

NY Penn Station Master Plan

WHITE PAPER

Through- Running

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wsp **fx**collaborative

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Through-Running

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Executive Summary

Penn Station currently operates at almost full capacity, and ridership is projected to increase at least 40% over the next 20 years. The Gateway Program, the Penn Station Master Plan study, the East River Tunnels Rehab, and other projects seek to address the need for increased resilience, rail capacity and passenger egress and circulation by:

1. Adding two more mainline tracks between Newark Penn Station and New York Penn Station;
2. Adding two new single-track tunnels under the Hudson River (the Hudson Tunnel project) and developing the full complement of Gateway Program infrastructure in New Jersey to deliver additional trans-Hudson capacity to New York;
3. Rehabilitating the two existing single-track tunnels under the Hudson River (the North River tunnels);
4. Rehabilitating the four existing single-track tunnels under the East River (track replacement in the 33rd Street tunnels and full tunnel rehabilitation in the 32nd Street tunnels);
5. Expanding Penn Station to add at least eight new tracks with new platforms and new concourses and entrances, potentially to the south of existing Penn Station (Penn Expansion); and
6. Reconstructing the existing station to better accommodate its growing population of users and integrate it architecturally and functionally with Moynihan Train Hall and the Penn Expansion (Penn Reconstruction).

Through-running could be another approach for increasing rail capacity at Penn Station. The station currently operates in a hybrid mode, under which some Amtrak trains run through the station between Boston and Washington, dropping off and picking up passengers (known as revenue-to-revenue through running), and some Long Island Rail Road (LIRR) and New Jersey Transit (NJT) trains drop off passengers then continue on through the station to storage in a yard (a form of through-running known as revenue-to-non-revenue). The majority of trains terminate at the station and then leave the station in the same direction from which they came (turning). Turning at the station causes conflicts when incoming and out-going trains have to cross paths, reducing the number of trains that can use the station during a given peak period (throughput). Through-running decreases these conflicts, potentially increasing the throughput of the station. A train running through a station generally needs less time at the platform (dwell time) than a turning train, also potentially increasing throughput.

The Penn Station Master Plan consultant team led by the Joint Venture of WSP and FX Collaborative, working with the three collaborating railroads (Amtrak, MTA and NJ Transit), has investigated the feasibility of implementing through-running at Penn Station to determine if it would be a viable alternative or complement to expanding the station.

Through-running at Penn Station could be as simple as trains arriving at Penn Station in revenue service, dropping off their passengers, then running through to storage yards on the opposite sides of the station. This is a mode of operation currently utilized by LIRR and NJT, especially during peak periods. Alternatively, through-running can be as complicated as a full suburb-to-suburb model, in which all trains run inbound on a branch line owned and operated by one railroad, drop off and pick up passengers at Penn Station, and then continue outbound on a branch line on the opposite side of the station owned and operated by a different railroad. The first depends largely on the configuration of the station tracks and platforms and the capacities of the supporting tracks, yards, and tunnels on each side of the station. The second depends on the same constraints, but also has vast implications for the various rail operators and their individual rail networks and markets well beyond the station. To address through-running comprehensively, we assessed costs, benefits, constraints, and technical challenges specific to Penn Station and its immediate supporting infrastructure, and the same issues and market implications more generally for the wider commuter rail networks.

We find that it is not feasible to convert to all through-running at Penn Station. Even with enormous investment, our analysis shows that converting to all through-running in any form would not increase the station's rail capacity nearly enough to meet projected future ridership demand, so expanding the station would still be necessary. The high cost, limited benefit, and difficulty of converting likewise makes through-running a poor candidate to supplement expanding the station.

The key to any through-running regime would be widening the existing narrow platforms that extend under both Penn Station and the newly-completed Moynihan Train Hall. This is necessary to allow passengers to simultaneously board and alight trains (which they cannot do now because the narrow platforms would be too crowded), thereby reducing dwell times and increasing throughput. However, Penn Station is uniquely ill-suited to making this conversion, for several reasons:

Four of the 21 existing tracks cannot be converted to through-running at all, because they do not connect to the interlockings at the east end of the station and cannot be extended to either the existing tunnels or new tunnels to the east due to property impacts and the deep elevation of the Sixth Avenue subway, nor can they be shifted to the west at reasonable cost to connect to the existing tunnels;

- The number of station tracks would have to be reduced by six to make room for the wider platforms, reducing throughput; and
- Some of the reduction in dwell time would be offset by the need to build-in extra dwelltime for trains arriving a few minutes late to still be able to leave in revenue service on schedule (recovery time). The required recovery time increases as the through-running network gets larger and travel distances become greater.
- The incremental increase in through-running train capacity per platform would tend to be offset by the overall loss of track capacity resulting from the reduction in the number of available tracks.

Through-running would also require structurally re-supporting and re-configuring the station buildings above. The service disruptions required to re-build the busiest train complex in North America would be massive and unprecedented, and commute times would lengthen dramatically. These disruptions and delays can be expected to generate fierce opposition from the riders of all three railroads and their advocacy organizations as well as elected officials in three states. Tearing apart and re-building the \$1.6 billion Moynihan Train Hall so soon after its completion likely would be seen by the public as a quintessential example of government malpractice.

The West Side and Sunnyside rail yards on either end of Penn Station do not have the capacity to store additional trains during peak periods, so new rail yards would be required further away from the station, beyond the Hudson and East Rivers. While the Hudson River Tunnel project will double the tunnel capacity under the Hudson River, additional

tunnels would have to be built east from the station to and under the East River to accommodate a large increase in through-running.

The cost to do this work, which we estimate would be in the range of \$40 to \$50 billion dollars, would be disproportionate to the limited benefits, and it could take as much as 15 or more years to design, fund and construct it all.

If the more complicated regional commuter integration approach were to be pursued as the through-running model, far greater investment, in the high tens of billions of dollars, would be required. The power, signal, communication, and dispatch systems and yards would all have to be modified or replaced to common standards, and the rolling stock of the railroads across the network would need to be modified or replaced to be compatible with the new common standards. Although there is potential demand for service to stations in the suburban counties with concentrations of employment, such as New Brunswick, Stamford or Mineola, the total magnitude of market demand for full suburb-to-suburb through running is limited, providing a very weak business case for full integration of the three regional railroads (LIRR, NJT and Metro North).

Although the full suburb-to-suburb regional through-running model is not commercially viable, a Regional Metro model could be, although it has not been analyzed in detail. In this model, transit-style service could operate on the inner portions of the regional rail network to currently under-served areas like the East Bronx, central and western Queens, west-of-Hudson counties and Bergen, Essex and Union counties in New Jersey. While similar technical and compatibility challenges would have to be overcome, this model could be run through the expanded portion of Penn Station if designed to better accommodate

through-running. Even this smaller vision would take many years to design, approve, fund, and construct.

Meanwhile, Penn Station is overcrowded, functions badly, provides a poor overall experience for the users of the station, and does not have the rail or concourse capacity to handle projected future ridership. There is an urgent need to improve Penn Station and increase its capacity, the drivers behind the Penn Station Master Plan study.

We conclude that the goals of the Master Plan study are best met through the following steps to address Penn Station's urgent needs and prepare the way for future through-running:

1. Expand the station to provide at least eight new tracks and at least four new platforms to increase station rail capacity, configured to permit through-running in the future if and when tunnels are built east to and under the East River;
2. Reconstruct the existing station to make it function far better, provide a much-improved environment for its hundreds of thousands of daily users and integrate Moynihan Train Hall, existing Penn Station, and the Penn Expansion (collectively known the Empire Station Complex) architecturally and functionally; and
3. Develop and integrate new service plans, customer information systems, and ticketing systems for the railroads that better meet the future needs of regional travelers and collectively allow the Empire Station Complex to operate as the central hub of a hub-and-spoke network that provides convenient and predictable transfers between branch lines.

Introduction

Converting Penn Station from its existing hybrid mode of operation for the Long Island Rail Road (LIRR) and NJTransit (NJT) to a station where all trains run through the station to storage, or the separate commuter operations are integrated, could increase the rail capacity of the station. In this white paper, we explore the concept of through-running at Penn Station including the potential benefits and required investments and decisions at the local and regional level. Although through-running has been successful at other stations in the U.S. and abroad, its application at Penn Station is complicated by many physical, operational, and institutional constraints that could limit its effectiveness and increase the costs. Operations at Penn Station also are integral to operations and rail service across the entire metropolitan region, and decisions about Penn Station have broad implications for regional rail planning and decision-making.

We begin this paper by defining through-running and summarizing existing railroad operations at Penn Station, which already include a significant amount of through-running. We then discuss the potential operational and ridership benefits of increased through-running, along with the significant constraints imposed by existing physical, operational, and institutional conditions. We first look at conditions within Penn Station itself, then at how Penn Station operations affect and are affected by facilities and operations beyond the station limits. We then consider potential travel market benefits and conclude with an assessment of the potential for through-running at Penn Expansion, the

extension of Penn Station, potentially to the south, currently in development. That addition of eight or more new tracks provides a greenfield opportunity to build a through-running station from the start and create a new rail thoroughfare through Manhattan.

We present the technical analysis to support the narrative in this paper in four appendices: local constraints at Penn Station itself ([Appendix A](#)), constraints on the regional rail network beyond the boundaries of the station complex ([Appendix B](#)), regional travel markets that would benefit from through-running service ([Appendix C](#)), and details on the Penn Expansion project ([Appendix D](#)).

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SECTION 1

Through-Running Overview

Turning vs. Through-Running

At a major rail station, trains can either change direction and return from where they originated (turning) or can continue on through the station (through-running).

At stub-end terminals such as Boston's South Station, for example, all trains turn at the platform. Depending on the configuration of a station's interlockings (the collection of track switches and signals that allow trains to be distributed between the mainline tracks and a larger number of station platform tracks), turning train movements can create conflicts where trains operating in opposite directions must cross each other's paths. These conflicts can cause train delays and limit the number of trains that enter or leave the station in a peak period (i.e., reduce throughput capacity). Turning conflicts also increase the time that a turning train must remain in the station waiting for clearance to exit (dwell time), further reducing the number of trains that can use the station tracks.

Through-running trains generally require shorter dwell times than turning trains, and they potentially can move more fluidly by replacing turning conflicts with less-severe, same-direction merging conflicts. Despite these operational advantages, however, an all through-running operation will not necessarily maximize throughput at a given station because of other considerations. Such is the case at Penn Station.

Train Movement Modes

Both turning and through-running trains at a major station handle passengers in one of three modes of operation ([Figure 1](#)). In revenue-to-revenue mode, trains arrive at a major station in revenue service (i.e., with passengers on-board), both dropping off and picking up passengers during the train's dwelltime, before departing from the station in revenue service.

In revenue-to-non-revenue mode, trains arrive with passengers who disembark at the station before the train departs without passengers (also referred to as "drop and go"). A revenue-to-non-revenue through-running train generally heads to a storage yard associated with the station terminal (such as an LIRR train heading to the West Side Yard, or an NJT train heading to Sunnyside Yard in Queens). These are also known as revenue-to-storage train movements. Turning trains also can be revenue-to-non-revenue, returning to an outlying yard for storage or sometimes to an outlying branch line terminal to make a second peak period trip. These non-revenue train movements are sometimes referred to as "deadhead" movements.

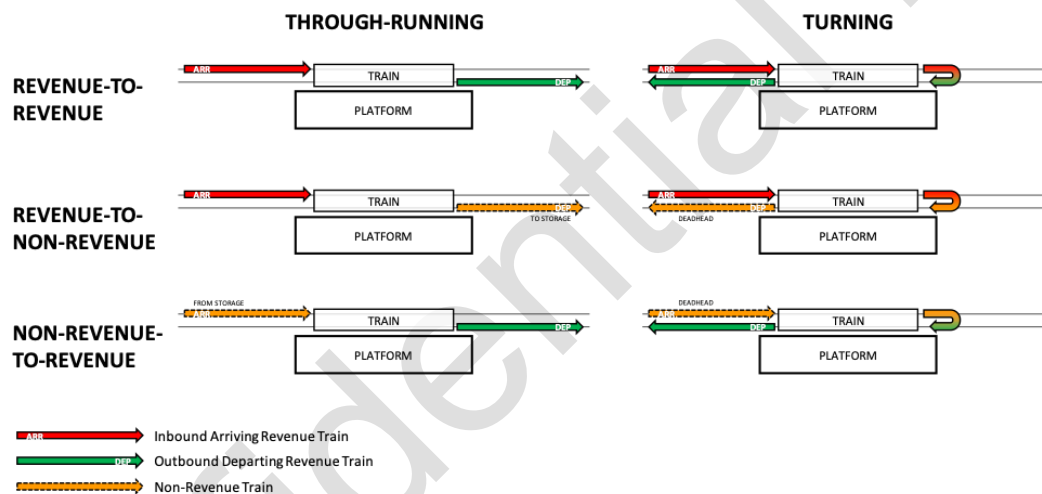
The third passenger-handling mode is non-revenue-to-revenue, where a train enters the station empty (from a storage yard or as a deadhead train), picks up boarding passengers at the station, and then departs as a revenue train.

These three passenger-handling modes require different dwell times at the station platform. Revenue-to-non-revenue movements generally have the shortest dwell times, and non-revenue-to-revenue trains generally occupy station platforms for a longer time period, allowing passengers to board over several minutes. Revenue-to-revenue dwell times for through-running can be relatively short provided that platforms are

able to safely accommodate alighting and boarding passengers simultaneously. Longer dwell times are needed when operating on a timetable, including allowances so that trains that arrive a few minutes late are still able to depart on time. Dwell times for turning revenue-to-revenue trains also must allow time for train crews to prepare the train for movement in the opposite direction of travel.

