3.0 Ridership Analysis

Overview

The most important element in any transportation plan is to understand who will potentially use the transportation service being considered. The objective of the passenger ridership analysis is to develop reliable forecasts of the market for intercity HSR travel in the BMHSR Corridor.

The ridership market will consist of both trips diverted from a different mode to the BMHSR service, and induced trips that would be made only if the proposed BMHSR rail service is available. The total trips for both diverted and induced riders will be a major indicator of the overall demand for the potential BMHSR service. The development of the ridership forecasts requires three major steps:

- Train Operation Planning and Modeling for development of conceptual HSR travel times
- Market Analysis of the BMHSR Corridor
- Model Analysis and Ridership Estimates

As detailed in the following sections, each one of these steps has been completed for the BMHSR Corridor. The specific ridership forecasts are identified in this chapter and details of the respective operating scenarios analyzed are given in Appendix A.

■ 3.1 Train Operations Planning and Modeling

Train Operation Model

To define specific travel times required to support the ridership forecasts, a rail network computer model of the study area for the BMHSR Corridor between North Station in Boston and Central Station in Montreal was developed to simulate anticipated train operations. The train performance calculator (TPC) simulation system is the Berkeley Simulation Software (BSS) Rail Traffic Controller (RTC) model. This modeling instrument accurately represents the characteristics of the rail infrastructure and realistically simulated train movements. The TPC simulates train operating characteristics, including movements through curves, up and down grades, and braking/acceleration. It will be utilized to identify dispatching conflicts in any subsequent study phases. The simulation presents accurate comparisons of rail network performance associated with trip time analysis, capacity, and train delays at specified levels of service for proposed improvements to the infrastructure and train operations. The working model of the BMHSR Corridor was designed as a flexible tool that is easily modified and upgraded. It provides significant utility in evaluating the operational and infrastructure improvements needed to achieve the operational and service objectives as defined by the stakeholders and the states of Massachusetts, New Hampshire and Vermont and Quebec Province.

Modeling Criteria

Trainset Technology Assumptions

For model simulation, F-59 PH locomotives and Bombardier Bi-Level coaches were selected for the analysis because they are widely used in passenger corridors throughout United States. For example, this trainset is used in the state of California on the Capitol Corridor, which is the fastest growing passenger corridor in the country, and on the Pacific Surfliner Corridor, which has the highest level of service and ridership outside of the Northeast Corridor.

The F-59 PH locomotive and Bombardier Bi-Level coaches were used to build two train consists for the simulation model. The first consist type was composed of one F-59 PH locomotive and six bi-level coaches. The second consist type was composed of two F-59 PH locomotives and six bi-level coaches. In both cases, a passenger load factor of .70 was assumed to account for the additional weight, equating to seventy percent of a seated load (ninety-eight passengers at one hundred fifty pounds each).

A third consist type representing the performance characteristics of the Talgo train was applied to the simulation model to examine the potential impact of passive tilt technology on speed and trip time over the BMHSR Corridor.

Infrastructure Assumptions

The network simulation model for the BMHSR Corridor was constructed using available track charts and timetable special instructions to replicate the physical characteristics of the infrastructure, including track distances, speeds, geometry, grades and curvature.

Three different infrastructure "case" characteristics were defined to test in the simulation model, as summarized below:

- Low Speed Case: Present alignment was utilized including existing track conditions, existing track geometry and existing timetable running speeds for passenger service on time respective lines. For the abandoned BMHSR Corridor segment between Concord, New Hampshire and White River Junction, Vermont, the last available published timetable was utilized. Maximum train speed is 60 mph. This would be similar to the existing Amtrak intercity service on the Vermont segment of the BMHSR Corridor.

- Mid Speed Case: FRA Class 6 was utilized with improved curve speeds. Present alignment was utilized with a 110 mph maximum speed with curve speeds restricted by track geometry. Non-geometric timetable speed restrictions were maintained. Existing grades were maintained

- High Speed Case: FRA Class 6 was utilized with no speed restrictions. A 110 mph maximum speed was utilized with no speed restrictions through curves. Existing grades were maintained.

The FRA regulations have established classes of track based on maximum operating speed as shown in Table 3.1 (reproduces Table 2.22). The FRA track safety standards are primarily related to track geometry and infrastructure conditions, but these standards do contain specific requirements for higher speed operation. For operation at Class 5 or higher speeds (above 80 mph), trains must be equipped with positive train stop and/or cab signal systems. A positive train stop system will automatically slow or stop a train if an engineer fails to respond to a signal indication. A cab signal system duplicates signal indications on a display within the locomotive cab.

Table 3.1 – FRA Track Classifications Maximum Operating Speeds

Class	Freight	Passenger
1	10 mph	15 mph
2	25 mph	30 mph
3	40 mph	60 mph
4	60 mph	80 mph
5	80 mph	90 mph
6	110 mph	110 mph
7	125 mph	125 mph

These three cases were developed in order to examine a range of trip times in the simulation model and provide a comparison of running times, depending on the specific track configuration assumptions.

The “Low Speed Case” model assumed a service similar to that of a typical Amtrak intercity train operating over existing railroad (i.e. freight) infrastructure. Running speeds were limited to those presented in the current timetables and track charts for the respective subdivisions. This scenario includes a maximum speed of 60 mph (for passenger trains) over the majority of the BMHSR corridor, with limited areas of 70 mph on the MBTA segment between Lowell and Boston, and 80 mph on a two mile segment of CN track in the area of Montreal. It is important to note that the current timetable track speeds include a multitude of restrictions. These slower speed limits are associated with specific track geometry or curve alignment, or a “local” condition such as a grade crossing speed restriction. The TPC model was constructed with the existing published speed restrictions for each segment of track. As noted below, the results of the “Case 1- Base Case” model yields the “low range” and longest trip time estimates for both express and local service between Boston and Montreal.

The "Mid Speed Case " model assumptions were developed to examine the effects of significant speed increases on trip time. The maximum running speed for this case was 110 mph, based upon applying an FRA Class 6 standard for track. Speed restrictions for reasons other than track geometry were not applied to this case. Existing horizontal alignment characteristics (degree of curvature) were retained, although speed increases through curves were achieved with increases in unbalance. An unbalance of three inches was applied to the simulation with the two conventional trainsets. The first consist was one F59-PH locomotive and six Bombardier bi-level coaches and the second consist was two F59PH locomotives and six Bombardier bi-level coaches. An unbalance of five inches and six inches, respectively, were applied to the two simulations with the Talgo train.

A specification of a maximum of six inches unbalance is currently in effect where the Talgo train is operated in revenue service for Amtrak in the Pacific Northwest. In addition, six inches of unbalance is also in effect for the operation of the Amtrak Acela train on the Northeast Corridor. The FRA has approved use of higher unbalanced conditions. Detailed operational analysis planned for subsequent Study phases will evaluate use of higher unbalanced limits.

An upper limit of 110 mph was identified to correlate with the likely maximum operating speed over the majority of the BMHSR Corridor. It is important to note that for train speeds from 111 mph to 125 mph highway grade crossings must be either grade separated or have a sophisticated FRA-approved warning/barrier; and for speeds above 125 mph, no at-grade highway crossings, public or private are permitted. Given the large quantity and locations of the grade crossings along the BMHSR Corridor, grade crossing eliminations would be challenging to implement. However, during future operational analysis, locations will be identified and analyzed to determine where segments of track could be operated at 125 mph, even though it is assumed that the overall distance subject to a potential speed of 125 mph is relatively small. Furthermore, any trip time reductions associated with 125 mph operation would likely be offset by retention of some geometry based speed restrictions in place today. Therefore, the upper limit of 110 mph for F-59 PH locomotive trainsets represents a reasonable approximation of the most favorable travel times that could be obtained on the BMHSR Corridor.

The "High Speed Case" model assumptions were developed to examine trip times associated with a train operation at a maximum speed of 110 mph but unimpeded by any horizontal geometric (curve) or other speed restrictions. The only impacts on running speed in this case are associated with station stops and vertical grades. The vertical profile specified in "Low Speed Case" and "Mid Speed Case" was maintained. "Case 3" represents the minimum optimal run time that could be achieved if all constraints associated with horizontal geometric and local speed restrictions were eliminated, approximating conditions similar to those that would be realized with the construction of a new, dedicated HSR rail alignment designed for the operation of passenger trains only. This approach would require significant capital investment and would likely have substantial environmental impacts. It is likely that the assumptions applied to this case would be extremely challenging to realize.

Service Plan Assumptions

The TPC was configured with certain operating assumptions. The assumptions included consideration of train operating parameters and other conditions noted below.

It is anticipated that by the time a BMHSR service is implemented, US/Canadian border regulations will be developed to allow operation with no stops for Customs or Immigration inspections. Chapter 4 of this report discusses the border security issues.

The TPC simulation assumes that sufficient passing tracks will be constructed to allow trains to pass in areas of single track. Since the TPC simulation did not include evaluation of HSR trains with freight and other passenger trains, the TPC simulation for each case alternative yields a "pure", unimpeded running time and establishes optimal trip times for the operation of a single train.

Initially, a conceptual service plan was defined specifying two stopping pattern configurations to test in the simulation; one for "express" service and one for "local" service. North Station in Boston and Central Station in Montreal were the end terminals in both service configurations. As shown Table 3.2, the station stops for the "express" configuration include three intermediate stations: Woburn Anderson, Massachusetts; Manchester, New Hampshire; White River Junction, Vermont; and Essex Junction/Burlington, Vermont. The station stops for the "local" configuration included all of the aforementioned "express" station stops plus seven additional intermediate stations: Lowell, Massachusetts; Nashua, New Hampshire; Concord, New Hampshire; Franklin, New Hampshire; Montpelier, Vermont; St. Albans, Vermont; and Saint-Jean-sur-Richelieu, Quebec. A schedule dwell time of two minutes was applied to each intermediate station stop in the simulation model.

Table 3.2 – Potential Station Stops

Local Station Stops	Express Station Stops
Boston – North Station, MA	Boston – North Station, MA
Woburn – Anderson, MA	
Lowell, MA	
Nashua, NH	
Concord, NH	
Franklin, NH	
White River Junction, VT	White River Junction, VT
Montpelier, VT	
Essex Junction/Burlington, VT	Essex Junction/Burlington, VT
Saint Albans, VT	
Saint-Jean-sur-Richelieu, QC	
Montreal – Central Station, QC	Montreal – Central Station, QC

Train simulations were performed using the RTC model developed for the BMHSR study area, applying the conceptual service plans, trainset characteristics and infrastructure assumptions. Table 3.3 shows the TPC simulated terminal-to-terminal run times.

Table 3.3 – Initial Conceptual Service Plan

	Express Run Times	Local Run Times
Low Speed Case		
1-F59PH	7 hrs 42 min	7 hrs 59 min
2-F59PH	7 hrs 40 min	7 hrs 56 min
Mid Speed Case		
1-F59PH	5 hrs 28 min	5 hrs 46 min
2-F59PH	5 hrs 13 min	5 hrs 29 min
Talgo (5 " unbalance)	4 hrs 37 min	4 hrs 55 min
Talgo (6" unbalance)	4 hrs 24 min	4 hrs 43 min
High Speed Case		
1-F59PH	4 hrs 07 min	4 hrs 42 min
2-F59PH	3 hrs 36 min	4 hrs 06 min

Operations Plans for Ridership Forecasts

To define specific travel times needed to support ridership forecasts, three specific service scenarios were identified. These scenarios were used in the TPC to determine the trip times associated with each scenario. As noted above, the Conceptual Service Plan simulation trip times are unimpeded by restrictions imposed by operations with existing passenger and freight service. The model was run using the single F-59 PH locomotive trainset, the slowest trainset that was studied. This was done because this resulted in run times that more closely approximate service that could reasonably be expected using faster tilting trains operated with existing freight and passenger service and with speed restrictions that are anticipated to remain within the BMHSR Corridor. As with the Conceptual Service Plan, the operations plans used for the ridership forecasts assume no stops required at the U.S./Canada border for customs or immigration inspections.

Low Speed Scenario

This Low Speed Scenario was defined as a basic local-type service operating on existing track conditions. The scenario utilized the "Low Speed Case" modeling criteria for infrastructure and speeds. The scenario represented the slowest speed and included all the cities defined as potential station locations. The results of this TPC simulation are displayed in Table 3.4.

Table 3.4 – TPC Simulation – Low Speed Scenario

Station	Arr/Dep	Schedule	Running Time
Boston – North Station, MA	Dep	0:00	
Anderson-Woburn, MA	Arr	0:19	0:19
	Dep	0:21	
Lowell, MA	Arr	0:35	0:14
	Dep	0:37	
Nashua, NH	Arr	0:52	0:15
	Dep	0:54	
Manchester, NH	Arr	1:11	0:17
	Dep	1:13	
Concord, NH	Arr	1:33	0:20
	Dep	1:35	
Franklin, NH	Arr	1:53	0:18
	Dep	1:55	
White River Junction, VT	Arr	2:51	0:56
	Dep	2:53	
Montpelier, VT	Arr	4:04	1:11
	Dep	4:06	
Essex Junction/Burlington, VT	Arr	4:41	0:35
	Dep	4:43	
Saint-Jean-sur-Richelieu, QC	Arr	7:03	2:20
	Dep	7:05	
Montreal – Central Station, QC	Arr	7:55	0:50

Mid Speed Scenario

The mid speed scenario was defined to represent a reasonable approximation of likely BMHSR Corridor travel times. This scenario utilized the "Mid Speed Case" modeling criteria for infrastructure and speeds. Specific station stops were identified based upon a limited stopping pattern service. The results of this TPC simulation are displayed in the following Table 3.5.

Table 3.5 – TPC Simulation – Middle Speed Scenario

Station	Arr/Dep	Schedule	Running Time
Boston – North Station, MA	Dep	0:00	
Lowell, MA	Arr	0:26	0:26
	Dep	0:28	
Manchester, NH	Arr	0:53	0:25
	Dep	0:55	
Concord, NH	Arr	1:10	0:15
	Dep	1:12	
White River Junction, VT	Arr	2:07	0:55
	Dep	2:09	
Montpelier, VT	Arr	3:05	0:56
	Dep	3:07	
Essex Junction/Burlington, VT	Arr	3:33	0:26
	Dep	3:35	
Montreal – Central Station, QC	Arr	4:48	1:13*

High Speed Scenario

The high speed scenario was defined to determine the minimum trip time for express-type service levels with stops to stations in the largest cities. This scenario utilized the "High Speed Case" modeling criteria. The high speed scenario is not expected to be realistically obtainable due to restrictions associated with utilizing an existing rail corridor. The results of this TPC simulation are displayed in Table 3.6.

Table 3.6 – TPC Simulation – High Speed Scenario

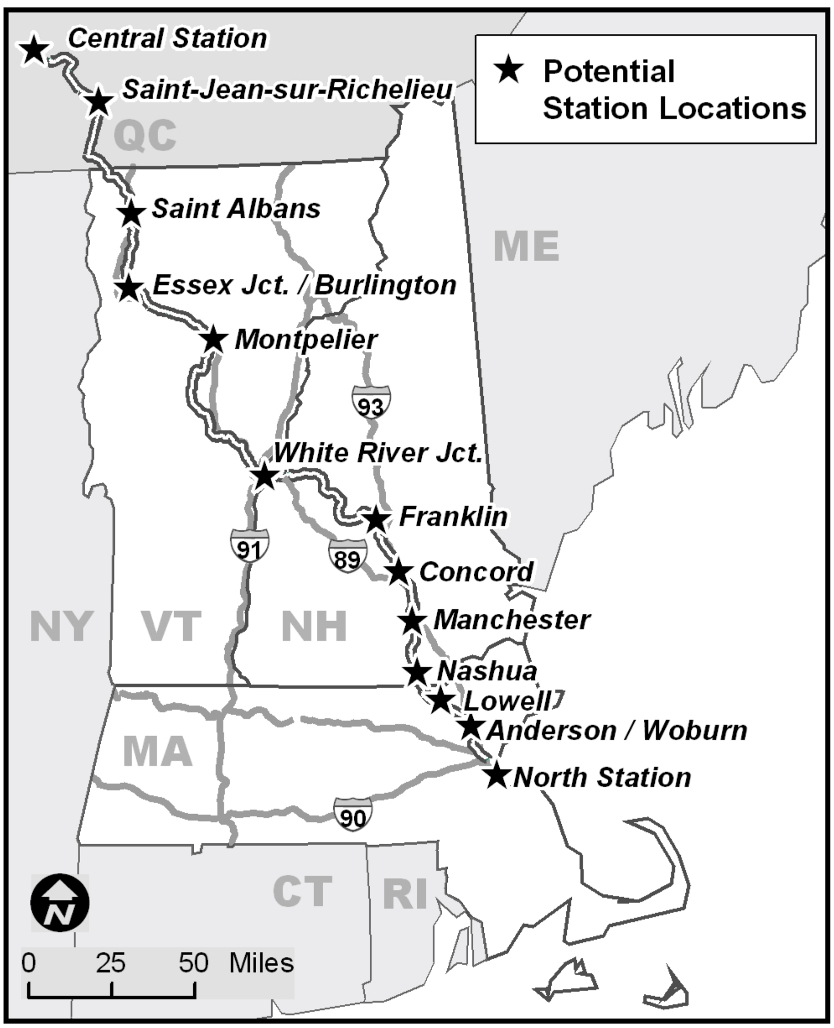
Station	Arr/Dep	Schedule	Running Time
Boston – North Station, MA	Dep	0:00	
Lowell, MA	Arr	0:21	0:21
	Dep	0:23	
Manchester, NH	Arr	0:42	0:19
	Dep	0:44	
Concord, NH	Arr	0:56	0:12
	Dep	0:58	
Essex Junction/Burlington, VT	Arr	2:32	1:34
	Dep	2:34	
Montreal – Central Station, QC	Arr	3:31	0:57

3.2 Market Analysis

BMHSR Corridor Overview

The BMHSR Corridor is 329 miles in length, roughly equal to the Northeast Corridor between Boston and Philadelphia. The study area links key population centers of northern New England and connects the major economic centers of Boston and Montreal. Figure 3.1 provides a summary of the alignment and details potential station locations.

