2

Planning for Regional Connectivity

Two imperatives drive the need for major investment at Penn Station:

1. The need for capacity to support future increases in rail traffic as the Gateway Program is implemented.

2. The opportunity to lay the groundwork for the future implementation of cross-regional service if the railroads and planning bodies determine that there is market demand for this type of service.

The existing station is not equipped to meet either need.

Other global cities have faced the same imperatives and have successfully implemented major investment programs to re-shape their rail networks to better serve regional travel demand and greatly increase the capacity of existing urban core stations. Case studies from Paris, London, Munich, Toronto, and Philadelphia are presented in this chapter and offer insights and guidance for the planning of similar investments at Penn Station.

In each of these example cities, new, purpose-built rail infrastructure was (or will be) created in the urban core and major core stations were (or will be) expanded to introduce what is typically referred to as regional metro service in a targeted portion of the region. This new service model in each city leverages a different combination of new routes and legacy rail lines, modified to be interoperable.

When designed well, dedicated facilities in the urban/suburban core of a metropolitan area, coupled with appropriate rolling stock, allow regional metro service to operate like transit, with uniform train performance and smooth train flow. Platforms in urban core station expansions can be designed with ample space and circulation capacity to permit rapid unloading and loading of trains. Shorter regional branch lines can be entirely converted to this type of service. Longer branch lines need to be configured to accommodate this new service type close to the urban core while still maintaining traditional commuter service from farther out on those routes to the city center. Intercity and international train service must be maintained as well.

Amtrak, MTA, and NJ TRANSIT have long understood the benefits of cross-regional rail service and support its development. All parties recognize the potential for bringing to the New York region the kind of cross-regional service that the passenger rail networks provide in Paris, London, Berlin, Munich, Leipzig, Madrid, Stockholm, Sydney, and elsewhere.

A solution that has been proposed by advocacy groups to both increase capacity and enable cross-regional service is an all-through-running regime at Penn Station. Responding to this suggestion, two variations of an alternative along those lines have been evaluated in this study.

Intercity and international (Canada) rail service will need to remain at Penn Station, as will long-distance suburban commuter services. The key to achieving smooth, high-capacity operations at Penn Station in the future is to keep regional metro services separate from legacy commuter and intercity rail services through the urban core. These different train types have very different performance characteristics and do not mix well on shared tracks. If the services were mixed on the same tracks, the regional metro service would not be able to achieve the transit-style close spacing (short headways) and high level of reliability that make it successful in the case studies in this chapter.

This chapter summarizes potential through-running regimes and a regional metro service model that best leverages the benefits of through-running at Penn Station. It considers the characteristics of the New York regional rail network and international best practices to paint a picture of what through-running regional metro service could look like in the New York metropolitan region.

Section 2.1

Key Terms and Concepts

The following key terms used in this document clarify the concepts that have been analyzed and evaluated:

Timetable-based Service

Timetable-based service is an operational regime where trains operate on a fixed schedule, with specified arrival and departure times. Timetable-based service generally is used on routes with longer intervals between trains than is typical on rail transit systems, such as intercity and commuter systems. Longer commuter and intercity routes operate on timetables and require longer dwell times at stations, especially major hub stations, because the dwell time incorporates recovery time allowances so that trains can usually depart on time, even if the train arrives at the station behind schedule. Current Amtrak, NJ TRANSIT, and LIRR service at Penn Station is entirely timetable-based.

Headway-based Service

Headway-based service is an operational regime where service is frequent enough, to regular destinations, that passengers do not need to consult a timetable in advance of traveling — they can just show up and catch the next train. The frequency is governed by the time (headway) between trains, similar to the service provided by the New York City subways or PATH. Systems with this service model typically have a limited number of routes and similar train stopping patterns, resulting in short dwell times at stations, without the need to build scheduled recovery time into timetables.

Dwell Time

The time spent by a train stationed at the platform is referred to as dwell time. It is controlled by a number of factors including:

- The time it takes for passengers to alight and/or board the rail cars (which itself depends on how many doors each car has, how wide the doors are, and how long it takes passengers to reach the doors from their seats, or vice-versa);
- Time required for the platform to clear, before it is safe to move the train out of the station;
- Time required for train support services such as crew changes, replenishment of food service cars, and baggage handling; and
- Recovery time that allows a train to leave on schedule if it arrives somewhat behind schedule.

Different types of service have different controlling factors and therefore require different dwell times.

Platform Reoccupation Time

The time that elapses between when a train arrives at a station track and the time that the next train arrives at the same platform track is referred to as platform reoccupation time. It is the sum of the dwell time, the time it takes the train to move through switches or interlockings on either or both ends of the station, the time required to throw switches to line a train up with its route through the station complex, plus a buffer time to ensure safe and reliable operations. The peak hour throughput capacity of a station is a function of the number of station tracks and the platform reoccupation time on each track.

Turnback Operation

Turnback service is an operational regime where trains reverse direction in the station and return in the direction from which they arrived. This operational regime is how a terminal station operates because all trains end their routes at the station. 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). Trains that turn back typically need a longer time on a platform track.

Intercity Rail

Intercity rail is the service currently provided by Amtrak at Penn Station. Trains cover longer distances, often several hundred miles, and operate on a fixed timetable. Passengers can include regular travelers but often include people less familiar with the station and train service than regular commuters. Amtrak actually operates three types of intercity service, each with different train-equipment and operational characteristics. Acela trains provide a premium fast service in the NEC. Northeast Regional, Keystone Corridor, and Empire Corridor trains offer regular service, and a handful of long-distance trains provide overnight service to the southern United States and Chicago and daytime service to Canada.

Commuter Rail

Commuter rail is the type of train service that the Long Island Rail Road and NJ TRANSIT operate to and from Penn Station. This service focuses on weekday peak travel between suburbs and the Manhattan central business district. Rail service is provided in both directions of travel, but the peak service patterns, fleets of train equipment, and station and yard facilities are all highly customized to maximize the number of passengers and trains that can be delivered to Penn Station during the weekday morning peak period and from Penn Station during the weekday evening peak period.

Cross-Regional Rail

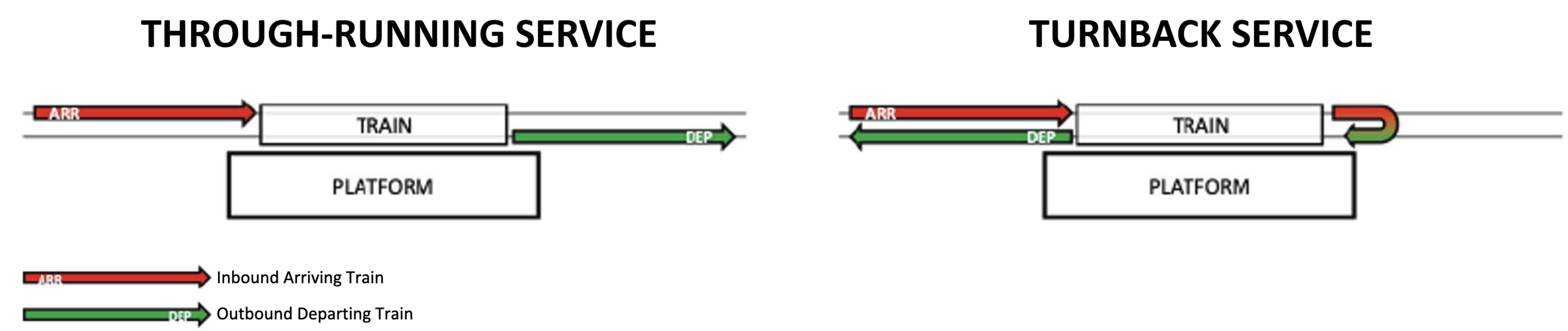
Cross-regional rail is a general term for any system providing service that connects communities and business centers to an urban center and to each other in a greater metropolitan region. Its focus is on providing regular, all-day bidirectional service among multiple origins and destinations, serving multiple travel purposes. Trains operate in highly predictable patterns at regular, repeating intervals, either timetable-based or headway-based. While cross-regional rail can provide more service during the weekday peak periods and can support the type of limited-stop express service that is common in the New York region, this peak service is not provided at the expense of the regular service patterns. Implementing cross-regional rail in the New York metropolitan region implies a greater level of service integration and coordination among the three existing commuter rail operators (LIRR, NJ TRANSIT, and Metro-North) and with Amtrak, but it does not necessarily require the merging of the railroads.

Regional Metro

Regional metro is a specific service concept for cross-regional rail. It is characterized by frequent, transit-style service (headways of 15 minutes or less) connecting urban and inner-suburban communities to each other, as well as to a city center. Regional metro systems rely on running trains through major stations in urban centers to connect communities on opposite sides of the urban center to each other. This type of service supplements conventional intercity and commuter service on an inner portion of a regional rail network that is configured to accommodate it, and where markets can support it, but does not replace the conventional intercity and commuter services that are so essential to their regional economies.

It entails the provision of subway-like service covering areas along existing railroad lines that are beyond the reach of the subway. Service is generally headway-based as opposed to timetable-based. As examples, existing commuter rail in the New York region is timetable-based, while subway service is headway-based.

Regional metro most often comprises a system of one or more trunk lines, fed at each end by multiple short-haul branch lines that feed into the trunk line. Generally, all trains operating along a regional metro trunk line make all local stops along the line, resulting in uniform and relatively simple operating patterns.



Suburban Rail Service

Suburban rail service serves longer-distance travel markets, for trips generally greater than 25 miles, on the rail network surrounding a large central city. These trains connect suburban and exurban communities with the central business district, and the largest volumes of passengers tend to be weekday commuters. Service frequency typically is less than regional metro, with trains operating on fixed timetables rather than headway-based. During peak periods, limited-stop express service may be offered in urban core areas with four-track systems where demand is sufficient, to provide faster trip times than can be achieved with all-stop local service.

Suburban service complements regional metro service. Regional metro and suburban service together could serve as a future replacement for traditional commuter rail in a future vision for a cross-regional rail network.

Through-running Operation

Although through-running is often used as a catch-all name for cross-regional service, it is actually an operational regime rather than a service type. It relates to the way trains move through a major station and the length of time they require when occupying platform tracks at the station. Through-running trains maintain their direction of movement through the station. It can be as simple as arriving at a major station in a city center in revenue service, dropping off their passengers, then running through in non-revenue service (without passengers) to a storage yard on the opposite side of the station, where it lays up until it is needed for the reverse movement back to its station of origin. This is called revenue-to-non-revenue or drop-and-go operation. Its main advantage is increasing train throughput capacity (i.e., the number of trains that can use the station in a given peak period). Alternatively, through-running can be used to connect destinations on opposite sides of the station to each other (revenue-to-revenue service), as well as increasing throughput. The term is generally applied to major stations that deliver high-density service, where the station tracks are connected to the rail network at both ends.

There are several potential benefits of through-running service:

- Improving the efficiency and reliability of train operations.
- Enabling growth in the volume of train movements that the station can serve during peak periods.
- Providing service to potential ridership markets beyond traditional journey-to-work commuting from suburbs to the central business district.
- Enabling a type of rail service and mode of train operation that has proven to be successful in many cities around the world, including London, Paris, and Munich.

Section 2.2

Existing Operations and Service at Penn Station

Regional Rail Network and Service Characteristics

The network of passenger rail lines feeding New York City is sprawling and extensive. Passenger service is provided on a total of nine branch lines in northern and mid-New Jersey, of which six currently offer some amount of direct service to Penn Station. When the Gateway Program is completed, direct service will be provided to all nine branches. The LIRR operates service to Penn Station from ten branch lines. During peak periods, express train service is offered from both New Jersey and Long Island from groups of stations along the major routes and branch lines, significantly increasing the number of discrete service patterns operated to and from Penn Station. **Table 2-1** summarizes existing branches, route lengths, and number of stations served on each branch in the existing regional network.

The major commuter rail lines in the greater New York region extend 40 to 60 miles from Penn Station in Manhattan, to places such as Trenton, Long Branch, and Dover in New Jersey and Ronkonkoma, Port Jefferson, and Babylon on Long Island. Several branch lines, however, extend for 100 miles or longer, to places like Montauk and Greenport on Long Island and Port Jervis on the west side of the Hudson River.

The Amtrak NEC Line operates as an integral part of the New York metropolitan region network, with intercity trains sharing tracks with commuter trains at Penn Station and along virtually the entire length of the corridor in New Jersey, New York, and Connecticut. The Amtrak Empire Corridor that runs along the east bank of the Hudson River also terminates at Penn Station and hosts Amtrak service to upstate New York and Vermont and daily long-distance trains to Chicago, Toronto, and Montreal. The degree of overlap between intercity and commuter tracks and infrastructure is also greater than that found in most regional rail networks around the world.

Amtrak operates three different types of trains on the NEC, each with different operational characteristics:

- Acela premium express service
- Regular intercity service, including Northeast Regional trains to Boston, Springfield, MA, Washington, D.C., and Virginia, as well as service to Vermont, North Carolina, Harrisburg, PA, and western Pennsylvania
- Long-distance service, including overnight trains to Florida, New Orleans, and Chicago

Travel demand patterns and travel markets in the greater New York region include local travel within New York City and the close-in suburbs, suburb-to-city travel markets, suburb-to-suburb travel markets (which are very small in magnitude compared with commuting to Manhattan), and intercity travel markets.

Table 2-1

Commuter Rail Network Feeding Penn Station

Existing Services

Railroad	Branch	Terminal Station	Distance from Penn Station (Miles)	Total Number of Stations on Route	Number of Stations on Branch
NJ TRANSIT	Northeast Corridor	Trenton	58	16	16
	North Jersey Coast Line	Bay Head	66	27	20
	Morris & Essex Line	Dover	43	20	19
	Gladstone Branch	Gladstone	45	24	12
	Montclair-Boonton Line	Montclair State Univ.	17	12	10
LIRR	Main Line	Ronkonkoma	47	24	8
	Port Washington Branch	Port Washington	20	14	12
	Port Jefferson Branch	Port Jefferson	59	26	10
	Babylon Branch	Babylon	39	23	13
	Montauk Branch	Montauk	121	34	16
	Oyster Bay Branch	Oyster Bay	35	23	10
	Hempstead Branch	Hempstead	21	15	5
	West Hempstead Branch	West Hempstead	23	12	5
	Long Beach Branch	Long Beach	25	15	6
	Far Rockaway Branch	Far Rockaway	23	16	7

Potential Future Services at Penn Station

Railroad	Branch	Terminal Station	Distance from Penn Station (Miles)	Total Number of Stations on Route	Number of Stations on Branch
NJ TRANSIT	Raritan Valley Line	High Bridge	56	20	18
	Montclair-Boonton Line	Hackettstown	62	26	14
	Main Line	Suffern	32	17	16
	Bergen County Line	Suffern	31	16	15
	Pascack Valley Line	Spring Valley	36	17	16
	Port Jervis Line	Port Jervis	96	24	8
LIRR	Main Line East	Greenport	97	30	14
	Rockaway Beach Branch	JFK Airport	14	7	5
Metro-North	New Haven Line	New Haven	75	31	31
	Hudson Line	Croton-Harmon	33	14	14

Hybrid Through-Running and Turnback Operations

Penn Station supports both through-running and turnback service. The station operates in a hybrid mode, with some trains running through the station and others turning (reversing direction) at the platform. Amtrak trains generally run through the station. Acela and Northeast Regional trains that run between Boston and Washington drop off and pick up passengers at Penn Station. Amtrak trains that originate or terminate in New York also operate through the station, since these trains generally serve the Northeast Corridor to the south of New York or the Empire Corridor, but the trains are stored and serviced at Amtrak's Sunnyside Yard in Queens.