Figure 1

Train Operating Modes at Major Station



SECTION 2

Current Penn Station Rail Operations

Penn Station currently operates in a hybrid mode, with some trains turning back at the station and others running through the station. Almost all Amtrak trains servicing the Northeast Corridor already run through Penn Station in either revenue-to-revenue or revenue-to-non-revenue mode. LIRR and NJT operate both turning trains and through-running trains at Penn Station.¹

Roughly one-third of LIRR 6:00AM to 10:00AM peak period trains arriving at Penn Station from the east drop off all their passengers then continue through to the West Side Yard. A similar percentage of NJT morning peak period trains arriving from the west do the same thing but continue through to Sunnyside Yard. This type of operation requires the shortest station dwell times of all Penn Station operations and helps achieve maximum throughput during the critical peak hour. The afternoon peak operation is similar to the morning but in reverse with the percentage of non-revenue to revenue trains growing.

The balance of daily trains turn at the station, either running back in revenue service or deadheading back to outlying termini to either return again to Penn Station as part of the current, robust off-peak service provided or await the next peak period. This hybrid regime is currently optimized for the peak commuter demand between the suburbs and Manhattan,

fully using the infrastructure available during weekday peak periods. The railroads maximize capacity utilization in the peak 60-90 minutes by filling the terminal yards (using revenue-to-non-revenue through-running trains with relatively short dwell times). In the early hours of the peak, trains turn back to suburban locations for a second peak trip. In the latter part of the peak period, after the terminal yards (West Side and Sunnyside) are full, trains turn back as non-revenue trains for storage at outlying yards.

The highly-optimized operating plans for each railroad result in unbalanced service that responds to the unbalanced peak demand, with much more service in the peak direction of travel (inbound to Manhattan on weekday mornings and outbound from Manhattan on weekday evenings).

¹ The LIRR and NJT through-running trains are all revenue-to-storage or storage-to-revenue. The LIRR and NJT turning trains offer mostly revenue-to-revenue service, although there are some turns in the morning peak period that are revenue-to-non-revenue, and in the evening peak non-revenue-to-revenue.

SECTION 3

Through-Running Benefits and Constraints

Possible benefits of increasing the proportion of trains that run through the station include **operational efficiency** and **ridership demand**. We consider each rationale below, describing the extent of potential benefits and identifying the constraints that limit the magnitude of potential benefits.

We then provide context for benefits and constraints by identifying two through-running concepts:

1. Converting rail operations to all through-running, by fully integrating the three commuter rail systems (Suburb-to-Suburb service), and
2. Continuing the hybrid operation but increasing the proportion of trains operating in through-running mode by focusing on short-haul travel markets (Regional Metro service).

achievable and potentially more cost-effective than full integration. This concept also requires major investment and substantial changes

For the first concept, we start with a description of the track and platform configuration that would ideally support integrated rail service with all through-running. We then identify the specific conditions at Penn Station that prevent the ideal configuration and ideal operations and examine what it would take to achieve those ideal conditions. The difficulty, cost and impact of those changes render the ideal solution impractical and potentially infeasible. Less costly solutions that compromise some of the features of the ideal configuration would be easier to implement. The compromises, however, would affect the throughput capacity and performance of the concept, and those effects are documented.

The second through-running concept – Regional Metro – would not require the same magnitude of intervention at Penn Station or on the regional rail network but could deliver many of the benefits, so it would be more

Appendix A presents additional analysis of the constraints at Penn Station, and **Appendix B** analyzes constraints that exist in the full regional rail network.

Appendix C provides additional detail about the travel market characteristics of the two service concepts.

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Operational Efficiency

Making train operations more efficient at Penn Station would increase peak utilization of the station's throughput capacity or perhaps increase its capacity. It also could improve reliability and reduce delays. Converting from turning to through-running would reduce:

- Platform dwell times
- The number of conflicting train movements at the station interlockings

Generally, proponents believe that through-running will achieve higher throughput capacity. Converting revenue-to-revenue and revenue-to-non-revenue trains from turning to through-running can shorten average dwell times and smooth train flows, and converting pairs of revenue-to-non-revenue trains into through-running revenue-to-revenue trains potentially can reduce the number of overall non-revenue movements. However, we find that physical and operational conditions at Penn Station limit the extent of any potential capacity increase, limiting its effectiveness or requiring massive capital investment.

XXX Add paragraph on new analysis

Local constraints within the Penn Station terminal include:

1. The lack of room in the West Side and Sunnyside Yards to store additional trains, which limits the ability to easily increase revenue-to-storage train movements;
2. The throughput capacity within the North River and East River Tunnels, which limits throughput capacity in Penn Station; and
3. The narrow widths of the existing station platforms, which limit passenger-handling capacity and result in longer dwell times and lower utilization of platform track capacity.

Regional constraints include:

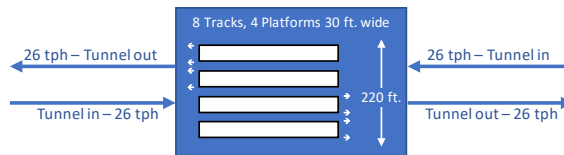
1. The existing commuter rail network infrastructure, which limits the ability to deliver a significantly greater number of trains to and from Penn Station; and
2. The relatively small number of people traveling from the suburbs on one side of the region to the other, which limits market potential and results in a weak and speculative business case for investment in regional revenue-to-revenue through-running.

All these constraints would have to be addressed to significantly increase train throughput at Penn Station, convert to all through-running, and fully realize travel market benefits.

Idealized Through-Running

Typical two-track system

The ideal station configuration for a pair of tunnel tracks set up for through-running service would provide station platform track capacity that matches or exceeds the capacity of the tunnels feeding the station. The configuration shown below would accomplish that at Penn Station, with two island platforms and four tracks for each direction of travel. This station would have a total of 8 tracks and four platforms at least 30 feet wide.



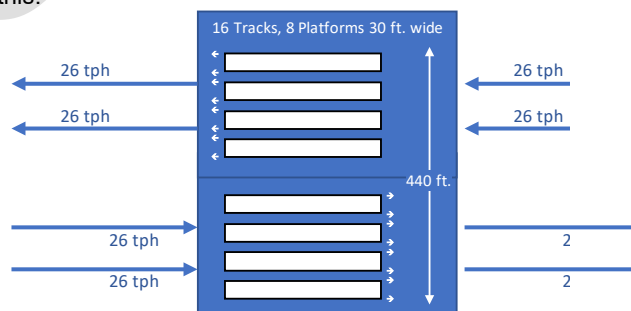
Assuming a maximum practical tunnel capacity of approximately 26 trains per hour (tph), the tunnels would deliver trains at a peak headway averaging 2.3 minutes. Each platform track would be able to serve a train every 8 minutes, providing a peak throughput of 7.5 tph per track. Average dwell times would need to be on the order of 5 to 6 minutes.

The practical capacity of this station would be 30 tph, which exceeds the practical tunnel capacity. Each platform and pair of tracks would occupy approximately 55 ft. of station width, so the full 4-platform station would require a site 220 ft. wide. This station would

Right-hand running system with four tunnel tracks feeding each side of the station

Once the new Hudson River tunnel is built, Penn Station will be served by two pairs of tunnel tracks beneath both the Hudson and East Rivers. The idea

Right-hand running operations would be desirable, to minimize train movement conflicts and maximize operational flexibility for train dispatchers to assign trains to platform tracks in a way that keeps the flow of trains moving. The ideal configuration would look something like this:

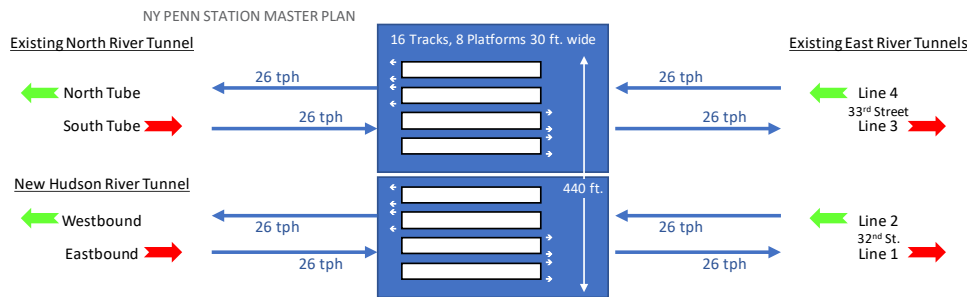


The station would have 8 30-ft. wide platforms and 16 tracks. The double pair of tunnels would be able to deliver 52 tph in each direction. The station maximum capacity would be 60 tph in each direction. A site approximately 440 ft. wide would be required.

Future Penn Station system with two side-by-side systems

The existing track configuration doesn't support right-hand running through the East River Tunnels, however. The tunnels under both 33rd St. and 32nd St. each have one track in each direction. As the four tunnel tubes cross the East River and enter Queens, the eastbound 33rd Street tunnel passes beneath the westbound 32nd Street tunnel, resulting in a track configuration through the Harold Interlocking complex in the Sunnyside area of Queens that has right-hand running. The track connections to Sunnyside Yard, to the LIRR Main Line and Port Washington Branch, to the Hell Gate Line and the LIRR's East Side Access connections to Grand Central Terminal are all highly customized for the existing track usage patterns and cannot be changed at reasonable cost. Realigning the East River Tunnels would require new tunnel segments with different vertical and horizontal alignments extending beneath the East River. If feasible, this would be an enormously costly and disruptive undertaking. Therefore, changing Penn Station to all right-hand running is not considered to be practical or cost-effective.

Consequently, the idealized Penn Station with full through-running would need to operate as two side-by-side systems, each with 8 tracks and 4 wide platforms, as shown in the following figure. The overall tunnel capacity would be 52 tph in each direction, and a total station width of 440 ft. would be required to accommodate the 16 tracks and 8 platforms.



Constraints on Through-Running at Penn Station

Platforms 1 and 2 at Existing Penn Station do not support through-running

Platforms 1 and 2, serving Tracks 1-4, are not suitable for through-running service. The remainder of the station area can theoretically accommodate 8 wide platforms, if rebuilt.

These tracks cannot be connected to the existing tunnels the east, since the connection would require extensive property taking – namely at 11 Penn Plaza on the east side of 7th Avenue between 31st and 32nd Streets. These tracks also cannot be extended eastward in a new 31st Street tunnel, because a new tunnel would not be able to descend quickly enough at an acceptable grade to pass beneath the 6th Avenue Subway. Similarly, the platforms cannot be extended west beneath the Manhattan West towers without having to re-frame and support these brand new structures.

Platform Widening

The least expensive option for widening platforms would be to cover over every second track, as has been proposed by some advocates of through-running. This would be possible at a relatively low capital cost, but it would reduce the number of station tracks below what would be needed to meet the throughput coming from the tunnels.

This approach would reduce the number of potential through-running platform tracks from 17 to 10, less than the 16 required for full capacity. To achieve the same throughput as the idealized case, train dwell times would need to be reduced by two minutes. Shorter dwell times would not be workable for Amtrak intercity trains, which need time built into their schedules for train servicing and schedule recovery. This also would reduce the overall ability of the railroad to recover from delays and would negatively impact reliability.

A more capital-intensive and disruptive solution could theoretically provide eight platforms, each approximately 29 ft. wide. Tracks 6-20 and all station platforms would need to be reconfigured, and re-framing of Madison Square Garden, the 8th Ave. Subway and the Moynihan Station building would be needed.

Track Connections West of Penn Station

The existing track configuration on west side of Penn Station doesn't support smooth parallel train flows between the tunnels and platform tracks. New crossovers and ladder tracks would be needed to enable parallel train movements, and these crossovers and tracks would be difficult to fit within the existing overall configuration of

tracks, switches and support structures for buildings and streets above the railroad. Where crossovers do exist to support parallel train movements, these movements are possible only at slow speeds, which would reduce overall throughput capacity.

Retaining LIRR access to West Side Yard would introduce train movement conflicts. Also, trains accessing the Empire Connection tunnel and the existing stub-ended station tracks 1-4 would introduce train movement conflicts that would reduce capacity.

Improving Penn Station's track and platform configuration would require major reconstruction, including major changes to recently-constructed improvements (such as Moynihan Station). These changes would be very disruptive to operations during construction and extremely costly.

Capital investment would entail:

- Tracks 6-20 and all platforms reconfigured; re-framing of Madison Square Garden, 8th Ave. Subway and Moynihan Station
- Extensive re-framing of structure supporting development above the tracks, e.g., Moynihan Station and Manhattan West
- The 'I' and 'G' ladder tracks would need to be reconfigured for parallel train movements
- Tracks 6-20 and all platforms reconfigured; re-framing of Madison Square Garden, 8th Ave. Subway and Moynihan Station

The estimated total capital cost for these station and track connection improvements at Penn Station is in the range of \$10 to \$15 billion.

This concept would entail extensive operational impacts, long construction duration and very high cost, so it is considered impractical as a solution.

Local Penn Station Constraints

Increasing Revenue-to-Storage Through-Running

Increasing the current revenue-to-storage through-running in Penn Station requires more room for mid-day storage of trains. The West Side Yard and Sunnyside Yards are currently maxed-out, so additional yard space would have to be found, either by expanding the existing yards, sending trains to other existing yards farther out, or building new yards.

Given the rapid redevelopment of the far west side of Manhattan, there is effectively no opportunity to significantly expand the West Side Yard. LIRR trains therefore would have to be routed into New Jersey for storage at an existing or new yard. Even if a new yard could be provided in New Jersey, the two existing single-track North River Tunnels and their two-track approaches do not have the throughput capacity to accommodate substantively more trains moving to and from yard storage.