Figure 3.1 – Potential Station Locations



The affected study area includes counties in eastern Massachusetts, southern New Hampshire, northern Vermont, as well as Administrative Regions in Southern Quebec. Specifically, the study area includes the following counties and administrative regions.

- Massachusetts Counties
  - Suffolk, MA
  - Plymouth, MA
  - Bristol, MA
  - Essex, MA
  - Norfolk, MA
  - Middlesex, MA

- New Hampshire Counties
  - Hillsborough, NH
  - Rockingham, NH
  - Strafford, NH
  - Belknap, NH
  - Merrimack, NH
  - Cheshire, NH
  - Sullivan, NH
  - Grafton, NH

- Vermont Counties
  - Grand Isle, VT
  - Franklin, VT
  - Chittenden, VT
  - Addison, VT
  - Orleans, VT
  - Lamoille, VT
  - Essex, VT
  - Caledonia, VT
  - Washington, VT
  - Orange, VT,
  - Windsor, VT

- Quebec Administrative Regions
  - Laval, QC
  - Laurentides, QC
  - Lanaudiere, QC
  - Monteregie, QC
  - Montreal, QC

BMHSR Corridor Demographics

Population and Employment

The BMHSR Corridor traverses Massachusetts, New Hampshire, Vermont, and the southern part of Quebec. Combined, these states and the Montreal metropolitan area have a population of approximately 11.6 million people. In the U.S. portion of the BMHSR Corridor, the population is concentrated in the southern end of the BMHSR Corridor, close to the Boston area, declining in density as the distance from Boston increases until the Chittenden County (Burlington) population center. Similarly, population in the Quebec province is concentrated in Montreal and decreases in density as the distance from the city increases. Table 3.7 provides a listing of population and employment figures based on recent U.S. Census and Statistics Canada data.

Table 3.7 – Population and Employment

	Population	Employment
United States	275,206,000	166,657,000
Canada	30,007,094	14,909,700
Massachusetts	6,349,097	4,099,000
New Hampshire	1,235,786	774,000
Vermont	608,827	405,000
Province of Quebec	7,237,479	3,474,500
Boston Metropolitan area (PMSA)	3,297,201	1,481,839
Montreal Metropolitan Area	3,426,350	1,609,820
Rockingham County, NH	282,041	173,744
Hillsborough County, NH	385,368	244,646
Strafford/Belknap County, NH	170,592	94,762
Merrimack/Grafton County, NH	220,925	157,011
Sullivan/Cheshire County, NH	114,915	64,352
Windsor County, VT	57,910	34,176
Orange/Washington County, VT	86,837	57,025
Chittenden County, VT	148,574	118,936
Franklin/Grand Isle County, VT	52,958	23,507
Addison County, VT	36,387	20,968
Caledonia/Essex County, VT	36,336	19,681
Orleans/Lamoille County, VT	50,119	30,360

Source: U.S. data sources: 2000 U.S. Census population data, 1997 Economic Census. Canadian data sources: 2001 Canadian Census population data, 1996 Economic Census.

Over the past decade, the population of U.S. states within the BMHSR Corridor has grown by 5.5 percent. While this is below the U.S. national growth of 13.1 percent for the decade, specific communities along the BMHSR Corridor are growing at a much faster rate. In particular, communities in southern New Hampshire are experiencing high growth rates, in part due to increasing housing costs in the Boston Metropolitan area.

While Boston shows a declining population of between 0.0 percent and -3.0 percent, counties north of Boston in New Hampshire and Vermont show significant growth rates.

Of the eight counties in New Hampshire and Vermont that are traversed by the rail line, all but one are expected to grow in population by more than 12 percent for the period of 2000 to 2025.

Employment is another key demographic factor that is necessary to analyze as part of the market assessment for the BMHSR Corridor. As the number of jobs in the BMHSR Corridor increases, so does the need for transportation services. Employment in the U.S. portion of the BMHSR Corridor is currently highest in the Boston area, decreasing as it moves farther outside the metropolitan area. A secondary 'hub,' albeit at a substantially reduced level exists in Burlington, Vermont providing another important node in the U.S. portion of the BMHSR Corridor.

Employment in the U.S. portion of the BMHSR Corridor is concentrated in metropolitan areas. Dominant of these cities is Boston, which accounts for an estimated 565,000 jobs in the BMHSR Corridor, based on Massachusetts Division of Employment and Training estimates. The Boston area is expected to add about 75,000 new jobs by 2008. Employment in the Canadian portion of the BMHSR Corridor is concentrated in the Montreal area, with dramatically lower employment totals in the outlying areas. Employment in Montreal has been projected to expand between 1996 and 2021 by 26 percent, resulting in approximately 400,000 new jobs.[1]

BMHSR Corridor Travel Options

Travel options within the BMHSR Corridor consist of three modes: private automobiles, motor coach (bus), and airplane. Each of these modes offers trade-offs in the level of convenience, flexibility, or price. The following section provides an overview of existing service characteristics of each mode.

Automobile Travel

The driving distance between Boston and Montreal is approximately 308 miles, 21 miles less than the 329 BMHSR route miles. The portion of the route between Boston and the Canadian border, about 250 miles, is all on interstate highways with speed limits of between 55 and 65 mph. The Quebec portion of the BMHSR Corridor has slightly lower speed limits of between 80 km/h (50 mph) and 90 km/h (55 mph) until reaching Highway 35 near Saint-Jean-sur-Richelieu, where the speed limit increases to 100 km/h (62.5 mph).[2] With an average travel speed of 60 mph, the trip from Boston to Montreal would take about five hours, however, there will necessarily be stops for people driving the length of the BMHSR Corridor, most notably at the U.S./Canadian border where delays,

[1] Martin Fernand (May 2002), *Crossing Scenario for the South River*. Report summarizing the Reduction of mobility between Montreal and Rive-Sud.

[2] Note: Highway 35 is anticipated to be upgraded to a four-lane divided highway from the U.S. border to St. Jean-sur-Richelieu by 2007.

particularly post-9/11, can significantly increase overall travel times. In addition, traffic congestion on either end of the BMHSR Corridor can also contribute to overall delays in the BMHSR Corridor. One portion of I-93 in New Hampshire has a nominal toll.

Daily traffic volumes on the segments of the roadways in the BMHSR Corridor that comprise the most direct route between Boston and Montreal are provided in Table 3.8. The traffic volumes in the southern half of the BMHSR Corridor are the highest, decreasing as the checkpoints move farther away from Boston. Volumes then increase or decrease relative to the population of surrounding towns. Traffic volumes increase significantly as one approaches Montreal. The significance of this table is that it provides an estimate of the existing travel pool from which the BMHSR service will draw its passengers.

Table 3.8 – Daily Traffic Volumes at Locations between Boston and Montreal

Roadway Segment	Year 2000 Daily Volume[1]
I-93 Boston to Concord (approx. 70 miles)	
Medford/Stoneham town line	185,000
Andover, north of Route 125	135,000
Massachusetts/New Hampshire line	112,000
Manchester at Merrimack River	49,000
Concord (North of NH 132)	36,000
I-89 Concord to Canadian border (approx. 200 miles)	
New Hampshire/Vermont line	38,000
Montpelier (between Exit 8 and Exit 9)	25,000
South Burlington (between Exit 13 and Exit 14)	38,000
South Burlington (between Exit 14 and Exit 15)	50,000
St. Albans (between Exit 20 and Exit 21)	10,000
Highgate Border Crossing	4,000
Canadian Border to Montreal (approx. 50 miles)	
Route 133	
North of Highgate border	5,000
At Sabrevois	9,000
Highway 35	
At Saint-Jean-sur-Richelieu	31,000
35/10 at Chambly	28,000
Highway 10/30	
At Longueuil	60,000
Champlain Bridge	115,000

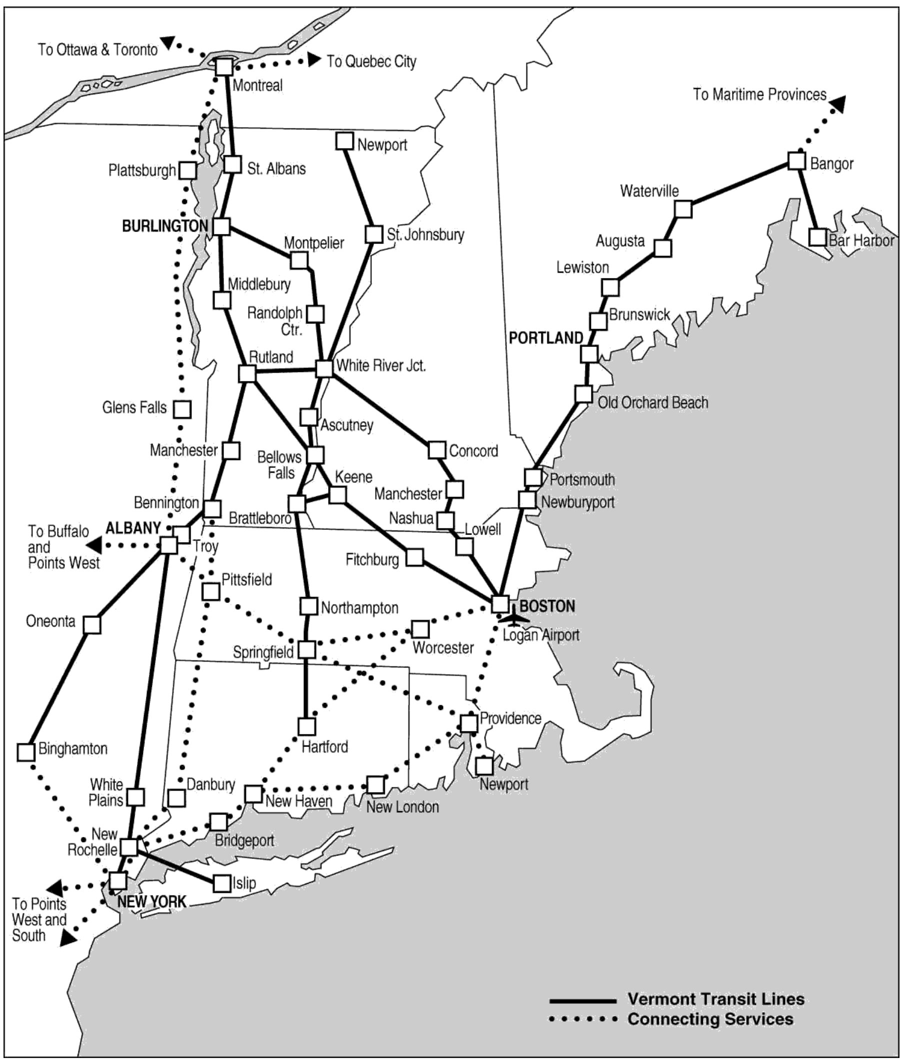
[1] Sources: www.nhdot.com, www.state.ma.us/mhd, www.aot.state.vt.us, MTQ.

Intercity Bus Services

Two intercity carriers, Greyhound/Vermont Transit and Concord Trailways, provide intercity bus service along the BMHSR Corridor.

Greyhound/Vermont Transit. Greyhound/Vermont Transit provides bus service in Vermont, New Hampshire, Maine, Massachusetts, and New York (Figure 3.2). Within the BMHSR Corridor, intercity routes operate between Boston and Montreal, with major stops in many of the cities proposed for stops on the BMHSR Corridor including: Concord, White River Junction, Montpelier, and Burlington (Essex Junction).

Figure 3.2 – Vermont Transit Intercity Bus Services



Vermont Transit currently runs four daily trips between Boston and Montreal, including one express trip in each direction that takes about six hours. The non-express buses stop in New Hampshire at Manchester, Manchester Airport, and Hanover and in Vermont at

White River Junction, Montpelier, and Burlington. With these stops, a typical one-way trip between Boston and Montreal takes between seven and eight hours. A few of these trips also serve Nashua, New Hampshire and Lowell, Massachusetts.

White River Junction is the primary transfer station where connections to Vermont Transit services south to Springfield, Hartford, and New York City are made. The travel time from White River Junction to New York City is about six hours. Table 3.9 shows current service levels for selected Vermont Transit services in the BMHSR Corridor.

Table 3.9 – Vermont Transit Intercity Bus Service in the BMHSR Corridor

Origin	Destination	Frequency (Daily Trips)	One-Way Travel Time	One-Way Fare (US$)
Boston	Montreal	4	6-8 hours	$58
Montreal	Boston	4	6-8 hours	$58
Boston	White River Junction	8	2.5-3.5 hours	$25
White River Junction	Boston	8	2.5-3.5 hours	$25
Burlington	White River Junction	3	2 hours	$16
White River Junction	Burlington	3	1.5-2 hours	$16
Burlington	Montreal	4	2.5 hours	$20
Montreal	Burlington	3	2.5 hours	$20
Boston	Nashua	6	1.0 hour	$9
Nashua	Boston	3	1.0 hour	$9
Boston	Lowell	4	45 minutes	$6
Lowell	Boston	3	45 minutes	$6

Source: Vermont Transit web site (www.vermonttransit.com), and Greyhound web site (www.greyhound.com), February 2002.

Concord Trailways. Another carrier is Concord Trailways, providing service in New Hampshire, Maine, and Massachusetts, primarily with routes for Boston-bound commuters from the southern New Hampshire cities of Concord, Manchester, and Londonderry. Concord Trailways also operates routes that serve Laconia, Berlin, and Littleton.

Concord Trailways operates frequent peak-period service from Concord and Manchester to downtown Boston and Logan Airport. The travel time between Concord and Boston South Station is about 90 minutes. Throughout the day, Concord Trailways operates about 20 inbound trips to Boston and 20 outbound trips to Concord/Manchester. Most of the inbound trips start in Concord and stop in Manchester before continuing into Boston. A few runs, however, start in Manchester, serving Boston directly.

Concord Trailways provides commuter bus service between Londonderry and downtown Boston with eight inbound morning trips to Boston and 10 outbound afternoon and evening trips to Londonderry. Table 3.10 summarizes the levels-of-service for selected Concord Trailways service in the BMHSR Corridor.

Table 3.10 – Concord Trailways Intercity Bus Service in the BMHSR Corridor

Origin	Destination	Frequency (Daily Trips)	One-Way Travel Time	One-Way Fare (US$)
Concord, NH	Boston	17	1.5 hours	$12.50
Boston	Concord, NH	19	1.5 hours	$12.50
Concord, NH	Manchester, NH	14	0.5 hour	$4.50
Manchester, NH	Concord, NH	17	0.5 hour	$4.50
Londonderry, NH	Boston	8	1.0 hour	$8.50
Boston	Londonderry	10	1.0 hour	$8.50

Source: Concord Trailways web site (www.concordtrailways.com), February 2002.