Some LIRR and NJ TRANSIT trains drop-and-go at Penn Station (a form of through-running), with LIRR trains continuing through to the west side storage yard in Manhattan and NJ TRANSIT trains continuing through the East River Tunnel to Sunnyside Yard in Queens. Other LIRR and NJ TRANSIT trains turn back at the Penn Station platforms.

The existing hybrid operation is depicted in **Figure 2-1**. Roughly 52 percent of all peak period trains run through the station in revenue-to-revenue service (Amtrak NEC service) or drop-and-go service (LIRR, NJ TRANSIT and Amtrak originating/terminating trains). The remainder of peak period trains engage in turnback operations at the station (LIRR and NJ TRANSIT).

Turning at the station causes conflicts when inbound and outbound trains must 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.

All Amtrak, NJ TRANSIT, and LIRR service at Penn Station operates on a fixed timetable. Given the complexity of the rail network feeding Penn Station and relatively long distances traversed by both intercity and suburban services, extra time is built into scheduled train dwell times at Penn Station to allow for recovery from modest delays to arriving trains — increasing the likelihood that departing trains leave the station on time, even in cases where the inbound train has been delayed. These recovery time allowances lengthen train dwell times and consume train throughput capacity — one of the factors constraining the overall capacity of the station complex.

Penn Station also hosts multiple types and styles of train service, with variable train operating and passenger behavior characteristics based on the type of service. This includes all three types of Amtrak intercity service, plus commuter rail service to both New Jersey and Long Island. (It also will include Metro-North commuter rail service to the East Bronx, Westchester, and Connecticut in the future.)

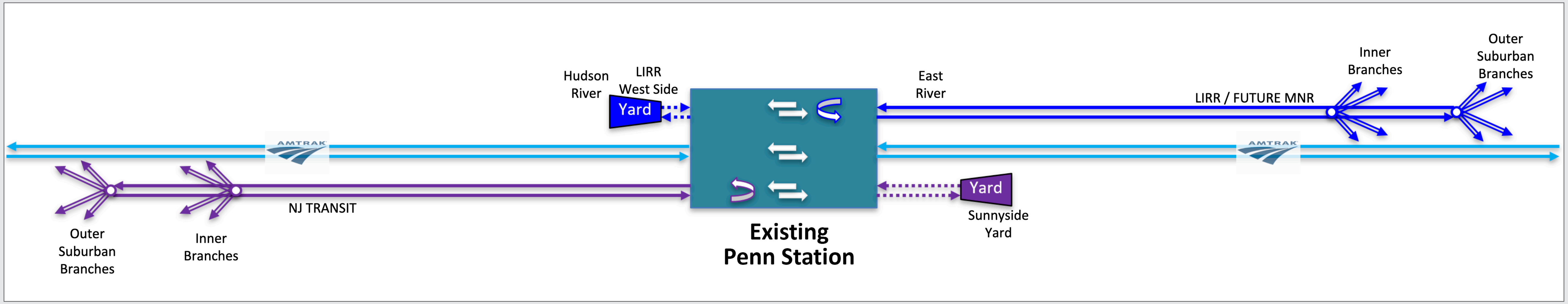
Amtrak trains tend to occupy the platforms at Penn Station for longer periods of time than commuter trains, due to allowing recovery time, a variety of train-servicing and passenger-handling functions that occur at the station, and the physical characteristics of the coaches and platforms. Most Amtrak trains offer food and beverage service, and the food service cars are re-stocked while the train is stopped at the platform in New York. In addition, the train crews change at New York for most Amtrak trains that run through the station, because of the length of the trips that these trains take. A new engineer and conductors typically board the train once it arrives and must run through a set of procedures to prepare the train for departure. Amtrak long-distance trains offer sleeping and dining car service and offer checked baggage service, so baggage needs to be unloaded and loaded onto these trains while they sit at the platform. Amtrak Intercity coaches are not configured for rapid alighting and boarding, with only two door locations at the ends of the coaches that are shared with the adjacent coaches.

Amtrak Acela trains are faster than Amtrak Regional trains, so they overtake Regional trains on a regular schedule. These overtakes are accommodated at Penn Station, the mid-point of the NEC, as well as at Philadelphia and New Haven, the quarter-points. Regional trains arrive at Penn Station first, followed by Acelas. The Regional trains are held in the station until the Acela has boarded and alighted passengers, handled baggage, re-stocked the cafe car, changed crews, and continued on. These overtakes will occur twice an hour during peak travel periods once Gateway is complete, consuming considerable time at four platforms, since the overtakes occur roughly simultaneously in both directions.

Finally, the platforms at Penn Station are too narrow to accommodate alighting and boarding passengers simultaneously, so boarding passengers are held in the station concourses until alighting passengers have cleared the platforms. These factors combine to generate relatively long dwell times for Amtrak trains at Penn Station.

Figure 2-1

Current Hybrid Operations at Penn Station



Penn Station does not operate as a monolithic station with universal access to every station track from all tunnel tracks. It operates instead as a system of zones, where groups of platform tracks are served by various combinations of routes to and from the tunnels feeding the station. These platform track groupings change by time of day, based on the specific schedules for each train operator and the types of trains that are operated. The following operational zones and their associated station- and tunnel-track connections, shown in **Figure 2-2**, indicate how Penn Station is used during weekday peak periods:

- East River Tunnel Line No. 3 and No. 4 — feeding station Tracks 16 through 21 (exclusively LIRR)
- East River Tunnel Line No. 1 and No. 2 connected to existing North River Tunnel — via station Tracks 5 through 16 (Amtrak trains and NJ TRANSIT trains running to or from midday storage at Sunnyside Yard in Queens; also includes LIRR trains during weekday peak periods)
- North River Tunnel — feeding stub-ended Tracks 1 through 4 (NJ TRANSIT turnback operations)
- Empire Tunnel — feeding Tracks 1 through 9 (Amtrak Empire Corridor service)
- West Side Yard — feeding station Tracks 13 through 21 (LIRR trains that run through to/from West Side Yard storage)

The station complex includes several major and minor storage yards and maintenance facilities, also identified in **Figure 2-2**:

- West Side Yard — LIRR
- Sunnyside Yard — Amtrak and NJ TRANSIT
- Penn Station Yards A, C, D, and E — in the southwest and northwest quadrants of the station superblock

Penn Station, therefore, has both a mix of train types with a wide range of performance characteristics, and a complicated operation that mixes these different types of trains together in different ways at different times of day.

Regional Metro Concept Overview

Regional metro service provides subway-like service over portions of the regional railroad network — effectively extending the reach of the rapid transit network to outer portions of the city and the inner suburbs. It provides high-quality transit-style service on a compact network that is relatively simple in design and reliable in operation. Key network characteristics include:

- All-stop service
- Limited number of branches
- Limited branch length

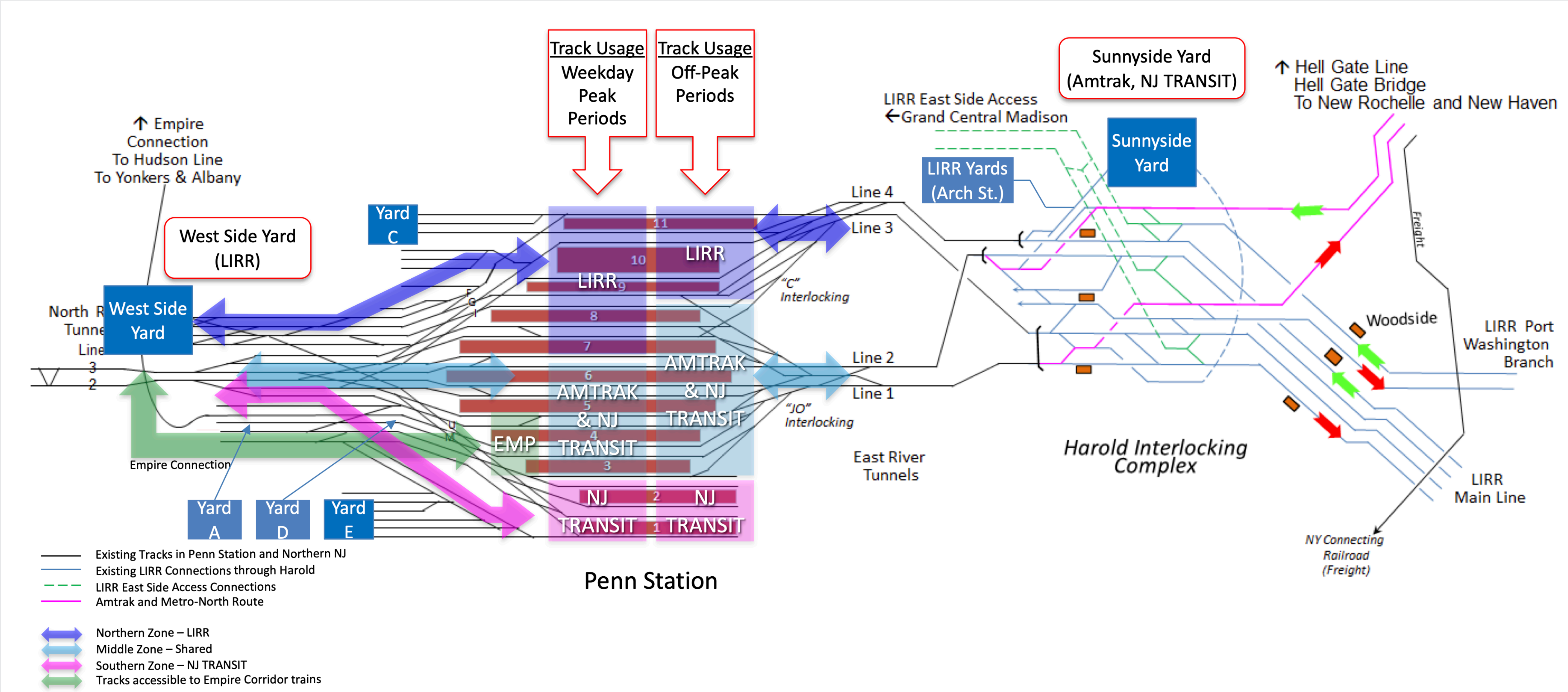
Regional metro service is headway-based, so that passengers do not need to consult timetables to ride the service. This also enables shorter dwell times at line stations since schedule recovery time generally is not needed. A typical regional metro service might include branch lines operating on 15-minute peak headways on each branch, with a total of six branches feeding a common trunk line operating at 24 tph. Or the network could comprise four branches feeding the trunk line, with ten-minute peak headways on each branch, delivering the same 24 tph on the trunk line.

Regional metro service works best with train equipment of uniform or similar performance characteristics, including similar acceleration and deceleration rates and interior layouts with large doors and vestibules for rapid alighting and boarding.

This type of service requires through-running on a central trunk line. At Penn Station, this potentially could be accomplished by either converting the existing station to through-running or expanding the station in a configuration that supports future through-running (the feasibility of which is documented in this report).

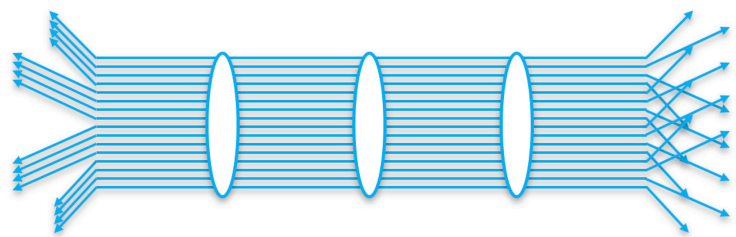
Figure 2-2

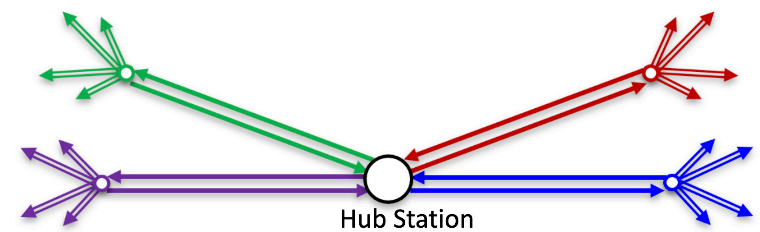
Penn Station Operational Zones and Yard Locations

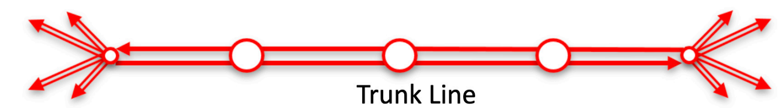


Section 2.3

Types of Cross-Regional Rail Service







Everywhere-to-Anywhere Service
Cross-regional service is sometimes mistakenly assumed to offer passengers a one-seat ride from everywhere to anywhere. This concept only works where the number of network branches is very small, and there are few examples of this type of service. The reason is simple mathematics.

The combination of the two existing North River Tunnel tracks and the two new Hudson River Tunnel tracks can process a total of 48 tph in each direction. Currently, there are ten commuter service zones (serving 9 branches) on the NJ side and 18 service zones (serving ten branches) on the NY side, generating 180 unique service patterns if every zone were connected to every other zone on the other side of the region. Given the combined tunnel capacity, and allowing for Amtrak service, each pair of service zones could be served by a single train once every four hours. This clearly would be an unacceptable way to operate rail service, but it demonstrates why one-seat everywhere-to-anywhere service is a mathematical impossibility.

Hub-and-Spoke
The most common service model for airlines, the hub-and-spoke concept has multiple lines and services converging on a central hub station. Cross-regional rail would be achieved with passenger transfers, which would be available among all rail services at the hub station. If service is frequent enough, or if service schedules are coordinated, transfers between routes at the hub station can be convenient and relatively quick. The hub station ideally would be configured to make those transfers as quick and convenient as possible. U.S. examples include Chicago Union Station, Washington Union Station, and the LIRR's Jamaica Station. Most traditional stub-ended rail terminals, such as Grand Central Terminal, Boston South Station, or Los Angeles Union Station, best support hub-and-spoke service. The existing Penn Station operates partially as a hub-and-spoke terminal in that commuters can transfer to Amtrak routes (e.g., from an LIRR train to Amtrak Empire service) or between LIRR and NJ TRANSIT routes.

