MEMORANDUM

TO: **Transportation Planning and Programming Committee** **April 1, 2009**

FROM: **Alicia Wilson**

RE: **Executive Summary: Alewife Station: Improvements to Feeder Bus Routes, Bus Access and Egress, and Route 2/Route 16 Intersection**

INTRODUCTION

On August 2, 2007, the Transportation Planning and Programming Committee of the MPO approved the technical memorandum "Route 2/Route 16 (Alewife Brook Parkway) Eastbound: Traffic Patterns and Alewife Station Garage Survey," which documented Phase I of the present study. In Phase I, staff recorded vehicle license plate numbers at nine roadway locations in the vicinity of the MBTA's Alewife Station and at the garage. Another task was to survey bicyclists who parked at the bicycle parking spaces of the garage. By matching the license plates of observed vehicles between logical survey location sets and to the Registry of Motor Vehicles (RMV) town-of-origin file, staff were able to identify travel patterns through the study area, including the spatial distribution of vehicles by town of origin.

The tasks of the second phase of this study, which is complemented by MAPC's Alewife Bicycle and Pedestrian Access Study, were to:

1. Reevaluate the traffic patterns that emerged from the Phase I license plate survey using the most recent RMV vehicle garage information.
2. Recommend improvements to MBTA feeder bus service to Alewife Station in order to increase feeder bus ridership to the Red Line.
3. Identify improvements to MBTA feeder bus access/egress between the Alewife garage and Route 2.
4. Recommend operational improvements to the Route 2/Alewife Brook Parkway (Route 16) intersection.

Three memos were produced during the course of Phase II:

1. 2006 Alewife License Plate Data Rematching with 2008 RMV Database, February 29, 2008
2. Recommended Improvements to MBTA Feeder Bus Routes to Alewife Station to Increase Feeder Bus Ridership to the Red Line, January 13, 2009

3. Traffic Operations and Bus Access and Egress at the Route 2/Route 16 Intersection and the Alewife MBTA Garage: Existing Conditions and Recommended Improvements, March 19, 2009

They are summarized below and included in the appendix in their entirety.

TECHNICAL MEMORANDA SUMMARIES

2006 Alewife License Plate Data Re-matching with 2008 RMV File

License plate data collected for the Alewife Phase I study[1] at ten locations on November 15, 2006, was initially matched with 2003 Registry of Motor Vehicles (RMV) files to determine the community in which each vehicle is garaged. The plates of 56% of total vehicles were matched with the 2003 file, with location matches ranging from a low of 50% to a high of 61%. (Unmatchable plates such as police, fire, and out-of-state vehicles were not included in the match rate.) A few TPPC members questioned the validity of the results given the age of the RMV file and requested that the data be rematched when new RMV files were received.

CTPS received the 2008 RMV files in February 2008. The plates of 81.8% of total vehicles were matched with this file, with match rates by location ranging from a low of 74.3% to a high of 86.4%. The older file produced fewer matches because, during the intervening years, people moved and registered their vehicles in different communities, and new vehicles were registered.

The margin of error for the 95% confidence level was used for the origin data. This means that for any location, the estimate of the proportion of vehicles originating in any given community falls within the range of plus or minus the margin of error 95% of the time. For example, with the 2003 file, it was estimated that 13% of the vehicles observed southbound on Alewife Brook Parkway at the Fresh Pond Rotary in Cambridge originated in Lexington, and the margin of error for this location is ± 1.5%. Then, 95% of the time, the proportion from Lexington would range between 11.5% and 14.5%. In other words, if this survey were conducted 100 times, 95 of those times the proportion of people from Lexington would be within 1.5 points of the percentage found in this survey. Excluding the "Other Massachusetts" category, the origin tables contain a total of 267 entries. Only six of the entries from the 2008 rematching (shaded in the tables) fall outside the margin of error. Five of the six are only one half of one percent or less outside the expected values, and that degree of difference might be attributable to rounding.

The conclusion is that the new origin tables validate the statistical methods used and indicate that conclusions drawn from using the 2003 RMV files are valid.

[1] Route 2/Route 16 (Alewife Brook Parkway) Eastbound: Traffic Patterns and Alewife Station Parking Garage Survey, July 19, 2007.

Recommended Improvements to MBTA Feeder Bus Service to Alewife Station in Order to Increase Feeder Bus Ridership to the Red Line

Phase I analysis revealed that almost one-third of vehicles observed parked at the Alewife MBTA station are garaged in Arlington and Lexington, both of which have bus service to the MBTA station. One of the tasks of the Phase II study was to examine the coverage of the bus routes to the garage to determine whether changes are needed to maximize their ridership potential.

Analyses revealed that MBTA bus routes generally operate on major roads in Arlington and Lexington; however, several routes do run on local roads in each community. Current routing of MBTA bus service through the study area seems to be appropriate. There is more service in densely populated neighborhoods. Block groups with the lowest level of vehicle ownership generally have the largest proportions of Boston/Cambridge commuters who live within one-quarter mile of an MBTA bus stop; have lower levels of single-occupancy-vehicle trips to Boston and Cambridge; and generally have fewer vehicles parked in the Alewife garage. In addition, bus service seems to effectively serve those with lower incomes, as 81% of those who have household incomes below the MPO median live within one-quarter mile of a bus stop.

Traffic Operations at the Route 2/Route 16 Intersection in Cambridge and Bus Access/Egress from the Alewife Garage

The intersection of Route 2 and Route 16 in Cambridge currently experiences long delays and queues during the morning and the evening peak periods, with roadway segment travel speeds consistently ranging from less than 10 mph to about 30 mph. These delays and queues also significantly impact MBTA bus travel times and possibly bus ridership. The two roadways fall under two different jurisdictions, MassHighway and the Department of Conservation and Recreation (DCR), with the traffic signal being operated by DCR.

In addition to the Route 2/Route 16 intersection, bus access to Alewife Station from Route 2 is provided along a service road, Alewife Station Service Road, which exits directly from Route 2 eastbound approximately 1,400 feet prior to the intersection. This service road also provides access to Acorn Park. Entrance to the ramp leading from Route 2 eastbound to the service road is often blocked by traffic queued at the Route 2/Route 16 intersection.

In May 2008, Massachusetts State Senator Stephen Tolman's office organized a working group to examine traffic operations in the Alewife area and at the intersection of Cambridgepark Drive and Route 16 in particular. The group included representatives from state, regional, and local agencies, as well as from the private sector. Several improvement options beyond the scope of the Alewife Phase II project were modeled and analyzed.

The options listed below are a comprehensive list developed within the context of this study and from the work of the Alewife Working Group. Some options were analyzed quantitatively using the microsimulation software VISSIM[2] or the software SYNCHRO,[3] and others were analyzed qualitatively. Of the eight options, the first four are low- to medium-capital-investment options; the last four are high-capital-investment options.

1. Optimize signal timings
2. Replace existing left-turn lane from Route 2 eastbound to Route 16 northbound with a double left-turn lane
3. Eliminate Route 2 eastbound left turns and divert traffic to Alewife Station Road
4. Add a third lane along Route 2 westbound from the Alewife Station Access Road approach to just past the Minuteman Bike Path overpass
5. Construct a fly-over from Route 16 northbound to Route 2 westbound
6. Replace intersection with conventional roundabout
7. Replace intersection with roundabout, including right-turn slip ramps
8. Replace intersection with roundabout, including a fly-over for traffic from Route 16 northbound to Route 2 westbound.

IMPROVEMENT RECOMMENDATIONS

Bus Service

The following are route modifications that would be expected to encourage more commuters to ride buses to Alewife Station. Possible difficulties are also mentioned.

- The MBTA does not have a service standard pertaining to the spacing of bus route stops. (The MBTA is working on a draft standard.) Local communities generally dictate placement and spacing of stops. The literature reveals that bus stop spacing affects demand by impacting access and travel time. "In general, there is a tradeoff between closely spaced, frequent stops with a shorter walking distance but more time on the vehicle and stops spaced further apart with a longer walking distance, but less time on the vehicle."[4] DC Metro officials indicate that bus service would be 20-30% faster in limited-stop corridors. After introducing skip stop service, which combines both local stop and limited-stop sections, Dallas Area Rapid Transit (DART) officials indicate that ridership increased by 12.3% and speed increased by 10% during a one-year period.[5] A CTPS memorandum indicates that a bus route strategy in a selected corridor that includes fewer bus stops would bring about reductions in peak hour average bus travel time that are in the range of those observed by D.C. Metro and DART.[6] With community input

[2] *Vissim Version 5.0*, PTV America, 2007
[3] *Synchro/SimTraffic Version 6*, Trafficware Corporation, 2003.
[4] *DC Metro May Increase Bus Stop Spacing to Improve Service*, The Urban Transportation Monitor, June 13, 2008, p. 1.
[5] Ibid., p2.
[6] "MBTA Transit Signal Priority Study: Arborway Corridor," draft memorandum, CTPS, July 11, 2008, p. 13.

and an awareness of local characteristics, consideration should be given to modifying the spacing of stops on some or all of the bus routes in the study area.

- Route 67 runs along the border of an Arlington block group that has one of the lowest levels of accessibility to bus service in Arlington, and the route also has a spur (now inactive until redevelopment in the area is complete) into that block group. Forty-seven percent of commuters from this block group to Boston and Cambridge live within one-quarter mile of this bus route, which appears to be routed through an area with less dense development near the former Symmes Hospital. The number of vehicles from this block group parked at the Alewife garage falls in the highest category of vehicles parked. Perhaps more of these commuters would use the bus if the bus were routed through the denser areas of the block group. However, the hilly terrain in this area is a possible impediment to rerouting buses here.

- At one point, the Route 67 bus extended from Turkey Hill in Arlington into a section of Lexington that has LEXPRESS service, but that portion of the route was discontinued. Perhaps the feasibility of reinstating the extension could be explored. However, the existing route already operates on a loop. Lengthening the distance and increasing the headway could affect existing ridership.

- Better coordination between LEXPRESS and MBTA services, particularly in Lexington Center, might attract some additional commuters; however, people generally dislike bus-to-bus transfers, and they would also have to pay fares on both the LEXPRESS buses and the MBTA buses. Coordinating services might add to LEXPRESS operating costs. Several LEXPRESS routes have sections in common with MBTA Routes 62/76. Since LEXPRESS stops on demand outside Lexington Center, riders can be encouraged to transfer to MBTA routes to Alewife.

- Under the Boston Region MPO's Suburban Mobility Program, the Town of Lexington could apply for funds for a peak period shuttle to Alewife. If the shuttle were to prove that there is ridership, perhaps the MBTA could offer service.

The Route 2/Route 16 Intersection and Bus Access/Egress to Alewife Station

Based on the quantitative and qualitative analyses of the various options and strategies for improving traffic operations at the Route 2/Route 16 intersection and for improving access to and egress from Alewife Station, staff have the following recommendations, made in conjunction with the Alewife Working Group.

- Adding a third westbound lane (Option 4) for a short distance between the Alewife Station Access Road approach (jug-handle) and the Minuteman Bike Path overpass is effective in reducing delays and queues at this intersection. The additional lane capacity frees up traffic signal green time for reallocation to other approaches, including the Alewife Station Access Road, resulting in shorter queues and delays on all approaches. Right-of-way is available for the portion of the third lane within the intersection. Right-of-way also appears to be available for the lane segment between the intersection and the Minuteman Bike Path overpass; however, the additional roadway width would have to be secured from an existing (possibly unused) sidewalk. The availability of right-of-way between the point where the Route 16 northbound approach meets Route 2 westbound and the overpass needs to be investigated further, including the need for a pedestrian corridor north of Route 2. Extending the third lane to Lake Street is not required in the short term but should be considered in the longer term.

- Reconstructing the Route 2 eastbound left-turn lane to Route 16 north into a double left-turn lane (Option 2 and also part of Option 4) would further benefit this intersection, as it would help reduce eastbound queuing on Route 2.

- Reconstructing the Alewife Station Access Road (jug-handle) into two lanes for as far back as possible would allow for bus and vehicle storage and for a priority bus lane with traffic signal priority for the buses.

- Following all above reconstruction, the traffic signal design would have to be reconsidered, including new equipment for demand-responsive operation and detectors/sensors for bus priority.

Excluding design and right-of-way, cost estimates for the recommended Route 2/Route 16 intersection improvements range between $200,000 and $400,000.

Potential implementation issues and opportunities include:

- The usefulness and purpose of the sidewalk along Route 16 southbound needs to be investigated.

- There are multiple stakeholders (DCR, MassHighway, City of Cambridge, Town of Arlington) that need to be consulted, with opportunities for cooperation and partnerships.

- Informing the general community in the area and seeking its support and cooperation are very important.

- Opportunities for regional programming or MassHighway and DCR standard maintenance could be sought for implementation of some of these improvements.

- Opportunities for development mitigation for some of these improvements need to be sought by the City of Cambridge.

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APPENDIX

MEMORANDUM

TO: **Transportation Planning and Programming Committee** **February 29, 2008**

FROM: **Alicia Wilson**

RE: **2006 Alewife License Plate Data Rematching with 2008 RMV Database**

BACKGROUND

License plate data collected for the Alewife Phase I study[1] at 10 locations on November 15, 2006, was initially matched with 2003 Registry of Motor Vehicles (RMV) database to determine the community in which each vehicle was garaged. The plates of 56% of total vehicles were matched with the 2003 database, with match rates by location ranging from a low of 50% to a high of 61%. (Unmatchable plates such as those of police, fire, and out-of-state vehicles were not included in the match rates.) A few TPPC members questioned the validity of the results given the age of the RMV database and requested that the data be rematched when new RMV database were received.

CTPS received the 2008 RMV database in February 2008. The plates of 81.8% of total vehicles were matched with this database, with match rates by location ranging from a low of 74.3% to a high of 86.4%. The older database produced fewer matches because, during the intervening years, people moved and registered their vehicles in different communities, and new vehicles were registered.

ANALYSIS AND RESULTS

Initially, the margin of error for the 95% confidence level was used for the origin data. This means that for any location, the estimate of the proportion of vehicles originating in any given community falls within the range of plus or minus the margin of error 95% of the time. For example, with the 2003 database, it was estimated that 13% of the vehicles observed traveling southbound on Alewife Brook Parkway at the Fresh Pond Rotary in Cambridge originated in Lexington, and the margin of error for this location is ± 1.5%. Then, 95% of the time, the proportion from Lexington would range between 11.5% and 14.5%. In other words, if this survey were conducted 100 times, 95 of those times the proportion of vehicles from Lexington would be within 1.5 points of the percentage found in this survey.

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1 "Route 2/Route 16 (Alewife Brook Parkway) Eastbound: Traffic Patterns and Alewife Station Parking Garage Survey," CTPS memorandum, July 19, 2007.

The attached tables show, for each location, the percent of vehicles garaged in given communities from the 2003 database, the percent ranges to be expected with the margin of error, and the proportions calculated from the 2008 RMV database. Excluding the "Other Massachusetts" category, the tables contain a total of 267 entries. Only six (shaded in the tables) of the entries from the 2008 rematching fall outside the margin of error. Five of the six are only one half of one percent or less outside the expected values, and that degree of difference might be attributable to rounding.

CONCLUSION

The analysis validates traditional statistical methods. Conclusions drawn from using the older RMV database are valid.

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Origins of Vehicles Observed in the Alewife Station Garage

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	Vehicles	Total	-1.8%	+1.8%	Community	Vehicles	Total
Lexington	358	14.4%	12.6%	16.2%	Lexington	378	15.2%
Arlington	325	13.1%	11.3%	14.9%	Arlington	342	13.7%
Out-of-State	166	6.7%	4.9%	8.5%	Out of State	166	6.7%
Acton	130	5.2%	3.4%	7.0%	Acton	123	4.9%
Waltham	127	5.1%	3.3%	6.9%	Waltham	158	6.3%
Concord	89	3.6%	1.8%	5.4%	Concord	93	3.7%
Bedford	72	2.9%	1.1%	4.7%	Bedford	74	3.0%
Belmont	69	2.7%	0.9%	4.5%	Belmont	73	2.9%
Billerica	55	2.2%	0.4%	4.0%	Billerica	57	2.3%
Boston	55	2.2%	0.4%	4.0%	Boston	40	1.6%
Burlington	48	1.9%	0.1%	3.7%	Burlington	57	2.3%
Maynard	45	1.8%	0.0%	3.6%	Maynard	42	1.7%
Westford	45	1.8%	0.0%	3.6%	Westford	44	1.8%
Chelmsford	43	1.7%	0.0%	3.5%	Chelmsford	33	1.3%
Leominster	41	1.6%	0.0%	3.4%	Leominster	33	1.3%
Sudbury	39	1.6%	0.0%	3.4%	Sudbury	47	1.9%
Littleton	38	1.5%	0.0%	3.3%	Littleton	41	1.6%
Medford	34	1.4%	0.0%	3.2%	Medford	24	1.0%
Boxborough	33	1.3%	0.0%	3.1%	Boxborough	33	1.3%
Watertown	31	1.2%	0.0%	3.0%	Watertown	21	0.8%
Woburn	31	1.2%	0.0%	3.0%	Woburn	44	1.8%
Cambridge	29	1.2%	0.0%	3.0%	Cambridge	16	0.7%
Lincoln	29	1.2%	0.0%	3.0%	Lincoln	40	1.6%
Winchester	29	1.2%	0.0%	3.0%	Winchester	27	1.1%
Somerville	27	1.1%	0.0%	2.9%	Somerville	13	0.5%
Carlisle	22	0.9%	0.0%	2.7%	Carlisle	26	1.0%
Lunenburg	22	0.9%	0.0%	2.7%	Lunenburg	16	0.7%
Framingham	21	0.8%	0.0%	2.6%	Framingham	8	0.3%
Wayland	21	0.8%	0.0%	2.6%	Wayland	21	0.8%
Fitchburg	17	0.7%	0.0%	2.5%	Fitchburg	28	1.1%
Groton	17	0.7%	0.0%	2.5%	Groton	16	0.7%
Harvard	17	0.7%	0.0%	2.5%	Harvard	12	0.5%
Stow	17	0.7%	0.0%	2.5%	Stow	17	0.7%
Natick	14	0.5%	0.0%	2.3%	Natick	9	0.4%
Townsend	14	0.5%	0.0%	2.3%	Townsend	13	0.5%
Lowell	12	0.5%	0.0%	2.3%	Lowell	17	0.7%
Newton	10	0.4%	0.0%	2.2%	Newton	13	0.5%
Shirley	10	0.4%	0.0%	2.2%	Shirley	10	0.4%
Winchendon	10	0.4%	0.0%	2.2%	Winchendon	5	0.2%
Other MA	283	11.3%					
Total	**2,494**	**100.0%**					

Origins of Vehicles Observed at Location 1 (Winter Street at Concord Avenue, Belmont)