The situation is similar for the Sunnyside Yard. Even if the yard could be expanded or yards farther out could be used, the approach tunnels from Penn Station to the East River and the East River Tunnels do not have the throughput capacity to accommodate more trains moving to and from storage in Sunnyside Yard or elsewhere.

It is theoretically possible to increase the throughput capacity of the existing tunnels by replacing the signal and control systems to permit shorter gaps between trains (headways). We estimate that this could increase capacity by about 10%, far less than necessary to accommodate the projected ridership growth, so converting to all through-running in this mode does not meet future needs by itself. Therefore, both new and/or expanded yards and new tunnels and approaches under both rivers still would be required.

A further complication with the concept of increasing revenue-to-storage through running is the current practice by both LIRR and NJT of turning trains at Penn Station through the early and middle portions of the AM peak

period to head back to suburban origin points in order to make a second peak direction trip back into New York. Converting these trips to revenue-to-storage through running would have implications for the size of the rolling stock fleet required as well as train crew operating costs.

Introducing Revenue-to-Revenue Through-Running

All through-running in revenue-to-revenue mode is not achievable at Penn Station in its existing configuration because of narrow station platforms and limited vertical circulation, which cannot accommodate simultaneous boarding and alighting. This forces the railroads to hold back boarding passengers from the platform until alighting passengers clear the platform and stairs. The longer time to alight and board passengers contributes to longer dwell times, reducing the number of trains that can enter and leave the station in a peak period. Further, four of the southernmost platform tracks used by NJT connect only to the interlockings on the west approach to the station (stub tracks). Connecting these stub tracks to the east interlocking is geometrically so difficult it would entail a disproportionate cost. Thus, it is not feasible to convert all tracks to through-running, reducing the efficacy of this approach. Previous studies² calculated that an all through-running regime in existing Penn Station would actually reduce peak-period throughput (up to 17% if confined to converting revenue-to-non-revenue trains), not increase it. This disadvantage is in addition to the same challenges to increasing the revenue-to-non-revenue operations presented by the lack of additional tunnel and approach throughput capacities at both rivers.

Reconfiguring Penn Station for All Revenue-to-Revenue Through-Running

The platforms would have to be widened, nominally from 20 feet to 30 feet, to allow for simultaneous boarding and alighting to reduce passenger handling times (except for platform 10, which is already wide enough). Widening the platforms this way would decrease the passenger handling

² Including the white paper by Amtrak, "Analyzing the Potential for Commuter Train Run-Through Service at New York Penn Station," August 2014.

times appreciably and permit dwell times to be reduced, allowing more trains to use each platform track and increasing peak period throughput.

However, a second factor in dwell times is a time cushion to account for delays in station arrival due to the normal variations from schedule in everyday operation. Several minutes of such schedule recovery time is needed due to the length and complexity of the rail network feeding Penn Station. The number of commuter rail lines feeding Penn Station will grow to 20 once various projects in planning or construction are completed. Converting revenue-to-storage trains into revenue-to-revenue trains increases the need for schedule recovery time. Paradoxically, this tends to offset the reduction in passenger-handling time.

Three platforms and their associated six tracks would have to be eliminated to make room for eight, 30-foot-wide platforms, reducing the number of available tracks by almost 30%. This would largely offset the capacity advantage from reduced passenger-handling times, shorter dwell times, and increased throughput on the reconfigured platform tracks. The result is estimated to be a very small net change in throughput capacity. We find that the net increase in throughput would not be enough to accommodate projected future increases in ridership. Given that tunnel throughput currently is the ultimate limiting factor in throughput at Penn Station, even the net increase in throughput from widening the platforms could not be achieved without new tunnels. Implementing all revenue-to-revenue through-running would therefore require both a major reconfiguration of the station and new tunnels for existing Penn Station. Even after these large investments, an expansion of Penn Station (with its associated new tunnels) would still be necessary to accommodate projected future demand, the very circumstance that the proposals to convert to all through-running intend to avoid.

Alternatively, only the middle platforms could be widened. The estimated capital cost to completely reconstruct just the middle zone of the Platform Level is approximately \$3 billion, for an estimated increase in peak capacity in the range of 10% (or 2 trains per hour in each direction), an investment of \$1.5 billion for each additional peak-period train. It is possible to handle this increase in the tunnels by improved signaling so that new tunnels would not be required, but the increase in capacity is small, the unit cost of new trains is eye-popping, and an expansion of Penn Station would still be required.

More importantly, such a major platform and track reconfiguration in the train shed below both Moynihan Train Hall and existing Penn Station would require construction on a scale never before attempted at a major commuter station in the United States, let alone at the highest-volume station in North America. Reconfiguring the existing platforms, tracks and interlockings and underpinning and re-supporting the subways and buildings above them would require taking several tracks and platforms out of service simultaneously for extended periods on a rolling basis, over multiple years. This would entail massive disruptions in service and correspondingly longer commute times unless additional train capacity were available first from an expansion of the station or a supplementary station nearby. Service disruptions on this scale likely would generate fierce opposition from the riders of all three railroads and their advocacy organizations as well as elected officials in three states. Again paradoxically, mitigating the massive disruptions associated with converting to all through-running becomes a persuasive argument for the Penn Expansion, the very investment that the proposals for all through-running intend to eliminate.

Regional Rail Network Constraints

Even with enormous capital investments within Penn Station and the river tunnels to configure them for high-density through-running, the regional rail system as currently designed, operated, and managed could not accommodate it. All potential through-service patterns would have significant operational impacts on the entire regional rail network and face challenges in institutional framework and governance, labor agreements, and cost- and revenue-sharing agreements. All would require investment in railroad infrastructure and fleet beyond the limits of the Penn Station complex, including increased line capacity, elimination of network choke points such as at-grade junctions, yard expansion/improvements, power- and signal-system modifications, electrification of non-electrified lines, and use of dual-power or dual-mode rolling stock able

to operate over routes with different traction power systems or no electrification. Achieving full network interoperability and adding sufficient main line and yard capacity would be difficult under any through-running strategy.

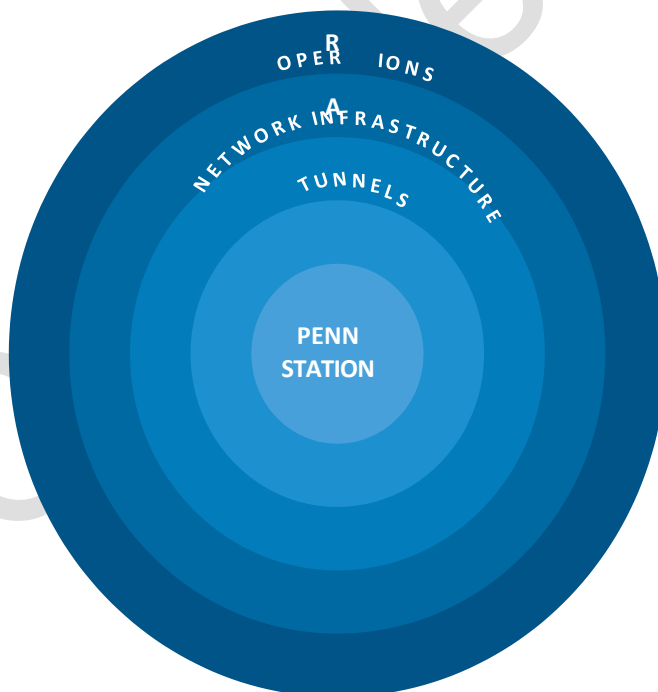
Implementing the changes needed to support service integration with through-running requires commitment to a major long-term region-wide capital initiative. The estimated capital cost for full integration of the regional rail network is expected to be in the range of \$40 to \$50 billion, including investments at Penn Station.

The following graphic shows the existing disparate systems and interoperability constraints that affect system capacity and impede through-running at Penn Station.

[Appendix B](#) provides additional detail on the network infrastructure constraints.

Figure 2

Train Operating Modes at Major Station



arket

- Compatibility of passenger demand, service levels, and maximum train lengths between branches on opposite sides of Penn Station

Rail Service Patterns

- Extent of service integration
- Timetable-based versus headway-based service
- Peak and reverse-peak imbalance

Operations

- Labor agreements
- Train crew availability and training
- Institutional and governance framework

Network Infrastructure

- Track capacity on trunk lines
- Traction power infrastructure
- Signaling system and PTC
- Rolling stock interoperability
- Storage yard and maintenance facility capacity

Tunnels

- Tunnel capacity drives system throughput capacity

Penn Station

- Platform lengths and heights

- Dwell times

Confidential Draft

Ridership Demand

Demand for rail travel to and from Penn Station is projected to increase substantially over the next two decades. The station will remain the primary gateway to the Manhattan central business district (CBD) for commuters from New Jersey and Long Island. The completion of the LIRR's East Side Access project will divert a significant number of existing LIRR riders to Grand Central Terminal. However, improved LIRR service in Queens is expected to attract new LIRR commuters to Penn Station, and Metro-North will introduce direct New Haven Line service to Penn Station as part of the Penn Station Access project, resulting in a net increase in peak riders through the East River Tunnels. Trans-Hudson commuting by rail has been constrained by the limited capacity available in the existing North River Tunnels. The expected construction of new Hudson River Tunnels will more than double NJT's peak capacity. Amtrak is replacing its Acela fleet with higher-capacity trains and plans to double its Acela train frequency during peak periods. Continued redevelopment of the far west side of Midtown Manhattan and the district surrounding Penn Station is projected to generate trips by rail from across the region. Overall rail passenger traffic at Penn Station in the weekday morning peak hour is estimated to increase from 65,000 in 2019 to 120,000 by 2038.

The COVID-19 pandemic has greatly reduced demand for rail travel in 2020 everywhere in the United States, including at Penn Station. The pace and extent to which rail travel demand will recover and resume its growth is uncertain, but Penn Station will continue to be a critical node in the region's transportation network, and plans for the passenger rail system must provide the capacity to accommodate potential regional population and employment growth over the long term.

Adjustments to operating practices at the existing station, such as increasing the proportion of through-running trains, could yield incremental increases in throughput capacity. However, the station must be expanded to fully meet future demand.

Through-running, by itself, offers potential benefits but cannot generate sufficient peak throughput capacity within the existing station. It can only play a part in a future solution that also increases station capacity and addresses

constraints that exist at Penn Station itself and elsewhere on the regional rail network.

Through-running at Penn Station has the potential to attract additional rail ridership by providing direct one-seat-ride service through Manhattan between the service territories of NJT and either LIRR or the MNR New Haven Line. To understand the business case for the level of capital investment needed, we examined two revenue-to-revenue through-running scenarios that focus on different ridership markets and have different operational and capital investment requirements: Suburb-to-Suburb and Regional Metro. As already stated, any such plan would require regional agreement and political and public support, which we are still far away from, so the following discussion remains speculative. It also assumes the widening of the platforms at Penn Station that would be used by the through-running trains, which would be needed to keep dwell times reasonably short for passengers remaining onboard trains running through Penn Station.

[Appendix C](#) provides additional information on market analysis.

Suburb-to-Suburb: Full System Integration with All Through-Running

If the commuter rail systems were merged and existing patterns of service retained, through-running service would connect suburban branch lines in New Jersey with other suburban branch lines on Long Island or the Metro-North New Haven Line. The resulting service would be timetable-based, with specified train arrival and departure times at Penn Station. Although this is what many people automatically assume as through-running service, it does not represent the only vision for through-running. The suburb-to-suburb ridership market is currently limited, and the costs to serve it with direct trains are high, which makes the business case for full integration of the entire Tri-State Region rail network weak.

Suburb-to-suburb through-running is predicated on the assumption that there is demand for travel to employment and business centers of similar size on both sides of Penn Station that can attract significant

numbers of trips from the entire metropolitan region, or a realistic expectation that such demand will develop in the foreseeable future. Reverse-commute demand on today's commuter rail network is very small relative to the core market of commuting from the suburbs to Manhattan.

Over the past decade or more, the reverse-commute and off-peak markets have been growing faster than rush hour commuting to the CBD, and promoting the use of transit for these trips is considered important locally and regionally. The success of the MNR New Haven Line in attracting trips from New York City to Stamford has been a model that LIRR is building upon. An important impetus for the LIRR Expansion project, which is adding a third Main Line track, has been to enable reverse-commute service that is not provided today due to capacity constraints. Most of the ridership benefits of reverse-commute service can be achieved by providing service from Penn Station and the NYC outer boroughs and NJ inner counties, such as:

- Manhattan and Queens to Long Island
- Manhattan, western Queens and the East Bronx to New Rochelle and Stamford
- Manhattan and Newark to points in New Jersey beyond Newark

Linking up the commuter rail services to extend the market for reverse-commuting to suburb-to-suburb commuting would not significantly increase the size of these markets, although rail could probably attract a relatively high share of these long commute trips, because driving through the urban core at rush hour is stressful and time-consuming. The incremental ridership benefits of through-running in the broader market for reverse-commuting to the suburbs, however, is still marginal.

Full integration of the suburban rail networks would result in many routes in the range of 100 to 150 miles long, requiring relatively long schedule recovery dwell times at Penn Station. The benefits of connecting the extremities of these routes would be very small, however, because the number of people making these long commute trips is small. Total daily work trips from the NJ

counties served by rail to Nassau and Suffolk counties on Long Island is only about 3,000 in each direction (compared with about 300,000 trips from the same origins to Manhattan).

Merging the commuter railroads together for the sake of connecting the suburbs of either side of New York City with each other via through-running trains, therefore, is a weak rationale for converting Penn Station to all through-running service. Transforming Penn Station into an attractive and convenient transfer hub would be far more productive and cost-effective.

Regional Metro: Partial System Integration

As a counterpoint to full integration linking the suburbs with each other, Regional Metro could provide a better way to conceive of through-running, as part of a longer term hybrid concept that is market-responsive and built on future regional rail capacity investments.

