Boston's Light Rail Transit Prepares for the Next Hundred Years

JAMES D. MCCARTHY

For over a century light rail transit (LRT) has played an important part in the development of the City of Boston and its suburbs by fulfilling its transportation needs. Today, LRT runs over many of the same routes it did a century ago. As we approach the century mark of Boston's first electric trolley, it is appropriate to review some of the accomplishments of light rail in Boston and to look at the future. The Massachusetts Bay Transportation Authority (MBTA) has two light rail projects currently in design. A third proposal would extend the light rail system in the future. At North Station, the Green Line (light rail) will be relocated to a new subway alignment that will create a new transportation center. At Lechmere Square in Cambridge, the existing Lechmere Station will be relocated across O'Brien Highway to a new site that will enable the MBTA to develop a new station and a light rail vehicle maintenance facility. The relocated Lechmere Station is the first phase of a plan to extend the Green Line beyond Lechmere into Somerville and Medford.

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY (MBTA) was created in 1964 as a political subdivision of the Commonwealth of Massachusetts to replace the Metropolitan Transit Authority. The MBTA has the responsibility of providing public transportation within the City of Boston as well as the surrounding 78 communities that make up the Regional Transportation District. The population of the 1,038-mi^2 district exceeds 2.6 million. The MBTA's net deficit after revenue and federal operating assistance comes from two sources: 50 percent from regional property tax assessments receipts and 50 percent from general state revenues.

Massachusetts Bay Transportation Authority, 10 Park Plaza, Boston, Mass. 02116.

The MBTA's system handles 600,000 passengers each weekday, employing 786 peak buses, operating over 150 routes covering 710 route mi; 4 light rail routes and 3 rapid transit routes operating on 183 mi of track; 4 trackless trolley routes covering 16 route mi; and a commuter rail system covering 357 route mi. The three rapid transit routes are distinguished as the Blue, Orange, and Red lines. The four-branch light rail system is known as the Green Line. The commuter rail system is the Purple Line (see Figure 1).

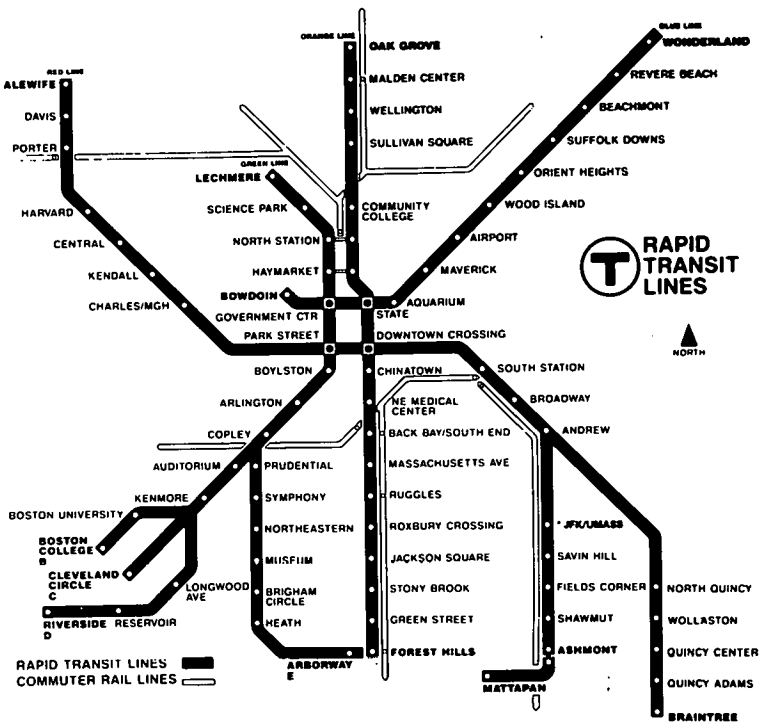

FIGURE 1 Boston transit system map.

HISTORICAL BACKGROUND

On January 1, 1889, the first electric trolley left the Allston Depot down Harvard Street to Beacon Street, traveling to its destination at Scollay Square in downtown Boston. As we approach the century mark of the first electric trolley to operate in Boston, it is appropriate to review the accomplishments of Boston's light rail system and look to its future.

This historic event had its origins in the first streetcar operation in the Boston region. On March 26, 1856, the Cambridge Horse Railroad, which had been organized in 1853 as the first street railway company in Massachusetts, inaugurated its first route, which ran from Harvard Square in Cambridge over Massachusetts Avenue, Main Street, and the West Boston Bridge to Bowdoin Square.

Not quite 33 years later, Boston's first electric car began operating from Allston to Scollay Square. The second electric line opened along Beacon Street less than two weeks later on January 12, 1889, running from what is now Reservoir Station at Cleveland Circle to Park Square. The third line opened the following day from Oak Square in Brighton to Park Square. By April 2, 1894, when the Boston Elevated Railway Company was chartered by the Massachusetts General Court, most of the streetcar lines were electrified and for the most part were still operating in the streets.

America's first subway was opened in Boston on September 1, 1897, when electric car No. 1752 from Allston entered the tunnel. Also in 1897, the Boston Elevated Railway Company took over the West End Street Railway. On September 3, 1898, the Tremont Street subway was extended from Park Street north to Causeway Street (North Station). There was a station at Scollay Square with the northbound side called Corn Hill and the southbound side, Tremont Row. The ensuing years saw the Boston Elevated Railway Company rapidly expand service, building the East Cambridge Viaduct to Lechmere that opened on June 1, 1912.

The Boston "El" was succeeded by the Metropolitan Transit Authority (MTA), and the MTA acquired the Boston & Albany Railroad from New York Central on June 24, 1958. On July 1, 1959, streetcar service was inaugurated on this new line into Brookline and Newton where the Riverside terminal is located.

Since August 4, 1964, when the MBTA succeeded the MTA, many improvements have been made to the Green Line. These include the modernization of Arlington, Government Center, Haymarket, Copley, Prudential, Kenmore, Auditorium (formerly Massachusetts Avenue), and Park Street stations; reconstruction of the Highland Branch (Riverside Line) by installing new roadbed and all-welded rail; and improving station platforms and lighting. In addition, new traction power and new signaling and communications equipment have been installed on the Riverside Line and in the Central Subway and a new track structure has been installed in the Central Subway.

