0
70	Vehicles	$0	$0
80	Professional Services	$0	$0
NA	No Action Alternative Projects	$19,860	$19,860
	TOTAL	**$19,900**	**$19,900**

Source: NEC FUTURE team, 2015

3.2.2 Action Alternative Cost Estimates

The cost estimates for the Action Alternatives were calculated based on numerous inputs including new segment lengths, new track lengths, stations, yards and junctions, all of which were developed to accommodate the Service Plans for the Action Alternatives.

Table 3: Alternative 1 Cost Estimate

FRA SCC	DESCRIPTION	LOW (millions)	HIGH (millions)
10	Track Structures and Track	$28,029	$29,381
20	Stations, Terminals, Intermodal	$5,900	$6,168
30	Support Facilities	$394	$419
40	Site work, Right-of-Way, Land, Existing Improvements	$7,408	$7,874
50	Communications & Signaling	$1,431	$1,496
60	Electric Traction	$1,772	$1,853
70	Vehicles	$2,550	$2,550
80	Professional Services	$6,774	$7,121
NA	No Action Alternative Projects	$9,330	$9,330
	TOTAL	**$63,600**	**$66,200**
	Cost per Route Mile of the Total	$112	$116
	Cost per Route Mile of the Linear Elements	$79	$83

Source: NEC FUTURE team, 2015
Note: Cost per route mile of the linear elements does not include stations, vehicles, yards & facilities, and the cost of the No Action Alternative Project List.

Table 4: Alternative 2 Cost Estimate

FRA SCC	DESCRIPTION	LOW (millions)	HIGH (millions)
10	Track Structures and Track	$64,118	$67,142
20	Stations, Terminals, Intermodal	$8,156	$8,526
30	Support Facilities	$801	$853
40	Site work, Right-of-Way, Land, Existing Improvements	$24,128	$24,865
50	Communications & Signaling	$2,165	$2,263
60	Electric Traction	$2,982	$3,118
70	Vehicles	$5,450	$5,450
80	Professional Services	$13,789	$14,476
NA	No Action Alternative Projects	$9,330	$9,330
	TOTAL	**$131,000**	**$136,100**
	Cost per Route Mile of the Total	$186	$193
	Cost per Route Mile of the Linear Elements	$151	$158

Source: NEC FUTURE team, 2015
Note: Cost per route mile of the linear elements does not include stations, vehicles, yards & facilities, and the cost of the No Action Alternative Project List.

Table 5: Alternative 3.1 (via Central CT/Providence route option) Cost Estimate

FRA SCC	DESCRIPTION	LOW (millions)	HIGH (millions)
10	Track Structures and Track	$162,322	$169,929
20	Stations, Terminals, Intermodal	$13,737	$14,361
30	Support Facilities	$1,743	$1,857
40	Site work, Right-of-Way, Land, Existing Improvements	$50,402	$51,832
50	Communications & Signaling	$2,957	$3,091
60	Electric Traction	$4,237	$4,429
70	Vehicles	$5,700	$5,700
80	Professional Services	$32,076	$33,667
NA	No Action Alternative Projects	$9,330	$9,330
	TOTAL	**$282,600**	**$294,200**
	Cost per Route Mile of the Total	$303	$316
	Cost per Route Mile of the Linear Elements	$269	$281

Source: NEC FUTURE team, 2015
Note: Cost per route mile of the linear elements does not include stations, vehicles, yards & facilities, and the cost of the No Action Alternative Project List.

Table 6: Alternative 3.2 (via Long Island/Providence route option) Cost Estimate

FRA SCC	DESCRIPTION	LOW (millions)	HIGH (millions)
10	Track Structures and Track	$137,245	$143,744
20	Stations, Terminals, Intermodal	$14,677	$15,344
30	Support Facilities	$1,743	$1,857
40	Site work, Right-of-Way, Land, Existing Improvements	$62,423	$63,734
50	Communications & Signaling	$3,061	$3,200
60	Electric Traction	$4,494	$4,698
70	Vehicles	$5,700	$5,700
80	Professional Services	$28,040	$29,438
NA	No Action Alternative Projects	$9,330	$9,330
	TOTAL	**$266,800**	**$277,100**
	Cost per Route Mile of the Total	$279	$289
	Cost per Route Mile of the Linear Elements	$244	$254

Source: NEC FUTURE team, 2015
Note: Cost per route mile of the linear elements does not include stations, vehicles, yards & facilities, and the cost of the No Action Alternative Project List.

