Making the Most of Transportation Infrastructure: MBTA's South Station Intermodal Transportation Center

Getting many different agencies to work together was instrumental in revitalizing an old railway terminal and making in into a model of integration for various modes of transport.

LAURENCE W. SHUMWAY

Transportation infrastructure is a vital contributor to a city's economic well-being and vitality. What began in Boston with an underutilized railroad station has been transformed into a unique transportation complex. The opening of the South Station Transportation Center/Bus Terminal Complex in October 1995 marked what is likely the most significant point in the history of South Station since the original groundbreaking over one hundred years ago. While the opening signified more than the revival of a grand railroad passenger station, it also signified the completion of a transformation of this historic relic of transportation infrastructure based on a new approach to public transit — the concept of *intermodal transportation*. Thanks to the commitment of a multitude of federal, state and local agencies, Boston's South Station Transportation Center Project brought together diverse transportation modes to more effectively and efficiently serve the city's thriving metropolitan area well into the next century. The South Station Transportation Center Project combined intercity and commuter railroad operations, intercity and regional bus operations, rapid transit, an airport link connection to Logan Airport and automobiles in a single location that is close to major regional highways and at the very edge of Boston's central business district.

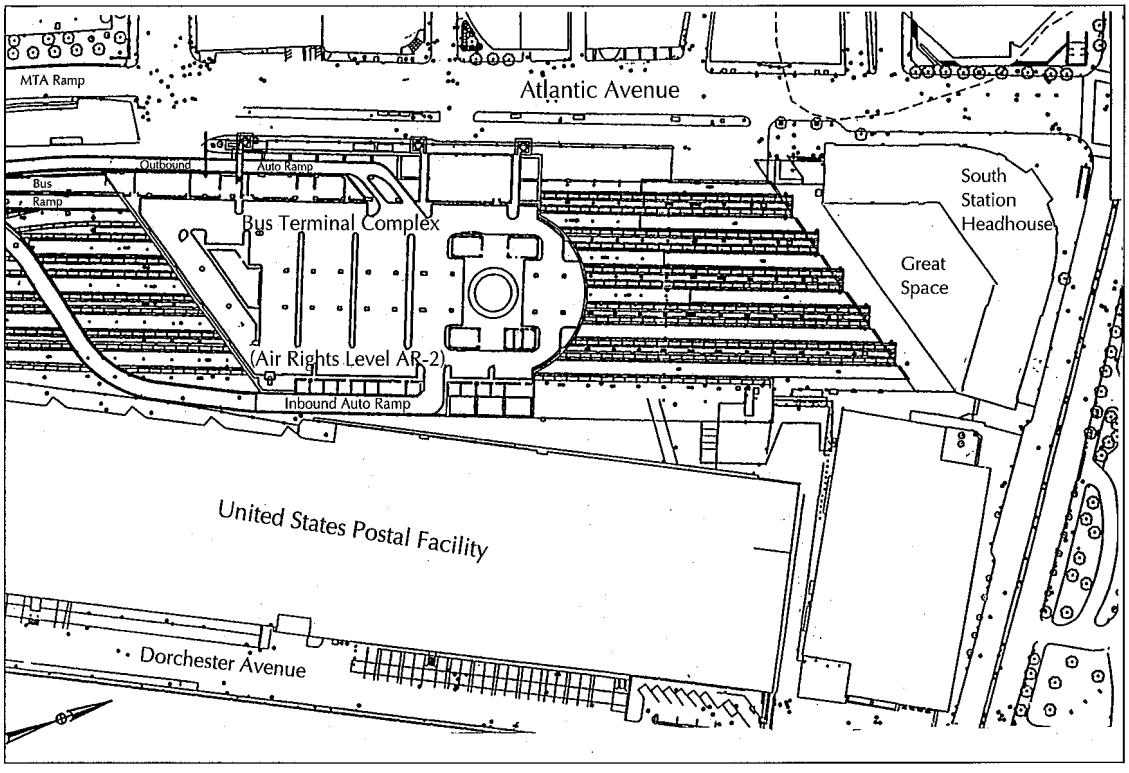

FIGURE 1. Plan of the MBTA South Station Intermodal Transportation Center.