TODAY'S LRT SYSTEM

The 27 mi of the Green Line (5 subway, 21 surface, and 1 mi elevated) and the 2.5 mi of the Mattapan-Ashmont branch of the Red Line are the last of the

network of trolley tracks that once covered Boston and many of its suburbs. The Green Line runs on an elevated track from Lechmere Station in Cambridge to North Station in Boston, where it goes into the subway for Haymarket and Kenmore. The Central Subway provides connections to the three rapid transit lines—to the Red Line at Park Street Station, to the Blue Line at Government Center Station, and to the Orange Line at Haymarket Station (see Figure 2).

Kenmore Station in Boston's Back Bay is the last subway station before the line branches off for Commonwealth Avenue to Boston College in Newton; Beacon Street to Cleveland Circle through Brookline; and the Riverside rail right-of-way through Brookline and Newton to Riverside Station near Route 128 and the Weston line. The Arborway Line branches off at Copley Square, continues underground to Symphony, and then runs on the street to the Arborway in Jamaica Plain.

Operations

The President's Conference Committee (PCC) cars no longer run on the Green Line; they have given way to the new light rail vehicles (LRVs). The Beacon Street, Commonwealth Avenue, and Huntington Avenue lines still exist today almost as they did a century ago. The Central Subway is unchanged with the exception of station modernization and facility improvements. The Green Line carries approximately 220,000 daily riders and is the spinal cord of the MBTA's transportation system.

There are 56 colleges and universities in the Boston area and one out of every 40 college students in the United States attends classes here. The Green Line has direct service to several of these institutions: Boston College, Harvard Medical, Boston University, Northeastern University, Emerson College, Massachusetts College of Art, and Wentworth Institute of Technology. Also, Boston is blessed with some of the finest medical institutions in the world. Education and medicine provide one of every six jobs in Boston. The Green Line serves many of these hospitals.

Because the colleges and hospitals are located outside the central business district (CBD), they give the Green Line the unique quality of a two-way ridership demand during the peak and off peak hours.

Ridership

Over the past 20 years the MBTA has made major improvements to its rapid transit system. Major extensions and upgrades have occurred on the Red and Orange lines and the Blue Line has received new vehicles and track structure.

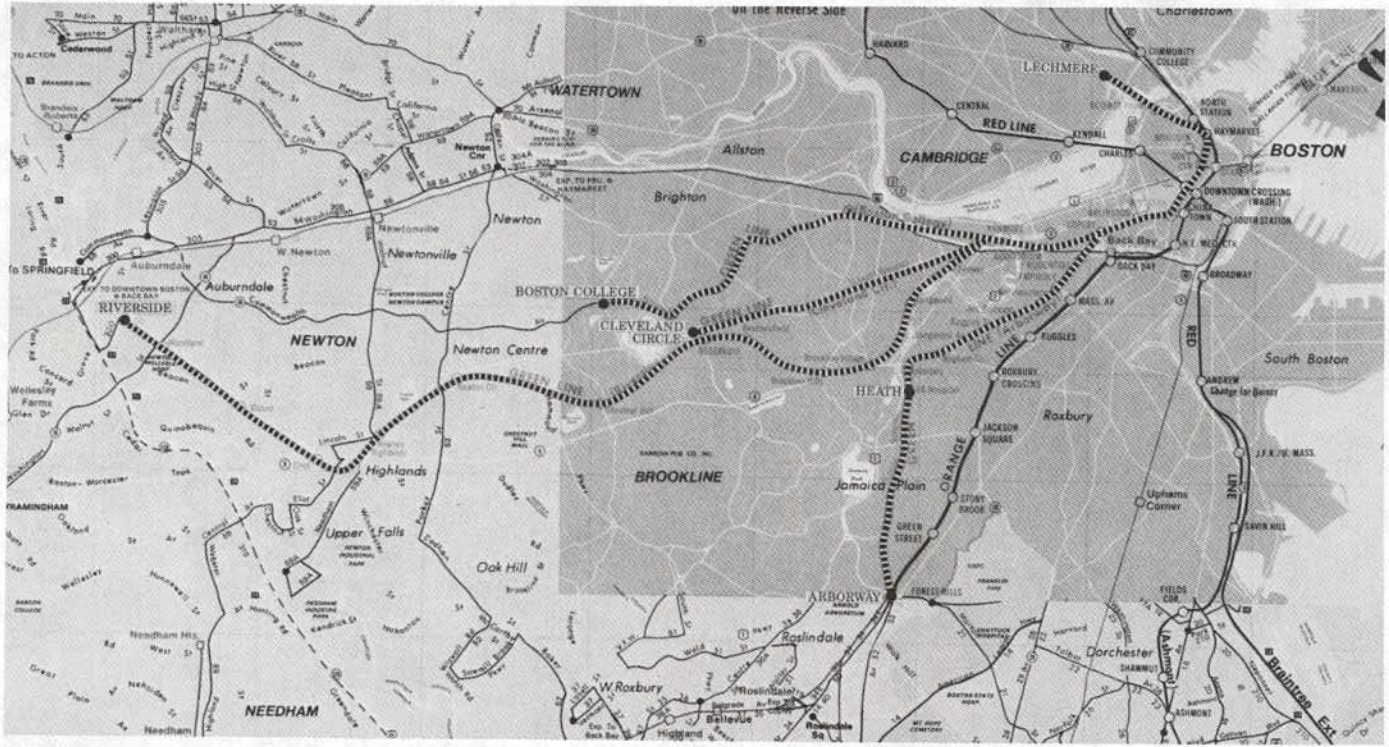

FIGURE 2 Green Line route map for Boston and its suburbs.

Demands for better transportation exist more today than ever. Ridership has increased on all lines, but the Green Line has experienced the most dramatic growth, with the usual consequences of operating at capacity. Although the other rapid transit lines have increased their capacity by adding cars to make longer train consists, the Green Line has been restricted by equipment problems, subway design, and a lack of LRVs to maintain an increased schedule.

Figure 3 shows the inbound surface ridership on the Green Line for all branches. Ridership has been on the increase for the past 10 years and indications are that it will soon pass the 25-year high. Of the 455,000 passengers/day that use the entire rapid transit and light rail system, approximately 220,000 include a Green Line segment. Of the total daily Green Line passengers, 39 percent make trips involving only the subway, and 17 percent make trips involving only surface segments. Table 1 breaks down the surface ridership of the Green Line. The figures for the Boston College line show that 35 percent of the total ridership is for surface only, indicating the strong student ridership for Boston University and Boston College.