Table 7: Alternative 3.3 (via Long Island/Worcester route option) Cost Estimate

FRA SCC	DESCRIPTION	LOW (millions)	HIGH (millions)
10	Track Structures and Track	$144,180	$151,018
20	Stations, Terminals, Intermodal	$14,019	$14,656
30	Support Facilities	$1,743	$1,857
40	Site work, Right-of-Way, Land, Existing Improvements	$68,255	$69,680
50	Communications & Signaling	$3,062	$3,201
60	Electric Traction	$4,493	$4,697
70	Vehicles	$5,700	$5,700
80	Professional Services	$29,187	$30,650
NA	No Action Alternative Projects	$9,330	$9,330
	TOTAL	**$280,000**	**$290,800**
	Cost per Route Mile of the Total	$291	$302
	Cost per Route Mile of the Linear Elements	$258	$268

Source: NEC FUTURE team, 2015
Note: Cost per route mile of the linear elements does not include stations, vehicles, yards & facilities, and the cost of the No Action Alternative Project List.

Table 8: Alternative 3.4 (via Central CT/Worcester route option) Cost Estimate

FRA SCC	DESCRIPTION	LOW (millions)	HIGH (millions)
10	Track Structures and Track	$169,256	$177,203
20	Stations, Terminals, Intermodal	$13,079	$13,673
30	Support Facilities	$1,743	$1,857
40	Site work, Right-of-Way, Land, Existing Improvements	$56,234	$57,778
50	Communications & Signaling	$2,957	$3,092
60	Electric Traction	$4,235	$4,428
70	Vehicles	$5,700	$5,700
80	Professional Services	$33,223	$34,878
NA	No Action Alternative Projects	$9,330	$9,330
	TOTAL	**$295,800**	**$308,000**
	Cost per Route Mile of the Total	$316	$329
	Cost per Route Mile of the Linear Elements	$283	$295

Source: NEC FUTURE team, 2015
Note: Cost per route mile of the linear elements does not include stations, vehicles, yards & facilities, and the cost of the No Action Alternative Project List.

Table 9: Cost of Alternative 3 Route Options – Stations and New Segments by FRA SCC

FRA SCC		New York City - Hartford				Hartford - Boston			
		New York City - Danbury - Hartford[5] (Alt. 3.1 & 3.4)		New York City - Long Island - Hartford[6] (Alt. 3.2 & 3.3)		Hartford - Worcester - Boston (Alt. 3.3 & 3.4)		Hartford - Providence - Boston (Alt. 3.1 & 3.2)	
FRA SCC	DESCRIPTION	LOW (millions)	HIGH (millions)	LOW (millions)	HIGH (millions)	LOW (millions)	HIGH (millions)	LOW (millions)	HIGH (millions)
10	Track Structures and Track	$71,427	$74,673	$44,203	$46,212	$34,683	$36,260	$31,369	$32,795
20	Stations, Terminals, Intermodal	$2,011	$2,103	$2,952	$3,086	$1,877	$1,963	$2,536	$2,651
40	Site work, Right-of-Way, Existing Imp.	$3,945	$4,424	$3,320	$3,665	$3,114	$3,447	$2,525	$2,797
50	Communications & Signaling	$459	$479	$538	$562	$405	$424	$453	$474
60	Electric Traction	$685	$717	$895	$936	$678	$709	$759	$794
80	Professional Services	$12,783	$18,248	$8,376	$11,905	$6,577	$9,359	$6,100	$8,659
	Subtotal	**$91,400**	**$100,700**	**$60,300**	**$66,400**	**$47,400**	**$52,200**	**$43,800**	**$48,200**

Source: NEC FUTURE team, 2015

Notes:

1. Includes the cost of new segments and stations with allocated contingency, environmental mitigation, professional services & finance charges.
2. Does not include curve modifications, new tracks, constructability access, junctions, yards & facilities, right-of-way acquisition, vehicles, and No Action Alternative projects.
3. Does not include railroad force account construction costs (adjacent to or in the center of existing tracks, or at railroad track cut-ins), temporary access agreements with railroads, or penalties/fees for maintenance of operations.
4. Does not include property acquisition costs for yards or stations.
5. New York City-Danbury-Hartford includes East River Tunnels 5&6.
6. New York City-Long Island-Hartford includes Ronkonkoma Station Local New Segment. East River Tunnels 5&6 are included in the New York City-Long Island-Hartford new segment.
7. Washington - New York City includes new segments and stations from Washington Union Station to Penn Station New York.
8. Columns may not add to the subtotal due to rounding.