Airline Services

Airline travel within the BMHSR Corridor originates either at Boston's Logan International Airport, Burlington International Airport in Burlington, Vermont or Dorval International Airport in Montreal, Quebec. While Manchester Airport in New Hampshire is located within the BMHSR Corridor, there are no commercial flights to Montreal, Boston or Burlington from this location. This section summarizes airline travel activity between Boston and Montreal, Montreal and Boston, Boston and Burlington, and Burlington and Boston. No commercial airline service is available between Burlington and Montreal.

Several sources of data were used to evaluate existing airline services and their operating characteristics, including the Official Airline Guide web site, and quarterly aviation reports obtained from Back Aviation Solutions for the period of the first quarter of 1996 through the second quarter of 2001. Because some of the data were not accurately reported, this study focused on a 12-month period from July 1, 2000 through June 30, 2001 for which most data is reliable. This period also predates September 11, 2001, which had a devastating influence on airline travel including the discontinuation of American Airlines service between Boston and Montreal in September 2001.

The quarterly data includes seating capacity of all flights by airline and the estimated number of passengers by airline. Based on this information the load factor (percent of seats occupied) was calculated for each market. Missing data is indicated by "na."

Boston to Montreal Three carriers currently serve the passenger airline market between Boston and Montreal: Air Canada, Delta Airlines and United Airlines. United Airlines flights, however, are operated by Air Canada. As shown in Table 3.11, these carriers provide nine direct flight options on weekdays and seven or eight options on the weekend. Scheduled flight time is between 70 and 95 minutes, depending on the time of day.

Table 3.11 – Current Non-stop Direct Flights between Boston and Montreal

Carrier	Weekday		Saturday		Sunday	
	Boston to Montreal	Montreal to Boston	Boston to Montreal	Montreal to Boston	Boston to Montreal	Montreal to Boston
Air Canada/ United Airlines	4	4	2	2	3	3
Delta Airlines	5	5	5	5	5	4
Total	9	9	7	7	8	7

Source: Official Airline Guide Web site (www.oag.com) February 2002.

The cost of airline tickets varies widely depending upon travel options and ticket restrictions. A sample of ticket prices during February 2002 show that the lowest round-trip cost for coach class is about US$204, and for business class about US$550. Connecting flights are available through New York, Pittsburgh or Philadelphia, and can reduce the fare slightly, although travel time is increased to four to six hours.

Table 3.12 shows the seating capacity, estimated passengers, and the load factor, for flights from Boston to Montreal. The data for this period includes information on American Airlines, which at the time was operating service between Boston and Montreal.

The results indicate that both American Airlines and Delta Airlines maintain an average load factor of 17 percent to 24 percent on all flights. Air Canada load factors could not be calculated due to missing data in the OAG database. Similar results can be seen for the service from Montreal to Boston. Overall, utilization is light with only 14 percent to 28 percent of available seats occupied.

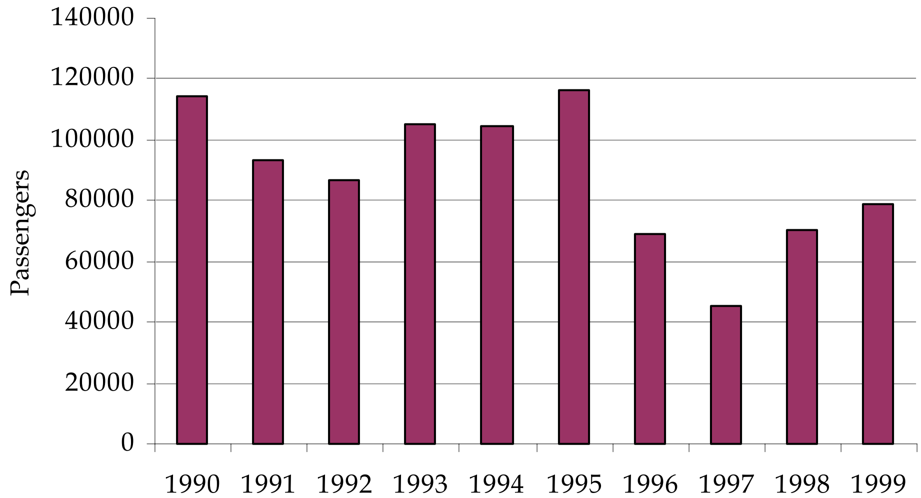
Table 3.12 – Airline Service Characteristics

		Year 2000 3rd quarter	Year 2000 4th quarter	Year 2001 1st quarter	Year 2001 2nd quarter
Boston to Montreal					
Air Canada	Seats	20,900	19,500	20,000	20,350
	Passengers	na	na	na	na
	Load Factor	na	na	na	na
American Airlines	Seats	2,618	10,846	8,738	11,662
	Passengers	630	2,200	1,600	2,650
	Load Factor	24%	20%	18%	23%
Delta Airlines	Seats	16,999	16,350	14,660	14,432
	Passengers	3,750	3,060	2,540	3,070
	Load Factor	22%	19%	17%	21%
Total	**Seats**	**40,517**	**46,696**	**43,398**	**46,444**
	Passengers	**na**	**na**	**na**	**na**
	Load Factor	**na**	**na**	**na**	**na**
Montreal to Boston					
Air Canada	Seats	20,900	19,500	20,000	20,350
	Passengers	na	na	na	na
	Load Factor	na	na	na	na
American Airlines	Seats	2,564	10,846	8,738	11,662
	Passengers	730	1,980	1,240	2,650
	Load Factor	28%	18%	14%	20%
Delta Airlines	Seats	16,999	16,350	14,660	14,432
	Passengers	3,690	3,000	2,540	3,070
	Load Factor	22%	19%	17%	21%
Total	**Seats**	**40,334**	**46,696**	**43,448**	**46,444**
	Passengers	**na**	**na**	**na**	**na**
	Load Factor	**na**	**na**	**na**	**na**

Source: Back Aviation Solutions, Official Airline Guide Database, January 2002.

Airline travel between Boston and Montreal has declined significantly between 1990 and 1999 (Figure 3.3). From 1990 through 1995, annual ridership remained in the 90,000 to 120,000 range. Airline travel between the cities dropped precipitously to a low of less than 50,000 passengers in 1997, due to a reduction in flights serving the Boston to Montreal market. Since that time, ridership has been picking up with annual passengers nearing 80,000 in 1999. Due to the volatility of annual airline ridership between Boston and Montreal in the period of 1990 through 1999, it is difficult to determine future trends in airline ridership. Given the events of 9/11 and the airport security aftermath, it is even more difficult to predict future ridership trends.

Figure 3.3 – Airline Passengers between Boston and Montreal



Boston to Burlington, Vermont Delta Airlines and U.S. Airways currently provide airline service between Boston and Burlington, Vermont. As shown in Table 3.13, these carriers provide eight direct flight options on weekdays and six or seven options on the weekend. Scheduled flight time is between 60 and 75 minutes, depending on the time of day.

Table 3.13 – Current Non-stop Direct Flights between Boston and Burlington

	Monday - Friday		**Saturday**		**Sunday**	
	Boston to Burlington	**Burlington to Boston**	**Boston to Burlington**	**Burlington to Boston**	**Boston to Burlington**	**Burlington to Boston**
Delta Airlines	4	4	4	4	4	4
U.S. Airways	4	4	3	3	2	2
Total	8	8	7	7	6	6

Source: Official Airline Guide Web site (www.oag.com) February 2002.

A sample of ticket prices during February 2002 show that the lowest roundtrip coach class ticket is about US$200. No business class travel is available on these non-stop flights. Connecting flights are available through Albany, White Plains, Newark, New York, or Washington D.C., increasing travel time to three to six hours. No fare savings are associated with the connecting flight options and the price can be substantially more. Business class tickets can be purchased for connecting flights for about US$1,000.

Table 3.14 shows the seating capacity, estimated passengers, and the load factor, for flights from Boston to Burlington. As with the Boston to Montreal data presented in the previous section, some of the data was not usable for this summary and is indicated by a "na." The valid results indicate that Delta Airlines and U.S. Airways exhibited load factors between 4.0 percent and 9.0 percent during the first six months of 2001.

Similar results can be seen in Table 3.14 for the service from Burlington to Boston, with 6.0 percent to 9.0 percent of available seats occupied.

Table 3.14 – Airline Service Characteristics

		Year 2000 3rd quarter	Year 2000 4th quarter	Year 2001 1st quarter	Year 2001 2nd quarter
Boston to Burlington					
Air Canada	Seats	29,138	21,318	17,986	21,828
	Passengers	na	na	1,550	1,770
	Load Factor	na	na	9%	8%
Continental	Seats	0	3,914	13,908	12,293
	Passengers	0	na	na	na
	Load Factor	-	-	na	na
Delta	Seats	0	0	9,440	14,368
	Passengers	0	0	530	880
	Load Factor	-	-	6%	6%
U.S. Airways	Seats	11,514	13,434	15,688	15,836
	Passengers	na	na	920	1,210
	Load Factor	na	na	6%	8%
Total	**Seats**	**40,652**	**38,666**	**57,022**	**15,836**
	Passengers	**na**	**na**	**na**	**na**
	Load Factor	**na**	**na**	**na**	**na**

Source: Compiled from data obtained from Back Aviation Solutions, Official Airline Guide Database, January 2002.

Airline Travel Summary

Table 3.15 summarizes the airline characteristics for service within the BMHSR Corridor, including number of flights, average load factor, travel times and cost. On average, the non-stop flights in the BMHSR Corridor operate at about 20 percent of capacity, and offer a maximum flight time of 90 minutes between Boston and Montreal. For travel between Boston and Burlington, the percent of seats occupied is very low at 7 percent, with a travel time of 75 minutes between Boston and Burlington, Vermont.

Coach seats can be purchased for about $200 or less for all connections. For travel between Boston and Montreal, a connecting flight can reduce the round-trip cost, but adds two to four hours to the travel time. For travel between Boston and Burlington, Vermont, a connecting flight will not save any money, but can add up to five hours to the travel time.

Table 3.15 – Airline Travel Characteristics Summary

	Type of Flight	Number of Weekday Flights Each Direction (2002 Data)	Load Factor (2001 Data)	Travel Time (2002 Data)	Round-trip Cost (2002 Data)
Boston to Montreal/ Montreal to Boston	Non-stop	13	20%	70-90 minutes	$250 coach $550 business
Boston to Montreal/ Montreal to Boston	Connection in New York, Pittsburgh, or Philadelphia.	About 5	NA	4-6 hours	$170 coach $800 business
Boston to Burlington/ Burlington to Boston	Non-stop	8	7%	60-75 minutes	$ 225 coach No first class or business class service is offered
Boston to Burlington/ Burlington to Boston	Connection in Albany, White Plains, Newark, New York, or Washington DC	About 20	NA	3-6 hours	$250-800 coach $1,000 business

Current Rail Services

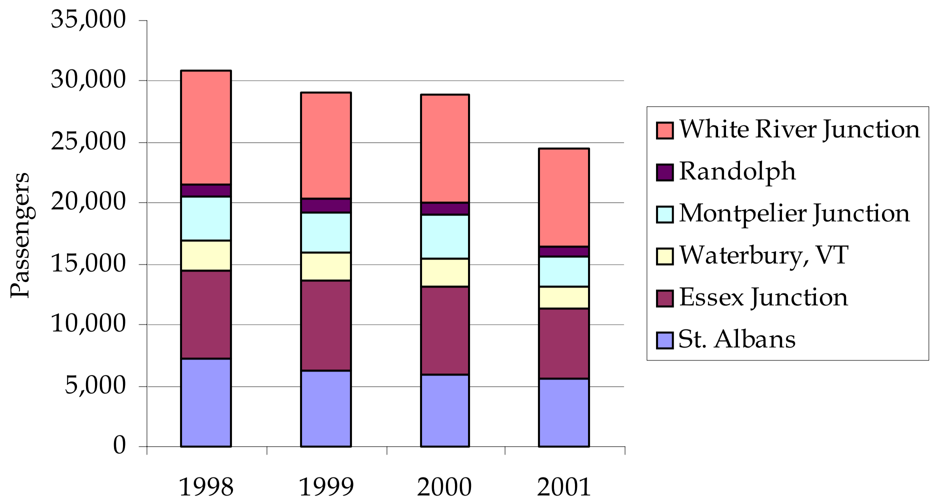
Amtrak Vermonter Service The Amtrak Vermonter train operates one daily trip in each direction between Washington, DC and St. Albans, Vermont, with major stops at New York City, Springfield, White River Junction, Montpelier, and Burlington. In both directions, the Vermonter schedule at St. Albans coordinates with the Vermont Transit bus service to and from Montreal, allowing a relatively easy transfer between train and bus. Table 3.16 shows travel time and fare for selected segments of the Vermonter service.

Table 3.16 – Amtrak Vermonter Service – Selected Connections

Origin	Destination	Frequency (Daily Trips)	One-Way Travel Time	One-Way Fare (US$)
New York City	St. Albans, VT	1	9 hours	$61
St. Albans, VT	New York City	1	14 hours	$61
White River Junction	St. Albans, VT	1	2.5 hours	$18
St. Albans, VT	White River Junction	1	2.5 hours	$18
White River Junction	Essex Junction, VT	1	2 hours	$18
Essex Junction, VT	White River Junction	1	2 hours	$18

Although passenger boardings at each of the Vermont stations between 1998 and 2001 have declined only slightly each year, the culmination of these declines has caused the overall ridership to drop from about 31,000 in 1998 to under 25,000 in 2001; a decline of 19 percent. Figure 3.4 shows boardings at each of the Vermont stations, and the cumulative on-counts for Vermont in total.

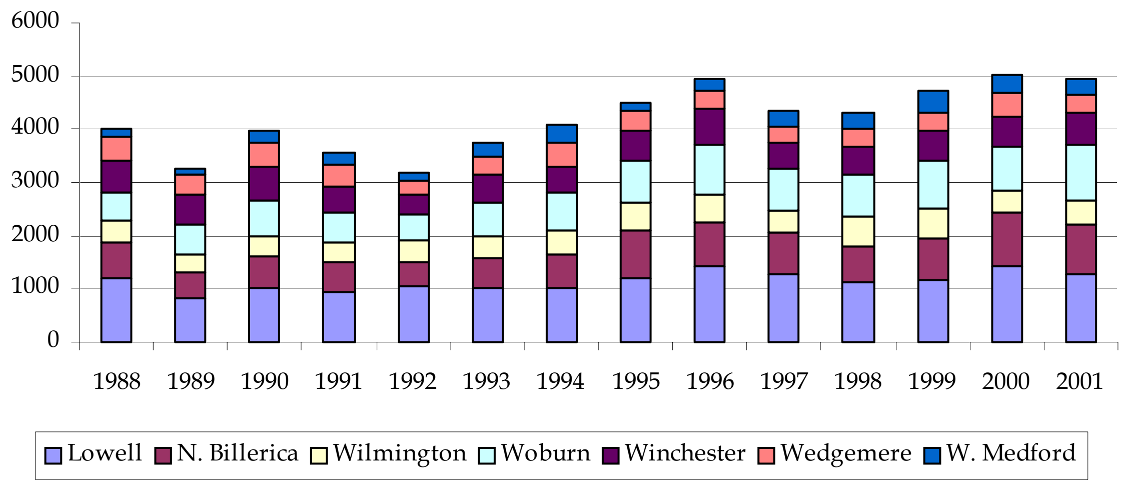
Figure 3.4 – Passenger Boardings on Vermonter Stops between St. Albans and White River Junction 1990-2001



Boston Area Commuter Rail Another rail service in the BMHSR Corridor is provided by the Massachusetts Bay Transportation Authority's Lowell line. The Lowell line operates between Lowell and North Station in Boston, with six intermediate stops in the communities of Medford, Winchester, Woburn, Wilmington and North Billerica. One-way travel time is about 45 minutes in either direction. On weekdays, 21 round trip trains operate between Lowell and North Station with a one-way fare of $4.50.

Ridership on the Lowell line has been increasing since the early 1990s, and as of February 2001, was nearly 11,000 daily (Figure 3.5). The station providing the highest number of boardings is the terminal station at Lowell. Recognizing the needs of commuters north of Lowell, the MBTA in partnership with the New Hampshire Department of Transportation, the Nashua Regional Planning Commission and the city of Nashua, is working to extend MBTA service on the Lowell line to Nashua. This extension is being provided to help meet the needs of residents of southern New Hampshire who commute to Boston. Upon completion of the extension, it is envisioned that ridership on the Lowell line will increase by approximately 1,000 riders per day.