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	Vehicles	Total	-3.1%	+3.1%	Community	Vehicles	Total
Lexington	127	17.2%	14.1%	20.3%	Lexington	137	18.5%
Arlington	58	7.8%	4.7%	10.9%	Arlington	52	7.1%
Burlington	48	6.5%	3.4%	9.6%	Burlington	43	5.8%
Woburn	43	5.8%	2.7%	8.9%	Woburn	41	5.5%
Belmont	36	4.9%	1.8%	8.0%	Belmont	39	5.2%
Out-of-State	34	4.6%	1.5%	7.7%	Out-of-State	34	4.6%
Watertown	28	3.8%	0.7%	6.9%	Watertown	19	2.6%
Bedford	23	3.1%	0.0%	6.2%	Bedford	19	2.6%
Billerica	21	2.9%	-0.2%	6.0%	Billerica	33	4.5%
Boston	20	2.7%	-0.4%	5.8%	Boston	7	0.9%
Wilmington	20	2.7%	-0.4%	5.8%	Wilmington	18	2.5%
Medford	18	2.5%	-0.6%	5.6%	Medford	10	1.4%
Acton	13	1.8%	-1.3%	4.9%	Acton	11	1.5%
Chelmsford	13	1.8%	-1.3%	4.9%	Chelmsford	15	2.0%
Somerville	13	1.8%	-1.3%	4.9%	Somerville	7	0.9%
Waltham	12	1.6%	-1.5%	4.7%	Waltham	9	1.2%
Other MA	213	28.7%					
Total	**741**	**100.0%**					

Origins of Vehicles Observed at Location 2 (Park Avenue at Prospect Street Rotary, Cambridge)

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	Vehicles	Total	-3.2%	+3.2%	Community	Vehicles	Total
Arlington	296	35.0%	31.8%	38.2%	Arlington	307	36.3%
Lexington	78	9.2%	6.0%	12.4%	Lexington	69	8.2%
Belmont	56	6.6%	3.4%	9.8%	Belmont	59	7.0%
Winchester	35	4.2%	1.0%	7.4%	Winchester	44	5.2%
Boston	26	3.1%	-0.1%	6.3%	Boston	11	1.3%
Woburn	20	2.4%	-0.8%	5.6%	Woburn	26	3.1%
Burlington	19	2.2%	-1.0%	5.4%	Burlington	23	2.8%
Newton	17	2.0%	-1.2%	5.2%	Newton	6	0.7%
Billerica	15	1.8%	-1.4%	5.0%	Billerica	12	1.5%
Cambridge	15	1.8%	-1.4%	5.0%	Cambridge	6	0.7%
Watertown	15	1.8%	-1.4%	5.0%	Watertown	4	0.5%
Out-of-State	14	1.7%	-1.5%	4.9%	Out-of-State	14	1.7%
Medford	13	1.5%	-1.7%	4.7%	Medford	11	1.3%
Somerville	13	1.5%	-1.7%	4.7%	Somerville	4	0.5%
Stoneham	11	1.3%	-1.9%	4.5%	Stoneham	10	1.1%
Other MA	202	23.9%					
Total	**846**	**100.0%**					

Origins of Vehicles Observed at Location 3 (Left Turns from Pleasant Street to Brighton Street, Belmont)

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	Vehicles	Total	-3.2%	+3.2%	Community	Vehicles	Total
Arlington	200	26.7%	23.5%	29.9%	Arlington	212	28.4%
Lexington	56	7.4%	4.2%	10.6%	Lexington	51	6.8%
Belmont	38	5.1%	1.9%	8.3%	Belmont	27	3.6%
Woburn	33	4.4%	1.2%	7.6%	Woburn	45	6.0%
Boston	26	3.5%	0.3%	6.7%	Boston	16	2.2%
Medford	26	3.5%	0.3%	6.7%	Medford	14	1.8%
Winchester	26	3.5%	0.3%	6.7%	Winchester	31	4.1%
Billerica	23	3.0%	-0.2%	6.2%	Billerica	20	2.7%
Out-of-State	19	2.5%	-0.7%	5.7%	Out-of-State	19	2.5%
Wilmington	16	2.1%	-1.1%	5.3%	Wilmington	10	1.3%
Cambridge	14	1.9%	-1.3%	5.1%	Cambridge	5	0.7%
Stoneham	14	1.9%	-1.3%	5.1%	Stoneham	7	1.0%
Chelmsford	12	1.6%	-1.6%	4.8%	Chelmsford	16	2.2%
Lowell	12	1.6%	-1.6%	4.8%	Lowell	10	1.3%
Burlington	10	1.4%	-1.8%	4.6%	Burlington	15	2.0%
Reading	10	1.4%	-1.8%	4.6%	Reading	10	1.3%
Tewksbury	10	1.4%	-1.8%	4.6%	Tewksbury	14	1.8%
Waltham	10	1.4%	-1.8%	4.6%	Waltham	7	1.0%
Other MA	194	25.9%					
Total	**749**	**100.0%**					

Origins of Vehicles Observed at Location 4 (Cross St. at Lake St., Belmont/Arlington Town Line)

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	Vehicles	Total	-3.1%	+3.1%	Community	Vehicles	Total
Arlington	215	29.7%	26.6%	32.8%	Arlington	246	33.9%
Medford	86	11.9%	8.8%	15.0%	Medford	79	10.9%
Belmont	54	7.5%	4.4%	10.6%	Belmont	46	6.4%
Somerville	41	5.6%	2.5%	8.7%	Somerville	29	4.0%
Boston	27	3.7%	0.6%	6.8%	Boston	10	1.4%
Cambridge	24	3.3%	0.2%	6.4%	Cambridge	23	3.1%
Lexington	22	3.0%	-0.1%	6.1%	Lexington	21	2.9%
Malden	20	2.8%	-0.3%	5.9%	Malden	18	2.4%
Out-of-State	16	2.2%	-0.9%	5.3%	Out-of-State	16	2.2%
Winchester	15	2.1%	-1.0%	5.2%	Winchester	10	1.4%
Melrose	12	1.6%	-1.5%	4.7%	Melrose	10	1.4%
Watertown	12	1.6%	-1.5%	4.7%	Watertown	14	1.9%
Billerica	10	1.4%	-1.7%	4.5%	Billerica	10	1.4%
Burlington	10	1.4%	-1.7%	4.5%	Burlington	8	1.0%
Other MA	160	22.1%					
Total	**725**	**100.0%**					

Origins of Vehicles Observed at Location 5 (Alewife Brook Parkway at Fresh Pond Rotary, Cambridge)

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	Vehicles	Total	-1.5%	+1.5%	Community	Vehicles	Total
Lexington	521	12.6%	11.1%	14.1%	Lexington	557	13.5%
Arlington	384	9.3%	7.8%	10.8%	Arlington	459	11.1%
Out-of-State	295	7.1%	5.6%	8.6%	Out-of-State	295	7.1%
Cambridge	235	5.7%	4.2%	7.2%	Cambridge	224	5.4%
Concord	228	5.5%	4.0%	7.0%	Concord	216	5.2%
Acton	184	4.4%	2.9%	5.9%	Acton	203	4.9%
Somerville	155	3.7%	2.2%	5.2%	Somerville	106	2.6%
Boston	142	3.4%	1.9%	4.9%	Boston	101	2.4%
Medford	127	3.1%	1.6%	4.6%	Medford	110	2.7%
Lincoln	120	2.9%	1.4%	4.4%	Lincoln	105	2.5%
Bedford	102	2.5%	1.0%	4.0%	Bedford	98	2.4%
Waltham	73	1.8%	0.3%	3.3%	Waltham	70	1.7%
Billerica	71	1.7%	0.2%	3.2%	Billerica	85	2.0%
Sudbury	66	1.6%	0.1%	3.1%	Sudbury	67	1.6%
Chelmsford	64	1.5%	0.0%	3.0%	Chelmsford	70	1.7%
Belmont	62	1.5%	0.0%	3.0%	Belmont	48	1.2%
Burlington	60	1.5%	0.0%	3.0%	Burlington	54	1.3%
Westford	60	1.5%	0.0%	3.0%	Westford	76	1.8%
Newton	47	1.1%	-0.4%	2.6%	Newton	25	0.6%
Winchester	47	1.1%	-0.4%	2.6%	Winchester	36	0.9%
Woburn	47	1.1%	-0.4%	2.6%	Woburn	57	1.4%
Carlisle	42	1.0%	-0.5%	2.5%	Carlisle	47	1.1%
Malden	42	1.0%	-0.5%	2.5%	Malden	47	1.1%
Maynard	40	1.0%	-0.5%	2.5%	Maynard	55	1.3%
Lowell	38	0.9%	-0.6%	2.4%	Lowell	52	1.3%
Littleton	36	0.9%	-0.6%	2.4%	Littleton	37	0.9%
Boxborough	35	0.8%	-0.7%	2.3%	Boxborough	39	1.0%
Leominster	31	0.7%	-0.8%	2.2%	Leominster	39	1.0%
Everett	27	0.7%	-0.8%	2.2%	Everett	24	0.6%
Watertown	27	0.7%	-0.8%	2.2%	Watertown	20	0.5%
Harvard	25	0.6%	-0.9%	2.1%	Harvard	25	0.6%
Groton	22	0.5%	-1.0%	2.0%	Groton	23	0.5%
Wayland	22	0.5%	-1.0%	2.0%	Wayland	21	0.5%
Unmatchable	21	0.5%	-1.0%	2.0%	Unmatchable	21	0.5%
Andover	20	0.5%	-1.0%	2.0%	Andover	13	0.3%
Brookline	20	0.5%	-1.0%	2.0%	Brookline	10	0.2%
Tewksbury	20	0.5%	-1.0%	2.0%	Tewksbury	19	0.5%
Tyngsborough	20	0.5%	-1.0%	2.0%	Tyngsborough	16	0.4%
Pepperell	18	0.4%	-1.1%	1.9%	Pepperell	13	0.3%
Revere	18	0.4%	-1.1%	1.9%	Revere	11	0.3%
Wakefield	18	0.4%	-1.1%	1.9%	Wakefield	14	0.3%
Reading	16	0.4%	-1.1%	1.9%	Reading	13	0.3%
Weston	16	0.4%	-1.1%	1.9%	Weston	13	0.3%
Ayer	15	0.4%	-1.1%	1.9%	Ayer	18	0.4%
Fitchburg	15	0.4%	-1.1%	1.9%	Fitchburg	21	0.5%
Marlborough	15	0.4%	-1.1%	1.9%	Marlborough	11	0.3%
North Reading	15	0.4%	-1.1%	1.9%	North Reading	12	0.3%
Quincy	15	0.4%	-1.1%	1.9%	Quincy	7	0.2%
Stoneham	15	0.4%	-1.1%	1.9%	Stoneham	16	0.4%

Origins of Vehicles Observed at Location 5 (Alewife Brook Pkwy. at Fresh Pond Rotary, Camb.), cont.

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	**Vehicles**	**Total**	**-1.5%**	**+1.5%**	**Community**	**Vehicles**	**Total**
Stow	15	0.4%	-1.1%	1.9%	Stow	16	0.4%
Framingham	13	0.3%	-1.2%	1.8%	Framingham	16	0.4%
Natick	13	0.3%	-1.2%	1.8%	Natick	11	0.3%
Dracut	11	0.3%	-1.2%	1.8%	Dracut	10	0.2%
Lancaster	11	0.3%	-1.2%	1.8%	Lancaster	8	0.2%
Lynn	11	0.3%	-1.2%	1.8%	Lynn	2	0.1%
Melrose	11	0.3%	-1.2%	1.8%	Melrose	24	0.6%
Shirley	11	0.3%	-1.2%	1.8%	Shirley	12	0.3%
Other MA	291	7.0%					
Total	**4,139**	**100.0%**					

Origins of Vehicles Observed at Location 6 (Concord Ave. at Fresh Pond Rotary, Cambridge)

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	**Vehicles**	**Total**	**-2.7%**	**+2.7%**	**Community**	**Vehicles**	**Total**
Belmont	300	22.0%	19.3%	24.7%	Belmont	354	25.9%
Cambridge	250	18.3%	15.6%	21.0%	Cambridge	243	17.8%
Arlington	122	9.0%	6.3%	11.7%	Arlington	106	7.8%
Watertown	91	6.6%	3.9%	9.3%	Watertown	87	6.4%
Lexington	80	5.8%	3.1%	8.5%	Lexington	95	6.9%
Somerville	65	4.7%	2.0%	7.4%	Somerville	42	3.1%
Boston	57	4.2%	1.5%	6.9%	Boston	37	2.7%
Waltham	46	3.4%	0.7%	6.1%	Waltham	46	3.4%
Out-of-State	33	2.4%	-0.3%	5.1%	Out-of-State	33	2.4%
Medford	28	2.0%	-0.7%	4.7%	Medford	17	1.3%
Newton	13	0.9%	-1.8%	3.6%	Newton	15	1.1%
Stoneham	13	0.9%	-1.8%	3.6%	Stoneham	7	0.5%
Winchester	13	0.9%	-1.8%	3.6%	Winchester	9	0.6%
Woburn	13	0.9%	-1.8%	3.6%	Woburn	14	1.0%
Burlington	11	0.8%	-1.9%	3.5%	Burlington	10	0.7%
Other MA	230	17%					
Total	**1,365**	**100.0%**					

Origins of Vehicles Observed at Location 7 (Left Turns from Pleasant St. to Concord Ave., Belmont)

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	Vehicles	Total	-2.5%	+2.5%	Community	Vehicles	Total
Arlington	272	21.0%	18.5%	23.5%	Arlington	257	19.8%
Belmont	263	20.3%	17.8%	22.8%	Belmont	295	22.8%
Lexington	201	15.5%	13.0%	18.0%	Lexington	218	16.8%
Cambridge	66	5.1%	2.6%	7.6%	Cambridge	48	3.7%
Boston	34	2.6%	0.1%	5.1%	Boston	21	1.6%
Waltham	34	2.6%	0.1%	5.1%	Waltham	33	2.6%
Out-of-State	28	2.2%	-0.3%	4.7%	Out-of-State	28	2.2%
Watertown	22	1.7%	-0.8%	4.2%	Watertown	15	1.1%
Winchester	22	1.7%	-0.8%	4.2%	Winchester	28	2.1%
Medford	20	1.5%	-1.0%	4.0%	Medford	19	1.4%
Newton	20	1.5%	-1.0%	4.0%	Newton	8	0.6%
Woburn	20	1.5%	-1.0%	4.0%	Woburn	25	1.9%
Bedford	16	1.2%	-1.3%	3.7%	Bedford	22	1.7%
Billerica	16	1.2%	-1.3%	3.7%	Billerica	17	1.3%
Burlington	16	1.2%	-1.3%	3.7%	Burlington	19	1.4%
Stoneham	16	1.2%	-1.3%	3.7%	Stoneham	12	0.9%
Acton	13	1.0%	-1.5%	3.5%	Acton	13	1.0%
Lincoln	11	0.8%	-1.7%	3.3%	Lincoln	11	0.8%
Somerville	11	0.8%	-1.7%	3.3%	Somerville	7	0.5%
Other MA	196	15.2%					
Total	**1,296**	**100.0%**					

Origins of Vehicles Observed at Location 8 (Grove St. from Bright and Blanchard Sts.)

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	Vehicles	Total	-2.3%	+2.3%	Community	Vehicles	Total
Arlington	305	20.4%	18.1%	22.7%	Arlington	302	20.2%
Belmont	287	19.2%	16.9%	21.5%	Belmont	329	22.0%
Lexington	188	12.6%	10.3%	14.9%	Lexington	180	12.1%
Cambridge	67	4.5%	2.2%	6.8%	Cambridge	66	4.4%
Boston	46	3.1%	0.8%	5.4%	Boston	23	1.5%
Medford	35	2.4%	0.1%	4.7%	Medford	35	2.3%
Woburn	35	2.4%	0.1%	4.7%	Woburn	40	2.7%
Out-of-State	33	2.2%	-0.1%	4.5%	Out-of-State	33	2.2%
Watertown	30	2.0%	-0.3%	4.3%	Watertown	31	2.1%
Newton	25	1.7%	-0.6%	4.0%	Newton	15	1.0%
Somerville	25	1.7%	-0.6%	4.0%	Somerville	16	1.1%
Winchester	25	1.7%	-0.6%	4.0%	Winchester	38	2.5%
Billerica	23	1.5%	-0.8%	3.8%	Billerica	24	1.6%
Bedford	21	1.4%	-0.9%	3.7%	Bedford	15	1.0%
Burlington	20	1.3%	-1.0%	3.6%	Burlington	23	1.5%
Acton	18	1.2%	-1.1%	3.5%	Acton	19	1.3%
Malden	16	1.1%	-1.2%	3.4%	Malden	13	0.9%
Chelmsford	14	0.9%	-1.4%	3.2%	Chelmsford	13	0.9%
Concord	14	0.9%	-1.4%	3.2%	Concord	13	0.9%
Waltham	12	0.8%	-1.5%	3.1%	Waltham	13	0.9%
Unmatchable	11	0.7%	-1.6%	3.0%	Unmatchable	11	0.7%
Tewksbury	11	0.7%	-1.6%	3.0%	Tewksbury	15	1.0%
Wakefield	11	0.7%	-1.6%	3.0%	Wakefield	8	0.5%
Other MA	223	14.9%					
Total	**1,496**	100.0%					

Origins of Vehicles Observed at Location 9 (Eliot Bridge, Cambridge)