Table 10: Cost of Alternative 3: New York City to Boston – Stations and New Segments by FRA SCC

FRA SCC		Alternative 3.1: New York City-Danbury-Hartford + Hartford-Providence-Boston		Alternative 3.2: New York City-Long Island-Hartford + Hartford-Providence-Boston		Alternative 3.3: New York City-Long Island-Hartford + Hartford-Worcester-Boston		Alternative 3.4: New York City-Danbury-Hartford + Hartford-Worcester-Boston	
FRA SCC	DESCRIPTION	LOW (millions)	HIGH (millions)	LOW (millions)	HIGH (millions)	LOW (millions)	HIGH (millions)	LOW (millions)	HIGH (millions)
10	Track Structures and Track	$102,796	$107,468	$75,572	$79,007	$78,886	$82,472	$106,110	$110,933
20	Stations, Terminals, Intermodal	$4,547	$4,754	$5,488	$5,737	$4,829	$5,049	$3,888	$4,066
40	Site work, Right-of-Way, Existing Imp.	$6,470	$7,221	$5,845	$6,462	$6,434	$7,112	$7,059	$7,871
50	Communications & Signaling	$912	$953	$991	$1,036	$943	$986	$864	$903
60	Electric Traction	$1,444	$1,511	$1,654	$1,730	$1,573	$1,645	$1,363	$1,426
80	Professional Services	$18,883	$26,907	$14,476	$20,564	$14,953	$21,264	$19,360	$27,607
	Subtotal	**$135,200**	**$148,900**	**$104,100**	**$114,600**	**$107,700**	**$118,600**	**$138,800**	**$152,900**

Source: NEC FUTURE team, 2015

Notes:

1. Includes the cost of new segments and stations with allocated contingency, environmental mitigation, professional services & finance charges.
2. Does not include curve modifications, new tracks, constructability access, junctions, yards & facilities, right-of-way acquisition, vehicles, and No Action Alternative projects.
3. Does not include railroad force account construction costs (adjacent to or in the center of existing tracks, or at railroad track cut-ins), temporary access agreements with railroads, or penalties/fees for maintenance of operations.
4. Does not include property acquisition costs for yards or stations.
5. New York City-Danbury-Hartford includes East River Tunnels 5&6.
6. New York City-Long Island-Hartford includes Ronkonkoma Station Local New Segment. East River Tunnels 5&6 are included in the New York City-Long Island-Hartford new segment.
7. Washington - New York City includes new segments and stations from Washington Union Station to Penn Station New York.
8. Columns may not add to the subtotal due to rounding.

Table 11: Cost of Alternative 3 Route Options – New Segments by Construction Type

CONSTRUCTION TYPE	New York City - Hartford				Hartford - Boston			
	New York City - Danbury - Hartford (Alt. 3.1 & 3.4)		New York City - Long Island - Hartford (Alt. 3.2 & 3.3)		Hartford - Worcester - Boston (Alt. 3.3 & 3.4)		Hartford - Providence - Boston (Alt. 3.1 & 3.2)	
DESCRIPTION	Cost (millions)	Construction Route Mileage	Cost (millions)	Construction Route Mileage	Cost (millions)	Construction Route Mileage	Cost (millions)	Construction Route Mileage
TUNNEL	$65,235	77	$34,258	51	$27,014	38	$26,069	41
TRENCH	$1,061	5	$5,648	30	$2,828	13	$2,150	10
AT-GRADE	$130	5	$626	19	$66	2	$800	23
EMBANKMENT	$577	16	$687	18	$879	22	$1,317	33
AERIAL	$1,458	11	$2,052	16	$3,529	27	$742	6
MAJOR BRIDGE	$173	1	$0	0	$0	0	$0	0
Subtotal	$68,634	**113**	**$43,271**	**132**	**$34,316**	**100**	**$31,077**	**111**
Cost per Construction Route Mileage	**$609**		**$328**		**$345**		**$279**	

Source: NEC FUTURE team, 2015

Note: Direct costs of new segments only. Does not include allocated contingency, environmental mitigation, or professional services costs. Columns may not add to the subtotal due to rounding.

