GPI

Greenman-Pedersen, Inc.
Engineering and Construction Services

City of Cambridge, MA
Porter Square – Post Construction Evaluation Study
December 1, 2008

GPI

TECHNICAL MEMORANDUM

PORTER SQUARE - POST CONSTRUCTION EVALUATION STUDY

CAMBRIDGE, MA

GPI

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DECEMBER 1, 2008

GPI

City of Cambridge, MA
Porter Square – Post Construction Evaluation Study
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TECHNICAL MEMORANDUM

REF: MAX-2007080.02.00003

DATE: December 1, 2008

TO: Mr. William Deignan
Transportation Program Manager
Community Development Department
City of Cambridge
344 Broadway
Cambridge, MA 02139

FROM: Mr. John W. Diaz, P.E., P.T.O.E.

RE: Porter Square – Post Construction Evaluation

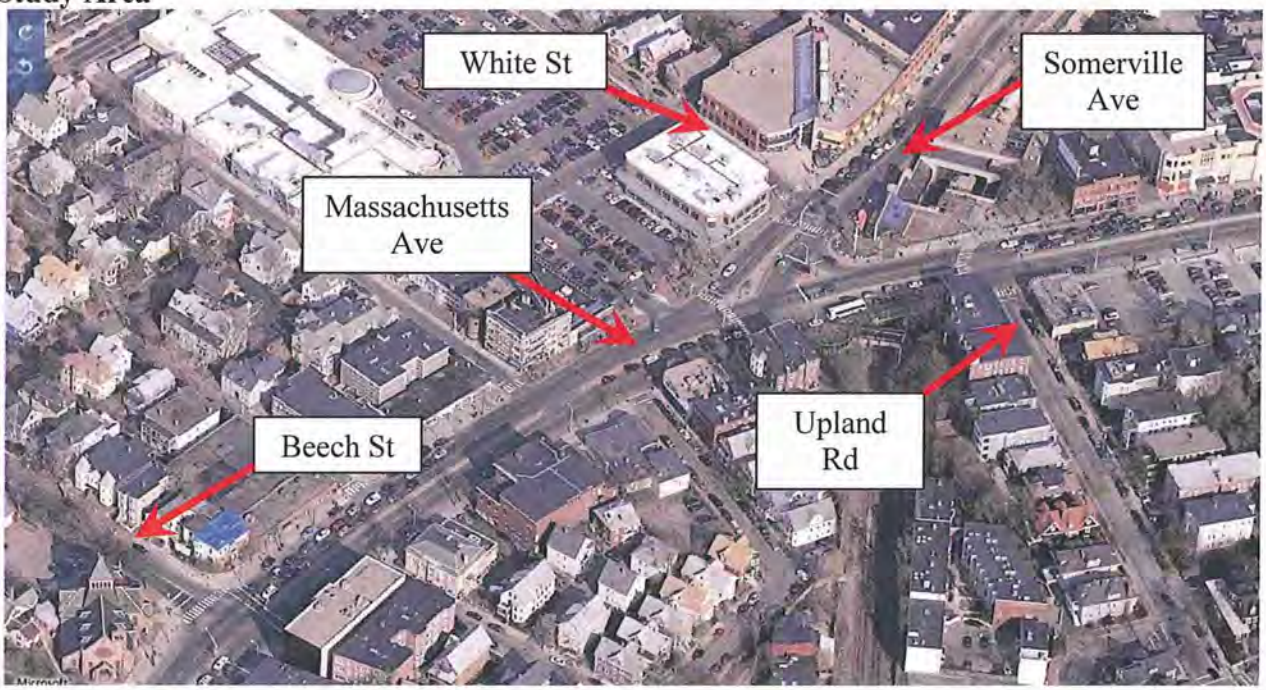
INTRODUCTION

Greenman-Pedersen, Inc. (GPI) has been retained by the City of Cambridge's Community Development Department to prepare an evaluation of the recently completed reconstruction of Porter Square. The project area encompasses Massachusetts Avenue from the intersection of Beech Street to the north to Upland Road to the south, as well as Somerville Avenue from Massachusetts Avenue to just beyond White Street. The project area is depicted in Figure 1 and includes the following major intersections:

- Massachusetts Avenue at Beech Street
- Massachusetts Avenue at Somerville Avenue
- Massachusetts Avenue at Upland Street
- Somerville Avenue at White Street.

