4 Develop Concepts

This chapter presents several potential concepts for modifying and/or redesigning MBTA service delivery. In the two previous chapters, the measurement of service-delivery standards and the existing and forecasted trip patterns of the study area were analyzed. This chapter will apply the same analysis to the presented service concepts as well as an evaluation of the concepts under various financial-constraint scenarios.

4.1 General Service Patterns

There are several general patterns for service structure. Each pattern's application to real-world settings is, by necessity, largely dependent on existing characteristics. However, from a purely theoretical perspective, a discussion of the different patterns and their associated positives and negatives is useful before considering potential real-world application and limitations.

4.1.1 Grid

A grid transit pattern provides a consistent level of service across a defined service area. Routes have the same frequencies and are spaced at a consistent distance, with no overlap except where routes cross and transfers are possible. Figure 72 provides an example of this service pattern.

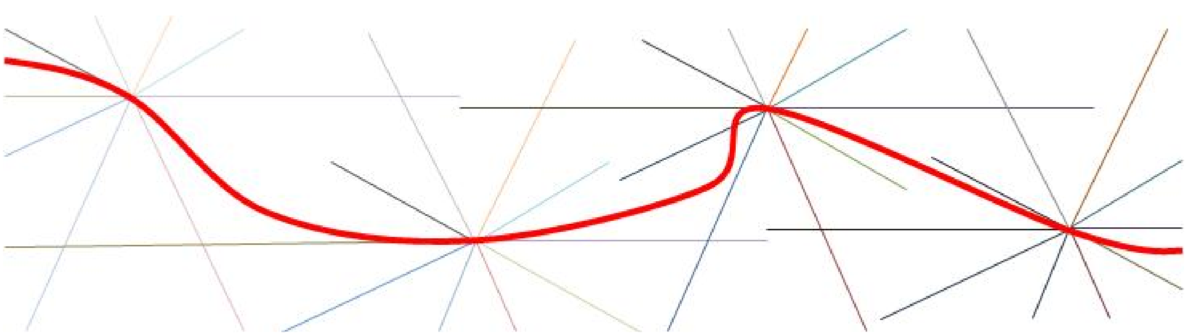
Figure 72
Theoretical Concept of a Grid Transit Pattern

Advantages of the grid transit pattern include a relatively higher level of service coverage (with the absolute coverage depending on the size of the individual grid boxes) and, consequently, a reduced probability of crowding occurring on any individual route, as ridership is diffused across the grid. However, since locations with greater demand for transit, such as the central business district, schools, or shopping centers, are generally not dispersed, this ridership dispersion across the grid means that fewer riders will be able to travel directly between their origin and destination with a one-seat ride. The extent to which riders would need to transfer between routes would likely increase, resulting in greater transit travel times.

4.1.2 Hub and Spoke

A hub-and-spoke transit pattern provides different levels of local and non-local service across a defined service area. These differences occur primarily in terms of service frequency and coverage. The local service funnels riders to a central hub along various spokes that connect to the hub. The non-local service then provides connections between different hubs, where all routes meet and transfers are possible. This service also typically offers greater frequency and capacity, given the greater expected numbers of riders. Figure 73 provides an example of this service pattern in which the bold line represents the non-local service that connects the hubs, which are each served by multiple spokes representing the local services.

Figure 73
Theoretical Concept of a Hub-and-Spoke Transit Pattern



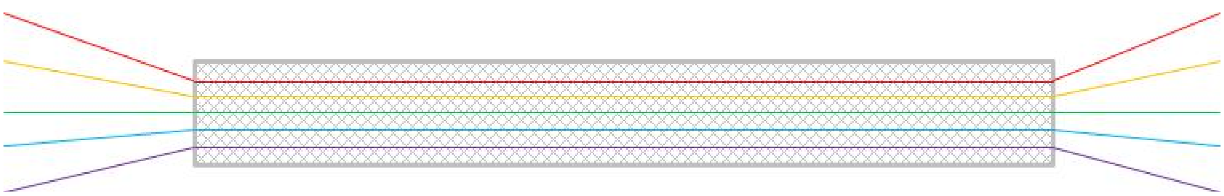
Advantages of the hub-and-spoke transit pattern include a reduction in the total number of route miles, as most routes are shorter-distance local “spokes” serving only the regional “hub,” which, along with other hubs, is only served by a few long-distance non-local routes. However, the reduction in total route miles comes at the expense of coverage. Riders must walk greater distances to access transit (represented by the distance between spokes) as the distance from the hub increases.

One option to reduce this walking distance would be to provide circumferential connections between the spokes at these greater distances from the hub. Another potential advantage can be realized if all local and non-local routes are scheduled to arrive at the hub at the same time. These so-called “pulse” transfers reduce the transfer waiting time. On the other hand, delays resulting from the failure to meet the schedule at any individual hub can reverberate across the entire transit network, owing to the inter-connected nature of the hub-and-spoke pattern.

4.1.3 Trunk

A trunk transit pattern provides different levels of feeder and trunk service across a defined service area. Like the hub-and-spoke pattern, these differences occur primarily in terms of service frequency and coverage. Multiple feeder routes funnel riders to a central meeting point, where all routes converge and operate along a shared, trunk segment before splitting into their individual routes once again. Transfers between individual routes are possible anywhere along the trunk segment. Given its greater number of routes, the trunk portion of any route offers greater frequency and capacity. Figure 74 provides an example of this service pattern in which the patterned box represents the trunk service.

Figure 74
Theoretical Concept of a Trunk Transit Pattern



The major advantage of the trunk transit pattern is the use of multiple feeder routes to create a trunk segment of every route with a higher level of transit service. The greater frequencies and capacities of the trunk segment come at the expense of reduced transit service coverage elsewhere. However, the service benefits, including the ability of riders to transfer among multiple routes anywhere along the trunk segment, may outweigh the reduction in coverage. Feeder routes face the same challenge as spoke routes do in the hub-and-spoke pattern: as the distance from the trunk segment increases, so does the distance that riders are required to walk to access the feeder service. In addition, some amount of route schedule-coordination is desirable to ensure consistent vehicle spacing in the trunk segment; however, unlike the hub-and-spoke pattern, delays on one route will not dramatically affect the entire network, as each route operates relatively independently.

4.1.4 Summary of General Service Patterns

No general transit pattern can be applied directly to a real-world situation. Geography, street network, land use/development, cost, and trip patterns, among other characteristics, will inevitably dictate the actual layout of transit service. However, each of the three patterns discussed above – grid, hub and spoke (with or without circumferential connections), and trunk – offer potential elements for guiding service structure. A grid pattern prioritizes universal coverage while the hub-and-spoke pattern sacrifices some coverage for greater potential efficiency in service delivery. Finally, the trunk pattern also trades coverage in certain areas for improved transit service in others.

4.2 Potential Service Concepts

The existing structure of MBTA service uses a combination of elements from the three general service patterns. While there is no strict application of the grid pattern, per se, the South End has a bus route running on almost every major street in both the north-south and east-west directions. Several North Shore routes join at various hubs at the Salem and Lynn commuter rail stations and at Wonderland Station on the Blue Line. Melnea Cass Boulevard between Ruggles and Dudley Stations and Warren Street south of Dudley Station act as the trunk portion of several routes that feed into these stations.

In its entirety, the core MBTA system largely functions as a general hub-and-spoke/trunk transit network in which rapid transit stations are radial hubs and bus routes are the spokes feeding into trunk corridors around rapid transit stations. Indeed, most bus routes serve one or more rapid transit or commuter rail stations. Riders typically use local bus routes to travel to the rapid transit station closest to their neighborhood, from which they take rapid transit to their destination, typically in the urban core. There are obviously many exceptions to this general trip pattern depending on where riders live and work and where various services operate. For instance, express buses from Waltham provide service directly to downtown Boston. While bus and commuter rail schedules are sometimes coordinated in order to facilitate a smooth transfer between the modes at certain commuter rail stations, rapid transit service operates at a high enough frequency such that no such schedule coordination with buses is needed.

Any potential adjustment or change to existing MBTA service must assume the continuation of the current rapid transit and commuter rail networks. The nature of these rail networks, with track and stations being largely immobile, means that the radial structure of the rail system is unlikely to change without a large capital expenditure. However, most bus routes can be re-routed with relatively little expense. Bus stop amenities, such as signs or shelters, can be relocated, maps can be changed, and on-street parking spaces can shift. As a result, most of the concepts developed for this report focus on changes to the bus network and little to no change in the rapid transit or commuter rail networks.

The following sections describe these concepts, and subsequent sections present an evaluation of each.

4.2.1 Rail Extensions and Expanded Coverage

The one potential change to the rail network that is considered in this report is the extension of the rapid transit network beyond its existing terminus stations. The following potential extensions of the rapid transit network, included in the 2009 Program for Mass Transportation (PMT), are included in this rail-extension concept:

- Extension of the Blue Line from Wonderland Station in Revere to Central Square, Lynn at the existing Lynn commuter rail station
- Extension of the Red Line from Alewife Station in Cambridge to Route 128, with five new stations in Arlington and Lexington
- Extension of the Green Line D Branch after Newton Highlands Station in Newton to Needham Junction, with a new station in Newton and stops at the existing Needham Heights, Needham Center, and Needham Junction commuter rail stations
- Extension of the Orange Line from Forest Hills Station in Boston to the Route 128 park-and-ride station adjacent to the Providence commuter rail line, with three stations in Boston: a new station (Mount Hope) in Roslindale and two at the existing Hyde Park and Readville commuter rail stations
- New Orange Line station at Assembly Square in Somerville to provide additional coverage on the existing line
- Extension of the Blue Line from Bowdoin Station in Boston to Charles/MGH Station, providing a connection with the Red Line
- Extension of the Green Line from Lechmere Station in Cambridge to Medford, with six new stations, a relocated Lechmere Station,

and a branch between Lechmere Station and Union Square in Somerville

- Improvements to the Fairmount Commuter Rail Line (including improvements to station amenities and the frequency of service) and addition of four new stations—Newmarket, Four Corners, Talbot Avenue, and Blue Hill Avenue—to improve coverage

Figure 75 shows the physical location of these proposed rail rapid transit extensions. Of these various proposals, only Assembly Square Station on the Orange Line, the Green Line extension from Lechmere Station, and improvements and additional stations on the Fairmount Commuter Rail Line are currently scheduled for construction, and construction on the Green Line in Medford is only planned as far as College Avenue Station. The other projects have been proposed as part of the most recent and past PMTs, but no current plan for their construction is underway.

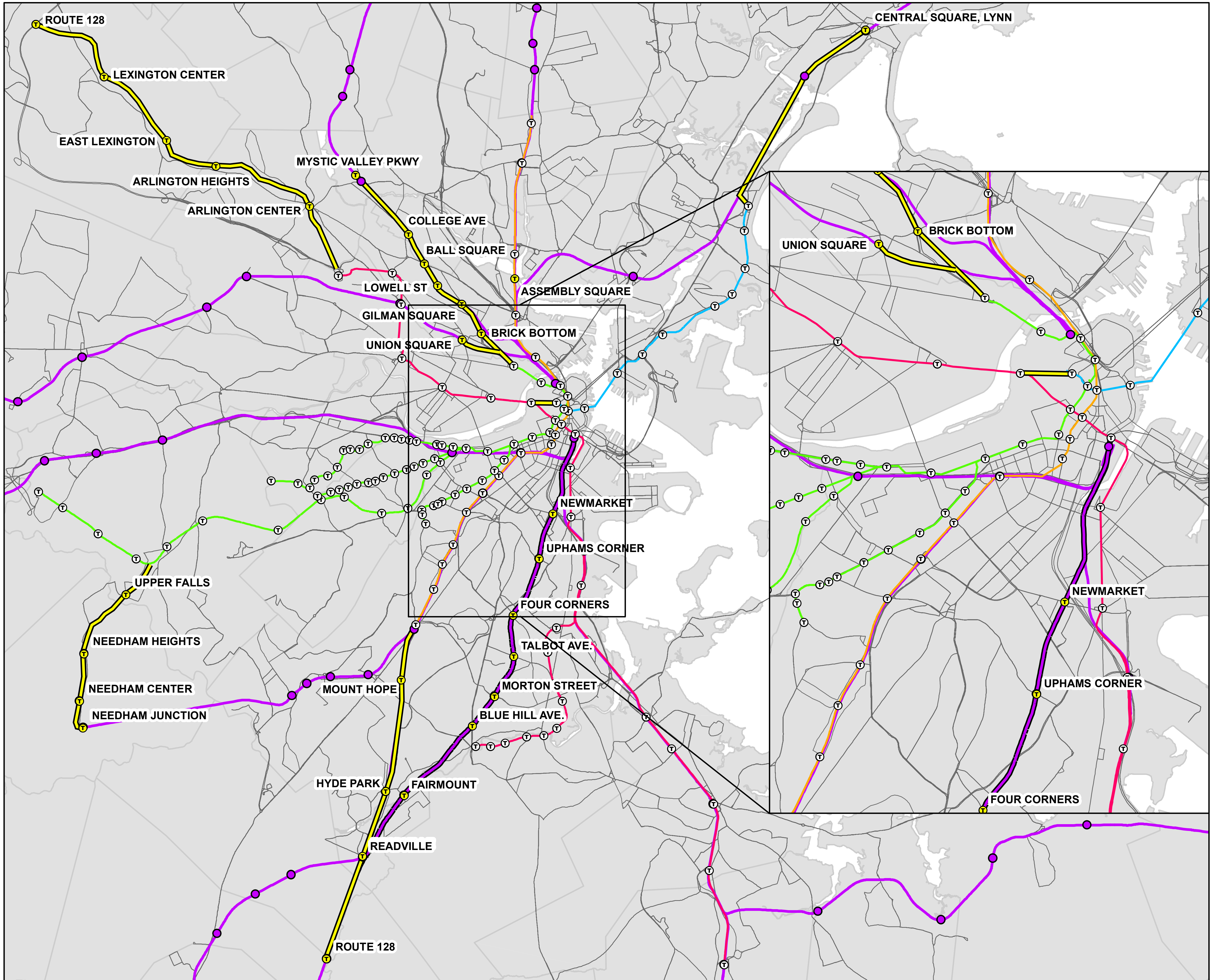
Extensions of the rail rapid transit network would not dramatically change the basic structure of the existing transit system. Some bus routes, such as Route 79 out of Alewife Station or Route 32 out of Forest Hills Station, that mirror the proposed extensions could likely be eliminated or modified. Some of the proposed stations, such as Lynn Station on the Blue Line and Union Square Station on the Green Line, would likely act as new hubs for bus routes, reducing bus trips to existing hubs. However, the use of buses as spokes, feeding trips to the rapid transit network, would not change. If anything, extensions of the rail rapid transit lines would expand this trip pattern.

4.2.2 BRT Corridors

This concept would balance a reduction in local bus coverage with an improvement in frequency and capacity on more heavily-used bus routes. The routes chosen for such improvements would receive various bus rapid transit (BRT) improvement measures, including dedicated rights of way, fare-collection equipment permitting pre-paid boarding, and transit signal priority, as well as frequencies that equal or exceed those of the rail rapid transit lines. As a trade-off for these bus improvements on some routes, other bus routes would be eliminated. Neighborhoods not receiving BRT service would maintain their local bus service at the existing frequencies.

Figure 76 presents an example of how this concept could potentially be realized. The routes selected for BRT improvements include all Key Bus Routes (Routes 1, 15, 22, 23, 28, 32, 39, 57, 66, 71, 73, 77, 111, 116, 117, and the various branches of the Silver Line) as well as other major

FIGURE 75
Rail Extension Concept



Legend

- New rapid transit stations
- Rapid transit extensions
- Fairmount Line
- MBTA bus routes
- Commuter rail stations
- Commuter rail lines
- Rapid transit stations

Rapid Transit Lines

- Blue
- Green
- Orange
- Red
- MBTA bus routes
- Town boundary

N

0 1.25 2.5 5 Miles

Core Efficiencies Study

BOSTON REGION MPO

This page left intentionally blank.

FIGURE 76
BRT Corridor Concept

Legend

BRT service

Eliminated bus service

No change in bus service

Commuter rail stations

Commuter rail lines

Rapid transit stations

Rapid Transit Lines

Blue

Green

Orange

Red

Town boundary

N

0 1.25 2.5 5 Miles

Core Efficiencies Study

BOSTON REGION MPO

This page left intentionally blank.

routes, with the goal of maintaining a relatively equal spacing between the BRT corridors and maintaining service along heavily-traveled corridors. All local routes within the service areas of these selected BRT routes would be eliminated. All other local routes outside the service areas of these selected BRT routes would be maintained. These local routes would operate at existing frequencies.

The figure shows changes in bus service by road segment. All maintained local routes that share a routing with a BRT route would use the BRT facilities along this route segment, stopping at only the BRT facilities, but return to local service in non-BRT segments. Eliminated bus service is only shown where no BRT or local service would operate. For example, even though Route 44 (Jackson Square Station – Ruggles Station) service would be eliminated along Humboldt Avenue, BRT service would remain on the route's other existing segments. Similarly, the elimination of Route 80 (Arlington Center – Lechmere Station) is only shown along Medford Street in Arlington and not along Boston Avenue in Medford where Route 94 (Medford Square – Davis Square) is maintained.

4.2.3 Limited-Stop Corridors

This concept would add limited-stop service during the AM- and PM-peak-weekday time periods on longer and more heavily-used bus routes. Stops would be at major boarding and alighting points, such as rapid transit stations, bus transfer opportunities, and major trip attractors. The goal would be to have sufficient spacing between stops (with a minimum average of approximately one-half mile) such that greater than 50 percent of route boardings and alightings would be served by the limited-stop service. Obviously, not all of these riders would actually be served by the limited-stop service, as one end of the trip could be at a local stop. However, those riders whose boarding and alighting are both served by the limited-stop service would receive a significant savings in their average trip time. The introduction of limited-stop service would be balanced with a decrease in the trip frequency for the route's local variation. Routes not receiving limited-stop service would maintain their local bus service at the existing frequencies.

Figures 77 and 78 present an example of how this concept could potentially be realized. The routes selected for limited-stop service include all Key Bus Routes (Routes 1, 15, 22, 23, 28, 32, 39, 57, 66, 71, 73, 77, 111, 116, 117, and the various branches of the Silver Line) as well as additional routes that travel longer distances and have a minimum of 4,000 daily trips (Routes 16, 34, 70, 86, and 101). Figure

77 shows the locations of the stops selected for limited-stop service in the inbound direction while Figure 78 does the same in the outbound direction.

As an example, the operation of limited-stop service on Route 28 is estimated to be feasible with 30-minute headways and an increase in the headway of local Route 28 service from 6-7 minutes and 8 minutes in the AM- and PM-peak-weekday time periods, respectively, to 9-10 minutes and 12-13 minutes. Two vehicles would be required for limited-stop Route 28 service in the AM-peak-weekday time period, and three vehicles would be required in the PM-peak-weekday time period. The existing vehicle requirement for Route 28 local service for both peak-weekday time periods would decrease from 13 to 11 vehicles in the AM peak and 10 vehicles in the PM peak. The limited-stop Route 28 service is estimated to have a savings in total route running time of over 30 percent.

4.2.4 Radial, Circumferential, and Neighborhood Services

This concept would reinforce the radial nature of the rail network by using buses primarily to shuttle passengers to the rail system or to points between rail lines. In neighborhoods without access to rail stations, BRT routes, with frequencies similar to those of other rapid transit lines and bus improvement measures to prioritize bus travel, would provide radial access to downtown Boston. Other BRT routes would operate on the major circumferential corridors, typically linking multiple radial routes but also serving non-radial trips that are entirely circumferential. Non-BRT bus routes would also operate as circumferential routes between radial lines. While the alignment of some local routes would not change from the current local bus network (particularly those outside the rapid transit service area), other local routes between the radial lines would be much shorter in terms of both distance and running times than they currently are. These routes would primarily serve a specific neighborhood, shuttling trips from that neighborhood to the nearest rapid transit lines. The shorter running times of these routes would also permit an increase in their service frequencies.

Figure 79 presents an example of how this concept could potentially be realized. Note that the Green Line extension to College Avenue, the new Assembly Square Station on the Orange Line, and the improvements to the Fairmount Line are assumed. Other new radial corridors that would be realized with BRT service are Routes 32, 34, 39, 57, 70, 73, 77, 109 (with an extension to Haymarket Station), 111, 220, 240, 455, and an extension of the Silver Line-Washington Street along

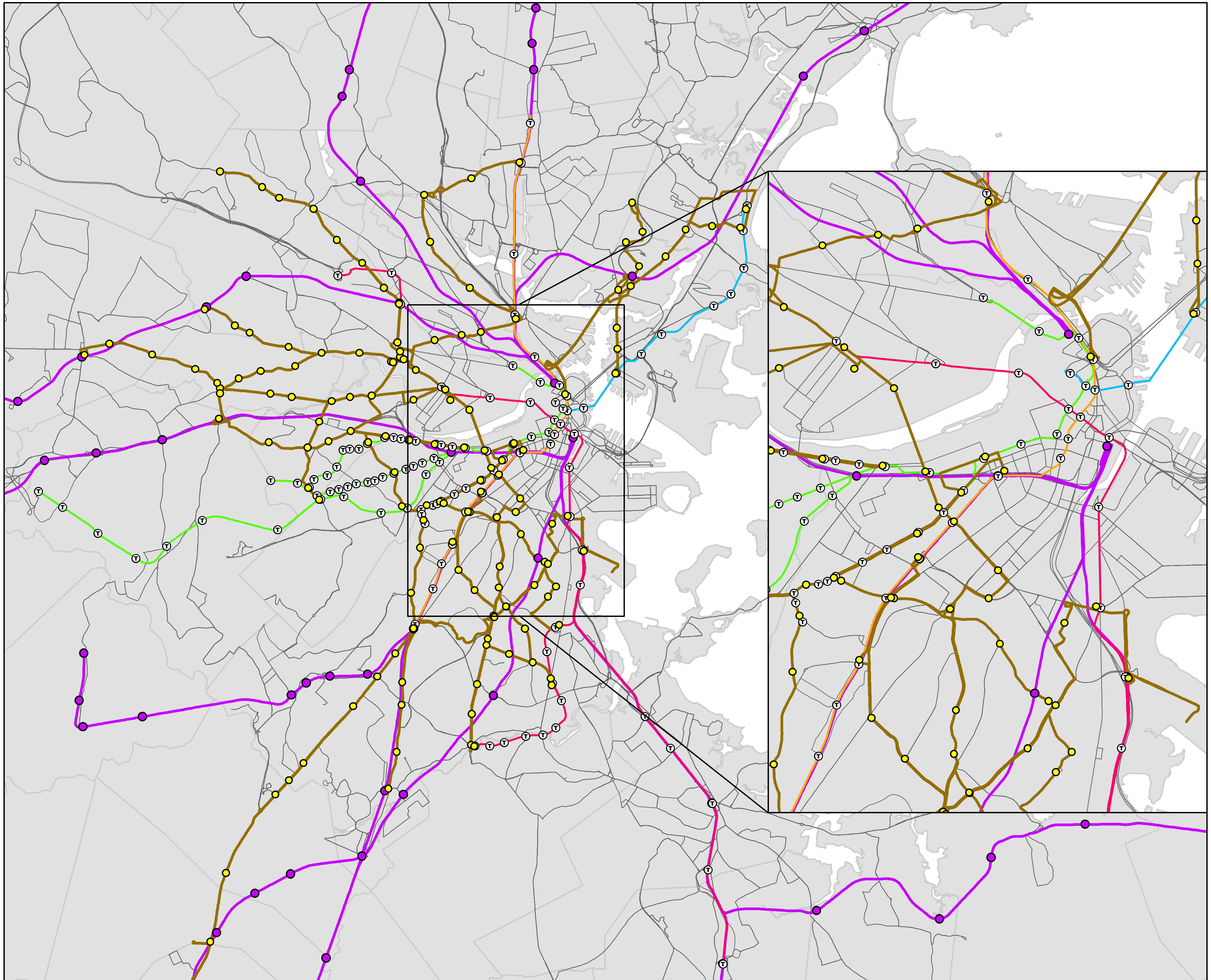


FIGURE 77
Limited-Stop Corridor Concept: Inbound Stops

Legend

Limited stops (inbound)
Limited-stop service
Local bus service
Commuter rail stations
Commuter rail lines
Rapid transit stations

Rapid Transit Lines

Blue
Green
Orange
Red
Town boundary

N

0 1.25 2.5 5 Miles

Core Efficiencies Study

BOSTON REGION MPO

Page left intentionally blank.