Table 12: Cost of Alternative 3: New York City to Boston – New Segments by Construction Type

CONSTRUCTION TYPE	Alternative 3.1: New York City-Danbury-Hartford + Hartford-Providence-Boston		Alternative 3.2: New York City-Long Island-Hartford + Hartford-Providence-Boston		Alternative 3.3: New York City-Long Island-Hartford + Hartford-Worcester-Boston		Alternative 3.4: New York City-Danbury-Hartford + Hartford-Worcester-Boston	
DESCRIPTION	Cost (millions)	Construction Route Mileage	Cost (millions)	Construction Route Mileage	Cost (millions)	Construction Route Mileage	Cost (millions)	Construction Route Mileage
TUNNEL	$91,304	118	$60,327	92	$61,272	89	$92,249	115
TRENCH	$3,211	14	$7,798	40	$8,475	43	$3,888	17
AT-GRADE	$930	28	$1,426	42	$692	21	$196	7
EMBANKMENT	$1,894	49	$2,003	51	$1,566	40	$1,457	38
AERIAL	$2,200	17	$2,794	22	$5,581	43	$4,987	38
MAJOR BRIDGE	$173	1	$0	0	$0	0	$173	1
Subtotal	**$99,711**	**224**	**$74,349**	**244**	**$77,587**	**232**	**$102,949**	**212**
Cost per Construction Route Mileage	**$445**		**$305**		**$335**		**$485**	

Source: NEC FUTURE team, 2015

Note: Direct costs of new segments only. Does not include allocated contingency, environmental mitigation, or professional services costs. Columns may not add to the subtotal due to rounding.

Table 13: Cost of Alternative 3 Route Options – New Tracks

CONSTRUCTION TYPE	New York City - Hartford				Hartford - Boston			
	New York City - Danbury - Hartford (Alt. 3.1 & 3.4)		New York City - Long Island - Hartford[2] (Alt. 3.2 & 3.3)		Hartford - Worcester - Boston[3] (Alt. 3.3 & 3.4)		Hartford - Providence - Boston (Alt. 3.1 & 3.2)	
DESCRIPTION	Cost (millions)	Upgrade Route Mileage	Cost (millions)	Upgrade Route Mileage	Cost (millions)	Upgrade Route Mileage	Cost (millions)	Upgrade Route Mileage
ADDITIONAL TUNNEL TRACK	$0	0	$0	0	$1,972	5	$0	0
ADDITIONAL TRENCH TRACK	$0	0	$480	3	$371	2	$0	0
ADDITIONAL AT-GRADE TRACK	$0	0	$137	5	$294	15	$146	8
ADDITIONAL EMBANKMENT TRACK	$0	0	$0	0	$246	11	$196	9
ADDITIONAL AERIAL TRACK	$0	0	$0	0	$0	0	$0	0
ADDITIONAL MAJOR BRIDGE TRACK	$0	0	$0	0	$0	0	$0	0
FREIGHT TRACK UPGRADE	$0	0	$0	0	$0	0	$0	0
CATENARY SYSTEM UPGRADE	$47	15	$47	15	$0	0	$0	0
SIGNAL SYSTEM UPGRADE	$147	40	$147	40	$0	0	$0	0
Subtotal	**$194**		**$811**		**$2,883**		**$342**	

Source: NEC FUTURE team, 2015

Notes:

1. Direct costs of new tracks only. Does not include allocated contingency, environmental mitigation, or professional services costs. Columns may not add to the subtotal due to rounding.
2. New York City-Long Island-Hartford includes same improvements as New York City-Danbury-Hartford, plus the Hell Gate Line 3rd and 4th Tracks (additional trench and at-grade tracks).
3. Hartford-Worcester-Boston includes the same improvements as Hartford-Providence-Boston, plus improvements along the existing NEC north of Providence: Malcom-Packard 3rd & 4th Track, Hebronville to Thatcher, and Canton Junction to Readville/Hyde Park.