Figure 3.5 – Daily Passenger Boardings on the Lowell Commuter Line



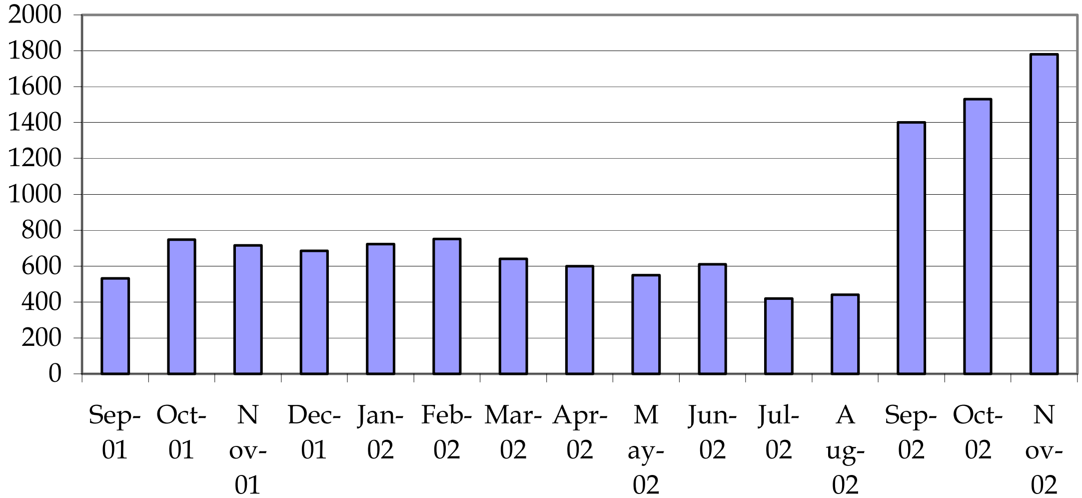
Source: MBTA, 2002.

Montreal Area Commuter Rail Similar to the MBTA, the Agence-Metropolitaine de-Transport (AMT) provides commuter rail service operating between Montreal Lucien-L'Allier Station and Delson, eight kilometers from Saint-Jean-sur-Richelieu with five intermediate stops in Vendome, Montreal-Ouest, LaSalle, Sainte-Catherine and Saint-Constant. This line was opened in September 2001 with a one-way trip time of 30 minutes. The service was instituted on a trial basis, and will be evaluated to determine if it should be continued. On weekdays, 4 inbound trains operate between 6:05 a.m. and 9:05 a.m. and 4 outbound trains operate between 3:40 p.m. and 6:10 p.m. There is no train service on weekends and holidays. One-way travel is CA$5.75 (about US$3.75). Current ridership levels on the service are relatively low, with approximately 650 total daily riders, however, ridership is expected to increase in time as commuters become more aware of this new option. Figure 3.6 provides monthly ridership compiled by Agence-Metropolitaine de-Transport from September 2001 to November 2002.

In addition to commuter rail services, a number of long distance, intercity services are provided by VIA Rail. These services include:

- Toronto-Montreal Overnight (the Enterprise)
- Oakville-Toronto-Montreal
- Ottawa-Alexandria-Montreal
- Quebec-Charny-Montreal
- Jonquiere-Montreal (the Saguenay)
- Senneterre-Montreal (the Abitibi)
- Gaspe-Perce-Montreal (the Chaleur)
- Halifax-Montreal (the Ocean)

Figure 3.6 – Daily Ridership on the Montreal/Delson Commuter Rail Line



Source: Agence-Metropolitaine de-Transport (AMT), 2002.

Burlington-Essex Junction. The Chittenden County Metropolitan Planning Organization (CCMPO) recently completed a study with the Vermont Agency of Transportation to examine the feasibility of passenger rail service in the Burlington-Essex corridor, as an extension of the Charlotte-Burlington passenger rail project. Two scenarios were estimated: an "All Day Scenario" that would provide service every 30 minutes, from 6:00 a.m. to 9:00 p.m., seven days a week (with a reduced level of service on weekends and holidays) and a "Moderate Scenario" that would provide hourly service only during the morning and evening peak traffic periods (three trains would depart Charlotte and Essex in the morning hours and three trains would repeat that service in the afternoon peak traffic period), weekdays only. A one dollar per trip (one way) fare is assumed in all scenarios.

CCMPO and VTrans are continuing to study this project to determine how this link might affect rail transportation in Vermont. While not a part of the Boston to Montreal alignment, this service, if constructed, could act as a direct feeder between the high-speed rail station and the cities of Burlington and Charlotte.

BMHSR Corridor Travel Demand

Border Crossing

Three U.S. border gates exist in the vicinity of the BMHSR Corridor: Champlain-Rouses Pt., New York, Highgate Springs, Vermont and Richford, Vermont. Over 2 million vehicle crossings occur annually between the three crossings.

Table 3.17 – Vehicles Crossing the U.S. Border from Canada in the BMHSR Corridor, 2000

	Cars		Trains		Buses		Trucks		Total
Champlain-Rouses Pt.	980,130	70.8%	1,386	0.1%	11,728	0.8%	390,836	28.2%	1,384,080
Highgate Springs	446,046	76.4%	353	0.1%	4,446	0.8%	132,709	22.7%	583,554
Richford	143,638	92.2%	242	0.2%	86	0.1%	11,758	7.6%	155,724
Total BMHSR Corridor	**1,569,814**	**73.9%**	**1,981**	**0.1%**	**16,260**	**0.8%**	**535,303**	**25.2%**	**2,123,358**

Source: U.S. Customs, 2002.

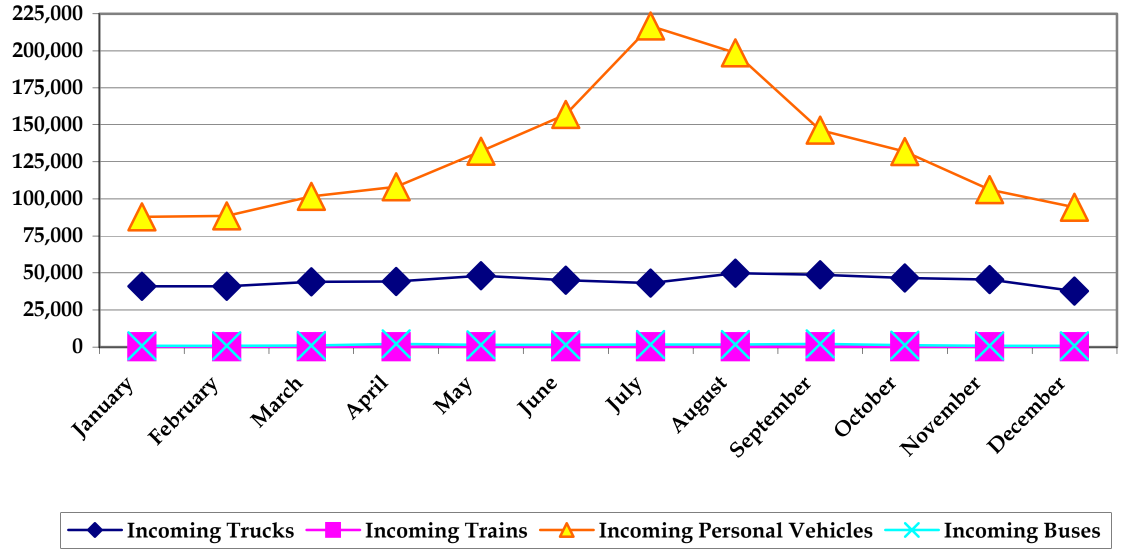
Table 3.18 – People Crossing the U.S. Border from Canada by Mode in the BMHSR Corridor, 2000

	Cars		Train		Bus		Pedestrians		Total
Champlain-Rouses Pt.	2,747,141	88.4%	38,459	1.2%	317,205	10.2%	3,281	0.1%	3,106,086
Highgate Springs	957,869	89.2%	706	0.1%	115,341	10.7%	314	0.0%	1,074,230
Richford	271,861	97.3%	784	0.3%	2,355	0.8%	4,348	1.6%	279,348
Total BMHSR Corridor	**3,976,871**	**89.2%**	**39,949**	**0.9%**	**434,901**	**9.8%**	**7,943**	**0.2%**	**4,459,664**

Source: U.S. Customs, 2002.

The total number of incoming vehicles at border crossings in the BMHSR Corridor is seasonal, with the highest volume of traffic occurring during summer months. Virtually all of the seasonal variation is attributable to personal vehicles that make up about 80 percent of traffic during the peak month of July. Figure 3.7 portrays the total number of vehicles by month for 2000.

Figure 3.7 – Vehicular Traffic from Canada to the U.S. at Border Crossings in the Vicinity of the BMHSR Corridor

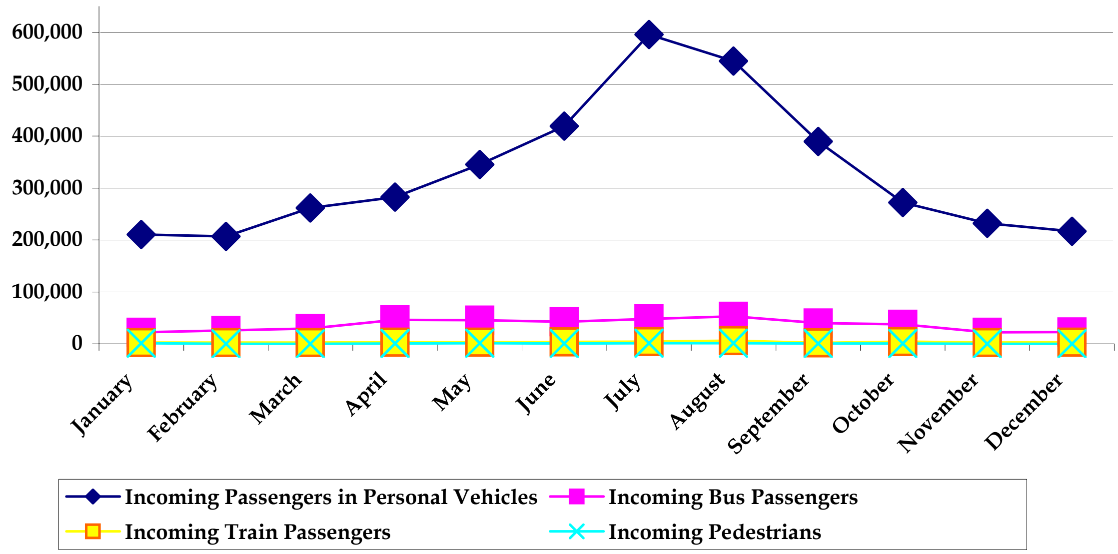


Note: Border Crossings included are Champlain/Highgate Springs, Vermont, Champlain-Rouses Point, New York and Richford, Vermont.

Source: U.S. Customs, 2002.

Similar to the seasonality of vehicular traffic in the BMHSR Corridor, the number of people entering the United States from Canada is also highest during summer months (Figure 3.8). During this time period, the average number of people per vehicle increases from about 1.1 passenger per personal vehicle to nearly 3 people per vehicle. While the number of vehicle border crossings increases during summer months, the number of people increases at an even faster rate.

Figure 3.8 – Incoming People from Canada to the U.S. at Border Crossings in the Vicinity of the BMHSR Corridor



Note: Border Crossings included are Champlain/Highgate Springs, Vermont, Champlain-Rouses Point, New York and Richford, Vermont.

Source: U.S. Customs, 2002.

Tourism Demand

The BMHSR Corridor provides access to the Quebec/New England tourism region by linking two major metropolitan areas in the Northeast and passing through key cities in Vermont, New Hampshire, and Massachusetts.

Quebec Travel to U.S. Corridor In 2001, 2.7 million Quebecois traveled within the three-state corridor of Massachusetts, New Hampshire and Vermont. Seventy-seven percent of these trips were to Vermont, 14 percent to New Hampshire, and 9.0 percent to Massachusetts. Twenty-six percent of those tourists stayed overnight: 56 percent in Vermont, 26 percent in Massachusetts and 18 percent in New Hampshire (Table 3.19).

Table 3.19 – Quebec Visitors and Tourists to the U.S. Portion of the BMHSR Corridor in 2001

Destination	Overnight Person-Visits		Total Person-Visits	
Massachusetts	189,000	26%	245,000	9%
New Hampshire	131,000	18%	385,000	14%
Vermont	404,000	56%	2,117,000	77%
BMHSR Corridor	725,000	100%	2,747,000	100%

Source: 2001 International Travel Survey (Statistics Canada, 66-201-XIE).

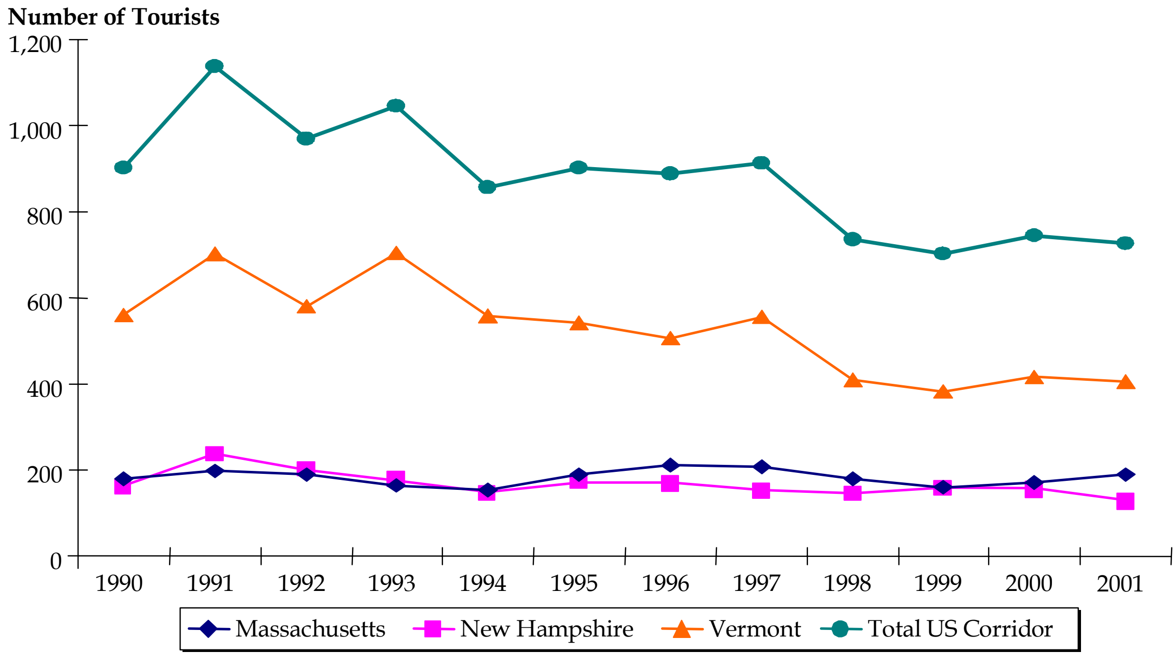
Travelers from Quebec represented 54 percent of Canadian overnight visits to the three states in 2001. This proportion was 70 percent in Vermont, and 40 percent and 45 percent in New Hampshire and Massachusetts, respectively. Quebec tourism to states in the BMHSR corridor declined from 1990 to 2001 largely due to a decline in visits to Vermont (Figure 3.9). This is due in part to a shift in the U.S./Canadian currency exchange rate, favoring the U.S. For example, a Canadian dollar that was worth 83 American cents in 1990 was worth about 60 American cents in 2001 – a decline of 28 percent.

Business trips represented on average 5 percent of all Quebec overnight visits to the three states. This proportion was highest in Massachusetts at 12 percent. The proportion was 5 percent in New Hampshire, and 3 percent in Vermont. More than 70 percent of Quebec tourists went to New Hampshire and Vermont for pleasure. Half of those pleasure trips to Vermont were to visit a second home, cottage or condominium. Pleasure trips represented 49 percent of trips to Massachusetts, whereas one third of Quebec tourist's trips were made to visit friends or relatives. Visit to friends and relatives represented 18 percent to 20 percent of Quebecois trips to Vermont and New Hampshire.

Seventy-five percent of Quebec parties are composed of adults without children. This proportion is highest in Vermont (80 percent) and lower in Massachusetts and New Hampshire where parties composed of adults and children represented one third of all parties in 2001.

Distance appeared to play a role in the length of the trip. Quebec tourists stayed on average 4.5 nights in Massachusetts, whereas they stayed 2.8 and 3.0 nights in Vermont and New Hampshire, respectively.

Figure 3.9 – Overnight Quebec Tourists to States within the BMHSR Corridor (1990-2001)



Source: 2001 International Travel Survey (Statistics Canada, 66-201-XIE).