The objective of this study is to provide a "before and after" comparison of transportation operations within the area. The study evaluates the operations of the traffic signals and levels of congestion prior to and after the construction project, as well as compare the use of the area by bicyclists and pedestrians. In addition, bicyclists were interviewed to gain information about their use of a new "jug handle" turn for those cyclists who make a left turn from Massachusetts Avenue southbound to Somerville Avenue. Pre-construction conditions are based on previous traffic counts and projections presented in the *Technical Memorandum Porter Square Traffic*

Figure 1
Study Area



Improvements, January 13, 2003 prepared by Earth Tech, Inc. Post-construction conditions are evaluated based on field observations and new traffic counts completed in May and June 2008.

PROJECT HISTORY

Porter Square is a multi-modal transportation hub within the City of Cambridge. The area is heavily utilized by pedestrians, bicyclists and transit users. Porter Station, a stop on the MBTA Red Line, is located at the intersection of Massachusetts Avenue and Somerville Avenue. In addition, there is heavy vehicular traffic through the area, particularly along the Massachusetts Avenue corridor. In 1997 and 1998 a Citizens Advisory Committee, appointed by the City Manager, was formed to help determine appropriate treatments to improve overall safety through the square with the primary focus on improving safety and operations for pedestrians, bicyclists and transit users. The overall goals of the project included:

- Reduce vehicular domination of Porter Square
- Improve conditions for pedestrians, bicyclists and transit users, particularly for pedestrians crossing Somerville Avenue at the MBTA Stop
- Reduce cut-through and shopping center related vehicular traffic on neighboring residential streets

- Improve streetscape and create a sense of place in Porter Square
- Improve traffic safety
- Maintain traffic level-of-service (LOS) at or near existing conditions or LOS D, whichever is lower.

The Committee had specific problems in Porter Square that they wanted the new design to address. Those problems included:

- The heaviest pedestrian crosswalk from the MBTA to White Street has a short pedestrian phase and many pedestrians walk in conflict with northbound vehicles on Mass Ave which were taking the right turn to Somerville Ave.
- The crosswalk on Mass Ave near the main entrance to the Shopping Center has two separate phases and pedestrians have to wait at the island part way across between phases.
- Pedestrians want to walk parallel to Mass Ave from the MBTA to Dunkin Donuts but there was no crosswalk at this location.
- Most vehicles entered on the Mass Ave side of the Shopping Center and exited on the Elm Street side.

The Committee reached a consensus in 1998 on a plan to reconfigure the area (Figure 3). The plan had strong support but implementation was tied to sewer work for Massachusetts Avenue whose schedule was being pushed back,

The City identified funding for the project and the Porter Square Citizen Advisory Committee reconvened in the fall of 2002 to assist the City of Cambridge in the final design phase of the reconstruction project. The final plan was developed to further address the following goals:

- To create a unique visual identity for Porter Square
- To integrate both sides of Massachusetts Avenue
- To create a pleasing space for pedestrians
- To visually unify the plaza area
- To reduce the visual clutter of the busy intersection through simplification and clarity of design.

Pre Construction Conditions

Figure 2 illustrates the pre construction conditions within the Porter Square Study area. Prior to the reconstruction of Porter Square, facilities for pedestrians, transit users and cyclists were non-existent or in poor condition.