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	Vehicles	Total	-1.2%	+1.2%	Community	Vehicles	Total
Belmont	706	12.2%	11.0%	13.4%	Belmont	793	13.7%
Cambridge	656	11.3%	10.1%	12.5%	Cambridge	720	12.4%
Arlington	543	9.4%	8.2%	10.6%	Arlington	518	8.9%
Lexington	512	8.8%	7.6%	10.0%	Lexington	571	9.9%
Watertown	503	8.7%	7.5%	9.9%	Watertown	524	9.0%
Boston	397	6.9%	5.7%	8.1%	Boston	306	5.3%
Waltham	231	4.0%	2.8%	5.2%	Waltham	238	4.1%
Out-of-State	200	3.5%	2.3%	4.7%	Out-of-State	200	3.5%
Concord	180	3.1%	1.9%	4.3%	Concord	168	2.9%
Somerville	157	2.7%	1.5%	3.9%	Somerville	122	2.1%
Newton	145	2.5%	1.3%	3.7%	Newton	107	1.9%
Acton	131	2.3%	1.1%	3.5%	Acton	152	2.6%
Medford	88	1.5%	0.3%	2.7%	Medford	68	1.2%
Bedford	79	1.4%	0.2%	2.6%	Bedford	74	1.3%
Lincoln	62	1.1%	-0.1%	2.3%	Lincoln	63	1.1%
Brookline	55	0.9%	-0.3%	2.1%	Brookline	35	0.6%
Winchester	48	0.8%	-0.4%	2.0%	Winchester	52	0.9%
Burlington	44	0.8%	-0.4%	2.0%	Burlington	39	0.7%
Billerica	41	0.7%	-0.5%	1.9%	Billerica	61	1.0%
Carlisle	37	0.6%	-0.6%	1.8%	Carlisle	36	0.6%
Leominster	37	0.6%	-0.6%	1.8%	Leominster	37	0.6%
Woburn	37	0.6%	-0.6%	1.8%	Woburn	41	0.7%
Chelmsford	35	0.6%	-0.6%	1.8%	Chelmsford	43	0.7%
Malden	32	0.5%	-0.7%	1.7%	Malden	27	0.5%
Westford	32	0.5%	-0.7%	1.7%	Westford	49	0.8%
Littleton	28	0.5%	-0.7%	1.7%	Littleton	23	0.4%
Quincy	28	0.5%	-0.7%	1.7%	Quincy	21	0.4%
Sudbury	26	0.5%	-0.7%	1.7%	Sudbury	21	0.4%
Everett	19	0.3%	-0.9%	1.5%	Everett	18	0.3%
Harvard	19	0.3%	-0.9%	1.5%	Harvard	24	0.4%
Lowell	19	0.3%	-0.9%	1.5%	Lowell	26	0.5%
Maynard	19	0.3%	-0.9%	1.5%	Maynard	23	0.4%
Wellesley	19	0.3%	-0.9%	1.5%	Wellesley	18	0.3%
Weston	19	0.3%	-0.9%	1.5%	Weston	21	0.4%
Melrose	18	0.3%	-0.9%	1.5%	Melrose	13	0.2%
Boxborough	16	0.3%	-0.9%	1.5%	Boxborough	17	0.3%
Fitchburg	16	0.3%	-0.9%	1.5%	Fitchburg	19	0.3%
Framingham	16	0.3%	-0.9%	1.5%	Framingham	14	0.2%
Groton	16	0.3%	-0.9%	1.5%	Groton	18	0.3%
Milton	14	0.20%	-1.0%	1.4%	Milton	12	0.2%
Tewksbury	14	0.2%	-1.0%	1.4%	Tewksbury	11	0.2%
Wayland	14	0.2%	-1.0%	1.4%	Wayland	14	0.2%
Ayer	12	0.2%	-1.0%	1.4%	Ayer	11	0.2%
Natick	12	0.2%	-1.0%	1.4%	Natick	8	0.1%
Needham	12	0.2%	-1.0%	1.4%	Needham	6	0.1%
Pepperell	12	0.2%	-1.0%	1.4%	Pepperell	11	0.2%
Stoneham	12	0.2%	-1.0%	1.4%	Stoneham	13	0.2%
Andover	11	0.2%	-1.0%	1.4%	Andover	10	0.2%
Lynn	11	0.2%	-1.0%	1.4%	Lynn	7	0.1%
Wakefield	11	0.2%	-1.0%	1.4%	Wakefield	8	0.1%

Origins of Vehicles Observed at Location 9 (Eliot Bridge, Cambridge), cont.

2003 RMV Database			Range within Margin of Error		2008 RMV Database		
Community	**Vehicles**	**Total**	**-1.2%**	**+1.2%**	**Community**	**Vehicles**	**Total**
Walpole	11	0.2%	-1.0%	1.4%	Walpole	6	0.1%
Other MA	381	6.6%					
Total	**5,792**	**100%**					

MEMORANDUM

TO: Transportation Planning and Programming Committee

January 13, 2009

FROM: Alicia Wilson

RE: Recommended Improvements to MBTA Feeder Bus Routes to Alewife Station to Increase Feeder Bus Ridership to the Red Line

INTRODUCTION

The purpose of this memorandum is to fulfill the requirements of Task 2 of the work program "Alewife Station: Improvements to Feeder Bus Routes, Bus Access and Egress, and Route 2/Route 16 Intersection," November 1, 2007. Task 2 pertains to improving feeder bus routes. Bus access and egress, and the operations of the Route 2/Route 16 intersection are examined in separate technical memos.

Alewife Phase I study analysis revealed that almost one-third of vehicles observed parked at the Alewife MBTA station are garaged in Arlington and Lexington, both of which have bus service to the MBTA station. Given that the Alewife Station garage is over capacity and the surrounding roadway network is severely congested, it makes sense to examine the coverage of the Arlington and Lexington bus routes to the garage to determine if there are potential route changes that would encourage many of those who presently drive to Alewife to take a bus to the station instead. This analysis was not performed for Bedford and Burlington, the other two communities served by MBTA buses from Alewife, since less than 5% of all parked vehicles are from these towns.

Figure 1 shows the number of vehicles by census block group observed at the Alewife garage in May 2007 that are garaged in Lexington and Arlington. The numbers of vehicles observed from each community are almost equal, even though Arlington's population is larger than Lexington's.

An analysis of the potential of fixed-route bus service requires the consideration of demographic characteristics such as population density, income, number of commuters who work in Boston and Cambridge, and the proportion of these commuters who live within one-quarter mile of an existing bus stop.[1]

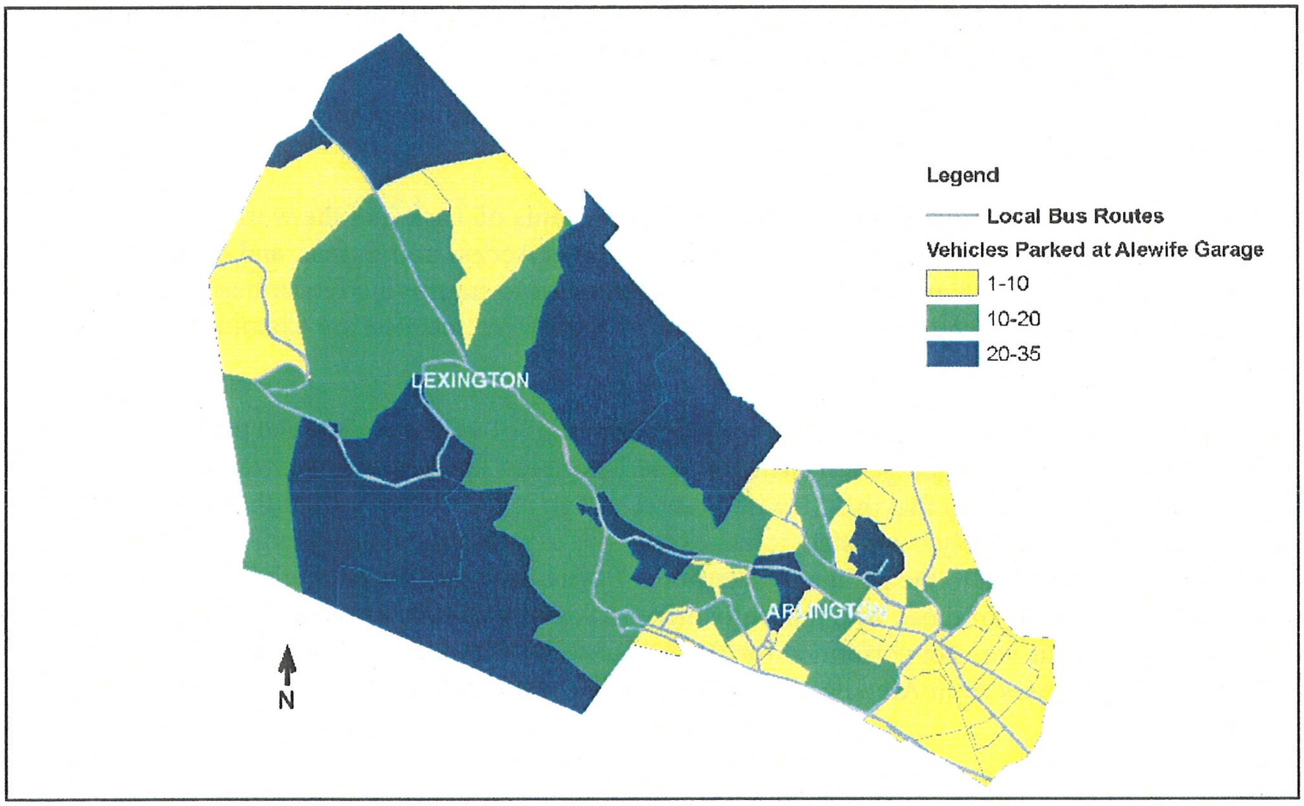
PHYSICAL CHARACTERISTICS

Development is spread throughout Lexington but is most concentrated in the very center of town and the area bounded by Route 2 to the south and Route 128 to the west and north. The

[1] One-quarter mile is the generally accepted maximum distance a person will walk to bus service.

concentration of development lessens outside this boundary, particularly in the western corner of town at the border of Lincoln and Bedford. The entirety of Arlington is quite densely developed. With a few exceptions, the bus routes operate on major roadways.

FIGURE 1
Origins of Vehicles Parked in the Alewife Garage



CHARACTERISTICS THAT AFFECT TRANSIT USAGE

Characteristics that often affect transit usage in the metropolitan area are:

- Population density
- Vehicle ownership
- Median household income
- Residents working in Boston and Cambridge
- Percent of residents working in Boston and Cambridge living within one-quarter mile of a bus stop

Each characteristic as it applies to Arlington and Lexington is discussed below.

Population Density

The 2006 MBTA accessibility standards/guidelines (the latest available[2]) define the minimum levels of service that should be provided, if possible, for access to the transit system, in terms of geographic coverage. Coverage is expressed as a guideline rather than a standard, because uniform geographic coverage cannot always be achieved due to constraints such as topographical and street network restrictions. In addition, coverage in some areas may not be possible due to the infeasibility of modifying existing routes without negatively affecting their performance.

The guideline states that on weekdays and Saturday, access to transit service will be provided within a quarter mile walk to residents of areas served by bus, light rail, and/or heavy rail with a population density of greater than 5,000 persons per square mile. Figure 2 shows population density by census block group for the two communities. Arlington is home to a population of 42,389 in 5.5 square miles, while Lexington has a population of 30,355 in 16.4 square miles. Even though there are some high-density block groups in Lexington, concentrated along Massachusetts Avenue, most of the block groups with the highest population densities are located in Arlington. Block groups in Lexington generally have less than 2,500 people per square mile, while many in Arlington have 8,000 or more people per square mile. Only one block group in Lexington has a density that exceeds 5,000 people per square mile.

Transit is generally assumed to be most suitable in areas of high density, less so in medium-density locations, and difficult to justify in low-density locations due to the low concentration of trip origins and destinations and the consequent challenges to providing these locations with public transit that is both convenient and cost-effective.[3] All of the higher-density block groups in both Arlington and Lexington currently have MBTA bus service.

Vehicle Ownership

The level of vehicle ownership can be an indicator of the demand for transit. The lower the level of vehicle ownership, the greater the demand for transit. The level of vehicle ownership is generally lower in Arlington than in Lexington (Figure 3). All block groups with less than one vehicle per household are located in Arlington. All with two or more vehicles per household are located in Lexington.

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[2] MBTA Service Delivery Policy, Service Standards, 2006, p. 6. The MBTA is in the process of updating its service standards.

[3] Draft technical report: *Analysis of the Potential for Demand-Responsive Service in the Town of Lexington*, Robert Guptill, CTPS, February 27, 2008, p. 8.

FIGURE 2
Population Density, 2000

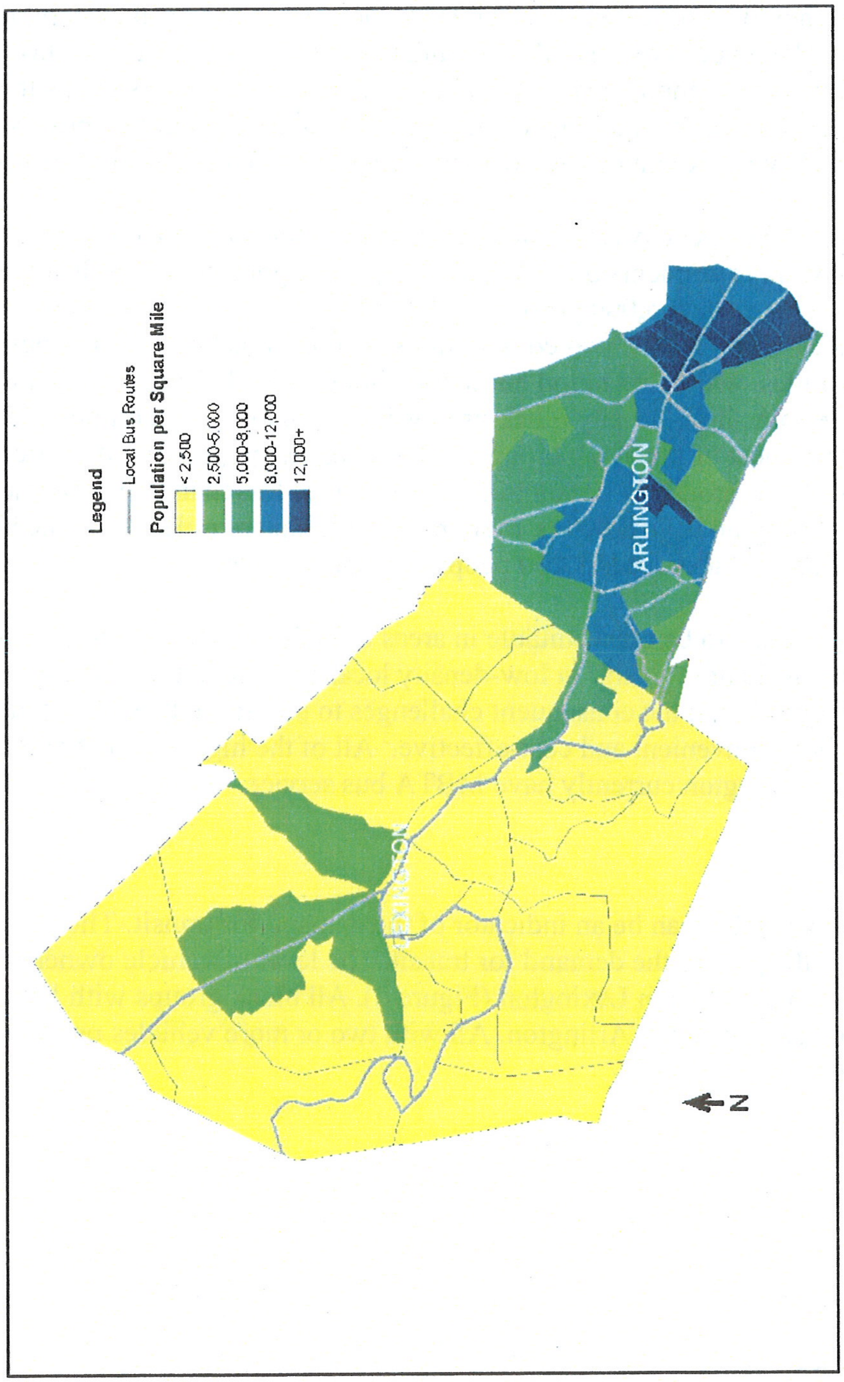
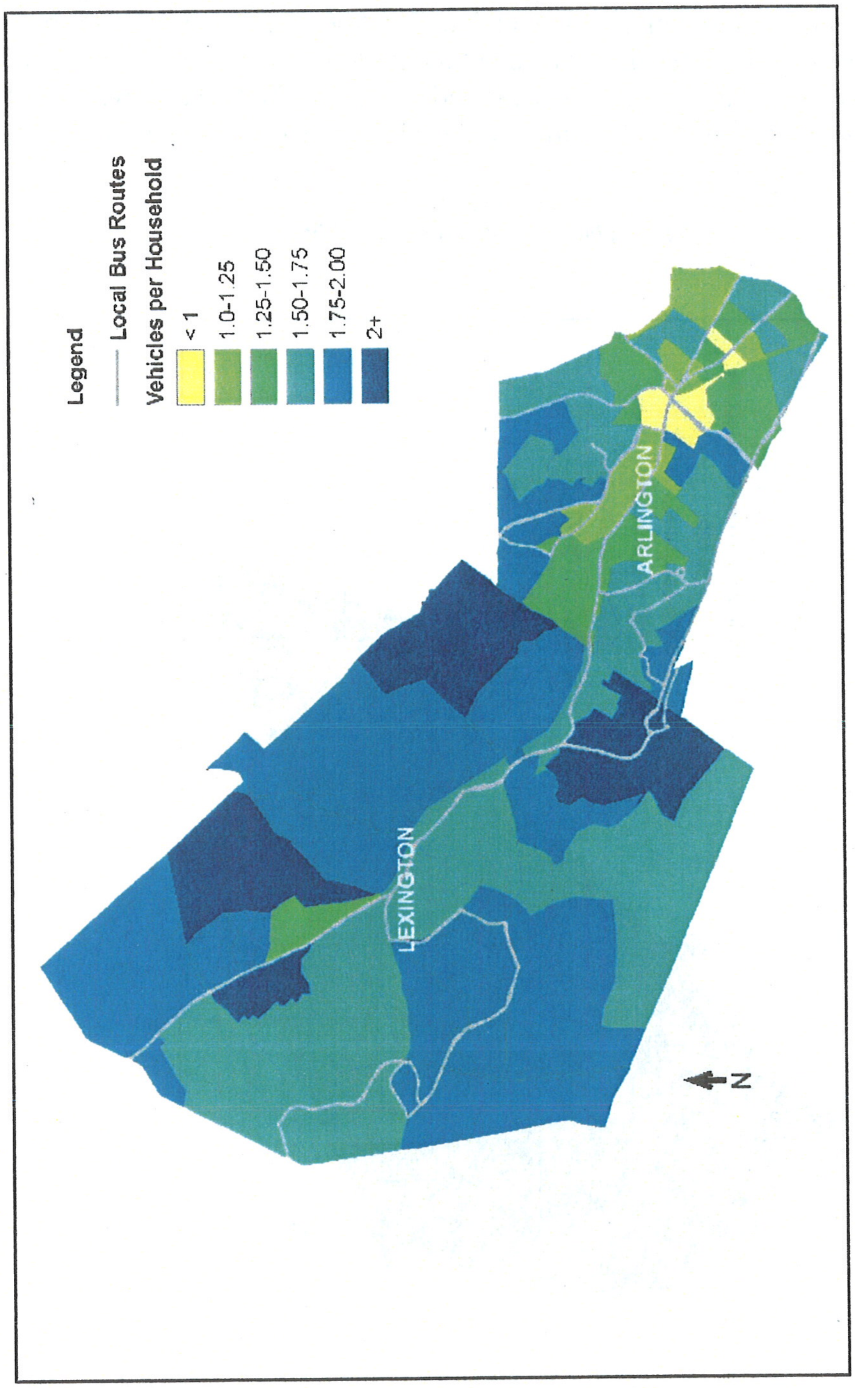