Trunk-and-Branch
In this route configuration for cross-regional rail, multiple branch lines feed a trunk line that runs through the city center, serving multiple stations. Stations along the trunk line route can become major hubs and economic activity nodes, since direct one-seat-ride rail service is available to all branches from the trunk line stations. For stations on branches beyond the trunk line, direct one-seat service is provided to only one branch on the far side of the trunk line. A transfer somewhere along the trunk line is required to reach the other far-side branches. Generally, these transfers involve passengers disembarking and waiting on the same platform for a subsequent train that runs to their desired destination.

Paris, London, and Munich are examples of major cities that have implemented trunk-and-branch networks for regional metro service. Paris and London have created robust networks with multiple regional rail trunk lines. Philadelphia's Center City Connector was built to create a trunk-and-branch regional rail network. The trunk-and-branch model appears to be the most applicable to the New York region and the rail corridor that runs across Manhattan through Penn Station.

Section 2.4

Worldwide Examples and Best Practices

Numerous examples of regional rail from around the world demonstrate where legacy rail lines have been connected through the city center and where transit-style, through-running service is operated. Three successful international examples of implementing through-running service in an urban core tied to existing legacy rail networks and train stations, which offer guidance for regional metro service implementation in the New York region, include:

- Paris RER Lines B and D
- Munich S-Bahn
- London Elizabeth Line (Crossrail) and Thameslink

Philadelphia began the same process 40 years ago with the construction of a four-track trunk line under Center City with three trunk line stations. It offers an instructive example of both the potential for and challenges of re-imagining cross-regional rail service. Toronto is in the process of converting its commuter rail system into a mixed regional metro and commuter network, applying best practices from the successful European examples, and offers perhaps the most relevant guidance for the NY/NJ region.

All of these systems have similar operational, station infrastructure, and rail network characteristics, and all of them were created by constructing purpose-built, new infrastructure that supports through-running operations through the city center and at the major rail stations. They leverage existing legacy rail networks that serve a region beyond the reach of the urban rail transit network. These are not the only cities that have implemented regional metro and invested in new, dedicated, purpose-built infrastructure at major train stations to support the service. Other examples in Europe include Stockholm, Sweden, Zurich, Switzerland and Leipzig, Germany.

Several major train stations on these networks provide useful examples of how station infrastructure was modified and supplemented to support regional metro service and are discussed in the case studies:

- Gare du Nord — Paris (RER)
- Hauptbahnhof — Munich (S-Bahn)
- Ostbahnhof — Munich (S-Bahn)
- Liverpool Street Station — London (Elizabeth Line/ Crossrail)
- Paddington Station — London (Elizabeth Line/Crossrail)
- St. Pancras International Station — London (Thameslink)
- Toronto Union Station

Paris RER

The Paris RER network comprises five train lines (designated A, B, C, D, and E) that link the Paris city center to its surrounding suburbs (Figure 2-3). The RER operates in a trunk-and-branch configuration with four different trunk lines through the city center, and with several hub stations where the trunk lines interconnect. Lines A, B, C, and D run through the city center trunk lines, connecting communities and destinations on opposite sides of the city center to each other, while the E line terminates at a station in the city center, but also provides transit-style frequent service. Less than one-third of the regional rail network in the province of Ile-de-France around Paris was reformatted to create the RER system, taking over 30 years to complete. The RER includes 33 stations within the city of Paris, that are spaced farther apart than the Paris Metro, so the RER acts as an express service through the city center. Beyond the Paris city center, the RER operates along legacy rail lines, connecting outlying suburbs and popular destinations such as Charles de Gaulle Airport (RER B Line), Disneyland Paris (RER A Line), and Versailles (RER C Line) to central Paris. The network comprises 365 route-miles, 47.5 route-miles of which is underground tunnel. The RER routes extend an average of 37 miles out from the center of Paris. Passengers transfer at hub stations such as Chatelet-Les-Halles between trunk lines or to reach suburban destinations on the far side of the city center beyond the reach of the regional metro service.

The two RER lines that are most comparable to conditions in the New York region are the B and D Lines. Line B opened in 1977 and comprises 50 route miles and 47 stations. Line D opened in stages between 1987 and 1996 and includes 59 stations over 118 route miles. Line D has the greatest overlap with legacy rail lines over the longest distances. It also offers less-frequent service than Line B but also has been described as having a lower level of on-time performance, due to its greater degree of interaction with the legacy rail network.

Between Châtelet-Les Halles and Gare du Nord, the RER B and D Lines share a two-track tunnel alignment. This trunk line segment governs the capacity of the two lines. The major stations along the trunk line, however, have dedicated platform tracks for each service. This benefits passenger wayfinding and allows for shorter headways in the tunnel since the station tracks can be fed by alternating

- Regional metro operates on four trunk links through central Paris
- Trunk lines used exclusively by regional metro trains
- Regional metro service merges with suburban and intercity traffic beyond the major stations
- Regional metro tracks and platforms separate from other rail services at major stations (Gare du Nord, Gare de Lyon, Gare de l'Est)

train services. The alternating feed to multiple station platforms from the single trunk line track allows for very close train spacing (2 minutes or less) on the trunk line and sufficient dwell times at the station for passenger alighting and boarding.

The RER B and D Lines provide regional metro service (Figure 2-4). During peak periods, the B Line operates 20 tph (3-minute headway), and the D Line operates 12 tph (5-minute headway). The B Line has two branches to the south and two branches to the north. The D Line has a single branch to the north and three principal branches to the south. The northern end of the B Line operates two services at 10 tph each (6-minute headway). The southern end of the B Line operates four services at 5 tph each, including one local service on the Robinson Branch and three zone express services on the Saint-Rémy-lès-Chevreuse Branch. Line D operates three separate services at 4 tph each (15-minute headway on outer branches).

These RER lines operate with both single- and bi-level rolling stock. The trains are also equipped for dual-power electrified operations (supporting 1.5kv DC traction power on the south side of Paris and 25kv AC power on the north side).

Gare du Nord is the major rail terminal serving trains running to the north of Paris, including international services to Belgium, the Netherlands, and the United Kingdom via the Channel Tunnel. It is a stub-end terminal, used by long-distance trains as well as suburban commuter trains. All tracks in the existing rail terminal are used for intercity and suburban turnback operations. The station has been expanded several times to accommodate increased service, most recently with a modern expansion to accommodate Eurostar service to London. An entirely separate lower-level shoulder station was constructed for RER service, as shown in Figure 2-5, with four tracks and two island platforms. The RER station, which opened in 1982, is connected to the existing station concourse with escalators and elevators. The RER tracks join the railroad right-of-way to the north of the existing station throat, keeping RER operations separate from other train movements at Gare du Nord. The RER service also operates on its own tracks within the existing rail right-of-way as it heads north from central Paris.

Figure 2-3

Paris RER Regional Metro Network

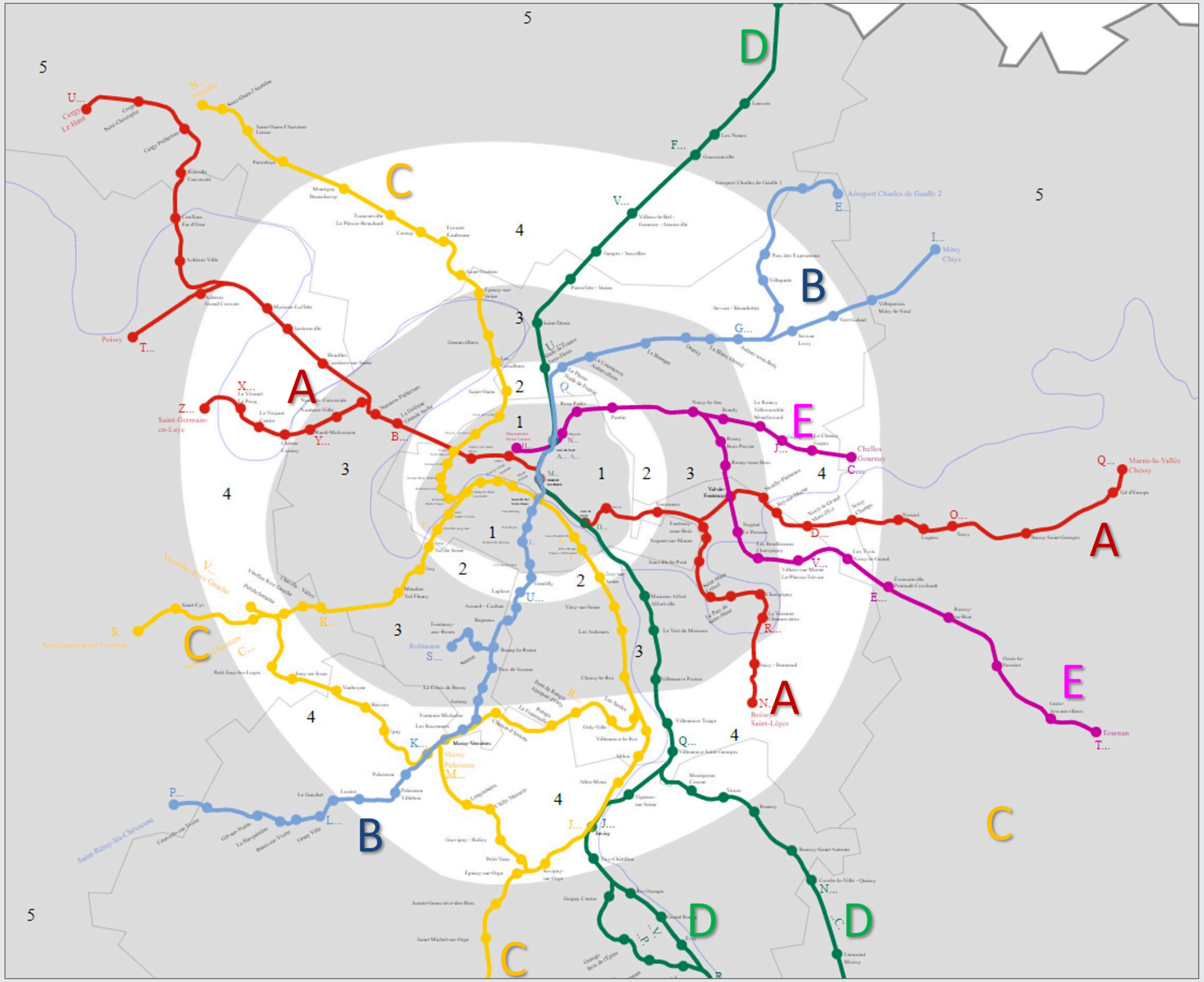


Figure 2-4
RER B and D Lines

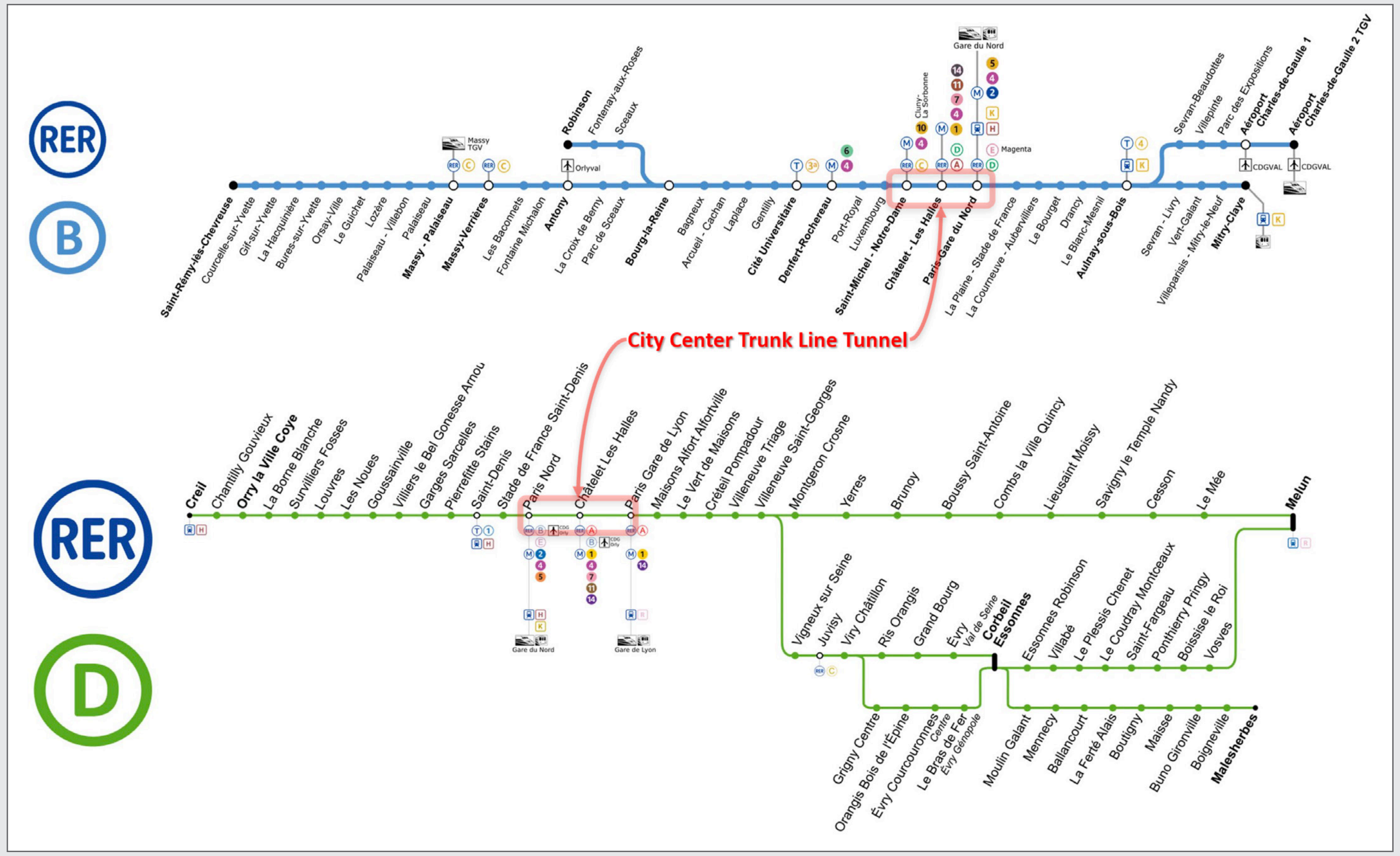
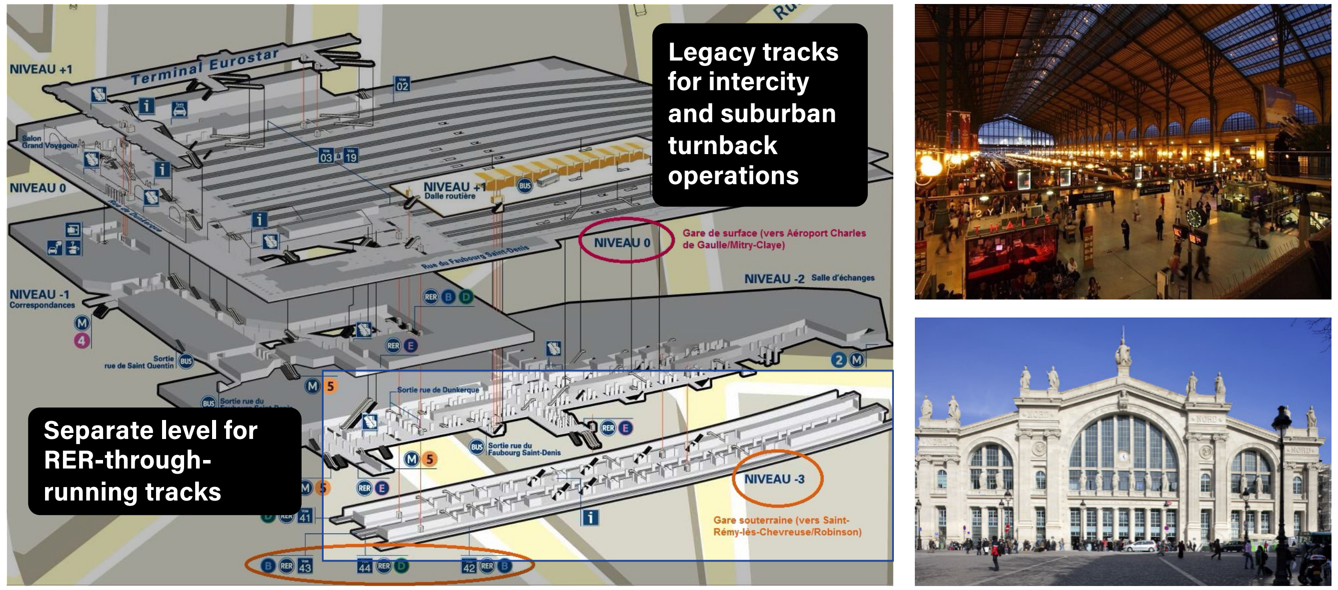