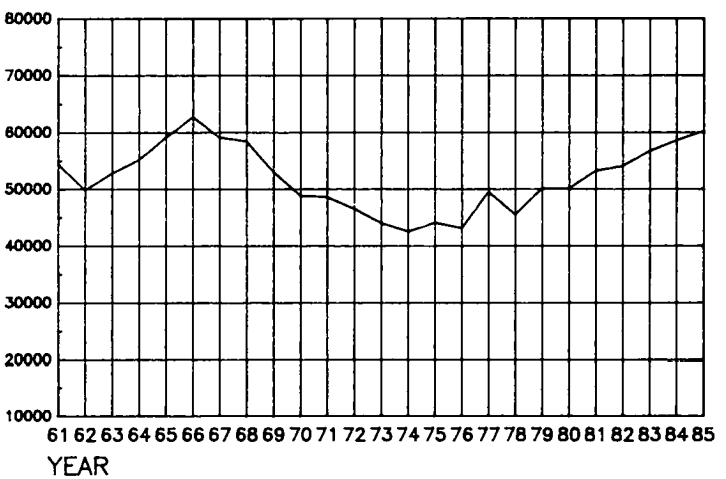

FIGURE 3 Light rail ridership, surface inbound.

Schedule

To meet the ever increasing demands on the Green Line, MBTA has developed two operating plans for future service levels—a 1990 service of 147 peak cars and a post-1990 service of 159 peak cars. Existing peak service is 125 cars.

TABLE 1 COMPARISONS OF GREEN LINE SURFACE TRIP GENERATION (7 a.m.–10 p.m.)

	Boston College (3.95 mi)[a]		Cleveland Circle (2.24 mi)		Riverside (9.25 mi)		Arborway Heath (3.6 mi)		All Branches	
	Total	Per Mile	Total	Per Mile	Total	Per Mile	Total	Per Mile	Total	Per Mile
In ons	15,837	4,009	9,310	4,159	13,729	1,484	16,153	4,487	55,029	2,888
Out offs	19,422	4,917	9,646	4,306	14,003	1,514	17,146	4,763	60,217	3,161
Two-way ridership	35,259	8,926	18,956	8,461	27,732	2,998	33,299	9,250	115,246	6,049
Inbound surface-subway	11,594	2,935	7,403	3,305	10,861	1,174	11,563	3,212	41,421	2,174
Inbound surface-only	4,243	1,074	1,907	850	2,868	310	4,590	1,275	13,608	714
Outbound subway-surface	11,196	2,834	6,624	2,957	9,442	1,021	10,793	2,998	38,055	1,998
Outbound surface-only	8,226	2,083	3,022	1,349	4,561	493	6,353	1,765	22,162	1,163
Two-way-surface-subway	22,790	5,770	14,027	6,263	20,303	2,195	22,356	6,210	79,476	4,172
Two-way-surface-only	12,469	3,157	4,926	2,199	7,429	803	10,493	2,915	35,770	1,878
Percent surface-only	35.4		26.0		26.7		31.5		31.0	

NOTE: 1985 counts.
[a]Surface length.

The post-1990 service will add cars to the 1990 schedule and possibly extend the Green Line beyond Lechmere. The impact of the proposed increased service levels will be discussed later in the context of the plans for the Lechmere Maintenance Facility and the extension beyond Lechmere. Table 2 shows the existing and projected Green Line service.

The following sections discuss how America's oldest subway system is preparing for the next hundred years.

PLANNED IMPROVEMENTS

In 1980 the MBTA undertook a study to examine the alternatives for making transportation improvements in the Green Line Northwest Corridor. The Green Line Northwest Corridor extends from Haymarket to Medford and lies between the Orange and Red lines. Three segments were identified for improvements in the corridor: North Station, Lechmere, and Beyond Lechmere.

The 1980 study was undertaken simultaneously with the City of Boston's unveiling of a plan to redevelop the North Station area. Two major components of the city's plans were the construction of a new federal office building and a new multipurpose arena. The Green Line presently rises from subway to elevated structure at North Station. The elevated structure, which is over 70 years old, has been a blight on the area and detrimental to the city's past revitalization efforts. North Station is a gateway to the city and the hub of the North Side's transportation network. The Orange Line serves the commuters to the north; the Green Line serves Cambridge and Somerville; and commuter rail serves the communities farther out to the north and northwest. In addition, many bus routes from the north now terminate nearby at Haymarket Station.

North Station

The City of Boston's redevelopment plans provided a unique opportunity for transportation improvements at North Station.

Initially, the MBTA identified eight alternatives to relocate the Green Line. An alternatives report and a draft Environmental Impact Statement were completed in 1982. Commuter rail improvements at North Station were expected to be a separate project but common to all Green Line alternatives. The following is a brief description of each alternative and the rationale for giving it or not giving it further consideration.

1. Alternative 1—No-Build: Alternative 1 would have maintained the existing Green Line rapid transit service and facilities in the North Station

TABLE 2 LIGHT RAIL OPERATIONS SCHEDULE: PEAK PERIOD

	1988				1990				Post-1990			
	Trips	Consist	Headway (min)	Total Cars	Trips	Consist	Headway (min)	Total Cars	Trips	Consist	Headway (min)	Total Cars
Boston College (via Commonwealth Ave.)	18	2	5	36	9	2	6	36	12	2	5	42
Cleveland Circle (via Beacon St.)	13	2	6/7	26	9	2	6	30	9	2	6	30
Riverside (via Highland Br.)	14	2	5	37	10	2	6	47	13	2	5	53
	3	3										
Arborway (PCC) (Forest Hills)	–	–	–	–	–	–	–	–	–	–	–	–
Arborway (Brigham/Heath)	6	1	6	16	10	2	5.6	20	10	2	5.6	20
	5	2										
Blandford Lechmere	–	–	–	–	6	2	10	12	6	2	10	12
Run as directed (RAD)	10	1	–	10	2	1	–	2	2	1	–	2
Totals				125				147				159
Average subway headway (sec)			75				75				62	

area. It would involve no physical modifications to either the elevated or the ground-level station facilities.