The Regional Metro concept would provide a transit-style service that operates on the inner portions of the regional rail network and augments the capacity of the rail transit system (subway and PATH). This approach would be built around new and augmented peak-hour service and more frequent mid-day service to under-served urban areas and higher density suburbs close to the Manhattan CBD that appear more able to support rail transit, including central and eastern Queens; the East Bronx; west-of-Hudson counties; and Bergen, Essex, and Union counties in New Jersey.

Regional Metro would not replace all suburban commuter trains, just the local service on the inner portion of the network, plus selected short-haul branch lines. Suburban commuter service would need to be provided in parallel to regional metro, operating on the express tracks where trunk links have more than two tracks. Some portions of the existing rail network could support Regional Metro and suburban commuter service in parallel. Other portions of the network would require capital investments to provide sufficient track capacity and eliminate points of conflict in the existing network. Introducing Regional Metro service would require a major reconfiguration of the rail network, affecting the service and operations of the entire system.

Several international cities have implemented some version of a Regional Metro system, including London (the Crossrail and Thameslink networks), Paris (the RER B & D Lines), Madrid (Cercanías), Sydney (construction of a new metro line through the city center with conversion of selected suburban corridors from commuter rail to metro) and Zurich, Munich and Berlin (S-Bahn). Each of these international cities have long histories of public rail transit and active government and popular support. An important lesson from these examples is that they all have networks that distribute passengers at multiple stations in their CBDs. The regional system being developed for Toronto, known as GO-RER, probably is the most comparable to the New York region, where multiple regional branch lines converge on a single major hub station in the CBD, served by subway lines that distribute trips within the business district. The region was able to develop a compelling business case for shifting traditional commuter rail to through-running regional rail. Current plans for integrated regional rail in southern California also focus on a single major CBD transit hub at Los Angeles Union Station, which is in the process of being reconfigured for through-running. So, although some evidence shows that a regional system with a large central hub can be workable, there also is evidence that expanding the rail trip destinations to include areas surrounding other close-in stations along the line is an important element that helps make regional metro successful.

Regional Metro would be an entirely new service concept for the New York area railroads and entail a reworking of the entire regional operating plan to add new seat capacity to avoid displacing existing commuters. It would face the same interoperability and infrastructure challenges and investments as Suburb-to-Suburb through-running. Major changes to existing institutional and labor arrangements (27 unions across the railroads including MNR when it comes into Penn Station) would be needed to create through-running Regional Metro routes that eliminate train crew changes at Penn Station. Benefits of this concept could include bringing metro-style service to underserved areas, providing high-quality service to a potentially large travel market (a share of 400,000 daily work trips crossing county boundaries within the urban core and inner suburbs), and providing relief for overcrowded parallel transit corridors. Regional Metro would be one of multiple alternatives for expanding regional transit capacity, such as construction of new subway lines. Further analysis would be required to understand the relative cost-effectiveness of the alternatives.

Penn Expansion

The Penn Expansion project proposes the addition of eight or more new tracks in the block immediately south of Penn Station (between 7th and 8th Avenues and 31st and 30th Streets). The track configuration for Penn Expansion is still under development, as is the sizing and configuration of platforms and vertical circulation elements (VCEs). It would be possible to design the Penn Expansion to support efficient future through-running service, even if the new tracks initially are only connected to the west to the existing North River Tunnels and new Hudson River Tunnels. The design could support the future development of new tunnel tracks to the east of the station, potentially extending under the East River to Queens.

To support future through-running, the Penn Expansion would need to incorporate the following elements into its design:

- A minimum of four tracks and two island platforms configured for through-running;
- Platforms at least 30 feet wide, to accommodate high-capacity VCEs and enable boarding passengers to wait on the platform while arriving passengers exit the train; and
- Tracks and platforms at an elevation sufficiently deep to ensure a feasible future track connection to the east beneath the 6th Avenue subway.

Pre-staging of boarding passengers on the platform would minimize train dwell times. If future service patterns use transit-style through-running based on headways rather than discrete timetables, significant recovery time would not need to be built into schedules at Penn Station, further reducing dwell times. Through service would reduce or eliminate the need for crossing train movements, improving service reliability and maximizing throughput capacity utilization.

The Penn Expansion alternatives under consideration as part of the Penn Station Master Plan incorporate all three elements listed above. This configuration of tracks and platforms at the Penn Expansion would work well – both as an interim stub-end terminal and ultimately as a station for high-density through-running service – as part of a regional vision for rail that addresses the interoperability and institutional issues associated with through-running revenue trains. The planned facilities at Penn Expansion could support Regional Metro service, which essentially was the concept put forward by RPA in its Fourth Regional Plan. [Appendix D](#) provides additional information about operational assumptions for Penn Expansion.

SECTION 4

Conclusions

Although through-running as a concept has merit, it

is not a practical solution for Penn Station in the short term. Its ridership and operational benefits would be fully achievable only with major investment and a commitment to fundamentally

change how rail service is operated in the region. Therefore, through-running is not a low-cost and quick-win solution for achieving transformational benefits. The versions of through-running service that are possible at reasonable cost cannot deliver the station capacity that will be needed to match the throughput

of trains that are planned for the tunnels crossing the Hudson and East Rivers by 2030. Only the expansion of Penn Station can provide capacity sufficient to enable the planned new Hudson River tunnel to be fully-utilized.

Through-running rail service at Penn Station has potential to help expand ridership markets and help deliver rail service more efficiently, as has been the case in regions that have successfully implemented such service. However, the existing rail and station infrastructure, rolling stock fleet and institutional and governance framework in the NY-NJ-CT region are not well-suited to the efficient delivery of through-running service. The business case in favor of investing in through-running would need to identify ridership and operational benefits that justify the high cost of implementation.

Its potential ridership benefits would be marginal if all it does is connect existing trains with each other. Greater ridership benefits would be possible only with major changes to the types and patterns of rail service offered in the region, which would require major prior investment in infrastructure capacity and the rolling stock fleet across the regional rail network – not just at Penn Station. Such a program would take many years to implement and require commitment from the various sponsors of rail service in the region that doesn't currently exist.

Its potential operational benefits are constrained by Penn Station's narrow platforms, the specific track connections that exist on both sides of the station, and the structures that have been built to support development above and adjacent to the railroad right-of-way. Modifying the platforms, track connections and structural elements to provide a station that can deliver through-running service at volumes that match the throughput capacity of the tunnels would be extremely costly, take a long time to implement, and negatively impact operations during construction.

The implications of through-running extend well beyond the limits of Penn Station itself. A decision to implement a certain type and amount of through-running at the station affects how the entire regional rail network operates, entails tradeoffs at the scale of the full network, and requires broad agreement on a long-range future vision for rail service in the region. The regional rail network has evolved over the past century based on independent actions by separate original railroads which are now controlled by separate states with distinct transportation priorities. The separate systems overlap at Penn Station, but they are currently incompatible beyond the boundaries of the station complex and associated yards. Running a train from the LIRR system to the NJT system, for example, is not simply a matter of adjusting where the train goes. It actually would require changing virtually all aspects of how the railroad operates.

Full integration with Suburb-to-Suburb service offers a weak business case. The size of the existing suburb-to-suburb travel markets in the region is very small, just 10% of the size of the county-to-county automobile commuter markets to the core of the urban area.

Regional Metro that offers transit-style service on the inner portions of the regional rail network, providing service in underserved urban areas is better suited to provide tangible benefits to the region, offering a stronger business case. However, this concept would still require substantial infrastructure investment and major changes to existing institutional and labor arrangements.

For the Regional Metro concept to succeed, consensus must be reached first by all parties — agencies, state and local governments, and unions — on the future vision for regional rail service. The dire need to address the deficiencies of Penn Station cannot wait for such a consensus to emerge, if it ever does. However, the Penn Expansion can provide a solid foundation for through-running, paving the way for the future.

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Appendix A

Local Penn Station

Operational and Infrastructure Constraints

Train Movements

Penn Station is currently configured with 11 platforms, 21 (platform) tracks, and four interlockings. [Figure A-1](#) presents a schematic of the Penn Station terminal complex, including the tracks, platforms, interlockings (switches and track connections) on both ends of the station, existing tunnel tracks connecting to Penn Station, and the principal yards connected to the station.

Two interlockings (C & JO) are used to route trains to and from the four East River Tunnel tracks while a third interlocking (A) routes trains to and from the two North River Tunnels. 'A' and 'KN' interlockings on the west side of Penn Station distribute the two

North River Tunnel tracks and LIRR West Side Yard to the 21 platform tracks. In this configuration, turning conflicts on the west side can have a significant impact on throughput (when parallel routing is not available). On the eastside, two interlockings each connect two of the four East River Tunnel tracks to only 17 of the 21 platform tracks (platform tracks 1–4 do not connect to the east). In this configuration, turning conflicts on the east side have less of an impact on throughput but frequent crossing conflicts at one of the interlockings for any type of train operation that is inherent in the design of the interlocking limits total throughput in the PM Peak.

Figure A-1

Schematic Diagram of Penn Station

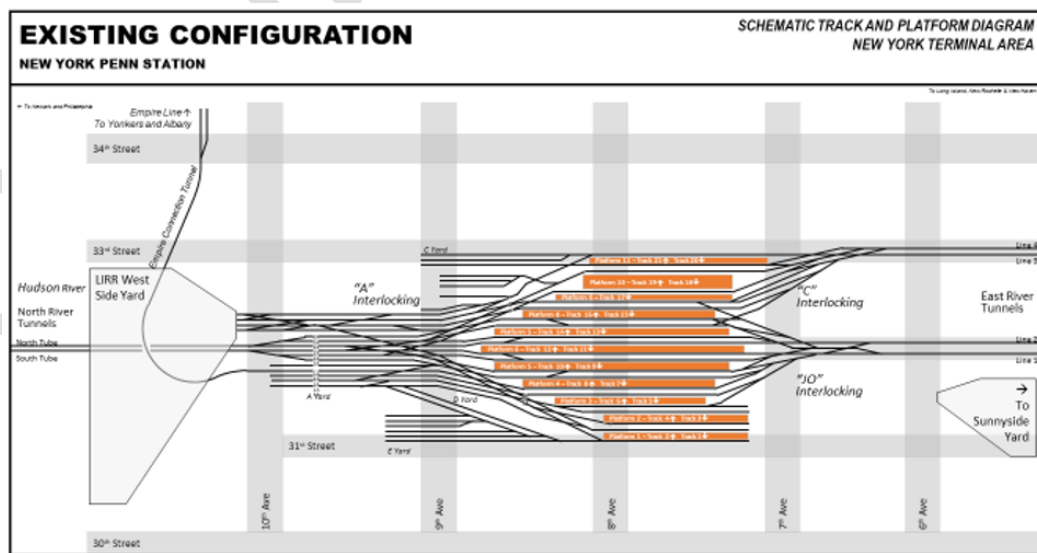


Table A-2**Current Train Movements in the Peak Hour at Penn Station**

Railroad	AM Peak	PM Peak
LIRR	• 64 LIRR trains arriving from Nassau and Suffolk counties and Queens turnaround in Penn Station • 36 trains “run-through” to West Side Yard for mid-day storage where they are serviced and made ready for a later return trip • 28 trains reverse direction in the station	• 89 LIRR trains depart Penn Station • 35 trains run-through from West Side Yard • 54 trains reverse direction in the station
NJT	• 39 NJT trains arriving from New Jersey reverse direction in Penn Station • 21 trains “run-through” to Sunnyside Yard for mid-day storage, servicing, and staging for the PM Peak service period	• 55 NJT trains depart Penn Station • 19 trains run through from Sunnyside Yard • 36 trains reverse direction
Amtrak	• 28 Amtrak trains operate through Penn Station including Northeast Corridor, Empire Corridor and Long-Haul inter-city services • All trains run through Penn Station, either as revenue trains or to and from Sunnyside Yard	• 31 Amtrak trains operate through Penn Station including Northeast Corridor, Empire Corridor and Long-Haul inter-city services. • All trains run through Penn Station, either as revenue trains or to and from Sunnyside Yard
Note: The majority of trains that reverse direction occur early or late in the peak periods when total train volumes are less than the Peak Hour. Reversing in the station allows more efficient use of train equipment instead of committing them to longer run times to/from the respective yards.		

In summary, about 193 commuter trains turn around in Penn Station during the combined Peak service periods, and 111 commuter trains run-through to West Side or Sunnyside Yards. Except for two short midday trains, all Amtrak inter-city service runs through Penn Station. Since the existing yards are at their practical capacity, any major increase in the proportion of revenue-to-storage through running commuter trains within the existing operating plan framework would require major expansion of yard capacity at or near Penn Station.

Station Platforms and Platform Tracks

The station's platforms and tracks are numbered from south to north. Tracks 1 through 4 (accessed via Platforms 1 and 2) on the south side of the station are stub-ended on the east end of the station at Seventh Avenue so they provide service only to and from the west (NJT). The remaining tracks 5 through 21 are through tracks with connections at both ends. Platform widths vary, with eight of the 11 platforms in the range of 19-20 feet wide. Platform 6 is the narrowest, at 17 feet, while Platform 1 is slightly wider, at 22 feet. Platform 10 is the widest platform, used exclusively by LIRR and nominally 38 feet wide.

The Penn Station master plan is proposing additional platform vertical circulation elements (VCEs), including stairs, escalators, and elevators, which will reduce the time needed to clear station platforms of alighting passengers following train arrivals to the range of 2-3 minutes during normal peak periods.