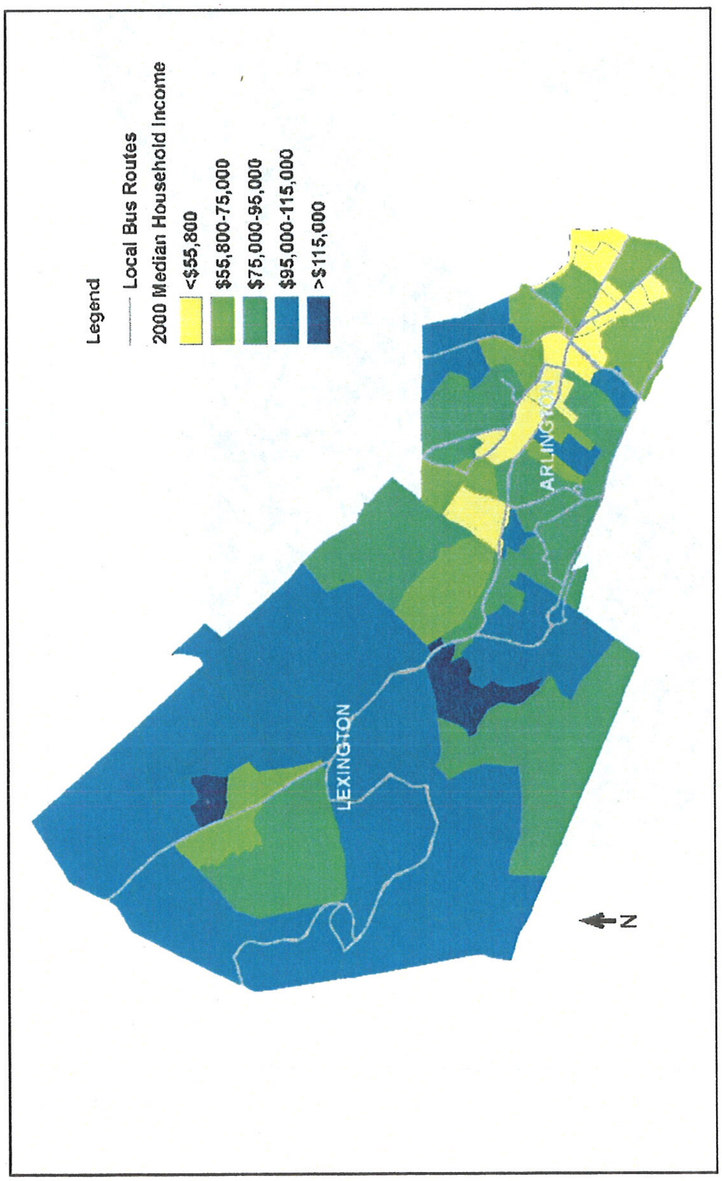
FIGURE 3
Vehicle Ownership, 2000



Median Income

Arlington's median household income is $64,344; Lexington's is $96,825. Both are higher than the median Boston Region MPO household income of $55,800.[4] Less than 20% of the census block groups in the two communities have median household incomes that fall below the MPO median. All are in Arlington, all have bus service, and all but one had 10 or fewer cars parked at the Alewife garage. More than 50% of Lexington's block groups have median incomes that exceed $100,000

FIGURE 4
Median Household Income, 2000



[4] 2000 U.S. Census

Residents Working in Boston and Cambridge

Most MBTA service is radial in nature, directed towards Boston and Cambridge, both of which have high employee concentrations. Thirty-nine percent of commuters from Arlington work in Boston and Cambridge; 27% of those from Lexington do so. Thirty percent of these commuters to Boston and Cambridge use transit, compared with 12% of all commuters from Arlington and Lexington.

One-quarter mile is generally considered to be the maximum distance a person will walk to bus service. Altogether, two-thirds of the communities' commuters to Boston and Cambridge live within one-quarter mile of a bus stop (Figure 5). However, the profile differs by community. Eighty percent of those who commute to Boston and Cambridge from Arlington live within one-quarter mile of a bus stop. Forty percent of these commuters use transit; 49% drive alone. Only 19% of Lexington's commuters to Boston and Cambridge live within one-quarter mile of a bus stop. Only 23% percent of these commuters use transit; 71% drive alone.

BUS SERVICE

MBTA Bus Service

MBTA bus routes 62, 67, 76, 79, 84 and 350 provide service to Alewife Station from the study area. Routes 62, 67, 76, and 84 operate on 30-minute headways during peak periods. Route 79 operates on 16-minute headways. Route 350 headways vary, but are approximately 20 minutes.

Table 1 shows how each route performs during weekday peak periods. During the morning peak period, the highest per-trip inbound boardings occur on Routes 62 and 67, the lowest on Route 79. Outbound during the evening peak period, the highest per-trip boardings occur on Route 62, the lowest on Route 84. Load factors, the ratio of passengers to capacity in the peak direction, are generally higher during the morning than in the evening. The load factors indicate that, on average, Route 62 inbound buses are close to seated capacity in the morning.

MBTA operations are generally level-funded. An existing route is evaluated on a net cost/passenger ratio that is determined by adding the cost per weekday peak hour, the cost per weekday off-peak hour, and the cost per mile, and subtracting the average fare per passenger. The average net cost during the last service plan was approximately $1.50 per passenger. A ratio that is three times the system average is failing. Route 76 exceeds this ratio.

FIGURE 5
Proportion of Commuters to Boston and Cambridge Living Within One-Quarter Mile of an MBTA Bus Stop

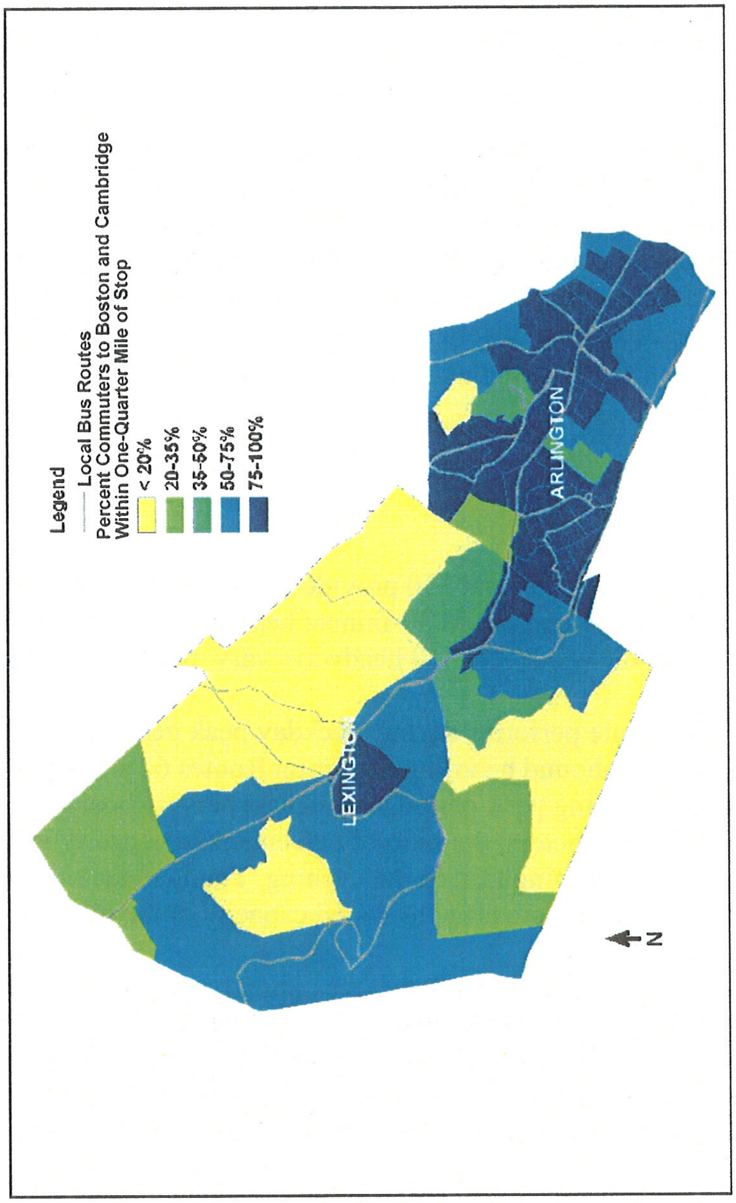


TABLE 1
MBTA Bus Route Performance Statistics

	Route					
AM PEAK						
Inbound	**62**	**67**	**76**	**79**	**84**	**350**
Average Time Period Maximum Load	38.2	35	21.8	15.3	27.3	29.2
Average Time Period Load Factor	0.96	0.88	0.54	0.38	0.68	0.73
Average Boardings per Trip	40	40	25	17	27.5	32
Total Scheduled Trips	4	4	4	9	4	6
Outbound						
Average Time Period Maximum Load	25.7	6.2	15.3	8.2	0	20.8
Average Time Period Load Factor	0.64	0.16	0.38	0.21	0	0.52
Average Boardings per Trip	31.7	1.2	14.5	9.7	0	23.6
Total Scheduled Trips	3	5	4	9	4	5
PM PEAK						
Inbound						
Average Time Period Maximum Load	29.3	4.2	15.8	5.2	5.6	15.8
Average Time Period Load Factor	0.73	0.1	0.39	0.13	0.14	0.39
Average Boardings per Trip	34.2	6.6	16.2	7	6.4	19
Total Scheduled Trips	5	5	4	11	5	6
Outbound						
Average Time Period Maximum Load	25.5	21.3	22	11.1	14	0.67
Average Time Period Load Factor	0.64	0.53	0.55	0.28	0.35	0.67
Average Boardings per Trip	29.3	18.7	24.5	13.4	9	32
Total Scheduled Trips	6	6	4	14	6	7
2006 Weekday Cost per Passenger*	$2.50	$3.69	$6.02	$3.09	$3.01	$3.39

Route 62: Bedford V.A. Hospital to Alewife Station

Route 67: Turkey Hill to Alewife Station

Route 76: Hanscom Air Base to Alewife Station via Mass. Ave.

Route 79: Arlington Heights to Alewife Station via Mass. Ave.

Route 84: Arlmont Village to Alewife Station

Route 350: North Burlington to Alewife Station via Burlington Mall

*2006 average weekday cost per passenger for all MBTA bus routes was $1.50.

Table 2 gives bus stop information for each route. Route 62 has the most stops, with 77 over 13 miles; Route 79 has the fewest, with 22 stops over 3.85 miles. The MBTA does not have an adopted service standard pertaining to the spacing of bus route stops (it is working on drafting such a guideline). Local communities generally dictate placement and spacing of stops.

Bus stop spacing affects demand by impacting access and travel time. "In general, there is a tradeoff between closely spaced, frequent stops with a shorter walking distance but more time on the vehicle and stops spaced further apart with a longer walking distance, but less time on the vehicle."[5] DC Metro officials indicate that bus service would be 20%-30% faster in limited-stop corridors. After introducing skip-stop service, which combines both local-stop and limited-stop sections, Dallas Area Rapid Transit (DART) officials indicate that ridership increased by 12.3% and speed increased by 10% during a one-year period.[6] A CTPS memorandum indicates that a bus route strategy in a selected corridor that includes fewer bus stops would bring about reductions in peak hour average bus travel time that are in the range of those observed by D.C. Metro and DART.[7]

TABLE 2
Distance Between Inbound MBTA Bus Route Stops (miles)

Route Number	Length (Miles)	Number Stops	Distance Between Stops			
			Median	Average	Minimum	Maximum
62	13	77	0.14	0.17	0.05	0.74
67	4.5	23	0.18	0.2	0.08	0.62
76	17.6	57	0.21	0.31	0.05	1.97
79	3.8	22	0.16	0.17	0.09	0.69
84	4.8	25	0.16	0.19	0.05	0.62
350	14.8	68	0.16	0.22	0.05	0.86

LEXPRESS Bus Service

The Town of Lexington operates LEXPRESS, a minibus system with six routes operating on one-hour headways. Service begins at 6:35 AM and ends at 6:25 PM. Figure 6 shows LEXPRESS and MBTA bus service in Lexington and Arlington. All routes stop on demand outside of Lexington Center. Within the Center, routes stop at the following locations, all of which are within easy walking distance of MBTA bus stops:

OUTBOUND

- Depot Square, *all routes*
- MBTA stop across from the Post Office, *Routes 1, 3*
- Grant Street next to Post Office, *Route 5*

INBOUND

- Depot Square, *all routes*
- Town Hall, *Routes 1, 3*
- MBTA stop across from Depot Square, *Routes 4, 5, 6*[8]

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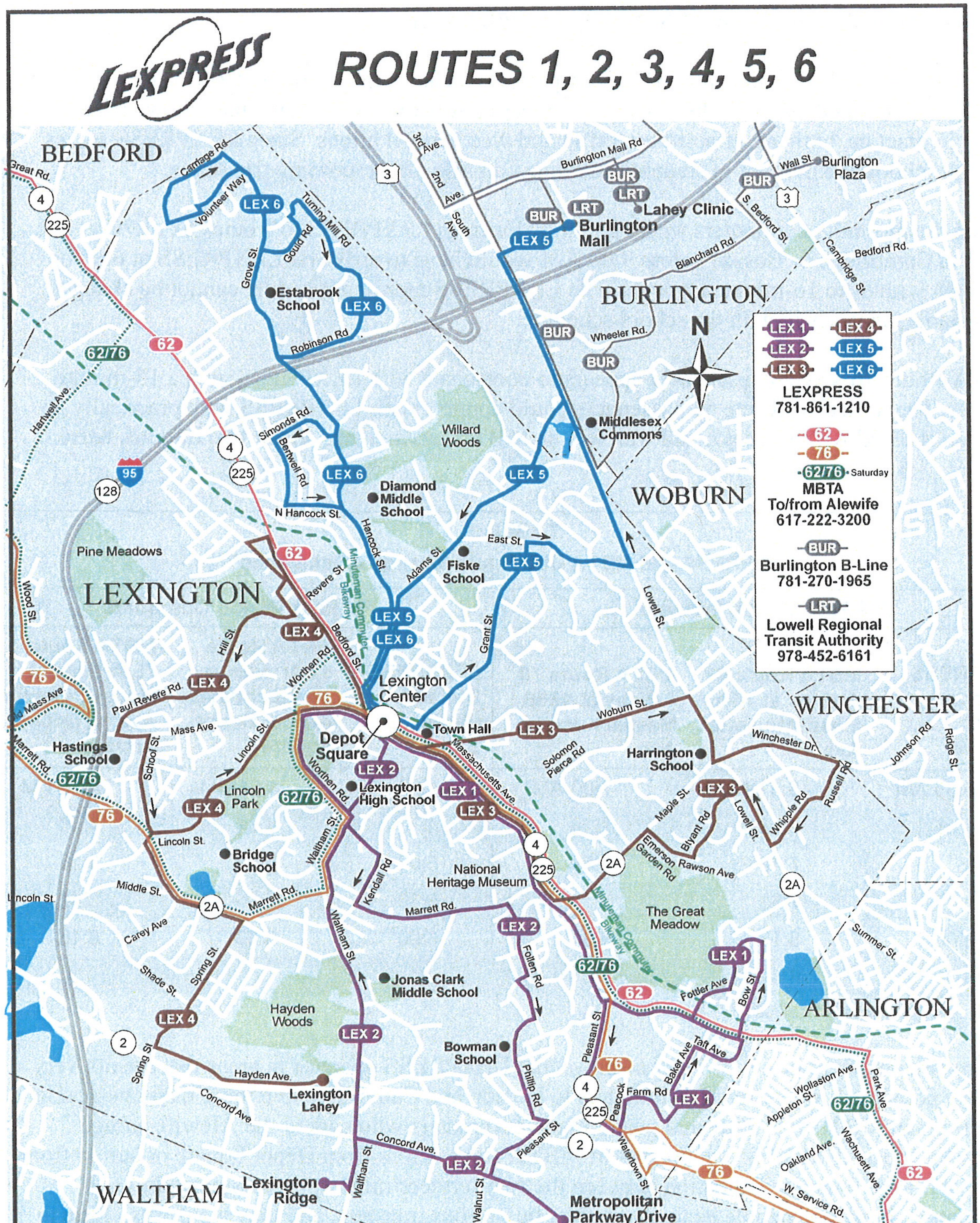
[5] "DC Metro May Increase Bus Stop Spacing to Improve Service," *Urban Transportation Monitor*, June 13, 2008, p. 1.
[6] Ibid., p. 2.
[7] "MBTA Transit Signal Priority Study: Arborway Corridor," draft memorandum, CTPS, July 11, 2008, p. 13.
[8] http//ci.lexington.ma.us/Lexpress/lexpress.htm.



Courtesy of the Town of Lexington

CTPS

FIGURE 6
LEXPRESS and MBTA Bus Routes 62 and 76

AlewifeStudy: Phase II

Potential Transfers Between LEXPRESS and MBTA Routes

Table 3 shows LEXPRESS and MBTA peak period schedules in Lexington Center. The LEXPRESS schedule shows when buses leave Depot Square; MBTA schedules show arrival times. In practice, both are affected by traffic and weather conditions. Since LEXPRESS serves the high school, the number of students boarding can also affect morning trip times.

During the morning, commuters wishing to transfer from LEXPRESS to Routes 62 or 76 to arrive in Cambridge or Boston before 9:00 AM would have to arrive on LEXPRESS at 6:35 or 7:05 AM with 8- to 16-minute layovers. The LEXPRESS morning schedule cannot be changed appreciably, as it ties in with the school schedule.

MBTA Route 76's evening schedule appears to coordinate with LEXPRESS with a 15-minute layover. Theoretically, Route 62 passengers could connect with LEXPRESS with practically no layover, if LEXPRESS buses could wait for the MBTA bus arriving one or two minutes later.

TABLE 3
LEXPRESS and MBTA Bus Route 62 and 76 Schedules*

AM Peak Period Inbound			PM Peak Period Outbound		
LEXPRESS Departs Depot Square	MBTA Route 62 Arrives at 1666 Massachusetts Ave.	MBTA Route 76 Arrives at 1666 Massachusetts Ave.	LEXPRESS Departs Depot Square	MBTA Route 62 Arrives at Massachusetts Ave. at Depot Square	MBTA Route 76 Arrives at Massachusetts Ave. at Depot Square
6:35 AM	6:51 AM	7:00 AM	4:00 PM	4:01 PM	4:16 PM
7:05	7:13	7:28	4:30	4:31	4:46
	7:42	7:58	5:00	5:01	5:16
	7:53		5:30	5:31	5:46
8:00	8:12	8:31	6:00	6:03	6:16
8:30	8:42	9:01			

*MBTA schedule effective 12/27/08

A comparison of Figures 1, 3, 5 and 6 shows that LEXPRESS operates in areas that are not very densely populated, where many commuters to Boston and Cambridge live more than one-quarter mile from an MBTA bus route and where many commuters who park at the Alewife garage originate. Most LEXPRESS routes stop at MBTA stops across from Depot Square or across from the post office. Better coordination between the two services might attract some additional commuters; however, people generally dislike bus-to-bus transfers, and they would also have to pay fares on both the LEXPRESS buses and on MBTA buses. If they chose to do this, LEXPRESS's operating costs would increase if an additional vehicle were required. Several LEXPRESS routes operate near MBTA stops on MBTA Routes 62/76. Since LEXPRESS stops on demand outside the Center, these locations are additional opportunities for riders to transfer to MBTA buses.