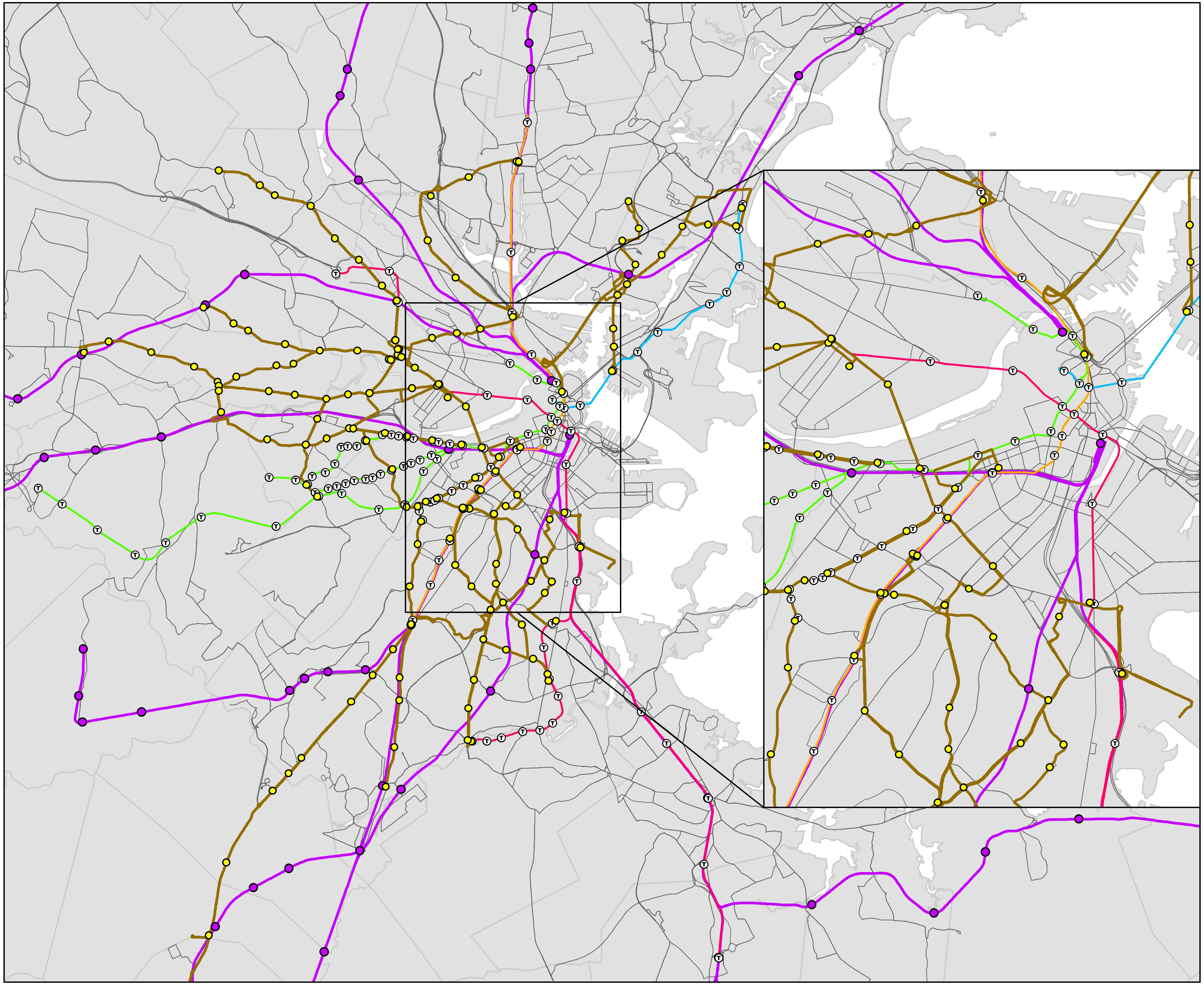


FIGURE 78
Limited-Stop Corridor Concept: Outbound Stops

Legend

Limited stops (outbound)
Limited-stop service
Local bus service
Commuter rail stations
Commuter rail lines
Rapid transit stations

Rapid Transit Lines

Blue
Green
Orange
Red
Town boundary

N

0 1.25 2.5 5 Miles

Core Efficiencies Study

BOSTON REGION MPO

Page left intentionally blank.

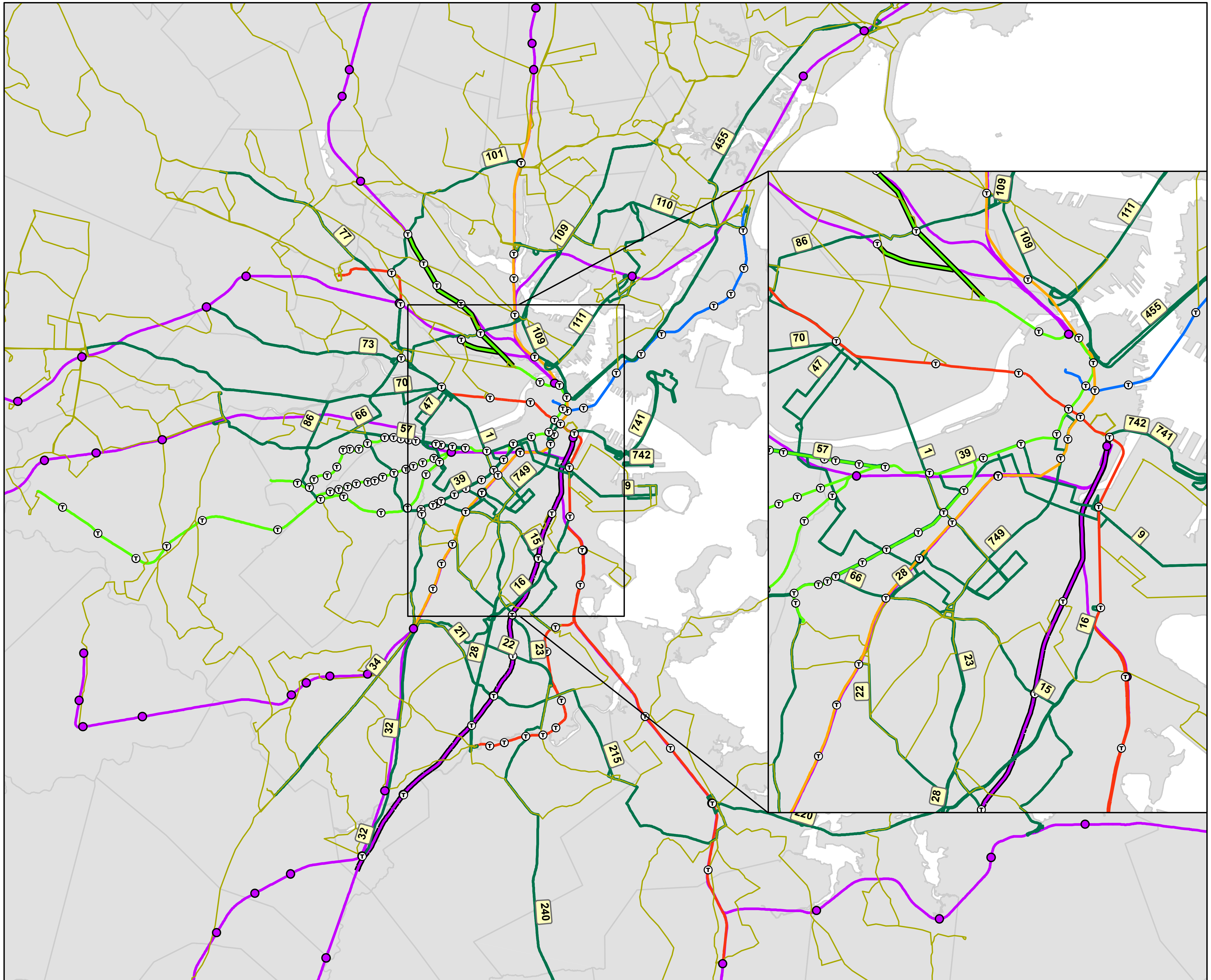


FIGURE 79
Radial, Circumferential, and Neighborhood Concept

Legend

- Neighborhood routes
- BRT routes 000
- Fairmount Line
- Green Line extension
- Commuter rail stations
- Commuter rail lines
- Rapid transit stations

Rapid Transit Lines

- Blue Line
- Green Line
- Orange Line
- Red Line
- Town boundary

N

0 1.25 2.5 5 Miles

Core Efficiencies Study

BOSTON REGION MPO

Page left intentionally blank.

Blue Hill Avenue to Mattapan Station and along Washington Street and Talbot Avenue to Ashmont Station. Circumferential routes that would be converted into BRT services are Routes 1, 9, 15, 16, 21, 22, 31, 47, 66, 86, 110, and 215. In addition, Route 101 could be converted into a circumferential route between Malden Station and Davis Station by rerouting Route 101 onto College Avenue from Main Street. Other existing routes would only be maintained if they provide service to an area not well served by the rapid transit routes. Some of these existing routes would be shortened. The total number of bus routes under this example concept would be reduced from the 166 existing (include the Silver Line-Washington Street and Silver Line-Waterfront) to 26 BRT routes and 82 neighborhood bus routes.

4.2.5 Summary of Potential Service Concepts

The four concepts presented in this section offer several different visions for how MBTA service could be potentially structured in the future. The rail extension concept essentially maintains the existing service structure with extensions of the radial rail network while using buses as primarily feeder routes or to serve circumferential trips. The BRT corridor concept replaces local bus service in the urban core with a reduced number of high-frequency, BRT-level services, while local bus service outside the core would remain the same. The limited-stop corridor concept replaces local bus service with a combination of local and limited-stop service during the peak travel periods along Key Bus Routes and other major routes that travel a longer distance. The final concept presents an entirely revised bus network, with new BRT routes along major radial and circumferential corridors and other bus routes linking local neighborhoods to these corridors and the rail lines.

4.3 Application of Service Standards

The second chapter in this study reviewed the various service standards used by the MBTA and other peer transit agencies. The following section analyzes the possible implications for these service standards of each of the defined potential service concepts: rail extensions; BRT corridors; limited-stop corridors; and radial, circumferential, and neighborhood services (referred to henceforth as “neighborhood services”). Given that the MBTA’s existing performance according to these standards has already been reviewed, this analysis will focus on the potential changes to this performance that can be linked to the specific service concept. These concepts are grouped by their general theme category: service structure, service provision, service efficiency, and physical infrastructure.

4.3.1 Service Structure

Coverage

The coverage standard measures the walking distance to the nearest transit service. The MBTA currently uses a minimum standard of 0.25 miles for areas with a minimum population density of 5,000 persons per square mile. Within the 65 municipalities of the MBTA's bus and rapid transit service area, 80 percent of street-miles that lie within census tracts with a population density of 5,000 or greater are within a quarter-mile of transit service. For all bus and rapid transit services, 158 square miles fall within the quarter-mile coverage standard.

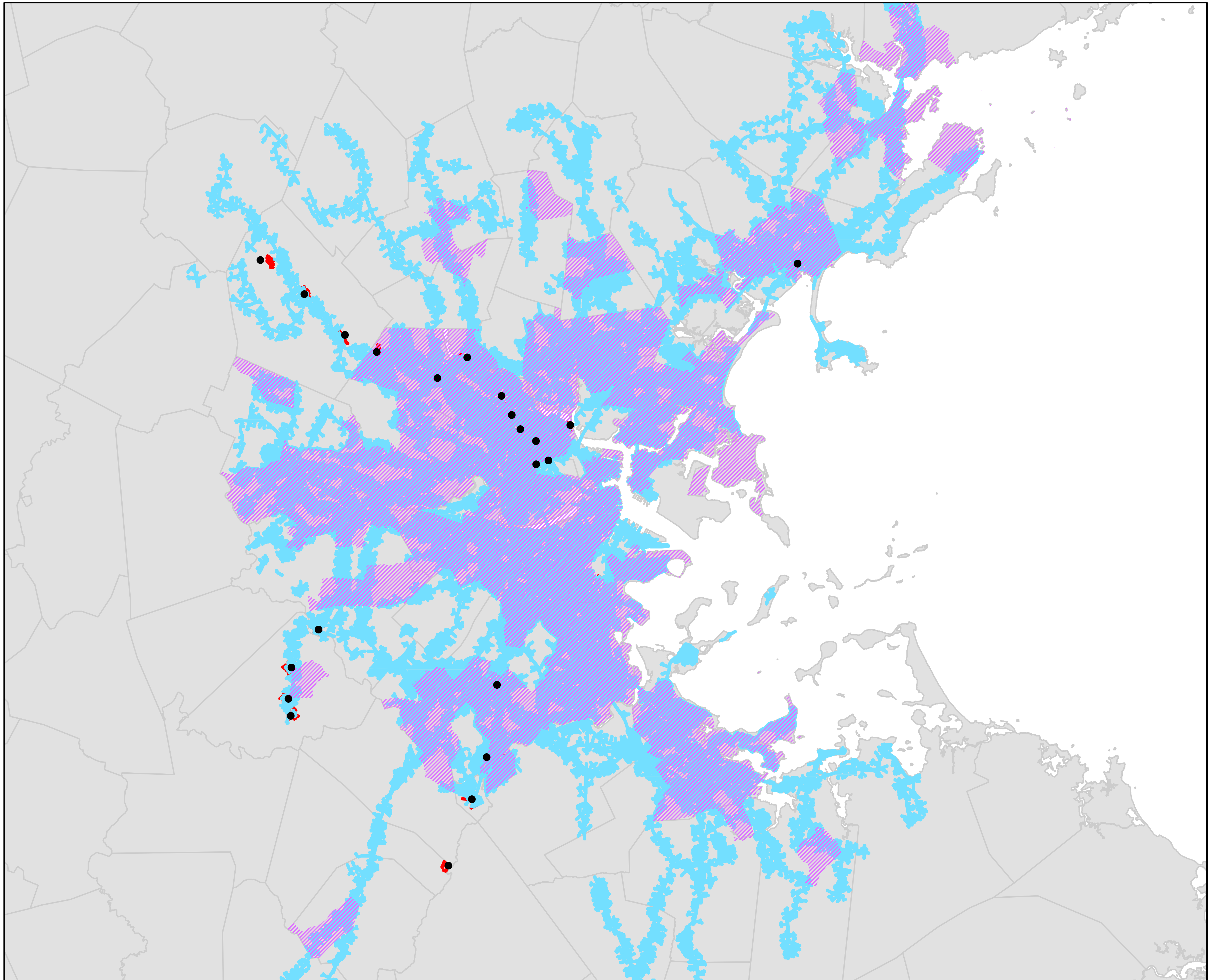
Rail Extension Concept

The rail extension concept would add coverage compared to the existing transit network, as it only involves additions to the rail network. Figure 80 shows the coverage of the existing transit network and the additional coverage that would be provided by adding to the rail network. This concept would increase the square miles of bus and rapid transit service coverage by 2.4 percent. Within census tracts with a population density of 5,000 or greater, square miles of service coverage would increase by 3.0 percent.

BRT Corridor Concept

The BRT corridor concept would reduce coverage compared to the existing transit network, as the provision of BRT services within the urban core would be offset by the reduction in local bus routes. Figure 81 shows the quarter-mile coverage of the BRT corridor concept and the reduced coverage compared to the existing transit network that would be caused by the elimination of non-BRT local bus routes in the urban core. This concept would decrease the square miles of service coverage for the entire bus and rapid transit system by 1.7 percent. Within census tracts with a population density of 5,000 or greater, the square miles of service coverage would decrease by 57.9 percent.

FIGURE 80
Rail Extension Concept: Existing and Additional Transit Coverage (area within quarter-mile walk to transit service)



Core Efficiencies Study

BOSTON REGION MPO

Page left intentionally blank.

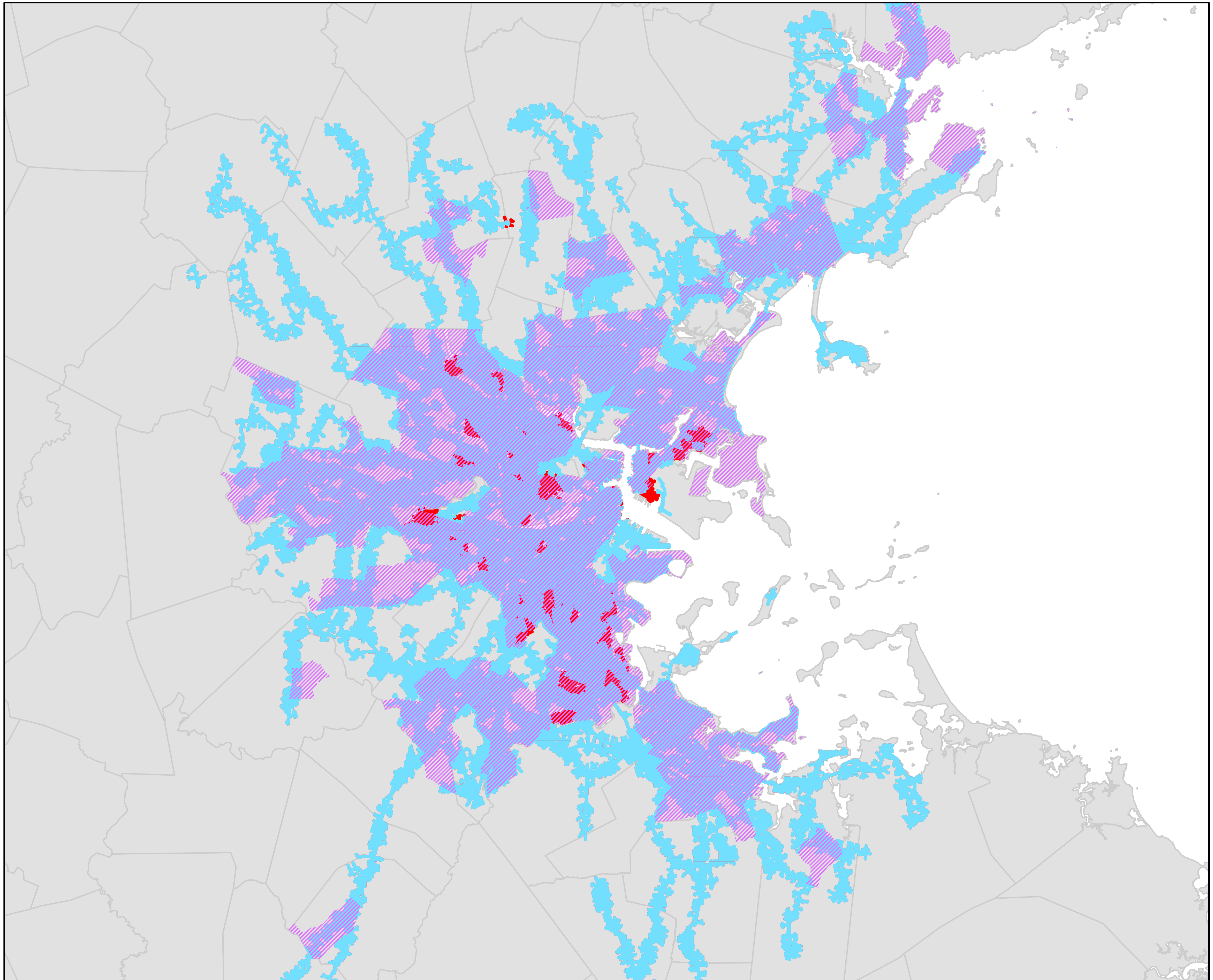


FIGURE 81
BRT Corridor Concept: Concept and Eliminated Transit Coverage (area within quarter-mile walk to transit service)

Legend

Census tract >= 5,000 pop. density

BRT corridor 0.25-mile coverage

Eliminted 0.25-mile coverage

Town boundary

N

0 2 4 8 Miles

Core Efficiencies Study

BOSTON REGION MPO

Page left intentionally blank.

Limited-Stop Corridor Concept

The limited-stop corridor concept would not change the coverage of the existing transit network, as no new routes would be added nor would any routes be eliminated. According to the standards by which the stops for the limited-stop routes were selected, all limited-stop routes have stops that serve at least 50 percent of the boardings and alightings for that route. Table 88 presents the percentage of boardings plus alightings that the stops of each limited-stop route serve. Routes with a greater concentration of boardings and alightings at specific stops, such as Route 111 where 81 percent of boardings plus alightings are at Haymarket Station, have greater percentages.

Table 88
Limited-Stop Corridor Concept: Percentage of Boardings plus Alightings Served by Stops

	Percent of Boardings + Alightings Served	
Bus Route	**Inbound**	**Outbound**
1: Harvard Sq. - Dudley Sta. via Mass. Ave.	65%	62%
15: Kane Sq. - Ruggles Sta.	56%	62%
16: Forest Hills Sta. - UMass	64%	70%
22: Ashmont Sta. - Ruggles Sta. via Talbot Ave.	61%	64%
23: Ashmont Sta. - Ruggles Sta. via Washington St.	60%	62%
28: Mattapan Sta. - Ruggles Sta.	60%	59%
32: Wolcott Sq. or Cleary Sq. - Forest Hills Sta.	72%	67%
34: Dedham Line - Forest Hills Sta.	35%	65%
39: Forest Hills Sta. - Back Bay Sta.	55%	51%
57: Watertown Yard - Kenmore Sta.	52%	49%
66: Harvard Sq. - Dudley Sta. via Brookline	57%	60%
70: Cedarwood - Central Sq. Cambridge	55%	60%
71: Watertown Sq. - Harvard Sta.	69%	65%
86: Sullivan Sta. - Cleveland Circle	66%	64%
101: Malden Sta. - Sullivan Sta. via Medford Sq.	52%	54%
111: Woodlawn or Bway. & Park - Haymarket Sta.	73%	73%
116: Wonderland Sta. - Maverick Sta. via Revere	56%	60%

Radial, Circumferential, and Neighborhood Services Concept

The neighborhood services concept would reduce coverage compared to the existing transit network in some areas where local bus routes are eliminated, but it would also add coverage in some areas that are not currently served by transit. Figure 82 shows the quarter-mile coverage of the neighborhood services concept and the eliminated coverage compared to the existing transit network. Overall, this concept would decrease the square miles of coverage for the entire bus and rapid transit network by 4.1 percent. The percentage decrease in the existing service coverage is actually 9.2 percent; however, an additional 8.8 square miles of new coverage would be provided to some areas that are not currently served by transit. Within census tracts with a population density of 5,000 or greater, the square miles of service coverage would decrease by 5.8 percent. This overall decrease would be made up of a 9.2 percent decrease in the existing service coverage, offset by an additional 3.3 square miles of new coverage.

Summary of Concepts

The proposed concepts would offer significantly different levels of coverage. The rail extension concept would only provide limited additional coverage, as several proposed stations are located in suburban areas that have limited walking access, and other stations are located in more urban areas that are already served by bus routes, such that the rail extensions there would provide no additional coverage. The BRT corridor concept proposes the greatest reduction in coverage, largely in the urban core where most proposed BRT routes would be located. This is caused by the elimination of local bus service in the BRT corridor concept. The limited-stop corridor concept would not change systemwide coverage as no routes would be added or eliminated. Finally, the neighborhood services concept has a slightly reduced coverage level compared to the existing system; however, it does add coverage to some areas that are not currently served by transit. This additional coverage would be provided by new neighborhood-based local routes while the reduced coverage would come from the elimination and rerouting of several local bus routes where BRT service would be provided. Under this concept, the primary role of local bus routes would be to serve as feeders to the major radial and circumferential rapid transit corridors.