2. Alternative 2—At-Grade Relocation: Alternative 2 provided at-grade service between Canal Street and the elevated structure at Science Park Station following the existing alignment or two potential alternative at-grade alignments. This alternative was not carried forward because at-grade transit operations would disrupt vehicular and pedestrian circulation within the North Station district, an area already suffering from vehicular congestion and numerous vehicle-pedestrian conflicts.

3. Alternative 3—Elevated on New Alignment: Alternative 3 provided a new elevated structure between the existing transition section near Canal Street and Science Park Station by way of a new elevated alignment, which would pass between the Boston Garden and the Anelex Building and then run parallel to the elevated Central Artery/Leverett Circle connector ramps to Science Park Station. Alternative 3 was selected for further study because it featured a station location that would facilitate intermodal transfers to commuter rail services and would also serve proposed development in the North Station district. Its alignment was almost totally within public rights-of-way, and its estimated construction cost was about half that of several subway alternatives.

4. Alternative 4—Subway Under Existing Alignment: Alternative 4, which proposed a subway under the existing elevated alignment, was not carried forward for further study. Construction of a subway beneath the existing viaduct, while maintaining present Green Line service above, would present extreme problems related to underpinning and structure security. While technically possible, this construction process would be extremely costly and time consuming.

5. Alternative 5—Subway Under Boston Garden: Alternative 5 provided a below-grade alignment that extended from Haymarket Station, beneath the Boston Garden, and then climbed to meet the elevated Science Park Station. This alternative was further studied and became the preferred alternative.

6. Alternative 6—Subway to Cambridge: Alternative 6 was a subway alignment similar to Alternative 5. Instead of making the transition to the elevated Science Park Station, the alignment continued under the Charles River in a tunnel and ultimately transitioned to Lechmere Station in East Cambridge. This alternative was not studied further due to the dramatically increased investment requirements associated with building a new subsurface river crossing.

7. Alternative 7—Merrimac Street-Lomasney Way Subway: Alternative 7 provided a subway alignment from Haymarket Station via Merrimac Street and Lomasney Way before making its transition to Science Park Station. This alternative was evaluated further because the alignment was totally within

public rights-of-way and was convenient to the (then-proposed) General Services Administration office building. The relocation of the Science Park Station was required by this alternative.

8. Alternative 8—Replacement Bus Service: Alternative 8 eliminated all Green Line service between North Station and Lechmere Station, and made North Station the terminus for the Green Line. Bus service would have replaced the Green Line service to Cambridge. This alternative was rejected because replacement of light rail with bus did not conform to the stated goals of the MBTA or the Northwest Corridor communities of Boston, Cambridge, and Somerville.

Because of the complexities of the project, a preliminary engineering analysis was undertaken as the initial design step and proved to be invaluable. The alternatives were again examined and a detailed engineering analysis was undertaken on the two most promising alternatives: relocating the elevated alignment that ran beside and behind the Boston Garden (Alternative 3); and providing a subway alignment under the Boston Garden (Alternative 5).

An extensive geotechnical program that included a number of test pits was undertaken. A peer review group was formed and contractors were invited to participate in the engineering analysis. The most difficult part of the subway alternative was the tunnel under the Boston Garden, which has to be kept open during construction.

The engineering analysis showed that the supposedly cheaper option, Alternative 3—the relocated elevated structure—would have such impact on an adjacent building that it would cause its taking at a value of $25 million. Nor would the elevated structure afford the simple modal interchange provided by the subway alternative.

The relocation of the Green Line to a new subway alignment will enhance the change of mode at North Station and create a major transportation center. The North Station Transportation Center will serve the MBTA commuter rail, the Green and Orange lines, commuter buses, taxis, pedestrians, and attendees of Boston Garden events. The transportation center will be more than a location where many transportation modes converge; it is being designed to facilitate intermodal transfers, improve existing facilities and transportation services, and increase user comfort. It is being designed with full understanding of the existing surroundings as well as future plans in order to maximize coordination and thereby minimize conflicts among objectives and projects.

The subway alignment runs parallel to the Orange Line with track spacing of 18 ft as far as the north wall of the Boston Garden. There, it swings to the west, simultaneously increasing the track spacing to provide storage facilities under the MBTA commuter rail tracks. Continuing west, it swings to the

north and emerges within the median of the proposed widened Lomasney Way to Science Park Station (see Figure 4).

Vertically, the alignment is governed by the existing profile at Haymarket and Science Park stations, the elevations of the Orange Line mezzanine and platform, and by the outfall sewer in Nashua Street. The profiles of inbound and outbound tracks are different within the station and beyond. The outbound track continues from Haymarket portal to Boston Garden nearly level and at the elevation of the mezzanine and then dips. The inbound track dips from the Haymarket portal to meet the elevation of the Orange Line platform. Beyond Boston Garden the profiles meet and continue nearly level to accommodate storage facilities. At Nashua Street, both profiles climb at constant 6.5 percent grade to Science Park Station.

The proposed Green Line station has been designed to serve existing and projected transit ridership. It will not only improve transit service but will also provide efficient connections with other transit modes, including the Orange Line, commuter rail, buses, taxis, and pedestrian routes. The station will have entrances at both ends of its platforms convenient to major pedestrian flow from the Government Center and financial districts to the south and the Boston Garden/commuter rail terminal to the north.

Entrances will be highly visible, clearly marked, and at ground level to promote security and street-level activity. Access to commuter rail will be provided through a pedestrian passageway under Causeway Street. A shared inbound ("super") platform will connect the Green Line directly with the Orange Line (see Figure 5). Direct connections will also be provided to the bus terminal above the Green Line station.

The station will be designed to provide the patron comfort and visual clarity to help them readily find their destinations. The spatial character of the station will accentuate major decision points such as collection areas, critical circulation elements, and the intersections of main paths.

There will be a four-track storage and turnback configuration behind the Boston Garden with storage space for 11 cars (see Figure 6). The turnback area will provide greater flexibility in handling extra or disabled cars. Also, it will serve as the turnback facility for the cars terminating at North Station. Extra cars will be stored in the area for the surge of patrons from Boston Garden events.