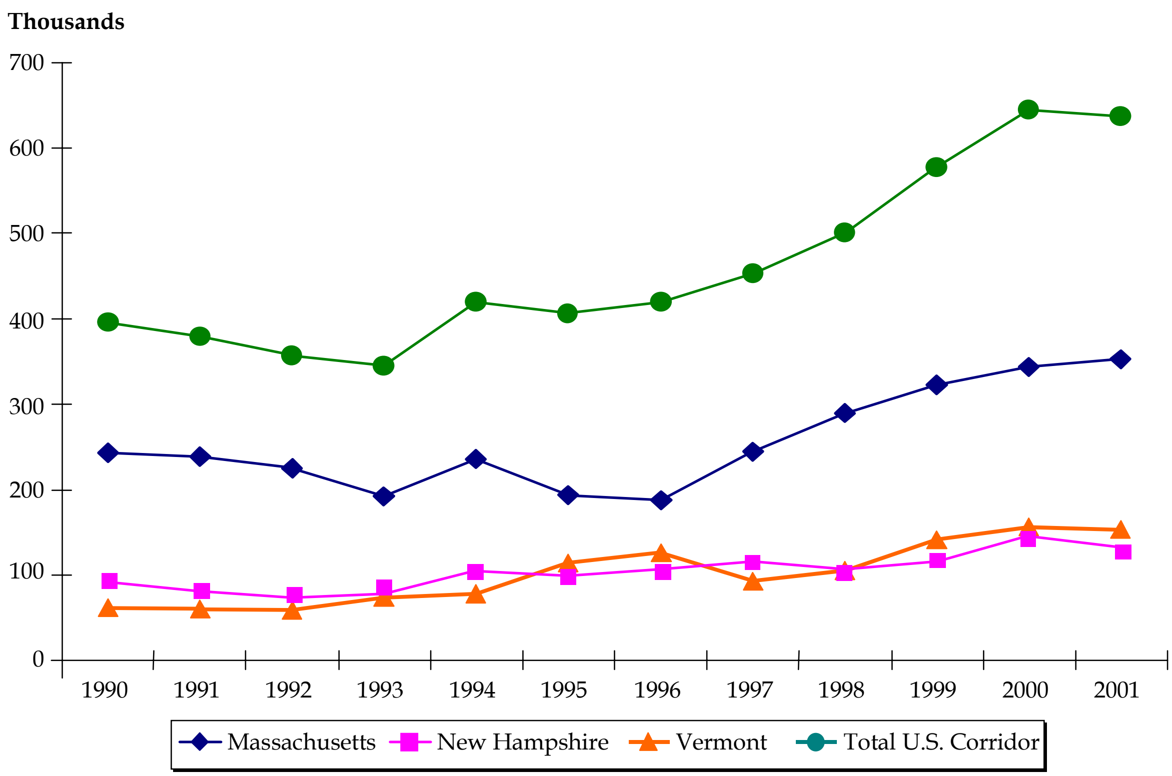
U.S. Tourism to Quebec Tourism is also important to the Quebec economy. More than 36 million people visited Quebec overnight in 1999. Fifty-three percent of those visitors spent more than one day in the province: 74 percent were from Quebec, 12 percent from other Canadian provinces, 11 percent from United States and 4.0 percent from other countries. Of those 36 million visitors to the province, about 10.1 million traveled to Montreal. About 5.8 million visitors spent at least one night in the Province. The visitors come from varied destinations: 32.4 percent come from within the province of Quebec, 29.7 percent from the rest of Canada, 23.7 percent from the United States and 14.2 percent from overseas.

Tourists who stayed overnight in Quebec spent $4.6 billion Canadian dollars (about $3.0 billion in U.S. dollars) in 1999 of which Americans contributed 24 percent. American visitors to Montreal spend about CA$2.0 billion dollars each year, of which CA$1.8 billion comes from tourists who stay overnight. Americans visitors to Quebec stayed on average 3.4 nights in 1999. The majority of these trips were for pleasure, as only 26.3 percent of visitors cite business as the purpose of their trip.

In 2001, 637,000 overnight tourists from Massachusetts, Vermont and New Hampshire visited Quebec. Fifty-five percent were from Massachusetts, 24 percent from Vermont and 21 percent from New Hampshire (Figure 3.10). Overall there are about 100,000 more Quebecois that spend the night in the three-state region than persons from the three-state region that spend the night in Quebec. This is primarily due to the fact that more than twice as many Quebecois have overnight trips in Vermont than the reverse. Tourists from Vermont and New Hampshire to Quebec increased slightly from 1990 to 1997, whereas tourists from Massachusetts fluctuated during that period. The number of tourists from the U.S. portion of the BMHSR corridor to Quebec increased 50 percent from 1996 to 2001, due to an increase in the number of tourists from Massachusetts during this period (Figure 3.11).

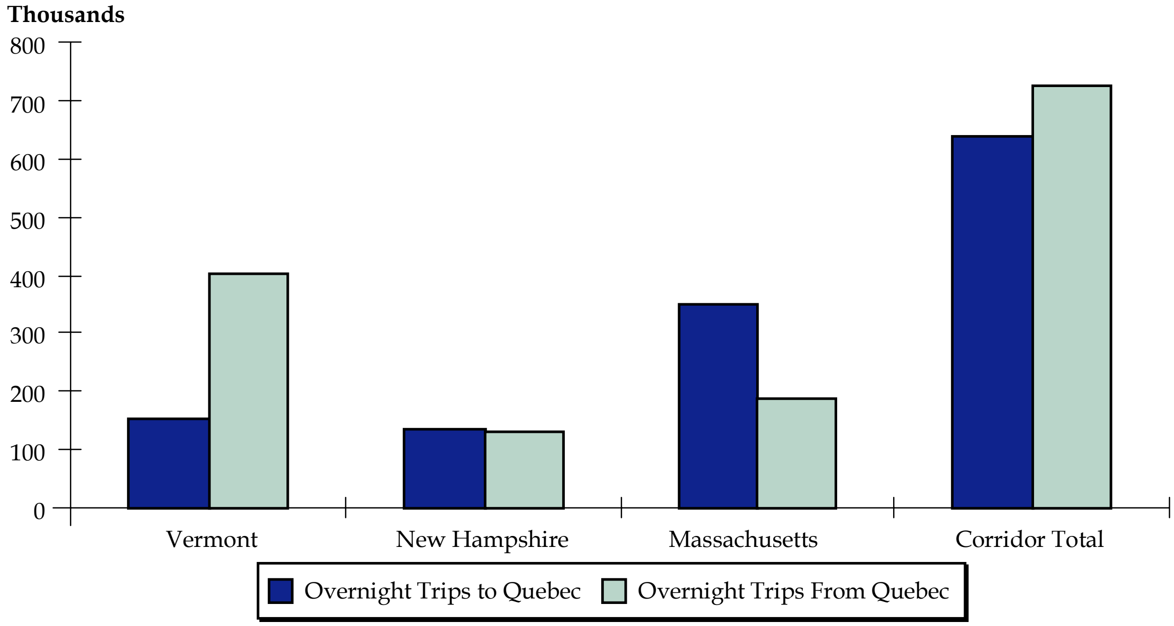
Tourist trips within the BMHSR Corridor are short in duration: visitors from Vermont, Massachusetts and New Hampshire stay on average 2.5, 2.9 and 3.0 nights, respectively. Tourists were predominantly comprised of adult parties with parties with children encompassing only between 12 and 23 percent of all trips depending on the state of trip origin. Most parties were comprised of two or more adults who traveled for pleasure (69 percent, 67 percent and 43 percent for Massachusetts, New Hampshire and Vermont) or to visit friends and relatives (18 percent, 25 percent and 44 percent, respectively). Business trips represent only 4.0 percent to 6.0 percent of all visits.

Figure 3.10 – Overnight Visitors to Quebec by State of Origin within BMHSR Corridor (1990-2001)



Source: 2001 International Travel Survey (Statistics Canada, 66-201-XIE).

Figure 3.11 – Overnight Visits Between Quebec and the BMHSR Corridor States



Source: 2001 International Travel Survey (Statistics Canada, 66-201-XIE).

Overall, there are more overnight visits from Quebecois to the U.S. than U.S. overnight visits to the Quebec province. This of course varies by state, with more Quebecois traveling to Vermont than Vermonters traveling to Quebec, but more Massachusetts residents traveling to Quebec than Quebec residents traveling to Massachusetts. The number of visitors between New Hampshire and Quebec is roughly equal.

Profiles of Domestic Tourism in Massachusetts, Vermont and New Hampshire

The American Travel Survey (ATS) is a national survey conducted by the U.S. Census Bureau. In 1995, the ATS collected information from approximately 80,000 households about their long-distance travel in 1995. Information from this survey provides a basis for origin/destination information within the BMHSR Corridor. Because the survey only looks at trips that are greater than 100 miles in length, short trips such as errands and most commuter trips are excluded from the study results.

Americans from Massachusetts, New Hampshire and Vermont made 17.9 million domestic trips of more than 100 miles in 1995. Thirty-four percent of all those trips were destined to locations within those three states, as shown in Table 3.20. Massachusetts, the most populated state, generates the most trips. Sixty-six percent of trips originated in Massachusetts, 21 percent in New Hampshire and 13 percent in Vermont. Of all trips within the U.S. corridor, 42 percent were destined to Massachusetts, 40 percent to New Hampshire, and 18 percent to Vermont.

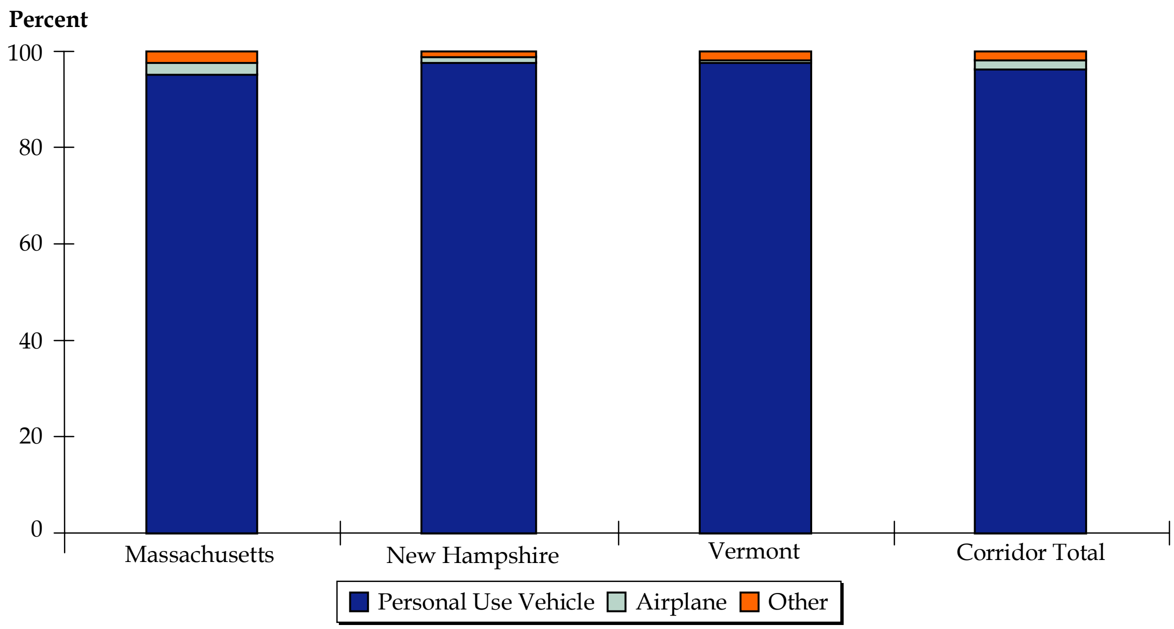
Table 3.20 – Trips Greater Than 100 Miles Inside the U.S. Corridor, 1995

From/To	Massachusetts	New Hampshire	Vermont	Total U.S. Corridor
Massachusetts	1,685,000	1,656,000	696,000	4,037,000
New Hampshire	516,000	566,000	189,000	1,271,000
Vermont	341,000	210,000	220,000	771,000
Total U.S. Corridor	2,542,000	2,432,000	1,105,000	6,079,000

Source: American Travel Survey (1995, No. BTS/ATS95-ESTC/1120).

Nationally, eight out of 10 trips greater than 100 miles in length use personal vehicles as their primary mode of transportation. In the U.S. BMHSR Corridor, however, this proportion increases to nearly 97 percent. Massachusetts had the highest use of modes other than automobile with about five percent of long-distance trips being made by airplane, bus or train. Figure 3.12 shows the mode of transportation for travelers within the U.S. portion of the BMHSR Corridor.

Figure 3.12 – Mode of Transportation for Trips Greater than 100 Miles in Length in the U.S. Portion of the BMHSR



Source: American Travel Survey (1995, No. BTS/ATS95-ESTC/1120).

Adults are the primary travelers in the U.S. portion of the BMHSR Corridor. According to the 1995 American Travel Survey, only about 11 percent of traveling parties include children as their members.

Profile of Travelers Based on BMHSR Corridor Surveys

As a component of the travel demand model, four individual survey efforts were conducted within the BMHSR corridor, as follows:

- Automobile users at the Hooksett tolls
- Automobile users at the Highgate Welcome Center near the Canadian border
- Bus passengers at locations along the corridor
- Airplane travelers at Logan Airport

The travel surveys were performed in order to obtain information for the development of mode choice, destination, and trip frequency models. The data elements obtained in these surveys included detailed trip information about relevant intercity trips within the corridor. This information also included trips between Montreal and Boston, and also other corridor trips to locations greater than 100 miles in length. Among the trip data items that were collected are:

- Details on the chosen mode
- Location of the trip origin
- Location of the trip destination
- Trip purpose
- Number of nights away from home on this trip
- Access and egress modes for each mode except auto
- Travel group size
- Type of non-home end location (hotel, rental home, etc.)

In addition to the trip information, demographic information for surveyed households was collected including:

- Age,
- Gender
- Auto ownership
- Educational characteristics
- Monthly household income
- Total number of long-distance trips by mode in past year

The surveys were not designed to provide detailed origin-destination trip pattern information. A much larger survey effort would be required to do so. Preferred origin and destination information was obtained from statewide and provincial travel demand models, as well as the Stats Canada international travel survey and American Travel Survey.

This enabled the Study team to focus the traveler surveys on obtaining information that would provide traveler profile and mode choice data.

As part of the surveys, respondents were asked to complete stated preference exercises. First, respondents were asked to make tradeoffs between their current travel mode with its current travel times, costs, and travel attributes and a hypothetical service consisting of the same mode with different travel times, costs, and travel attributes. Respondents were then asked to choose between their current mode and hypothetical intercity rail services with different times and costs.

Several versions of the tradeoff exercises were developed and respondents were randomly assigned a set of relevant exercises. The specific tradeoff levels were developed using a design which ensures that the choice experiment is relevant to the particular respondent, through the using where appropriate short, medium and long trip lengths, that there are no dominant choices, and that individual variables are not overly correlated with each other.

In order to develop a reliable mode choice model, the survey data collection effort intercepted travelers in the corridor using a variety of modes including: airplanes, buses and automobile.

To collect stated preference data from air travelers, survey crews were stationed at departure gates at Logan airport in Boston to meet statistically selected travel trips over a two week period which included early mornings, nights, and weekends. Passengers traveling to Montreal or Burlington were asked to complete a survey, which was then either collected in the passenger waiting area or else mailed back to the consultant team's offices for processing. All survey forms were available in both French and English.

Bus travelers were also surveyed to determine their preferences with regard to travel within the BMHSR Corridor. To conduct this survey, surveyors rode selected buses in the corridor and requested passengers complete a survey. As with the airplane surveys, both French and English versions were available and the passengers were able to fill them out en-route or mail them back at the leisure.

The vast majority of travelers in the BMHSR Corridor travel by private automobile. For this reason, a large number of surveys were distributed at the Hooksett toll in New Hampshire. Subsequent to this survey, additional surveys were distributed at the Highgate Welcome Center to provide greater geographic distribution and to gauge the effects that a border crossing would have on travelers' choices.

The combined results of the surveys provided an overview of both typical traveler characteristics and stated preference with regard to service characteristics of current and potential travel modes in the corridor. The results of each of the responses have been presented as percentages of responses to allow for easy comparisons between modes where the absolute number of surveys may have been different.

State of Origin

In composite, the stated preference surveys provided a good representation of the views of residents of each of the three states in the study, as well as residents of Quebec and most specifically Montreal. Table 3.21 provides an overview of the distribution of the surveys by place of residence for each of the surveys included in this analysis.