Stop Spacing

The MBTA does not currently have a stop-spacing standard, but a majority of distances between stops fall between 0.05 miles and 0.15 miles.

Rail Extension Concept

The approximate distances between new rapid transit stations in the rail extension concept are presented in Table 89. Most of the new stations

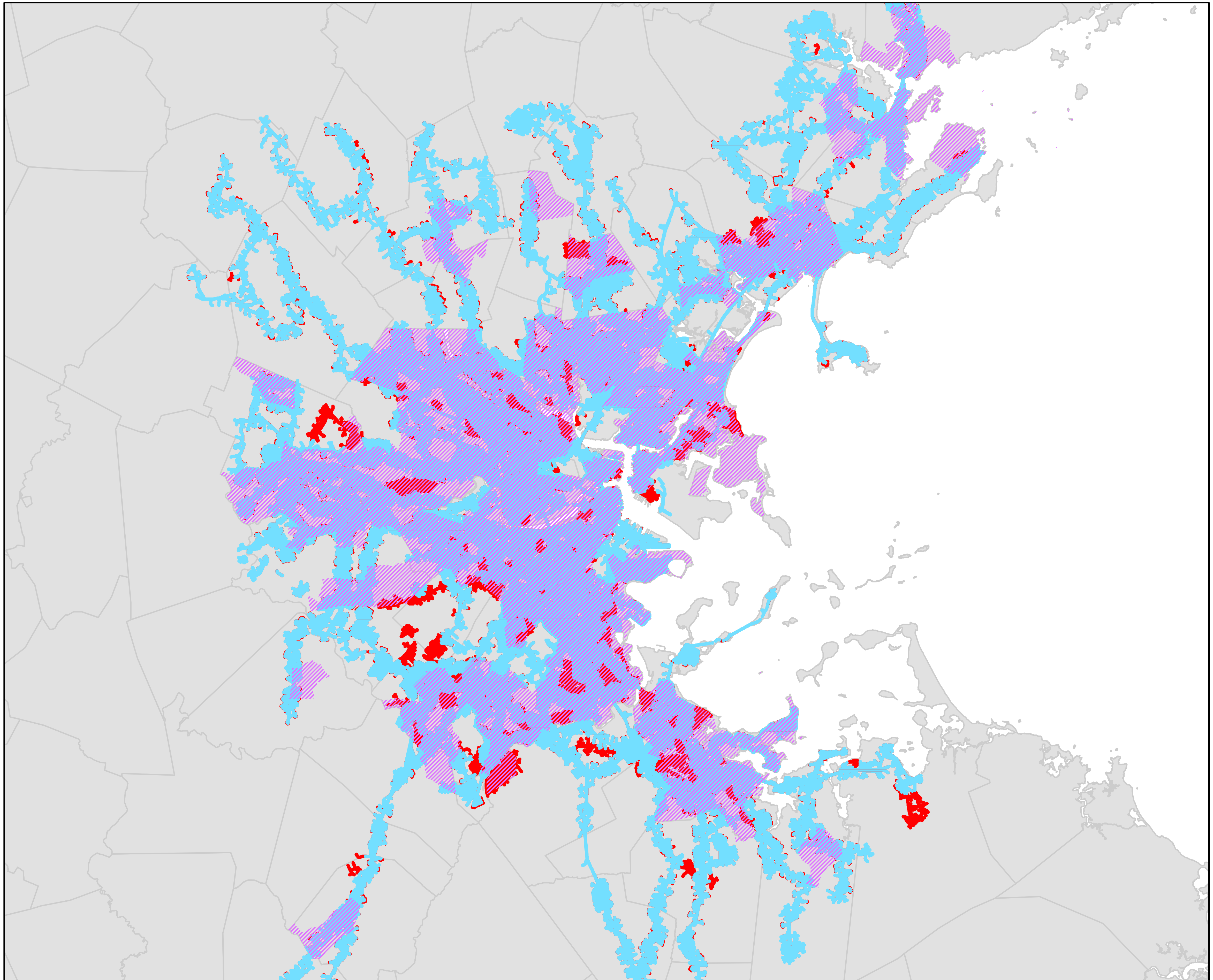


FIGURE 82
Neighborhood Services Concept: Concept and Eliminated Transit Coverage (area within quarter-mile walk to transit service)

Legend

Census tract >= 5,000 pop. density

Remaining 0.25-mile coverage

Eliminted 0.25-mile coverage

Town boundary

N

0 2 4 8 Miles

Core Efficiencies Study

BOSTON REGION MPO

This page left intentionally blank.

Table 89
Rail Extension Concept: Distances between New Rapid Transit Stations and Average Line Distance

Rail Line	Stations: From	Stations: To	Distance btwn. Stations (mi.)	Average Station Distance (mi.)
Blue	Wonderland	Central Square, Lynn	4.252	
Red	Alewife	Arlington Center	1.419	
	Arlington Center	Arlington Heights	2.042	
	Arlington Heights	East Lexington	1.150	
	East Lexington	Lexington Center	1.716	
	Lexington Center	Route 128	1.843	
	Alewife	*Route 128*	*8.170*	*1.634*
Green D Branch	Newton Highlands	Upper Falls	1.213	
	Upper Falls	Needham Heights	1.435	
	Needham Heights	Needham Center	0.908	
	Needham Center	Needham Junction	0.607	
	Newton Highlands	*Needham Junction*	*4.163*	*1.041*
Orange	Forest Hills	Mount Hope	1.831	
	Mount Hope	Hyde Park	2.151	
	Hyde Park	Readville	1.286	
	Readville	Route 128	2.054	
	Forest Hills	*Route 128*	*7.322*	*1.831*
Orange	Sullivan Square	Assembly Square	0.687	
	Assembly Square	Wellington	0.457	
	Sullivan Square	*Wellington*	*1.144*	*0.572*
Red-Blue Connector	Bowdoin	Charles/MGH	0.475	
Green E Branch	Lechmere	Brick Bottom	0.857	
	Brick Bottom	Gilman Square	0.677	
	Gilman Square	Lowell Street	0.592	
	Lowell Street	Ball Square	0.484	
	Ball Square	College Avenue	0.630	
	College Avenue	Mystic Valley Parkway	1.490	
	Lechmere	*Mystic Valley Parkway*	*4.730*	*0.788*
	Lechmere	Union Square	1.136	
Fairmount Line	South Station	Newmarket	1.595	
	Newmarket	Uphams Corner	0.893	
	Uphams Corner	Four Corners	1.194	
	Four Corners	Talbot Avenue	0.779	
	Talbot Avenue	Morton Street	0.855	
	Morton Street	Blue Hill Avenue	0.699	
	Blue Hill Avenue	Fairmount	1.841	
	Fairmount	Readville	1.408	
	South Station	*Readville*	*9.264*	*1.158*

This page left intentionally blank.

are separated by distances greater than one mile. The addition of Assembly Square Station on the Orange Line reduces the line's average station distance. The Green Line E Branch extension from Lechmere to Mystic Valley Parkway has the smallest spacing between stations of any rail extension. The rail extensions would increase the average station spacing for all of the lines in the current rail rapid transit system. Station spacing for each line is currently below one mile.

BRT Corridor Concept

The implementation of BRT service is often accompanied by an increase in the average distance between stops. Table 90 presents the existing average inbound and outbound stop spacing for the 34 routes selected under the BRT corridor concept for BRT service. As seen in the table, all routes except for the two Silver Line Waterfront branches, Route 31 in the inbound direction, and the Silver Line Washington Street in the outbound direction have an average stop spacing below 0.20 miles, and 65 percent and 74 percent of routes in the inbound and outbound directions, respectively, have an average stop spacing below 0.16 miles. The revised stop spacing for most BRT routes would likely mirror that of the Silver Line Washington Street, with an average stop spacing between 0.20 and 0.25 miles.

Limited-Stop Corridor Concept

Limited-stop service would operate at an average stop-spacing distance greater than that under the BRT corridor concept. Note that, under the limited-stop corridor concept, all routes with limited-stop service would also have local service. Table 91 presents the existing average stop-spacing distance for the local service by direction as well as the potential average stop spacing for limited-stop service by direction. The average stop-spacing distance of local routes in both directions is approximately 0.15 miles while the average potential stop-spacing distance of the limited-stop routes is 0.68 miles in the inbound direction and 0.66 miles in the outbound direction.

Radial, Circumferential, and Neighborhood Services Concept

As with the BRT corridor concept, the neighborhood services concept would also increase the average distance between stops on routes selected for BRT service, largely to within the range of 0.20 to 0.25 miles. Neighborhood routes would maintain a maximum distance between stops of 0.20 miles, but most stop distances would fall within the range of 0.05 to 0.15 miles.

Table 90
BRT Corridor Concept: Existing Stop Spacing for Selected BRT Routes

	Average Stop Spacing (mi.)	
Bus Route	**Inbound**	**Outbound**
1: Harvard Sq. - Dudley Sta. via Mass. Ave.	0.148	0.138
7: City Point - Otis & Summer Sts.	0.182	0.163
8: Harbor Point/UMass - Kenmore Sta.	0.168	0.173
9: City Point - Copley Sq. via Broadway Sta.	0.153	0.137
11: City Point - Downtown	0.133	0.130
15: Kane Sq. - Ruggles Sta.	0.109	0.131
16: Forest Hills Sta. - UMass	0.188	0.192
21: Ashmont Sta. - Forest Hills Sta.	0.186	0.169
22: Ashmont Sta. - Ruggles Sta. via Talbot Ave.	0.178	0.158
23: Ashmont Sta. - Ruggles Sta. via Washington St.	0.142	0.134
28: Mattapan Sta. - Ruggles Sta.	0.146	0.137
31: Mattapan Sta. - Forest Hills Sta.	0.233	0.157
32: Wolcott Sq. or Cleary Sq. - Forest Hills Sta.	0.155	0.149
39: Forest Hills Sta. - Back Bay Sta.	0.156	0.160
47: Central Sq. Cambridge - Broadway Sta.	0.158	0.166
57: Watertown Yard - Kenmore Sta.	0.133	0.130
66: Harvard Sq. - Dudley Sta. via Brookline	0.147	0.155
71: Watertown Sq. - Harvard Sta.	0.156	0.138
73: Waverley Sq. - Harvard Sta.	0.144	0.149
77: Arlington Heights - Harvard Sta.	0.153	0.144
86: Sullivan Sta. - Cleveland Circle	0.152	0.143
87: Clarendon Hill - Lechmere Sta. via Somerville Ave.	0.154	0.135
88: Clarendon Hill - Lechmere Sta. via Highland Ave.	0.153	0.136
89: Clarendon Hill - Sullivan Sta.	0.126	0.114
91: Sullivan Sta. - Central Sq. Cambridge	0.138	0.137
93: Sullivan Sta. - Downtown via Bunker Hill	0.157	0.138
109: Linden Sq. - Sullivan Sta.	0.166	0.153
110: Wonderland Sta. - Wellington Sta.	0.160	0.148
111: Woodlawn or Bway. & Park - Haymarket Sta.	0.176	0.132
116: Wonderland Sta. - Maverick Sta. via Revere	0.126	0.113
117: Wonderland Sta. - Maverick Sta. via Beach	0.130	0.124
741 Silver Line 1: Logan Airport - South Sta.	0.451	0.629
742 Silver Line 2: Boston Marine Industrial Park - South Sta.	0.302	0.344
749 Silver Line 5: Dudley Sta. - Downtown	0.189	0.219

Table 91
Limited-Stop Corridor Concept:
Stop Spacing for Local and Limited-Stop Routes

	Average Stop Spacing (mi.)			
	Inbound		Outbound	
Bus Route	**Local**	**Limited**	**Local**	**Limited**
1: Harvard Sq. - Dudley Sta. via Mass. Ave.	0.148	0.560	0.138	0.551
15: Kane Sq. - Ruggles Sta.	0.109	0.607	0.131	0.634
16: Forest Hills Sta. - UMass	0.177	0.809	0.213	0.791
22: Ashmont Sta. - Ruggles Sta. via Talbot Ave.	0.178	0.587	0.158	0.536
23: Ashmont Sta. - Ruggles Sta. via Washington St.	0.142	0.582	0.134	0.568
28: Mattapan Sta. - Ruggles Sta.	0.146	0.530	0.137	0.601
32: Wolcott Sq. or Cleary Sq. - Forest Hills Sta.	0.155	0.650	0.149	0.656
34: Dedham Line - Forest Hills Sta.	0.162	1.133	0.166	1.118
39: Forest Hills Sta. - Back Bay Sta.	0.156	0.554	0.160	0.580
57: Watertown Yard - Kenmore Sta.	0.133	0.650	0.130	0.548
66: Harvard Sq. - Dudley Sta. via Brookline	0.147	0.616	0.155	0.618
70: Cedarwood - Central Sq. Cambridge	0.186	0.777	0.171	0.777
71: Watertown Sq. - Harvard Sta.	0.156	0.581	0.138	0.573
86: Sullivan Sta. - Cleveland Circle	0.148	0.605	0.143	0.612
101: Malden Sta. - Sullivan Sta. via Medford Sq.	0.124	1.065	0.131	0.941
111: Woodlawn or Bway. & Park - Haymarket Sta.	0.176	0.579	0.132	0.548
116: Wonderland Sta. - Maverick Sta. via Revere	0.126	0.695	0.113	0.676
117: Wonderland Sta. - Maverick Sta. via Beach	0.130	0.619	0.124	0.573

Summary of Concepts

All of the potential service concepts offer a greater average stop-spacing distance compared to the existing system. The rail extension concept proposes greater distances between stations than the existing station spacing on the same line. All proposed BRT routes, either in the BRT corridor concept or the neighborhood services concept, have a greater average distance between stops to reduce the frequency with which buses must stop to pick up or drop off passengers. Finally, the limited-stop corridor concept has the greatest average distance between stops, as this service is intended to primarily serve longer-distance trips between major boarding and alighting points.

Route Duplication/Competition

The MBTA does not currently have either a route-duplication or route-competition standard. Most duplication in the MBTA system exists on the highway portion of express bus routes or around the roads leading to rapid transit stations. The closer proximity of bus routes increases the likelihood of competition between the routes for riders, but it appears that most MBTA transit routes are serving specific geographic or demographic markets.

Rail Extension Concept

The rail extension concept does extend some rail lines along corridors served by existing bus routes. For example, the Orange Line extension to Route 128 mirrors Route 32 to Readville Station. However, several existing cases do exist where bus routes mirror a portion of rail rapid transit lines, such as Route 1 along the Red Line between Harvard Station and Central Station or Route 18 along the Red Line between Andrew Station and Ashmont Station, providing local service between the stations. Thus, while these services are somewhat duplicative, they do not compete, as they each serve different markets. Nevertheless, it is likely that some bus routes would be eliminated or rerouted due to an expected reduction in their ridership caused by competition with rail rapid transit extensions, for example, if the Red Line was extended to Lexington or the Blue Line was extended to Lynn.

BRT Corridor Concept

The duplication of services along BRT corridors is not entirely negative, as this allows the physical investments needed for BRT service to be shared with multiple routes. However, while certain BRT routes would share the same corridors, the BRT corridor concept would likely reduce overall route duplication due to the elimination of non-BRT routes within the service area of the BRT corridors. Note that the BRT corridor concept does not affect express bus routes, which have the greatest amount of route duplication.

Limited-Stop Corridor Concept

Route duplication would not be affected by the limited-stop corridor concept, as this concept proposes no changes to the existing route structure, only the scheduling of local and limited-stop variations on certain routes.

Radial, Circumferential, and Neighborhood Services Concept

One of the goals of the neighborhood services concept is actually the reduction of duplicative services. This is achieved by using neighborhood routes to transport riders to the nearest rapid transit corridor, from which riders can use the needed circumferential or radial rapid transit route. As a result, neighborhood routes remain much more local in nature, having little overlap with other neighborhood or rapid transit routes.

Summary of Concepts

Most of the potential concepts would not dramatically affect route duplication or competition. The rail extension concept would necessitate a review of which local bus routes that serve the same markets should be eliminated or rerouted. Most of the existing route duplication exists on express bus routes, which are largely left unaffected by the proposed concepts, or around rapid transit stations. The limited-stop corridor would not affect route duplication at all. The BRT corridor concept would reduce route duplication simply by reducing the number of bus routes, as would the neighborhood services concept. This concept would also reduce duplication by limiting the routings of several local bus routes so that they would not go beyond the boundaries of their specific neighborhood.

Route Travel Time

The MBTA does not currently have a standard for route travel time. More than 90 percent of all bus routes have an average one-way route running time at or below 45 minutes, while only 10 percent have a maximum route running time greater than 60 minutes.

Rail Extension Concept

The rail extension scenario would lengthen the running times of trains from one end of the line to the other. Table 92 presents the existing scheduled AM one-way running times by line and estimates of the additional running time caused by each potential rail expansion. As seen in the table, several expansions are estimated to result in at least a 40 percent increase in the one-way running times, with the potential expansions of the Red Line to Route 128 and the Green Line to Mystic Valley Parkway estimated to have the greatest absolute increases in the one-way running time.

BRT Corridor Concept

Under the BRT concept scenario, all routes selected for BRT service would have reduced running times. This would be caused by the various BRT improvement measures, such as dedicated or exclusive rights-of-way, pre-paid boarding, and traffic signal priority (TSP), as well as the reduction in the number of stops due to an increase in distance between stops. BRT services with an exclusive right-of-way typically operate at average speeds between 17 and 30 miles per hour while

Table 92
Rail Extension Concept: Existing Scheduled AM One-Way Running Times and Estimated Additional Running Times by Line

Rail Line Extension	Direction	Existing One-Way Running Time	Estimated Additional Running Time
Blue Line to Central Square, Lynn	Northbound	20	7
	Southbound	21	7
Blue Line to Charles/MGH	Northbound	20	2
	Southbound	21	2
Red Line-Ashmont to Route 128	Northbound	40	26
	Southbound	38	24
Red Line-Braintree to Route 128	Northbound	54	26
	Southbound	49	24
Orange Line to Route 128	Northbound	35	14
	Southbound	35	14
Orange Line – Assembly Square Station	Northbound	35	3
	Southbound	35	3
Green Line D Branch to Needham	Eastbound	35	15
	Westbound	32	13
Green Line E Branch to Mystic Valley Pkwy.	Northbound	31	27
	Southbound	27	23
Green Line E Branch to Union Square	Northbound	31	5
	Southbound	27	4
Fairmount Line	Northbound	28	0
	Southbound	28	0

arterial BRT services operating in mixed-flow traffic or with dedicated lanes typically operate at average speeds between 12 and 17 miles per hour.[24] The estimated existing average speed of the Silver Line Washington Street is 9.7 miles per hour in the inbound direction and 13.1 miles per hour in the outbound direction. Most BRT routes under the BRT concept are assumed to use the latter BRT treatment. Table 93 presents the existing AM-peak running times for each of the proposed BRT routes as well as assumptions for each route's revised AM-peak running times with the various BRT improvements. These assumptions were made by taking the range of 12 to 17 miles per hour scaled to the range of existing running times for each proposed BRT

[24] "Characteristics of Bus Rapid Transit for Decision-Making." Page ES-5. Federal Transit Administration (August 2004). www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf

route. The resulting AM-peak running times are reduced between 11 and 54 percent.

Limited-Stop Corridor Concept

Under the limited-stop corridor concept, each limited-stop route would have a reduced running time due to the smaller number of stops served by the route. The increased average route speed is assumed to be slightly greater than those for the BRT concept, despite the fact that limited-stop routes would operate in mixed traffic. Based on this assumption, the estimated range is 15 to 20 miles per hour. Table 94 presents the existing AM-peak running times for each of the proposed limited-stop routes as well as assumptions for each route's revised AM-peak running times for serving only the limited-stop locations. These assumptions were made by taking the range of 15 to 20 miles per hour scaled to the range of existing running times and the proposed average stop spacing for each proposed limited-stop route. The resulting AM-peak running times are reduced between 20 and 61 percent.

Radial, Circumferential, and Neighborhood Services Concept

As with the BRT corridor concept, the neighborhood services concept would also reduce the average route running time on routes selected for BRT service. Neighborhood routes would likely operate at similar speeds to existing local bus routes and have equivalent running times relative to the route length. Figure 83 shows potential running times for BRT and neighborhood routes, assuming a range of speeds for BRT routes between 12 and 17 miles per hour and an average neighborhood route speed of 10 miles per hour. Most BRT routes have a route running time under 30 minutes, with the only exception being the express service to Lynn. The longest running times for neighborhood routes are largely for existing local bus routes that are largely located on the periphery of the urban core. The only neighborhood routes with running times greater than 30 minutes that serve the urban core are express bus routes.

Summary of Concepts

The potential service concepts offer varying changes to existing route running times. The rail extension concept would lengthen the various rapid transit lines and increase the one-way running time, in some cases, by a significant amount. All proposed BRT routes, either in the BRT corridor concept or the neighborhood services concept, would generally reduce running times compared to existing local bus routes due to various BRT improvement measures. Finally, the limited-stop corridor concept would also reduce running times, likely by a slightly greater amount than proposed BRT routes, due to the elimination of all stops except the major boarding and alighting points.

Directness of Travel (Comparison to Auto Trip Times)

The MBTA does not currently have a standard for directness of travel, which compares in-vehicle transit travel times to private vehicle travel times. As an example, the travel times of the Silver Line Washington Street were compared to the equivalent auto trip times between Dudley Station and Temple Place. The calculated ratios of bus to auto travel times were 187 percent in the inbound direction and 157 percent in the outbound direction. The ratios for the proposed concepts were not calculated, as it as it would require the use of the Boston Region MPO travel demand model set.

Rail Extension Concept

The rail extension concept would facilitate the radial trips that many individuals take to access the urban core. Several of the rail extensions, such as the Green Line extensions to West Medford or Needham, the Orange Line extension to Route 128, and the Fairmount Line, provide a much more direct path to downtown Boston than any path along the street network. However, intermediate stops invariably increase transit travel times compared to auto travel times. When combining all factors, it is likely that the rail extension concept would offer transit travel times that are comparable to or only slightly greater than auto travel times.

BRT Corridor Concept

Most existing bus routes, from which all BRT routes in the BRT corridor concept are selected, do not serve a completely direct path between their origin and destination timepoints. Some routes, such as Route 1 or Route 28, do largely mirror the same path that a driver would take between the routes' origin and destination timepoints; however, intermediate stops along all bus routes increase the ratio of transit to auto travel times. The increase in stop spacing for BRT corridors, combined with BRT improvement measures to improve average speeds, would reduce this ratio compared to existing local bus routes. When combining all factors, it is likely that the BRT corridor concept would offer transit travel times along BRT corridors that are greater than comparable auto travel times, but not significantly so. Local bus routes, given the shorter distance between stops, would continue to have the greatest transit to auto travel time ratios.