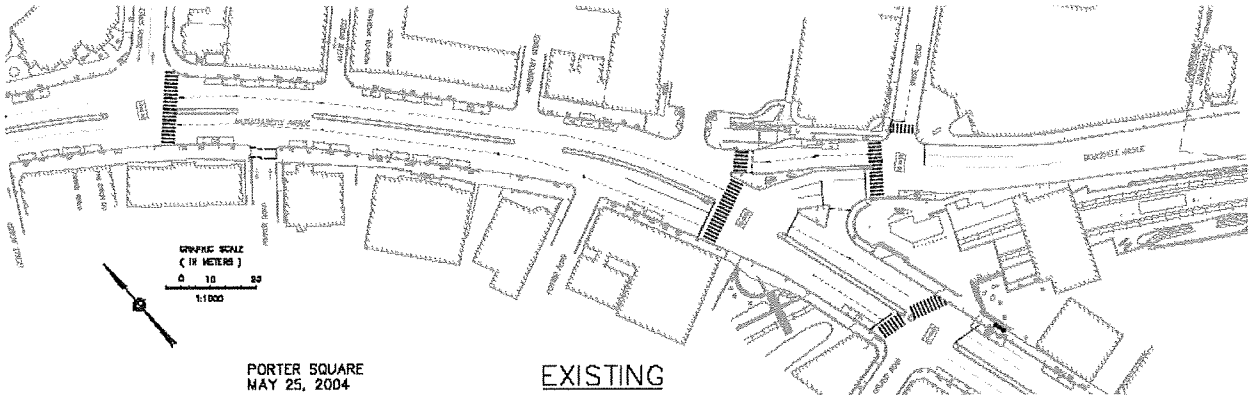


Figure 2
Pre Construction Conditions

Pedestrians

There were only four marked crosswalks in the area. There were three (3) crossings along Massachusetts Avenue, one located on the southerly side of the Beech Street intersection, one at the Somerville Avenue intersection and one on northerly side of the Upland Road intersection. In addition there was one crossing along Somerville Avenue on the westerly side of the White Street intersection. There were marked crosswalks crossing the minor streets approaches at Beech Street, Allen Street, Davenport Street and Upland Road. There was no marked crossing of the major shopping center driveway. Pedestrian signal phases were short and signals did not have count down pedestrian signal heads. Most sidewalks were constructed in 1985 or earlier and had poor pavement conditions and did not necessarily meet ADA/AAB regulations.

Cyclists

There were no marked bicycle lanes or facilities for cyclists, making the area less than ideal for cycling. Also, southbound cyclists who wanted to take a left from Massachusetts Avenue onto Somerville Avenue had to either dismount and cross as a pedestrian, stay in traffic and take a lane or maneuver between the left turn lane and a shared, through/left lane.

Transit Users

Due to limited marked crossings, transit users had less than optimal access to Porter Station, at the intersection of Massachusetts Avenue and Somerville Avenue. There were few marked crossings directly to the station making transit users either go out of their way to use a crossing, or, more commonly, to take the most direct route to the station without a protected crossing. The crosswalk between White Street and the MBTA station was the most heavily used in the study area. However, pedestrians often walked in conflict with the Mass Ave northbound vehicles make the right onto Somerville Ave.

Parking and Vehicle Circulation

On street parking was provided in many locations with a total of 29 spaces within the project limits. One issue which was identified by the City of Somerville, residents of Porter Road and users of the shopping center was that vehicles exiting the shopping center had no way to take a left turn out of the shopping center to travel south on Massachusetts Avenue. This forced drivers to exit onto Elm Street, Somerville and proceed to Mossland or Beech Streets (the shopping center is located in Cambridge), make illegal u-turns on Massachusetts Avenue or use Porter Road, which is U-shaped, to turn around.