Figure 2-5
Gare du Nord - Paris



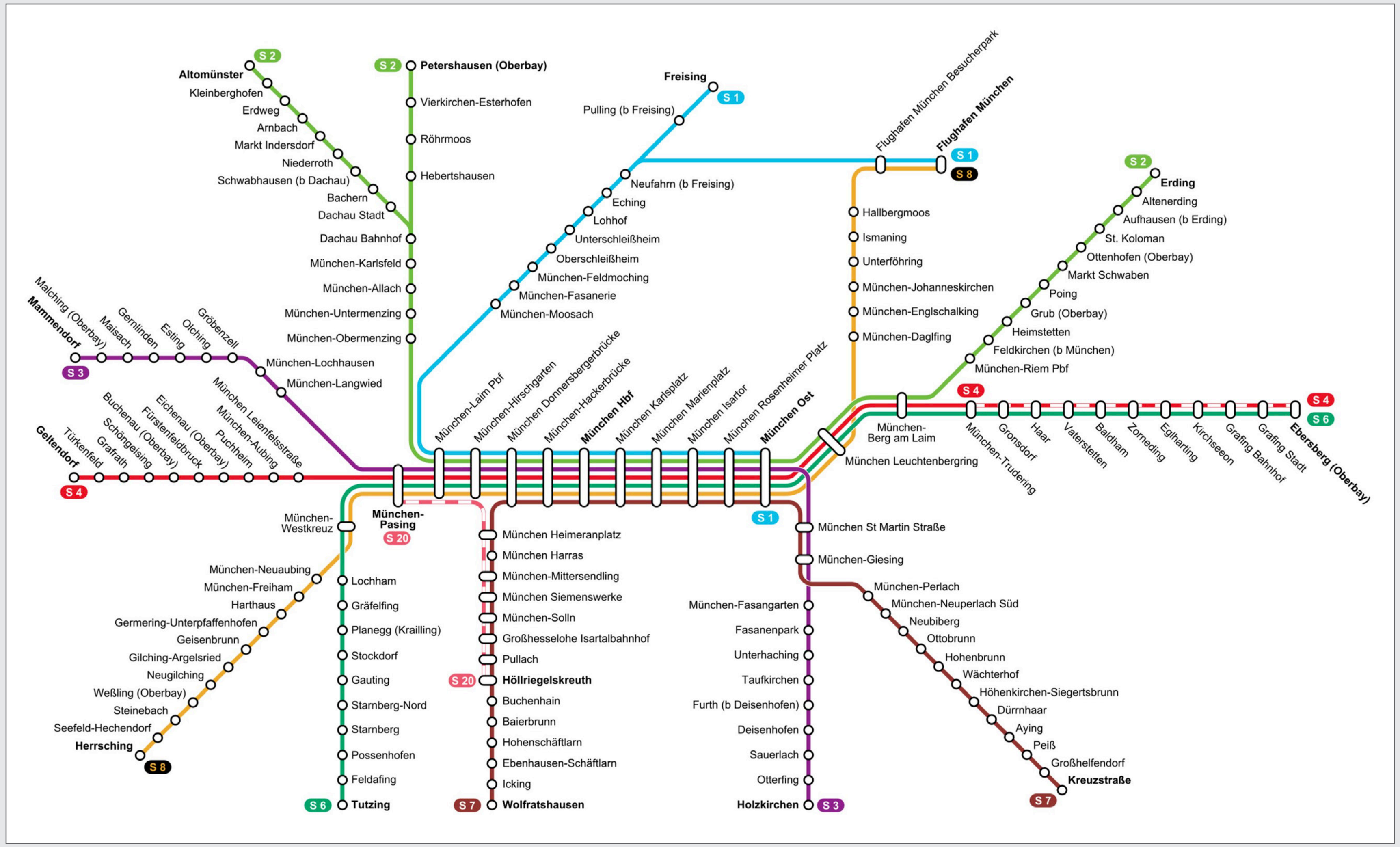
Munich S-Bahn

Munich, Germany has a well-developed regional rail network that provides extensive coverage of the region surrounding the city in the state of Bavaria. Munich has a single 7-mile-long trunk line constructed in tunnel through the city center with 10 stations, including Munich's two primary railway stations, the Hauptbahnhof (main station) and Ostbahnhof (east station). The network has eight branch lines to the west and five branch lines to the east, as shown in Figure 2-6. The S-Bahn branch lines extend an average of 35 miles out from the city center, with the shortest branch only 10 miles in length. These branch line distances are significantly shorter than the commuter rail branch lines in New York, reflecting Munich's smaller regional population of 2.7 million. The various branches were reformatted to create the S-Bahn in several stages spread out over a total of 46 years.

The Munich S-Bahn is a classic regional metro service. The base service headway on each S-Bahn route is 20 minutes (3 tph) on each branch, which generates 2½-minute headways (24 tph) on the trunk line during peak periods. All trains operate as all-stop local trains through the trunk line. Peak express service is offered on selected branches outside the urban core. Off-peak trains run with the same service patterns and in the same schedule slots as peak trains, with selected trains deleted from the off-peak schedule. This results in a highly predictable operation and simplifies train merging and diverging movements at the S-Bahn's many junctions. Passengers originating or destined for locations along the central trunk line can catch trains directly to and from every branch line in the network. Most passengers traveling between suburban locations transfer between routes at stations along the trunk line.

- Regional metro service in trunk and branch configuration
- Trunk line used exclusively by regional metro trains
- Regional metro service merges with suburban and intercity traffic beyond the major stations
- Regional metro tracks and platforms separate from other rail services at major stations (Munich Hauptbahnhof and Ostbahnhof)

Figure 2-6
Munich S-Bahn Regional Metro Network



The relationship of the S-Bahn to other rail services at the two major stations closely resembles the configuration of the RER at Gare du Nord, as shown in Figure 2-7 and Figure 2-8. S-Bahn stations are adjacent to but separate from the legacy train stations that predominantly serve other types of trains, including longer-distance suburban and intercity trains, as well as international trains. The S-Bahn station at the Hauptbahnhof was purpose-built for transit-style S-Bahn service. The S-Bahn tracks join the legacy rail lines beyond the limits of the main station platforms and throat area.

In Munich, a new parallel S-Bahn tunnel has been approved and funded, with construction scheduled to begin in 2028. The expanded trunk line capacity would allow for more frequent service on the branch lines, including the expansion of express services.

Figure 2-7
Main Train Station - Munich

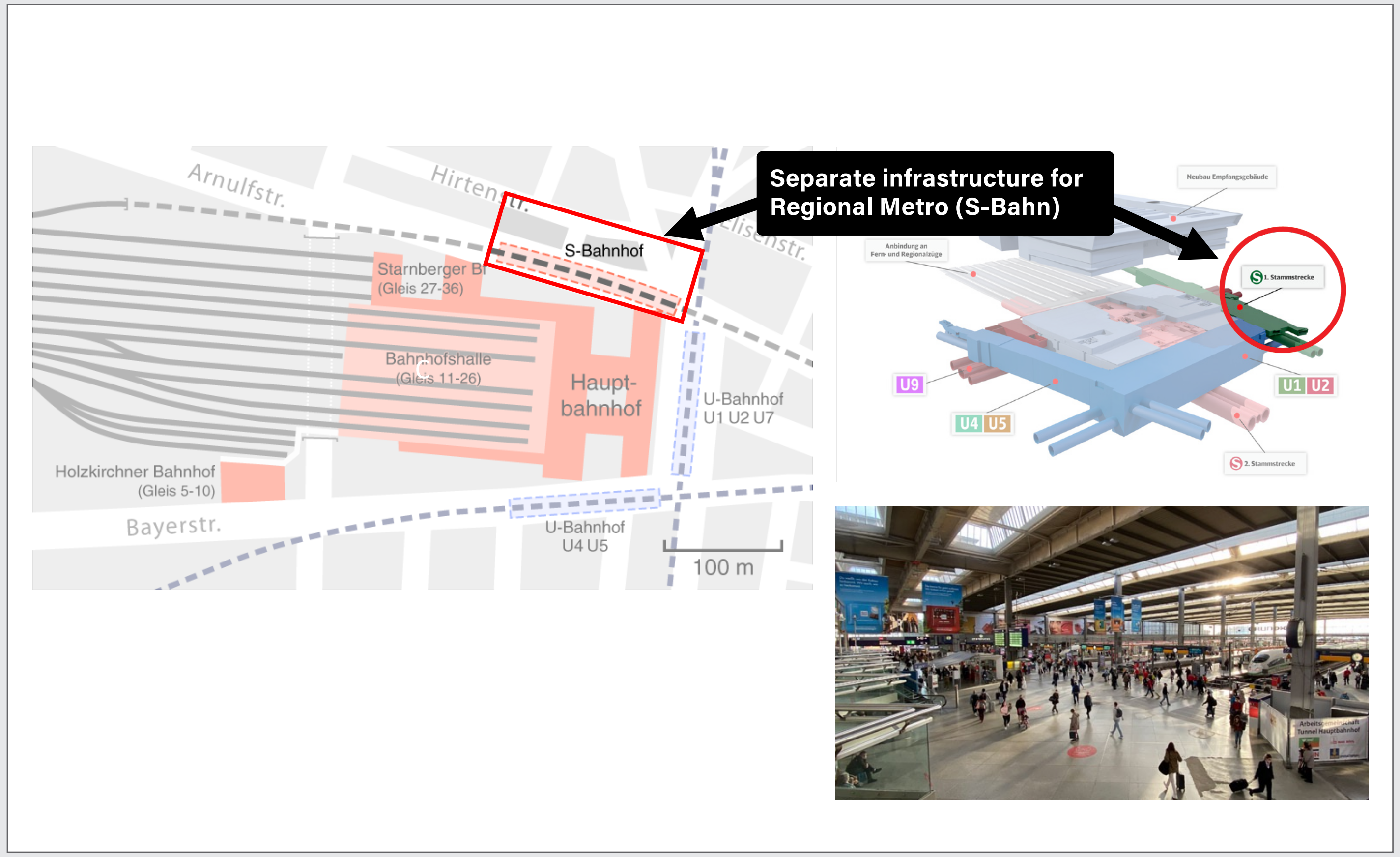
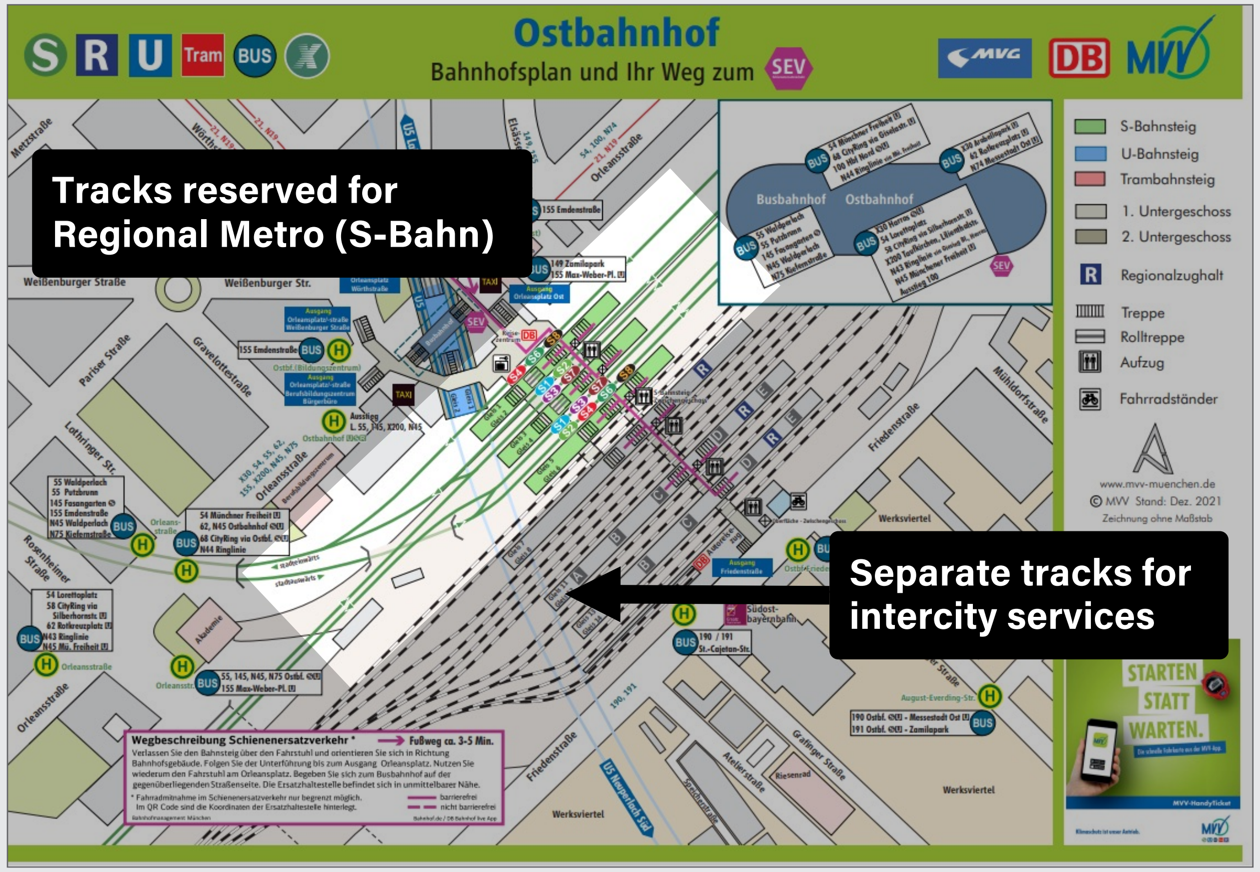