To avoid issues with changing LEXPRESS service, perhaps the Town of Lexington, under the Boston Region MPO's Suburban Mobility Program, could apply for funds for a peak period shuttle to Alewife. If the shuttle proves that there is ridership, perhaps the MBTA can offer service.

CONCLUSIONS AND RECOMMENDATIONS

MBTA bus routes generally operate on major roads in Arlington and Lexington; however, several routes do run on local roads in each community.

The major conclusion from this study is that the current routing of MBTA bus service through Arlington and Lexington seems to be appropriate. There is more service in densely populated neighborhoods. Block groups with the lowest level of vehicle ownership generally have the largest proportions of Boston/Cambridge commuters who live within one quarter mile of an MBTA bus stop, and these block groups also have fewer vehicles parked in the Alewife garage. In addition, bus service seems to effectively serve those with lower incomes, as 81% of those who have household incomes below the MPO median live within one-quarter mile of a bus stop.

The following are possible route modifications that might encourage more commuters to ride buses to Alewife Station. Possible difficulties are also mentioned.

- With community input and an awareness of local characteristics, the MBTA and the communities involved should consider modifying the spacing of stops on some or all of the bus routes in the study area.

- Route 67 runs along the border of an Arlington block group that has one of the lowest levels of accessibility to bus service in the town, and the route also has a spur (now inactive until redevelopment in the area is complete) into that block group. Forty-seven percent of this block group's commuters to Boston and Cambridge live within one quarter-mile of this bus route, which is routed through what appears to be one of the less densely developed areas of the block group, near the former Symmes Hospital. The number of vehicles from this block group parked at the Alewife garage falls in the highest category of vehicles parked. Perhaps more of these commuters would use the bus if it were routed through the denser areas of the block group. It is unclear whether there is a specific grade beyond which the MBTA will not operate buses. However, the hilly terrain in this area is a possible impediment to rerouting buses here. This is also a predominantly residential area where local streets might not be able to accommodate regular-size buses.

- At one time, the Route 67 bus extended from Turkey Hill in Arlington into a section of Lexington that has LEXPRESS service, but that portion of the route was discontinued. Perhaps Lexington and the MBTA could explore the feasibility of reinstating the extension.

However, the existing route already operates on a loop. Lengthening the distance and increasing the headway could affect existing ridership.

- Better coordination between LEXPRESS and MBTA services, particularly in Lexington Center in the morning, might attract some additional commuters; however, people generally dislike bus-to-bus transfers, and they would also have to pay fares on both the LEXPRESS buses and MBTA buses. Coordinating services would add to LEXPRESS operating costs and would disrupt school service. Several LEXPRESS routes have sections in common with MBTA Routes 62 and 76. Since LEXPRESS stops on demand outside Lexington Center, riders can be encouraged to transfer to these MBTA routes to Alewife.
- Under the Boston Region MPO's Suburban Mobility Program, the Town of Lexington could apply for funds for a peak period shuttle to Alewife. If the shuttle were to prove that there is sufficient demand, perhaps the MBTA could offer service.

AW/aw

MEMORANDUM

TO: Transportation Planning and Programming Committee — **April 1, 2009**

FROM: Seth Asante, Mark Abbott, Efi Pagitsas, and Alicia Wilson

RE: Traffic Operations and Bus Access and Egress at the Route 2/Route 16 Intersection and the Alewife MBTA Garage: Existing Conditions and Recommended Improvements

INTRODUCTION

The purpose of this memorandum is to fulfill the requirements of Tasks 3 and 4 of the work program "Alewife Station: Improvements to Feeder Bus Routes, Bus Access and Egress, and Route 2/Route 16 Intersection," November 1, 2007. In addition, this memorandum incorporates many of the issues and potential solutions discussed as part of the Alewife Working Group that was convened by Massachusetts State Senator Stephen Tolman. In May 2008, Senator Tolman's office organized a working group to examine traffic operations in the Alewife MBTA station area, including the intersections of Route 16 with Cambridgepark Drive and Rindge Avenue. The group included representatives from the Department of Conservation and Recreation (DCR), MassHighway, Massachusetts State Police, Cambridge Traffic and Parking, Cambridge Police, the Boston Region MPO, Wyeth Corporation, the MBTA, Cambridge Chamber of Commerce, Senator Tolman's office, and Jones Lang LaSalle; Representative William Brownsberger,. The Alewife Working Group met four times in 2008.

This memorandum describes geometric and operational issues at the Route 2/Route 16 intersection, presents analysis results for existing conditions and several alternatives, and makes recommendations for improvements. It also deals with issues related to bus access and egress at the Alewife MBTA station; improvements to the Route 2/Route 16 intersection are critical to reducing bus access and egress delays. The text that follows contains observations of the traffic operations at various roadway segments and intersections in the vicinity of the Route 2/Route 16 intersection and Alewife Station that cause delays to traffic, including delays to buses to and from the MBTA garage at the station. The memorandum also explores various options to reduce these delays and recommendations for improvements at locations that presently have problems related to access and egress of buses at the station.

Operations at the Route 2/Route 16 intersection are crucial. They impact schedule adherence for MBTA feeder buses to/from Alewife Station and slow down motorists and passengers driving through it. The intersection is typically severely congested during both peak hours, with queues extending in all four directions far enough to impede other traffic flow. Travel speeds of the roadway segments feeding into the intersection consistently range from less than 10 mph to about 30 mph, compared to posted speed limits of between 55 and 25 mph on Route 2 and 30 mph on Route 16 in the vicinity.

A side impact of the delays through this intersection is the diversion of traffic to other roadways in the area. For example, eastbound Route 2 traffic bypasses this intersection and uses the Route 2 eastbound off-ramp, the Alewife Station Access Road, and Cambridgepark Drive to reach Alewife Brook Parkway southbound and northbound. Diversion of traffic through this internal network of streets clogs access to the station and egress from local commercial developments.

INTERSECTION DESCRIPTION

The Route 2/Route 16 signalized intersection is at the eastern terminus of the limited-access portion of Route 2 (Concord Turnpike). At this intersection, Route 2 merges with Route 16 (Alewife Brook Parkway). The intersection is commonly referred to as Alewife Circle, because up to the mid-1980s this location operated as a traffic circle. The two roadways are under different jurisdictional control. Up to a point just east of the bridge over the Minuteman Bike Path, MassHighway operates Route 2. Route 16 is a Department of Conservation and Recreation (DCR) roadway. The intersection is controlled by a DCR-operated and -maintained traffic signal, which is coordinated with those at Route 16/Cambridgepark Drive and Route 16/Rindge Avenue.

Figure 1 shows the roadway network in the general area surrounding the Alewife garage, where the intersection is located. As may be seen, the Route 2/Route 16 intersection actually consists of four intersections, with the conflicting traffic movements spread out among these smaller intersections. All approaches to the intersections are under signalized control. Essentially, the signals work as a coordinated signal system controlled by one traffic controller.

The Route 2 eastbound approach has two primary lanes, which split at the intersection into one left-turn lane (used by drivers as two lanes during peak hours) and two through lanes. However, during congested periods, the inner of the two through lanes is blocked by left-turning traffic, essentially resulting in only one eastbound lane's being available to serve the eastbound through traffic. The Route 16 northbound approach has two lanes which split into four lanes at the intersection: two lanes leading to Route 2 westbound and two lanes going to Route 16 northbound. Route 16 on the southbound approach, from Massachusetts Avenue, is also two lanes wide. These lanes split at the intersection, with two lanes continuing south to Route 16 and one lane turning right to Route 2 westbound. The fourth approach to the intersection is the Alewife Station Access Road. This approach provides direct egress from the MBTA station and Cambridgepark Drive to Route 2 westbound and Route 16 northbound. It is a single-lane approach, which splits into one through lane to Route 2 westbound and a right-turn lane to Route 16 northbound, with a small island separating these lanes. During the PM peak period, drivers use it as two travel lanes from the Route 16 underpass up to the intersection.

Bus access to Alewife Station from Route 2 is provided along a ramp/service road, which exits directly from Route 2 eastbound approximately 1,400 feet prior to the intersection. This service road also provides access to Acorn Park and Cambridgepark Drive.

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FIGURE 1
Roadway Network

Route 2/Alewife Brook Parkway Traffic Study

BUS ROUTE NETWORK IN THE ALEWIFE AREA

There are six routes to/from Alewife Station that use Route 2 and Route 16 in the study area. Figure 2 shows the layout of the bus routes to/from the station. Buses 79 and 350 arrive at and leave the station via Route 16 (blue line in the figure) and the Alewife Station Service Road (jug-handle), respectively. Buses 62, 67, 76, and 84 access the station via Route 2 eastbound (yellow line) and the Alewife Station Service Road; they leave the station via the Alewife Station Service Road (jug-handle), the Route 2/Route 16 intersection, and Route 2 westbound. The Alewife Station Service Road south of Route 2 connects with Route 2 eastbound via the Route 2 eastbound off-ramp, approximately 1,400 feet west of the Route 2/Route 16 intersection, and also provides access to Acorn Park (not shown in Figure 2). At the other end, the Alewife Station Service Road passes under Route 16 and connects with the Route 2/Route 16 intersection via a jug-handle configuration (see Figure 2).

This description of bus access and egress shows that all westbound, southbound, and northbound buses must pass through the Route 2/Route 16 intersection, which experiences lengthy delays and queues during peak periods. In addition, all Route 2 eastbound buses arrive at the station via the Route 2 eastbound off-ramp, which is often blocked by Route 2 eastbound traffic backed up from the Route 2/Route 16 intersection.

FIELD OBSERVATIONS

As mentioned previously, the area is heavily congested during the peak traffic periods. Field visits to the area, augmented by insights from the Cambridge Traffic Department,[1] provided the following observations of the traffic operations in the area of Alewife Station, including operations at the Route 2/Route 16 intersection. Note that the observations described below make up a comprehensive list of known problems on the roadways surrounding the MBTA garage and that many of these were discussed in the Alewife Working Group in 2008. Figure 3 is a map showing the operations issues observed in the field, including the traffic diversion routes (shown in yellow lines) from the Route 2 eastbound off-ramp.

Although the operations problems include other intersections in the vicinity besides the Route 2/Route 16 intersection, the scope of this study is mainly to address operational issues at the Route 2/Route 16 intersection and access/egress issues of MBTA buses to/from the garage.

Route 2/Route 16 Intersection (see Figure 3)

Route 2 Eastbound:
In both lanes, queues extend back to the off-ramp to the Alewife Station Service Road. Queuing sometimes extends back past the off-ramp to the Lake Street interchange and prohibits buses and other ramp-destined vehicles from reaching the off-ramp. Due to congestion at the intersection, the left-most of the two through lanes is used by vehicles destined for Route 16 northbound, and vehicles headed to Route 16 southbound use the right lane. Thus, this approach limits the effectiveness and capacity of the four lanes at the intersection.

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[1] City of Cambridge and CTPS staff presentation to the Alewife Working Group, May 2008.

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FIGURE 2
Bus Routes to/from Alewife MBTA Station

Route 2/Alewife Brook Parkway Traffic Study

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FIGURE 3
Traffic Operations Issues at the Alewife MBTA Station

Route 2/Alewife Brook Parkway Traffic Study

Alewife Station Access Road (Jug-handle):
During the evening peak hour, the queue on the single-lane roadway prevents vehicles turning right from reaching the intersection. Also the heavy queuing delays MBTA bus service.

Route 16 Southbound:
This approach has a heavy right-turn movement to Route 2 westbound during both peak periods. Queuing is significant in this single right-turn lane and limits the effectiveness of the two southbound through lanes, which southbound Route 16 buses use to reach the station.

Route 16 Northbound (including the merge area):
At the merge point north of the intersection, Route 2 eastbound and Route 16 northbound traffic merge from four lanes total into two lanes. Queues from the Route 16-to-Route 2 movement spill back past the diverge point and block vehicles destined for Route 16 northbound. This operational difficulty affects the overall level of service of the intersection; impacts on buses are included in the effects.

Route 2 Westbound Merge:
The merging area of the Route 16-to-Route 2 westbound traffic and the Alewife Station Access Road westbound traffic is very short and limits the capacity of these two movements at the intersection.

Route 2 Eastbound Off-Ramp to Alewife Station Access Road (see Figure 3)

Route 2 Off-Ramp:

- The queues from the Route 2/Route 16 intersection extend back past the ramp and block access to it.
- As a result of the queuing, MBTA buses are blocked from the station.
- Review of the AM and PM peak period traffic volumes reveals that traffic uses the Route 2 eastbound off-ramp to bypass the congested Route 2/Route 16 intersection as follows:

    1. Drivers divert from Route 2 using Acorn Park Road from the Lake Street interchange to access the Alewife Station Access Road (see yellow lines in Figure 3). They connect to Route 16 northbound and southbound using the Access Road (jug-handle) or Cambridgepark Drive. This diversion occurs when the Route 2 eastbound traffic queue builds up beyond the off-ramp to Alewife Station.

    2. Drivers also divert from the off-ramp to Alewife Station to avoid congestion at the Route 2/Route 16 intersection (see yellow lines in Figure 3). They usually do this when the Route 2 eastbound traffic queue is close to the off-ramp but not beyond it. They connect to Route 16 northbound or southbound using the same roads described earlier.

    In both situations drivers travel for a longer distance, but the total delay is perceived by drivers to be less than the delay of passing through the Route 2/Route 16 intersection from Route 2 eastbound.

Alewife Station Access Road/Cambridgepark Drive Intersection (see Figure 3)

Cambridgepark Drive Eastbound:

- During the evening peak period, this approach experiences long queues. These queues then block access to the bicycle lane.
- Eastbound vehicles frequently travel down the wrong side of the center yellow line into oncoming traffic due to congestion and long waiting times during the PM peak period.

Cambridgepark Drive Westbound:

- Frequent drop-offs are made at MBTA/Bertucci's on this approach; afterwards vehicles proceed to make U-turns at the intersection.

Alewife Station Access Road Southbound:

- The previously mentioned bypass vehicles make left turns at the intersection, thus delaying vehicles exiting from Cambridgepark Drive.
- Double left turns are permitted concurrently with the northbound movement.
- Left-turning vehicles do not yield to pedestrians in the crosswalk during the concurrent pedestrian phase.

Route 16/Cambridgepark Drive Intersection (see Figure 3)

Route 16 Northbound:

- Limited capacity on Route 16 limits access for vehicles turning left from Cambridgepark Drive.
- Left-turning vehicles are frequently using the yellow and red clearances to complete turns.
- The protected left-turn movement is constrained by southbound vehicles continuing during yellow and red phases.
- In the morning, there is a long queue on Route 16 at Cambridgepark Drive and at Rindge Avenue, while there is room for vehicles north of Cambridgepark Drive.

Route 16 Southbound:

- Due to extended delays, southbound vehicles continue during yellow and red phases.
- Right turns from Cambridgepark Drive fill the single right lane to Route 16 southbound. Additional vehicles turning right use the right-most of the two left-turn lanes to go around the channelization island in order to turn onto Route 16 southbound.

Cambridgepark Drive Eastbound:

- MBTA buses exit the garage across four lanes of traffic. (Note that this might no longer occur because of routing changes.)
- Queuing from the Route 2/Route 16 intersection spills back, limiting left turns from Cambridgepark Drive.
- Due to queuing from the Rindge Avenue intersection, right turns are being made from the left-turn lane, around the channelization island, to the second southbound lane.

INTERSECTION LEVEL OF SERVICE

As explained in the *Highway Capacity Manual (HCM 2000),* the concept of levels of service uses qualitative measures that characterize operational conditions within a traffic stream and how motorists and passengers perceive them. The criterion defining the levels of service for a signalized intersection is based on six ranges of control delay that is estimated from intersection geometry, operational parameters, and approaching traffic volumes. Figure 4 shows the levels of service for signalized intersections from HCM 2000. Level of service (LOS) A represents the most favorable condition, with minimal traffic delay. LOS F represents the worst condition, with significant traffic delay. LOS D is generally considered acceptable in an urban environment.

Using the peak hour traffic volumes and intersection geometry data collected in field reconnaissance, staff analyzed the existing traffic operations through the application of Synchro/ SimTraffic,[2] a traffic analysis and simulation software package that contains methodologies based on HCM 2000. Although the operations problems include other intersections in the vicinity besides the Route 2/Route 16 intersection, the scope of this study is to address mainly operational issues at the Route 2/Route 16 intersection and access/egress issues of MBTA buses to/from the garage. Therefore, analysis of existing conditions was focused only on this particular intersection. The results of the existing condition analysis are described below.

EXISTING CONDITIONS: ROUTE 2/ROUTE 16

Figure 5 shows existing traffic volumes. Tables 1 and 2 summarize existing conditions analysis results for the AM and PM peak hours, respectively. As previously stated, this intersection was analyzed as four smaller intersections, all coordinated with each other. (Refer to Figure 2, which shows how the intersections are numbered for the purposes of the analysis.)

As the tables show, many movements at the intersection are operating over capacity (volume-to-capacity ratio, V/C, is greater than 1.0) and with LOS E or F, causing significant delays and queuing (in the tables, see 95% queue,[3] Q, in feet). These delays and queuing also significantly impact the operations of the MBTA buses.

The next sections describe possible options for improving traffic operations at the Route 2/Route 16 intersection and for improving access to/from Alewife Station.

POTENTIAL ROUTE 2/ROUTE 16 INTERSECTION IMPROVEMENT OPTIONS

Eight options were developed for improving the operations and traffic flow at the Route 2/Route 16 intersection; many of them were developed and analyzed by staff as part of the work performed for the Alewife Working Group. The list of options below is a comprehensive list of those developed within the context of this study and from the work of the Alewife Working Group. Some options were analyzed quantitatively using the microsimulation software VISSIM[4] or the software SYNCHRO, and others were analyzed qualitatively.