Existing Penn Station platforms are too narrow to allow boarding passengers down to the platform prior to the arrival of the incoming train. Constraints imposed by the existing narrow platforms include:

- Long dwell times for through-running trains—driven by lack of reservoir capacity for passengers at platform level, precluding boarding passengers from waiting at the platform in advance of a train's arrival and requiring them to wait within the concourses until all alighting passengers have cleared the platform. This extra time required is a critical component of the overall dwell time.
- Longer and more stressful boarding queues at concourse gates—boarding process begins right before train departure, maximizing the number of passengers in the queue and adding to passenger stress and uncertainty.

Figure A-3

Existing Tracks and Platforms at Penn Station

Platform	Tracks	Existing Number of Stairs	Existing Number of Escalators	Existing Number of Elevators	Total Number of VCEs	Relative Length (number of cars per train)	Nominal Width (ft.)
1	1 & 2	6	2	2	10	8	22
2	3 & 4	5	3	2	10	8	20
3	5 & 6	4	2	4	10	10/8	20
4	7 & 8	3	5	5	13	12	20
5	9 & 10	3	6	5	14	12	19
6	11 & 12	4	6	4	14	12	17
7	13 & 14	4	6	4	14	12	20
8	15 & 16	5	5	4	14	12	20
9	17	7	0	2	9	12	20
10	18 & 19	7	2	1	10	12	38
11	20 & 21	7	1	1	9	12	20

- More reservoir space required for passenger queuing and waiting at concourse level (or more congestion if additional space is not provided)—because the platforms are unable to accommodate a significant number of waiting passengers.
- Lack of compliance with ADA accessibility standards for platform edge-train door gaps and platform edge clearances. (Existing station platforms do not fully meet these standards at multiple locations.)
- Platforms can only accommodate single stairs or escalators, resulting in multiple separate VCEs creating a “swiss cheese” effect of a large concourse filled with individual stairs and escalators down to the platforms as opposed to the more efficient and better organized configuration with side-by-side escalators and/or stairs and fewer overall penetrations of the concourse floor. The station plan results in more difficult wayfinding, unbalanced loading, and longer passenger queues.

The most common international standard for platform widths is 10 meters (or approximately 33 feet). In U.S. applications for new installations, notably California High-Speed Rail and on the Northeast Corridor for new construction or where space constraints do not exist, 30 feet is the nominal standard. At various existing U.S. locations, the minimum design standard for wide platforms is 24 feet for platforms without columns or other obstructions, and 26 feet with 2 foot- wide structural columns occupying space on the platforms. However, at Penn Station, where there is an extremely high turnover of boarding and alighting passengers, 30 feet is suggested as the most appropriate design standard for island platforms supporting through-running service.

Without platform widening, through-running at the existing station will be constrained by long dwell times (see [Figure A-2](#)). Widening the existing platforms to support through-running with shorter dwell times would be difficult and expensive and reduce the number of available station tracks, thereby limiting the potential for a major increase in throughput capacity. Simply covering over selected tracks to widen existing platforms by approximately 10 feet has been proposed as an inexpensive solution. However, this approach would result in rows of columns immediately adjacent to tracks, which does not meet ADA standards

for level train boarding. Properly widening platforms to provide ADA- compliant access to tracks on either side would entail major structural reframing of the 8th Avenue subway and the foundations and structural supports for buildings that sit above the station, including Moynihan Station, Madison Square Garden, and Two Penn Plaza. The reframing work is expected to require continuous removal of 3 to 6 station tracks for extended time periods and is not considered feasible under normal operations.

Based on the analysis performed by LTK of station platform track occupancy with reduced dwell times, the throughput capacity of the station could be increased with through-running and dwell times for through trains reduced from 12 minutes to 6 minutes. Dwell times for through or turning trains would shorten by allowing boarding passengers to descend to platform level in advance of the arrival of the incoming train. This would require widening of platforms at Penn Station, which could only be done within the footprint of the existing station by reducing the number of platform tracks. Reducing the number of tracks, however, will largely cancel out the benefits of achieving higher throughput on the remaining tracks. The end result, therefore, would not be a major increase in overall station capacity.

The southern zone of the station (Tracks 1-4) are stub-end tracks and cannot reasonably be converted to through-running due to conflicts to the east. The northern zone (Tracks 17-21) feeds the West Side Yard, which is effectively at capacity and additional storage tracks would be needed to support more through-running. There are essentially no physical ways to augment the storage space in this yard, especially with the recent development of Hudson Yards. If the middle zone (Tracks 5-16) of the existing station is considered for through-running, then the existing 12 tracks in the middle zone would need to be reduced to 9-10 tracks to gain the requisite widths for through-running. Those 9-10 tracks would be able to support a slightly higher throughput of trains with reduced dwell times. Data from the LTK analysis indicate that an overall increase in capacity of about 10% (or 2 trains per hour in each direction) could be achieved by operating trains through the middle zone with dwell times of 6 minutes (i.e., 3 minutes for boarding/alighting and 3 minutes for recovery).

A complete reconstruction of the tracks and platforms would cost approximately \$4.7 billion. We could reduce

Figure A-4

Penn Station Minimum Policy Scheduled Dwell Times for Trips with Terminating or Originating Non- Revenue Operation

Service Type	Minimum Penn Station Policy Scheduled Dwell (minutes)
Amtrak Acela Westbound Origination from Yard	40
Amtrak Regional Westbound Origination from Yard	30
Amtrak Long Distance Westbound Origination from Yard	40
Amtrak Acela Eastbound Termination to Yard	15
Amtrak Regional Eastbound Termination to Yard	15
Amtrak Long Distance Eastbound Termination to Yard	30
NJ Transit Westbound Origination from Yard	12
NJ Transit Eastbound Termination to Yard	7
LIRR Eastbound Origination from Yard	12
LIRR Westbound Termination to Yard	7

that number down to about \$2.7- 3 billion if we are only rebuilding the middle zone. This reconstruction would include demolition and replacement of all concrete-embedded tracks; modification of the interlockings on either side of the station, reconstruction of the original network of utility tunnels beneath the tracks and platforms; reframing of all the suspended platforms; extensive relocation of all structural columns supporting Penn Station, Moynihan Train Hall, Madison Square Garden, and Two Penn Plaza; replacement of all stairs, escalators, and elevators; and extensive waterproofing, mechanical, electrical, and plumbing re-work.

Two time periods could accommodate this extensive structural work in a reasonable time and cost framework, using rolling permanent track outages (as opposed to construction limited to nights and weekends). The first would be immediately following the opening of LIRR East Side Access and delaying the initiation of MNR Penn Station Access, assuming that levels of peak rail service remain below normal levels as peak travel demand gradually recovers from the COVID-19 pandemic. Design decisions would have to be made in 2021 to support construction in the 2023-24 timeframe, and regional consensus on the business case for through-running would seem to be unlikely by that time. The second potential construction interval would be in the late 2020s, immediately following the opening of the new Hudson Tunnel and Penn Expansion, when NJT trains could be shifted to the new station platforms and construction in the existing station can be undertaken prior to restoration of full-service levels. While this would be a more reasonable timeframe, the reconstruction of Penn Station would be delayed for at least a decade.

As described above, the cost and difficulty of construction would not be justifiable based solely on incremental capacity benefits, which would be modest at best. A more logical approach is offered at the proposed Penn Expansion within Block 780, where the new station expansion could be built with platforms 30 feet wide or greater, facilitating potential future through-running in this portion of the station.

Variable dwell times among Penn Station's train operators and for different types of intercity trains also would present a challenge to the smooth operation of a through-running station that relies on reducing dwell times to increase train throughput. For example, the additional time built into Amtrak dwell times to accommodate baggage handling, food service re-stocking and train crew changes limits the throughput capacity of the platform tracks used by these trains and would not be affected by platform widening.

Rail Infrastructure and Major Impacts of Complete Penn Station Reconstruction

A complete reconstruction of Penn Station, although unprecedented in size and complexity, is feasible if supported with thorough planning and staging, precise scheduling and implementation, and an understanding among all Northeast Corridor rail operators and their customers that there will be periods of service impacts (including reductions) and potential disruptions over many years. These impacts are unavoidable because of the profound infrastructure modifications required to reconfigure Penn Station to enable sufficient through-running capabilities to justify the extended periods of inconvenience for customers and the high costs. The breadth of such infrastructure modifications includes:

- Tracks, switches, and signals for the three interlockings (A, C, & JO) that route all trains into and out of Penn Station. Retaining the ability to operate multiple trains simultaneously (parallel train movements), inbound and outbound, to/from the platform tracks is paramount.
- Tracks and signal system integration for the platform tracks.
- Electric traction systems, third rail (DC) for LIRR trains and overhead catenary (AC) for Amtrak and NJT trains.
- Platforms with surface area to provide adequate horizontal circulation and interface with new vertical access/egress capabilities.
- Relocation of columns and support structures; reconfiguring tracks and platforms requires significant structural considerations in re-distributing (Levels A& B station area, Madison Square Garden, and the commercial office buildings) the “load” to new columns and girders, noting that column placement is subject to stringent clearance requirements associated with moving trains.

To understand the magnitude of the impacts on service delivery during the demolition and removal of existing tracks and platforms, accompanied by construction of new infrastructure, consider the effects of recent state of good repair (SOGR) initiatives in Penn Station. This SOGR program, largely focused on tracks and switches, caused Amtrak, LIRR, and NJT to reduce service for about eight weeks to perform work activities that required continuous, 24-hour per day track outages. The SOGR work prevented trains from operating over certain routes and station tracks (i.e., no access to three platform tracks and switches in ‘A’ interlocking) thereby reducing static capacity by 14% (3 platform tracks as a percentage of 21 platform tracks). The track outages required for through-running operation including demolition of tracks and platforms, relocation of columns and girders, installation of new tracks (with signals, third rail, and overhead catenary), and widening of platforms and construction of new platforms, could reduce capacity by as much as 35 to 55% (from 7 to 11 platform tracks) for extended periods of time (measured in months, not weeks) during the many years needed to complete the entire reconstruction project. This greatly exceeds any levels of continuous track outages experienced in the Penn Station environs to date.

Appendix B

Regional Rail Network

Operational and Infrastructure Constraints

Similar to tunnel terminal system constraints, mainline infrastructure throughout the through-running operating territory may require substantial upgrades in capacity to accommodate the planned increase in train volumes. Required improvements could include:

- Additional main track along the entire route or at critical choke-point locations. This requirement appears to be true for both the Suburb-to-Suburb and Regional Metro concepts where very high frequency operations are envisioned for a high percentage of the inner zone locations on routes east and west of Manhattan.
- Enhanced signal systems, similar to the 7 cab-code system installed by Amtrak and NJT on the Northeast Corridor west of New Brunswick, NJ, the 6-aspect high-density signal system on the corridor between Newark and New York, or the 6 cab-code system being installed by Metro-North and CTDOT along the new Haven Line to reduce headways while sustaining higher speeds.
- Substantial investments in the traction power system along all affected electrified routes to accommodate the large increases in train volume.
- Station expansions, including construction of island platforms to accommodate express and local trains at key stations. The Regional Metro concept, in particular, will likely require major investments in this type of station improvement.

Expanded or new storage yards and turnback facilities will be needed to support the high-volume increases associated with through-running and likely require grade-separated turnback facilities at the endpoints of their territories to avoid unmanageable levels of crossing movements as the trains reverse direction to return to Penn Station. Substantial new storage and maintenance yard facilities, potentially accommodating up to 100 new trainsets, are also likely necessary to support the increases in train volume. Finding suitable locations for new facilities, especially in the inner zone sections of the network, will likely involve locations within existing or adjacent industrial or residential development zones and require careful analysis to determine the feasibility of a proposed location.

Rolling Stock

Interoperable Equipment

The rail network surrounding NYC is as diverse as any found globally. It reflects the technologies available at the time investments were made any time in the last 125 years and, in part, the underlying design philosophies found within predecessor railroad organizations. It presents a complex operating environment for existing services and an even more complex situation for a through-running operation.

Equipment in through-running service that spans territories with multiple traction power systems will need to be designed to operate under a wide range of traction power sources as shown in the following table.

Figure B-1 presents a list, indicating the type of traction power utilized in each segment of the network. Virtually any train operated through Penn Station between New Jersey and points beyond Sunnyside Yard in Queens entails operating utilizing different traction power systems, or operation on non-electrified lines using dual mode diesel-electric locomotives.

Figure B-1

New York City Regional Railroad Electrification Systems

Voltage	Frequency / Phase	Type	Territory
25kv	60hz / 3 Phase AC	Catenary	Boston, MA to New Haven, CT
12kv	60hz / 3 Phase AC	Catenary	New Haven, CT to Pelham, NY
12kv	60hz / 3 Phase AC	Catenary	New Rochelle to Queens, NY (Astoria)
12kv	25hz / 1 Phase AC	Catenary	Queens, NY to Washington, DC
12kv	25hz / 1 Phase AC	Catenary	Empire Tunnel (36th St) to Penn Station
25kv	60hz / 3 Phase AC	Catenary	Hoboken, NJ to Dover/Gladstone, NJ
12kv	25hz / 1 Phase AC	Catenary	Rahway, NJ to South Amboy, NJ
12kv	60hz / 3 Phase AC	Catenary	South Amboy, NJ to Matawan, NJ
25kv	60hz / 3 Phase AC	Catenary	Matawan, NJ to Long Branch, NJ
750v	DC / Underrunning	3rd Rail	Pelham, NY to Grand Central Terminal
750v	DC / Overrunning	3rd Rail	Sections of LIRR System to Penn Station
750v	DC / Overrunning	3rd Rail	Harold Interlocking to GCT (In Construction)
750v	DC / Overrunning	3rd Rail	Empire Tunnel to Penn Station

Harold Interlocking, the East River Tunnels, Penn Station, and the Empire Tunnel are uniquely constructed to contain both overhead catenary and 3rd rail infrastructure. The North River Tunnel has 3rd rail, but it is only suitable for emergency operations at slow speeds.