As a result of combining the Orange and Green line platforms, an opportunity exists to bring the existing Orange Line station up to current MBTA design criteria. New handicapped access will be provided with an elevator from the north mezzanine to the Orange Line outbound platform. New wall and ceiling finishes and accessories will be coordinated with the new Green Line portion of the station. The existing substandard portions of the platforms will be widened to a minimum of 8 ft and new access from the south end of

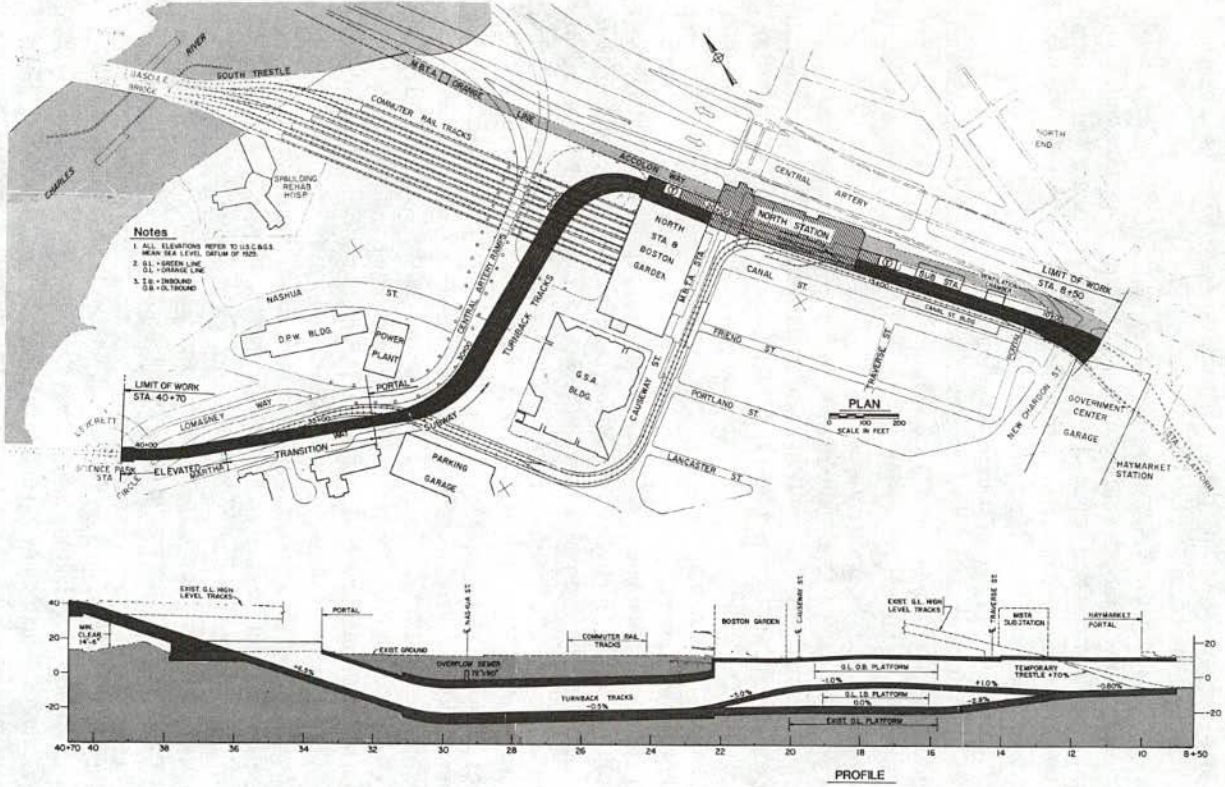

FIGURE 4 North Station plan and profile.

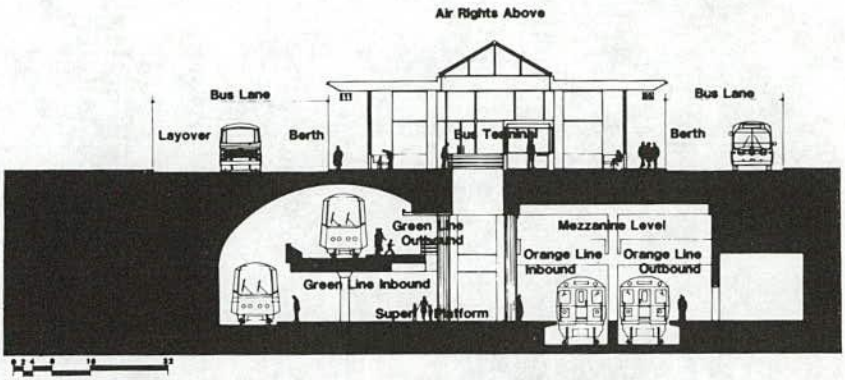

FIGURE 5 New North Station Transportation Center cross section.

the station will be provided via a stair/escalator unit from the new south mezzanine. The roof will be raised to a higher level, allowing natural light from skylights to reach both Orange Line platforms. In addition, all new artificial lighting and graphics will be coordinated with the Green Line portion of the station to provide a uniform, cohesive visual effect within the facility.

The depression of the Central Artery (the major north/south freeway), which presently runs through the city on an elevated structure, will have on and off ramps at Causeway Street across from the new station. The new ramps are ideal for the buses coming from the north and terminating at North Station. A new bus terminal will be constructed at grade above the Green/Orange station to serve bus routes from the north, making the station the best location for the transfer from bus to rail. As previously discussed, the Green/Orange station will have a combined platform for inbound riders and, because both lines provide service to some of the same areas, many transit riders will have the opportunity to take the first train to arrive, whatever color line it runs on.

The development of the station and the bus terminal will create the opportunity to develop the air rights above the transportation center as well. A feasibility study on the potential of air rights that will identify the highest and best use will soon be undertaken; however, preliminary indications are that an office use would be very marketable. The air rights development will provide additional funds for the transit project. In exchange for the air rights, a developer will make a contribution, such as a lease agreement, maintenance, or paying for a portion of the project.