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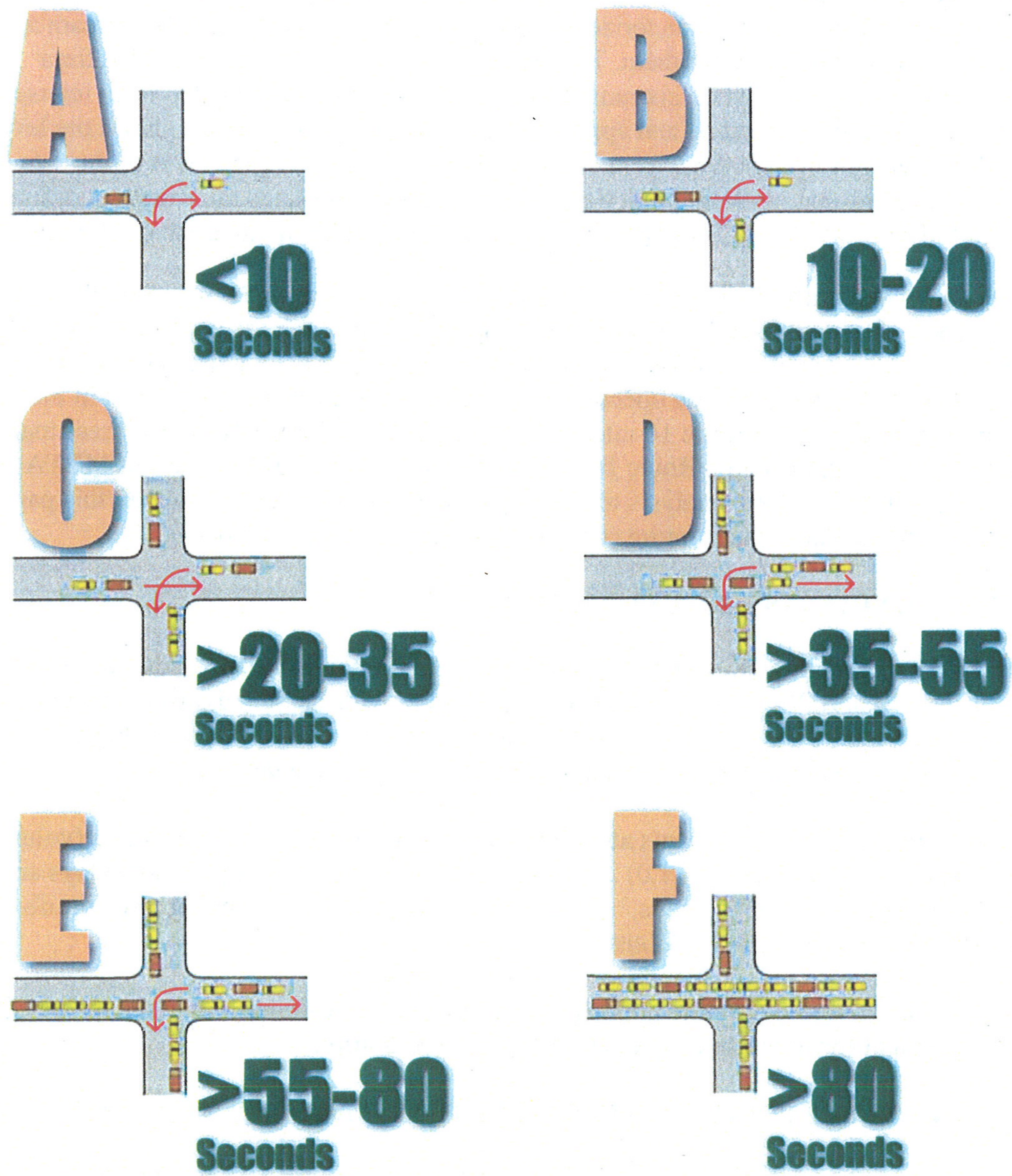
[2] *Synchro/SimTraffic Version 6*, Trafficware Corporation, 2003.

[3] A 95% approach queue is one which is expected to be longer than indicated 5% of the time.

[4] *VISSIM Version 5.0*, PTV America, 2007.



The average control delay per vehicle is estimated for each lane group and aggregated for each approach and for the intersection as a whole. The level of service is directly related to the control delay value.

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FIGURE 4
Concept of Level of Service for Signalized Intersection
Average Control Delay

Route 2/Alewife Brook Parkway Traffic Study

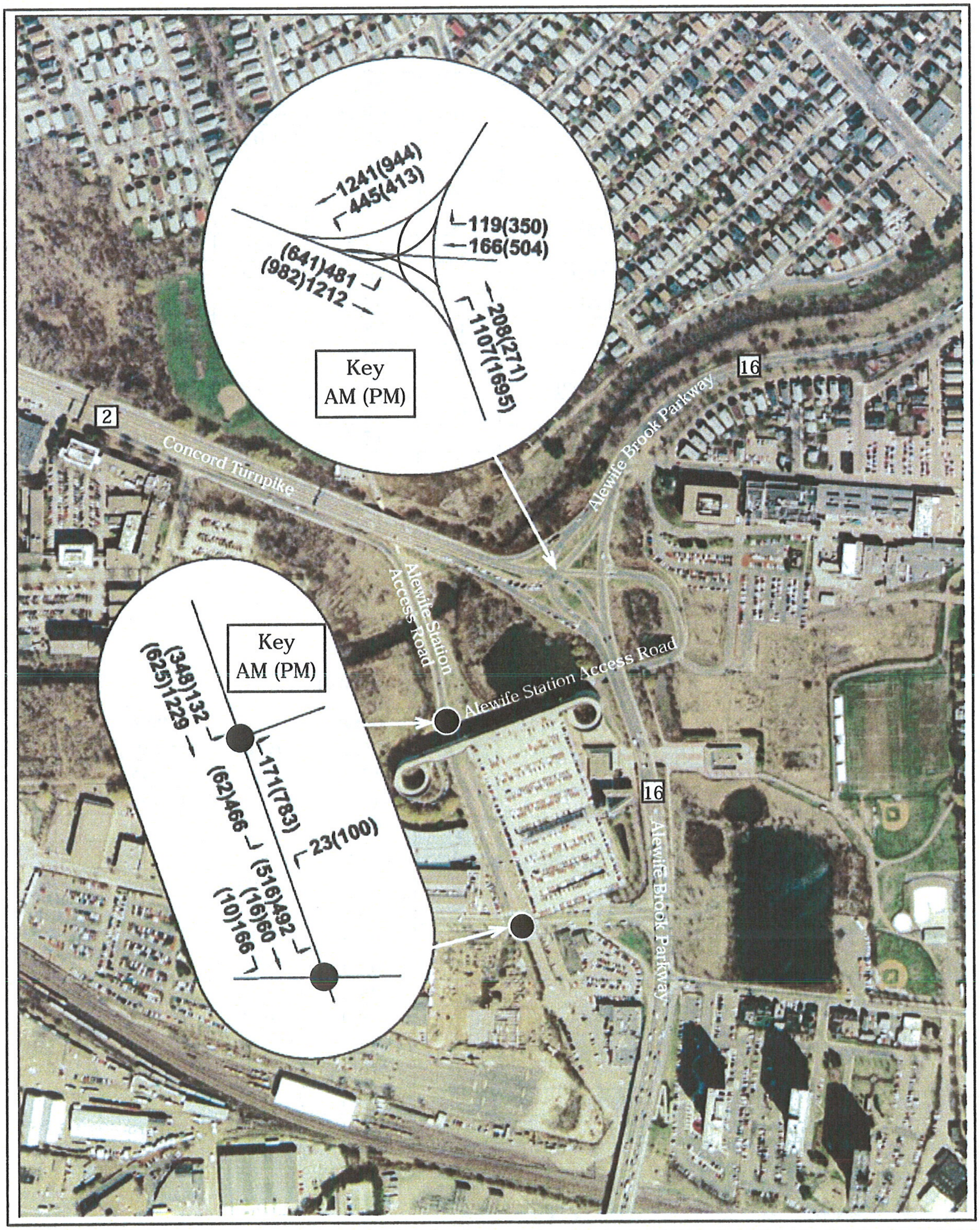

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FIGURE 5
Existing Traffic Volumes

Route 2/Alewife Brook Parkway Traffic Study

TABLE 1
Existing Conditions - AM Peak Hour

Intersection #	Movement	LOS	Delay (Sec)	V/C Ratio	95% Queue (ft)
	Route 2 WB	C	34.9	1.02	m127
1	Alewife to Route 2 WB	F	290.3	1.57	#1745
	Overall	F	160.7	1.34	n/a
	Alewife Station Exit - Through	A	1.9	0.25	3
	Alewife SB to Alewife	C	33.7	0.43	206
2	Alewife NB to Route 2 WB	F	136.5	1.14	#680
	Route 2 EB to Alewife NB	E	57.3	0.81	#274
	Overall	F	88.0	0.75	n/a
	Alewife NB to Alewife	A	2.6	0.12	m17
3	Alewife Station Exit - Through	C	26.2	0.26	154
	Alewife Station Exit - Right	C	23.9	0.08	40
	Overall	C	15.9	0.18	n/a
	Route 2 EB to Alewife SB	C	21.6	0.72	415
	Alewife SB to Alewife	A	5.6	0.44	14
	Overall	B	17.3	-	n/a

Note: # - 95% volume exceeds capacity, queue may be longer.
m - Volume for 95% queue is metered by upstream signal.

TABLE 2
Existing Conditions - PM Peak Hour

Intersection #	Movement	LOS	Delay (Sec)	V/C Ratio	95% Queue (ft)
	Route 2 WB	F	113.6	1.22	m1145
1	Alewife to Route 2 WB	F	435.9	1.87	#1465
	Overall	F	207.9	1.46	n/a
	Alewife Station Exit - Through	A	2.6	0.59	10
	Alewife SB to Alewife	F	82.5	0.95	#288
2	Alewife NB to Route 2 WB	E	68.2	1.07	m#907
	Route 2 EB to Alewife NB	F	125.6	1.13	#451
	Overall	E	69.5	1.03	n/a
	Alewife NB to Alewife	C	28.1	0.24	m110
3	Alewife Station Exit - Through	B	18.9	0.59	417
	Alewife Station Exit - Right	B	14.2	0.32	80
	Overall	B	19.4	0.46	n/a
	Route 2 EB to Alewife SB	A	6.6	0.48	161
	Alewife SB to Alewife	E	63.4	1.02	m#98
	Overall	C	23.4	0.55	n/a

Note: # - 95% volume exceeds capacity, queue may be longer.
m - Volume for 95% queue is metered by upstream signal.

Of the eight options, the first four are low- to medium-capital-investment options; the last four are high-capital-investment options. Each option is discussed in detail in the subsections below.

1. Optimize signal timings
2. Replace existing left-turn lane from Route 2 eastbound to Route 16 northbound with a double left-turn lane
3. Eliminate Route 2 eastbound left turns and divert traffic to the Alewife Station Access Road
4. Add a third lane along Route 2 westbound from the Alewife Station Access Road approach to just past the Minuteman Bike Path overpass
5. Construct a fly-over from Route 16 northbound to Route 2 westbound
6. Replace intersection with a conventional roundabout
7. Replace intersection with a roundabout, including right-turn slip ramps
8. Replace intersection with a roundabout, including a fly-over for traffic from Route 16 northbound to Route 2 westbound

Option 1: Optimize signal timings
Optimizing signal timings is the easiest and least expensive way to improve operations at an intersection. Optimization aims at improving the efficiency of the intersection's operations by examining the allocation of green time in the signal and, if necessary, reallocating it among the various signal phases/approaches to reduce overall intersection delays and queues. However, as Table 3 shows, this option is not effective for this intersection, as it cannot, as a stand-alone strategy (without geometric changes), reduce sufficiently the significant delays and queues at this location.

Option 2: Replace existing left-turn lane from Route 2 eastbound to Route 16 northbound with a double left-turn lane
At present, traffic for the single left-turn lane from Route 2 eastbound to Route 16 northbound spills onto the Route 2 eastbound through lanes, reducing the processing capacity of that movement. Although for a short distance within the intersection left-turning vehicles line up in two lanes, this lane use is not sufficient to store enough vehicles and prevent the spillover. The recommended improvement would be to construct a longer double left-turn lane that would allow for full use/storage and increased capacity for left turns without impacting through movements. However, analysis (Table 4) showed that this minor lane adjustment is not sufficient by itself to improve traffic operations at the intersection and needs to be combined with another option.

Option 3: Eliminate Route 2 eastbound left turns and divert traffic to the Alewife Station Access Road
This proposed improvement would place the left-turning vehicles onto the Alewife Station Access Road. The left turns would exit Route 2 at the Alewife Station Access Road off-ramp, continue onto the access road past the garage, and eventually reach the Route 2/Route 16 intersection from the east (via the jug-handle) to make the right turn to Route 16 northbound. This improvement allows for the elimination of one phase from the design of the traffic signal, giving additional time to the other critical movements. Table 5 shows the results of this improvement.

TABLE 3
Option 1: Optimize Signal Timings

Intersection	Movement	LOS		Delay		Volume-to-Capacity Ratio		95% Queue Length	
		Existing	Option 1	Existing	Option 1	Existing	Option 1	Existing	Option 1
AM Peak Hour									
1	Route 2 WB	C	B	39.4	18.3	1.02	0.91	m127	m135
	Route 16 SB to Route 2 WB	F	F	290.3	365.6	1.57	1.73	#1745	#1810
	Overall	F	F	160.7	189.4	1.34	1.34	n/a	n/a
2	Alewife Station Exit to Route 2 WB	A	A	1.9	1.6	0.25	0.23	3	3
	Route 16 SB - Through	C	D	33.7	39.4	0.43	0.51	206	222
	Route 16 NB to Route 2 WB	F	E	136.5	57.7	1.14	0.91	#680	#569
	Route 2 EB to Route 16 NB	E	E	57.3	57.3	0.81	0.81	#274	274
	Overall	F	D	88	49.6	0.75	0.74	n/a	n/a
3	Route 16 NB - Through	A	A	2.6	5.7	0.12	0.13	m17	m42
	Alewife Station Exit - Through	C	C	26.2	22.1	0.26	0.23	154	141
	Alewife Station Exit - Right	C	C	23.9	20.2	0.08	0.08	40	36
	Overall	B	B	15.9	14.9	0.18	0.18	n/a	n/a
4	Route 2 EB to Route 16 SB	C	B	21.6	17.4	0.72	0.68	415	381
	Route 16 SB - Through	A	A	5.6	6.6	0.44	0.53	14	14
	Overall	B	B	17.3	14.5	N/A	0.64	n/a	n/a
PM Peak Hour									
1	Route 2 WB	F	F	113.6	239.7	1.22	1.48	m#1145	m#1174
	Route 16 SB to Route 2 WB	F	F	435.9	221.9	1.87	1.38	#1465	#1593
	Overall	F	F	207.9	234.5	1.46	1.43	n/a	n/a
2	Alewife Station Exit to Route 2 WB	A	A	2.6	4.2	0.59	0.71	10	9
	Route 16 SB - Through	F	E	82.5	663.0	0.95	0.73	#288	285
	Route 16 NB to Route 2 WB	E	F	68.2	236.3	1.07	1.41	m#907	#1376
	Route 2 EB to Route 16 NB	F	E	125.6	57.0	1.13	0.76	#451	408
	Overall	E	F	69.5	140.0	1.03	1.02	n/a	n/a
3	Route 16 NB - Through	C	C	28.1	24.1	0.24	0.18	m110	120
	Alewife Station Exit - Through	B	D	18.9	36.7	0.59	0.72	417	644
	Alewife Station Exit - Right	B	C	14.2	26.1	0.32	0.35	80	135
	Overall	B	C	19.4	30.6	0.46	0.46	n/a	n/a
4	Route 2 EB to Route 16 SB	A	B	6.6	11.8	0.48	0.51	161	260
	Route 16 SB - Through	E	A	63.4	3.0	1.02	0.61	m#98	1
	Overall	C	A	23.4	9.2	0.55	0.53	n/a	n/a

Note: # - 95% volume exceeds capacity; queue may be longer.
m - Volume for 95% queue is metered by upstream signal.

TABLE 4

Option 2: Install a Double Left-Turn Lane for Route 2 Eastbound Traffic

Intersection	Movement	LOS		Delay		Volume-to-Capacity Ratio		95% Queue Length	
		Existing	Option 2	Existing	Option 2	Existing	Option 2	Existing	Option 2
AM Peak Hour									
1	Route 2 WB	C	B	39.4	18.3	1.02	0.91	m127	m135
	Route 16 SB to Route 2 WB	F	F	290.3	365.6	1.57	1.73	#1745	#1810
	Overall	F	F	160.7	189.4	1.34	1.34	n/a	n/a
2	Alewife Station Exit to Route 2 WB	A	A	1.9	1.6	0.25	0.23	3	3
	Route 16 SB - Through	C	D	33.7	39.4	0.43	0.51	206	222
	Route 16 NB to Route 2 WB	F	E	136.5	57.7	1.14	0.91	#680	#569
	Route 2 EB to Route 16 NB	E	E	57.3	61.3	0.81	0.83	#274	300
	Overall	F	D	88	49.6	0.75	0.74	n/a	n/a
3	Route 16 NB - Through	A	A	2.6	5.7	0.12	0.13	m17	m42
	Alewife Station Exit - Through	C	C	26.2	22.1	0.26	0.23	154	141
	Alewife Station Exit - Right	C	C	23.9	20.2	0.08	0.08	40	36
	Overall	B	B	15.9	14.9	0.18	0.18	n/a	n/a
4	Route 2 EB to Route 16 SB	C	B	21.6	17.4	0.72	0.68	415	381
	Route 16 SB - Through	A	A	5.6	6.6	0.44	0.53	14	14
	Overall	B	B	17.3	14.5	N/A	0.64	n/a	n/a
PM Peak Hour									
1	Route 2 WB	F	F	113.6	239.7	1.22	1.48	m#1145	m#1174
	Route 16 SB to Route 2 WB	F	F	435.9	221.9	1.87	1.38	#1465	#1593
	Overall	F	F	207.9	234.5	1.46	1.43	n/a	n/a
2	Alewife Station Exit to Route 2 WB	A	A	2.6	4.2	0.59	0.71	10	9
	Route 16 SB – Through	F	E	82.5	663.0	0.95	0.73	#288	285
	Route 16 NB to Route 2 WB	E	F	68.2	236.3	1.07	1.41	m#907	#1376
	Route 2 EB to Route 16 NB	F	E	125.6	57.0	1.13	0.76	#451	408
	Overall	E	F	69.5	140.0	1.03	1.02	n/a	n/a
3	Route 16 NB - Through	C	C	28.1	24.1	0.24	0.18	m110	120
	Alewife Station Exit - Through	B	D	18.9	36.7	0.59	0.72	417	644
	Alewife Station Exit - Right	B	C	14.2	26.1	0.32	0.35	80	135
	Overall	B	C	19.4	30.6	0.46	0.46	n/a	n/a
4	Route 2 EB to Route 16 SB	A	B	6.6	11.8	0.48	0.51	161	260
	Route 16 SB - Through	E	A	63.4	3.0	1.02	0.61	m#98	1
	Overall	C	A	23.4	9.2	0.55	0.53	n/a	n/a

Note: # - 95% volume exceeds capacity; queue may be longer.
m - Volume for 95% queue is metered by upstream signal.
Currently drivers line up in two lanes to turn left; this option helps in storage of left-turn vehicles. The results for Option 2 are similar to those of Option 1.