Beginning with the implementation of this transformation as a part of the Northeast Corridor Improvement Project (NECIP), the South Station Transportation Center is the best example of bringing many elements of a major city's transportation infrastructure together, combining a multitude of transportation modes to more effectively serve the transportation needs of a metropolitan area. Implementation of the project involved diversified institutional and political entities, funds from several federal agencies and physical plans responsive not only to specific transportation needs but also providing a framework for future major commercial air-rights development at a new gateway to Boston.

The Massachusetts Bay Transportation Authority (MBTA) led this multi-agency project that included the Federal Railroad Administration (FRA), the Federal Transit Administration (FTA), the Federal Highway Administration (FHWA), the Massachusetts Executive Office of Transportation and Construction (EOTC), the Massachusetts Highway Department (MHD) and the Boston Redevelopment Authority (BRA).

Background

Until reconstruction of South Station began in June 1984, its history was similar in many ways to numerous other major railroad terminals across the country. When it opened in 1899, South Station — with its 28 tracks — occupied the entire block between Atlantic and Dorchester avenues in the southeast corner of downtown Boston (see Figure 1). The station, with its neo-classical facade, was one of the largest in the country and it set a standard for numerous stations that followed. In 1918, South Station was the busiest train station in the country, handling 38 million passengers. However, railroad passenger demand began to fall sharply at South Station in the late 1940s as part of a general decline nationwide in rail ridership. The station fell into disrepair, and major portions of the facility were demolished in the 1960s and 1970s to make way for "urban renewal."

However, the future existence of South Station was assured when the small portion of the headhouse with its curving granite facade was placed in the National Register of Historic Places in 1975. The FRA (as part of NECIP), the MBTA (which acquired the property and was designated lead agency) and the BRA (which retained development rights above the transportation center) began planning the South Station Transportation Center in the late 1970s. Conceptual and preliminary designs were completed by the FRA's consultant team in 1979. In 1980, after negotiations and the execution of two multi-agency agreements and the transfer of the station property from the BRA to the MBTA, the FRA design team began design development for the rail facilities. In addition, two separate consultant teams for the MBTA began design development of the subway station modernization and the bus terminal facilities, and a consultant team to the BRA began feasibility and design studies for air-rights commercial development.

Transportation Elements

Railroad. A realigned track plan and reconstructed concourse were the key elements in the design of the rehabilitated railroad facilities. The tracks were shifted to the west to align with Atlantic Avenue and lengthened so that there would be a direct relationship to the station concourse. Pairs of tracks were served by high-level platforms, providing full accessibility. The two edges of each platform were treated with tactile warning strips. The new concourse was on-axis with the headhouse main entrance from Dewey Square. Its geometry was developed from the symmetry of the headhouse so that the original station's awkward joining of headhouse and concourse was corrected. The glass wall between the concourse and the trackheads was angled, creating an exciting three-quarter view of trains in the train room.

South Station's historic landmark headhouse formed the anchor of the new South Station Transportation Center. The headhouse was designed to be the focal point of patron access to this multimodal facility. The MBTA's goal was to achieve the transformation of the headhouse into a high-quality, well maintained, mixed-use facility. The six-level headhouse was rehabilitated and expanded by the construction of a new west wing. The basement, first mezzanine and second floors were designated for transportation and public uses (approximately 68,800 square feet) and ancillary retail/concession services (approximately 40,430 square feet). The third through fifth floors were developed as Class A office space (approximately 73,360 square feet).

The existing elevator core had been reconstructed to make the upper level commercial space more attractive and rentable as office space. To complete the original symmetry of the headhouse facade, the new west wing containing retail and commercial office space was built and the east wing was extended to accommodate a new fire stair. Both of these wings were constructed using details composed primarily of precast units that mimic the historic facades in the neoclassical style of the original architecture.

Rapid Transit. Another important element serving the rail concourse level was a pair of escalators and stairs to the MBTA's Red Line subway station, providing direct access to and from the rapid transit system. Under separate contracts, the Red Line station was modernized and platforms were lengthened to accommodate six-car trains to significantly increase the capacity of the station.