Figure 2-8
East Train Station - Munich



London Elizabeth Line (Crossrail)

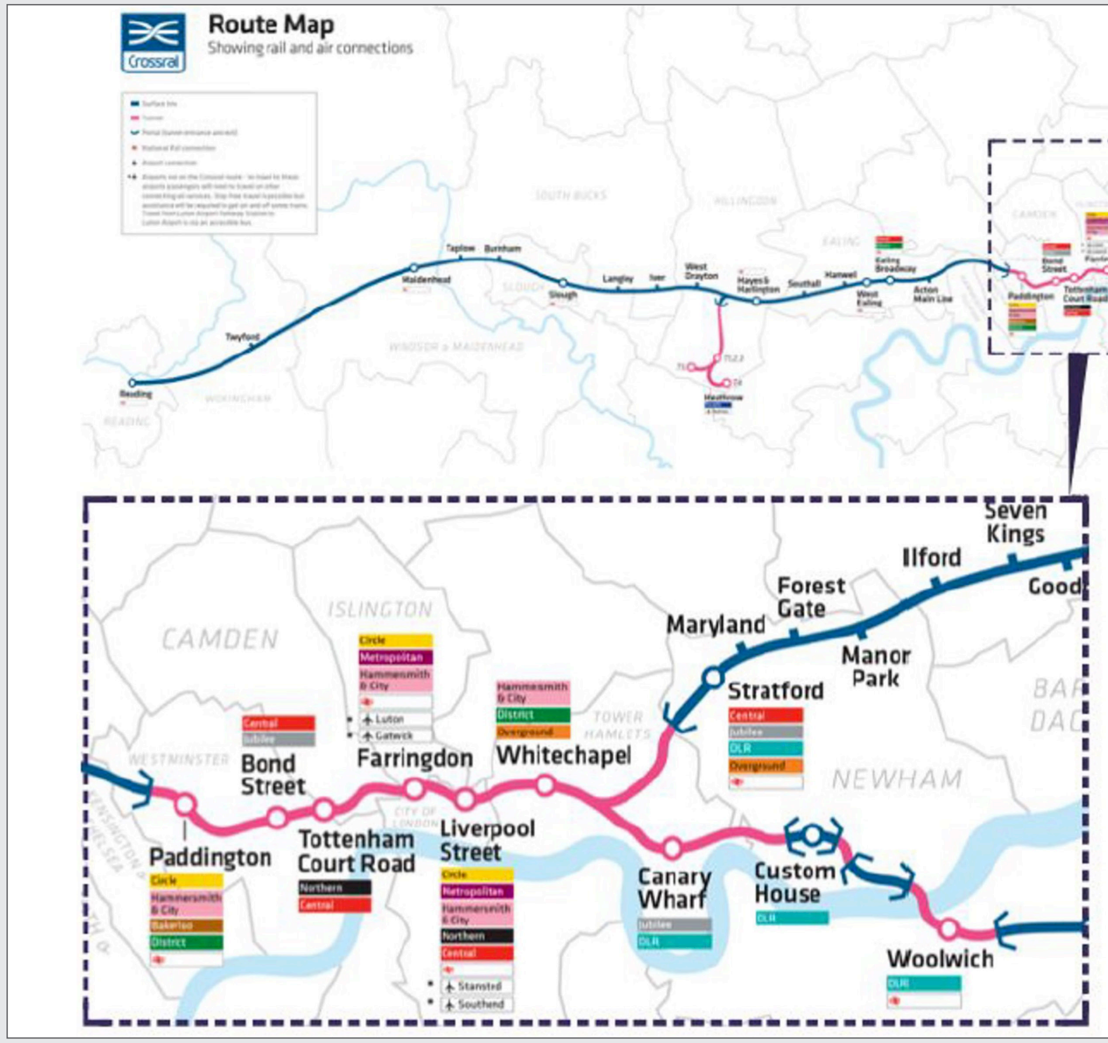
The Elizabeth Line is a regional rail service that operates on a newly opened east-west tunnel alignment through central London (Figure 2-9). Crossrail was the name of the construction program that built the new infrastructure that supports the service. The new central trunk line is used exclusively by Elizabeth Line trains, but the services operate via legacy rail lines to the west and east of central London. Two branches — Reading and Heathrow Airport to the west and Shenfield and Abbey Wood to the east — feed the trunk line on each end. The route distance from Paddington to Reading is 34 miles and from Paddington to Heathrow is 12 miles. The eastern branch distance from Liverpool Street to Shenfield is 19 miles and from Liverpool Street to Abbey Wood is 9 miles. Again, these distances are much shorter than regional commuter routes in the New York metropolitan region. It took a total of 19 years to plan, fund and construct the Elizabeth Line, though the first proposal to fund such a line dates back to 1974.

- Regional metro service in trunk and branch configuration
- Trunk line used exclusively by regional metro trains
- Regional metro tracks and platforms separate from other rail services at major stations (Paddington and Liverpool Street)

The Elizabeth Line provides regional metro service, offering rapid transit (i.e., subway-style) service. The trunk line operates at up to 24 tph during peak periods, which equates to headways averaging 2½ minutes. Several new purpose-built underground stations have been constructed along the trunk line, each with a single platform face for each direction of travel. A single operating entity provides all service, with a single rolling stock type designed for heavy passenger loading and rapid boarding and alighting. All train equipment has the same operational performance characteristics. Several stations serve central London, with multiple opportunities for transfers to and from other underground transit lines.

Figure 2-9

London Elizabeth Line Regional Metro



London's Crossrail service map.
Image Source: Crossrail.

The interface points with the legacy rail network are at Liverpool Street Station and Paddington Station, both major stub-end rail stations. Figure 2-10 and Figure 2-11 show the relationship of the new Elizabeth Line stations with the existing railway terminals. At each location, the Elizabeth Line right-of-way diverges from the legacy rail corridors before reaching the terminal interlockings and drops into a tunnel. The Elizabeth Line shoulder stations at both Paddington and Liverpool Street are located underground, adjacent to the legacy stations and readily accessible by passengers. The train operations within the Elizabeth Line shoulder stations are totally separate from the legacy train operations at the existing terminal stations. The Elizabeth Line trunk line joins the legacy rail network at junction points beyond the immediate throat of the legacy stations, simplifying operations of both the Elizabeth Line and the rail services using the legacy stations.

Figure 2-10

Liverpool Street Station - London

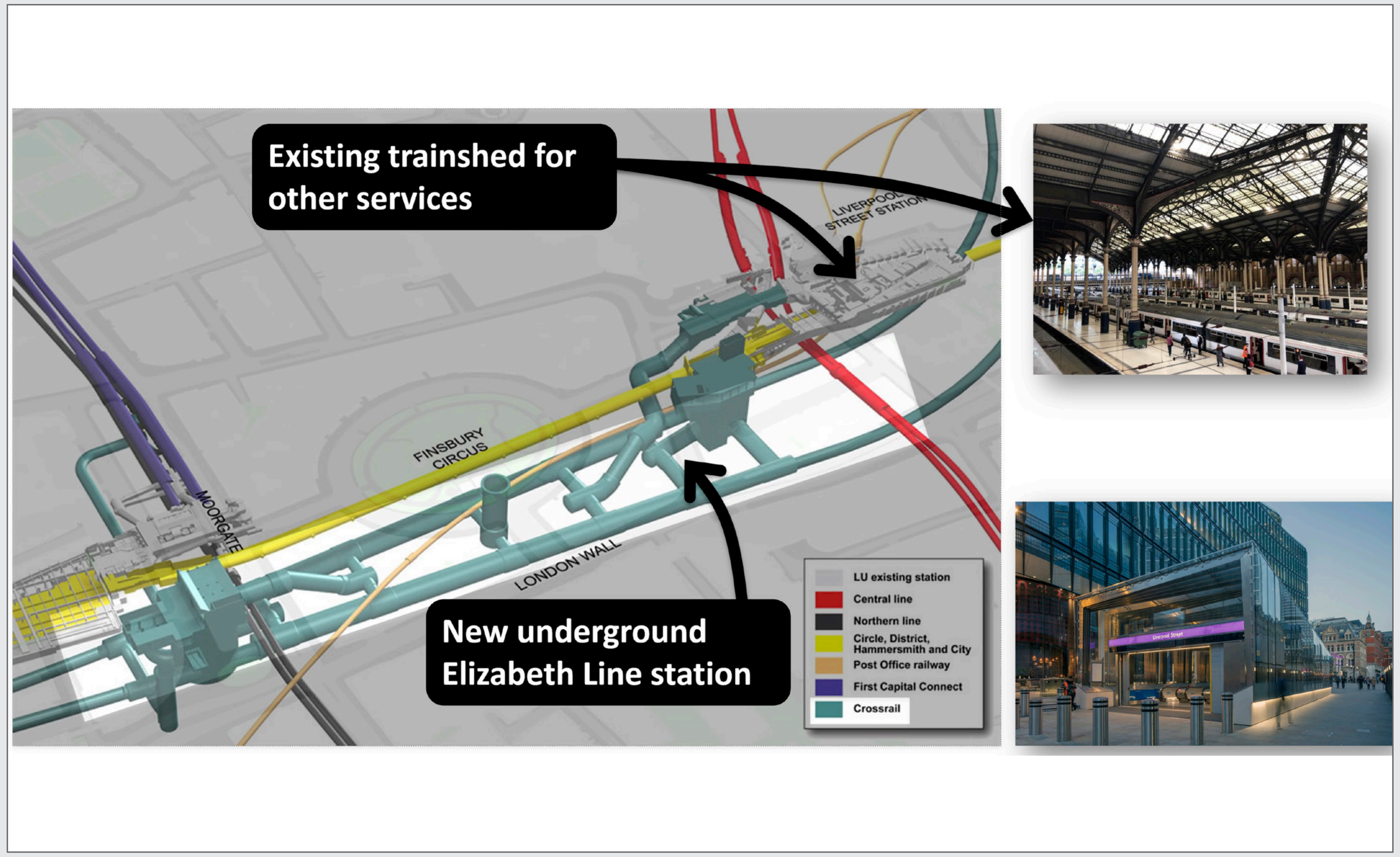
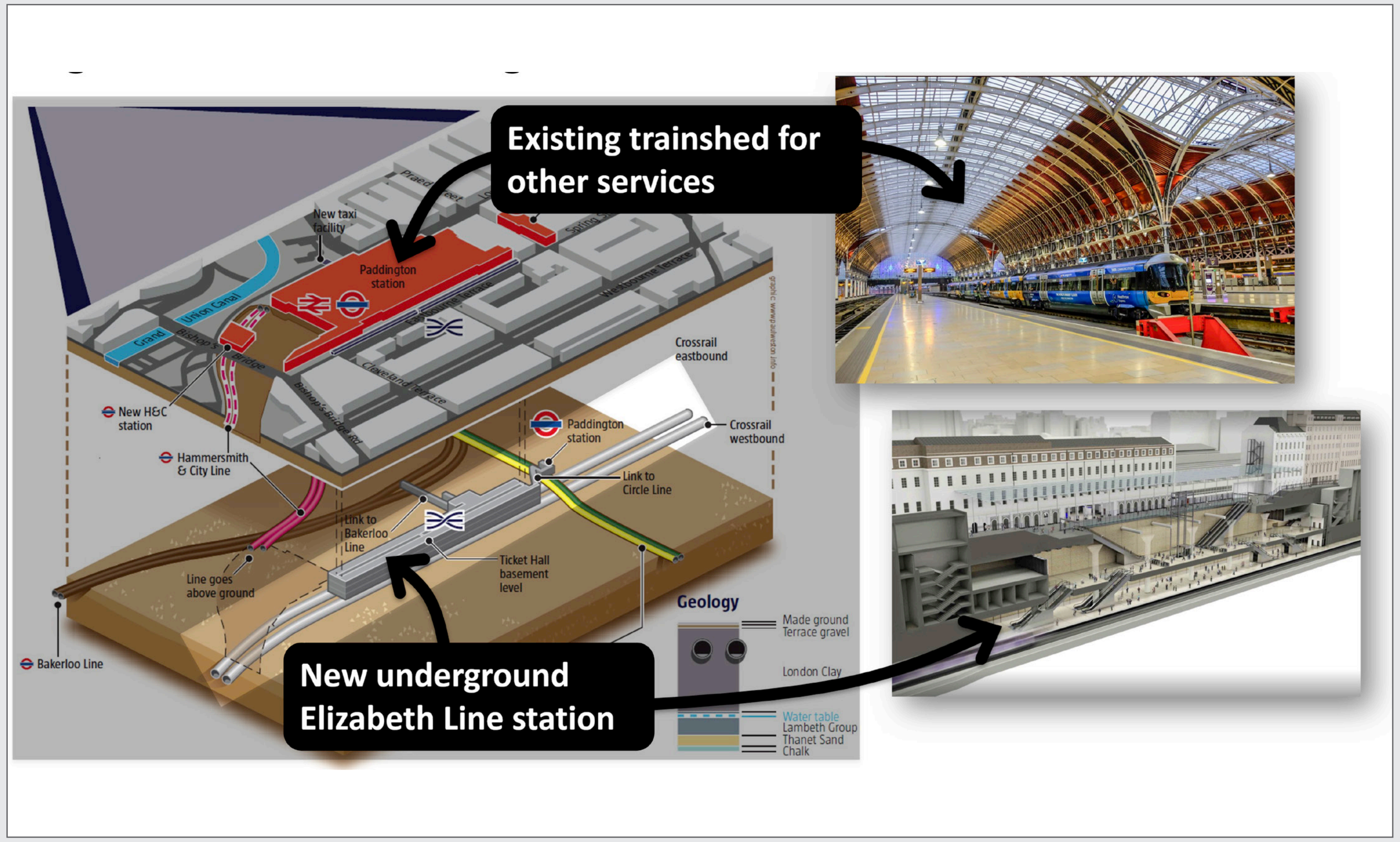


Figure 2-11

Paddington Station - London



London Thameslink

London's Thameslink is another regional north-south rail line that runs through the city center (Figure 2-12). The Thameslink network has some characteristics similar to the rail network feeding Penn Station, which makes it a useful comparison. The Thameslink route is a two-track trunk line in tunnel through central London. The common trunk line has four stations serving central London and is fed by three branch lines from the north and six branch lines from the south.