Table 14: Cost of Alternative 3: New York City to Boston– New Tracks

CONSTRUCTION TYPE	Alternative 3.1: New York City-Danbury-Hartford + Hartford-Providence-Boston		Alternative 3.2: New York City-Long Island-Hartford + Hartford-Providence-Boston		Alternative 3.3: New York City-Long Island-Hartford + Hartford-Worcester-Boston		Alternative 3.4: New York City-Danbury-Hartford + Hartford-Worcester-Boston	
DESCRIPTION	**Cost (millions)**	**Upgrade Route Mileage**	**Cost (millions)**	**Upgrade Route Mileage**	**Cost (millions)**	**Upgrade Route Mileage**	**Cost (millions)**	**Upgrade Route Mileage**
ADDITIONAL TUNNEL TRACK	$0	0	$0	0	$1,972	5	$1,972	5
ADDITIONAL TRENCH TRACK	$0	0	$480	3	$851	4	$371	2
ADDITIONAL AT-GRADE TRACK	$146	8	$283	12	$431	19	$294	15
ADDITIONAL EMBANKMENT TRACK	$196	9	$196	9	$246	11	$246	11
ADDITIONAL AERIAL TRACK	$0	0	$0	0	$0	0	$0	0
ADDITIONAL MAJOR BRIDGE TRACK	$0	0	$0	0	$0	0	$0	0
FREIGHT TRACK UPGRADE	$0	0	$0	0	$0	0	$0	0
CATENARY SYSTEM UPGRADE	$47	15	$47	15	$47	15	$47	15
SIGNAL SYSTEM UPGRADE	$147	40	$147	40	$147	40	$147	40
Subtotal	**$536**		**$1,153**		**$3,695**		**$3,077**	

Source: NEC FUTURE team, 2015

Notes:

1. Direct costs of new tracks only. Does not include allocated contingency, environmental mitigation, or professional services costs. Columns may not add to the subtotal due to rounding.
2. New York City-Long Island-Hartford includes same improvements as New York City-Danbury-Hartford, plus the Hell Gate Line 3rd and 4th Tracks (additional trench and at-grade tracks).
3. Hartford-Worcester-Boston includes the same improvements as Hartford-Providence-Boston, plus improvements along the existing NEC north of Providence: Malcom-Packard 3rd & 4th Track, Hebronville to Thatcher, and Canton Junction to Readville/Hyde Park.

Table 15: Cost of Alternatives 1, 2, and 3: Washington to New York City – New Segments by Construction Type

CONSTRUCTION TYPE	Alternative 1		Alternative 2		Alternative 3	
DESCRIPTION	Cost (millions)	Construction Route Mileage	Cost (millions)	Construction Route Mileage	Cost (millions)	Construction Route Mileage
TUNNEL	$2,566	6	$3,194	8	$29,178	50
TRENCH	$44	1	$405	2	$3,365	15
AT-GRADE	$88	4	$343	11	$2,470	69
EMBANKMENT	$196	6	$494	15	$2,450	67
AERIAL	$35	1	$211	2	$4,132	32
MAJOR BRIDGE	$3,061	6	$4,262	8	$3,193	6
Subtotal	**$5,990**	**20**	**$8,908**	**42**	**$45,156**	**235**
Cost per Construction Route Mileage	**$302**		**$210**		**$192**	

Source: NEC FUTURE team, 2015

Note: Direct costs of new segments only. Does not include allocated contingency, environmental mitigation, or professional services costs. Columns may not add to the subtotal due to rounding.

Table 16: Cost of Alternative 1, 2, and 3: Washington to New York City – New Tracks by Construction Type

CONSTRUCTION TYPE	Alternative 1		Alternative 2		Alternative 3	
DESCRIPTION	Cost (millions)	Upgrade Route Mileage	Cost (millions)	Upgrade Route Mileage	Cost (millions)	Route Mile
ADDITIONAL TUNNEL TRACK	$743	2	$743	2	$743	2
ADDITIONAL TRENCH TRACK	$13	1	$13	1	$13	1
ADDITIONAL AT-GRADE TRACK	$964	49	$764	39	$649	33
ADDITIONAL EMBANKMENT TRACK	$513	18	$364	10	$287	9
ADDITIONAL AERIAL TRACK	$455	4	$78	1	$78	1
ADDITIONAL MAJOR BRIDGE TRACK	$0	0	$0	0	$0	0
FREIGHT TRACK UPGRADE	$504	31	$504	31	$504	31
CATENARY SYSTEM UPGRADE	$503	156	$430	134	$503	156
SIGNAL SYSTEM UPGRADE	$559	151	$517	140	$601	163
Subtotal	**$4,255**		**$3,414**		**$3,378**	

Source: NEC FUTURE team, 2015

Note: Direct costs of new segments only. Does not include allocated contingency, environmental mitigation, or professional services costs. Columns may not add to the subtotal due to rounding.