Table 3.21 – State of Origin by Survey

	Massachusetts	New Hampshire	Vermont	Quebec
Hooksett Tolls	26%	60%	13%	1%
Highgate Visitor Center	23%	10%	34%	33%
Bus	45%	6%	22%	27%
Logan Airport (Boston)	72%	6%	7%	15%

Source: Cambridge Systematics, Inc. Corridor Travel Surveys, 2002.

Gender of Survey Respondents

The gender of people who submitted surveys varied by mode (Table 3.22). Most striking is the air travel market, which reflects a 70 percent male response to the survey whereas females completed 62 percent of the bus surveys. Men, at 57 percent of the surveys, also predominantly submitted responses to the automobile surveys.

Table 3.22 – Gender of Survey Respondents by Mode

	Car	Bus	Air
Male	57%	38%	70%
Female	43%	62%	30%

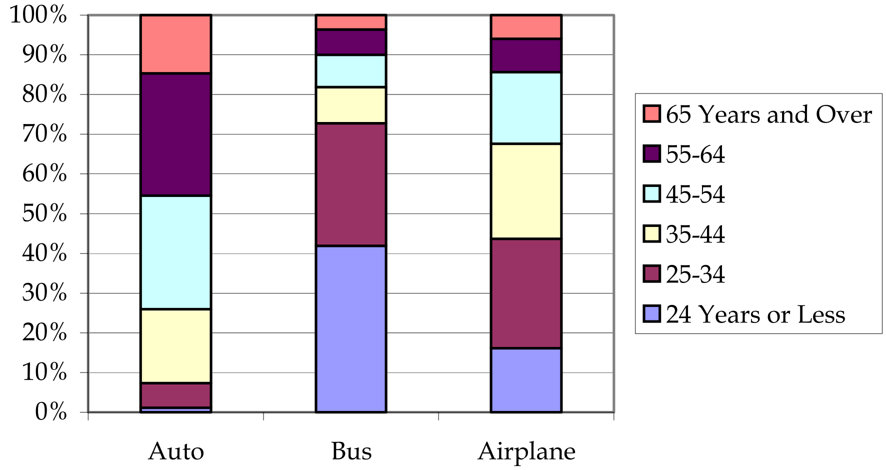
Source: Cambridge Systematics, Inc. Corridor Travel Surveys, 2002.

Age of Respondents

There was also a distinct variation in the age of survey respondents by mode (Figure 3.13). Older automobile respondents (55 years in age or older) filled out proportionally four times as many surveys as either the bus or airline passengers. Conversely, 72 percent of the bus respondents were 34 years of age or less, a proportion greater than either of the other modes.

Based on the survey responses, older travelers are more likely to drive, younger travelers are more likely to take the bus and airplane travelers have fairly even distribution in the age groups below 55 years in age, with a lower proportion of respondents older than 55 years old.

Figure 3.13 – Age of Survey Respondents by Mode

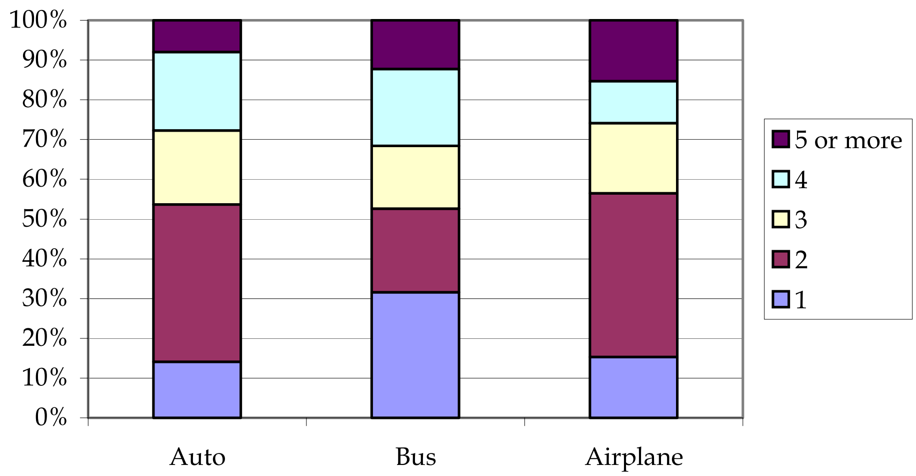


Source: Cambridge Systematics, Inc. Corridor Travel Surveys, 2002.

Household Size

Survey respondents also were asked to report the size of their household (Figure 3.14). This figure varied by mode. Interestingly, more than 30 percent of all bus riders reported that they lived alone. This figure is almost twice as high as either of the other modes.

Figure 3.14 – Size of Household by Mode



Source: Cambridge Systematics, Inc. Corridor Travel Surveys, 2002.

Vehicles per Household

The number of vehicles per household also varied by mode. Not surprisingly, persons surveyed in their automobiles possessed significantly more cars per household than the other modes. Eighty-five percent of the auto surveys indicated they had two or more vehicles in their household, whereas only 30 percent of the bus riders and 60 percent of the airplane respondents had the same level of car ownership. Bus riders had the lowest car ownership of any of the modes, with 65 percent reporting that they had one or no vehicle in their households. This figure was more than four times greater than the number reported by airplane passengers. Table 3.23 reflects the number of vehicles per household as reported by the survey results.

Table 3.23 – Number of Vehicles per Household by Mode

Vehicles per Household	Automobile	Bus	Airplane
0	0%	36%	8%
1	15%	29%	32%
2	52%	19%	42%
3	22%	13%	13%
4 or More	11%	3%	5%
TOTAL	**100%**	**100%**	**100%**

Source: Cambridge Systematics, Inc. Corridor Travel Surveys, 2002.

Education Level

Based on the survey results, level of educational attainment did not vary with mode choice. Table 3.24 provides a breakdown of the level of education attainment by mode. The greatest difference between modes was that persons with some college experience (between 1 and 3 years) were 5-6 percent more likely to be traveling by bus than the other modes, reflecting the popularity of the bus among college students.

The greatest percentage of automobile and bus survey respondents came from college graduates, with the proportion of airplane survey respondents being highest for those with graduate or professional degrees. Persons without a high school education were the least likely respondent for the automobile and airplane surveys.

Table 3.24 – Level of Educational Attainment by Mode

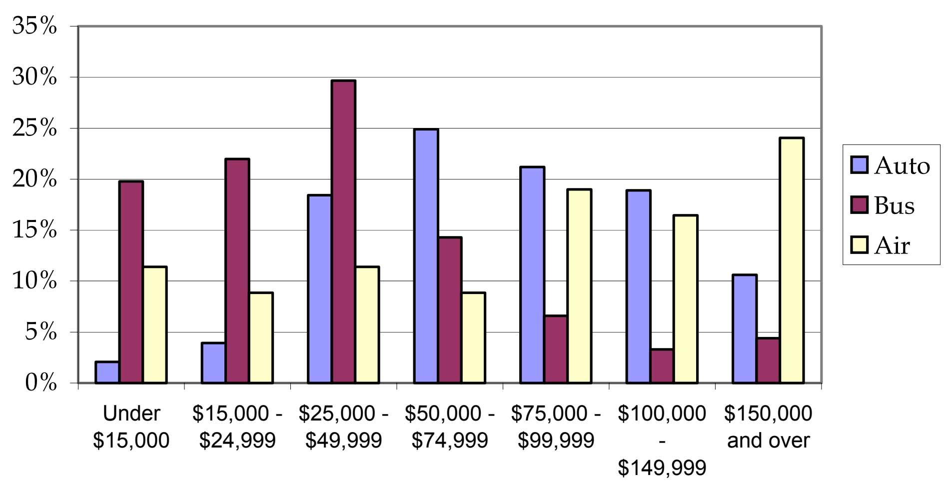
	Automobile	Bus	Airplane
Some High School	1%	4%	2%
High School Graduate or Equivalent	8%	3%	4%
Technical or Vocational School	5%	1%	4%
Some College (1-3 Years)	16%	22%	17%
College Graduate	36%	40%	36%
Graduate or Professional Degree	34%	30%	37%

Source: Cambridge Systematics, Inc. Corridor Travel Surveys, 2002.

Household Income

Household income had a strong correlation with mode choice. Based on the survey results, bus riders had the lowest income levels, people who drove had moderate incomes and airline travelers had the highest incomes. Figure 3.15 provides a summary of household income by mode.

Figure 3.15 – Household Income by Mode

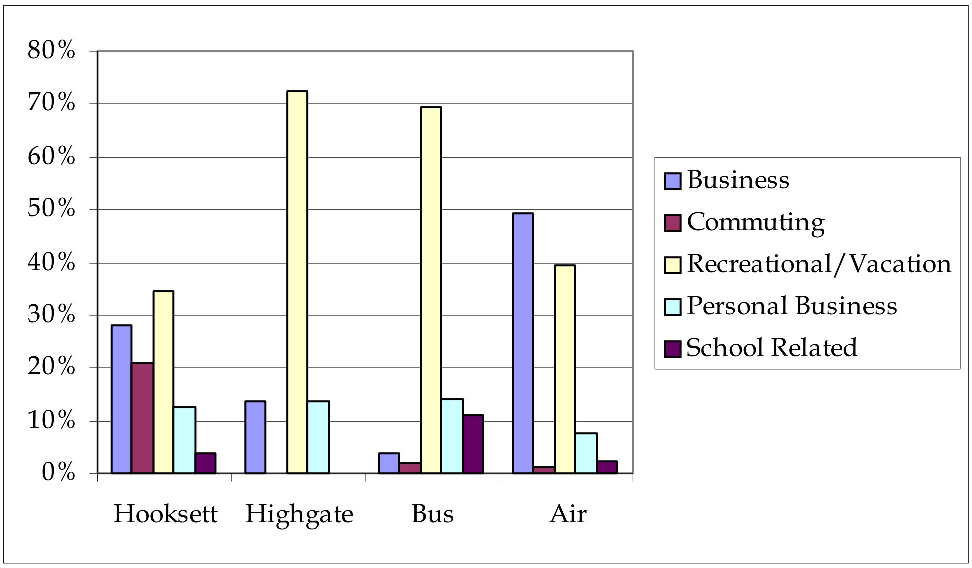


Source: Cambridge Systematics, Inc. Corridor Travel Surveys, 2002.

Trip Purpose

Trip purpose also varied by mode (Figure 3.16). For the purpose of this discussion, auto trips were broken out by both those from the Hooksett tolls and those from the border survey at the Highgate Welcome Center. This was done primarily to accentuate the variation in trip purpose between the two auto surveys. In this instance, about 72 percent of the Highgate border surveys indicated that they were traveling for recreational purposes. The Hooksett surveys, however, had a lower proportion with this response – only 35 percent. Overall, recreation was the dominant trip purpose in the BMHSR Corridor.

Figure 3.16 – Trip Purpose by Mode



Origins and Destinations

Two important pieces of information that were collected through the traveler surveying process were trip origin and destination. This information is similar to trip purpose, but provides additional information on the combining of multiple trip purposes. Each of the surveys requested the traveler state his or her trip origin and destination. The most common origin and destination was to a private home, accounting for more than half of all trips regardless of travel mode. The Highgate Springs welcome center and the airplane survey also expressed a high level of travel to and from hotel rooms, reflecting the importance of tourism as indicated by the trip purpose figure. The origin and destination information for the traveler surveys was utilized to supplement principal origin and destination information obtained from statewide and provincial travel demand models, as well as the Stats Canada international travel survey and the American Travel Survey. A summary of trip origins and destinations for the traveler surveys is provided in Table 3.25.

Table 3.25 – Trip Origins and Destinations

	Hooksett		Highgate		Bus		Airplane	
	O	**D**	**O**	**D**	**O**	**D**	**O**	**D**
Private home	56%	56%	59%	52%	71%	68%	59%	58%
Place of work or business	26%	32%	0%	0%	4%	10%	14%	10%
Hotel or motel	7%	3%	34%	34%	17%	14%	20%	26%
Tourist attraction	9%	5%	3%	7%	3%	7%	1%	5%
School	2%	1%	0%	0%	1%	2%	6%	0%
Airport	0%	3%	3%	7%	3%	0%	NA	NA

Source: Cambridge Systematics, Inc. Corridor Travel Surveys, 2002.

Access and Egress

A unique component of modal choice is how travelers access that mode. For automobile travel it was assumed that the car was readily available and did not require another mode to access it. For bus and airline travel, however, people had to determine how to reach that mode. These choices affect many aspects of the job including total overall travel time. Table 3.26 provides an overview of intermodal connections for bus and airplane travel in the BMHSR Corridor. Getting dropped off by a privately owned vehicle or using public transit were the key methods of access for those passengers surveyed on the bus. For airplane travelers, the connections were more evenly split across several modes including driving a privately owned vehicle, being dropped off, rental cars and taxis.

Table 3.26 – Airplane and Bus Access and Egress Methods

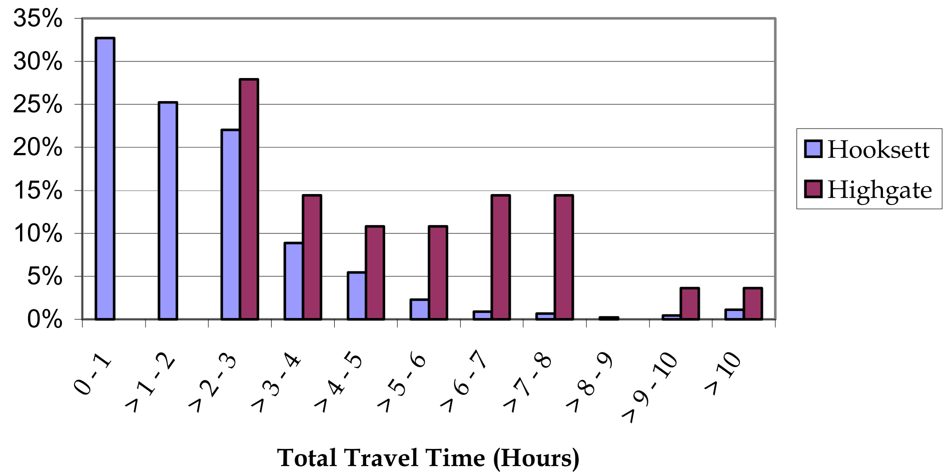
	Bus		Airplane	
	Access	**Egress**	**Access**	**Egress**
Drove Privately Owned Vehicle	3%	14%	19%	18%
Drop off/Pick up by Privately owned Vehicle	37%	28%	11%	19%
Rental Car	0%	1%	13%	19%
Taxi	16%	17%	23%	31%
Limo or Van	2%	0%	9%	3%
Public Transit	36%	40%	18%	7%
By Foot or Bike	6%	1%	7%	2%

Source: Cambridge Systematics, Inc. Corridor Travel Surveys, 2002.

Auto Trip Times

Automobile survey respondents were asked to estimate their trip travel times. The reported average trip times varied significantly, with the median trip time being about one hour and forty-five minutes. Average trip times at the Highgate welcome center were significantly longer with a median trip time of 5 hours, although it was not specified what proportion of this time was attributable to border delays. Figure 3.17 provides an overview of the average trip times for each of the survey locations.

Figure 3.17 – Automobile Travel Times



Source: Cambridge Systematics, Inc. Corridor Travel Surveys, 2002.

Mode Choice

Automobile travel is the most common mode of travel in the BMHSR Corridor. The most common reason that people cited for using automobiles was that they were the only practical alternative to make the trip. The top three reasons cited for auto use are as follows:

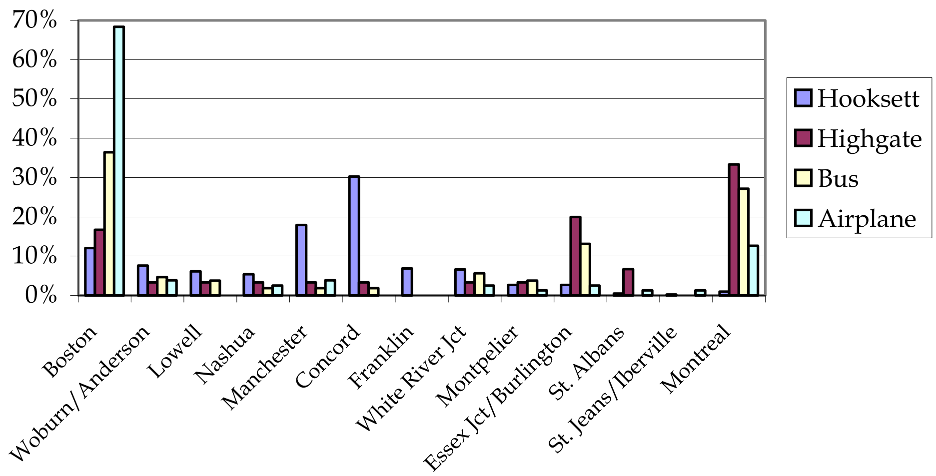
- Auto only practical alternative,
- Auto is needed at destination, and
- Auto is needed along the way.