The two traction power systems require special signal system designs to operate in an environment with large amounts of Alternating Current (AC) and Direct Current (DC) being drawn simultaneously. Car/trainset designs must also protect against stray current and leakage between the two types of power that could damage the equipment. Any extensions of the 3rd rail system on moderate-speed routes already equipped with overhead catenary will also require reconstruction of its

signal system. Similarly, the rolling stock used on such routes would require designs to allow it to safely operate over the different traction power and signal systems employed.

High-speed rail (90+ mph) operations and maintenance of its infrastructure is not compatible with 3rd rail operations. Poor 3rd rail shoe contact capability at high speeds, poorer electric traction transmission characteristics, compared to AC catenary, and incompatible design elements of high-speed track with 3rd rail infrastructure, especially through interlockings and many under-grade bridges, will limit 3rd rail extensions over the NEC in NJ to no farther west than Secaucus where maximum speeds are still low.

Equipment Design and Operations

Clearances

Horizontal and vertical clearances vary on each route. The NYC region has some of the most restrictive clearances at critical locations and throughout wider portions of the regional network preventing use of many equipment designs. Locations include:

- LIRR 63rd Street Tunnel under the East River, approaches to Atlantic Avenue. All multi-level, bi-level, and locomotives owned by any of the three agencies will not fit in them.
- East River Tunnels, North River Tunnels, Penn Station, and Atlantic Avenue. Terminal vertical clearances effectively prevent use of the majority of multi-level, bi-level, gallery style, and Amtrak Superliner cars found in most commuter rail and state-supported systems across the nation.
- Grand Central Terminal, like Penn Station, was constructed only for single-level equipment. While its vertical clearances are slightly better than Penn Station, existing tunnel arch and side clearances in various locations of the terminal complex currently prevent use of the NJT-style or other multi-level equipment.

Rolling Stock Designs

The various equipment electrical and clearance restrictions described above have substantial influence on potential through-running scenarios. Designs of the current equipment may, or may not, be able to support modifications to readily adapt it for through-running operations. As a consequence, equipment assigned to through-running service likely will need to be acquired new for the purpose or heavily modified (if feasible) to meet the multiple operating criteria necessary to operate from one side of the NYC region to the other—all at a substantial cost. Issues could include:

- Metro-North/CTDOT M8 equipment cannot operate under the 12 kV, 25 Hz catenary system between Queens and Washington, DC. The primary transformers this equipment uses can only operate with 60 Hz traction power and a larger and heavier transformer under the car body necessary to use the 25 Hz was not provided for.
- LIRR M7/M9 equipment design did not envision operation under catenary. The car body structure, electrical wiring, piping runs, and under car machinery layout did not provide for additional capability to shift from standard DC operation to AC operation.
- The MTA family of single-level electric cars is designed only for high platform operation, with quarter-point door locations on the car body and without stair vestibules that can allow passengers to access low-level or track-level platforms. In 3 or 4-track territory, when trackwork takes the normal track out of service, temporary, narrow gangways are erected to bridge the out-of-service track and provide level boarding to the train. All NJT and Amtrak equipment (except Acela) is designed with end-point doors that can provide stair access to low platforms or track-level walkways used when a train stops at a low-level platform (common on NJT routes) or in territories with more than two tracks when one is out for maintenance. The end-point door configurations may not be fully compatible with the gangway placements used along MTA lines.

- Single-level equipment operated by LIRR and MNR can seat about 100 passengers per car. New NJT multi-level equipment can seat about 140 passengers per car. Because only the LIRR single-level fleet can operate in the 63rd Street Tunnel or into Atlantic Avenue Terminal, a majority of its fleet has been built to fit in the low clearance routes, allowing maximum flexibility in assigning it to any run in the electrified system. Operating LIRR “M” style equipment to New Jersey in lieu of multi-level equipment would constitute nearly a 30% reduction in seat capacity. Conversely, extension of NJT-style multi-level equipment into Long Island would preserve higher seat capacity but would also create bifurcated operations on Long Island, reducing flexibility in assignments, potentially requiring expanded layover facilities and impacting overall reliability.
- It is expected use of NJT-style multi-level equipment and dual-power locomotives able to operate under catenary or using 3rd rail would require operation of a locomotive on either end of the train. Use of two locomotives provides for a means of bridging sometimes lengthy gaps in the 3rd rail system that are found throughout the LIRR electrified network. With only one locomotive, the risk of the train stalling in one of the gaps increases greatly. It may be possible to install 3rd rail shoes on the car immediately behind the locomotive to provide another current collection source,

but the Federal Railroad Administration has historically discouraged this type of arrangement. NJT is currently acquiring new cars under its “Power Car” strategy that places a power unit between multi-level cars and avoids using locomotives. Operation of a train with more than one Power Car should provide the same capability that use of two locomotives provides. The Power Car concept may be adaptable to 3rd rail operation but it would likely come at the expense of reducing seats in the car and adding weight to provide for the additional 3rd Rail electrical components.

Each of the above issues may be manageable in isolation but, collectively, they present substantial and wide-ranging challenges to smooth operations of a through-running operation. They also point to an anticipated need to plan for very large acquisitions of new fleet able to operate throughout the through-running territory without being burdened by the above restrictions. Depending upon the scenario, investment in new fleet could be in the 500- to 1,000-vehicle range. At \$4-5 million per car and \$8-10 million per locomotive, typical of recent acquisition prices, the financial cost of these acquisitions would be \$3-6+ Billion. If the new fleet was purchased over time as a part of the typical vehicle acquisition cycles for each agency, the full conversation would probably take 30+ years.

Track Capacity and Yard Capacity

The following matrix provides an overview of impacted facilities and services for different through-running concepts. This overview is for preliminary discussion purposes only. The scope of required work under each category would likely differ based on the

needs of the specific operating concept. The matrix describes the change in infrastructure (e.g., need for four tracks between Secaucus and Newark) based upon the envisioned use.

Figure B-3

Infrastructure Improvements for Through Running

		Concept 1: Suburb- to-Suburb	Concept 2: Regional Metro
Infrastructure in New Jersey	4 tracks, Secaucus-to-Newark (part of Gateway)	•	•
	Bergen Loops (part of Gateway)	•	•
	Hunter Flyover	•	•
	Mid-Line Loop	•	•
	Trenton interlocking capacity	•	
	M&E, RVL capacity improvements	•	•
	Main, Bergen, and Pascack Valley Line capacity improvements	•	•
	Regional Metro terminal improvements		•
	Far-side yard for LIRR/MNR trains		•
	Regional yard storage and equipment maintenance facilities	•	•
	Third rail electrification to Secaucus (yard location)		•
	Inner branch line electrification		•
	Potential full branch line electrification, or new dual-mode trainsets	•	
Infrastructure in Queens, Bronx, Long Island, and Westchester	5th Main Line track, Harold-Jamaica	•	•
	4-track Hell Gate Line		•
	Jamaica Station capacity improvement	•	• Queens
	Valley, Shell Interlocking capacity	•	• Regional
	Metro terminal improvements		•
	Far-side yard for NJ trains (Queens or Bronx)		•
Major Tunnel Infrastructure	Regional yard storage and equip maintenance facilities	•	
	Branch line electrification (e.g., Port Jefferson)	•	
	New Hudson River Tunnel (part of Gateway)	•	•
	New East River Tunnel at 30th/31st St		•
Fleet and Technology	Major junction in western Queens		•
	Interoperable signaling and train control (PTC) system	•	•
	Dual-power interoperable rolling stock	•	•
	Dual-mode locomotives and interoperable coaches	•	?
Penn Station Tracks and Platforms	Platform widening desirable to reduce dwells (or, longer dwell times to allow safe alighting and boarding)	•	•

Tunnel Systems and Capacity

Penn Station is accessed via seven single-track tunnels: two under the Hudson River, four under the East River that collectively connect to the Northeast Corridor/LIRR systems, and a shorter “Empire Tunnel” located under HudsonYards that ultimately connects to the Metro-North Hudson Line. Each under-river tunnel is approximately 3 miles long. The shorter Empire Tunnel is approximately 0.3 mile. The tunnels are equipped with three types of signal system designs reflecting, in part, the available technologies when they were built or reconstructed and the recent installation of Positive Train Control (PTC). The signal and track system designs that lead to the station tracks have a direct bearing on overall capacity of the tunnels to process trains to and from the station. Capacity of the system is determined through a combination of infrastructure and operational elements that include:

- Establishment of safe stopping distance criteria, referred to as “the braking curve” using a specified rate of deceleration for a train receiving an indication of a stopped or slower speed condition.
- Minimum signal system headways³ based upon the above selected braking curve and as established through *Union internationale des chemins de fer* (UIC) guidelines for same direction trains.
- Effect of PTC commands on trains approaching the terminal’s interlockings as well as when entering into the Passenger Terminal Main Track Exclusion Addendum (MTEA) territory.
- Tunnel ventilation and passenger emergency egress train control system requirements to comply with NFPA-130 “One Train per Zone” standards establishing life-safety criteria for tunnel operations. The existing East River and North River tunnels are currently exempt from compliance.
- Effect of same direction switching actions at the transition point from the respective tunnel track to the terminal trackage to establish routes to individual station tracks.
- Effect of opposing direction switching actions from trains traveling in opposite directions and one of them crossing overtracks in front of the other.

The first four of the above elements are components of the fixed infrastructure and will be present for every train movement. The last two elements are derived from the specific operating plans and will vary between through-running concepts. Through-running scenarios target reducing the frequency of opposing movements, the last element, but may also cause an increase in same direction switching movements to alternate trains from one station track to another.

Current capacity in the Hudson River tunnels along with established operations provides for 24-25 trains per hour in each peak direction. East River Tunnel operations provide 20-21 trains per hour in the peak direction. Detailed analyses of the tunnel systems indicate that capital improvements on the order of \$50-100+ million could increase the maximum practical capacity of the tunnels to the range of 26-28 trains per hour (tph) beneath the Hudson River and 22-24 tph under the East River, about a 10% increase. The tunnel system capacity, even after enhancements, will remain a limiting factor in train throughput at Penn Station.

Any plan aimed at increasing tunnel capacity must be responsive to addressing all six elements listed above and conform with the four railroads’ operations safety standards that provide an operating environment train crews can reasonably comprehend and safely respond to.

³ Signal system headways are the minimum distance needed between two trains running in the same direction such that the second train will always receive a clear signal indication.

Appendix C

Regional Travel Markets

Penn Station could support several potentially feasible types of through-running service; through-running is not a single concept.

Table C-1 lists markets that could benefit from through-running. The first market listed, suburb-to-suburb travel, is typically what comes to mind when considering the merging or integration of the three commuter rail systems that will feed Penn Station in the future. The other markets potentially entail larger volumes of travelers, but very few of

these travelers are able to take the train today, and the existing commuter rail service patterns are not well-equipped to tap these markets. New types of service would need to be offered to attract significant ridership. The existing rail infrastructure, however, is not configured to easily support these new service types, and substantial investment across the region would be required to maximize the ridership potential in these markets.

Table C-1

Potential Ridership Markets for Through-Running Service

Travel Market	Type of Rail Service	Examples of Locations Served
Suburb-to-suburb travel	Fully integrated regional rail, with all run-through service at Penn Station	Pairing of existing suburban branch lines
Commute to expanded central business district (CBD)	Commuter rail service extended to stations in the urban core beyond Penn Station	Trips from Long Island, Queens, East Bronx and New Haven Line to Secaucus, Newark and Newark Airport; Trips from New Jersey rail corridors to Long Island City/Sunnyside, Woodside, Jamaica/JFK
Travel to edge cities and regional employment centers	Limited-stop express service, linking major hub stations in the region	Stamford, Bridgeport, New Haven, New Rochelle, Metropark, New Brunswick, Princeton Jct., Trenton, Mineola/Nassau Hub, Hicksville, Route 110, Ronkonkoma
Travel within expanded urban core area	Regional Metro service — transit-style all-stop local service at frequent intervals, using local tracks on trunk lines and serving inner branch lines	Includes the expanded CBD territory, plus areas beyond the reach of the subway/ PATH network or where subway trips are long and crowded, such as Elizabeth, Perth Amboy, Orange, Paterson, Hackensack, Central, Eastern and Southeast Queens, Hempstead, Valley Stream, Willets Point/LGA, Flushing, East Bronx

All of these markets would be served at some level by the three independent commuter railroads each operating on their own at Penn Station. Transfers would be available at Penn Station from any branch line on one system to any other branch line on another system. With the improved platform access and increased station concourse capacity envisioned in the Penn Station Master Plan, the quality and convenience of these transfers is expected to be significantly improved over existing conditions. Wait times for connecting trains in the peak periods can be expected to be reasonably short. This future condition would be the baseline condition, and the business case for through-running would need to be based on any incremental ridership growth over and above the baseline generated by providing a one-seat ride from origins on one side of Manhattan to destinations on the other side. It would not be possible to offer high-frequency one-seat rides between all branch line combinations, so only selected markets would benefit from through-running service.

A comparison of the relative sizes of travel markets within the greater New York metropolitan region sheds light on the prospects for the ridership benefits of through-running. To assess relative market size, we obtained data from the NYMTC Best Practices Model of regional travel demand on daily county-to-county work trips. County-level data were aggregated into groups of adjacent counties based on distance from Manhattan to analyze ridership potential. Table C-2 on the following page presents daily journey-to-work travel volumes by all modes between selected counties and groups of counties. Not surprisingly, commuter travel is dominated by trips to Manhattan, most of which are destined for the CBD below 60th Street. Travel to and from the ring of counties surrounding Manhattan, including the NYC outer boroughs and inner counties of northern New Jersey, is smaller in magnitude but still significant. Travel between suburban counties is very small, particularly for those counties beyond the inner ring. It is therefore logical to conclude that the ridership potential of through-running would be greatest for travel to, from and within the urban core and counties or boroughs immediately surrounding the core.