Table 17: Cost of Alternative 1, 2, and 3: New York City to Boston – New Segments by Construction Type

CONSTRUCTION TYPE	Alternative 1		Alternative 2		Alternative 3	
DESCRIPTION	Cost (millions)	Construction Route Mileage	Cost (millions)	Construction Route Mileage	Cost (millions)	Construction Route Mileage
TUNNEL	$7,954	18	$25,443	39	$60,327 – $92,249	89 – 118
TRENCH	$1,471	7	$2,837	13	$3,211 – $8,475	14 – 43
AT-GRADE	$56	2	$1,323	45	$196 – $1,426	7 – 42
EMBANKMENT	$686	17	$2,077	53	$1,457 – $2,003	38 – 51
AERIAL	$821	7	$2,874	22	$2,200 – $5,581	17 – 43
MAJOR BRIDGE	$2,117	4	$1,093	2	$0 – $173	0 – 1
Subtotal	**$13,105**	**52**	**$35,648**	172	**$74,349 – $102,949**	**212 – 244**
Cost per Construction Route Mile	**$254**		**$207**		**$305 – $485**	

Source: NEC FUTURE team, 2015
Note: Direct costs only. Does not include allocated contingency, environmental Mitigation, or professional services costs. Columns may not add to the subtotal due to rounding.

Table 18: Cost of Alternative 1, 2, and 3: New York City to Boston – New Tracks by Construction Type

CONSTRUCTION TYPE	Alternative 1		Alternative 2		Alternative 3	
DESCRIPTION	Cost (millions)	Upgrade Route Mileage	Cost (millions)	Upgrade Route Mileage	Cost (millions)	Construction Route Mileage
ADDITIONAL TUNNEL TRACK	$1,972	5	$0	0	$0 – $1,972	0 – 5
ADDITIONAL TRENCH TRACK	$851	4	$0	0	$0 – $851	0 – 4
ADDITIONAL AT-GRADE TRACK	$431	19	$177	7	$146 – $431	8 – 19
ADDITIONAL EMBANKMENT TRACK	$246	11	$83	3	$196 – $246	9 – 11
ADDITIONAL AERIAL TRACK	$0	0	$433	4	$0	0
ADDITIONAL MAJOR BRIDGE TRACK	$0	0	$0	0	$0	0
FREIGHT TRACK UPGRADE	$0	0	$0	0	$0	0
CATENARY SYSTEM UPGRADE	$47	15	$47	15	$47	15
SIGNAL SYSTEM UPGRADE	$147	40	$194	53	$147	40
Subtotal	**$3,695**		**$934**		**$536 – $3,695**	

Source: NEC FUTURE team, 2015
Note: Direct costs only. Does not include allocated contingency, environmental mitigation, or professional services costs. Columns may not add to the subtotal due to rounding.

4. Conceptual Engineering Design Documentation

4.1 SOURCE DATA

The typical cross sections used for estimating purposes in this effort were developed using Amtrak Design standards and minimum clearance requirements for high-speed rail service. The typical cross sections used in the cost methodology of the Preliminary Alternatives were developed for the Amtrak NextGen HSR. With the addition of new details and the development of additional track configurations as part of NEC FUTURE, the FRA further refined and expanded these typical cross sections to accommodate multiple track configurations, and more-specific site conditions and construction methods.

Where specific information was not available, the FRA reached out to the CAHSR Program team for similar design parameters that could be used to generate sketches that could then be estimated and incorporated into the model.

The information available to assist in the cost estimating efforts described in this technical memorandum was limited to the following:

- Horizontal alignment and assumed vertical profile of the route centerline based upon existing aerial imagery
- Assumptions regarding special track work to be employed on the system (e.g., desired diverging move speeds on turnouts) and general interlocking layouts and locations
- Assumptions regarding general systems requirements for train control signal systems and communications
- Assumptions regarding traction power supply and catenary system requirements
- Assumed typical cross sections for the expected general infrastructure configurations
- Assumed typical layouts for stations
- General requirements for shops and yards based on the operating plan