It took two decades to reformat portions of the regional rail network to create Thameslink, between the 1970s and 1990s. The initial Thamelink line proved inadequate for its ridership, and it took another decade to upgrade it to its current, much improved configuration, completed in 2018.

Less than 20% of the London regional rail network was reformatted to create Thameslink and the Elizabeth line, which intersect at Paddington Station and together form a regional metro network similar in size to those in Paris and Munich.

Thameslink provides regional metro service on the trunk line connecting close-in branch lines on the north and south sides of London. The route also handles longer-distance regional train services, which operate on a timetable at peak headways of 30 minutes.

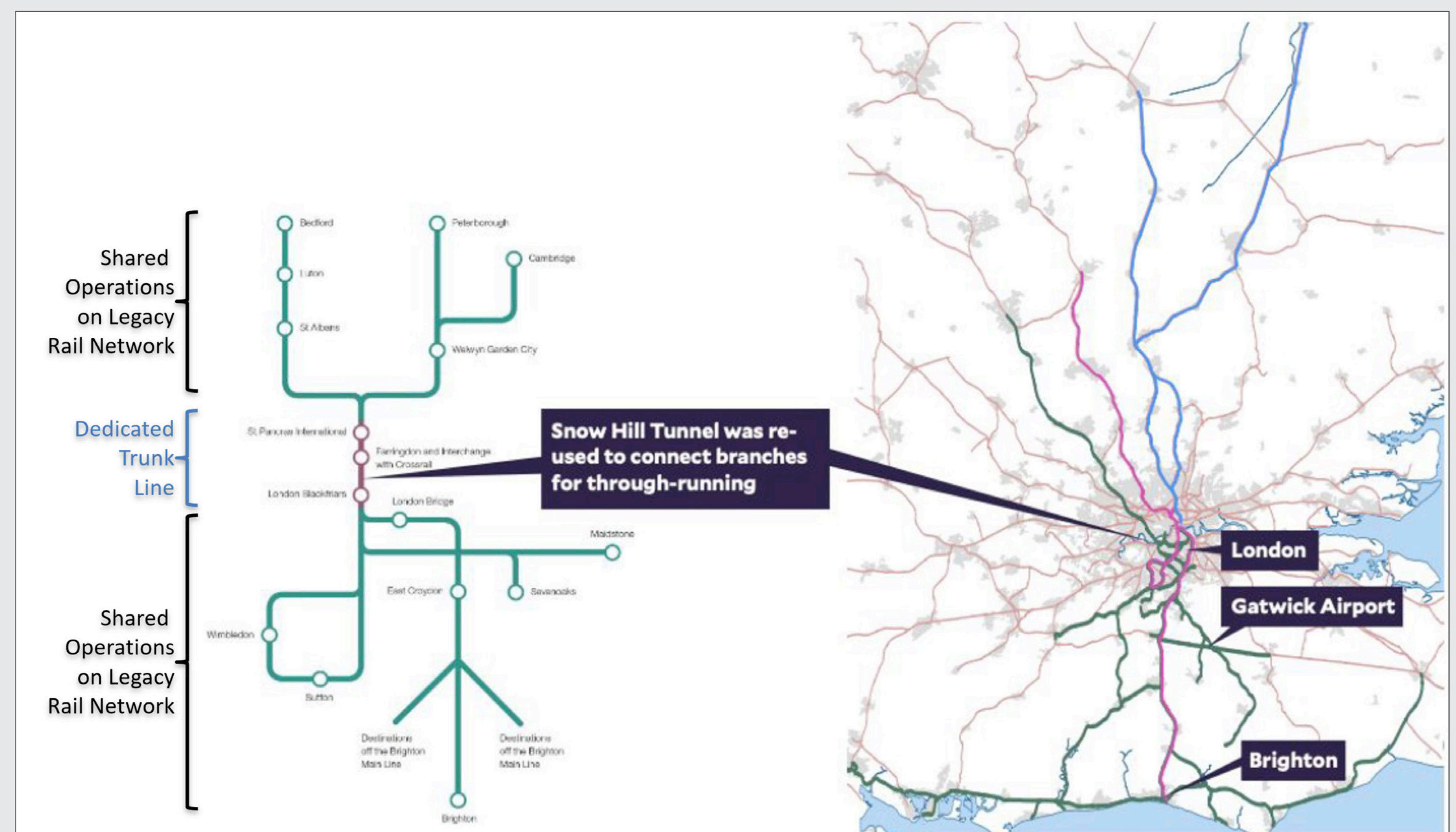
- Regional metro service in trunk and branch configuration
- Regional metro service merges with other suburban and intercity traffic beyond the trunk line
- Regional metro tracks and platforms separate from other rail services at major stations (St. Pancras International and London Bridge)
- Trains operate on timetable, with variable route lengths and frequencies, but trunk line operates like headway-based transit

Trunk line peak capacity is 24 tph. Peak headways on the outer branch lines are 15 to 30 minutes. The service operates with trains scheduled at regular, repeating clockface intervals. Though some trains operate on fixed timetables, the overall service on the common trunk line operates as a headway-based subway-style service. Late trains are either fit into available slots or are cancelled. The Thameslink train schedules do not build schedule recovery time into the dwell times at any of the trunk line stations. All trains operate on the trunk line with uniform performance characteristics, with high-capacity train doors for rapid alighting and boarding, enabling short dwell times at the trunk line stations. The services operate with dual-power rolling stock, operating under third-rail power south of London and with overhead catenary north of London. All trains on the common trunk line are operated by the same operator, which simplifies the operation of the line.

St. Pancras International Station is a major legacy station on the Thameslink trunk line. It is the most recent example of doubling the train capacity of a legacy station, so it is particularly relevant to this feasibility study (see Figure 2-13).

Originally a regional rail terminal with 6 tracks elevated above street level, it now has 15 tracks on two levels in a

Figure 2-12
London Thameslink Network

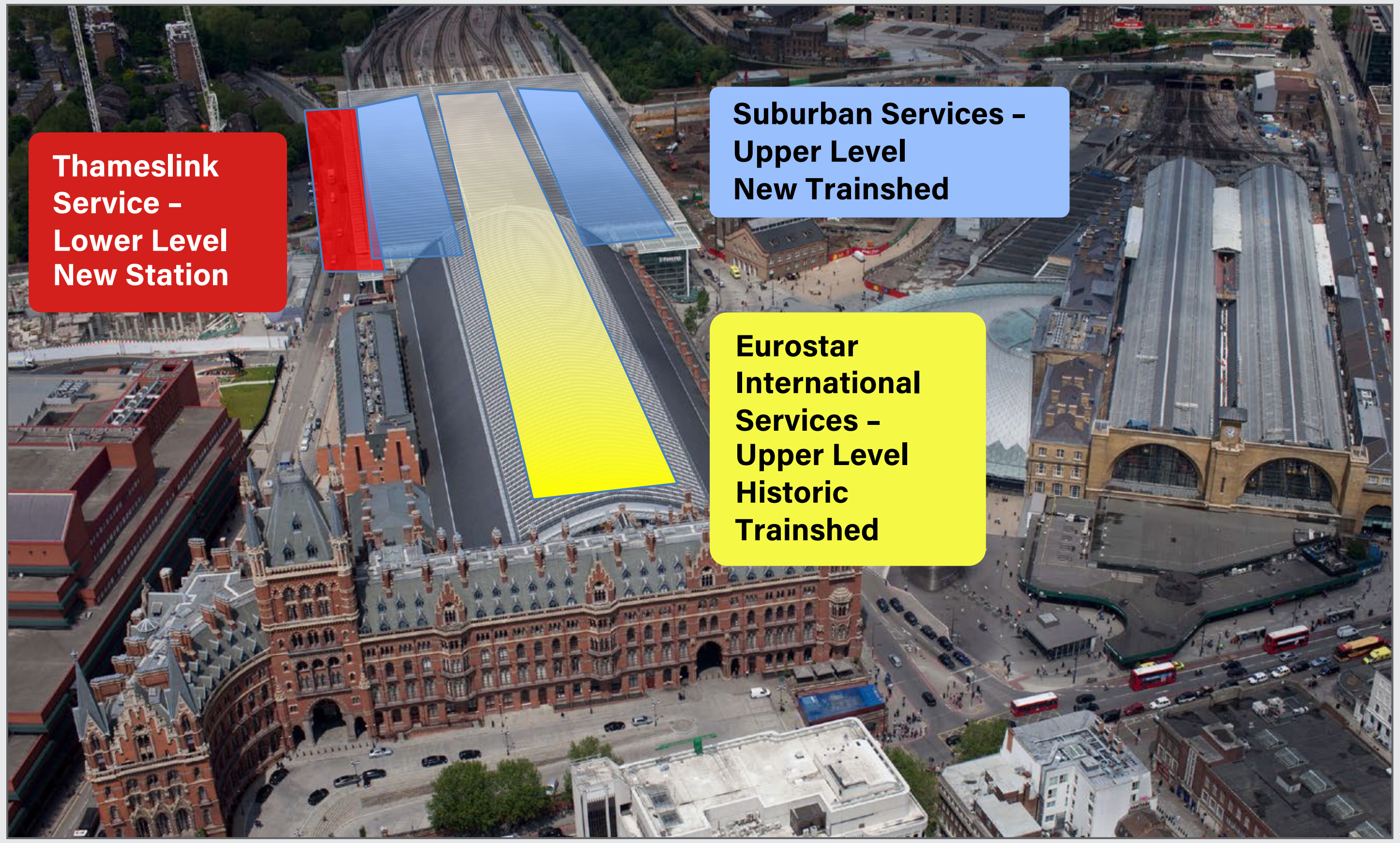


greatly expanded footprint. A modern expansion was built behind the historic train shed, over the original approach tracks, similar to that at Gard-du-Nord in Paris. Within the original train shed, the six tracks were reconstructed and their new platforms lengthened into the expansion to serve the longer Eurostar trains to Paris. The suburban services were relocated to seven new tracks in shoulder stations in the expansion, on either side of the Eurostar approach tracks. Another new shoulder station was purpose-built for Thameslink through-running service underground, below the west suburban shoulder station, bypassing the upper-level interlocking. Transfers between all the services are convenient, and the original train shed was opened to a renovated lower level, formerly station operations space, with customs control for the international trains and extensive retail amenities.

Introducing two new services at St. Pancras — Eurostar and Thameslink — required expanding the station to add more tracks and platforms in conventional terminal service and a new, separate shoulder station for the Thameslink through-running service, with all other services continuing to terminate at the station. The Thameslink route joins the railway main line away from the throat area of the legacy station. At the south end of the Thameslink trunk line, the major through station at London Bridge was rebuilt to provide separate, dedicated tracks for Thameslink service operating through this station.

Figure 2-13

St. Pancras International Station — London Thameslink



Philadelphia Regional Rail

Philadelphia was originally served by two separate commuter rail networks each operating out of their own stub-end terminals in Center City. The Pennsylvania Railroad terminated at Suburban Station, and the Reading Railroad terminated at Reading Terminal. Operation of these regional passenger rail services subsequently passed to SEPTA, a public authority of the Commonwealth of Pennsylvania. These commuter rail services are in addition to Amtrak NEC service, Amtrak Keystone Service to Harrisburg, PA, and NJ TRANSIT's Atlantic City line, all operating out of or through the lower level of what is now Amtrak's 30th Street Station. The Pennsylvania Railroad's Main Line, originally an intercity and freight service and later a passenger operation serving the wealthy suburbs of the city, also terminated at the upper level of 30th Street Station.

SEPTA's Center City Commuter Connection (CCCC) project constructed a 1.7 mile-long, four-track tunnel under Philadelphia Center City, completed in 1984, enabling through-running between the Pennsylvania Railroad and Reading Railroad termini and the upper level of 30th Street Station, and functionally eliminating the stub-end terminals in favor of three trunk line stations. The system was modeled on the German S-Bahn regional metro concept, pairing the six former Pennsylvania Railroad branch lines with the seven former Reading Railroad branch lines, each intended to operate as a single line continuous through the Center City trunk line. The branches extend out an average of 24 miles from Center City, somewhat shorter than the European examples discussed in this chapter.

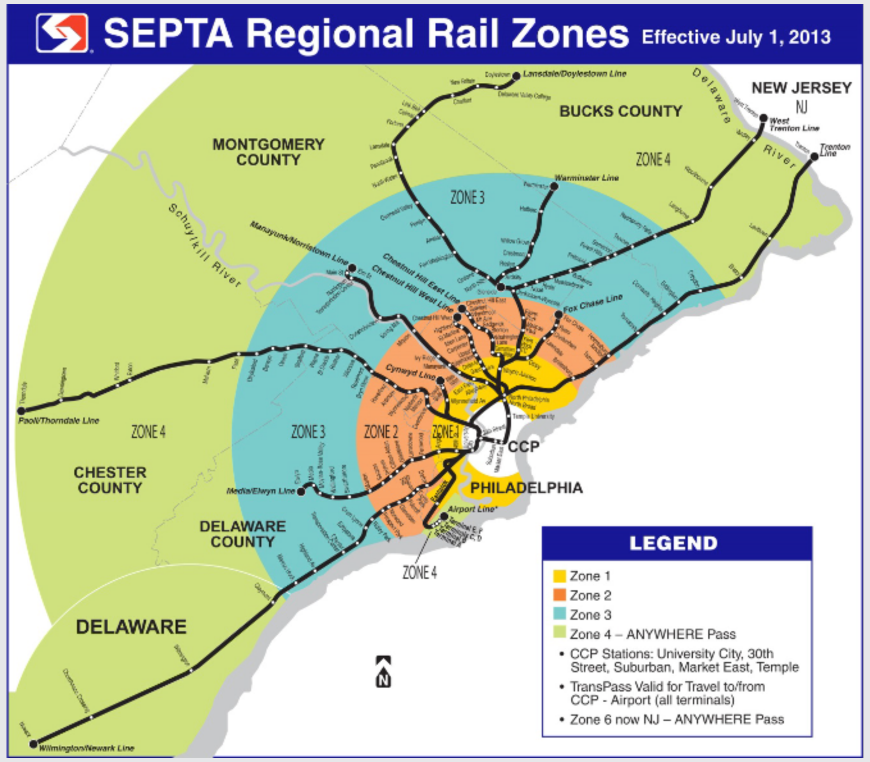
The downtown operation included crew changes at one of the downtown stations, which was accomplished within a three-minute dwell time. The system was designed to operate up to 22 tph on each of the four tracks, with directional capacity of up to 44 tph in the peak hour. **Figure 2-14** shows the network of SEPTA regional rail lines.