Post Construction Conditions

The reconstructed Porter Square provides enhanced facilities for bicyclists and pedestrians throughout the area. Figure 3 below illustrates the level of improvements within proximity to the Massachusetts Avenue/Somerville Avenue intersection. The following are highlights of the improvements:

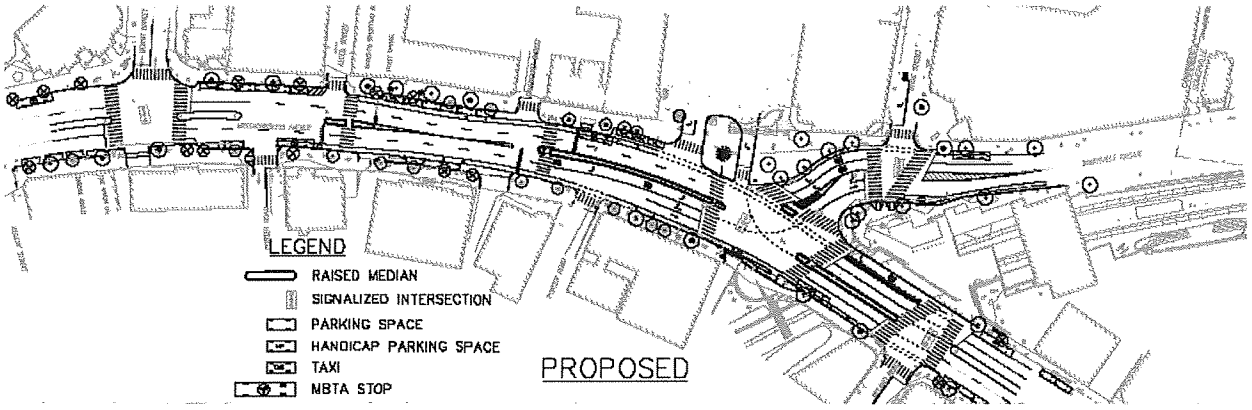


Figure 3
Post Construction Conditions

- Increase the number of marked crossings along Massachusetts Avenue from three to eight by providing crossings at the following locations:
  - Northbound and southbound Massachusetts Avenue approaches at Beech Street
  - Northbound Massachusetts. Avenue approach at the Allen Street intersection
  - Northbound Massachusetts Avenue approach at the Davenport Street intersection
  - Northbound and southbound Massachusetts Avenue approaches at the Somerville Avenue intersection
  - Northbound and southbound Massachusetts Avenue approaches at the Upland Road intersection

- Increase the number of marked crossings along Somerville Avenue from one to three by providing crossings at the following locations:
    - Eastbound and westbound Somerville Avenue approaches to White Street
    - Westbound Somerville Avenue approach to Massachusetts Avenue
- Provide a new crossing of the shopping center driveway on Massachusetts Avenue where the sidewalk remains level for pedestrians and the approach grade is raised for vehicles.
- Provide a new left hand turn for drivers exiting the shopping center onto Massachusetts Avenue southbound through the traffic signal at the intersection of Massachusetts Avenue and Somerville Avenue. This allows drivers to make this turn directly instead of exiting onto Streets in Somerville or making illegal u-turns on Massachusetts Avenue to change direction.
- Reconfigure the southbound Somerville Avenue approach to Massachusetts Avenue to provide more of a 90 degree approach to slow westbound right turning vehicle movements and to provide a one phase crossing of Mass Avenue
- The reconfiguration of the intersection of Massachusetts Avenue and Somerville Avenue and removal of the slip lane and consolidation of three traffic islands allowed for the creation of the new crosswalks and a new pedestrian plaza. The Cambridge Arts Council, under the Percent for Art program, worked with the citizen advisory committee to select an artist to design the plaza and black and white pavers, local granite boulders and other new tree plantings.

Pre Construction-Looking North


Post Construction-Looking North

- Provide a signalized bike crossing for the southbound left turn from Massachusetts Avenue to Somerville Avenue via a "Bike Jug-Handle".
- Add bicycle lanes along Massachusetts Avenue and the portion of Somerville Avenue in Cambridge.
- Increase the sidewalk area by moving the curb six (6) feet between Porter Road and the bridge over the commuter rail. On street parking was removed and relocated to accomplish this. Curb extensions were also added at the corner of Upland Road and Beech Street.
- Provide new traffic signal equipment and controllers at the intersections of Massachusetts Avenue at Somerville Avenue and Upland Road and a new traffic controller and additional pedestrian heads at Massachusetts Avenue at Beech Street
- Provide coordination between the three signalized intersections to improve vehicular progression through Porter Square and reduce traffic congestion.