Table 93
BRT Corridor Concept: Existing and Potential AM-Peak Running Times for Selected BRT Routes

	Running Times (min.)					
	Existing		Potential		Percent Change	
Bus Route	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound
1: Harvard Sq. - Dudley Sta. via Mass. Ave.	35	36	20	18	-44%	-49%
7: City Point - Otis & Summer Sts.	22	15	13	11	-42%	-26%
8: Harbor Point/UMass - Kenmore Sta.	51	50	29	31	-43%	-38%
9: City Point - Copley Sq. via Broadway Sta.	33	21	19	15	-44%	-30%
11: City Point - Downtown	28	24	16	16	-41%	-34%
15: Kane Sq. - Ruggles Sta.	28	30	16	18	-41%	-41%
16: Forest Hills Sta. - UMass	28	24	18	16	-35%	-32%
21: Ashmont Sta. - Forest Hills Sta.	18	21	13	14	-26%	-31%
22: Ashmont Sta. - Ruggles Sta. via Talbot Ave.	33	30	22	21	-34%	-31%
23: Ashmont Sta. - Ruggles Sta. via Washington St.	33	31	20	20	-39%	-35%
28: Mattapan Sta. - Ruggles Sta.	38	36	23	24	-41%	-35%
31: Mattapan Sta. - Forest Hills Sta.	18	16	12	12	-33%	-23%
32: Wolcott Sq. or Cleary Sq. - Forest Hills Sta.	15	13	11	12	-23%	-11%
39: Forest Hills Sta. - Back Bay Sta.	36	34	20	19	-45%	-44%
47: Central Sq. Cambridge - Broadway Sta.	51	50	23	24	-54%	-51%
57: Watertown Yard - Kenmore Sta.	34	28	22	21	-35%	-26%
66: Harvard Sq. - Dudley Sta. via Brookline	47	52	25	26	-48%	-50%
71: Watertown Sq. - Harvard Sta.	28	23	16	16	-43%	-32%
73: Waverley Sq. - Harvard Sta.	30	20	17	16	-42%	-21%
77: Arlington Heights - Harvard Sta.	30	26	21	21	-29%	-19%
86: Sullivan Sta. - Cleveland Circle	40	46	27	27	-34%	-41%
87: Clarendon Hill - Lechmere Sta. via Somerville Ave.	28	22	17	16	-40%	-28%
88: Clarendon Hill - Lechmere Sta. via Highland Ave.	33	23	18	15	-47%	-33%
89: Clarendon Hill - Sullivan Sta.	20	19	13	14	-36%	-29%
91: Sullivan Sta. - Central Sq. Cambridge	22	14	12	10	-48%	-29%
93: Sullivan Sta. - Downtown via Bunker Hill	19	15	11	10	-42%	-35%
109: Linden Sq. - Sullivan Sta.	31	27	20	19	-34%	-30%
110: Wonderland Sta. - Wellington Sta.	28	28	21	22	-23%	-20%
111: Woodlawn or Bway. & Park - Haymarket Sta.	35	29	19	14	-45%	-52%
116: Wonderland Sta. - Maverick Sta. via Revere	30	30	20	19	-32%	-37%
117: Wonderland Sta. - Maverick Sta. via Beach	32	28	19	18	-40%	-36%
741 Silver Line 1: Logan Airport - South Sta.	23	15	15	10	-34%	-34%
742 Silver Line 2: Boston Marine Industrial Park - South Sta.	14	10	11	8	-24%	-23%
749 Silver Line 5: Dudley Sta. - Downtown	14	11	9	9	-38%	-20%

Table 94
Limited-Stop Corridor Concept: Existing and Potential AM-Peak Running Times for Selected Limited-Stop Routes

	Running Times (min.)					
	Existing		Potential		Percent Change	
Bus Route	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound
1: Harvard Sq. - Dudley Sta. via Mass. Ave.	35	36	17	15	-51%	-58%
15: Kane Sq. - Ruggles Sta.	28	30	14	15	-49%	-50%
16: Forest Hills Sta. - UMass	28	24	16	14	-43%	-43%
22: Ashmont Sta. - Ruggles Sta. via Talbot Ave.	33	30	20	18	-41%	-40%
23: Ashmont Sta. - Ruggles Sta. via Washington St.	33	31	18	17	-47%	-45%
28: Mattapan Sta. - Ruggles Sta.	38	36	20	20	-48%	-44%
32: Wolcott Sq. or Cleary Sq. - Forest Hills Sta.	15	13	11	10	-30%	-20%
34: Dedham Line - Forest Hills Sta.	58	58	45	45	-22%	-23%
39: Forest Hills Sta. - Back Bay Sta.	36	34	17	16	-53%	-54%
57: Watertown Yard - Kenmore Sta.	34	28	19	18	-43%	-35%
66: Harvard Sq. - Dudley Sta. via Brookline	47	52	21	21	-55%	-59%
70: Cedarwood - Central Sq. Cambridge	55	52	28	28	-49%	-46%
71: Watertown Sq. - Harvard Sta.	28	23	14	13	-51%	-42%
86: Sullivan Sta. - Cleveland Circle	40	46	24	23	-41%	-51%
101: Malden Sta. - Sullivan Sta. via Medford Sq.	32	35	17	18	-47%	-48%
111: Woodlawn or Bway. & Park - Haymarket Sta.	35	29	17	11	-53%	-61%
116: Wonderland Sta. - Maverick Sta. via Revere	30	30	18	16	-39%	-48%
117: Wonderland Sta. - Maverick Sta. via Beach	32	28	17	15	-48%	-45%

Page left intentionally blank.

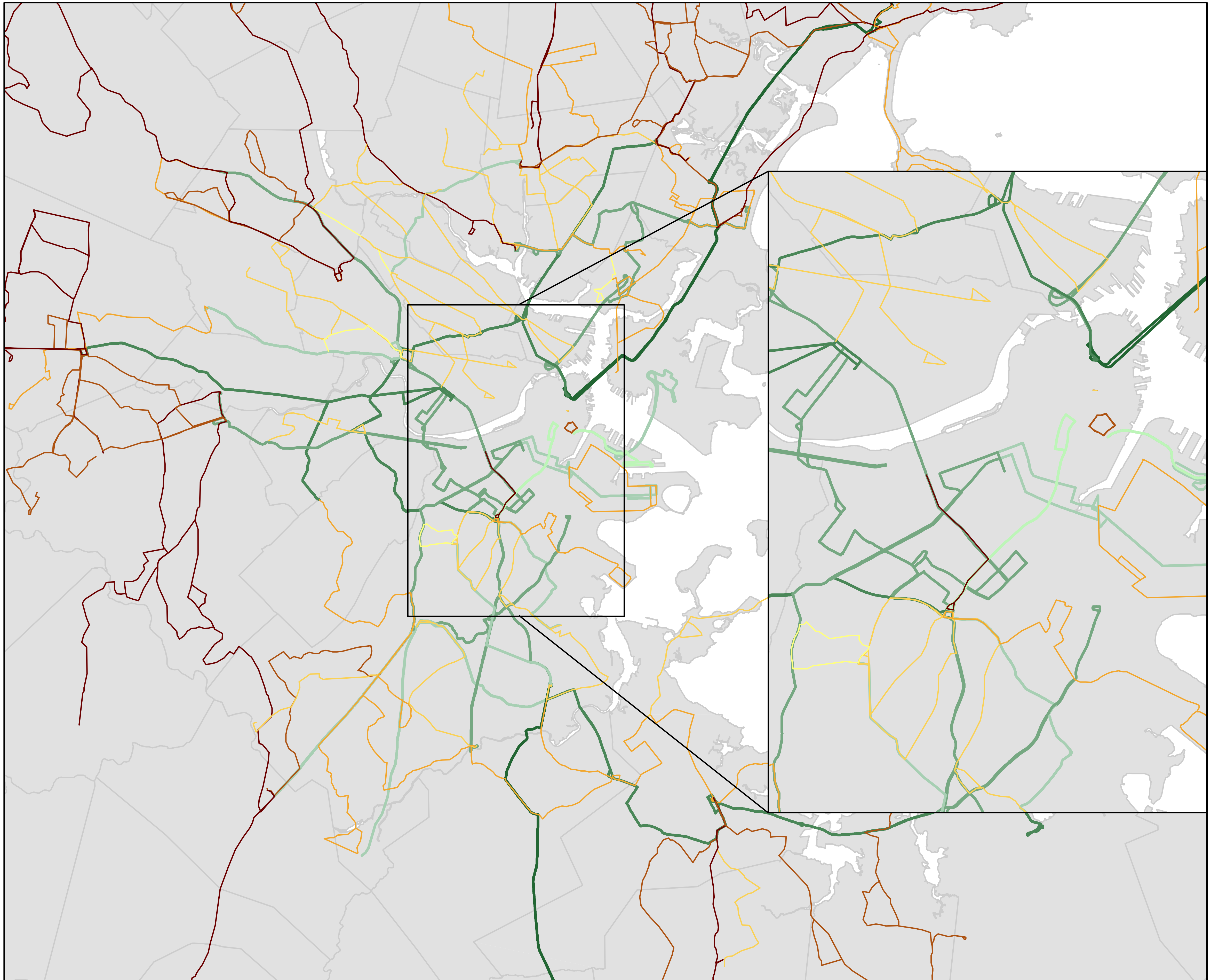


FIGURE 83
Neighborhood Services Concept: BRT and Neighborhood Route Running Time (minutes)

Legend

Neighborhood Routes

Running Time (min.)

- 9 - 14
- 15 - 29
- 30 - 44
- 45 - 59
- 60 - 127

BRT Routes

Running Time (min.)

- 10 - 14
- 15 - 19
- 20 - 24
- 25 - 29
- 30 - 49

Town boundary

N

0 1.25 2.5 5 Miles

Core Efficiencies Study

BOSTON REGION MPO

Page left intentionally blank.

Limited-Stop Corridor Concept

The limited-stop corridor concept would likely offer the smallest ratios of transit to auto travel times for any type of bus route, due to the small number of stops served by the limited-stop routes. The indirectness of each bus route would still increase the ratio to the same extent as in other concepts, however. When combining all factors, it is likely that the limited-stop corridor concept would offer transit travel times along limited-stop corridors that are only slightly greater than comparable auto travel times. Local bus routes, given the shorter distance between stops, would continue to have the greatest transit to auto travel time ratios.

Radial, Circumferential, and Neighborhood Services Concept

As with the BRT corridor concept, the neighborhood services concept would reduce the ratio of transit travel times to auto travel times for comparable trips when compared to the ratio for existing local bus routes. The reduced ratios would be caused by longer distances between stops and various BRT improvement measures. Several neighborhood bus routes in this concept would likely score worse than existing local bus routes in terms of directness of travel given the route’s path that is necessary to provide coverage to an entire neighborhood.

Summary of Concepts

The various concepts offer a range of probable ratios of transit travel times to comparable auto travel times, governed by the respective concept’s stop spacing as well as the transit route’s directness. The rail extension scenario likely offers the most direct transit service with the longest average distances between stop, followed by limited-stop routes in the limited-stop corridor concept and then the BRT routes in both the BRT corridor concept and neighborhood services concept. Local bus routes in the limited-stop corridor concept and BRT corridor concept would have significantly greater ratios of transit travel times to comparable auto travel times given their shorter distances between stops, while neighborhood routes in the neighborhood services concept would likely have the greatest ratios due to the non-direct nature of their trip paths.

Ease of Use

The MBTA does not currently have a standard for ease of use. This standard is typically based on the extent of clock-face headways[25] so that the service schedule is easy to remember, the extent to which routes run consistently throughout the day with minimum variations, and several other factors related to technology and training. Routes with headways less than or equal to 10 minutes are assumed for walk-up service where riders are less likely to consult a schedule given the short wait-times. For the MBTA, routes with clock-face headways range from 25 percent to 30 percent of all routes over various time periods. In terms of minimizing variations, the ratio of route variations to general routes is the highest during the weekday, at 2.83, and falls to 1.70 on Saturday and 1.44 on Sunday.

Rail Extension Concept

The rail extension concept would duplicate the schedule of the existing rail rapid transit system. On these extensions, trains would operate at headways less than or equal to 10 minutes. Since riders would not typically need to consult a schedule, clock-face headways would not be necessary. The Green Line extension to West Medford is the only rapid transit extension in this concept that will have a variation: some service will serve Union Square in Somerville rather than West Medford. This variation would be unlikely to create confusion as most passengers would already be comfortable with the system of different Green Line branches. The other proposed rail extensions do not have any variations. Finally, the connection of the Blue Line to the Red Line at Charles/MGH Station would likely reduce the current confusion of passengers who must make a double transfer in order to transfer between the two lines.

BRT Corridor Concept

The BRT corridor concept would offer headways equivalent to those on the rail rapid transit system. Therefore, headways set at or below 10 minutes would make clock-face headways unnecessary. The headways of local bus routes outside the urban core would not change. Many of these routes, due to their reduced frequencies, already use clock-face

[25] Clock-face headways are ones that correspond to regular increments on the face of an analog clock, for example, a 20-minute headway with departures at :00, :20 and :40 past the hour.

headways. The BRT corridor concept would also simplify the system in the urban core by reducing the number of bus routes and variations.

Limited-Stop Corridor Concept

The limited-stop corridor concept would likely operate at headways greater than 10 minutes. Given passengers' desire to know when a local- versus a limited-stop route is approaching, the use of clock-face headways on both types of services would be useful. Because scheduling is largely dependent on route cycle times (which include running and recovery times) and the most efficient use of resources, clock-face headways might not be possible. The addition of limited-stop service would also increase the complexity of the system. Buses would need to clearly indicate whether they were operating local- or limited-stop service. The operation of limited-stop service only in the AM- and PM-peak periods would also increase complexity.

Radial, Circumferential, and Neighborhood Services Concept

As with the BRT corridor concept, the neighborhood services concept would also offer headways less than 10 minutes for the BRT routes, making the use of clock-face headways unnecessary. The headways of some neighborhood bus routes could also be set at or below 10 minutes given reduced route running times. In routes with headways greater than 10 minutes, clock-face headways are advisable, but, as discussed above, might not always be possible. The neighborhood services concept would also simplify the system by reducing the number of bus routes and variations.

Summary of Concepts

The various concepts likely have varying levels of ease of use. The rail extension scenario would simply extend the existing rail system with the only additional complexity being the Green Line spur to Union Square. Construction of the Red-Blue connector would also eliminate the need for and confusion associated with double transfers between the Red and Blue lines. All proposed BRT routes, either in the BRT corridor concept or the neighborhood services concept, would generally be easier to use given their headways below 10 minutes and the reduced number of routes. Finally, the limited-stop corridor concept would add some complexity to the system by introducing additional route variations and operating only in certain time periods.

Transfers/Waiting Time

The MBTA does not currently have a standard for transfers or waiting time. However, such a standard could be set at a maximum average transfer rate (number of unlinked trips per linked trip[26]) or a maximum average waiting time. Headways below 10 minutes, which characterize walk-up service, are associated with lower average waiting times compared to routes with longer headways, for which riders typically consult a schedule.

Rail Extension Concept

The rail extension concept would likely reduce the overall number of transfers. A large number of existing transfers are between buses and the rail rapid transit network. Extending the rail network would allow more passengers to walk or drive directly to rail stations. This concept would also likely reduce the average waiting time, as rapid transit headways below 10 minutes would be extended to additional areas. In addition, the connection of the Blue Line to the Red Line at Charles/MGH Station would eliminate the need to use the Green Line to transfer between the two lines, therefore reducing in half the number of required transfers.

BRT Corridor Concept

The BRT corridor concept would also likely reduce the overall transfer rate. The elimination of local bus service in the urban core would require more passengers to walk to the nearest BRT corridor. BRT routes would also have headways below 10 minutes, which would reduce the average waiting time for passengers in the BRT service area.

Limited-Stop Corridor Concept

The limited-stop corridor concept would not affect the transfer rate, as this concept does not eliminate any routes or propose new service to any area that is not currently served by transit. However, given the longer headways that would be required on both local- and limited-stop

---

[26] Linked trips represent the travel between a trip's origin and destination, regardless of how many different transit vehicles a rider must use to make that trip. Unlinked trips represent the travel on each transit vehicle. Thus, a linked trip with one transfer equals two unlinked trips.

routes in the limited-stop corridors, this would likely increase the average waiting time.

Radial, Circumferential, and Neighborhood Services Concept

The neighborhood services concept would be likely to slightly reduce the overall transfer rate, as more passengers would likely walk to the nearest BRT corridor. However, neighborhood routes are structured specifically to facilitate transfers to and from rapid transit corridors. This increase in transfers with neighborhood routes would likely partially offset the decrease in transfers with BRT routes. BRT routes would also have headways below 10 minutes while neighborhood routes would have headways greater than 10 minutes. As a result, the average waiting time would decrease for BRT passengers but increase for passengers on neighborhood routes.

Summary of Concepts

The various concepts offer a range of potential effects on the MBTA's overall transfer rate and average waiting time. The rail extension concept would likely have the greatest decrease in the transfer rate, as greater numbers of passengers would be able to walk or drive directly to rapid transit without needing to transfer from a local bus and the Red-Blue Connector would reduce in half the number of transfers needed to travel between the two lines. The BRT corridor concept and the neighborhood services concept would similarly permit greater numbers of passengers to directly access rapid transit or BRT routes without needing to use a local bus, though the neighborhood services concept would moderate this somewhat by providing neighborhood feeder routes that would increase transfers. The limited-stop corridor concept would be unlikely to affect the transfer rate. In all cases where headways are provided below 10 minutes, this would reduce the average waiting time. As a result, the rail extension, BRT corridor, and neighborhood services concepts would all reduce the average waiting time by increasing the amount of rapid transit service with headways below 10 minutes. The limited-stop corridor would likely increase the average waiting time given the greater headways of local- and limited-stop routes.

Summary of Service Structure Standards

Table 95 summarizes the potential effects of each proposed concept (as compared to existing services) with regard to each of the service structure standards.

The rail extension concept would likely have:

- a limited increase in coverage, as several proposed stations would be located in suburban areas that have limited walking access, and other stations would be located in more urban areas that are already served by bus routes, such that the rail extensions there would provide no additional coverage
- an increase in the average distance between stations compared to the existing station spacing on the same line
- a decrease in route duplication due to the elimination or rerouting of some local bus routes that serve the same markets
- an increase in one-way running times, in some cases, by a significant amount
- a decrease in the ratio of in-vehicle transit travel time to the comparable auto travel time due to the greatest average distance between stops of any of the proposed scenarios
- an increase in the ease of use, except for the slight complexity added by the Green Line spur to Union Square
- a decrease in the transfer rate, as greater numbers of passengers would be able to walk or drive directly to rapid transit without needing to transfer from a local bus, and the Red-Blue Connector would eliminate the need to use the Green Line to transfer between these two lines
- a decrease in the average waiting time, due to a greater number of passengers using rapid transit service with headways below 10 minutes

The BRT corridor concept would likely have:

- a decrease in coverage, caused by the elimination of local bus service in the BRT service area
- an increase in the average distance between stops to reduce the frequency with which buses must stop to pick up or drop off passengers
- a decrease in route duplication due to the elimination of local bus routes in the BRT service area
- a decrease in one-way running times due to an increase in average stop spacing and various BRT improvement measures
- a decrease in the ratio of in-vehicle transit travel time to the comparable auto travel time due to an increase in average stop spacing and various BRT improvement measures

- an increase in the ease of use due to a reduction in routes and a greater percentage of routes with headways below 10 minutes
- a decrease in the transfer rate, as greater numbers of passengers would be able to directly access rapid transit without needing to transfer from a local bus
- a decrease in the average waiting time, due to a greater number of passengers using rapid transit service with headways below 10 minutes

The limited-stop corridor concept would likely have:

- no impact on coverage, as no routes would be added or eliminated
- an increase in the average distance between stops for limited-stop routes, as this service is intended to primarily serve longer-distance trips between major boarding and alighting points
- no impact on route duplication, as no routes would be added or eliminated
- a decrease in one-way running times due to the elimination of all stops except the major boarding and alighting points on limited-stop routes
- a decrease in the ratio of in-vehicle transit travel time to the comparable auto travel time on limited-stop routes given the greater stop spacing
- a decrease in the ease of use due to the introduction of additional route variations and their operation only in certain time periods
- no impact on the transfer rate, as no routes would be added or eliminated
- an increase in the average waiting time given the greater headways of local- and limited-stop routes

The radial, circumferential, and neighborhood services concept would likely have:

- a slight decrease in coverage, caused by the elimination of some existing local bus service, but offset to some extent by the addition of some neighborhood bus service in areas currently not served by transit
- an increase in the average distance between stops to reduce the frequency with which buses must stop to pick up or drop off passengers

- a decrease in route duplication due to the elimination of local bus routes in the BRT service area and the use of neighborhood routes that are limited to serving only specific neighborhoods
- a decrease in one-way running times for BRT routes due to an increase in average stop spacing and various BRT improvement measures and for neighborhood routes due to their smaller service area
- a decrease in the ratio of in-vehicle transit travel time to the comparable auto travel time for BRT routes due to an increase in average stop spacing and various BRT improvement measures, but offset to some extent by an increase in the ratios for neighborhood routes due to the non-direct nature of their trip paths
- an increase in the ease of use due to a reduction in routes and a greater percentage of routes with headways below 10 minutes
- a decrease in the transfer rate, as greater numbers of passengers would be able to directly access rapid transit without needing to transfer from a local bus, but offset to some extent by providing neighborhood routes that would increase transfers
- a decrease in the average waiting time, due to a greater number of passengers using rapid transit service with headways below 10 minutes

Table 95
Service Structure Standards: Summary of Potential Effects of Proposed Service Concepts

Standard	Rail Extension	BRT Corridor	Limited-Stop	Neighborhood Services
Coverage	↑	↓↓↓	–	↓
Stop Spacing	↑↑	↑	↑↑↑	↑
Route Duplication	↓	↓↓	–	↓↓↓
Route Travel Time	↑↑	↓	↓↓↓	↓↓
Ratio to Auto Trip Times	↓↓↓	↓	↓↓	↓
East of Use	↑↑	↑	↓	↑
Transfer Rate	↓↓↓	↓↓	–	↓
Average Waiting Time	↓↓	↓↓	↑	↓↓

Key: "↑" represents an increase, "↓" represents a decrease, and "–" represents no change. The number of arrows represents the relative size of the increase or decrease.

4.3.2 Service Provision

Span of Service

The span-of-service standard stipulates the exact hours of operation or a minimum range of hours. The MBTA's weekday span-of-service standards require service to be provided between 6:00 AM and 12:00 AM for heavy and light rail routes and Key Bus Routes and between 7:00 AM and 6:30 PM for local bus routes. According to the 2008 Service Plan, 19 directly-operated weekday MBTA bus routes, composing 11 percent of all service, failed the span-of-service standard.

Rail Extension Concept

The rail extension concept would not change the existing rail system's span-of-service. The areas served by the rail extensions would receive a longer span of service, however, compared to that provided by existing local bus routes that currently end service before 12:00 AM. This would likely require some of the bus routes that would serve the proposed rail stations to extend their current spans of service.

BRT Corridor Concept

The BRT corridor concept would extend the span of service because all new BRT routes would operate until 12:00 AM. Since BRT routes serve the entire urban core, this would ensure a consistent span of service throughout the urban core. Local bus routes outside the BRT service area would continue to use their existing span-of-service standard, from 7:00 AM to 6:30 PM.

Limited-Stop Corridor Concept

The limited-stop corridor concept would maintain the schedule for local service in the early AM and night time periods, only providing limited-stop service during the AM- and PM-peak time periods. Therefore, this concept would not change existing spans of service for any existing routes.

Radial, Circumferential, and Neighborhood Services Concept

As with the BRT corridor concept, the neighborhood services concept would also extend the span of service because all new BRT routes would operate until 12:00 AM. Neighborhood routes would likely use the existing span-of-service standard for local bus routes, from 7:00 AM to 6:30 PM.

Summary of Concepts

All but one of the potential service concepts would extend the hours of service in some fashion. The rail extension concept would increase service hours to the areas served by the new stations as well as for some local bus routes serving those stations. All proposed BRT routes, either in the BRT corridor concept or the neighborhood services concept, would use a span of service from 6:00 AM to 12:00 AM while other local or neighborhood bus routes would use the existing local bus route standard of 7:00 AM to 6:30 PM. Finally, the limited-stop corridor concept would not change the system's span of service, as any changes to the schedule caused by limited-stop routes would only occur during the AM- and PM-peak time periods.