Bus. Phase II of the South Station project involved the construction of a new consolidated bus terminal and parking on air rights above the railroad tracks and platforms. The work consisted of the construction of two structural decks (including railroad ventilation, bus terminal operations facilities and parking), construction of roadway ramps from the local street network for access to the bus terminal and parking (with provisions for direct connections to the highway network), construction of a service facility to serve the headhouse and railroad operations and construction of the Atlantic Avenue frontage. This new frontage construction extended from the end of the new west wing of the headhouse to Kneeland Street and included a bus terminal lobby entrance.

Prior to the completion of the project, bus operations in Boston were dispersed through-

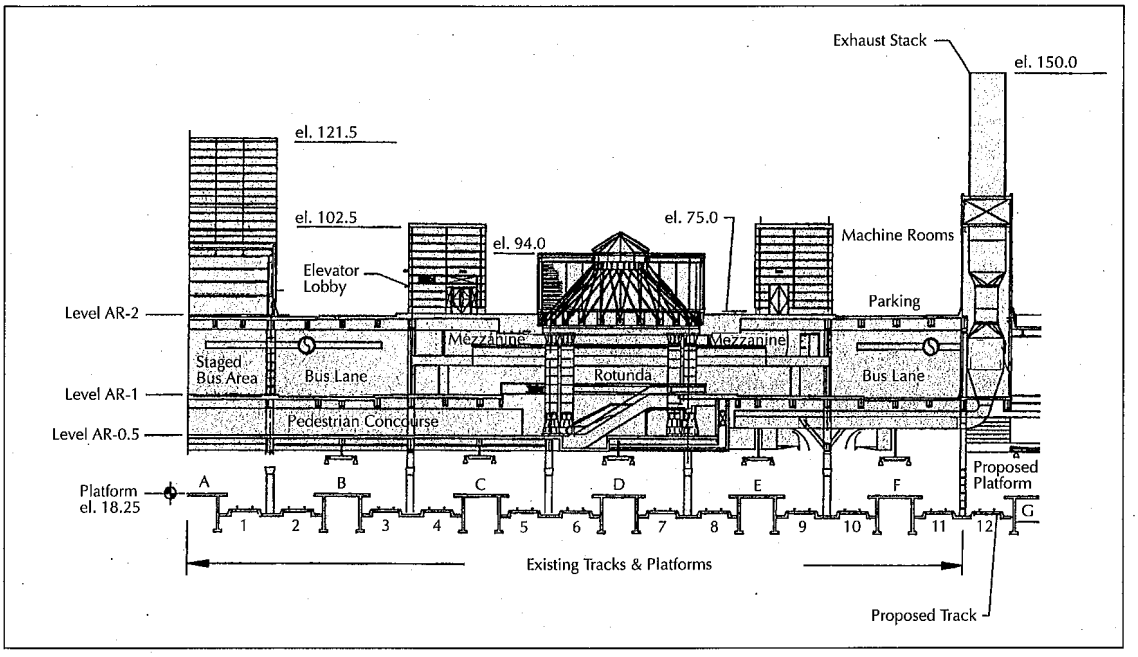

FIGURE 2. Section through the building concourse.

out the city. Privately owned bus companies provided commuter and intercity service to the suburbs of Boston and the towns and cities in the Northeast, with connections to the remainder of the United States and Canada. The old Greyhound and Peter Pan/Trailways terminals and a South Station commuter bus facility functioned as the Boston termini for most of the private carriers. A small number of private commuter bus companies operated from curbside locations scattered around downtown Boston.

The design of the bus terminal facility achieved the goals of:

- Creating an attractive and inviting image;
- Affording clarity and ease of movement for patrons;
- Providing a central location for many different bus operations servicing the city; and,
- Delivering adequate and discrete space for those bus operations.