The CCCC route through Center City is shown in **Figure 2-15**, serving three main stations in the urban core. A new underground, four-track, through-running station, called Market East Station (now renamed Jefferson Station) replaced the stub-end Reading Terminal. Suburban Station in the heart of Center City was converted from a stub-end terminal to a through-running station. Four of the eight tracks at Suburban Station were connected to the connector tunnel. The remaining stub tracks are used for SEPTA trains that terminate in Center City. The connector tunnel extended west to include the upper level of 30th Street Station.

- Links all regional branch lines with single trunk line through Center City
- Trunk line serves only regional trains — intercity trains operate to separate station facilities
- Does not currently operate as through-running regional metro
  - Regional network infrastructure investment has been insufficient to support reliable headway-based service across the entire network
  - Limited demand for through service

The Center City Connection project was able to take advantage of the existing railroad configuration at 30th Street Station, where the SEPTA Main Line commuter service was on an upper level of the station and the Amtrak and NJ TRANSIT intercity rail services were on a lower level of the station, on different sets of tracks and platforms. Amtrak's 30th Street Station demonstrates the same separation of regional metro and intercity train operations that is present at the other international stations that were researched as best practice examples. The other two stations on the trunk line handle only regional rail, so the connector is free to operate at high frequency without conflicts with other types of service. Integrating the operations of the two separate regional networks resulted in operational efficiencies and the ability to deploy trains flexibly throughout the system to meet market demand.

Figure 2-14
SEPTA Philadelphia Regional Rail Network



On paper, this network was a good candidate for completely converting to regional metro service. The CCCC project was successful in providing new capacity and reliability of rail service through the central trunk line and made it possible for passengers to reach different points in Center City, resulting in an initial increase in ridership.

However, the regional metro vision of 40 years ago still has not been realized. While the shape and scale of the Philadelphia regional rail network would seem to be able to support regional metro service, the ridership market for cross-regional rail service did not materialize in the way that was envisioned. There is strong commuter ridership to the three Center City stations on the trunk line, but there is a wide disparity between peak-direction and reverse-peak-direction ridership, with generally much less demand for suburb-to-suburb travel. Fully 95% of all rider trips originate or terminate in Center City. The capital investment required to provide frequent, reliable, headway-based service over the entire network was never made, so the capacity still does not exist across the network to deliver frequent headway-based rail service on all branches, and lingering state-of-good-repair needs have hampered both line capacity and service reliability. Aligning travel markets with rail service frequencies on both ends of the trunk line has proved difficult, adjusted many times in generally unsuccessful attempts to achieve an economical balance. The paired branch lines have been discontinued in favor of service that is more customized to the demands of each branch line, with inter-line transfers available at any of the three core stations. SEPTA no longer brands the system as a through-running network, but rather as a conventional regional rail network, naming each branch for its outer terminus and even publishing its ridership statistics measured to and from Center City.

Though originally well-conceived, the CCCC project provides an important lesson: creating a productive and successful integrated regional rail network requires system planning and investment across the entire network to provide the necessary capacity and utility that will attract increased ridership. Targeting investment on the core trunk line and stations only will not automatically achieve travel benefits across the full network.

There are some key differences between the Philadelphia Center

Figure 2-15

Philadelphia Center City Commuter Connection

Source: NORTH SOUTH RAIL LINK

City Connection and the rail route through New York's Penn Station. The rail network serving Philadelphia is smaller and less densely-utilized than the network serving New York. Branch lines in Philadelphia are shorter, and the extent of longer-distance suburban service is much more limited. Ridership markets are smaller than New York, with shorter trains and generally lighter passenger loads. Also, the Center City Philadelphia trunk line serving the three core stations is limited exclusively to regional metro trains, which have similar operational characteristics. Intercity trains do not operate on these routes, greatly simplifying operations.

Toronto GO Expansion

The regional transportation agency for greater Toronto, Metrolinx, is investing in a major capital program to convert the regional rail system, formerly known as the Toronto GO system, to a combination of regional metro and traditional commuter service. The new regional metro network was originally called GO-RER, taking inspiration from the Paris RER system, but has now been re-branded as GO Expansion, reflecting a change in emphasis that mirrors the change in emphasis in Philadelphia. Re-evaluating their original premise, Metrolinx's emphasis is now on delivering two-way, all-day service every 15 minutes or less over five of its seven core branches that they now believe can support frequent, bi-directional service. Two branch lines, which have limited capacity for bi-directional operations, will continue to provide service focused on weekday peak travel to downtown Toronto.

- Connects to all regional rail lines
- Regional metro will be implemented using newly-built track and platform infrastructure at Union Station
- Station will continue to serve longer-distance commuter and intercity trains
- System-wide major investment to enable inter-operability and support headway-based regional metro service

Figure 2-16 depicts the network of regional metro lines, which has its focal point at Toronto Union Station, directly serving the Toronto central business district. Union Station is the third busiest rail station in North America after New York Penn Station and Grand Central Terminal, handling about 300,000 daily passenger trips. The future GO Expansion network will connect four branch lines to the west of Union Station and three branch lines to the east. Service on the regional network will be a combination of regional metro and more traditional suburban commuter rail service.

Like Penn Station, the existing Union Station had been originally designed for long-distance train service and was ill-suited for through-running regional metro service, with narrow platforms and limited vertical circulation for passengers to and from the platforms, so the existing station tracks and platforms will be completely reconfigured, and new

Figure 2-16

Toronto — GO Expansion — Regional Metro Network

tracks and platforms are being added adjacent to the existing tracks. The track and platform layout will be customized to support through-running regional metro on dedicated tracks, through-running suburban and intercity service on other tracks, and suburban and regional metro turnback service on dedicated stub-ended tracks. Also like the New York/New Jersey regional rail system, the GO network includes both short and long branch lines. Four branch lines will operate all-day, through-running regional metro service on the inner portions of the line, with traditional commuter trains during peak periods serving the outer portions of each line and running express through the inner zones. One branch line will operate regional metro service that turns back at Union Station. Two branch lines will continue to operate peak-only commuter service to and from Union Station.

The capital program also includes major improvements to the entire rail network, including line electrification, 93 miles of new track capacity, new stations, bridges and tunnels, extending some of the branch lines, grade crossing eliminations, removing capacity bottlenecks and acquiring new rolling stock. The program is expected to take 10 years to construct, estimated to cost $13.5 billion in 2017 Canadian dollars. The GO Expansion is being delivered by an international consortium selected as the Private Partner, in a progressive design, build, operate and maintain format, or DBOM. Progressive means that there is a two-year development phase, which began in 2022, in which the Private Partner, working with Metrolinx, is defining the scope of the project, how the network will operate, and the commercial terms and structure. Certain early tasks such as eliminating grade crossings and work in the train shed at Toronto Union Station have begun during this development phase. The actual cost will be negotiated with the Private Partner during the development phase, including the construction costs and how much the Private Partner will be paid for operating and maintaining the system over an agreed timeframe.

Figure 2-17
Toronto Union Station

As is the case in New York, the future full regional rail network in Toronto will need to serve multiple types of passenger rail service, including:

- Through-running regional metro
- Airport express trains
- Longer distance suburban trains
- Intercity trains
- Long-distance cross-country trains

The GO Expansion project at Union Station includes improvements to the tracks, platforms, interlockings, concourses, and passenger access. It features two new wide platforms and the reconfiguring and widening of tracks and existing narrow platforms in the station. It also includes new and wider concourses, a new lower concourse, new skylights around the perimeter of the building to bring in daylight, and new passenger amenities (Figure 2-17). Frequent bi-directional train service on the five principal branches will be an important feature of future operations at Union Station.

Worldwide Best Practices Summary

Key characteristics of the Paris RER, Munich S-Bahn, and London Crossrail systems are listed in Table 2-2. These successful regional metro systems all share a number of common features:

- A new service type that complements, but does not replace, traditional commuter, intercity, or international service types
- Headway-based operations, with trains running at regular, repeating intervals
- Transit-style service, with all trains making all local stops and with short station dwell times
- Routing around or below existing terminal interlockings
- Uniform rolling stock types and performance
- Limited number of branch lines feeding a central trunk route
- Relatively short branch lines, generally serving urbanized areas
- Regional integrated fare payment systems

Regional metro service using the trunk and branch route configuration represents the standard solution for cross-regional connectivity, as seen in the international examples cited above (Paris, Munich, and London). This type of service operates best along the trunk line as a self-contained transit line, offering high-density, headway-based service with uniform train performance and station dwell time characteristics along corridors that can support high-density through service.

In four-track systems, regional metro trains can run on the local tracks through denser, more urbanized areas closer to the urban center, which permits higher frequency of service, with longer-haul commuter trains running on the express tracks, bypassing the regional metro stations. In two-track systems, regional metro trains must share the tracks with the longer-haul commuter trains, which generally constrains metro service frequency to 15-minute headways and precludes express operations of the commuter trains. If more frequent headways are justified by market demand, then investment in expanding to a four-track system has proven to be necessary and economical.

Multiple metro branch lines feed a trunk line that runs through the city center on headways as short as 2 minutes if reserved for metro trains only, sometimes serving multiple trunkline stations. Stations along the trunk line route can become major hubs and economic activity nodes, since direct rail service is available to all branches that feed the trunk line. The trunk and branch concept does not eliminate the need for transfers for passengers traveling between suburbs beyond the limits of the trunk line or to destinations not served by the metro line they originated on. Major cities such as Paris and London have multiple regional metro trunk lines.

Regional metro service typically does not operate within the original historic train sheds. Serving regional metro and other passenger rail services at separate facilities acknowledges the significant differences that exist in the operational characteristics and passenger behavior characteristics of these service types.

The major legacy rail stations that host regional metro service also have similarities:

- Purpose-built new trackways and station infrastructure to support through-running, generally below and/or adjacent to the legacy train station
- Intercity, long-distance and longer commuter services generally retained at the legacy train station

At major stations within the urban core, regional metro trains operate on a dedicated alignment, bypassing terminal interlockings, with tracks and platforms dedicated to the regional metro service, as illustrated schematically in Figure 2-18. At two example stations — Paddington Station in London on the Elizabeth Line and the Hauptbahnhof (main train station) in Munich — the schematic cross-sections in Figure 2-19 show the relationship of purpose-built regional-metro tracks and platforms with the original traditional portions of the train station used by other suburban and intercity services.

Figure 2-18

International Best Practice Configuration for Regional Metro at Major Rail Stations

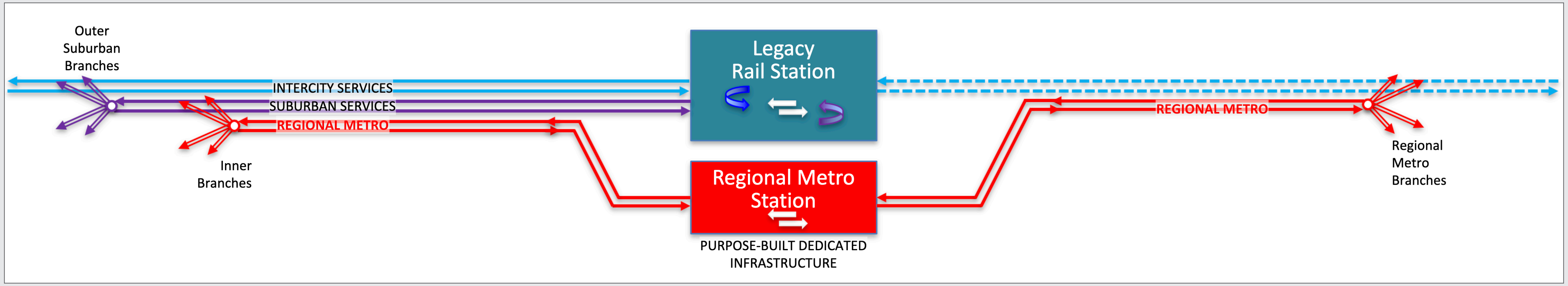
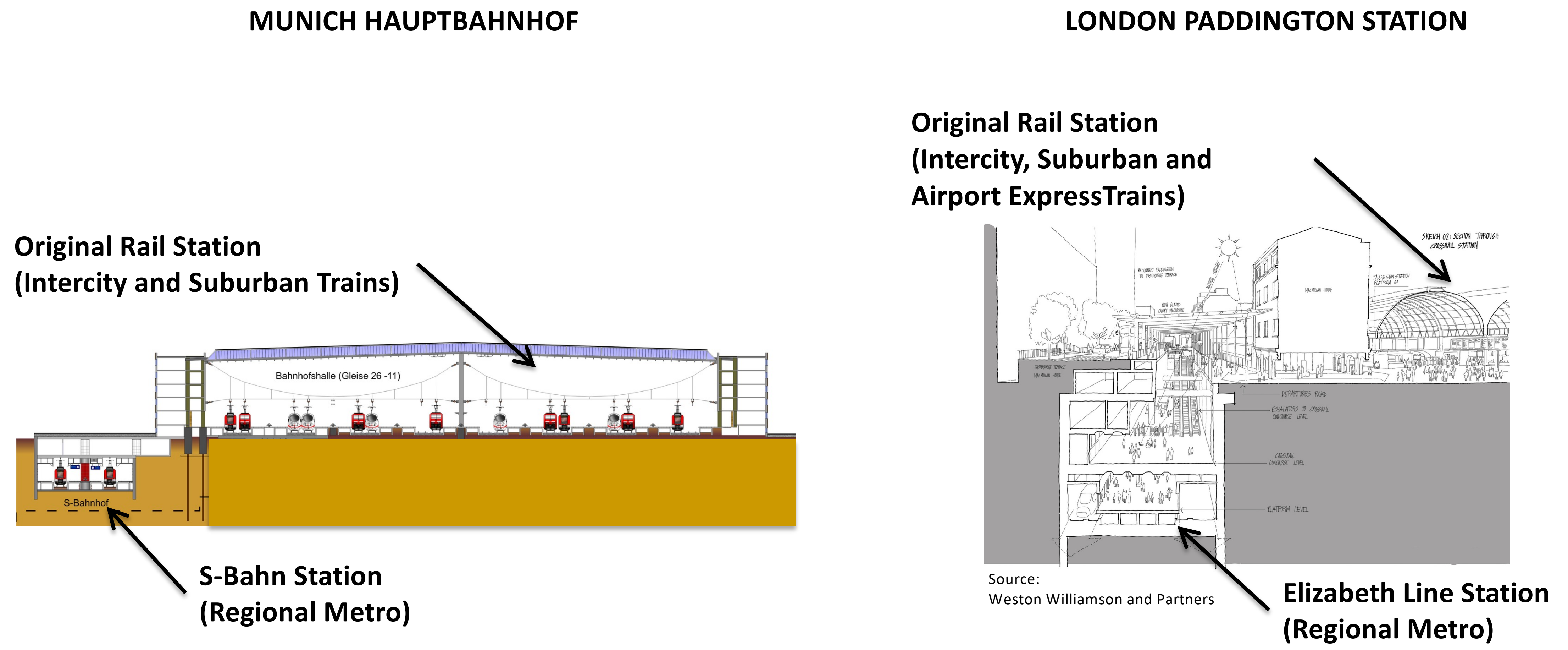