Preferred Station Locations

An interesting finding from the stated preference surveys was preferred station of origin. Figure 3.18 provides a composite view of the preferences for station of origin across each of the four surveys. The most convenient station of origin for the travelers varied, of course, by where the surveys were distributed. For airplane travel, for example, the preferred station of origin for that trip was Boston, with 67.5 percent of the respondents choosing it. Preferred destination stations were Montreal, Boston and Burlington with a small number of respondents indicating other destinations along the BMHSR Corridor. This information is skewed, however, due to the fact that the surveys were distributed in Boston on flights traveling to Montreal and Burlington – the only cities with intercorridor airplane service in the BMHSR Corridor.

The border survey also indicated station origin preferences in Montreal, Burlington and Boston, in that order. Responses for station destination preferences produced a similar distribution.

Figure 3.18 – Stated Preference of Origin Station by Mode



Source: Cambridge Systematics, Inc. Corridor Travel Surveys, 2002.

The bus surveys, which occurred on both northbound and southbound trips, revealed a preference for trip origination on both the Boston and Montreal ends of the trip with smaller, but significant demand in Burlington and White River Junction. The destination preferences mirrored these findings, with additional demand for service to Montpelier and Anderson Station in Woburn.

3.3 Model Analysis and Ridership Estimates

The Ridership Modeling Process

A key component in determining the feasibility of HSR service from Boston to Montreal is the development of reliable forecasts for intercity rail travel in the BMHSR Corridor. To forecast the ridership, the Study team assembled data on how travelers in the BMHSR Corridor currently make their choices. Mathematical relationships between the measures of transportation supply and demand in the BMHSR Corridor were developed. And, then these mathematical relationships were applied to different future year scenarios to predict how people will travel in the BMHSR Corridor in the future.

For this Study, an integrated discrete choice model was developed to predict ridership for a series of intercity rail alternatives. The projected ridership consists of both diverted trips (trips that would be made by a different travel mode if the proposed rail service was not available) and generated trips (trips that will be made only if the proposed rail service is available).

To predict the demand for high-speed intercity rail, service characteristics such as travel times and station locations were simulated and integrated with information regarding the set of choices that individuals make with regard to intercity travel in the BMHSR Corridor. Overall demand was predicted for each high-speed rail alternative by aggregating the individual choices to the relevant population. The first basic choice an individual makes is whether and how often to travel for a specific purpose. This choice is a function of the traveler's individual and household characteristics and the overall accessibility of the traveler's home to potential intercity destinations.

At the same time that an individual chooses whether and how much to travel, he or she makes a decision as to the location of the trip destination. The choice of destination may be modeled with information on the trip being made, information on the characteristics of the traveler's household, measures of the relative size or attractiveness of the different potential destinations, and the cost (both in time and money) of traveling between the traveler's home location and each specific potential destination. Finally, the individual chooses the means by which to travel and by which routes. Mode choice is a function of trip characteristics, the traveler's household characteristics, and the relative levels of service of the different modes and routes for the origin-destination pair in question.

Most transportation demand models treat these choices sequentially through a set of separate model elements. Trip frequency choice is modeled with trip generation equations. Destination choice is modeled with trip distribution relationships (such as gravity models), and mode/route choice is modeled with mode split and assignment algorithms. These model components generally stand alone, and usually do not reference the other components.

The model developed for this Study, however, connects the different model components by passing information from one choice component to the others during model development. Therefore, the model components are fully consistent with each other and are sensitive to each other's changes. In this model system, changes to the transportation infrastructure, such as the introduction of new intercity rail service, affect each component of the model system. The discrete choice model outputs are forecasts of travel by each available mode between specific origins and destinations.

The objective of the passenger demand forecasting effort was to develop reliable forecasts of intercity rail travel in the BMHSR Corridor through the development and application of an integrated discrete choice model system that predicts both diverted and generated traffic.

The following general steps were performed:

1. Intercity travel patterns within the BMHSR Corridor were defined;

2. Mode choice (diverted demand) models based on newly-collected BMHSR Corridor travel surveys were developed;

3. Induced demand models were constructed; and

4. Diverted and induced demand models were applied to the BMHSR Corridor travel patterns to obtain forecasts.

The first step of the forecasting effort was to define the trip patterns within the BMHSR Corridor. This was accomplished by synthesizing market segment specific trip tables based on available information, including statewide and provincial travel demand model outputs and available travel survey data that have been compiled by tourism agencies in the BMHSR Corridor and by national statistical agencies. Using these data sources, base year and forecast year estimates of the number of trips between each of the communities in the study area were defined.

The next step was to develop mode choice models that were used to forecast rail demand. The key methodological issue for the mode choice models relates to the use of the available travel data. For this modeling effort, the revealed-preference survey data was used to estimate models of mode choice behavior for the base year. In addition, the data collected through the stated-preference surveys were used to assess the attractiveness of the rail mode. Revealed preference data shows what people do. Stated preference data is what people say they would do. From the combined revealed preference and stated preference analyses, models of intercity travel choice were developed.

The mode choice models were used to predict the number of travelers that would choose high-speed rail over other competing travel modes. The logit models also provide a measure of the relative impedance (across all travel modes) between different towns in the study area. Using multinomial regression techniques, this measure of interzonal impedance was related to the number of trips between zones. Then, the number of trips that would be generated for each zone pair as a result of the improved intercity travel options was derived.

The passenger demand forecasting process estimated future year inputs to forecast the key model inputs for the future year inputs. A simplified forecast-year intercity highway network and alternative air, bus, and rail transportation scenarios were developed and utilized to define the future transportation network. In addition, zone-level forecasts of population, households and characteristics of households were assembled. The diversion models and induced travel model were applied in a spreadsheet-based forecasting tool to develop demand forecasts.

Advantages of the Model System

The model system selected for use in this study offered several advantages over other demand models:

- It maximizes the use of revealed-preference data, rather than stated-preference data;
- It provides an integrated approach to analyzing diverted trips and generated trips, both in terms of new trips and trips to new destinations;
- It results in fairly sophisticated statistical models that can produce reliable forecasts, but which are straightforward in application; and
- It provides a validated model system with which to perform a wide range of future intercity travel demand analyses.

The biggest advantage of the model approach is that it relies, to the extent possible, on models developed from travelers' actual behavior. This technique is highly desirable because stated-preference data often are prone to a number of biases that are difficult to detect or correct. Careful survey design and experimental analysis minimize these biases, but the possibility of reduced reliability of these forecasts persists.

A second advantage of the model system is that it integrates the forecasts of diverted trips and generated trips by using models that are linked to each other. Information from the mode/route choice models is used in the destination model, and information from the destination model is used in the trip frequency model. Therefore, projections of the different components of travel are consistent with each other. Often in intercity forecasting efforts, forecasts of generated and diverted trips are developed independently for individual market segments, leading to inconsistencies.

Another advantage of the approach is that it relies on fairly sophisticated statistical estimation procedures that are rooted in microeconomic consumer theory, but that can be applied effectively without a detailed knowledge of the estimation procedures. To accomplish this, the model system has been converted to a spreadsheet application for ease of use.

The final advantage of the modeling approach is that the resulting forecasting tool is flexible, which allowed a range of high-speed rail operating scenarios to be tested.

Detailed Market Definition and Identification

At the beginning of the passenger demand forecasting effort, a segmentation scheme was developed for the BMHSR Corridor. Segmentation defines the pieces of the BMHSR Corridor and allows them to be assigned values, such as travel times, that affect the potential ridership in the BMHSR Corridor. While the ultimate market segmentation was developed through testing a variety of service scenarios, the results from each iteration of the model provided valuable information regarding the influence of each variable and its effects on BMHSR Corridor ridership including sub-market travel patterns.

Initial travel markets were defined based on trip purpose, directionality, traveler characteristics, and characteristics of the journey (number of days away from home, need for an auto at the destination, etc.). To ensure that all relevant market data was obtained during the data collection process, a complete list of potential travel markets was developed prior to the design of the travel surveys.

In addition to defining travel markets, the project's study area was established. For the purpose of this model, the study area included all cities that were served by rail service between Boston and Montreal. Within the study area, analysis zones were defined.

In total, the travel demand model developed for the BMHSR Study accounted for several key inputs:

- Zone-Based demographic and development data and forecasts;
- Level of service data by mode;
- Travel volume statistics;
- Available intercity travel patterns data; and
- Travel survey data (stated preference).

Zone-Based Demographic and Development Data and Forecasts. Zone-based data and forecasts provide measures of the overall attractiveness of individual zones as long-distance trip destinations, and are used to determine the overall growth in BMHSR Corridor intercity trips. Relevant base year and forecast year data include:

- Population by zone;
- Households by income category;
- Employed labor force;
- Total employment;
- Employment by sector;
- Land area and;
- Population and employment densities.

These data were assembled from the U.S. Census Bureau, Statistics Canada, state and provincial demographers' offices, state and provincial agencies such as the offices of labor and tourism, and metropolitan planning organizations (MPOs). In addition, county level forecasts were obtained from commercial data sources.

Level of Service Data by Mode The model system relies on a database of level-of-service data for each travel mode which provides current information on and forecasts of the various components of travel time, travel cost, and service frequency by each intercity mode in the study area.

The primary source of highway-related time and operating cost data is existing highway planning networks, combined and modified to incorporate the larger intercity zone system. Statewide models were also used to obtain intercity highway times and costs, and metropolitan models were used to obtain access and egress costs and times for public transportation modes. Travel times, costs, and frequencies for airlines, intercity buses, and Amtrak services were obtained from timetables and fare schedules.

The components of the travel levels-of-service include:

- In-vehicle travel time: Terminal-to-terminal (airport-to-airport, bus station-to-bus station, and rail-station-to-rail station) times for public modes; Door-to-door times for auto trips. These times were developed from Statewide and Provincial travel demand model travel times.

- Access/egress time: Time to travel between trip origins and origin terminals (airports, bus and rail stations), plus time from the destination terminals to trip destinations; Access/egress times are not relevant for auto trips. These times were developed from Statewide and Provincial travel demand model travel times.

- Terminal time: Time needed at origin and destination terminals to check-in, deal with baggage, and maneuver through customs/immigration; for auto trips, terminal processing time is the customs/immigration time at the border crossing, plus (for longer trips only) time for one twenty minute break in driving.

- Frequency: Number of services per day offered by public modes; not relevant for auto trips;

- Fares: Cost per person to use the public modes; not relevant for auto trips;

- Auto operating cost: Per-mile cost per vehicle; not relevant for public mode trips. The cost of $0.12 per mile was used based on operating cost estimates developed by the American Automobile Association (AAA). These costs include the average per mile cost of gas, oil, and tires. They do not include ownership related costs of the vehicles. The average auto occupancy for relevant trips was set to 1.8 persons per vehicle based on the travel survey results.

- Access/egress cost: Per-mile cost per person to go between trip origins and origin stations and to go between destination stations and trip destinations. This is not applied to auto trips.

Travel Volume Statistics To calibrate and fine-tune the estimated model system to more accurately reflect actual base-year travel patterns, travel data collected by local agencies and transportation providers were used. Aggregate statistics assembled through this process reflect summary counts of passengers using each of the modes under study. Traffic counts from the states and Quebec transportation agencies were also incorporated. Aviation data was obtained via origin-destination aviation data from Back Aviation Solutions, a commercial vendor of airline industry data, and the U.S. Department of Transportation and Statistics Canada databases. In addition, travel volumes for both intercity bus and rail service providers were obtained from public and private sources.

Intercity Travel Patterns Data Prior to the start of this study, limited data sources existed to estimate travel behavior and preferences data needed for developing high-speed rail ridership forecasts in the corridor. Nevertheless, data from several surveys and travel demand models were used to validate the intercity model. Among these data were the outputs of statewide and provincial travel demand models, the American Travel Survey dataset, the Nationwide Personal Transportation Survey dataset, and household travel surveys and vehicle intercept surveys recently performed in the corridor, including information from recent Canadian studies. In addition, available tourism data was assembled from the various tourism agencies in the corridor.

Based on the statewide and provincial models, there are a substantial number of annual trips within the corridor. However, the BMHSR system will serve only a segment of these trips: the longer distance intercity trips. Table 3.27 shows the forecast number of interstate trips of more than 50 miles in the corridor. It is important to note that the figures shown in this table under represent the number of corridor trips that the BMHSR service will affect. Longer distance intrastate trips will also be served by the BMHSR, as will shorter distance trips where HSR station-to-station travel is a reasonable alternative. The number of trips in the corridor that fit these descriptions and that are eligible for the BMHSR to serve depends on the location and number of stations.

Table 3.27 – Forecast of Year 2025 Annual Interstate Trips of More than 50 Miles

From:	**To:**				
	Massachusetts	**New Hampshire**	**Vermont**	**Quebec**	**Total**
Massachusetts	---	7,096,831	1,277,795	722,130	**9,096,756**
New Hampshire	7,096,831	---	1,231,344	439,190	**8,767,365**
Vermont	1,277,795	1,231,344	---	705,637	**3,214,775**
Quebec	722,130	439,190	705,637	---	**1,866,957**
Total	**9,096,756**	**8,767,365**	**3,214,775**	**1,866,957**	**22,945,853**

Source: Cambridge Systematics, Inc. based on Statewide and Provincial Models, American Travel Survey, and Stats Canada International Travel Surveys, 2002.

As discussed, the year 2025 trip forecasts are based on the projected growth in corridor trips that have been forecast by the Statewide and Provincial travel demand models. The number of corridor trips forecast for 2025 is about 22 percent higher than that of the year 2000. This represents about a 0.8 percent annual increase in long-distance corridor travel.

Development of the Modeling System

The development of the ridership model required the estimation and linkage of three separate categories of models. The three categories of models can be summarized as follows:

1. The **Mode Choice Models** relate travelers' choice of a mode to the level of service and price attributes of the competing options;

2. The **Destination Choice Models** relate travelers' choice of a destination to attributes of the destination and the level of service provided to each destination; and

3. The **Trip Frequency Models** relate the number of trips taken by different travelers to their socioeconomic characteristics and the overall accessibility offered by the multi-modal transportation system.

These three main modeling components are discussed below.

Mode Choice Models The mode choice model development includes the estimation and validation of a group of market specific models. The key methodological issue for the mode choice models relates to the use of the available travel data. This modeling effort relied to the greatest extent possible on the revealed-preference data to estimate models of mode choice behavior for the base year. In addition, the data collected through the stated-preference surveys was used to guide the assessment of the attractiveness of intercity rail services that might be available in the future-year horizon. The mode choice models relate the choice of travel mode to specific characteristics of the traveler, the trip being made, and attributes of each mode.

The modal estimation effort was an iterative process. Many different modal specifications with various combinations of explanatory variables and model structures of different complexity were tested until a set of final models was developed. The estimation process began by testing simple model specifications and as information about particular variables was included, more complex model specifications and model structures were created and evaluated.

The basic decisions in developing the mode choice models were:

- The selection of the variables to be included in the utility function for each mode along with the mathematical forms of each variable; and

- The selection of the appropriate model structure (multinomial logit or nested logit) as allowed by the data and the nature of the choice behavior under study.

The estimated mode choice model was validated to ensure that the model outputs were reasonable and accurate when evaluated in comparison to observed and known travel conditions and behavior. The model validation steps consisted of the following:

- Reasonableness checks;
- Disaggregate validation; and
- Aggregate validation.

Reasonableness checks consist of comparisons of model parameters and results to known or expected values. This form of model validation was conducted throughout the model estimation process on each interim model result. The **d*isaggregate validation*** consisted of tests where the model was applied to see whether the results match observed or expected values. The best way to do this is to apply each model to a disaggregate data set other than the one from which the model was estimated. For the purpose of this study, information from the *American Travel Survey* and other data sources were used. Finally, the model used an **a*ggregate validation*** process to compare the model results to known aggregate data that was not used in model estimation.