An attractive and inviting image for the bus terminal was created at street level by a modest yet visible entry lobby. Special consideration was given to security by providing clear open spaces in and around the lobby and prominently positioning security operations for high visibility. A drop-off curb length was designed at the street in the vicinity of the lobby. A domed skylight covered the terminal's two-story rotunda, serving as the focal point for ticketing, baggage-handling and services for bus patrons. Throughout the terminal, sophisticated, durable interior finishes were utilized to provide a more easily maintained appearance. Clarity and ease of movement for bus patrons was achieved by zoning air rights Level AR-0.5 for pedestrian use (see Figure 2).

Adequate space for bus operations was provided by zoning air-rights Level AR-1 exclusively for bus circulation. Within the site constraints, bus docking spaces were maximized. Project construction Phase IIA provided 23 saw-tooth docking positions, four pull-through positions and two positions for the bus connection to Logan Airport (the Airport Link) to accommodate the ten private companies utilizing the new facility. Current estimates have approximately 12,000 patrons using the facility daily.

Parking. The parking level at air-rights Level AR-2, including parking spaces for 225

vehicles and a package express facility, was served by ramps to and from Kneeland Street. Additional ramp connections directly to the adjacent highway system, as well as the new Ted Williams Tunnel to Logan Airport, have been anticipated and will be constructed as part of the MHD's Central Artery/Tunnel (CA/T) Project. The parking level not only provides much-needed parking to serve the transportation center, but also serves as the "roof" covering the bus operations and it has been designed to support construction activities anticipated for the future development of air rights.

Project Cooperation

At the outset of the conceptual design process, the South Station project was perceived as a multiphased project. At each phase, the preferred design concept was defined by a set of broad, interrelated criteria. Later, and throughout the project's development, individual attention was focused on particular elements of the complex, including the headhouse with its new west wing, the bus terminal, access ramps and the local street network, and future air-rights development. With the design development of each of these elements, key design issues — including pedestrian circulation, architectural treatment, railroad ventilation, special systems, utility considerations and proposed utilities — were addressed.

By agreement of the parties, the FRA (under the NECIP Project) was responsible for the bidding and construction of the railroad elements, and the MBTA was responsible for the bidding and construction of the Red Line modernization and construction of the bus terminal complex. Although numerous technical and funding issues were encountered, the parties of interest had the common objective of moving forward with completion of construction of the entire transportation center since it was designed to meet the diversified needs of a wide range of users.

Project Coordination

Interagency Coordination. Coordination of the overlapping — and occasionally competing — requirements of the FRA, the MBTA and the BRA was the key to the ultimate successful completion of the transportation center. Beginning in the earliest stages of the project's development, each agency and its consultant team endeavored to advance coordinated designs for each respective agency's program. This effort, which required good-faith negotiations and compromise by the parties on a number of design and technical issues, led to the eventual designs meeting the needs of all of the parties.

Establishment of Overall Project Goals & Objectives. In order to realize the fullest potential of the combination of transportation elements at a single facility, the following design objectives were established jointly by the participating agencies:

- To provide facilities that meet the operational and support needs of the intercity, commuter and local transportation operators and users with the maximum efficiency.
- To provide an environment that meets contemporary standards for passenger safety, comfort and enjoyment.
- To provide an overall setting, massing and image that enhances the historic headhouse.
- To provide convenient interchange between the various transportation modes and metropolitan Boston.
- To provide transportation facilities that complement and encourage both state and city plans for commercial development at South Station and the surrounding area.
- To provide barrier-free access for the physically challenged.
- To provide a distinct identity for each transportation mode and operator.
- To provide maximum frontage along Atlantic Avenue for the competing automobile pick-up/drop-off needs of the rail and bus carriers, and potential air-rights development.
- To provide clear, efficient access between the local street and highway systems as well as between the bus and automobile parking levels.
- To provide a network of ramps for automobiles, buses and package express

trucks that allows for direct access from the air-rights levels to the highway system and that can be implemented in multiple phases.

The Design Process

Pedestrian Circulation. The preferred design concept recognized the entry from the MBTA subway as the most heavily used intermodal connection. The new passenger tunnel provided access from the Red Line station directly into the lowest level of the headhouse. Within the existing headhouse, escalators from the Red Line station delivered patrons on-axis to the edge of the "Great Space" concourse. The connection was clearly organized and sufficiently sized to accommodate pedestrian traffic with minimal disruption.