Frequency of Service

The frequency standard stipulates the maximum headway at which a transit service may operate. The MBTA's frequency standard requires a maximum 10-minute headway for the services and in the time periods most in demand. This includes AM- and PM-peak trips on light rail, heavy rail, and the Key Bus Routes. A 15-minute maximum headway is required at all other times for these services, with the exception of Key Bus Routes, which operate at a 20-minute maximum headway during the evening and on the weekend. Local bus routes are required to have a maximum 30-minute headway during the peak periods and a maximum 60-minute headway at all other times. According to the 2008 Service Plan, 48 directly-operated weekday MBTA bus routes, composing 27 percent of all service, failed the frequency-of-service standard.

Rail Extension Concept

The rail extension concept would ideally use the existing headways on each rail line. This would require putting additional rail vehicles into service in order to maintain current headways.

BRT Corridor Concept

The BRT corridor concept would use rapid transit headways on all BRT routes; that is, a maximum 10-minute headway during the AM- and PM-peak time periods and a maximum 15-minute headway at all other times. The headways of local bus routes outside the BRT service area would not change from their current levels.

Limited-Stop Corridor Concept

Since the limited-stop corridor concept does not add extra service to existing bus routes, the headways of local bus routes would need to increase to compensate for the new limited-stop variations. While a full service plan would need to be created for each combination of local- and limited-stop routes, it is likely that the headways of the limited-stop routes would be approximately 30 minutes and no less than 20 minutes. This would cause the headways of local-stop routes to increase slightly above 10 minutes. Greater headways for the limited-stop variations would be necessary in order to continue to provide a high level of bus frequency at all local bus stops.

Radial, Circumferential, and Neighborhood Services Concept

As with the BRT corridor concept, the neighborhood services concept would also use rapid transit headways on all BRT routes; that is, a maximum 10-minute headway during the AM- and PM-peak time periods and a maximum 15-minute headway at all other times. The headways of neighborhood bus routes would vary, as the small distances of some routes would permit greater frequencies. However, in general, neighborhood bus headways would likely range from 20 minutes to 30 minutes in the peak and up to 60 minutes off-peak.

Summary of Concepts

The potential service concepts offer varying changes to existing bus and rail frequencies. The rail extension concept would increase headways on all extended rail lines unless additional rail vehicles could be put into operation. Both the BRT corridor concept and the neighborhood services concept would use existing rapid transit headways on all BRT routes. The headways of local routes in the BRT corridor concept would not change and the headways of neighborhood routes in the neighborhood services concept would generally range between 20 and 30 minutes in the peak and up to 60 minutes off-peak, depending on the route distance. Finally, the limited-stop corridor concept would result in greater headways for both local- and limited-stop variations. The limited-stop headway would likely be 30 minutes and no less than 20 minutes in order to maintain a high level of bus frequency at all local bus stops.

Schedule Adherence

The schedule-adherence standard sets the acceptable number of minutes a service is late or early compared to the scheduled arrival or departure time. The MBTA uses two types of metrics to determine bus route schedule adherence: a timepoint test, which varies based on service frequency, and a route test. The timepoint test for scheduled-departure trips (those with a headway of 10 minutes or more) states that trips must depart the origin timepoint 0-3 minutes late, depart the mid-route timepoints 0-7 minutes late, and arrive at the destination timepoint 3 minutes early to 5 minutes late. The timepoint test for walk-up trips (those with a headway of less than 10 minutes) states that trips must depart the origin and mid-route timepoints within 1.5 times the scheduled headway and arrive at the destination timepoint with a trip running time within 20 percent of the scheduled running time. The determination of route schedule adherence is based on the route test, which states that at least 75 percent of all timepoints on a given route must meet the timepoint test. According to the 2008 Service Plan, the average weekday timepoint on-time percentage weighted across all directly-operated MBTA bus routes by each route's respective average weekday daily ridership was 59.1 percent.

Generally, the likelihood that transit fails the on-time standard increases with the length of the transit line and the number of stops along the line. This happens when a constant headway between vehicles is not maintained and the first vehicle falls behind schedule for any reason. The vehicle will continue to fall increasingly behind schedule as the number of passengers boarding and alighting at each subsequent stop increases and the vehicle must spend additional dwell time at the stop. As the first vehicle falls further behind schedule, a second vehicle catches up (or "bunches") with the first vehicle, creating a gap in the schedule between the second and third vehicles. Like the first vehicle, the third vehicle will fall increasingly behind schedule as the number of passengers boarding and alighting at each subsequent stop increases and the vehicle must spend additional dwell time at the stop. The pattern will then repeat. Greater route length and the number of stations or stops create more opportunities for vehicles to fall behind schedule and for those delays to magnify at subsequent stops.

Rail Extension Concept

By lengthening various rail lines and adding several new stations, the rail extension concept would increase the potential of trains arriving early or late at stations towards the terminals of the lines regardless of whether they depart their origins on-time. Table 96 shows the distance and the number of stations associated with each existing rail line and the additional distance and stations associated with each proposed extension. Of the various extensions, the Red Line and Orange Line

Table 96
Rail Extension Concept: Distances of Rail Extensions

		Distance (mi.)		Number of Stations	
Rail Line	**Extension**	**Rail Line**	**Extension**	**Rail Line**	**Extension**
Blue	Wonderland – Central Square, Lynn	5.83	4.252	12	1
Red-Ashmont	Alewife – Route 128	11.91	8.170	17	5
Red-Braintree	Alewife – Route 128	17.91	8.170	18	5
Green D Branch	Newton Highlands – Needham Junction	8.80*	4.163	16*	4
Orange	Forest Hills – Route 128	11.22	7.322	19	4
Orange	Assembly Square	11.22	N/A	19	1
Red-Blue Connector	Bowdoin – Charles/MGH	5.83**	0.475	12**	1
Green E Branch	Lechmere – Mystic Valley Parkway	5.54	4.730	20	6
	Lechmere – Union Square	5.54	1.136	20	1
Fairmount Line	South Station - Readville	9.26	9.264	4	4

** Rail line distance and number of stations equal the distance to Newton Highlands Station.*
*** Rail line distance and number of stations equal the distance of the Blue Line.*

extensions to Route 128 are the longest, but the Green Line extension to Mystic Valley Parkway has the greatest number of stations.

BRT Corridor Concept

The BRT corridor concept would select existing local bus routes for BRT service. Table 97 presents the existing inbound and outbound distances of each of these routes. Routes such as Routes 8, 66, and 86 have a greater potential for delay given their longer lengths and large number of stops. While stop spacing would vary for each BRT route depending on route specifics, most stops would be spaced at a distance of 0.20 to 0.25 miles, reducing the total number of stops, which would improve on-time performance. Finally, various BRT improvements, such as exclusive or dedicated rights-of-way, pre-paid boarding, and TSP, should help these routes maintain a more consistent schedule, as each reduces the potential of random delays. Therefore, in terms of schedule adherence, the BRT corridor concept should improve on-time performance within the urban core.

Limited-Stop Corridor Concept

The limited-stop corridor concept would improve on-time performance for limited-stop routes by reducing the number of stops and passengers served by the route. Table 98 presents the existing inbound and outbound distances of each of these routes. Shorter routes such as Routes 15, 32, and 71 would tend to see less benefit while longer routes such as Routes 34, 70, and 86 would likely have the greatest improvement in schedule adherence.

Radial, Circumferential, and Neighborhood Services Concept

As with the BRT corridor concept, the neighborhood services concept would also improve the schedule adherence of routes selected for BRT service. In addition, neighborhood routes that have only a small neighborhood service area would tend to have good on-time performance given their shorter route length and their travel on streets with less vehicle traffic.

Summary of Concepts

The potential service concepts offer varying levels of potential schedule adherence compared to the existing system. The rail extension concept would likely increase the possibility of delays due to greater route lengths and additional stations. The three bus-related concepts, on the other hand, would likely improve on-time performance by reducing the number of stops. The BRT corridor concept and neighborhood services

Table 97
BRT Corridor Concept: Existing Route Distances for Selected BRT Routes

	Route Distance (mi.)	
Bus Route	**Inbound**	**Outbound**
1: Harvard Sq. - Dudley Sta. via Mass. Ave.	5.04	4.41
7: City Point - Otis & Summer Sts.	3.28	2.93
8: Harbor Point/UMass - Kenmore Sta.	7.41	7.79
9: City Point - Copley Sq. via Broadway Sta.	4.75	3.83
11: City Point - Downtown	4.25	4.04
15: Kane Sq. - Ruggles Sta.	4.25	4.44
16: Forest Hills Sta. - UMass	4.88	4.22
21: Ashmont Sta. - Forest Hills Sta.	3.73	3.72
22: Ashmont Sta. - Ruggles Sta. via Talbot Ave.	5.87	5.36
23: Ashmont Sta. - Ruggles Sta. via Washington St.	5.24	5.11
28: Mattapan Sta. - Ruggles Sta.	5.83	6.01
31: Mattapan Sta. - Forest Hills Sta.	3.27	3.29
32: Wolcott Sq. or Cleary Sq. - Forest Hills Sta.	3.25	3.28
39: Forest Hills Sta. - Back Bay Sta.	4.99	4.64
47: Central Sq. Cambridge - Broadway Sta.	5.69	5.80
57: Watertown Yard - Kenmore Sta.	5.85	5.48
66: Harvard Sq. - Dudley Sta. via Brookline	6.16	6.18
71: Watertown Sq. - Harvard Sta.	4.06	4.01
73: Waverley Sq. - Harvard Sta.	4.46	4.31
77: Arlington Heights - Harvard Sta.	5.82	5.74
86: Sullivan Sta. - Cleveland Circle	7.13	6.73
87: Clarendon Hill - Lechmere Sta. via Somerville Ave.	4.32	4.19
88: Clarendon Hill - Lechmere Sta. via Highland Ave.	4.44	3.95
89: Clarendon Hill - Sullivan Sta.	3.41	3.53
91: Sullivan Sta. - Central Sq. Cambridge	2.89	2.60
93: Sullivan Sta. - Downtown via Bunker Hill	2.82	2.49
109: Linden Sq. - Sullivan Sta.	5.47	4.89
110: Wonderland Sta. - Wellington Sta.	6.08	6.05
111: Woodlawn or Bway. & Park - Haymarket Sta.	4.86	3.29
116: Wonderland Sta. - Maverick Sta. via Revere	5.56	4.73
117: Wonderland Sta. - Maverick Sta. via Beach	4.95	4.58
741 Silver Line 1: Logan Airport - South Sta.	4.06	2.52
742 Silver Line 2: Boston Marine Industrial Park - South Sta.	3.02	2.07
749 Silver Line 5: Dudley Sta. - Downtown	2.27	2.41

concept would increase average stop spacing on BRT routes to between 0.20 and 0.25 miles. The limited-stop corridor concept would increase average stop spacing to 0.50 miles or greater. Finally, the shorter distances of several neighborhood routes in the neighborhood services concept should also reduce the likelihood of delays.

Table 98
Limited-Stop Corridor Concept:
Existing Route Distances for Limited-Stop Routes

	Route Distance (mi.)	
Bus Route	**Inbound**	**Outbound**
1: Harvard Sq. - Dudley Sta. via Mass. Ave.	5.04	4.41
15: Kane Sq. - Ruggles Sta.	4.25	4.44
16: Forest Hills Sta. - UMass	4.88	4.22
22: Ashmont Sta. - Ruggles Sta. via Talbot Ave.	5.87	5.36
23: Ashmont Sta. - Ruggles Sta. via Washington St.	5.24	5.11
28: Mattapan Sta. - Ruggles Sta.	5.83	6.01
32: Wolcott Sq. or Cleary Sq. - Forest Hills Sta.	3.25	3.28
34: Dedham Line - Forest Hills Sta.	15.08	14.90
39: Forest Hills Sta. - Back Bay Sta.	4.99	4.64
57: Watertown Yard - Kenmore Sta.	5.85	5.48
66: Harvard Sq. - Dudley Sta. via Brookline	6.16	6.18
70: Cedarwood - Central Sq. Cambridge	8.54	8.55
71: Watertown Sq. - Harvard Sta.	4.06	4.01
86: Sullivan Sta. - Cleveland Circle	7.13	6.73
101: Malden Sta. - Sullivan Sta. via Medford Sq.	5.33	5.65
111: Woodlawn or Bway. & Park - Haymarket Sta.	4.86	3.29
116: Wonderland Sta. - Maverick Sta. via Revere	5.56	4.73
117: Wonderland Sta. - Maverick Sta. via Beach	4.95	4.58

Service Delivery, Service Failure, Vacancy Rate/Vehicle Availability, Accident and Incident Rate, and Passenger Complaints

A description of these measures can be found in section 2.2.2 in the previous chapter.

The MBTA does not currently have standards for any of these measures. However, the MBTA does present information in its monthly online ScoreCard about its performance with respect to these measures. It is not predicted that performance on any of these measures would be different for the proposed concepts as compared to existing services.

Summary of Service Provision Measures

Table 99 summarizes the potential effects of each proposed concept (as compared to existing services) with regard to each of the service provision standards.

The rail extension concept would likely have:

- an increase in the span of service for areas served by the new stations and for some local bus routes serving those stations
- a decrease in frequency (increase in headways) on all extended rail lines unless additional rail vehicles could be put into operation
- a decrease in schedule adherence and increase in the possibility of delays due to greater route lengths and additional stations
- no impact on service delivery, service failure, vacancy rate/vehicle availability, the accident and incident rate, and passenger complaints

The BRT corridor concept would likely have:

- an increase in the span of service for all BRT routes
- an increase in frequency (decrease in headways) for all BRT routes, while the headways of local routes would not change
- an increase in schedule adherence and decrease in the possibility of delays for BRT routes given BRT improvement measures and an increase in the average stop spacing
- no impact on service delivery, service failure, vacancy rate/vehicle availability, the accident and incident rate, and passenger complaints

The limited-stop corridor concept would likely have:

- no impact on span of service, as limited-stop routes would only operate during the AM- and PM-peak time periods
- a decrease in frequency (increase in headways) for both local- and limited-stop routes in order to maintain a high level of bus frequency at all local bus stops
- an increase in schedule adherence and decrease in the possibility of delays given an increase in the average stop spacing on limited-stop routes
- no impact on service delivery, service failure, vacancy rate/vehicle availability, the accident and incident rate, and passenger complaints

The neighborhood services concept would likely have:

- an increase in the span of service for all BRT routes

- an increase in frequency (decrease in headways) for all BRT routes, while the headways of neighborhood bus routes would depend on the route distance
- an increase in schedule adherence and decrease in the possibility of delays for BRT routes given BRT improvement measures, an increase in the average stop spacing, and the shorter route distances for some neighborhood routes
- no impact on service delivery, service failure, vacancy rate/vehicle availability, the accident and incident rate, and passenger complaints

Table 99
Service Provision Standards: Summary of Potential Effects of Proposed Service Concepts

Standard	Rail Extension	BRT Corridor	Limited-Stop	Neighborhood Services
Span of Service	↑	↑	—	↑
Frequency of Service	↓	↑	↓	↑
Schedule Adherence	↓	↑	↑	↑
Service Delivery	—	—	—	—
Service Failure	—	—	—	—
Vacancy Rate/Vehicle Availability	—	—	—	—
Accident and Incident Rate	—	—	—	—
Passenger Complaints	—	—	—	—

Key: "↑" represents an increase, "↓" represents a decrease, and "—" represents no change.

4.3.3 Service Efficiency

Net Cost per Passenger, Cost Effectiveness, and Passenger Productivity

Net cost per passenger, cost effectiveness, and passenger productivity measure service efficiency in three different ways. Net cost per passenger is the ratio of operating costs, minus service revenue, to the number of passengers; cost effectiveness is the ratio of service revenue to operating costs; passenger productivity is the ratio of the number of passengers to the amount of service (measured as the number of trips or revenue-hours). For the MBTA, any bus route for which the net cost per passenger is three times the system average fails the standard (the MBTA does not have a net cost standard for other modes). According to the 2008 Service Plan, 20 weekday bus routes, or 11 percent of all routes, failed the net-cost-per-passenger standard.

Rail Extension Concept

According to National Transit Database (NTD) fiscal year (FY) 2010 figures, the net cost per passenger for all heavy rail services (Blue, Orange, and Red Lines) is $1.10 and the net cost per passenger for all light rail services (Green Lines and Mattapan High-Speed Line) is $1.09. All of the proposed rail extensions would have greater operating costs than service revenue. Under the rail extension concept, most of the proposed extensions would likely increase the existing net cost per passenger. Extended service to stations that are, for the most part, at greater distances than existing stations would likely result in proportionately greater increases in the operating costs compared to the number of passengers and resulting service revenue. The exceptions under this concept might be extensions that are largely in the urban core: the Green Line extension to West Medford and the improvements and additional stations on the Fairmount Line.

BRT Corridor Concept

The BRT corridor concept would likely lower the net cost per passenger for BRT routes. While BRT routes would cost more to operate, due to their greater service frequency, they would likely have a greater proportionate increase in the number of riders and resulting service revenue. This would be achieved by the elimination of existing local bus routes with higher costs and lower ridership, with the effect of moving these riders to the BRT routes. According to NTD FY 2010 figures, the bus system’s average weekday net cost per passenger, in which total bus service revenue is subtracted from total bus operating costs and divided by total bus passengers, is $2.41. According to the 2008 Service Plan, when the weekday net cost per passenger of each bus route is weighted by each route’s ridership, the average net cost per passenger is $1.59. This indicates that a large percentage of bus operating costs are contributed by bus routes with relatively small ridership totals.

Table 100 presents the existing net costs per passenger of the bus routes selected for BRT service under this concept. The weighted average net cost per passenger of these 34 bus routes is $1.02. Only two of these routes exceed the bus system’s average net cost per passenger of $2.41, while only six of these routes exceed the weighted average of $1.59. The weighted average net cost per passenger of the 37 routes selected for elimination is $1.72, indicating that their elimination will lower the bus system’s average cost. However, many of the most costly local bus routes lie outside the BRT service area. Under this concept, these routes would be maintained. Their weighted average net cost per passenger is $2.63.

Table 100
BRT Corridor Concept:
Existing Net Cost per Passenger for Selected BRT Routes

Bus Route	Net Cost per Passenger
1: Harvard Sq. - Dudley Sta. via Mass. Ave.	$0.57
7: City Point - Otis & Summer Sts.	$2.11
8: Harbor Point/UMass - Kenmore Sta.	$2.53
9: City Point - Copley Sq. via Broadway Sta.	$1.58
11: City Point - Downtown	$2.62
15: Kane Sq. - Ruggles Sta.	$0.78
16: Forest Hills Sta. - UMass	$1.24
21: Ashmont Sta. - Forest Hills Sta.	$0.86
22: Ashmont Sta. - Ruggles Sta. via Talbot Ave.	$1.21
23: Ashmont Sta. - Ruggles Sta. via Washington St.	$0.88
28: Mattapan Sta. - Ruggles Sta.	$1.05
31: Mattapan Sta. - Forest Hills Sta.	$1.11
32: Wolcott Sq. or Cleary Sq. - Forest Hills Sta.	$0.97
39: Forest Hills Sta. - Back Bay Sta.	$0.62
47: Central Sq. Cambridge - Broadway Sta.	$2.21
57: Watertown Yard - Kenmore Sta.	$1.31
66: Harvard Sq. - Dudley Sta. via Brookline	$0.90
71: Watertown Sq. - Harvard Sta.	$1.19
73: Waverley Sq. - Harvard Sta.	$1.34
77: Arlington Heights - Harvard Sta.	$2.02
86: Sullivan Sta. - Cleveland Circle	$1.07
87: Clarendon Hill - Lechmere Sta. via Somerville Ave.	$1.14
88: Clarendon Hill - Lechmere Sta. via Highland Ave.	$0.79
89: Clarendon Hill - Sullivan Sta.	$1.05
91: Sullivan Sta. - Central Sq. Cambridge	$1.29
93: Sullivan Sta. - Downtown via Bunker Hill	$1.06
109: Linden Sq. - Sullivan Sta.	$1.29
110: Wonderland Sta. - Wellington Sta.	$1.79
111: Woodlawn or Bway. & Park - Haymarket Sta.	$1.35
116: Wonderland Sta. - Maverick Sta. via Revere	$0.63
117: Wonderland Sta. - Maverick Sta. via Beach	$0.69
741 Silver Line 1: Logan Airport - South Sta.	$0.48
742 Silver Line 2: Boston Marine Industrial Park - South Sta.	$0.15
749 Silver Line 5: Dudley Sta. - Downtown	$0.09

Limited-Stop Corridor Concept

Many of the routes selected for limited-stop service with a low net cost per passenger would match those selected for BRT service in the BRT corridor concept. Table 101 lists these routes and their existing net costs per passenger. The weighted average net cost per passenger of these 18 routes is $0.99. While some new riders may be attracted to the limited-stop service, this concept is unlikely to dramatically shift ridership patterns since there would be no change in the actual service coverage. Therefore, the combined net cost per passenger for both the local- and limited-stop variations is unlikely to change. However, depending on the number of vehicles allocated to each variation and the ridership split, one variation will have a greater net cost per passenger than the other.

Table 101
Limited-Stop Corridor Concept:
Existing Net Cost per Passenger for Limited-Stop Routes

Bus Route	Net Cost per Passenger
1: Harvard Sq. - Dudley Sta. via Mass. Ave.	$0.57
15: Kane Sq. - Ruggles Sta.	$0.78
16: Forest Hills Sta. - UMass	$1.24
22: Ashmont Sta. - Ruggles Sta. via Talbot Ave.	$1.21
23: Ashmont Sta. - Ruggles Sta. via Washington St.	$0.88
28: Mattapan Sta. - Ruggles Sta.	$1.05
32: Wolcott Sq. or Cleary Sq. - Forest Hills Sta.	$0.97
34: Dedham Line - Forest Hills Sta.	$1.29
39: Forest Hills Sta. - Back Bay Sta.	$0.62
57: Watertown Yard - Kenmore Sta.	$1.31
66: Harvard Sq. - Dudley Sta. via Brookline	$0.90
70: Cedarwood - Central Sq. Cambridge	$1.85
71: Watertown Sq. - Harvard Sta.	$1.19
86: Sullivan Sta. - Cleveland Circle	$1.07
101: Malden Sta. - Sullivan Sta. via Medford Sq.	$1.22
111: Woodlawn or Bway. & Park - Haymarket Sta.	$1.35
116: Wonderland Sta. - Maverick Sta. via Revere	$0.63
117: Wonderland Sta. - Maverick Sta. via Beach	$0.69

Radial, Circumferential, and Neighborhood Services Concept

As with the BRT corridor concept, the neighborhood services concept would also likely have lower net-cost-per-passenger figures for the BRT routes. Neighborhood routes, like existing local bus routes, would likely have a much greater average net cost per passenger. However, neighborhood routes that operate over shorter distances using fewer vehicles may have a smaller net cost per passenger than routes that extend outside the urban core into suburban areas. Because the ratio of proposed BRT routes to non-BRT routes is equivalent in the BRT corridor and neighborhood services concepts, it is likely that the systemwide net cost per passenger of the two concepts would also be similar.

Summary of Concepts

The various concepts likely have varying impacts on the average net cost per passenger of the entire transit system as well as individual routes. The rail extension concept would probably increase the net cost per passenger of the rail system since rail extensions to largely suburban areas are unlikely to generate new riders that contribute sufficient service revenue to compensate for increased operating costs. However, certain urban rail extensions would likely have a net cost per passenger close to the existing rail system average. All proposed BRT routes, either in the BRT corridor concept or the neighborhood services concept, would likely have lower net costs per passenger due to a greater proportionate increase in service revenue from new riders than in operating costs from additional vehicles. Both of these concepts would also eliminate several local bus routes with greater net costs per passengers. Finally, the limited-stop corridor concept might attract some new riders, but the overall impact on systemwide net cost per passenger would likely be minimal.