Table 2-2

Key Characteristics of Selected Through-Running Regional Metro Services

Successful examples of Through-Running	London—Crossrail (Paddington & Liverpool Street stations)	Paris—RER Line B/D (Gare du Nord station)	Munich—S-Bahn (Hauptbahnhof & Ostbahnhof stations)
Investment in new tracks and wider platforms in new shoulder stations adjacent to legacy rail terminal to enable through-running	✓	✓	✓
Through-running transit-style service separated from longer-distance legacy service	✓	✓	✓
Network Complexity — Branches on both sides	2 branch lines on West end (20-58 km) and 2 branch lines on east end (up to 80 km)	3 branches to the North end and 4 branches to the South end	7 branches to the West end and 5 branches to the East
Service type (headway- or timetable-based)	Headway-based	Headway-based	Headway-based
Peak-hour average headways in the trunk section	2.5 minutes	1.5-2 minutes	1.5-2 minutes
Peak-hour dwell times	45-60 seconds	50-60 seconds	33-45 seconds
Platform Width sufficient to accommodate arriving and departing passengers simultaneously	✓	✓	✓
Uniform rolling-stock performance	Yes	Yes	Different sets of vehicles
Other non-through-running service at major stations, using legacy platform tracks separate from regional metro	All services by train operators other than Crossrail/Elizabeth Line (suburban and intercity)	Transilien routes H & K (suburban) TER service (regular intercity) TGV service (high-speed rail)	RB (local suburbs & adjacent cities) RE (limited-stop regional express) IC (regular intercity) ICE (high-speed)

Figure 2-19
Major Station Cross-Sections



Source:
Weston Williamson and Partners

Application of Worldwide Best Practices to New York Region

The international-standard regional metro model described above would be the most reasonable fit for the New York region, the configuration of the existing rail network, and the regional travel markets that need to be served. Regional metro for the New York metropolitan region could include a central trunk line across Midtown Manhattan in the 30th to 34th Street corridor, serving Penn Station and having multiple branches both west and east of Manhattan. Convenient transfers to other rail and transit services would be available at Penn Station and potentially at other locations along the trunk line. This concept best represents the type of investment and operation seen in the most successful regional rail networks around the world. Table 2-3 presents key statistics for several urban metropolitan areas with rail networks providing or supporting regional metro service and presents comparable statistics for the New York metropolitan region.

Despite some similarities, it is important to note that the extent of the rail service territory served by Penn Station is much larger and the routes are much longer than those covered by the RER in Paris, Crossrail in London, and the Munich S-Bahn. This can be easily appreciated in Figure 2-20, which compares graphically the extent of these three existing regional metro networks with the full New York regional network, at the same scale. Each of the three European cities supports a much larger suburban and intercity rail network than the territory over which through-running regional metro trains operate. The full rail networks feeding the main train stations in Paris, London, and Munich cover distances comparable to those that feed New York Penn Station, but regional metro only covers selected portions of that network, primarily focused on branches close to the city center.

Also, not all branches and service zones in the New York metropolitan region have potential demand sufficient to support the service frequencies required for headway-based service, so the regional rail network cannot be completely converted to regional metro and still be run economically. The potential demand for transit-like service decreases in more distant, less dense suburban markets. Whereas there are numerous markets in the inner, more urbanized metropolitan areas that likely can justify high-frequency service in both directions during peak hours and increased service frequency during off-peak hours, markets farther out cannot. Including more distant markets in such service would result in both peak-direction and reverse-peak direction trains running with too few passengers over much of their routes to be economically viable, a difficulty that SEPTA in Philadelphia has wrestled with for almost 40 years now.

Although market demand for travel within and between the outer counties of the region may be growing, the mode of transportation to serve such markets needs to be right-sized to the market potentials. Frequent service with 12-car trains can be a highly uneconomical modal choice for small markets. Buses, bus rapid transit (systems where traffic signals prioritize buses to obtain higher speeds and shorter travel times), or light rail targeted more specifically to different routings such as circumferential patterns and timed transfers are generally a better match. The Hudson-Bergen Light Rail line in New Jersey, though not complete as planned, is a good example. Another is the Interborough Express, a proposed light rail line between Brooklyn and Queens currently in planning by MTA. Both are local examples of service right-sized to their markets.

Perhaps the foremost example of a right-sized public transportation system in the U.S. is TriMet, which serves the Portland, Oregon metropolitan region, an area with a total population of 2.2 million. This is a region with significantly less traditional commuting than the New York metropolitan region and greater inter-suburban travel. TriMet operates only a single heavy-rail commuter line, with five light-rail lines and 85 bus lines providing service to multiple destinations, serving multiple travel markets. The light rail lines and 17 of the bus lines operate on 15-minute headways or less, with 58 percent of bus trips on the frequent service lines. A total of 17 transit centers facilitate timed-transfers between bus and light rail lines. The success of the TriMet system as a widely distributed network with four different service types reinforces the perspective that heavy rail is not necessarily the best mode to accommodate multi-destination travel markets in more lightly-populated areas.

A robust network of longer-distance suburban routes and expanded Amtrak intercity services, also operating through a major connectivity hub at Penn Station, would complement the regional metro service. Because of their different operating characteristics, Amtrak intercity services cannot be easily blended with frequent, transit-style service, even though all of its peak period trains already run through Penn Station. None of the successful regional metro examples we have studied blends headway-based regional metro with timetable-based suburban and intercity service on shared tracks through major stations with shared platforms. Stations have uniformly been expanded to accommodate the new regional metro service, with legacy commuter and intercity services continuing to use the legacy platforms. Toronto Union Station is a good example of a major rail hub with hybrid rail operations, including both turnback and through-running service and purpose-built infrastructure, where regional metro trains will utilize platforms separate from those used by intercity and suburban trains, but where all three types of service will operate together on the tracks feeding Union Station.

Converting the entire regional rail network to be fully integrated and interoperable would also be prohibitively expensive. A comparison with the cost of the Toronto GO-RER conversion is a useful reference point. The 10-year GO Expansion project to make their regional metro network interoperable and satisfactory for the planned new service model was estimated to cost approximately $13.5 billion. To a rough approximation, the full New York metropolitan regional rail network centered on Penn Station

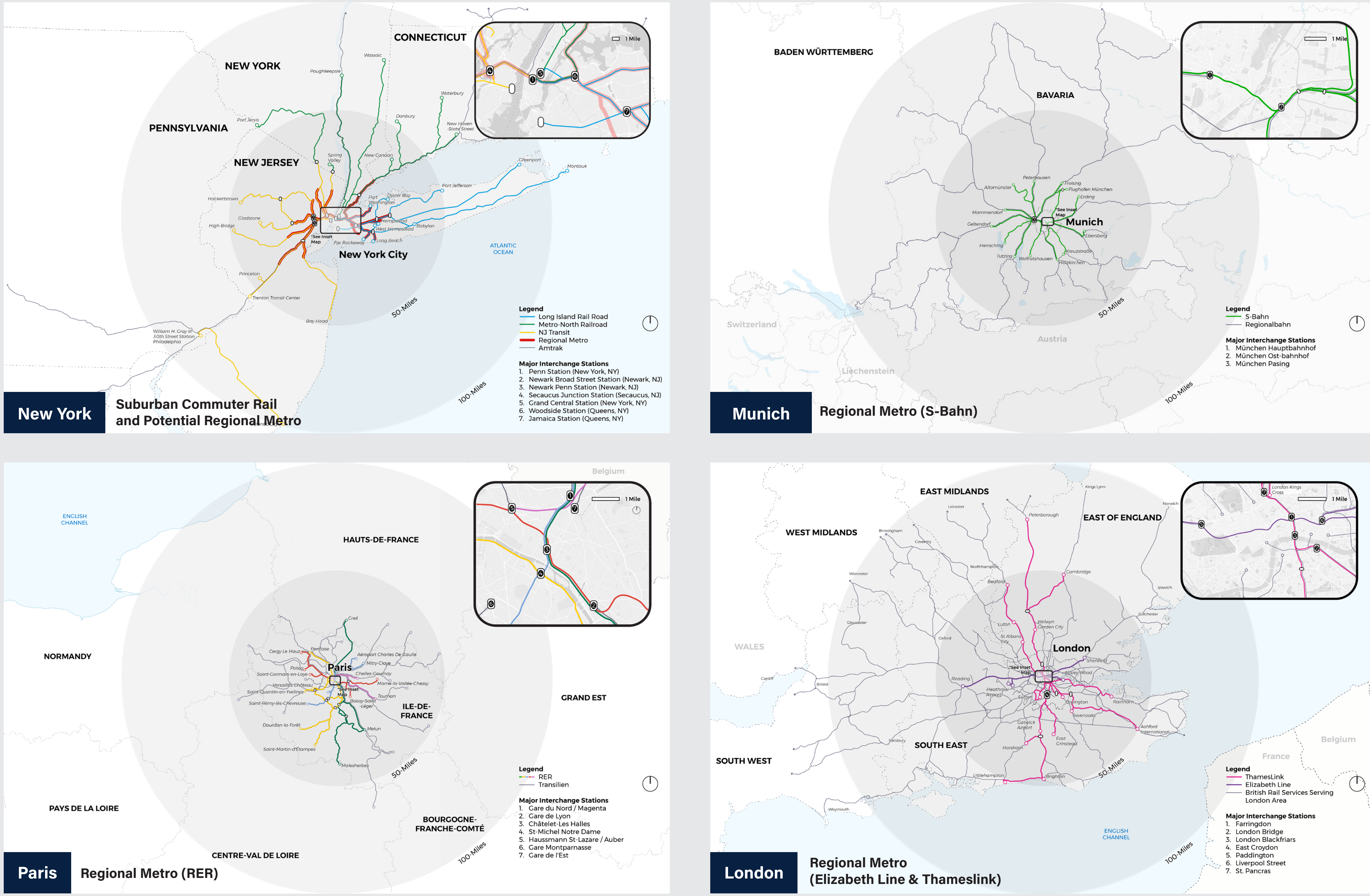
Table 2-3

Comparative Statistics for Metropolitan Areas with Regional Rail Networks

	Paris Ile de France	London Metropolitan London	Munich Munich Metro Area	Toronto Greater Toronto Area	Philadelphia Philadelphia CSA	New York Metro Region New York MSA
Metropolitan Region Data						
Region Size (square miles)	4,617	3,870	2,074	2,750	4,603	6,685
Population	12,329,432	14,372,596	2,935,114	6,711,985	6,107,906	19,768,458
Employment	5,525,000	7,223,000	1,377,000	3,568,500	5,041,350	16,032,587
Rail Network Data						
Regional Rail Network (through-running)						
Lines Branches	5 22 RER A, B, C, D, E	2 13 Elizabeth Line & Thameslink	8 14 S-Bahn	3 5 GO-Expansion	8 13 Regional Rail	N/A
Suburban Network (non-through-running)						
Lines Branches	6 20 Transilien Service (stub-ended at Paris terminals)	60 Branch service by other regional operators	14 RB (local) Routes	1 Richmond Hill Line 1 Milton Line 4 Line extensions	1 PATCO Line 1 Atlantic City Line	26 To Penn Station 18 To other terminals
Major stations / terminals	6	13	3	1	3	6
Total Branch Line Services	**42**	**73**	**28**	**8**	**15**	**44**
Network Route Data						
	Regional Metro Only	**Regional Metro Only**	**Regional Metro Only**	**Full Network**	**Regional Rail**	**Full Network**
Network Route Mileage	365	456	270	327	223	1,067
Stations	257	195	150	68	155	409
Branch Length — Minimum (miles)	13	12	16	29	6	20
Branch Length — Average (miles)	37	38	35	47	24	54
Branch Length — Maximum (miles)	75	78	46	82	41	118

Figure 2-20

Regional Rail Network Scale Comparison — New York, London, Paris, and Munich



These factors suggest that we should expect a full network conversion in the New York metropolitan region to cost as much as $60 to $70 billion, disrupting rail service for 15 years.

is more than three times the size of the GO network, and far more complex. Implementing a fully-integrated regional rail network would entail extensive infrastructure design and operations analysis, environmental study, reaching cross-operation agreements between the railroads, and securing funding, all processes that are subject to delay — amplified by the scale and complexity of the network. The construction period would be at least 15 years, so the midpoint of construction here would lag behind that in Toronto by at least 10 years, inflating the cost basis by the same amount compared with Toronto's. These factors suggest that we should expect a full network conversion in the New York metropolitan region to cost as much as $60 to $70 billion, disrupting rail service for 15 years.

The incremental benefits of full network integration above the benefits of converting only a portion of the network to support regional metro service would not justify such a high cost. Funding, if it could even be obtained, would have to be spread out over multiple five-year federal and state funding cycles. Disruption of the regional rail system for this long would create hardships for regional travelers. Taken together, these observations highlight the need to right-size a regional metro system while maintaining conventional legacy services, as the successful systems in the European case studies have done.

Based on our review of international best practices, the future cross-regional rail network for the New York metropolitan region, focused on Penn Station, should include three types of rail service:

- Regional metro in a headway-based trunk and branch configuration, serving NYC and the inner suburbs
- Suburban trains covering the full commuter territory with timetable-based service
- Intercity trains providing express, regular and long-distance service

Regional metro ideally should operate through the trunk line and at Penn Station on dedicated tracks, separate from those handling suburban and intercity trains.