The pedestrian path from both the Red Line transit station and the street continued directly into the Great Space. The advantage of bus patrons participating in the life of the Great Space was obvious. However, there was concern about the capacity of the Great Space to accommodate peak period activities, as well as the effects of diverting pedestrian activity away from Atlantic Avenue. Early in the design development process, it became apparent that the concept of the transportation center would make very significant changes to the fundamental character and function of the Great Space concourse (the area of the transportation center complex that is the natural as well as physical focal point). The area changed essentially from a railroad station waiting area to the primary activity center of this major intermodal transportation center. The key project elements and issues that were considered during the development of the transportation center concept included:

- Train gates and railroad passenger access;
- Pedestrian circulation issues;
- Pedestrian movement safety issues;
- Inherent clarity of movement;
- Display of directional information;
- Pedestrian security;
- Movement of special needs persons;
- Activation of public spaces;
- Bench seating; and,
- Retail kiosks.

Clearance Requirements. The basic structural grid supporting air-rights construction was dictated by the railroad track/platform configuration established by the FRA in concert with the MBTA. The structural support for the first air-rights level had to be designed without full-height bracing or shear wall elements in order to maintain the required clearances for railroad operations. Furthermore, for adequate train room ventilation a maximum clearance had to be maintained between the top of trains and the first air-rights level.

The structural system that was developed for the required lateral stability of the structure is a two-way, fully welded, moment-resisting frame. The use of a composite structural deck system utilizing a longitudinally post-tensioned cast-in-place deck on precast, prestressed planks responded to the concerns for differential deflection, while also addressing constructability issues (including time of erection, shielding of terminal operations and performance as an intermediate working platform).

Railroad Operations. Because the bus terminal complex was to be constructed on air rights above the diesel locomotive operations, early studies were undertaken to develop a design strategy that would address the problem of train ventilation in the simplest and most cost-effective manner without major compromises to either bus or train operations. Obviously, ventilation requirements were directly related to the operating modes of MBTA commuter rail and Amtrak service, schedules and equipment. In response, the design solutions developed to address the concerns for both initial and operating costs for ventilation combined adjustments to the railroad operations along with modifications to the size and shape of the building complex.

Current rail traffic into South Station consists of a combination of MBTA and Amtrak revenue trains as well as a number of non-revenue train movements for maintenance and storage purposes. The MBTA, recognizing the problems associated with collecting diesel emissions along the entire length of eleven or more tracks, determined that normal MBTA operation might be best arranged with locomotives on the outbound, or southerly end, of each

train. This approach was made with the realization that this situation could change if the MBTA's South Side locomotive fleet were equipped with electric traction power capability. The other basic approaches were that the MBTA air-rights development would only be constructed over the length that a nine-car train occupied (leaving the locomotive uncovered), and that trains shorter than nine cars would be stopped so that locomotives were not under the air-rights development. An additional stipulation in the development of railroad ventilation alternative strategies was that Amtrak would operate only on station tracks 8, 9 and 10. This decision was used to further refine ventilation alternatives.

Design Innovations. The South Station project produced many engineering achievements as the result of the project's design requirements:

- Specifications for curved trapezoidal box girders now can be more effectively interpreted better for radii significantly less than 300 feet;
- The structural framing system provides engineers with a constructed example of how air-rights construction can be effectively accomplished within constrained dimensions over railroads and expressway facilities; and,
- Air-rights development over diesel-locomotive operations utilizing a practical ventilation system provides new opportunities for intermodal transportation, the expansion of rail transportation and public/private air-rights development.

Accommodations for vehicular access to the project air-rights bus terminal complex was severely constrained by the site and its surroundings. Design constraints included the inability to control the location and configuration of the ramp's substructure support system due to the proximity of MHD's CA/T Project, vertical clearance requirements and geometry mandating a minimum radius of 120 feet. Steel trapezoidal box girders were utilized as the primary structural element for the viaduct roadways. AASHTO specifications and normal practice had previously only addressed steel trapezoidal box girders with radii of 300 feet or greater. The engineers' innovation and judgment reconciled the intent of AASHTO with MHD's CA/T Project design criteria and the specific requirements of the South Station project.