Vehicle Load

The vehicle-load standard sets the maximum ratio of passengers to a transit vehicle's seating capacity. The MBTA provides a detailed list of vehicle-load standards that depend on the mode, type of vehicle, the time period, and the location. According to the 2008 Service Plan, 23 directly-operated weekday MBTA bus routes, composing 13 percent of all service, failed the vehicle-load standard.

Rail Extension Concept

The rail extension concept would likely increase vehicle load throughout the rail line; however, the impacts on crowding would likely be greater closer to the downtown. Most riders use rapid transit to travel to the downtown from outer stations and this concept would intensify this usage pattern. Therefore, along with vehicle loads at downtown stations likely increasing, some existing riders at outer stations would now use the new stations on the rail extension. This would shift the crowding point further up the line. For instance, vehicle loads at Alewife Station, Davis Station, and Porter Station would likely increase as riders who formerly took Route 77 from Arlington Heights and Arlington Center to Harvard Station now boarded the Red Line at these stations. Similarly, riders who currently take a bus from Lynn to Wonderland or downtown would now likely board the Blue Line at the new Central Square, Lynn Station. These shifts would likely make boarding more difficult at stations near the downtown, such as Central Square or Kendall Square on the Red Line. The Green Line extension to West Medford and the Fairmount Line improvements would likely represent exceptions to this pattern, as they are not the same type of "extension." These extensions would provide practically new rapid transit service to the downtown. Therefore, aside from Lechmere and Science Park Stations on the Green Line, there are no intermediate stations at which crowding is likely to occur.

BRT Corridor Concept

The BRT corridor concept would increase vehicle loads on selected BRT routes. However, many of the BRT routes would likely use articulated buses or have more frequent service, so the ratio of passengers to seats should not exceed the standard. Of the 34 bus routes selected for BRT service, 10 currently exceed the MBTA's vehicle-load standard. Local bus routes outside the BRT service area would maintain their existing service levels, so vehicle loads would not be expected to change. Of these 98 routes, only eight currently exceed the vehicle-load standard.

Limited-Stop Corridor Concept

Under the limited-stop corridor concept, crowding would depend on the split of existing and potentially new riders between the local- and limited-stop variations. The stop locations selected for the limited-stop routes represent a minimum of 50 percent of all boardings and alightings. However, a percentage of riders may have either a boarding or an alighting that is not one of the limited stops, so would not use the limited-stop service. While each route would vary, a probable split between the two variations is 25 percent for the limited-stop service and 75 percent for the local-stop service. Of the 18 routes selected for limited-stop service, seven currently fail the vehicle-load standard. Increasing the headways of the local-stop variations of these routes, even marginally, to permit the limited-stop operations could increase crowding. Ideally, the allocation of vehicles and resulting headways for each variation would mirror passenger demand such that vehicle load would not be affected.

Radial, Circumferential, and Neighborhood Services Concept

As with the BRT corridor concept, the neighborhood services concept would also increase vehicle loads on BRT routes. However, many of the BRT routes would likely use articulated buses or have more frequent service, so the ratio of passengers to seats should not exceed the standard. Neighborhood routes would have many fewer riders, as the service area for some routes is limited to the immediate neighborhood. Therefore, these routes are unlikely to experience crowding problems.

Summary of Concepts

The various concepts are likely to affect vehicle loads and crowding by differing degrees. The rail extension concept would attract additional riders at the new stations, increasing vehicle loads throughout the line but particularly at stations nearer to the downtown. All proposed BRT routes, either in the BRT corridor concept or the neighborhood services concept, would likely have greater vehicle loads; however, crowding would presumably be kept to a minimum by providing these routes with greater frequencies permitted by the elimination of some local bus routes. Neighborhood routes or maintained local bus routes would likely have smaller vehicle loads given their service areas. Finally, the limited-stop corridor concept should not increase crowding on either the local- or limited-stop variations unless the ratio of vehicles to passengers is too low.

Summary of Service Efficiency Measures

Table 102 summarizes the potential effects of each proposed concept (as compared to existing services) with regard to each of the service efficiency standards.

The rail extension concept would likely have:

- an increase in the net cost per passenger since rail extensions to largely suburban areas are unlikely to generate new riders that contribute sufficient service revenue to compensate for increased operating costs
- an increase in vehicle loads and crowding throughout the line but particularly at stations nearer to the downtown

The BRT corridor concept would likely have:

- a decrease in the net cost per passenger due to a greater proportionate increase in service revenue from new riders than in operating costs from the addition of vehicles and the elimination of several high-cost local bus routes
- an increase in vehicle loads with crowding presumably kept to a minimum due to the provision of more frequent service, which would be made possible through the elimination of some local bus routes

The limited-stop corridor concept would likely have:

- no impact in the net cost per passenger given a minimal expected increase in riders
- no impact on vehicle loads or crowding unless the ratio of vehicles to passengers is too low

The neighborhood services concept would likely have:

- a decrease in the net cost per passenger due to a greater proportionate increase in service revenue from new riders than in operating costs from the addition of vehicles and the elimination of several high-cost local bus routes
- an increase in vehicle loads with crowding presumably kept to a minimum by providing these routes with more frequent service, which would be made possible through the elimination of some local bus routes

Table 102
Service Efficiency Standards: Summary of Potential Effects of Proposed Service Concepts

Standard	Rail Extension	BRT Corridor	Limited-Stop	Neighborhood Services
Net Cost per Passenger	↑	↓	—	↓
Vehicle Load	↑	↑	—	↑

Key: "↑" represents an increase, "↓" represents a decrease, and "—" represents no change.

4.3.4 Physical Infrastructure

Distribution of Revenue Equipment

The MBTA does not currently have a standard for the distribution of revenue equipment. Such a standard would govern policies for the distribution of buses with air conditioning, the average age of buses, and the number of buses at each garage. The BRT corridor concept and the neighborhood services concept could improve the ease with which revenue equipment is distributed by reducing the number of overall bus routes. The rail extension concept and the limited-stop corridor concept would be unlikely to affect the distribution of revenue equipment.

Distribution of Transit Amenities

While the MBTA does have a policy for the placement of shelters, it does not currently have standards for the distribution of other transit amenities. Such standards would govern policies for the distribution of amenities such as benches and trash cans. While most proposed rail stations would mirror the facilities of existing rail stations, the characteristics of stations along the Green Line extension to West Medford would more likely mirror those of existing surface Green Line stops. As such, each station would need benches, shelters, and trash cans. Similarly, all BRT stops in the BRT corridor concept and the neighborhood services concept would need these amenities, as would all limited-stop locations in the limited-stop corridor concept. Each concept would therefore increase the distribution of transit amenities.

4.3.5 Summary of Service Standard Applications

The four proposed concepts – rail extension, BRT corridor, limited-stop corridor, and neighborhood services – have varying levels of performance when measured against the service standards used by the MBTA and other peer transit agencies. To summarize, the rail extension concept focuses on strengthening the existing radial structure of the heavy and light rail network by extending several rail lines outward. Most extensions would serve areas outside the urban core; however, two extensions are located entirely within Boston and an area of Somerville that is currently only served by buses. As such, this concept would not dramatically change the MBTA's performance according to most service standards. The BRT corridor concept reduces service in the urban core to high-frequency BRT routes. Coverage in the core would, therefore, decrease and passengers would be required to walk longer distances on average to access transit. However, that transit would offer faster and more efficient trips with reduced headways. Local bus routes outside the BRT service area would remain. The limited-stop corridor concept would add a limited-stop variation to several routes with the largest ridership or longest distances. The vehicles used for this limited-stop variation would be taken away from local-stop service, requiring headways on local-stop service to increase. Passengers for whom both the origin and destination of their trip were served by the limited-stop service would have a significant increase in their trip times. Finally, the neighborhood services concept would also use BRT routes throughout the system. The service area of remaining local routes would largely be limited to specific neighborhoods, and the routes serving them would shuttle riders to the nearest radial or circumferential rapid transit corridor. Each concept therefore has positive and negative aspects, and the choice of which concept to more fully study depends on which service standards are deemed most important.

4.4 Modeled Trips for Each Service Concept

In the previous chapter, the existing MBTA bus and rapid transit system was analyzed according to how well each transit route served existing (2009) trips and the projected (2030) change in trips[27] with an origin and/or a destination in that route's service area. Using this analysis, the percentage of trips with an origin served by the route that also have a destination served by the route and the percentage of trips with a destination served by the route that also have an origin served by the route were calculated. Greater percentages indicate routes that offer more direct trips with fewer necessary transfers and generally shorter trip times. This section applies the same analysis to the four proposed concepts for trips that would exist in 2009 (if the concept were implemented) and the projected change in trips. The results of this analysis are summarized in Table 103 at the end of this section.

4.4.1 Summary of Existing System

For all existing trips on the MBTA bus and rapid transit system, an average of 50.5 percent of trips that have an origin served by the route used for the trip also have a destination served by that route. The routes with the greatest individual percentages could be grouped into rapid transit lines, service to the Waterfront, local bus service to the Downtown, and express bus service to the Downtown. An average of 38.9 percent of existing trips that have a destination served by the route used for the trip also have an origin served by that route. The routes with the greatest individual percentages could be grouped into rapid transit lines and local bus service to Back Bay, Cambridge, Dorchester, East Boston, Lynn, and Roxbury.

---

[27] As determined using the Boston Region MPO's travel demand model set.

For the projected change in trips, an average of 55.6 percent of trips that have an origin served by the route used for the trip also have a destination served by that route. The routes with the greatest individual percentages could be grouped into local bus service to Allston, Brighton, Brookline, Cambridge, Dorchester, Jamaica Plain, Roxbury, Salem, Somerville, and Quincy. An average of 58.6 percent of the projected change in trips that have a destination served by the route used for the trip also have an origin served by that route. The routes with the greatest individual percentages could be grouped into rapid transit lines and local bus service to Arlington, Back Bay, Belmont, Cambridge, East Boston, Lynn, and the South End.

Figure 84 presents the percentage of trips with an origin served by a route that also have a destination served by the same route. Figure 85 presents the percentage of trips with a destination served by a route that also have an origin served by the same route. In both figures, percentages are presented for existing trips and the projected change in trips and for the entire MBTA system as well as for the rapid transit and bus modal categories.

Figure 84
Percentage of Existing Trips and the Projected Change in Trips with an Origin Served by a Route that also have a Destination Served by the Same Route

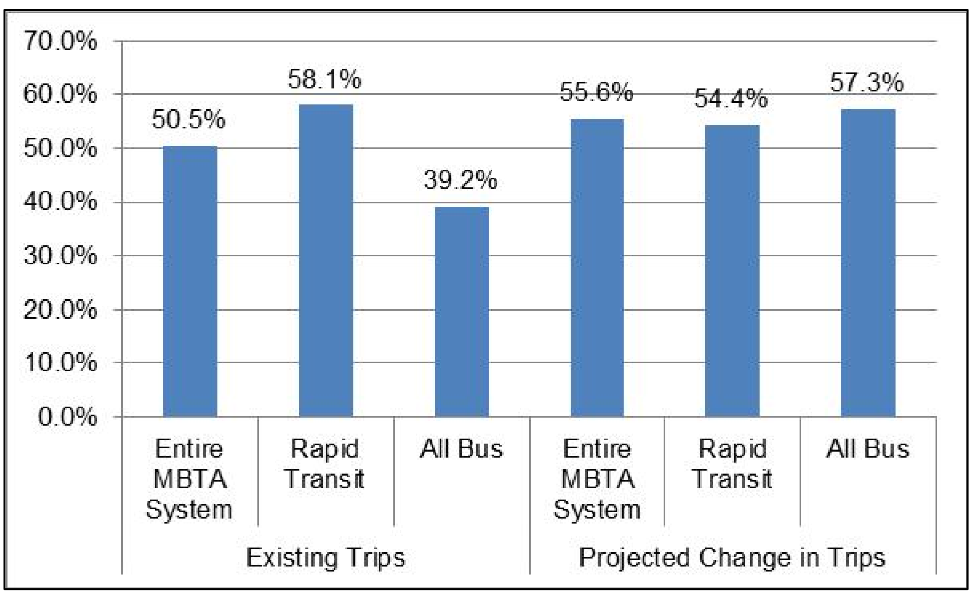
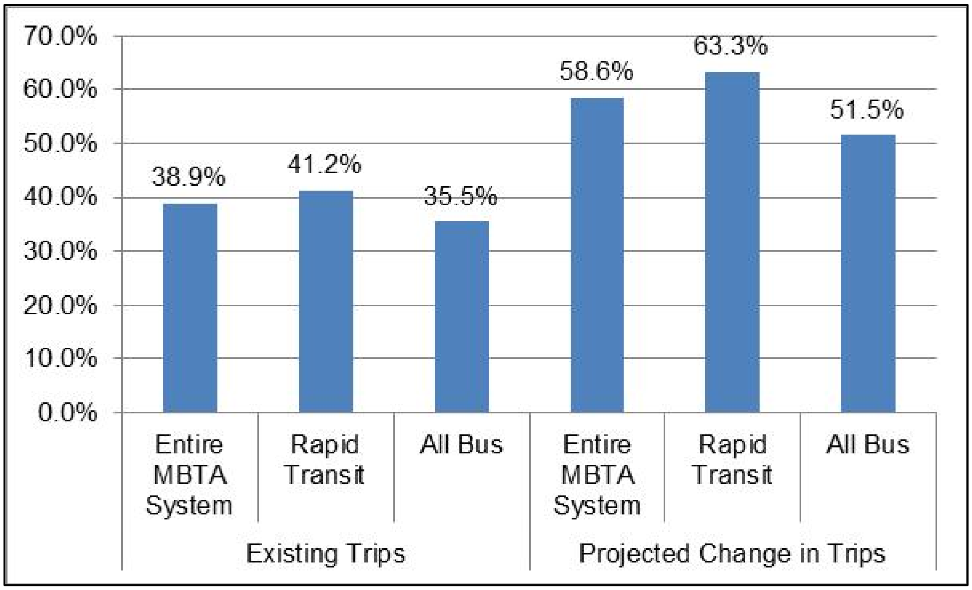


Figure 85
Percentage of Existing Trips and the Projected Change in Trips with a Destination Served by a Route that also have an Origin Served by the Same Route



In all cases, the average percentage for each measure is weighted by existing daily ridership.

4.4.2 Rail Extension Concept

The only changes to the existing MBTA system proposed by the rail extension concept are the extensions to several rail lines and various improvements to the Fairmount Line. Therefore, the service areas for all routes in this concept match those of the existing system except for the Blue Line (extension to Central Square, Lynn), Green Line E Branch (extension to West Medford), Red Line (extension to Route 128), Green Line D Branch (extension to Needham), and Orange Line (extension to Route 128 and the new Assembly Square Station). In addition, the service area of the Fairmount Line is included in the list of rapid transit services.

For all trips that would exist (in 2009) on the proposed MBTA bus and rapid transit system if the rail extension concept were in place today, an average of 49.8 percent of trips that would have an origin served by the route used for the trip would also have a destination served by that route. This would represent a decrease of 0.7 percent compared to the existing MBTA system that would largely be composed of declines in the percentage for the Red Line (56.3% to 55.5%), Orange Line (59.3% to 57.5%), and Green Line E Branch (67.3% to 61.5%). The overall rail percentage would decrease from 58.1 percent to 56.7 percent. An average of 38.8 percent of existing trips that would have a destination served by the route used for the trip would also have an origin served by that route. This would represent a decrease of only 0.1 percent compared to the existing MBTA system that would largely be composed of a decline in the percentage for the Red Line (40.5% to 40.2%). The overall rail percentage would decrease from 41.2 percent to 41.0 percent.

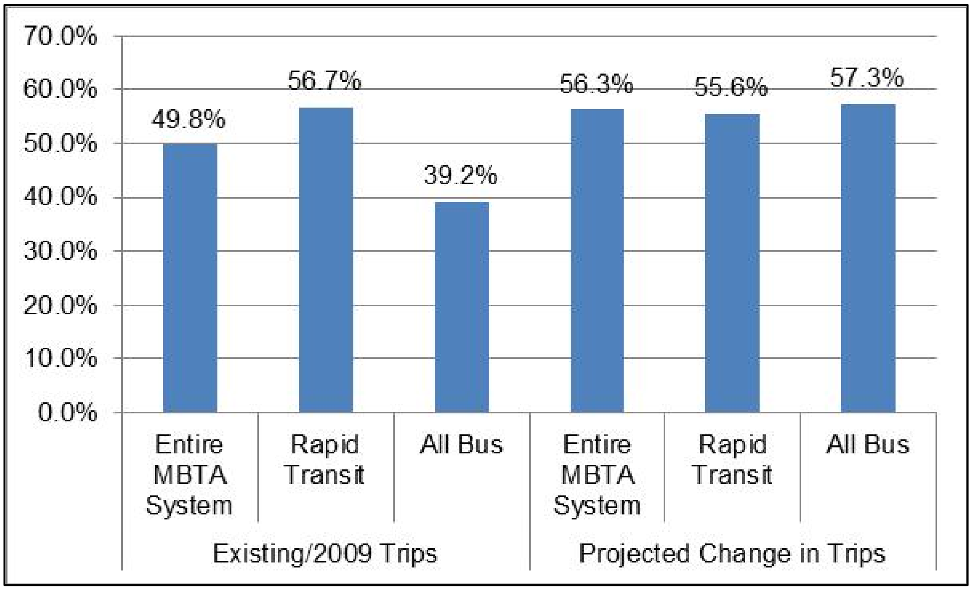
For the projected change in trips that would exist if the rail extension concept were in place today, an average of 56.3 percent of trips that would have an origin served by the route used for the trip would also have a destination served by that route. This would represent an increase of 0.7 percent compared to the existing MBTA system that would largely be composed of gains in the percentage for the Blue Line (41.9% to 45.4%), Orange Line (61.6% to 63.8%), Green Line D Branch (57.4% to 58.4%), and Green Line E Branch (60.9% to 64.7%). The overall rail percentage would increase from 54.4 percent to 55.6 percent. An average of 56.7 percent of the projected change in trips that would have a destination served by the route used for the trip would also have an origin served by that route. This would represent a decrease of 1.9 percent compared to the existing MBTA system that would largely be composed of declines in the percentage for the Red Line (61.3% to 59.4%) and Orange Line (72.5% to 60.3%) despite gains for the Blue Line (49.4% to 51.6%) and Green Line E Branch (71.6% to 73.0%). The overall rail percentage would decrease from 63.3 percent to 60.0 percent.

In all cases, the average percentage for each measure is weighted by daily ridership that would exist (in 2009) if the rail extension concept were implemented for all routes with added daily riders for those routes with extensions.

None of the neighborhoods served by new stations in the rail extension concept represent markets that are currently underserved by the existing MBTA system. As a result, the rail extension concept does not appear to dramatically affect the existing percentages of trips with both an origin and destination served by a route. Overall, the projected change in trips with both an origin and destination served by a route similarly does not dramatically change. However, projected trip increases in East Somerville and East Lynn, which are both listed among the top 20 neighborhoods that have the greatest projected increases in origins and destinations, do result in greater projected percentages of the changes in trips with both an origin and destination served by the Green Line E Branch and the Blue Line due to their extensions.

Figure 86 presents the percentage of trips with an origin served by a route that also have a destination served by the same route. Figure 87 presents the percentage of trips with a destination served by a route that also have an origin served by the same route. In both figures, percentages are presented for trips that would exist (in 2009) if the rail extension concept were in place today and for the projected change in trips. Percentages are also presented for the entire MBTA system as well as for the rapid transit and bus modal categories.

Figure 86
Percentage of Existing Trips (that Would Exist in 2009 if the Rail Extension Concept Were in Place Today) and the Projected Change in Trips with an Origin Served by a Route that also have a Destination Served by the Same Route

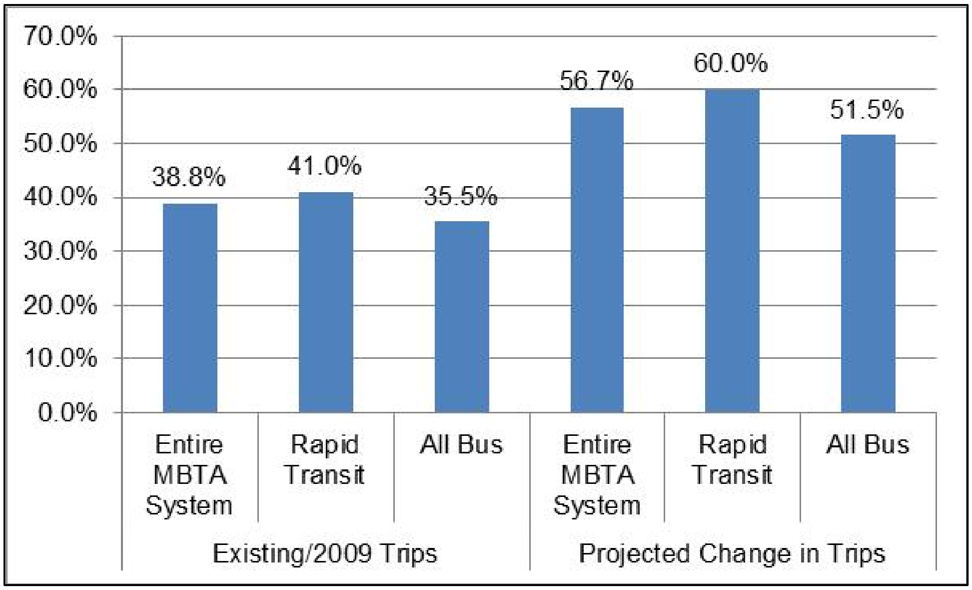


4.4.3 BRT Corridor Concept

This concept proposes significant changes to the bus network within the urban core. Specifically, several existing bus routes would become BRT services, and all other routes within the BRT service area would be eliminated. Local bus routes outside the BRT service area would not be affected. Therefore, within the urban core, this concept would balance a reduction in local bus coverage with an improvement in frequency and capacity on more heavily-used bus routes.

For all trips that would exist (in 2009) on the proposed MBTA bus and rapid transit system if the BRT corridor concept were in place today, an average of 51.3 percent of trips that would have an origin served by the route used for the trip would also have a destination served by that

Figure 87
Percentage of Existing Trips (that Would Exist in 2009 if the Rail Extension Concept Were in Place Today) and the Projected Change in Trips with a Destination Served by a Route that also have an Origin Served by the Same Route



route. This would represent an increase of 0.8 percent compared to the existing MBTA system that would largely be driven by the elimination of several existing local bus routes with lower percentages. For all existing trips on local routes in the urban core that would be eliminated under this concept, 36.9 percent of origins served by these routes would have corresponding destinations that would also be served by these routes. If the BRT corridor concept were in place, 42.3 percent of origins served by the BRT routes proposed in this concept would have corresponding destinations that would also be served by these routes compared to 34.2 percent for the remaining local bus routes. The resulting overall bus percentage would increase from 39.2 percent to 39.6 percent. In addition, since the rail mode has a higher average percentage (58.1%), the elimination of some local bus routes would cause the ratio of rail trips to bus trips to increase from 1.47 to 1.73, thereby weighing the higher rapid transit percentages more heavily than the lower bus percentages. These two factors would increase the overall concept's percentage.

If the BRT corridor concept were in place today, an average of 39.1 percent of existing trips that would have a destination served by the route used for the trip would also have an origin served by that route. This would represent an increase of only 0.2 percent compared to the existing MBTA system. For all existing trips on local routes in the urban core that would be eliminated under this concept, 36.2 percent of destinations served by these routes would have corresponding origins that would also be served by these routes. If the BRT corridor concept were in place, 36.8 percent of destinations that would be served by the BRT routes proposed in this concept would have corresponding origins that would also be served by these routes compared to 32.4 percent for remaining local bus routes. The resulting overall bus percentage would decrease from 35.5 percent to 35.3 percent. As is the case with origins, since the rapid transit mode would have a higher average percentage (41.2%), the elimination of some local bus routes would cause the ratio of rail trips to bus trips to increase from 1.47 to 1.73, thereby weighing the higher rapid transit percentages more heavily than the lower bus percentages. This would offset the decrease in the overall bus percentage and slightly increase the overall concept percentage.