Lechmere Station

Lechmere Station is the northern terminus of the Green Line and is connected to Science Park Station by an arched viaduct across the Charles River. The

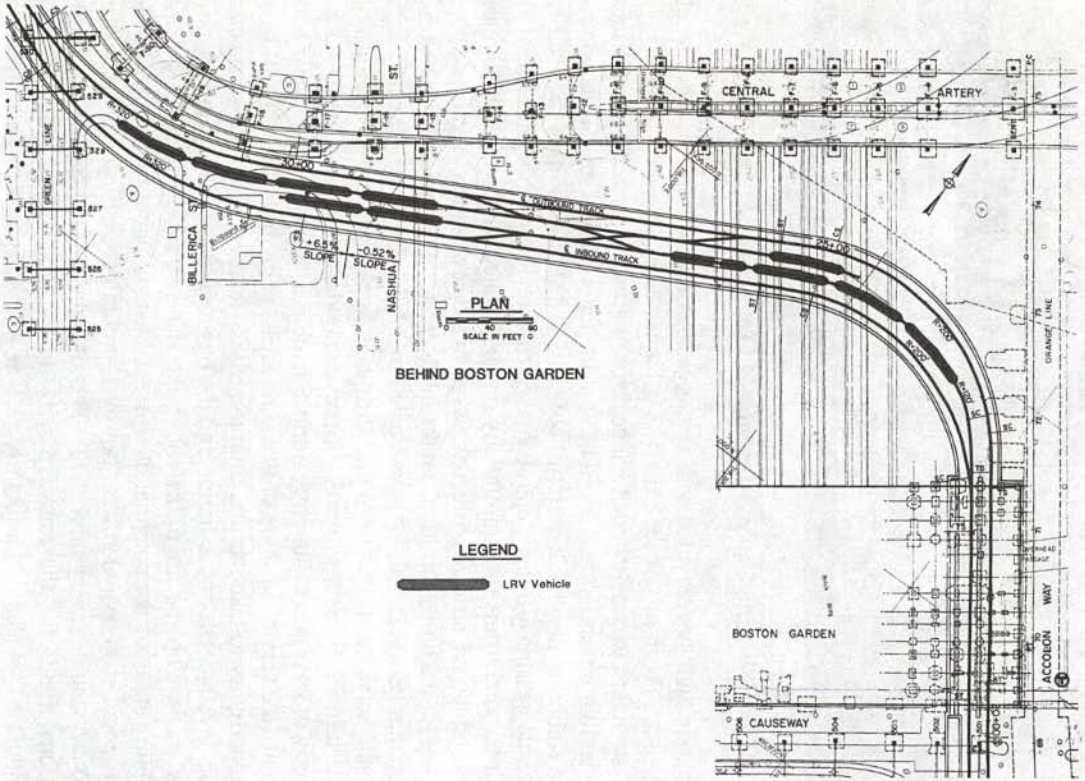

FIGURE 6 North State storage tracks.

arched viaduct was constructed in 1912 and is a historic landmark. The existing Lechmere Station was also constructed in 1912 and has operational deficiencies: lack of storage space, difficult bus movements, and a site that prohibits extension or expansion.

The Lechmere Canal area is undergoing a significant redevelopment. The City of Cambridge, as well as other public and private entities, has invested a great deal of effort and money in the revitalization of this area. The new Lechmere Station is a major component of this effort (see Figure 7). In addition to upgrading Green Line service, the new station will greatly improve the appearance of the area, while encouraging future developments such as the Canal Park project.

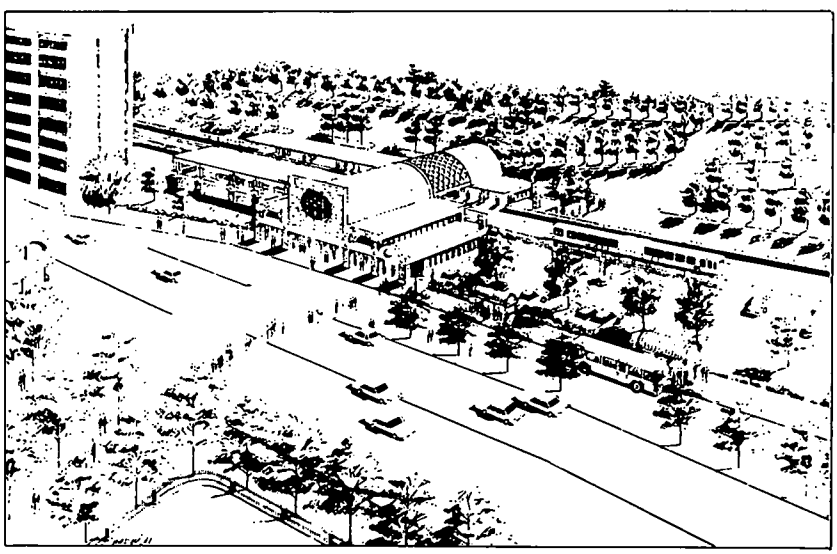

FIGURE 7 Lechmere Station rendering.

The site is primarily occupied now by MBTA parking north of Monsignor O'Brien Highway and across from the existing station. The relocated Green Line track will enter the station area on a viaduct from the east, gradually sloping down to grade level on the west side of the station. The station is located at this transition point on an embankment between elevated and at-grade track.

The relocated station will be highly visible from Monsignor O'Brien Highway and First Street, the major approach routes. The station will form one side of the new Lechmere Square, created by the Lechmere Canal buildings and the development of the existing station site. The eventual

removal of the existing station will allow the center of this area to be redeveloped with a combination of open space and a new building.

A major roadway improvement project for Monsignor O'Brien Highway is under way. The relocation of the station will allow further improvements by removing the viaduct from the O'Brien-Cambridge Street intersection and by making other minor improvements possible, such as the upgrading of East Street. Access to the station site will be via East Street. The extension of First Street to O'Brien Highway, a project of interest to the City of Cambridge, would significantly ease traffic flow in the area and help bus and automobile movement to and from the new station.

Pedestrians will cross the highway at-grade at signaled crosswalks. The Cambridge Community Development Department and local East Cambridge groups are interested in a pedestrian bridge that would be fully accessible to handicapped and elderly patrons, and would be located to serve both the East Cambridge community and the Lechmere Canal area.

The station entrance is oriented toward the south and Monsignor O'Brien Highway, the primary approach for pedestrians and motorists. This area also will serve as the drop-off and pick-up area for bus passengers (see Figure 8). A covered platform for five buses will extend from the entrance, parallel to O'Brien Highway. A covered drop-off area will be provided for kiss-and-ride patrons; 300 parking spaces, controlled by one collection booth, also will be provided. A covered walkway will provide a path from the north side parking areas and the industrial development of the North Point area.

The entrance to the station will be through an enclosed brick structure that will contain the pay area, bus waiting, the concession, and vertical circulation. Within this space, access will be provided directly to the inbound rail platform and to a passage under the tracks to the outbound platform. Access to public toilets and the station service areas will be from the passageway under the tracks.

The rail platforms, located on an embankment one level above the entrance, will be reached by way of stairs, ramps, and possibly escalators. Both platforms are to be sheltered, with the track area open.