A unique framed-in capbeam and merging box girder system was designed in response to the restricted substructure envelope allocated to the ramp structure. It consisted of two vertical webs having separate top and bottom flange connection plates with a bolted full-width flange plate to create a box shape. The steel fabricators built scale models to assess their ability to fabricate and assemble this "one-of-a-kind" structure. The transportation of the box girders required careful consideration because the severe curvature limited the length of each box girder segment that could be practically transported. The design, fabrication and construction of these unique steel trapezoidal box girders and the framed-in capbeam had never been done on a site with such significant constraints. Their design extended the limits of existing technology.

The ability of the structure to achieve the required lateral stability was severely limited by the existing railroad tracks and structural grid. The structural support for the first air-rights level had to be designed without full-height bracing or shear wall elements. Furthermore, for proper train room ventilation, a maximum height between the ground level and the first air-rights level had to be maintained. The new structural system was original and innovative. The lateral resisting system was developed as a two-way, fully welded, moment-resisting frame. The use of a composite structural deck system, utilizing a longitudinally post- tensioned, cast-in-place deck on precast prestressed deck planks responded to concerns of differential deflection, while addressing constructability issues (including time of erection, shielding of terminal operations and performance as an immediate working platform). The concrete for the precast deck planks was designed to resist the corrosive diesel exhaust from below and chlorides from above.

Bus traffic, truck traffic and accommodations for future air-rights construction loadings were unusual factors that had to be taken into

account in designing the structural system for the building. The South Station building structure was truly unique because AASHTO specifications had to be interpreted for application on the air-rights levels in conjunction with applicable AISC specifications. This combination expanded the application of these existing technologies.

While train stations with air rights and low ceilings have been built in Canada and the United States, none of these facilities have been completely successful in venting diesel locomotive exhaust. Engineers had to develop a method of capturing a 70-foot-per-second diesel engine exhaust jet within a relatively low ventilation slot velocity while minimizing pressure losses and fan power requirements and fitting the total ventilation system within an 11.67-foot-high space directly over the railroad clearance envelope. The concept of the new ventilation duct system utilized the kinetic energy of the engine exhaust jet in combination with the suction of the ventilation fans to capture essentially 100 percent of the diesel exhaust fumes. The new ventilation duct system included a 34-inch wide slotted duct above and along the tracks, and a curved and contracting passage leading through a nozzle and orifice into a manifold, and exhausted through fan ducts.

Using the train room's basic dimensions, configuration and established pollutant concentration criteria, a mathematical model was developed utilizing finite element techniques. The computer model evaluated various design and railroad operation alternatives ranging from standard solutions to innovative "uniform slot ventilation systems." These systems exhibited the greatest promise and exhibited additional benefits as the hood was curved and made deeper. A physical model of the proposed ventilation system was constructed to validate the mathematical modeling findings.

Conclusions

The South Station Transportation Center Project utilized the initiative of NECIP as well as initiatives of the FTA to secure sizable additional federal, state and local funds to bring to fruition a unique multimodal transportation center. Successful completion and inauguration of this facility has made a substantial contribution to solving some of the critical issues that face any large urban area today:

- Preservation of historic resources and the urban fabric;
- Reduction of energy consumption and air pollution;
- Improvement of basic transportation systems; and,
- Continued revitalization of the urban core.

Because the South Station project makes available simple direct connections between the various modes of public transportation, it will foster greater, more efficient use of these systems by the traveling public.

LAURENCE W. SHUMWAY, *P.E., is a Senior Project Manager with HNTB Corporation at its Tampa, Florida, office. He is responsible for the design and review of transit projects, as well as for operations and maintenance services related to the financing, operation and maintenance of toll highway facilities. A graduate of the University of Maine, he has over 30 years of experience in the design of major transportation and transit projects, including the Southwest Corridor and South Station Transportation Center projects in Boston, and the Miami Intermodal Center.*