For the projected change in trips that would exist if the BRT corridor concept were in place today, an average of 55.1 percent of trips that would have an origin served by the route used for the trip would also have a destination served by that route. This would represent a decrease of 0.5 percent compared to the existing MBTA system. For the projected change in trips for all existing local routes in the urban core that would be eliminated under this concept, 63.8 percent of origins served by these routes would have corresponding destinations that would also be served by these routes. If the BRT corridor concept were in place, 58.2 percent of origins that would be served by the BRT routes proposed in this concept would have corresponding destinations that would also be served by these routes compared to 52.1 percent for remaining local bus routes. Since the percentages of the remaining bus routes would be lower than those of the eliminated bus routes, the resulting overall bus percentage would decrease to 56.2 percent. In addition, since the rail mode would have a higher average percentage (54.4%), the elimination of some local bus routes would cause the ratio of rail trips to bus trips to increase from 1.47 to 1.73, thereby weighing the higher rapid transit percentages more heavily than the lower bus percentages and lessening the decrease in the overall concept percentage.

If the BRT corridor concept were in place today, an average of 58.7 percent of the projected change in trips that would have a destination served by the route used for the trip would also have an origin served by that route. This would represent an increase of only 0.1 percent compared to the existing MBTA system. For the projected change in trips for all existing local routes in the urban core that would be eliminated under this concept, 55.9 percent of origins served by these routes would have corresponding destinations that would also be served by these routes. If the BRT corridor concept were in place, 54.4 percent of origins that would be served by the BRT routes proposed in this concept would have corresponding destinations that would also be served by these routes compared to 43.4 percent for remaining local bus routes. Since the percentages of the remaining bus routes would be lower than those of the eliminated bus routes, the resulting overall bus percentage would decrease to 50.8 percent. In addition, since the rail mode would have a higher average percentage (63.3%), the elimination of some local bus routes would cause the ratio of rail trips to bus trips to increase from 1.47 to 1.73, thereby weighing the higher rapid transit percentages more heavily than the lower bus percentages. This would offset the decrease in the overall bus percentage and slightly increase the overall concept percentage.

The BRT corridor concept appears to marginally improve the existing percentages of trips with both an origin and destination served by a route. It does this primarily by eliminating local bus routes that have lower percentages. However, this concept does not provide any improvement in service to neighborhoods with greater projected increases in trips. This is not surprising given that the concept largely replicates the existing rail and bus system, albeit with the elimination of several local bus routes and a different model of service delivery for the remaining routes in the urban core.

Figure 88 presents the percentage of trips with an origin served by a route that also have a destination served by the same route. Figure 89 presents the percentage of trips with a destination served by a route that also have an origin served by the same route. In both figures, percentages are presented for trips that would exist (in 2009) if the BRT corridor concept were in place today and for the projected change in trips. Percentages are also presented for the entire MBTA system as well as for the rapid transit and bus modal categories.

4.4.4 Limited-Stop Corridor Concept

This concept does not alter the service area of any route in the existing system. Routes selected for limited-stop service would have an average stop spacing above 0.5 miles, but for most limited-stop routes the average stop spacing would not exceed 0.75 miles. Therefore, the service area for different stops for limited-stop routes (defined as all TAZs with a centroid within 0.5 miles of the transit stop location) would still overlap. The percentages of existing and projected trip origins and destinations served by each route that have corresponding destinations

Figure 88
Percentage of Existing Trips (that Would Exist in 2009 if the BRT Corridor Concept Were in Place Today) and the Projected Change in Trips with an Origin Served by a Route that also have a Destination Served by the Same Route

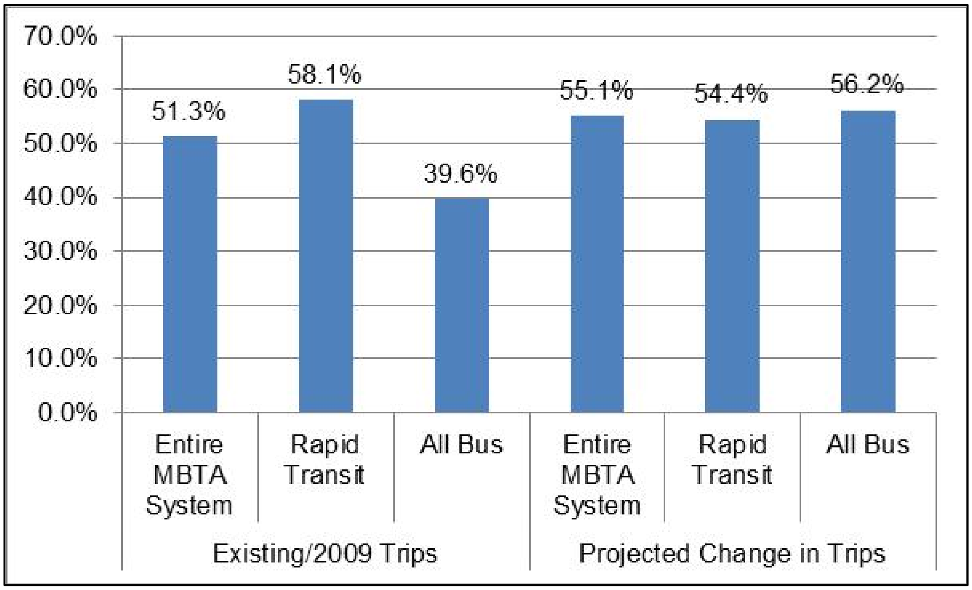
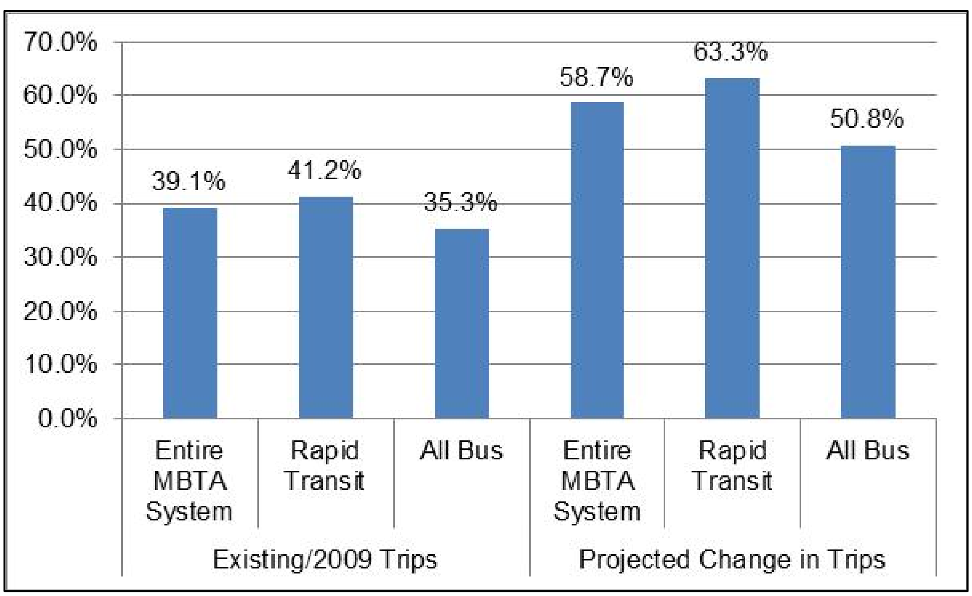


Figure 89
Percentage of Existing Trips (that Would Exist in 2009 if the BRT Corridor Concept Were in Place Today) and the Projected Change in Trips with a Destination Served by a Route that also have an Origin Served by the Same Route



and origins also served by the same route would not change from the current MBTA rail and bus system.

4.4.5 Neighborhood Services Concept

This concept proposes significant changes to the bus network. Specifically, several existing bus routes would become BRT services, with the routing of some routes modified or extended, such that a network of major radial and circumferential rapid transit corridors would exist. While the routing of some local routes would not change from the current local bus network (particularly those outside the rapid transit service area), other local routes between the radial lines would primarily serve a specific neighborhood, shuttling trips from that neighborhood to the nearest rapid transit lines. This concept also assumes the extension of the Green Line to West Medford and the improvements to the Fairmount Line as additional radial rapid transit corridors.

For all trips that would exist (in 2009) on the proposed MBTA bus and rapid transit system if the neighborhood services concept were in place today, an average of 49.9 percent of trips of trips that would have an origin served by the route used for the trip would also have a destination served by that route. This would represent a decrease of 0.6 percent compared to the existing MBTA system that would be driven by the decline in this percentage for the Green Line E Branch (67.3% to 61.5%) and in the overall bus percentage (39.2% to 38.1%). The decrease in the bus percentage would be caused by the replacement of several existing local bus routes with neighborhood routes that would have lower percentages (36.6% to 32.8%). Note that 38.5 percent of origins that would be served by the BRT routes proposed in this concept would have corresponding destinations that would also be served by these routes. These calculations for this concept also assume a greater reliance on rail rapid transit in which the ratio of assumed rail to bus trips would be 1.52 compared to an existing ratio of 1.47. This increased ratio would weighs the higher overall rail percentage (57.3%) more heavily than the lower bus percentages, thereby lessening the overall decrease in the percentage of existing trip origins served by a route that also have a destination served by the route.

If the neighborhood services concept were in place today, an average of 39.0 percent of existing trips that would have a destination served by the route used for the trip would also have an origin served by that route. This would represent an increase of only 0.1 percent compared to the existing MBTA system that would occur despite a decline in the overall rail percentage (41.2% to 41.1%) and the overall bus percentage

(35.5% to 35.0%). The decrease in the bus percentage would be caused by the replacement of several existing local bus routes with neighborhood routes that would have lower percentages (34.2% to 31.0%). Note that 35.8 percent of destinations that would be served by the BRT routes proposed in this concept would have corresponding origins that would also be served by these routes. Given the higher ratio of rail to bus trips assumed for this concept (1.52 versus 1.47), the higher rail percentages would be weighed more heavily than the lower bus percentages, offsetting the small decreases in the overall rail and bus percentages and resulting in a small increase overall.

For the projected change in trips that would exist if the neighborhood services concept were in place today, an average of 56.5 percent of trips that would have an origin served by the route used for the trip would also have a destination served by that route. This would represent an increase of 0.9 percent compared to the existing MBTA system that would be driven by gains in this percentage for the Green Line E Branch (60.9% to 64.7%), for the Orange Line due to Assembly Square Station (61.6% to 64.8%), and in the overall bus percentage (57.3% to 57.5%). The increase in the bus percentage would occur despite the replacement of several existing local bus routes with neighborhood routes that would have lower percentages (56.1% to 54.9%). Note that 59.1 percent of origins that would be served by the BRT routes proposed in this concept would have corresponding destinations that would also be served by these routes. Given the higher ratio of rail to bus trips assumed for this concept (1.52 versus 1.47), the higher rail percentages would be weighed more heavily than the lower bus percentages, thereby augmenting the increases in the overall rail and bus percentages.

If the neighborhood services concept were in place today, an average of 57.6 percent of the projected change in trips that would have a destination served by the route used for the trip would also have an origin served by that route. This would represents a decrease of 1.0 percent compared to the existing MBTA system that would be driven by a decline in this percentage for the Orange Line (72.5% to 67.7%) and in the overall bus percentage (51.5% to 49.6%). The decrease in the bus percentage would be caused by the replacement of several existing local bus routes with neighborhood routes that would have lower percentages (48.8% to 45.9%). Note that 50.8 percent of destinations that would be served by the BRT routes proposed in this concept would have corresponding origins that would also be served by these routes. While there is an overall percentage decrease, the Green Line E Branch would have an increase (71.6% to 73.0%). Given the higher ratio of rail to bus trips assumed for this concept (1.52 versus 1.47), the higher rail percentages would be weighed more heavily than the lower bus percentages, thereby lessening the decrease in the overall rail and bus percentages.

The neighborhood services concept appears to marginally decrease the existing percentages of trips with both an origin and destination served by a route. This decrease largely occurs as a result of the replacement of several existing local bus routes with neighborhood routes that have lower percentages. These lower percentages are due to the fact that several neighborhood routes have smaller service areas caused by their shorter route length. Despite the overall decrease in the bus percentage, the proposed BRT routes consistently have greater percentages. Similarly, this concept appears to marginally decrease service to neighborhoods with greater projected increases in trips. Once again, this decrease is caused by the replacement of several existing local bus routes with neighborhood routes. Neighborhood routes serving areas that have greater projected increases in trips, such as a local Somerville service and a local Brighton service, have greater projected percentages; however, overall, most neighborhood routes have smaller percentages. As with existing trips, the proposed BRT routes generally serve greater percentages of the projected change in origins and destinations.

Figure 90 presents the percentage of trips with an origin served by a route that also have a destination served by the same route. Figure 91 presents the percentage of trips with a destination served by a route that also have an origin served by the same route. In both figures, percentages are presented for trips that would exist (in 2009) if the neighborhood services concept were in place today and for the projected change in trips. Percentages are also presented for the entire MBTA system as well as for the rapid transit and bus modal categories.

4.4.6 Summary of Modeled Trip Analysis

Table 103 presents a summary of the figures presented in the previous sections. None of the proposed concepts would dramatically improve or worsen the percentages of origins or destinations served by the routes compared to the existing MBTA system. The rail extension concept would slightly lower these percentages for trips that would exist (in 2009) but would increase them for the projected change in trips. Unlike 2009 trips, for which the potential rail extensions would not serve any identified missing market, the locations of projected trip increases in East Somerville and East Lynn would be well served by their rail extensions. The BRT corridor concept would marginally improve the

Figure 90
Percentage of Existing Trips (that Would Exist in 2009 if the Neighborhood Services Concept Were in Place Today) and the Projected Change in Trips with an Origin Served by a Route that also have a Destination Served by the Same Route

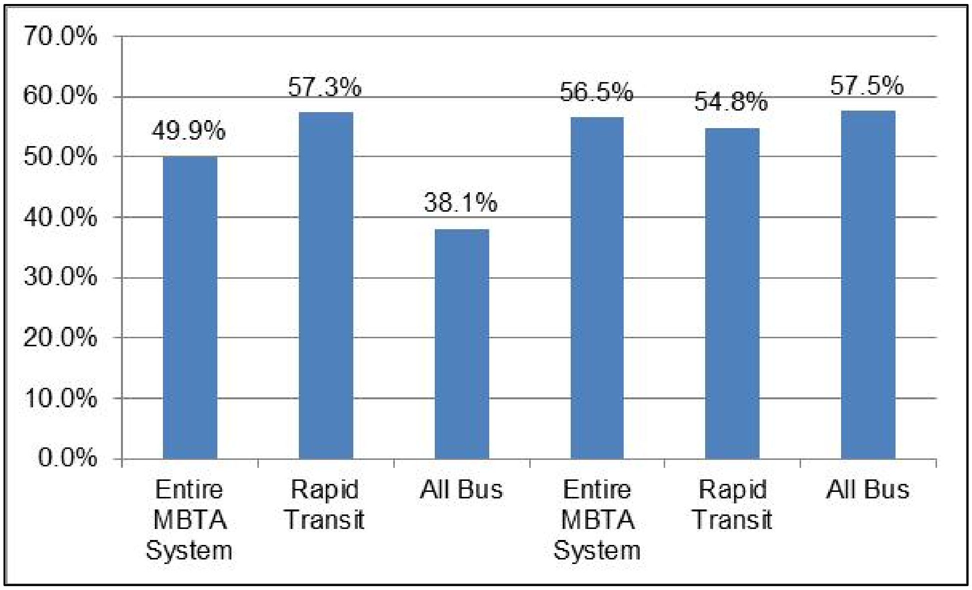
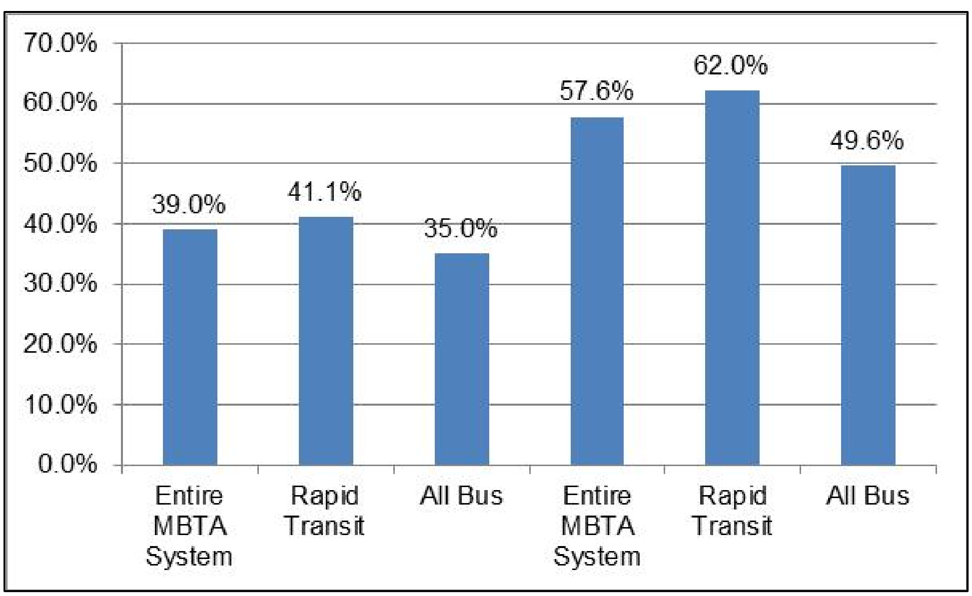


Figure 91
Percentage of Existing Trips (that Would Exist in 2009 if the Neighborhood Services Concept Were in Place Today) and the Projected Change in Trips with a Destination Served by a Route that also have an Origin Served by the Same Route



percentages of trips that would exist (in 2009) with both an origin and destination served by a route and would not affect service to neighborhoods with greater projected increases in trips. The 2009 changes would be caused by the elimination of some local bus routes within the BRT service area. The limited-stop corridor concept would not alter the service area of any route in the existing system. Finally, the neighborhood services concept would marginally lower the percentages of both the trips that would exist (in 2009) and the projected change in trips with both an origin and destination served by a route. This is caused by the replacement of several existing local bus routes with neighborhood routes that would have lower percentages. However, as with the BRT corridor concept, the individual BRT routes proposed in the neighborhood services concept would offer greater percentages for both 2009 trips and the projected change in trips.

Table 103
Summary of Modeled Trip Analysis

Concept	Ratio of Rail Trips to Bus Trips	Percentage of Trips with an Origin Served by a Route that also have a Destination Served by the Same Route		Percentage of Trips with a Destination Served by a Route that also have an Origin Served by the Same Route	
		Existing/ 2009 Trips	Projected Change in Trips	Existing/ 2009 Trips	Projected Change in Trips
Existing MBTA System	1.47	50.5%	55.6%	38.9%	58.6%
Rapid Transit		58.1%	54.4%	41.2%	63.3%
All Bus		39.2%	57.3%	35.5%	51.5%
Rail Extension Concept	1.54	49.8%	56.3%	38.8%	56.7%
Rapid Transit		56.7%	55.6%	41.0%	60.0%
All Bus		39.2%	57.3%	35.5%	51.5%
BRT Corridor Concept	1.73	51.3%	55.1%	39.1%	58.7%
Rapid Transit		58.1%	54.4%	41.2%	63.3%
All Bus		39.6%	56.2%	35.3%	50.8%
BRT Routes		42.3%	58.2%	36.8%	54.4%
Local Routes		34.2%	52.1%	32.4%	43.4%
Eliminated Routes		36.9%	63.8%	36.2%	55.9%
Neighborhood Services Concept	1.52	49.9%	56.5%	39.0%	57.6%
Rapid Transit		57.3%	54.8%	41.1%	62.0%
All Bus		38.1%	57.5%	35.0%	49.6%
BRT Routes		38.5%	59.1%	35.8%	50.8%
Neighborhood Routes		32.8%	54.9%	31.0%	45.9%
Replaced Routes		36.6%	56.1%	34.2%	48.8%

4.5 Financial-Constraint Analysis

The MBTA currently faces a challenging future with regards to its finances. Both in terms of its operating and capital budgets, the MBTA currently faces deficits, and these deficits are projected to increase in the coming years. While bus and rapid transit fares make up only approximately one-fifth of total operating revenue, with the dedicated sales tax as the single largest source with more than half of all operating revenue, cost savings in the bus and rapid transit systems are one potential way to reduce the deficit. This section will briefly describe the financial situation faced by the MBTA in 2011 and present several potential future financial scenarios, including potential budgets for bus and rapid transit service. Each service concept discussed in previous sections will then be analyzed according to these financial-constraint scenarios.

4.5.1 Summary of MBTA Finances

MBTA finances can be broken down into operating and capital categories. The MBTA faces existing and future deficits in both. Over the next five fiscal years (2012 to 2016), the average projected operating expense is approximately twice the average projected capital expense. This does not include debt expenses, which are projected to add nearly an additional 25 percent to total capital plus operating costs. In terms of revenue, operating revenues exceed currently available capital revenues by nearly 40 percent. The inclusion in the total operating budget of non-operating revenues from dedicated assessments and the sales tax results in an increase in operating revenues of more than 200 percent. Table 104 presents total operating and capital expenses and revenues and the resultant differences. The projected average annual operating and capital deficit between FY2012 and FY2016 is over $500 million.

Table 104
MBTA Projected Average Annual Operating and Capital Expenses and Revenues (Millions), FY2012–FY2016

Source	Expenses	Revenue	Difference
Capital	-$694.0	$368.2	-$325.8
Operating	-$1,399.1	$515.5	-$883.6
Non-Operating	$0	$1,161.3	$1,161.3
Debt	-$464.0	N/A	-$464.0
Total	**-$2,557.1**	**$2,045.1**	**-$512.0**

Table 105 compares the FY2012─FY2016 budgeted and FY2001─FY2010 actual average annual percentage changes for several components of the operating budget's revenues and expenses. As seen in the table, the current budget forecasts most revenue sources to increase at a lesser rate between FY2012 and FY2016 than they did from FY2001 to FY2010. For instance, operating revenue from transportation (including the entire bus, rapid transit, commuter rail, and paratransit systems) is assumed to increase between FY2012 and FY2016 by 1.2 percent on average per year. This is less than the actual average annual percentage increase of 6.0 percent from FY2001 to FY2010 in operating revenue from transportation. Note that this time period included two fare increases in 2003 and 2007. One exception is revenue from dedicated local assessments. The historical average

Table 105
Comparison of Average Annual Percentage Change for Operating Budget Revenue and Expenses, FY2012─FY2016 Assumptions versus FY2001─FY2010 Actual

	Assumed	Actual	Difference
Revenue	**1.2%**	**5.0%**	**-3.8%**
Total Operating Revenue	0.9%	6.1%	-5.2%
Revenue from Transportation	1.2%	6.0%	-4.7%
Other Operating Revenue	-1.2%	7.7%	-8.9%
Total Non-Operating Revenue	1.4%	4.7%	-3.3%
Dedicated Local Assessment Revenue	1.9%	0.4%	1.4%
Dedicated Sales Tax Revenue	2.1%	3.1%	-1.1%
Expenses	**4.1%**	**5.0%**	**-0.9%**
Total Operating Expenses	4.4%	5.4%	-0.9%
Wages	1.8%	3.6%	-1.8%
Fringe Benefits	3.9%	7.1%	-3.2%
Payroll Taxes	1.6%	5.3%	-2.6%
Materials, Supplies, and Services	8.6%	5.6%	3.0%
Casualty and Liability	1.6%	5.3%	-3.7%
Purchased Commuter Rail Expenses	3.9%	5.5%	-1.5%
Purchased Local Service Expenses	9.8%	13.8%	-4.0%
Financial Services Charges	5.1%	18.9%	-13.8%
Total Debt Service Payments	3.3%	4.5%	-1.2%
Interest Payments	2.7%	4.8%	-2.1%
Principal Payments	6.3%	7.2%	-0.9%
Lease Payments	-14.8%	1.8%	-16.7%

annual increase is 0.4 percent while the MBTA budget to FY2016 assumes an average annual increase of 1.9 percent. In terms of dedicated sales tax revenue, when the substantial increase in sales tax revenue from FY2001 to FY2002 is removed from the average, the annual increase in this measure is reduced to 1.8 percent from 3.1 percent. The MBTA budget assumes an average annual increase in dedicated sales tax revenue of 2.1 percent.