While this improvement addresses some of the problems associated with some movements within the intersection, it does not adequately improve the overall operations of the entire intersection. For example, it does not improve the Route 2 westbound/Route 16 southbound merge. Delays and queuing on the Alewife Station Access Road approach, the jug-handle, would necessitate widening the roadway to two lanes along its entirety, including widening the Route 16 bridge over the Alewife Station Access Road. In addition, as this option would add 500 to 600 vehicles to the off-ramp and the Alewife Station Access Road, MBTA bus routes would suffer additional delays, and drivers and passengers would incur additional vehicle-miles and vehicle-time traveled (VMT and VHT). This option was dropped because of its impacts on MBTA bus operations to/from the Alewife Station.

Option 4: Add a third lane along Route 2 westbound from the Alewife Station Access Road approach (jug-handle) to just past the Minuteman Bike path overpass or to Lake Street

Adding a third lane westbound on the north side of Route 2 is an effective measure, as it frees up green time at the intersection for reallocation to other approaches, including the Alewife Station Access Road. This option, shown in Figure 6, also includes a double right-turn lane from Route 16 southbound to Route 2 westbound and a double left-turn lane from Route 2 eastbound to Route 16 northbound. Analysis showed that adding the third lane westbound, along with the other two features, would result in lower delays and shorter queues on all approaches of the intersection. This option has overarching benefits that include reductions in travel times and delays for vehicles and buses. Option 4 also reduces the eastbound queue that blocks the off-ramp, thus improving bus access from the west.

For the portion of the third lane within the intersection, there is right-of-way available for its construction. For the portion of the third lane west of this area, specifically between the intersection and the Minuteman Bike Path overpass, right-of-way appears to be available. The additional roadway width would have to be secured from an existing and potentially abandoned, sidewalk that begins just north of the intersection on the western side of Route 16 and ends at the Minuteman Bike Path overpass. (MAPC's draft report, *Alewife Access Study*, March 2009 states that there is a need to maintain a pedestrian corridor on the north side of Route 2.) In addition, analysis showed that extension of the third lane to Lake Street is not required in the short term but should be reconsidered in the longer term (Table 6). This option has the potential of improving traffic operations at the Route 2/Route 16 intersection with minimal cost and minimal adverse construction impacts.

Option 5: Construct a Route 2 westbound fly-over

This option is the most beneficial of the improvements presented, but also has the greatest cost. The fly-over removes the most traffic overall from the intersection and allows the other, accompanying improvements to operate better. Figure 7 shows this option. As the figure shows, a single-lane fly-over ramp would be constructed to remove the Route 16 northbound-to-Route 2 westbound traffic from the intersection. Also, a third departing lane would be constructed for a short distance on Route 2 westbound so that the fly-over ramp would have its own lane westbound while Route 16 southbound and Alewife Station Access Road traffic would use the remaining two lanes.

This option eliminates the need for a signal at intersection #1 (see Figure 1). The widening also allows for improved traffic flow through the Lake Street interchange, where Route 2 widens to four lanes. As Table 7 shows, the operations of the remaining intersections improve greatly, with V/C ratios for all movements well below one.

TABLE 5
Option 3: Eliminate Route 2 Eastbound Left Turns

Intersection	Movement	LOS		Delay		Volume to Capacity Ratio		95% Queue Length	
		Existing	Option 3	Existing	Option 3	Existing	Option 3	Existing	Option 3
AM Peak Hour									
1	Route 2 WB	C	F	39.4	425.6	1.02	1.86	m127	m122
	Route 16 SB to Route 2 WB	F	B	290.3	15.4	1.57	0.84	#1745	#1853
	Overall	F	F	160.7	217.5	1.34	1.34	n/a	n/a
2	Alewife Station Exit to Route 2 WB	A	A	1.9	4.1	0.25	0.21	3	17
	Route 16 SB - Through	C	C	33.7	21.5	0.43	0.30	206	163
	Route 16 NB to Route 2 WB	F	E	136.5	61.9	1.14	0.93	#680	#581
	Route 2 EB to Route 16 NB	E	-	57.3	-	0.81	-	#274	-
	Overall	F	D	88	45.7	0.75	0.56	n/a	n/a
3	Route 16 NB - Through	A	A	2.6	5.6	0.12	0.14	m17	m40
	Alewife Station Exit - Through	C	C	26.2	25.2	0.26	0.52	154	310
	Alewife Station Exit - Right	C	C	23.9	20.5	0.08	0.27	40	56
	Overall	B	B	15.9	19.2	0.18	0.34	n/a	n/a
4	Route 2 EB to Route 16 SB	C	C	21.6	33.4	0.72	0.82	415	467
	Route 16 SB - Through	A	A	5.6	3.4	0.44	0.30	14	12
	Overall	B	D	17.3	25.4	N/A	0.57	n/a	n/a
PM Peak Hour									
1	Route 2 WB	F	F	113.6	106.4	1.22	1.20	m#1145	m#1101
	Route 16 SB to Route 2 WB	F	F	435.9	456.7	1.87	1.91	#1465	#1476
	Overall	F	F	207.9	209	1.46	1.46	n/a	n/a
2	Alewife Station Exit to Route 2 WB	A	A	2.6	2.1	0.59	0.58	10	m21
	Route 16 SB - Through	F	D	82.5	31.5	0.95	0.38	#288	185
	Route 16 NB to Route 2 WB	E	E	68.2	76.7	1.07	1.09	m#907	m#919
	Route 2 EB to Route 16 NB	F	-	125.6	-	1.13	-	#451	-
	Overall	E	D	69.5	53.6	1.03	0.78	n/a	n/a
3	Route 16 NB - Through	C	C	28.1	27.5	0.24	0.25	m110	m108
	Alewife Station Exit - Through	B	D	18.9	39.5	0.59	0.93	417	#987
	Alewife Station Exit - Right	B	C	14.2	26.9	0.32	0.80	80	571
	Overall	B	C	19.4	32.6	0.46	0.69	n/a	n/a
4	Route 2 EB to Route 16 SB	A	B	6.6	17.1	0.48	0.57	161	263
	Route 16 SB - Through	E	A	63.4	4.5	1.02	0.38	m#98	11
	Overall	C	B	23.4	13.4	0.55	0.50	n/a	n/a

Note: # - 95% volume exceeds capacity, queue may be longer.
m - Volume for 95% queue is metered by upstream signal.

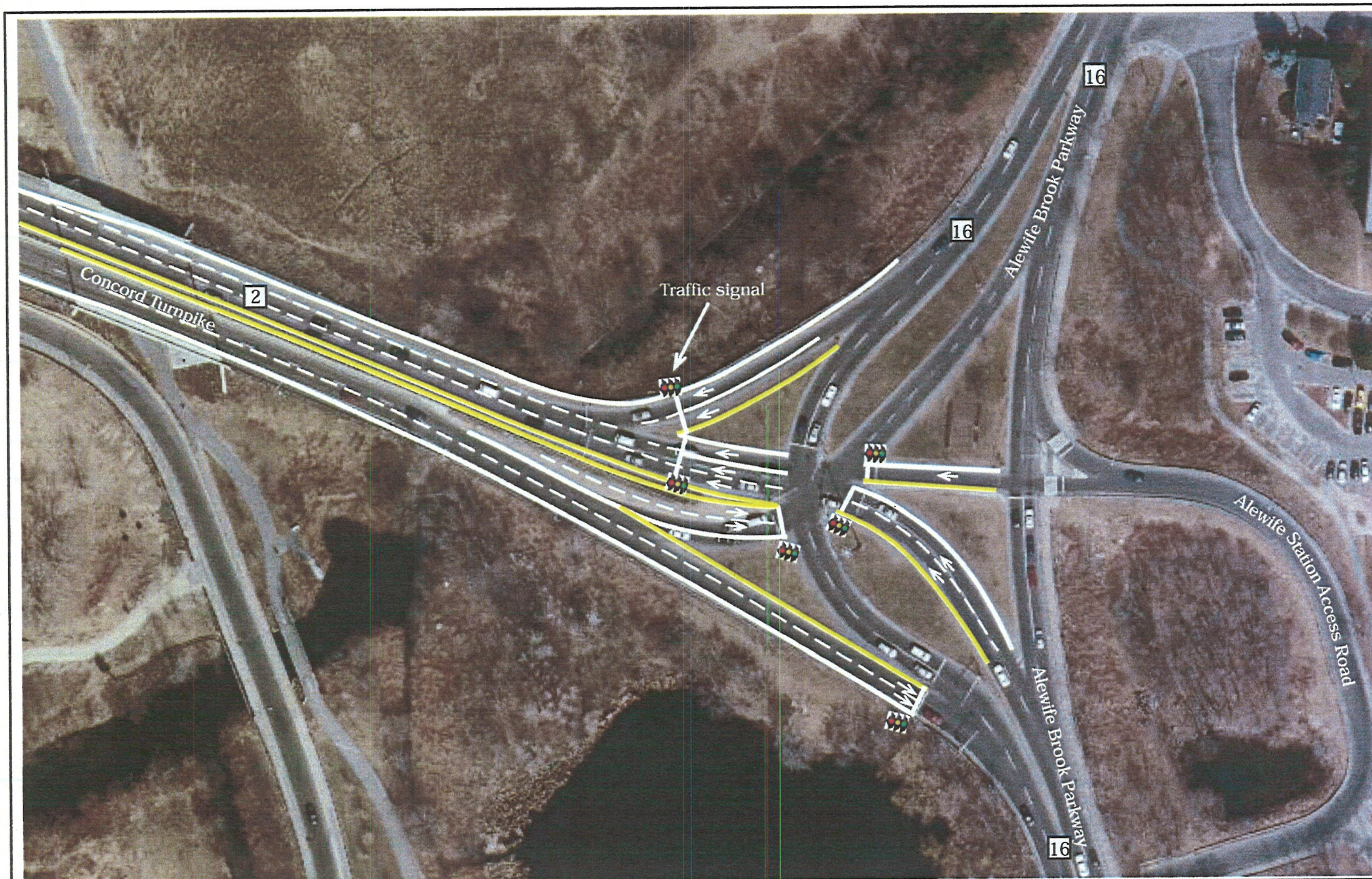

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FIGURE 6
Option 4: Add a Third Lane Along Route 2 Westbound

Route 2/Alewife Brook Parkway Traffic Study

TABLE 6
Option 4: Add a Third Lane Along Route 2 Westbound from Alewife Station Access Road to Minuteman Bike Path Overpass*

Approach	Movement	LOS		Delay	
		Existing	Option 4	Existing	Option 4
AM Peak Hour					
Route 16 SB	Route 2 WB	D	B	42.1	14.3
	Route 16 SB	F	C	103.0	24.8
	Overall	E	B	57.8	17.1
Route 16 NB	Route 16 NB	F	B	117.0	13.2
	Route 2 EB	F	C	256.1	33.2
	Overall	F	C	234.0	30.0
Jug-Handle	Route 16 NB	C	C	29.2	22.4
	Route 2 WB	C	C	32.0	22.9
	Overall	C	C	30.8	22.7
Route 2 EB	Route 16 SB	F	B	133.5	17.9
	Route 16 NB	F	D	85.2	41.7
	Overall	F	C	119.8	24.7
PM Peak Hour					
Route 16 SB	Route 2 WB	D	B	41.8	20.0
	Route 16 SB	E	D	64.7	46.7
	Overall	D	C	48.8	28.1
Route 16 NB	Route 16 NB	F	B	81.0	18.9
	Route 2 EB	F	C	131.6	34.9
	Overall	F	C	124.6	32.7
Jug-Handle	Route 16 NB	D	C	36.2	30.9
	Route 2 WB	F	D	134.5	45.7
	Overall	F	D	94.2	39.6
Route 2 EB	Route 16 SB	F	B	33.5	18.7
	Route 16 NB	B	D	123.5	46.8
	Overall	E	B	69.0	19.1

Results are from VISSIM software
* This option includes a double right-turn lane from Route 16 southbound and a double left-turn lane from Route 2 eastbound to Route 16 northbound.

Based upon MassHighway layout plans, the widening could occur within the existing 100-foot right-of-way. However, it would require the reconstruction of Route 2 in both directions from Route 2/Route 16 to the Lake Street interchange to ease impacts to the properties located along the north side of Route 2. This option was dropped owing to the high costs of construction and of construction impacts.

Option 6: Replace intersection with conventional roundabout

Analysis of a two-lane conventional roundabout revealed a long traffic queue on Route 16 southbound (Figure 8). This phenomenon usually occurs at a roundabout when traffic is not balanced at the intersection, as indicated by the high directional traffic flow between Route 2 and Route 16 and the lack of sufficient left and right turns from the approaches. The net effect of this condition is a constant flow of traffic (from Route 16 northbound to Route 2 westbound) across the entrance of Route 16 southbound, resulting in excessive delays and queuing on that approach (Table 8). Based on the results of the analysis, this option was dropped.

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FIGURE 7
Option 5: Route 2 Westbound Fly-Over

Route 2/Alewife Brook Parkway Traffic Study

TABLE 7
Option 5: Eliminate Route 2 Westbound Flyover

Intersection	Movement	LOS		Delay		Volume to Capacity Ratio		95% Queue Length	
		Existing	Option 5	Existing	Option 5	Existing	Option 5	Existing	Option 5
AM Peak Hour									
1	Route 2 WB	C	n/a	39.4	n/a	1.02	n/a	m127	n/a
	Route 16 SB to Route 2 WB	F	n/a	290.3	n/a	1.57	n/a	#1745	n/a
	Overall	F	n/a	160.7	n/a	1.34	n/a	n/a	n/a
2	Alewife Station Exit to Route 2 WB	A	A	1.9	3.1	0.25	0.25	3	7
	Route 16 SB - Through	C	C	33.7	33.7	0.43	0.43	206	206
	Route 16 NB to Route 2 WB	F	E	136.5	57.3	1.14	0.81	#680	#274
	Route 2 EB to Route 16 NB	E	-	57.3	-	0.81	-	#274	-
	Overall	F	D	88	39.2	0.75	0.43	n/a	n/a
3	Route 16 NB - Through	A	A	2.6	2.6	0.12	0.12	m17	m17
	Alewife Station Exit - Through	C	C	26.2	26.2	0.26	0.26	154	154
	Alewife Station Exit - Right	C	C	23.9	23.9	0.08	0.08	40	40
	Overall	B	B	15.9	15.9	0.18	0.18	n/a	n/a
4	Route 2 EB to Route 16 SB	C	C	21.6	21.6	0.72	0.72	415	415
	Route 16 SB - Through	A	A	5.6	5.6	0.44	0.44	14	14
	Overall	B	C	17.3	17.3	N/A	0.62	n/a	n/a
PM Peak Hour									
1	Route 2 WB	F	n/a	113.6	n/a	1.22	n/a	m#1145	n/a
	Route 16 SB to Route 2 WB	F	n/a	435.9	n/a	1.87	n/a	#1465	n/a
	Overall	F	n/a	207.9	n/a	1.46	n/a	n/a	n/a
2	Alewife Station Exit to Route 2 WB	A	B	2.6	10.8	0.59	0.87	10	m49
	Route 16 SB - Through	F	C	82.5	34.9	0.95	0.42	#288	196
	Route 16 NB to Route 2 WB	E	E	68.2	78.1	1.07	0.98	m#907	#414
	Route 2 EB to Route 16 NB	F	-	125.6	-	1.13	-	#451	-
	Overall	E	D	69.5	43.2	1.03	0.75	n/a	n/a
3	Route 16 NB - Through	C	A	28.1	2.6	0.24	0.16	m110	39
	Alewife Station Exit - Through	B	D	18.9	26.2	0.59	0.89	417	#677
	Alewife Station Exit - Right	B	C	14.2	23.9	0.32	0.35	80	120
	Overall	B	C	19.4	15.9	0.46	0.46	n/a	n/a
4	Route 2 EB to Route 16 SB	A	B	6.6	21.6	0.48	0.55	161	256
	Route 16 SB - Through	E	A	63.4	5.6	1.02	0.44	m#98	13
	Overall	C	B	23.4	17.3	0.55	0.51	n/a	n/a

Note: # - 95% volume exceeds capacity, queue may be longer.
m - Volume for 95% queue is metered by upstream signal.

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FIGURE 8
Option 6: Conventional Roundabout

Route 2/Alewife Brook Parkway Traffic Study

TABLE 8
Option 6: Conventional Roundabout

Approach	Movement	LOS		Delay	
		Existing	Option 6	Existing	Option 6
AM Peak Hour					
Route 16 SB	Route 2 WB	D	F	42.1	151.2
	Route 16 SB	F	F	103.0	151.2
	Overall	E	F	57.8	151.2
Route 16 NB	Route 16 NB	F	A	117.0	8.6
	Route 2 EB	F	A	256.1	8.6
	Overall	F	A	234.0	8.6
Jug-Handle	Route 16 NB	C	E	29.2	50
	Route 2 WB	C	E	32.0	50
	Overall	C	E	30.8	50
Route 2 EB	Route 16 SB	F	A	133.5	4.4
	Route 16 NB	F	A	85.2	4.4
	Overall	F	A	119.8	4.4

Results are from VISSIM software

Option 7: Replace intersection with roundabout, including right-turn slip ramps

To reduce the effect of a long traffic queue and excessive delay on Route 16 southbound, staff analyzed a two-lane roundabout with right-turn slip ramps on all approaches (Figure 9). The purpose of the right-turn slip ramps was to allow these streams of traffic to change direction without conflicting with traffic within the roundabout, thus proceeding directly to Route 2 or Route 16. The slip ramps increase the capacity of the roundabout, but they also send more traffic quickly downstream to the intersection of Route 16 and Cambridgepark Drive; that intersection is unable to handle the increase in traffic during the AM peak period. The end result of this operation is excessive traffic delay and a queue that backs up into the roundabout, causing long traffic queues on Route 2 eastbound (Table 9). During the PM peak period, the high volumes of left turns from Route 2 eastbound cause excessive delays on Route 16 northbound and the off-ramp to Alewife Station. Based on the results of the analysis, this option was dropped.

Option 8: Replace intersection with roundabout, including a fly-over for traffic from Route 16 northbound to Route 2 westbound

A roundabout with slip ramps and a fly-over from Route 16 northbound to Route 2 westbound works well in the PM peak period (Figure 10). However, it does not work well during the AM peak period, because it sends more traffic quickly downstream to the intersection of Route 16 and Cambridgepark Drive, and that intersection is unable to handle this. The end result of this operation is excessive traffic delay and a queue that backs up into the roundabout, causing long traffic queues on Route 2 eastbound (Table 10). Based on the results of the analysis, this option was dropped.