Destination Choice Models Destination choice models were used to describe the probability that individuals will decide to travel for a specific purpose to a particular destination rather than other destinations that are available in the study area based on:

- The relative ease or difficulty of travel to the destination in question compared to the other destinations;
- The relative size or attractiveness of the zone under study compared to the other zones;
- Unobserved characteristics of the destination zone; and
- Characteristics of the household or the individual decision maker.

The destination model used a set of traditional gravity models complemented by a multinomial logit model with the model zones as potential choices to determine the effect on intercity travel levels that would occur if one or more of these destinations became more accessible to other BMHSR Corridor locations through the introduction of high-speed rail service.

Trip Frequency Models The objective of the trip frequency model estimation was to examine the number of trips made by each purpose to all of the available destinations, and to quantify the determinants of a traveler's trip making. The model structure uses trip frequency categories to differentiate among travelers with different travel patterns. The utility of each trip frequency category is that it accounts for a traveler's socioeconomic characteristics associated with his/her propensity to travel and the composite utility of traveling to all the destinations that are included as part of the study area. Existing data sources and the recently completed surveys provided the necessary travel data, including retrospective descriptions of all household intercity trips made over an extended period within the study area. The surveys completed through the course of this study also provided household characteristic data that provides explanatory variables in the trip frequency models.

The accessibility measures used in the modeling process were developed from the mode and destination choice models. These measures capture the differences in the ability of residents of different study area zones to travel to all the other study area zones. The hypothesis underlying the trip frequency models is that residents of zones from which it is easier to travel will on average have higher trip rates than residents of zones from which it is more difficult to travel. The implication of this hypothesis in forecasting is that major improvements in transportation infrastructure which improve the accessibility of potential travel destinations, such as the addition of a high-speed rail line, will increase trip rates.

The destination choice and trip frequency phases of model development provide future-year origin-destination trip tables for the study area that are sensitive to changes in transportation infrastructure, such as the proposed intercity rail service. These future-year trip tables reflect changes in both the total amount of travel between the base and future years and the distribution of travel among the various origin-destination zone pairs.

Model Alternatives

The project steering committee reviewed seven alternative service scenarios to determine the potential ridership range of the BMHSR service. Initially three base alternatives were defined: low speed, mid speed and high speed. Operating speeds were developed based on existing conditions for the low speed scenario, 110 mph with FRA regulation restrictions for curves and travel through towns for the mid-speed scenario, and unrestricted 110 mph for the high-speed alternative.

To test sensitivity of the ridership to variations in the services, five scenarios were developed for the mid speed alternative. These variations include:

- **Mid Speed Base Case**: In this alternative, the mid speed scenario was tested with an assumed cost of $0.26 cents per mile. The fare rate was selected based on a fare of approximately 80 percent of the cost of an airline ticket. This costing assumption was utilized in the FRA Report *High-Speed Ground Transportation for America*.[3]

- **Mid Speed High Fare**: In this alternative, the mid speed scenario was tested with an increase in the cost per mile. The mid speed high fare scenario raised this fare to $0.30 cents per mile. This reflects the upper range of HSR corridor costs per mile.

- **Mid Speed Low Frequency**: In this alternative, the mid speed scenario was tested with a decrease in the frequency of service. In the original mid speed alternative, trains were tested with an operational frequency of six trains per day, the mid speed low frequency scenario decreased the number of trains from six to two.

[3] U.S. Department of Transportation, September 1997.

- **Mid Speed All Stations**: In this alternative, the mid speed scenario was tested with additional station stops. In the original mid speed alternative, trains served eight station locations, the mid speed all stations scenario increased the number of stations from eight to twelve. It is important to note however, that for the purpose of this test travel time was held constant to test the sensitivity of the number of station stops at this level of analysis.

- **Mid Speed Low Fare**: In this alternative, the mid speed scenario was tested with a decrease in the cost per mile. The mid speed low fare scenario decreased fares to $0.20 cents per mile. The fares of the Amtrak Vermonter and Downeaster trains range between $0.16 and $0.26 per mile for relevant station pairs. Thus, the fare rate of $0.20 per mile was selected to test the average fare rate of these two existing New England intercity trains.

Model Results

Table 3.28 provides definitions of the operational scenarios used to estimate ridership for the BMHSR service. This table outlines the service parameters including cost, frequency and speed of service for each of seven scenarios: low speed, mid speed, mid speed high fare, mid speed low fare, mid speed low frequency of service, mid speed all station stops and high speed.

By applying the parameters shown in Table 3.28 to the model, ridership numbers have been generated for each of the seven alternative scenarios. Table 3.29 provides a summary of each scenario's projected ridership along with other pertinent service information such as trip time from Boston to Montreal.

Total trip time for each alternative can be calculated by adding the in vehicle trip time and terminal time. Terminal time for BMHSR service includes time required to be at the station in advance of the train as well as customs/immigration processing time. Terminal time for air travel was estimated based on arriving at the airport one hour in advance of the flight and one hour to complete customs/immigration processing. Terminal time for bus includes time to arrive before the bus gets to the station and processing time at the border. Auto terminal time includes 20 minutes for customs and immigration processing and a 20-minute gasoline/services break. It is anticipated that by the time a BMHSR service is implanted, US/Canadian border regulations would be developed to allow operation with no stops at the border for customs or immigration services. For further discussion, see section 4.4.

Table 3.28 – Scenario Definitions for BMHSR Ridership Forecasts*

Parameters	**Scenario Name**						
	Low Speed	**Mid Speed**	**Mid Speed High Fare**	**Mid Speed Low Freq**	**Mid Speed All Stations**	**Mid Speed Low Fare**	**High Speed**
Trip Table	Year 2025 trip tables synthesized from statewide and MTQ demand models for all alternatives.						
High Speed Rail Characteristics							
Stations:	Boston Woburn Lowell Nashua Manchester Concord Franklin White River Junction Montpelier Burlington/ Essex Junction St. Jean Montreal	Boston Lowell Manchester Concord White River Junction Montpelier Burlington/ Essex Junction Montreal	Boston Lowell Manchester Concord White River Junction Montpelier Burlington/ Essex Junction Montreal	Boston Lowell Manchester Concord White River Junction Montpelier Burlington/ Essex Junction Montreal	Boston Woburn Lowell Nashua Manchester Concord Franklin White River Junction Montpelier Burlington/ Essex Junction St. Jean Montreal	Boston Lowell Manchester Concord White River Junction Montpelier Burlington/ Essex Junction Montreal	Boston Lowell Manchester Concord Burlington/ Essex Junction Montreal
Travel Times	475	288	288	288	288	288	211
Fares	$0.16	$0.26	$0.30	$0.26	$0.26	$0.20	$0.36
Train Frequency	4 trains per day in each direction	6 trains per day in each direction	6 trains per day in each direction	2 trains per day in each direction	6 trains per day in each direction	6 trains per day in each direction	8 trains per day in each direction
Access and Egress Times and Costs Based on future year highway origin/destination tables from available demand models for all alternatives. Additional terminal processing times were added to each mode to account for ticketing/check-in, security procedures, and baggage processing.							
Competitive Mode Characteristics							
Auto times	Based on future year highway origin/destination tables from available demand models.						
Auto Operating Cost	$0.12 per mile	$0.12 per mile	$0.12 per mile	$0.12 per mile	$0.12 per mile	$0.12 per mile	$0.12 per mile
Intercity bus times, fares and frequencies	Current year operating levels as reported on Vermont Transit, Concord Trailways and Dartmouth Coach websites						
Airline times, fares and frequencies	Current year operating levels as reported in the OAG with representative fares of US$102 for Boston-Montreal and US$96 for Boston-Burlington						
Competing Rail Services	Montrealer, Downeaster, and commuter rail lines: - Haverhill Line as currently configured - Lowell Line extended to Nashua - Montreal Delson Line extended to St. Jean Fare per mile, speeds, and frequencies assumed to be the same as current						

*All figures in 2001 U.S. dollars.
Source: Cambridge Systematics, Inc. Model Input Assumptions, 2002.

Table 3.29 – 2025 Summary Table of BMHSR System Ridership

	Low Speed	Mid Speed	Mid Speed High Fare	Mid Speed Low Frequency	Mid Speed All Stations	Mid Speed Low Fare	High Speed
Annual Ridership							
Total Corridor	213,276	446,710	330,097	86,962	588,630	683,667	644,232
Boston-Montreal	13,469	129,508	84,428	27,143	129,508	221,227	200,564
Annual Passenger Revenue							
Total Corridor	$4,784,504	27,893,059	22,559,907	5,724,020	32,291,348	34,614,601	59,062,561
Boston-Montreal	$744,341	11,619,093	8,739,297	2,434,820	11,619,093	15,271,257	24,917,799
Annual Passenger-Miles							
Total Corridor	29,903,149	107,267,243	75,189,849	22,013,126	124,183,740	173,050,633	164,062,668
Boston-Montreal	4,652,131	44,688,819	29,130,991	9,364,691	44,688,819	76,356,287	69,216,109
Cost per Passenger Mile							
HSR	$0.16	$0.26	**$0.30**	$0.26	$0.26	**$0.20**	$0.36
Auto	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12
Air	$0.31	$0.31	$0.31	$0.31	$0.31	$0.31	$0.31
Bus	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14	$0.14
Frequency							
HSR	4	6	6	**2**	6	6	8
Air	8	8	8	8	8	8	8
Bus	6	6	6	6	6	6	6
Auto	NA	NA	NA	NA	NA	NA	NA
Number of Stations	12	8	8	8	**12**	8	6
HSR Speed	60 mph	110 mph restricted	110 mph restricted	110 mph restricted	110 mph restricted	110 mph restricted	110 mph no restrictions
Average Miles per Hour	41 mph	68 mph	68 mph	68 mph	68 mph	68 mph	92 mph
In Vehicle Trip Time (mins)							
HSR**	475	288	288	288	288*	288	211
Air	80	80	80	80	80	80	80
Bus	320	320	320	320	320	320	320
Auto	312	312	312	312	312	312	312
Terminal Time (mins)							
HSR	60	60	60	60	60	60	60
Air	120	120	120	120	120	120	120
Bus	60	60	60	60	60	60	60
Auto	40	40	40	40	40	40	40
Total Trip Time (hours)							
HSR	8h 55m	5h 48m	5h 48m	5h 48m	5h 48m	5h 48m	4h 31m
Air	3h 20m	3h 20m	3h 20m	3h 20m	3h 20m	3h 20m	3h 20m
Bus	6h 20m	6h 20m	6h 20m	6h 20m	6h 20m	6h 20m	6h 20m
Auto	5h 52m	5h 52m	5h 52m	5h 52m	5h 52m	5h 52m	5h 52m

Notes: *Travel trip time was not increased to test only the sensitivity of number of stations stops at this level of the analysis.

** Travel time for HSR service can vary depending on equipment choice. For this analysis, F-59 PH locomotive and Bombardier Bi-Level coach technologies were selected because they are widely used for the delivery of rail service in a multitude of passenger corridors throughout United States. See Chapter 2 for details. All dollar figures are shown in year 2001 U.S. dollars.

Source: Cambridge Systematics, Inc. Model Input Assumptions, 2002.

Ridership for each of the BMHSR alternative varies significantly depending on the service attributes. For example, the reduction of service levels on the mid speed scenario from six trains per day to two trains per day resulted in a drop in ridership levels to less than 20% of the ridership for the six trains a day scenario. Furthermore, reduction in the fares from $0.26 per mile to $0.20 per mile resulted in an increase of ridership from 446,710 to 683,667. Interestingly, the increase in ridership at the lower fare actually resulted in a 24% increase in total passenger revenue. The following provides a summary of each scenario:

- **Low Speed Scenario**: The low speed scenario provided the second lowest ridership of any of the alternatives. With a travel time between Boston and Montreal of nearly nine hours, projected ridership levels within the BMHSR Corridor on this alternative only reached 213,276, with only 13,469 riders traveling the full distance between Montreal and Boston.

- **Mid Speed Scenario**: The mid speed scenario projected ridership of more than double that of the low speed scenario. Aside from increased operating speed, this alternative also ran an increased number of trains from the low speed alternative, six versus four, however, the mid speed only stopped at eight stations as compared with the low speed alternative which stopped at twelve station locations.

- **Mid Speed High Fare**: In this alternative, the mid speed scenario was tested with an increase in the cost per mile. In the original mid speed alternative, fares were listed at $0.26 cents per mile, the mid speed high fare scenario raised this fare to $0.30 cents per mile. This increase resulted in a decrease of ridership of 26 percent, highlighting the fare sensitivity of ridership in the BMHSR Corridor.

- **Mid Speed Low Frequency**: In this alternative, the mid speed scenario was tested with a decrease in the frequency of service. In the original mid speed alternative, trains were tested with an operational frequency of six trains per day, the mid speed low frequency scenario decreased the number of trains from six to two. Results of this service reduction caused ridership to plummet, resulting in the lowest ridership of any of the alternatives (86,962 annual riders). This indicates the importance of frequent service to attract riders.

- **Mid Speed All Stations**: In this alternative, the mid speed scenario was tested with additional station stops. In the original mid speed alternative, trains served eight station locations, the mid speed all stations scenario increased the number of stations from eight to twelve. It is important to note however, that for the purpose of this test the travel time for this alternative was not increased. Results of this alternative showed particularly heavy ridership gains in the vicinity of Concord and Saint-Jean-sur-Richelieu.

- **Mid Speed Low Fare**: In this alternative, the mid speed scenario was tested with a decreased cost per mile. In the original mid speed alternative, fares were listed at $0.26 cents per mile, the mid speed low fare scenario used a fare of $0.20 cents per mile to estimate ridership. In this scenario, the ridership increased by more than 50 percent, resulting in the highest projected ridership of any of the alternatives.

- **High Speed Scenario**: The High Speed Scenario for the BMHSR service projected the second highest ridership and the highest passenger revenue of any of the alternatives. Under the high-speed rail alternative, fares were increased to $0.36 per mile and the number of stations was reduced to 6 key locations. In addition, the frequency of the service was increased to 8 round trips per day.

Diverted and Induced Trips

Most of the trips projected to be taken by the BMHSR Service users are diverted from other modes. That is, the trips would have occurred without the construction of the BMHSR but would have used another mode, in this case mainly automobile, to make the trip. In addition, each alternative also produces additional trips that would not have been taken without the availability of the BMHSR. These trips are called "induced" trips. Table 3.30 provides a breakdown of each of the alternatives by diverted and induced trips.

Table 3.30 – Annual Diverted and Induced Trips by Service Alternative

	Diverted	Induced	Total
Low Speed	205,230	8,046	213,276
Mid Speed	435,152	11,558	446,710
Mid Speed High Fare	320,826	9,271	330,097
Mid Speed Low Frequency	86,651	311	86,962
Mid Speed All Stations	570,291	18,338	588,630
Mid Speed Low Fare	666,983	16,685	683,667
High Speed	627,785	16,447	644,232

Source: Cambridge Systematics, Inc. Travel Demand Model Output, 2002.

Appendix A provides a series of station by station matrices for diverted and induced ridership based on the service parameters presented in Table 3.27 and 3.28. Overall, the proportion of induced trips for the BMHSR service is relatively small, ranging from 0.4% to 3.8% depending on the alternative.

Additional Ridership

The ridership analysis conducted for this feasibility study focused on long distance travel within the corridor study area. However, high-speed rail investment will support a number of additional rail traveler benefits to the corridor, and could attract additional rail passengers.

BMHSR passengers will find improved connections with other intercity rail services. In Montreal, VIA Rail provides service to most other major Canadian cities. From Boston North Station, Amtrak provides the Downeaster service to Portland, ME, and from Boston South Station, Amtrak serves the Northeast Corridor and the rest of the U.S. national rail network. The BMHSR service can therefore allow rail to be used for a wider range of origins and destinations for trips that have one end in the corridor and for through trips.

In addition to connecting rail service opportunities, BMHSR service could become an option for corridor residents seeking to make long distance air trips. BMHSR Corridor residents frequently travel long distances by auto and bus to reach Boston Logan Airport to complete travel throughout the world. BMHSR trains could provide this service, as well (albeit with the need for a short shuttle trip between the rail station and the airport). Similar service could be provided in Montreal where airport-rail station access service already exists.

Since the construction of BMHSR will result in improvements to the existing track and structure over which the MBTA, Amtrak, VIA Rail and Montreal commuter rail systems are operated, improvements in travel times and reliability for passengers of all these services could be realized. Because extensions of existing MBTA commuter rail operations into southern New Hampshire is actively being studied, this study did not focus on the large potential of attracting shorter distance commuter trips. Depending on the conclusions of the commuter rail analysis, significant additional ridership could be realized for the BMHSR service.