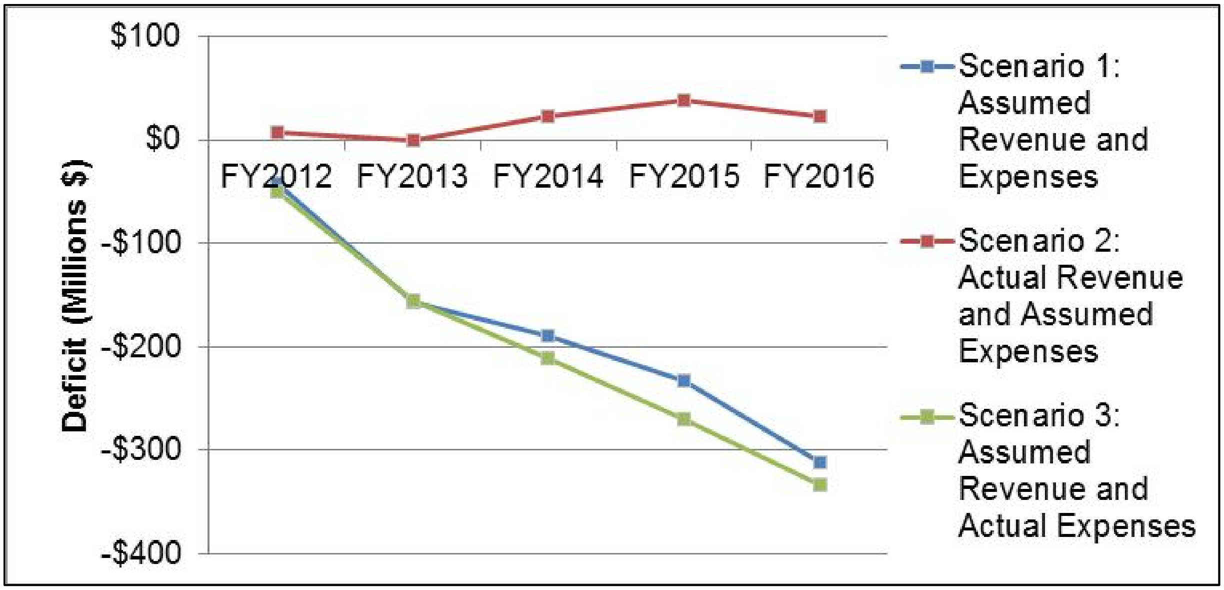
In terms of expenses, as seen in the table, the MBTA budget to FY2016 generally assumes annual percentage increases that are smaller than those averaged between FY2001 and FY2010. For instance, fringe benefits are forecast to increase by 3.9 percent per year on average while the actual average annual increase in fringe benefits from FY2001 to FY2010 was 7.1 percent. The difference between forecasted and actual average annual percent changes for total operating expenses is 4.4 percent versus 5.4 percent. Total debt service expenses are also projected to increase at a lesser amount compared to the actual FY2001–FY2010 average annual increase.

4.5.2 Financial-Constraint Scenarios

Figure 92 presents several potential financial scenarios for FY2012 to FY2016 based on the comparison of the MBTA's FY2011 budget to the actual FY2001–FY2010 figures. Scenario 1 equals the MBTA assumptions for both revenue and expenses. Scenario 2 replaces the MBTA's assumed percentage increase in revenues with the actual FY2001–FY2010 percentage change but equals the MBTA assumptions for expenses. Scenario 3 equals the MBTA assumptions for revenue but replaces the MBTA's assumed percentage increase in expenses with the actual FY2001–FY2010 percentage change.

According to the FY2011 MBTA operating budget (Scenario 1), the average annual deficit between FY2012 and FY2016 is projected to be $186.3 million. This projected deficit ranges from $42.0 million in FY2012 to $311.4 million in FY2016. Over the entire five-year period, the deficit is projected to total $931.5 million. A comparison of the FY2011 MBTA budget for expenses with the actual FY2001–FY2010 percentage change in revenue (Scenario 2) results in a projected surplus between FY2012 and FY2016. The surplus occurs because the actual percentage change in revenue exceeds the budgeted percentage change by a significant amount (5.0% vs. 1.2%). The resulting average annual surplus equals $17.8 million while the total surplus over the entire five-year period equals $89.2 million. Finally, a comparison of the FY2011 MBTA budget for revenues with the actual FY2001–FY2010 percentage change in expenses (Scenario 3) results in an average annual deficit between FY2012 and FY2016 of $204.1 million. This potential deficit ranges from $50.1 million in FY2012 to $333.8 million in FY2016. Over the entire five-year period, this potential deficit totals over $1.0 billion dollars. This deficit is greater than the budgeted deficit because the actual percentage change in expenses exceeds the budgeted percentage change (5.0% vs. 4.1%).

Figure 92
Potential MBTA Deficits (Revenues minus Expenses), FY2012–FY2016



According to these three financial scenarios, the size of the potential deficits that the MBTA will need to address in coming years could vary significantly. If the MBTA continues to face deficits between its annual expenses and revenues similar to what it has budgeted or worse, however, it is likely that some of that total deficit will need to be addressed through fare increases to increase operating revenues and/or service changes to reduce operating expenses. The deficit between expenses and available revenues in the capital budget is an additional financial issue that, while not typically addressed by measures on the operating side, does affect where the MBTA is able to dedicate resources.

Potential changes to the bus and rapid transit system alone will obviously not address this entire financial deficit. According to the FY2011 budget, all bus and rapid transit services currently contribute approximately $310.9 million, or one-fifth of the MBTA's total existing operating revenues. In terms of expenses, the FY2010 recovery ratio (the percentage of operating expenses that is recouped by operating revenues) can be used to calculate the total bus and rapid transit operating expense for FY2011 based on the corresponding total operating revenue. Dividing $310.9 million by the recovery ratio (37.8%) results in a total estimated bus and rapid transit operating expense of $822.2 million, or 48.5 percent of all operating expenses. Therefore, the net cost of MBTA operations (costs minus revenue) equals $511.3 million.

Addressing the MBTA financial constraints with changes to the bus and rapid transit system could therefore be achieved through changes to operating revenues, operating expenses, and/or the relationship between revenues and expenses, or the recovery ratio. Fare increases would increase operating revenues while keeping expenses constant, thereby increasing the recovery ratio. Improvements in cost efficiency would increase the recovery ratio. These improvements could be achieved by cutting inefficient services or reorganizing services in a more efficient manner. The following sections will analyze each of the proposed concepts with respect to their potential for using each of these potential measures.

4.5.3 Rail Extension Concept

The primary financial implications of this concept would be on the capital side. However, the extended rail lines would require longer trip times and a greater number of operators. Table 106 lists the estimated capital cost and weekday operating cost along with the estimated daily ridership and net riders (new transit riders minus riders attracted from other existing transit modes) attributed to each proposed rail extension, along with the resulting cost-per-net-rider figures. These figures are from the 2003 PMT. Note that most if not all of these estimates have changed since the 2003 PMT; however, the relative differences between the various extensions likely remain consistent.

Of the various extensions, the most costly for both capital and operating expenses is the Red Line extension to Route 128. The new station at Assembly Square on the Orange Line is not estimated to result in greater operating expenses. The Blue Line extension to Charles/MGH (the Red-Blue Connector) is also estimated to have a relatively low operating cost per new rider. The next tier of projects in terms of the operating cost per new rider includes the Blue Line to Wonderland, the Green Line to West Medford, and the Fairmount Line improvements. Relatively large cost-per-new-rider ratios are estimated for the extensions of the Green Line D Branch to Needham, the Orange Line to Route 128, and the Red Line to Route 128.

Table 107 applies these ridership and revenue estimates to the existing ridership and revenue totals from FY2010. As seen in the table, the various heavy and light rail extensions increase costs more than revenue, increasing the net cost per trip and reducing the recovery ratio. The total net cost (costs minus revenue) caused by the sum of the proposed rail extensions is estimated to increase by $83.8 million.

Since this scenario includes only extensions, improvements, or new stations, and since each extension costs additional money to construct and operate, it is difficult to envision this scenario being pursued given the uncertainty of future finances. Indeed, only in a financial situation where the MBTA did not run a regular operating deficit, such as Scenario 2, would the MBTA likely even consider these various extensions. The MBTA has already committed to three of these projects: Assembly Square Station on the Orange Line; the Green Line extension to West Medford; and the Fairmount Line improvements. Each of these projects is included in the MBTA's current capital budget. The Green Line extension to College Avenue (not Mystic Valley Parkway) and the Fairmount Line improvements are both in the State Implementation Plan (SIP) and are federally required to be funded by the Commonwealth. Assembly Square Station on the Orange Line has secured some funding from the federal New Starts Program and a developer, though approximately $8.9 million in undedicated funding remains, according to figures presented in the MBTA's draft FY2012–FY2016 Capital Investment Program (CIP). With the construction of these three rail projects, if the deficits of Scenarios 1 or 3 appear, the MBTA would likely be forced to raise fares by a substantial amount, eliminate a significant amount of service, or implement a combination of both measures with slightly less substantial fare increases or service cuts.

4.5.3 BRT Corridor Concept

As noted previously in this memorandum, in the section analyzing each concept under the net-cost-per-passenger standard, the average net cost per passenger for the routes selected for BRT service is less than other local routes that are eliminated: $1.02 versus $1.72. The elimination of these routes with higher costs, along with various improvements to BRT corridors, will shift more passengers onto the BRT routes, lowering their average cost per passenger. Local bus routes outside the BRT service area would not be eliminated, and these routes have a much greater net cost per passenger of $2.63. Assuming existing net-cost-per-passenger values, the systemwide weighted average net cost per passenger for all existing bus routes would be

Table 106
Rail Extension Concept: Estimated Capital and Operating Costs and Riders

Rail Extension	Capital Cost (Millions)	Weekday Operating Cost	Daily Ridership Increase	Net Increase in Daily Ridership	Capital Cost/ New Transit Rider	Weekday Operating Cost/ New Transit Rider
Blue Line to Wonderland	$357.6	$72,500	21,000	7,900	$45,300	$9.20
Red Line to Route 128	$749.3	$121,800	6,700	1,700	$440,800	$71.70
Green Line to Needham	$123.9	$16,600	3,400	500	$247,800	$33.30
Orange Line to Route 128	$342.8	$94,900	4,700	2,000	$172,300	$47.70
Orange Line at Assembly Sq.	$29.3	$0	1,700	1,100	$26,900	$0
Blue Line to Charles/MGH	$174.6	$7,200	6,500	2,800	$63,500	$2.60
Green Line to W. Medford	$375.0	$41,700	8,400	3,500	$105,900	$11.80
Fairmount Line	$70.0	$2,800	6,500	220	$318,180	$12.70

Table 107
Rail Extension Concept: Revenue Scenarios

Mode	Scenario	Trips	Costs	Fare Revenue	Costs minus Revenue	Recovery Ratio	Net Cost per Trip
Heavy Rail	Existing	139,039,529	$306,460,723	$153,168,117	$153,292,606	50.0%	$1.10
	Extensions	3,297,145	$76,296,000	$5,603,187	$70,692,814	7.3%	$21.44
	Total	142,336,674	$382,756,723	$158,771,304	$223,985,420	41.5%	$1.57
Light Rail	Existing	65,471,593	$140,761,339	$69,637,279	$71,124,060	49.5%	$1.09
	Extensions	1,020,000	$14,866,500	$1,734,000	$13,132,500	11.7%	$12.88
	Total	66,491,593	$155,627,839	$71,371,279	$84,256,560	45.9%	$1.27

$1.55. This represents a 35.8 percent decrease compared to the FY2010 net cost per passenger for the entire bus system.

Table 108 presents several potential scenarios for directly-operated bus revenues as well as existing ridership and revenue totals from FY2010. If, under the BRT concept, the same number of bus riders was served as in the existing system, the total net cost of the bus system (costs minus revenue) would decrease by $92.4 million and the recovery ratio would increase to 31.7 percent. If the fares for BRT routes under this concept were increased in proportion to the ratio of the current rapid transit fare ($1.70) to the existing local bus fare ($1.25) while all local routes maintained the existing fare, the weighted average fare for all bus routes (BRT and local) would increase by an estimated 24.0 percent. This percentage increase in the average bus fare would result in a loss in ridership but an increase in fare revenue (assuming a fare elasticity of -0.33). Under this scenario, the total net cost of the bus system (costs minus revenue) would decrease by $103.3 million and the recovery ratio would increase to 36.2 percent.

4.5.4 Limited-Stop Corridor Concept

This concept is revenue neutral, meaning that no change in costs or fare revenue is anticipated. No additional vehicles or operators would be needed, as buses used for limited-stop service would be removed from local-stop service, reducing the frequency of this service but having no other effect. While some change in ridership may occur ─ either a decrease caused by the reduced frequency of local-stop service or an increase caused by the introduction of limited-stop service ─ the overall change is not expected to be substantial. This concept also assumes that fares on the limited-stop and local-stop services would both be the same as the current local bus fare. The same fare is justified in that limited-stop service has the benefit of faster trip times but the detriment of reduced coverage and frequency, while local-stop service has the benefit of greater coverage and frequency but the detriment of longer trip times. As a result, this concept would not be useful in terms of addressing the MBTA’s financial situation.

4.5.5 Neighborhood Services Concept

As with the BRT corridor concept, the neighborhood services concept would also likely have lower net-cost-per-passenger figures for the BRT routes but a greater average net cost per passenger for non-BRT routes. Under the route structure assumed for the neighborhood services concept, there would be 26 BRT routes and 82 neighborhood routes. Assuming $1.00 as the net cost per passenger for BRT routes, $2.50 as the net cost per passenger for neighborhood routes and a ratio of five to one in terms of the number of riders on BRT routes compared to neighborhood routes, this would result in a weighted average net cost per passenger for the directly-operated bus mode of $1.58. This represents a 34.5 percent decrease compared to the FY2010 net cost per passenger for the entire bus system. This concept also includes three rail improvements: the Green Line extension to College Avenue, Assembly Square Station on the Orange Line, and the improvements to the Fairmount Line. As mentioned in the financial analysis of the rail extension scenario, these extensions would increase costs more than revenue for the heavy and light rail modes.

Table 109 presents estimates for the potential effects of the neighborhood services concept on existing ridership and revenue totals from FY2010. As seen in the table, the proposed rail projects do not dramatically affect total heavy rail costs and revenue while the proposed Green Line extension increases the light rail net cost per trip and lowers the light rail recovery ratio. The proposed bus system in the neighborhood services concept lowers the net cost per trip and increases the recovery ratio of the directly-operated bus mode. When all modes are combined, the net cost per trip does not change compared to the existing system while the recovery ratio increases slightly. Under this scenario, the total net cost of the entire system (costs minus revenue) would decrease by $79.9 million.

4.5.6 Summary of Financial-Constraint Analysis

The four proposed concepts – rail extension, BRT corridor, limited-stop corridor, and neighborhood services – have varying levels of impacts on MBTA finances. The rail extension concept would increase the net cost (costs minus revenue) while the BRT corridor concept and the neighborhood services concept would decrease the net cost. The limited-stop corridor concept is structured to be revenue neutral, meaning that net costs should not change. Reductions in the net cost of operations could address a portion of the average annual operations deficit that is projected for the next five years. If costs and revenues match MBTA budget projections, this average deficit would equal $186.3 million per year. Estimated reductions in the net cost of core transit services under the neighborhood services and BRT corridor concepts range from $79.9 million to $103.3 million, respectively. Therefore, these potential savings could address between 42.9 percent and 55.5 percent of the projected average annual deficit.

Table 108
BRT Corridor Concept: Revenue Scenarios

Scenario	Trips	Costs	Fare Revenue	Costs minus Revenue	Recovery Ratio	Net Cost per Trip
Existing	107,071,648	$335,275,968	$76,926,402	$258,349,566	22.9%	$2.41
BRT Concept: Service Changes	107,071,648	$242,887,456	$76,926,402	$165,961,054	31.7%	$1.55
BRT Concept: Service & Fare Changes	98,591,573	$242,887,456	$87,867,830	$155,019,627	36.2%	$1.57

Table 109
Neighborhood Services Concept: Revenue Scenarios

Mode	Scenario	Trips	Costs	Fare Revenue	Costs minus Revenue	Recovery Ratio	Net Cost per Trip
Heavy Rail	Existing	139,039,529	$306,460,723	$153,168,117	$153,292,606	50.0%	$1.10
	Concept	139,376,129	$307,174,723	$153,740,337	$153,434,386	50.0%	$1.10
Light Rail	Existing	65,471,593	$140,761,339	$69,637,279	$71,124,060	49.5%	$1.09
	Concept	66,364,093	$151,394,839	$71,154,529	$80,240,310	47.0%	$1.21
Bus	Existing	107,071,648	$335,275,968	$76,926,402	$258,349,566	22.9%	$2.41
	Concept	107,071,648	$246,119,808	$76,926,402	$169,193,406	31.3%	$1.58
Total	*Existing*	*311,582,770*	*$782,498,030*	*$299,731,798*	*$482,766,232*	*38.3%*	*$1.58*
	Concept	*312,811,870*	*$704,689,370*	*$301,821,268*	*$402,868,102*	*42.8%*	*$1.58*

5 Conclusion

The Core Efficiencies Study has three major objectives. The first is to review the Service Delivery Policy and determine whether existing standards should be revised and/or new standards should be added that would help to identify the most efficient services. The second objective is to consider the MBTA system in light of these standards, as well as development, trip, and financial patterns. The third objective is to propose concepts for how the system might be adjusted or potentially redesigned to respond to the prioritized service standards or demonstrated patterns.

In terms of service standards, those currently used by the MBTA—coverage, span of service, frequency of service, schedule adherence, vehicle load, and net cost per passenger—provide a satisfactory assessment of the existing level of service. Other peer agencies use additional standards to measure aspects of service structure (stop spacing, route duplication and competition, route travel time, directness of travel, ease of use, and number of transfers and transfer waiting time), service provision (the percentage of scheduled service hours that are delivered, the average number of miles between service failures, the employee vacancy rate, the average number of miles between accidents and incidents, and passenger complaints), service efficiency (cost-effectiveness and passenger productivity), and physical infrastructure (the distribution of revenue equipment and transit amenities). The MBTA could include some of these as standards or guidelines in its Service Delivery Policy to provide an additional level of assessment of the level of service.

This study also assessed some demographic, trip, and financial characteristics that are likely to affect MBTA service both today and in the future. Demographic trends in population and employment density and in the number of zero-vehicle households indicate areas where existing and future transit demand may be the greatest. Modeled trips between neighborhoods also demonstrate the existing and future areas where people are expected to want to travel. Finally, the financial situation currently facing the MBTA will limit the amount of operating expenditures that can be devoted to transit, and may require that service is provided in even more cost-efficient ways.

Four different concepts are proposed as modifications or alternatives to the existing structure of MBTA service. The rail extension concept essentially maintains the existing service structure with extensions of the radial rail network, while primarily using buses as feeder routes or to serve circumferential trips. The BRT corridor concept replaces local bus service in the urban core with a reduced number of high-frequency, BRT-level services, while local bus service outside the core would remain the same. The limited-stop corridor concept replaces local bus service with a combination of local- and limited-stop service during the peak travel periods along Key Bus Routes and other major routes that travel a long distance. The neighborhood services concept presents an entirely revised bus network, with new BRT routes along major radial and circumferential corridors, and other bus routes linking local neighborhoods to these corridors and the rail lines.

Each of the four proposed concepts and the existing MBTA structure have varying levels of analyzed performance with respect to the various service standards and indicators of transit demand. The coverage standard, in terms of the walking distance to the nearest transit service, is met for most required areas with the existing service. The BRT corridor concept would increase this walking distance in the urban core where service would only operate along BRT corridors and all other local service would be eliminated. None of the proposed concepts would dramatically alter the span of service of any transit routes, though areas with new rapid transit service would receive greater hours of service. The frequency of service would increase on BRT routes in either the BRT corridor concept or neighborhood services corridor concept. The implementation of limited-stop service would necessitate the decrease in the frequency of local-stop service. Vehicle loads and crowding would likely increase in the rail extension concept throughout the lines but particularly at stations nearer to the downtown. Finally, the rail extension concept would likely increase the net cost per passenger while the BRT corridor concept and neighborhood services concept would likely decrease the net cost per passenger.

In terms of other standards used by peer agencies, all of the proposed concepts would lengthen the average distance between stops and reduce or have no effect on route duplication. All concepts except the rail extension concept would decrease route running times and all concepts would decrease the ratio of in-vehicle transit travel time to the comparable auto travel time. All concepts except the limited-stop corridor concept would improve the ease of use and all concepts would decrease or have no impact on the transfer rate. None of the proposed concepts would likely have a significant impact on service delivery, service failure, the employee vacancy rate, vehicle availability, the accident and incident rate, and passenger complaints. The BRT corridor concept and the neighborhood services concept could improve the ease with which revenue equipment is distributed by reducing the number of overall bus routes, and each concept would likely increase the distribution of transit amenities.

Each of the concepts was also analyzed according to the demographic, trip, and financial indicators. Both the data on population density and the modeled trips demonstrate likely increases in transit demand in the neighborhoods of East Somerville, East Cambridge, the Waterfront, and East Lynn, among others. While the existing MBTA system provides service to these neighborhoods, the cost of these transit trips is typically greater than the systemwide average. The BRT routes proposed in the BRT corridor concept and the neighborhood services concept do have greater percentages of origins and destinations served by the routes. The rail extension to West Medford provides service to the East Somerville neighborhood. However, the effects at the systemwide level are marginal. Finally, if the MBTA continues to face deficits between its annual expenses and revenues similar to what it has budgeted or worse, it is likely that some of that total deficit will need to be addressed through fare increases and/or service changes to increase operating revenues or service changes to reduce operating expenses. Of the proposed concepts, the BRT corridor concept offers the greatest financial savings.

In conclusion, each of the proposed concepts, as well as existing MBTA service, performs better with some service standards and transit indicators and worse with others. If coverage is the primary goal, the existing system performs just as well if not better than all of the proposed concepts. The rail extension concept makes transit compare more favorably to automobile travel in certain areas, reducing transit travel times and the number of transfers. The rail extension to West Medford in particular addresses service to a neighborhood with significant projected increases in trips. The BRT corridor concept prioritizes frequency, schedule adherence, and net cost per passenger, resulting in the greatest cost savings of any concept. The primary goal of the limited-stop corridor concept is reduced trip times. Finally, the neighborhood services concept includes BRT routes as well as the rail extension to West Medford, the new station at Assembly Square, and improvements to the Fairmount Line. This concept therefore prioritizes many of the same service standards and transit indicators as the rail extension concept and the BRT corridor concept, such as coverage and service to neighborhoods with greater transit demand as well as frequency, schedule adherence, and net cost per passenger. Each concept therefore has positive and negative aspects, and the choice of which concept to more fully study depends on which characteristics are prioritized.