From portions of New Jersey with NJT rail service, there are a total of 182,000 work trips to Manhattan. By contrast, there are 9,000

trips from New Jersey to Queens, 3,000 trips to Nassau and Suffolk Counties, and 2,000 trips to the Connecticut suburbs. From Long Island, there are 111,000 daily work trips to Manhattan, 2,300 trips to the inner ring counties of New Jersey (Bergen, Passaic, Essex, Union), and 1,000 trips to the NJ suburban counties (Mercer, Middlesex, Monmouth, Morris, Ocean, Somerset). The small size of the suburb-to-suburb market is evident, for travel between the counties beyond the NYC boroughs and inner ring NJ counties. Most of the through-running market potential would be realized by bringing NJ commuters to Queens and Long Island commuters to the inner ring counties in northern NJ—stopping short of full network integration and potentially reducing the required capital investment.

The total travel market for Regional Metro service is difficult to quantify without detailed service analysis and travel demand modeling. The total travel market for county-to-county trips in the urban core area defined as Manhattan, Queens, and the inner ring NJ counties (excluding trips that remain within the same county) is over 400,000 daily trips. Although much of this territory is served by NYC subways, PATH, and commuter buses, the rail corridors extend to portions of the territory not well served by other transit, or where existing transit is overcrowded and limited in its ability to support growth. Regional Metro, if well-designed, could capture a small portion of this substantial market, offering greater ridership potential than aiming service at the suburb-to-suburb markets.

Two primary potential through-running concepts are described below, each targeting a particular travel market with unique operating characteristics at Penn Station and within the regional rail network. For each concept, we highlight some potential challenges and benefits. In addition, following those two concepts, we briefly describe other service concept variations.

All potential through-service patterns would have significant operational impacts on the entire regional rail network and face challenges related to institutional framework and governance, labor agreements, cost, and revenue-sharing agreements. All would require investment in railroad infrastructure and fleet beyond the limits of the Penn Station complex, including increased line capacity,

yard expansion/improvements, and use of dual-power or dual-mode rolling stock able to operate over routes with different traction power systems or no electrification. These service patterns would benefit from electrification of all or portions of currently non-electrified lines but do not necessarily require it. However, replacing service on an already-electrified route with new diesel-powered trains is a non-starter.

The negative environmental and community impacts and reduced performance of diesel trains over high-speed routes would outweigh any perceived market/capacity benefits. Although none of these service concepts is achievable easily, inexpensively, or in the short term, they could offer a range of benefits to ridership markets in the region.

Table C-2

County-to-County Work Trips for Selected Counties

Existing Total Daily Journey-to-Work Trips by All Modes

Home Counties	Workplace Counties								
Core CBD Commute Market									
	Manhattan	Queens	LI Suburbs	Westchester	CT Suburbs	NJ Inner Ring	NJ Suburbs	West Suburbs	SUBTOTAL
NJ Rail Territory	182,297								182,297
LI Suburbs	111,072								111,072
Westchester	76,563								76,563
CT Suburbs	28,839								28,839
Total	398,771	-	-	-	-	-	-	-	398,771
Reverse-Commute Markets									
	Manhattan	Queens	LI Suburbs	Westchester	CT Suburbs	NJ Inner Ring	NJ Suburbs	West Suburbs	SUBTOTAL
Manhattan		15,798	5,584	7,421	4,306	7,987	3,742	1,188	46,026
Queens			67,227						67,227
Bronx				28,135	1,595				29,730
NJ Inner Ring							112,058	9,587	121,645
Total	-	15,798	72,811	35,556	5,901	7,987	115,800	10,775	264,628
Suburb-to-Suburb Markets									
	Manhattan	Queens	LI Suburbs	Westchester	CT Suburbs	NJ Inner Ring	NJ Suburbs	West Suburbs	SUBTOTAL
NJ Rail Territory			3,307	n.a.	2,009				5,316
LI Suburbs						2,320	975	366	3,661
CT Suburbs		1,158				1,161	555	467	3,341
Total	-	1,158	3,307	-	2,009	3,481	1,530	833	12,318
Expanded CBD Through-Running Markets									
	Manhattan	Queens	LI Suburbs	Westchester	CT Suburbs	NJ Inner Ring	NJ Suburbs	West Suburbs	SUBTOTAL
NJ Rail Territory		9,039							9,039
LI Suburbs						2,320			2,320
CT Suburbs						1,161			1,161
Total	-	9,039	-	-	-	3,481	-	-	12,520
Regional Metro Markets									
	Manhattan	Queens	LI Suburbs	Westchester	CT Suburbs	NJ Inner Ring	NJ Suburbs	West Suburbs	SUBTOTAL
Manhattan		15,798				7,987			23,785
Queens	259,522					4,078			263,600
NJ Inner Ring	113,161	5,799							118,960
Total	372,683	21,597	-	-	-	12,065	-	-	406,345

LI Suburbs= Nassau, Suffolk counties

CT Suburbs=Fairfield, New Haven counties

NJ Inner Ring= Bergen, Passaic, Essex, Union counties

NJ Suburbs= Mercer, Middlesex, Monmouth, Morris, Ocean, Somerset countiesWest

Suburbs=Rockland, Orange counties

NJ Rail Territory=NJ Inner Ring plus NJ Suburbs

Source: NYMTC travel data.

Suburb-to-Suburb Service

Suburb-to-Suburb service would connect suburban branch lines under a timetable-based service with specified train arrival and departure times at Penn Station. Existing commuter railroad service frequencies, including to areas of the Bronx and Queens that have limited or no service today, would be maintained, with concentrated suburb-to-city zone express service in the weekday peak direction of travel; local branch line service in the reverse-peak direction; and off-peak local service at regular semi-hourly, hourly, or bi-hourly intervals.

Although Suburb-to-Suburb service is what many people automatically assume as through-running service, it likely serves the smallest potential market of any through-running concept; as a result, it offers a weak business case.

If fully implemented, Suburb-to-Suburb service would fully integrate the commuter rail systems feeding Penn Station. Full integration of the suburban rail networks would result in many routes in the range of 100 to 150 miles long. These longer trip times increase the potential for lateness at Penn Station, so recovery time would have to be built into the Penn Station dwell times. At existing, narrow Penn Station platforms, passenger alighting and boarding may need to be time-separated to avoid overcrowding—further lengthening dwell times.

Many branch line combinations are possible. Branches would be matched based on market size, traction power technology, and compatibility of potential rolling stock. Existing electric locomotives could be used to connect NJ electrified branch lines with the MNR New Haven Line. Otherwise, new customized rolling stock—either locomotives or multiple-unit trainsets—would be required to handle each specific combination of electric traction power offered on suburban routes west and east of NYC, such as LIRR 3rd rail and the various types of AC overhead catenary on the NJT system. This new equipment would need to be designed and procured. Branch lines and service zones then could be paired up based on the relative size of their travel markets and lengths of trains operated. Higher

ridership branches served at peak periods by longer trains include Trenton/New Brunswick, Dover, Ronkonkoma, Huntington, Babylon, and Stamford. Existing stations and yards on some branches limit the length of trains that can be operated. Branches and service zones generally served by shorter trains with somewhat smaller ridership markets might include South Amboy, Montclair, Gladstone, Hempstead, Long Beach, and Far Rockaway.

Non-electrified branch lines could be linked with each other and served by trains with dual-mode locomotives. Non-electrified branch lines in New Jersey include the routes to Bay Head, Raritan/High Bridge, Hackettstown, Suffern/Port Jervis, and Spring Valley. Long Island non-electrified branches currently include Port Jefferson, Speonk/Montauk, Oyster Bay, and Greenport. The Metro-North New Haven Line branches to Danbury and Waterbury also currently are non-electrified. The Empire connection to the MNR Hudson Line also is non-electrified beyond the limits of the Penn Station tunnels. LIRR currently uses dual-mode locomotives capable of operating under diesel power and on the LIRR 3rd rail. These locomotives could operate to NJ branches only if 3rd rail is extended to the junction points, such as Secaucus, Kearny, or Newark. As noted in [Appendix B](#), extending 3rd rail on the Northeast Corridor main line would limit future top speeds. NJT operates dual-mode locomotives capable of operating under overhead AC catenary power or diesel power. These units would be limited to operating between NJ and the MNR New Haven branches and could serve Long Island branches only if under diesel power east of Harold Interlocking in Queens. Non-electrified branch lines also could be considered for electrification, which would add considerable capital cost but offer environmental benefits and potential higher performance in terms of average train speed.

Challenge: Pairing Trains

Off-peak service frequencies on the three commuter railroads are similar and tend to be based on clockface or near-clockface intervals,⁴ lending themselves to through-running pairs. However, peak direction service patterns do not match up well with reverse-peak patterns. Limited-stop zone express trains in the peaks, which provide critical seat capacity and deliver competitive travel times, only serve a portion of a route's stations—making it difficult to pair trains from one side of Manhattan to the other.

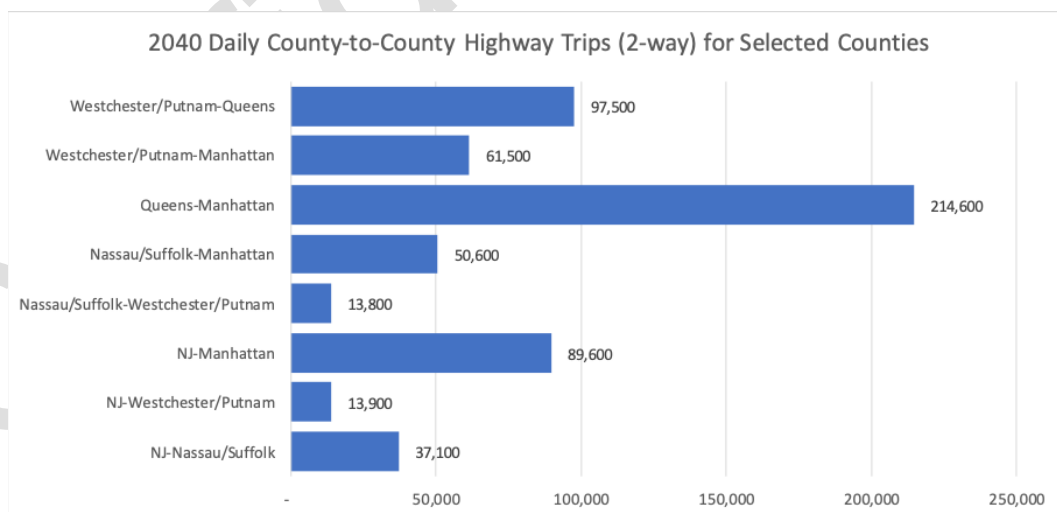
Challenge: Small Impact

The business case for this type of through-running is weak, given the documented small size of the existing Suburb-to-Suburb travel markets (compared with commuting to the CBD), as shown in [Table C-2](#). This finding is supported by data from NYMTC on projected county-to-county highway trips in 2040 (which is the market that is potentially divertible to rail with improved service). The expected future volume of Suburb-to-Suburb trips is much smaller than trips with origin and/or destination points within the urban core of Manhattan and the outer boroughs of New York City. In particular, the New Jersey to

Long Island highway travel market is only 37,000 trips, and the New Jersey to Westchester/Putnam market is only 13,900 trips. This compares with auto travel between the suburbs and Manhattan/Queens at the level of 300,000 trips, and between Manhattan and Queens of 215,000 trips, which are markets that are an order of magnitude greater than the Suburb-to-Suburb markets. Making a \$5-10 billion investment for such a small market of new passengers is not a strong return on investment.

Challenge: This market can be better served by an improved transfer hub at Penn Station

Implementation of the Penn Station master plan will greatly improve conditions for passengers transferring between trains. Reasonable rail-to-rail transfers will be available at Penn Station across the full spectrum of Suburb-to-Suburb trips. The quality of the transfer experience will be greatly improved over existing Penn Station conditions, which will enable Penn Station to serve as the centerpiece of a hub and spoke system reaching throughout the entire region and serving the full range of regional rail travel markets.

Table C-1**2040 Daily County-to-County Highway Trips (2-way) for Selected Counties**

Source: NYMTC Congestion Management Process Status Report Update, 2040 Traffic Congestion Forecasts, 2013

⁴ Trains operating at regular, repeating intervals—stopping at stations at the same times every hour (e.g., trains to Trenton leaving New York Penn Station at 10 minutes and 40 minutes after the hour, every hour).

Regional Metro Service

The Regional Metro concept is an all-stop, headway-based service on local tracks of 4+-track trunk lines and inner suburban branch lines. It provides transit-style service on the inner portions of the regional rail network, augmenting the capacity of the rail transit system (subway and PATH) and providing service in under-served urban areas, such as central and eastern Queens; the East Bronx; and Bergen, Essex, and Union counties in New Jersey.

Local Metro rail service would be headway-based rather than timetable-based, which reduces the need for recovery time to be built into train schedules at Penn Station. The longer suburban branch lines would continue to operate commuter service as they do today, with extensive peak zone express service. On the trunk lines feeding the tunnels to and from Penn Station, regional metro service would work best operating on dedicated local tracks, with the commuter zone express and Amtrak service (where provided) sharing separate express tracks.

This would be an entirely new service concept for the New York area railroads and entail a re-working of the entire regional operating plan. In turn, this concept would trigger the need for substantial capacity-related infrastructure investment (e.g., potential additional main tracks) to provide for maintaining sufficient parallel express operations that are otherwise displaced by the Metro service concept.