The building form and the materials to be used in the station are based on those commonly found in the older commercial and public buildings in East Cambridge. Brick columns, walls, and arches, in combination with the concrete viaduct and the glass enclosure and canopies, will emphasize this relationship between the station and the local context.

The construction sequence allows for continuous train service throughout construction. Both tracks can be maintained in operation, servicing the existing station and subsequently the new station, except for a period of 1 to 2 months during the phased rerouting when only one track will be in use.

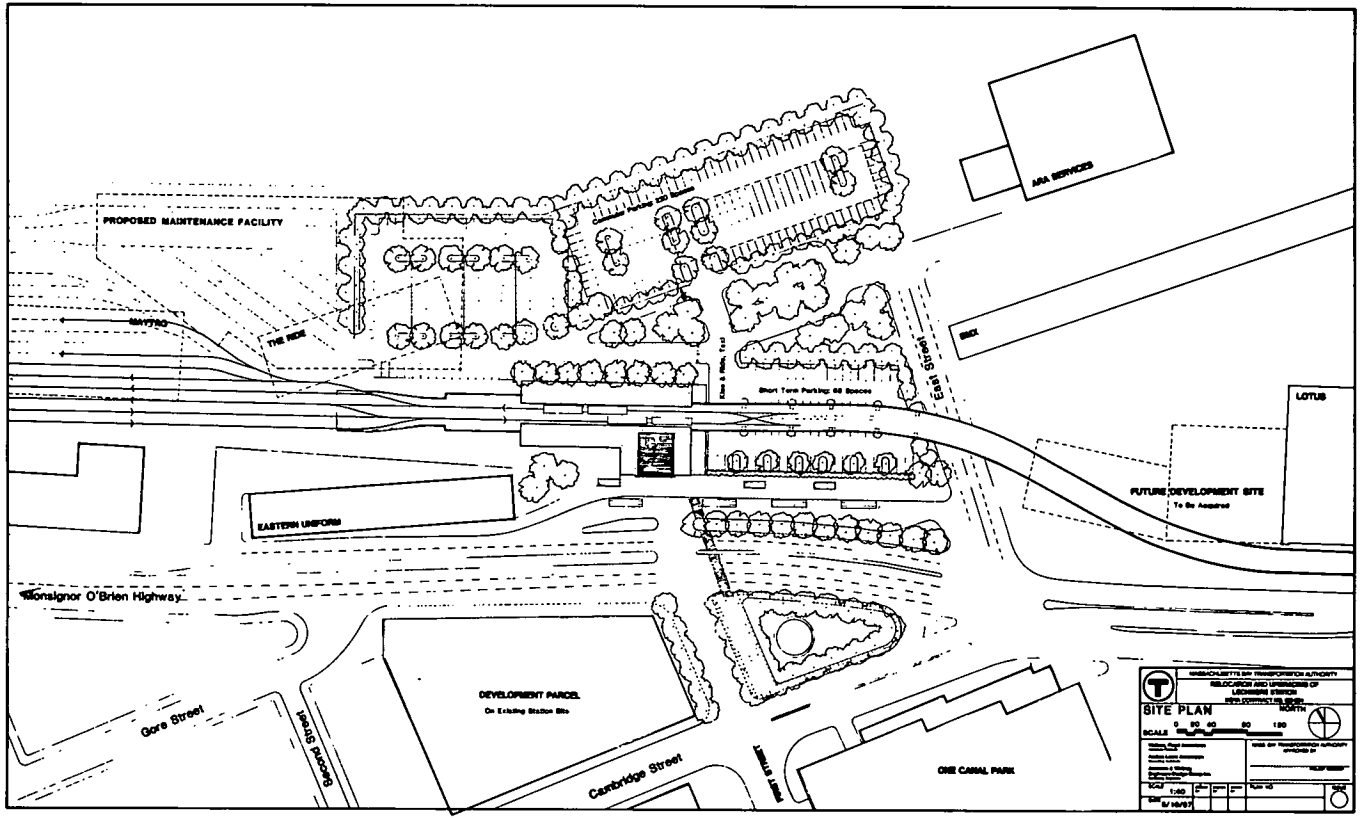

FIGURE 8 Lechmere Station site plan.

The new, relocated Lechmere Station will provide several operational benefits. The new site will be of sufficient size to provide train storage, operators lobby, bus area, maintenance facility, and work train area. In addition, the new station site will be next to the New Hampshire commuter rail right-of-way that may be used for an extension of Green Line service beyond Lechmere into Somerville and Medford.

Initially, a three-level station and LRV storage on a viaduct were studied, but emphasis on the related maintenance facility favored the current two-level embankment station. With the current station design, the related LRV storage can occur at grade rather than on viaduct, the connection between the rail line and buses is improved, the maintenance facility can be closer to the station, and the overall cost is significantly lower.

Lechmere Maintenance Facility

The Green Line is one of the largest light rail operations in North America, with four branches merging from the west into the Central Subway to downtown Boston and then north to a terminus at Lechmere. But vehicle maintenance deficiencies exist in the present system. All the LRV maintenance facilities are located at the western terminus points at Riverside and Reservoir with a running repair shop at Boston College. This arrangement requires all disabled cars running from the Central Subway to be moved a significant distance for repairs.

The existing Green Line facilities cannot provide the levels of maintenance and storage needed to support a larger fleet and expanded service. Nor can they be economically enlarged to satisfy increased requirements. A new LRV maintenance facility at Lechmere would be ideally located near downtown and the Central Subway. The Lechmere site is directly accessible to all branches and would produce a significant savings in car miles. It would also greatly improve the flow of disabled cars to be repaired, especially for failures occurring inbound in the Central Subway. In addition, the new Lechmere facility will provide a secondary benefit to Green Line operations by reducing the backlog of cars waiting to be repaired at the already overtaxed Riverside and Reservoir facilities.

Maintenance

Maintenance functions can generally be divided into the following areas:

- Running repairs,
- Periodic inspections (performed every 30 days),

- Annual inspections, and
- Heavy repairs (which include numerous categories and take more than one day to perform).

A recent review of shop records for two time periods showed an average of 50 cars out of service. Of this total, 32.5 or two-thirds were projected to be out of service 1 day or less, 20 percent for 2 to 5 days, and 14 percent for 6 or more days. It is estimated that there are approximately 40 maintenance actions per day, the bulk of which are running repairs.