In summary, of the eight options considered in this analysis, the first three offer minor operational improvements that are insufficient to significantly benefit the intersection of Route 2/Route 16. The last four options entail capital-intensive reconstruction solutions that either are not effective, have construction impacts, or cause bottlenecks elsewhere. Option 4, however, appears to offer an effective solution with opportunities for immediate implementation by transportation agencies, the City of Cambridge, or a development proponent, or by various combinations/partnerships of the above entities.

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FIGURE 9
Option 7: Roundabout with Right-Turn Slip Lanes

Route 2/Alewife
Brook Parkway
Traffic Study

TABLE 9
Option 7: Conventional Roundabout with Slip Lanes

Approach	Movement	LOS		Delay	
		Existing	Option 7	Existing	Option 7
AM Peak Hour					
Route 16 SB	Route 2 WB	D	A	42.1	1.4
	Route 16 SB	F	B	103.0	14.9
	Overall	E	A	57.8	5.0
Route 16 NB	Route 16 NB	F	C	117.0	20.4
	Route 2 EB	F	C	256.1	20.4
	Overall	F	C	234.0	20.4
Jug-Handle	Route 16 NB	C	B	29.2	11.5
	Route 2 WB	C	B	32.0	11.5
	Overall	C	B	30.8	11.5
Route 2 EB	Route 16 SB	F	F	133.5	138.6
	Route 16 NB	F	F	85.2	145.3
	Overall	F	F	119.8	143.2
PM Peak Hour					
Route 16 SB	Route 2 WB	D	A	41.8	2.4
	Route 16 SB	E	B	64.7	16.2
	Overall	D	A	48.8	6.6
Route 16 NB	Route 16 NB	F	C	81.0	20.4
	Route 2 EB	F	C	131.6	20.4
	Overall	F	C	124.6	20.4
Jug-Handle	Route 16 NB	D	F	36.2	218
	Route 2 WB	F	F	134.5	218
	Overall	F	F	94.2	218
Route 2 EB	Route 16 SB	F	B	33.5	10.4
	Route 16 NB	B	A	123.5	9.2
	Overall	E	A	69.0	9.9

Results are from VISSIM software

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FIGURE 10
Option 8: Roundabout with Right-Turn Slip Lanes
and a Route 2 Westbound Fly-Over

Route 2/Alewife
Brook Parkway
Traffic Study

TABLE 10
Option 8: Conventional Roundabout with a Fly-Over

Approach	Movement	LOS		Delay	
		Existing	Option 8	Existing	Option 8
AM Peak Hour					
Route 16 SB	Route 2 WB	D	A	42.1	0.7
	Route 16 SB	F	A	103.0	3.8
	Overall	E	A	57.8	1.5
Route 16 NB	Route 16 NB	F	A	117.0	0.6
	Route 2 EB	F	A	256.1	5.5
	Overall	F	A	234.0	1.4
Jug-Handle	Route 16 NB	C	A	29.2	10.0
	Route 2 WB	C	A	32.0	10.0
	Overall	C	A	30.8	10.0
Route 2 EB	Route 16 SB	F	F	133.5	139.9
	Route 16 NB	F	F	85.2	116.5
	Overall	F	F	119.8	133.1
PM Peak Hour					
Route 16 SB	Route 2 WB	D	A	41.8	3.0
	Route 16 SB	E	B	64.7	9.2
	Overall	D	A	48.8	4.9
Route 16 NB	Route 16 NB	F	C	81.0	20.4
	Route 2 EB	F	C	131.6	20.4
	Overall	F	C	124.6	20.4
Jug-Handle	Route 16 NB	D	E	36.2	42
	Route 2 WB	F	E	134.5	42
	Overall	F	E	94.2	42
Route 2 EB	Route 16 SB	F	A	33.5	6.3
	Route 16 NB	B	A	123.5	4.0
	Overall	E	A	69.0	5.4

Results are from VISSIM software

The section that follows examines treatments to improve bus access/egress to/from the station.

IMPROVING BUS ACCESS/EGRESS TO/FROM ALEWIFE STATION

Improving Access from the West (Route 2 Eastbound)

Improvements to this access point would reduce delays to buses 62, 67, 76, and 84. These buses approach the garage via the Route 2 eastbound off-ramp, which is often blocked by the eastbound queue seeking to be processed through the Route 2/Route 16 intersection. Three options were evaluated for improving bus access from the west at the Route 2 eastbound off ramp:

- Improve the Route 2/Route 16 intersection so that the queue from the eastbound traffic does not block the entrance to the ramp.
- Provide priority entrance to the off-ramp for MBTA buses only.
- Allow buses to use Acorn Park Road.

Improve the Route 2/Route 16 Intersection
Improving the operations at this intersection has overarching benefits that include reductions in travel times and delays for vehicles and buses. Of the eight options that were examined, Option 4 offers an effective, relatively immediate operational solution for the intersection (merits of this option are discussed earlier in this memo and again later under Summary and Recommendations) and also reduces the eastbound queue that blocks the off-ramp, thus improving bus access from the west (Route 2 eastbound).

Provide Auxiliary Lane on Route 2 Eastbound for Bus Use Only
This treatment, which was analyzed qualitatively, would extend the deceleration lane leading to the Route 2 eastbound off-ramp to a point just east of the Lake Street bridge and would allow only buses to use this extension, or auxiliary lane. Other vehicles would continue exiting Route 2 at the present location; however, they would have to weave/merge with bus traffic that would have entered at the start of the auxiliary lane. The entrance to the auxiliary lane would have to be heavily enforced to keep vehicles other than buses from entering. The auxiliary lane would work better with a service road beginning west of the Lake Street bridge, but that would likely necessitate widening the bridge and making design changes to incorporate the eastbound Lake Street on-ramp. In addition, constructing a service road may require land acquisition on the south side of the highway. Based on high construction cost, safety concerns, operations issues, and enforcement requirements, this treatment was dropped from further consideration.

Allow Buses to Use Acorn Park Road
This treatment was analyzed qualitatively. MassHighway counts show that vehicles use the Acorn Park Road to bypass a section of Route 2 and the ramp. One way to solve this problem would be to limit traffic on Acorn Park Road to those drivers who work in Acorn Park by installing a gate and letting them use transponders or gate keycards. Then buses could also be allowed to use the road to bypass part of the queue. However, Acorn Park Road is a public roadway, and access to it cannot be limited. For this reason, it would be difficult to implement this strategy, and it would also place a burden on developers and employers at Acorn Park. Therefore, this option was also dropped from further consideration.

Improving Access from Route 16 Southbound

This access point is actually one of the approaches to the Route 2/Route 16 intersection. Any improvements that would affect the level of service through this intersection would also improve the processing time of buses traveling south on Route 16 to reach Alewife Station. Improvements to the Route 2/Route 16 intersection were described under eight various options above, with Option 4 being more promising than the others (this outcome is also discussed later in this memorandum.). Bus routes 79 and 350 would be affected positively by improvements at this intersection, as the level of service at the Route 16 southbound approach would be in the acceptable range. Furthermore, access of these buses to the station would also be affected by improvements at the intersection of Route 16 and Cambridgepark Drive; this intersection is not included in the analysis in this study.

Improving Egress to Route 2 Westbound and Route 16 Northbound

Presently, MBTA buses heading westbound and northbound use the jug-handle at the eastern end of the Alewife Station Access Road to proceed straight onto Route 2 westbound or turn right onto Route 16 northbound. All these buses would benefit from the Option 4 improvements at the Route 2/Route 16 intersection, as has been described. In addition, the following two treatments were considered:

Install a new Route 2 westbound on-ramp

The main concept under this treatment would be to construct a new Route 2 westbound on-ramp just west of the Minuteman Bike Path for Alewife Station Access Road traffic to join Route 2 westbound directly from under the Path bridge, thus bypassing the Route 2/Route 16 intersection (Figure 11). Buses 62, 67, and 84 would use this egress point to Route 2 westbound as well. The advantages of this ramp include taking vehicles and buses exiting from Alewife Station off of the jug-handle to Route 2 westbound directly, thus reducing Route 2 westbound delay significantly during the evening peak hour. The disadvantages of the ramp include encroachment on environmentally sensitive land (that would have to be acquired) and possible weaving problems with vehicles from Route 16 southbound. The bridge support structure (below deck) would need to be reconstructed for this ramp to share the right-of-way under the bridge with the Minutemen Bike Path. Based on the high construction cost, adverse environmental issues, and potential weaving and merging safety issues, this option was dropped from further consideration.

Widen Alewife Station Access Road (Jug-handle)

Under this strategy, the entire length of the jug-handle would become two lanes as far back as possible to the Alewife transit station. The two lanes could be operated in the following ways:

<u>Bus-Only Lane and General-Purpose Lane:</u> To improve bus operations leaving Alewife Station, one of the two lanes in the jug-handle could be designated as a bus-only lane and the other as a general-purpose lane (Figure 12). A proposed bus priority at the Route 2/Route 16 traffic signal would allow buses to get onto Route 2 westbound with minimal delay.

On the one hand, this treatment would greatly improve bus operations by allowing buses leaving Alewife Station to get onto Route 2 westbound instead of being stuck in a long vehicle queue in

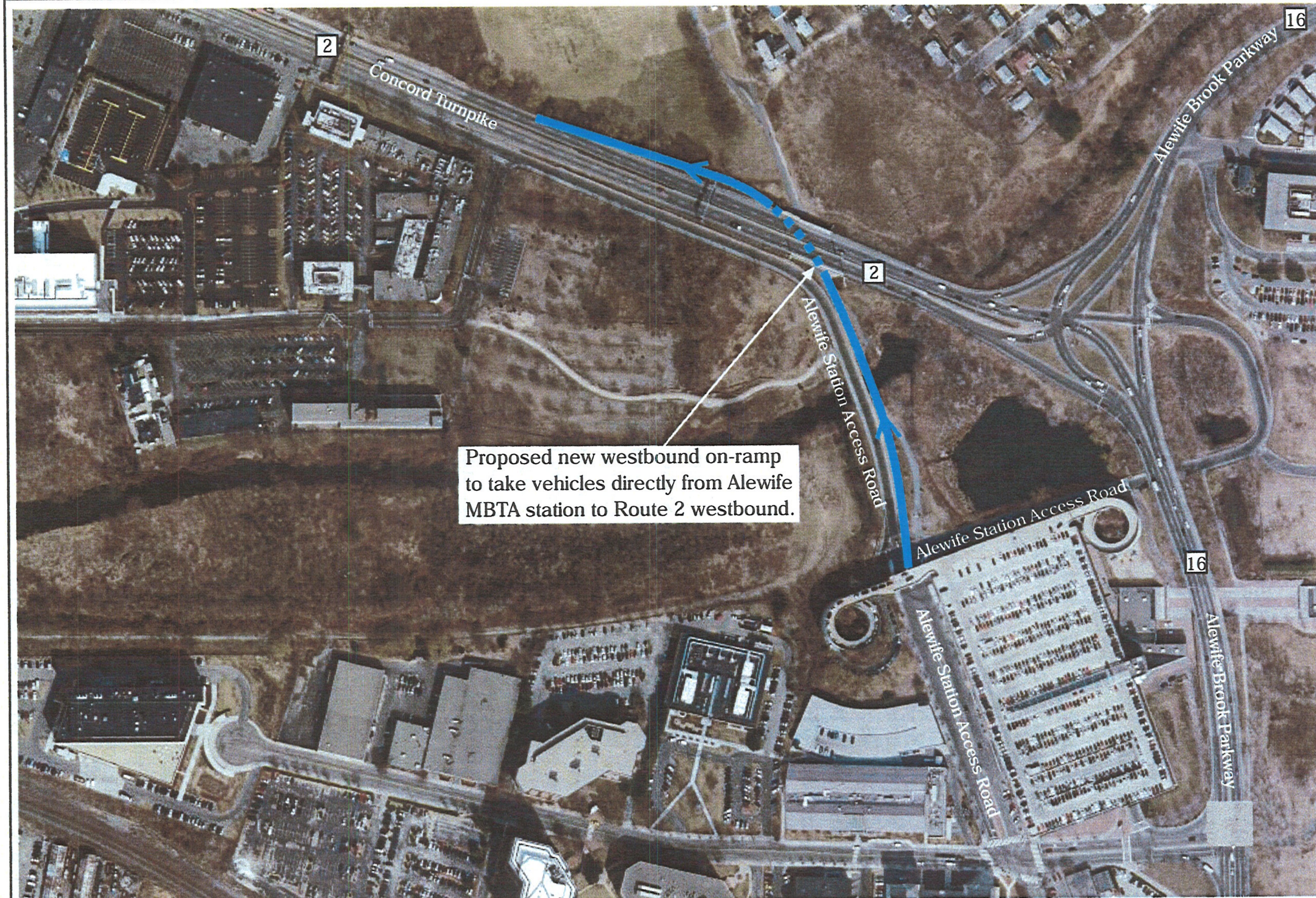

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FIGURE 11
Install a New Route 2 Westbound On-Ramp from the Garage

Route 2/Alewife
Brook Parkway
Traffic Study

CTPS

FIGURE 12
Widen Alewife Station Access Road (Jug-handle) to Two Lanes and Install Bus Priority

Route 2/Alewife Brook Parkway Traffic Study

the jug-handle, and thus reducing bus travel time. On the other hand, because drivers currently line up in two lanes on the jug-handle (one lane for traffic proceeding to Route 2 westbound and the other lane for traffic proceeding to Route 16 northbound), this improvement would cause severe congestion in the general-purpose lane, possibly affecting egress for buses and other traffic from Alewife Station.

During the peak hour, about 22 buses are expected to exit Alewife Station and use the proposed bus priority system on the jug-handle. Based on MBTA bus schedules, the departure times for these 22 buses during the peak hour (5:00 – 6:00 PM) are uniformly distributed. On the average, this results in a bus arriving at the jug-handle every 3 minutes during the peak hour. Such arrival times would affect somewhat about two thirds of the traffic signal cycles at the intersection. A bus-only lane at the Route 2/Route 16 intersection would reduce somewhat total green time for the rest of the traffic at other approaches. In addition, a bus-only lane could lead to empty-lane syndrome or violation by drivers of general-purpose vehicles, as 22 buses are expected to use the lane during peak hour. However, buses carry more persons than single-occupant vehicles; based on number of persons, the bus-only lane may be justified.

Bus Signal Priority System: Under this system, all vehicles would use the two lanes. However, MBTA buses would be equipped with transponders for switching a red light to green on command as they approach the Route 2/Route 16 intersection from the jug-handle. The traffic light at the Route 2/Route 16 intersection would also be equipped with the priority system. The lights would go from red to green or stay green slightly longer on the approach of the jug-handle to allow MBTA buses to pass through the intersection. The result would be faster travel for bus riders and less pollution from idling. Bus preemption systems eliminate empty-lane syndrome and violations while providing the similar benefits as for a bus-only lane. However, a bus-only lane would bring buses faster to the approach of the jug-handle than a preemption system.

This system would affect somewhat about two thirds of the traffic signal cycles at the intersection. A bus preemption system at the Route 2/Route 16 intersection would reduce somewhat total green time for the rest of the traffic at other approaches.

Queue Jumping

Another strategy is to add a third lane at the approach of the jug-handle for buses to jump or bypass the queue, moving to the front (Figure 13). A queue jump is a type of roadway geometry that consists of an additional travel lane on the approach to a signalized intersection. This lane is restricted to transit vehicles only, and the intent of the lane is to allow the high-occupancy vehicles (buses) to cut to the front of the queue, reducing the delay caused by the signal and improving the operational efficiency of buses.

A queue jump lane is generally accompanied by a signal which provides a phase specifically for vehicles within the queue jump lane. Such a signal reduces the need for a designated receiving lane, as vehicles in the queue jump lane get a leading green light "head start" over other queued vehicles and can therefore merge into the regular travel lanes immediately beyond the signal.
The main obstacles to a queue jump lane strategy are that constructing the third lane would require land acquisition on the jug-handle and realignment of the existing right-turn lane. Also, buses would encounter some queuing on the jug-handle until they are able to access the queue jump lane.

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FIGURE 13
Widen Alewife Station Access Road (Jug-handle) to Two Lanes and Install a Queue Jump Lane for Buses

Route 2/Alewife Brook Parkway Traffic Study

SUMMARY AND RECOMMENDATIONS

The intersection of Route 2 and Route 16 in Cambridge currently experiences long delays and queues during the morning and evening peak periods. These delays and queues significantly impact MBTA bus travel times and possibly bus ridership. Bus access to Alewife Station from Route 2 is provided along the Alewife Station Access Road via the Route 2 eastbound off-ramp. The entrance to this access road from Route 2 eastbound is often blocked by eastbound traffic queued at the Route 2/Route 16 intersection.

Based on quantitative and qualitative analyses of various options and strategies described above for improving traffic operations at the Route 2/Route 16 intersection and for improving access to and egress from Alewife Station, staff have the following recommendations, made in conjunction with the Alewife Working Group.

- Add a third westbound lane (Option 4) for a short distance between the Alewife Station Access Road approach (jug-handle) and the Minuteman Bike Path overpass (Figure 6). This would be effective in reducing delays and queues at this intersection. The additional lane capacity frees up traffic signal green time for reallocation to other approaches, including the MBTA Access Road, resulting in shorter queues and delays on all approaches. Right-of-way is available for the portion of the third lane within the intersection. Right-of-way also appears to be available for the lane segment between the intersection and the Minuteman Bike Path overpass; however, the additional roadway width would have to be secured from an existing (possibly unused) sidewalk. The availability of right-of-way between the point where the Route 16 north approach meets Route 2 westbound and the overpass needs to be investigated further, including the need for a pedestrian corridor north of Route 2. Extending the third lane to Lake Street is not required in the short term but should be considered in the longer term.

- Reconstruct the Route 2 eastbound left-turn lane to Route 16 north into a double left-turn lane (Option 2 and also part of Option 4). This would further benefit this intersection, as it would help reduce eastbound queuing on Route 2.

- Reconstruct the Alewife Station Access Road (jug-handle) into two lanes for as far back as possible. This would allow for bus and vehicle storage and for priority bus lane/traffic signal priority for the buses.

- Following all above reconstruction, the traffic signal design would have to be reconsidered, including new equipment for demand-responsive operation and detectors/sensors for bus priority.

Excluding design and right-of-way, the estimated cost of the recommended improvements to the Route 2/Route 16 intersection ranges between $200,00 and $400,000.

IMPLEMENTATION CONSIDERATIONS AND OPPORTUNITIES

Potential implementation issues and opportunities include:

- The usefulness and purpose of the sidewalk along Route 16 southbound needs to be investigated.
- There are multiple stakeholders (DCR, MassHighway, City of Cambridge, Town of Arlington) that need to be consulted, with opportunities for cooperation and partnerships.
- Informing the general community in the area for support and cooperation is very important.
- Opportunities for regional programming or MassHighway and DCR standard maintenance could be sought for implementation of some of these improvements.
- Opportunities for development mitigation for some of these improvements need to be sought by the City of Cambridge.