Regional Metro service is analogous to regional service in several international cities: Crossrail & Thameslink in London; RER B & D Lines in Paris; Cercanias in Madrid; Sydney Metro in Australia; S-Bahn services in Zurich, Munich, Berlin, etc.; and the planned GO-RER service in Toronto. These systems generally have track and signaling infrastructure that supports high-density operations and minimizes operational conflicts, uniform rolling stock, station design and traction power systems, and a network that provides multiple stations within the CBD. None of these are features of the New York network. There are exceptions, however, that demonstrate how the New York region might overcome these hurdles. The London Thames link service employs dual-power trainsets that operate on both catenary and

3rd-rail power. Sydney, Australia has a through-running commuter rail network that operates with transit-like characteristics through the city center. The system currently is being expanded with a new city center tunnel designed for Regional Metro service, connected to selected existing suburban branch lines that are being converted from commuter rail to Metro service. The Paris RER system until recently relied on train crew changes at the central downtown station to tie together branch lines with different labor and institutional arrangements, and the Toronto GO-RER system will rely on a single downtown station (Union Station) to serve the core or the CBD.

Regional Metro services, building on legacy suburban rail assets, have been proposed or are under study in other U.S. regions, including Boston, Chicago, Los Angeles, and the San Francisco Bay Area. As in New York, these systems require substantial investment in new capacity through the urban core, including stations with track and platform configurations that support through-running. Philadelphia is the only large U.S. city with regional rail built for through-running. All suburban lines feed a common 4-track trunk line through the city center. The system originally operated as an integrated suburb-to-suburb network. It no longer links the suburban branch lines, instead focusing each branch on serving three major stations within the CBD on the common trunk line. The system provides a transit-style regional metro service within the core area.

A successful Regional Metro system for greater New York would expand high-quality rail service to locations beyond Penn Station. It could create an east-west spine that focuses local service at close headways on a string of existing and new stations that could evolve over time as an expanded CBD, with significant new employment and mixed-used development, is developed.

Challenge: Rail Infrastructure Capacity, Yard Facilities and Equipment

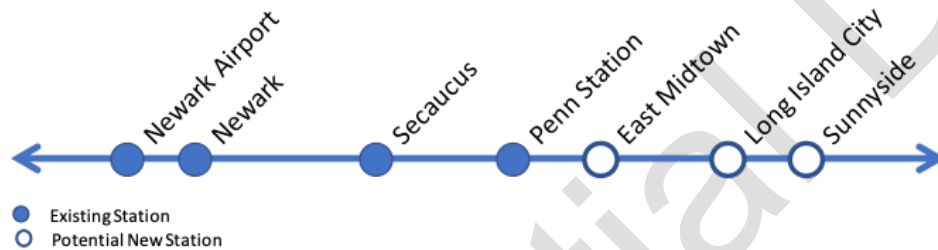
Ideally, these services would operate on the local tracks of the Northeast Corridor, LIRR Main Line, and Hell Gate Line and be separate from the remaining, but still very substantial, commuter and intercity services, which would operate on the express tracks. This service

Figure C-4

Potential Regional Metro Spine

The Regional Metro concept would include branch lines off the spine that would serve areas of the region beyond the reach of existing rail transit, where improved rail service could help promote economic revitalization and equity. Candidate inner branch lines for provision of regional metro service could include:

- Hempstead, Far Rockaway & Long Beach branches via LIRR Main Line and Atlantic Branch, and potential future JFK Airport service⁵
- East Bronx (Hell Gate Line) and inner New Haven Line to Port Chester
- Rahway, Perth Amboy (NJCL), South Orange (M&E), Montclair, Plainfield⁶ (RVL), Paterson² (Main Line), and Hackensack² (PVL)



Source: NYMTC Congestion Management Process Status Report Update, 2040 Traffic Congestion Forecasts, 2013

⁵ Although Port Washington Branch is a good candidate for regional metro service, it physically aligns best with ESA tunnels and ERT Lines 3 & 4, so it is not ideal for through-running via the Penn Station expansion.

⁶ With line electrification or high-performance dual mode equipment.

This service would work best if operated in parallel with the commuter service, with new track capacity provided on the LIRR Main Line between Harold and Jamaica (i.e., fifth track); full 4-tracking of the Hell Gate Line; and a 4-track system to the Oranges, a 4-track system to Plainfield, and/or a 6-track system to Rahway, New Jersey. Similarly, substantial investment in new storage and maintenance yards/turnback facilities to accommodate the increase in equipment needed and to support the high-frequency operation is anticipated. Virtually all existing storage facilities throughout the entire region operate near capacity and could not accept maintaining and storing any sizeable increment of equipment. New facilities would be required and likely need to be located in well-developed areas of the region to serve the inner zone territory of the service. By contrast, the majority of new commuter rail yard investments made by the three railroads over the past decades have tended to be located in less-dense outer-zone locations (e.g., Morrisville, Port Morris, Poughkeepsie, Southeast, East Bridgeport, Ronkonkoma).

Benefit: Improved Public Transportation Access to Underserved Communities

Regional Metro has the potential to extend the effective reach of the rail transit network beyond the territory served by the subways and PATH—into areas that may be economically challenged and are not as well served by transit as other parts of the region (e.g., southeast Queens, central Queens, Hempstead, southeast Bronx, Perth Amboy, Paterson, Hackensack and the Oranges). The business case, therefore, could have strong regional equity benefits.

Benefit: Economic Growth and Subway Congestion Relief

The existing rail network generally runs in corridors in Queens and the East Bronx that are also served by subway lines that were crowded up until the COVID-19 pandemic. In New Jersey, downtown Newark is served by both the rail line and PATH. Regional Metro service can help relieve congestion on these subway/transit lines and provide capacity for future growth in population, employment and travel demand. The ability of regional metro

to attract travelers from the subways and PATH will be a function of both frequency and fare. Current commuter rail fares are intentionally high in the NY City Zone and inner NJ areas, because the existing systems are capacity-constrained and intended to primarily serve the suburbs. With additional rail capacity through Manhattan, fare policy could be adjusted to reach a new equilibrium that can encourage filling a substantial amount of the new capacity in the regional metro market areas.

To the extent that commuting from the NYC outer boroughs and northern NJ inner counties rebounds once the COVID-19 pandemic is over and then continues to grow as previously forecast over the next two decades, accommodating that growth on regional metro rather than on the subways, PATH, and commuter buses could reduce congestion on those other modes of transportation. Such a shift in ridership to the Regional Metro service described for this concept could avoid or defer the need for major capital investment in new subway lines and reduce the long-term rate of growth in commuter bus demand within the CBD.

Other Service Concepts

The two concepts presented above represent two distinct approaches to through-running. There are other variations that also are possible. For example, combining the two concepts together would create a truly integrated regional system that would combine the capacity and operational benefits of increased through-running with the market benefits of Regional Metro. It also would facilitate new types of service, such as trans-regional express train services linking the major stations across the region with fast, frequent, and direct rail service. To be successful, however, it would require a complete rebuilding of the Penn Station tracks and platforms as well as all the network rail investments described earlier, which perhaps could be accomplished at some point in the future but is not practical at this time.

Partial through-running—focusing on specific branch line services or types of service—could deliver a portion of the benefits of full network integration, at a lower capital cost. Labor and institutional issues must be addressed in all alternative concepts. As an example, a more modest idea for through-running would focus only on the portions of

the rail network relatively close to Penn Station, aiming to increase the throughput of trains via the existing tunnels by expanding mid-day storage yard capacity on the far side of Penn Station (in northern New Jersey for LIRR and MNR, and in western Queens or the Bronx for NJT).

The planned increase in rail service needed to accommodate the projected future growth in rail ridership will require additional train equipment and an increase in the capacity of storage yards for that equipment. The railroads currently are planning for expanded yard capacity, with NJT looking to expand yards and potentially develop new yards in New Jersey, and LIRR and MNR looking to expand their yard capacity on their existing systems. Current yard expansion plans are based on planned service increases and are not necessarily aligned with what would be needed to support through-running service concepts. The existing Penn Station terminal yards cannot meet this long-term need, so future operations must rely on bringing more morning peak trains back from Penn Station to mid-day storage somewhere on the system, which will increase the volume of turning train movements at Penn Station (either as revenue or deadhead trains).

Depending upon where additional yard capacity is built, the potential exists for limited revenue-to-revenue through-running service, by allowing LIRR and MNR trains to access storage yards in northern NJ and NJT trains to access storage yards in Queens or the Bronx. This would not reduce the number of train movements or the requirements for yard expansion, but it would enable passengers to travel directly on trains that serve stations within the urban core on the far side of Manhattan (e.g., LIRR trains serving Secaucus and Newark, and NJT trains serving stations in Queens). All of the investments needed to support interoperability would be required within the territory where these through-running trains would run, and all of the institutional and labor hurdles still would need to be overcome. However, the required investment would be considerably less than what would be needed for full network integration.

This partial through running concept would be expected to generate somewhat more Penn Station capacity than the Suburb-to-Suburb concept, because the new through-

running train movements would be largely of the drop-and-go type, with significantly shorter dwell times than in the prior example, and the expansion of yard capacity would reduce the current practice of deadheading of empty trains back to suburban mid-day storage locations.

The difficulty of making the institutional and labor changes needed to extend service beyond Penn Station would be similar to the two initial concepts, as would the need for expanded train storage yards. The capital cost impact would be lower, however, because rail infrastructure improvements would be limited to the territory between Penn Station and the locations where expanded storage yard capacity could be provided.

The business case for this sample concept appears to be better than for Suburb-to-Suburb service, with capital costs limited to a smaller geographic area and higher incremental ridership potential associated with improved rail service to stations on the inner portions of the rail network that could be destinations for increasing numbers of suburban commuters and important for regional economic growth. However, the relatively small size of the incremental travel market benefits would not justify the costs by themselves. The rationale for serving expanded yard capacity with through-running train movements rather than increasing turning movements would have to be based more on operational rather than market considerations.

Another service variation relying on through-running would be limited-stop express service that would extend across the entire region but make stops only at stations that are employment centers or transit hubs. By limiting station stops, these trains would have faster run times, improving the accessibility of existing and potential new outlying regional employment and economic activity centers. This type of service could be introduced as part of a different long-range vision for regional rail service. Investment in rail infrastructure capacity and rolling stock would be required to support this kind of service. A business case would need to be made for the ridership and economic benefits of such service, in relation to the costs, for travel markets that are quite small today.

Summary

The Suburb-to-Suburb and Regional Metro concepts would have difficult technical and institutional challenges to overcome, such as achieving rolling stock, train control, and traction power compatibility; addressing variations in train length and passenger loads by branch; negotiating labor agreements and interagency agreements with respect to operations; cost and revenue allocation; revenue collection; liability; and customer service responsibility. The following table identifies key benefits and challenges for the two primary service concepts.

Table C-5

Summary of Through Running Concepts

Concept of Operations	Benefits	Challenges
1. Suburb-to-Suburb	Reduces turnback and conflicting train movements at Penn Station	- Small travel market served - High cost and difficulty to achieve interoperability
2. Regional Metro	- Brings metro-style service to underserved areas - Significant travel market - Potential to relieve parallel transit corridors	- Requires a whole new operating concept for the NY region - Substantial cost and difficulty to achieve interoperability on inner portions of rail network

Appendix D Penn Expansion Configuration and Operations

The Penn Expansion project could be designed to accommodate future through-running. Design implications would begin with the depth of the new tracks, to ensure feasibility of future through-running. The depth of the 6th Avenue subway line is the most significant obstacle, and at least some of the new tracks would have to be sufficiently deep to eventually pass under that subway line heading east from Penn Station.

If the long-term plan for operation of the new Hudson Tunnel and a new tunnel to the east of Penn Station was for transit-style through-running, Penn Expansion must include wide platforms to permit pre-staging of boarding passengers on the platform and minimize dwell times. With each tunnel track feeding two station tracks in each direction, and trains alternating between the two tracks, service patterns at the station would be regular, and crossing train movements could be eliminated.

Penn Expansion's design should include a minimum of four station tracks (two pairs of tracks, each serving an island platform) for long-term connection with the future fifth and sixth East River Tunnel tracks.

Dwell times of 3 minutes (with 2 minutes clear time before the next train arrival) would yield throughput of 24 trains per hour per direction. The 3-minute dwell would provide about 2 minutes for passenger boarding/alighting in the peak direction and another one minute or so for a smaller number of passengers in the reverse-peak direction.

Although dwell times of 2 minutes would allow throughput of 30 trains per hour, this would leave little room for recovery in the event of delayed trains or extended dwells driven by passenger incidents, equipment failures, or very large train loads. The fifth run-through track at Penn Expansion would help mitigate such delays. The practical capacity of the through-running system, therefore, should range somewhere between 24 and 30 trains per hour. A reasonably conservative assumption for station planning purposes would be to estimate ridership volumes associated with a long-term future run-through operation at Penn Expansion of 28 trains per hour in each direction.

To fully take advantage of a future through-running system of new Hudson and East River tunnels served by platforms at Penn Expansion sized to handle bi-directional peak passenger flows, the network compatibility challenges described earlier in this paper would need to be resolved. Challenges include rolling stock/ rail systems compatibility, including clearances, platform boarding heights, power supply, cab signal compatibility, signal design safe braking distance compatibility, and PTC compatibility; variations in train length and passenger loads by branch (e.g., avoiding unproductive car-miles because one leg of the through-running does not fully subscribe the train capacity required to satisfy ridership demand on the other leg); labor agreements; institutional agreements with respect to operations, cost and revenue allocation, liability, police force jurisdiction and customer service responsibility; and fare structure including harmonization of 10-trip, weekly, monthly, senior, student, and many other fare types, as well as fare media (traditional paper tickets, ticket vending machine tickets, electronic tickets) and joint ticketing (NICE Bus etc.).

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WHITE PAPER

Through-Running

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