A statistical summary of the three principal maintenance facilities on the Green Line—Riverside, Reservoir, and Boston College (Lake Street)—is shown in Table 3.

TABLE 3 GREEN LINE MAINTENANCE AND STORAGE FACILITIES

Carhouse	Running Repair Spots	Heavy Repair Spots	Yard Storage Capacity
Lechmere	–	–	18
Riverside	12	20	72
Reservoir	12	–	62
Boston College	2	–	21
Total	26	20	173

Storage

To determine the requirements for storage at Lechmere, several car-flow plans were developed. Essentially, it was determined that 40 to 44 cars were to be left at Lechmere during midday storage. The car-flow plans require that some trains be operated on different branches during a run. Although this is often done on an unscheduled basis, it is a change from current scheduling practice. This change will prevent any scheduled headway gaps or increases in car miles.

Lechmere Yard Storage Requirements

In addition to the midday storage, space has to be provided for storage of spare cars and for shop support. The 1990 service plan calls for the number of spare cars to be about a third of those operating. It would be operationally unwise to assume that all spare cars would be kept at Reservoir or Riverside. Therefore, some spare car space should be provided at Lechmere. The

number of spaces required for shop support should permit resetting the shop on a given day.

The planned overnight storage at Lechmere, exclusive of the spare cars and the shop support, is as follows:

Storage	*No. of Cars*
Heath Street	20
Blandford Street	12
Run as directed (RAD)	2
Total	34

If one-third of these cars are designated as spares, about 10 spaces would be required to store them. Therefore, the estimated 1990 storage requirements for Lechmere is as follows:

Storage	*No. of Cars*
Midday	45
Spare	10
Shop support	15
Total	70

Because midday storage requirements exceed the overnight storage requirements, the space may be used to begin morning start-up service from Lechmere for other lines, too.

Shop Requirements

The ultimate shop requirements for the Green Line depend upon a number of factors. For example, by the year 2000, the Boeing LRVs will be over 25 years old and candidates for replacement. Thus, the composition of the fleet could be significantly different than it is today. Given this uncertainty, the analysis provides general guidelines for the shop requirements with post-1990 service levels.

Assumptions

The following assumptions were used for the analysis:

- The fleet will consist of 250 cars with 200 required for service. This results in an improved availability ratio of 80 percent.
- System car miles would increase in the same ratio as the increase in peak period car requirements. Thus post-1990 car miles will increase by a ratio of 1.33 to 8,342,666 mi.

- Mean distance between failures will approximately double to 3,000 mi.
- Approximately 50 percent of the failures will be sent to Lechmere compared with 40 percent in 1990. The increase is the result of new extensions for which Lechmere will be most accessible.

A summary of the storage and shop requirements at Lechmere based on a preliminary analysis is contained in Table 4.

TABLE 4 MAINTENANCE AND STORAGE REQUIREMENTS AT LECHMERE

Category	Existing	1990	Post-1990
Assumptions			
Active fleet	175	225	250
Peak cars required	105	150	200
Mean distance between failure (mi)	1,300	2,250	3,000
Car miles (thousands)	4,526	6,257	8,343
Maintenance incidents per day (system)	40	37	37
Maintenance incidents—Lechmere	0	15	19
Results			
Storage—Lechmere (cars)	18	70	100
Running repair spots—Lechmere	–	10	13–14
Heavy repair spots—Lechmere	–	15	15
Total repair spots—Lechmere	–	25	28–29

Beyond Lechmere

Travel in the corridor beyond Lechmere to Somerville is strongly oriented towards downtown Boston and neighboring urban centers. Analysis of origin-destination studies reveals that about a quarter of a million trips begin or end in the study area on a typical weekday. While 16 percent of these trips occur entirely within the study area, about 25 percent of the trips are oriented towards downtown Boston and Cambridge. In particular, journey-to-work trips show a strong orientation towards downtown Boston.

Transit accounts for 70 percent of the study area trips made to downtown Boston. An analysis of the demographic profile reveals some of the reasons for this high level of transit dependency and usage. The area has a high population density, a high percentage of elderly and low- to moderate-income residents, and a low level of automobile ownership—all indicators of transit dependency. Given such a high rate of public transit usage, transit system improvements (excluding new ridership from transit-induced new developments) are more likely to provide better service for existing riders than to attract new riders from an untapped transit market.

The corridor is served by an extensive system of buses, which primarily feed Lechmere Station. Ridership statistics indicate that a high proportion of trips originating in the corridor have destinations within it or in the North Station area of downtown Boston. These trips will not be well served by the Orange and Red lines because these heavy rail facilities are too distant and because of the inconvenience caused by the multiple intermodal transfers required to reach them via local bus.

An evaluation report on the alternatives beyond Lechmere was completed in 1984. The report evaluated a number of transit alternatives for the beyond-Lechmere corridor, including light rail, bus, busway, and combination light rail and busway. Most promising of the alternatives is an extension of the Green Line along the New Hampshire Main Line commuter rail route. The New Hampshire Main Line runs through the middle of the study corridor and is of sufficient width to accommodate both commuter rail and the Green Line.

The Green Line extension would be approximately 3.5 mi long and terminate in the vicinity of Tufts University. Although this alternative would not attract a large number of new riders because the area is already heavily dependent on transit, it would provide passengers with a one-seat ride to downtown Boston. One of the operational goals of an extension of the Green Line beyond Lechmere is the reduction of bus miles that would result.

An extension of Green Line service beyond Lechmere can be easily accomplished due to the availability of a portion of the New Hampshire Main Line right-of-way, which is depressed, and the flexibility that comes with light rail. The project can be constructed in segments to meet available funding. Simple platforms with crossovers can serve as temporary stations. No major parking structures or expensive stations will be required for the extension.

CONCLUSION

As we approach the 21st century, the need for mass transit becomes even more demanding. Although recent improvements to the heavy rail lines have increased their capacity and efficiency, Boston's oldest system, the Green Line, must also be improved. New, relocated facilities at the Lechmere and North stations are the first improvements. The new North Station will provide riders with improved transfer capabilities and operations with much needed storage and turnaround facilities for the LRVs. The relocated Lechmere Station will provide the opportunity to develop an LRV maintenance facility for the growing fleet and to extend service beyond Lechmere into Somerville. After a century of service, Boston's light rail is still looking to the future.