As illustrated below in Table 1, the pedestrian times at the three signalized intersections have been enhanced. While the Flashing Don't Walk (FDW) time, or clearance interval, at Beech Street has been reduced, the pedestrian crossing distance across Massachusetts Avenue was reduced with the reconstruction, resulting in a shorter distance and thus a shorter necessary clearance interval. It should be noted, that the WALK indication is only meant to notify pedestrians that it is safe to enter the crosswalk. The critical time is the FDW period, which is based on the time it takes for a pedestrian to cross the entire roadway surface. Based on the MUTCD[1]the WALK interval is generally fixed at 7 seconds while the FDW time is based on site characteristics.

[1] Manual on Uniform Traffic Control Devices for Streets and Highways, 2003 Edition, U.S. Department of Transportation, Federal Highway Administration, Section 4E.10

Table 1
Pedestrian Signal Timing

PEDESTRIAN TIME COMPARISON

	Pre Construction			Post Construction			
	WALK	FDW	TOTAL	WALK	FDW	TOTAL	CHANGE
Mass Ave at Upland Rd	6	14	20	7	17	24	4
Mass Ave at Beech St	6	17	23	7	14	21	-2
Mass Ave at Somerville Ave							
Crossing Somerville Ave at Mass Ave	48	7	55	7	21	28	-27
Crossing Mass Ave north of Somerville Ave	0	0	0	7	21	28	28
Crossing Somerville Ave at White St	8	11	19	7	18	25	6
Crossing Shopping Center Dr	0	0	0	86	16	102	102
Crossing Mass Ave south of Somerville Ave	0	0	0	11.5	16	27.5	27.5

- At the intersection of Massachusetts Avenue and Somerville Avenue, the pedestrian crossings have been enhanced with an increased number of marked crosswalks across both Massachusetts Avenue and Somerville Avenue. Under pre-construction conditions, the only crossings at the intersection were on the southbound Massachusetts Avenue approach to a traffic island and then across the Somerville Avenue westbound approach. Under post-construction conditions, in addition to new crosswalks, the crossing movements have been separated to provide safer, more direct and shorter crossings.
- Provide dedicated protected pedestrian signal phasing at the three signalized intersections surrounding the transit station along with countdown pedestrian signal heads.
- Move the median on the bridge to provide a right turn only lane on the northbound Mass. Avenue approach to allow better coordination with pedestrian movements.
- Relocate bus stops to more convenient locations and added two bus shelters at the Porter station, opposite Upland Road, and at Davenport Street.

Data Collection

Traffic data for the pre-construction condition was obtained from the *Technical Memorandum Porter Square Traffic Improvements, January 13,* 2003 prepared by Earth Tech, Inc. Networks from the 2003 study are presented in the Appendix depicting vehicular, pedestrian and bicycle volumes and movements.

In order to evaluate the changes in Porter Square, new Manual Vehicular Turning Movement Counts (TMC) and pedestrian counts were conducted in May 2008 and bicycle counts were

completed in June 2008 within the study area. Manual traffic observations were completed during a weekday between 7-9 AM and 4-6 PM as well as on a Saturday between 11 AM- 2 PM. Vehicles , pedestrians and bicyclists were observed at the following locations.

- Massachusetts Avenue at Beech Street
- Massachusetts Avenue at Somerville Avenue including two driveways from the shopping center
- Massachusetts Avenue at Upland Road
- Somerville Avenue at White Street
- Shopping Center Drive at White Street
- Eastern Shopping Center Drive on Elm Street
- Western Shopping Center Drive on Elm Street

In addition, pedestrian and bicycle counts were completed at the following locations:

- New Massachusetts Avenue crosswalk at Allen Street
- New Massachusetts Avenue crosswalks at Davenport Street

Forty-Eight (48 hr) Automatic Traffic Recorder counts were conducted in June 2008 at the following locations to determine daily traffic levels and trends:

- Massachusetts Avenue south of Somerville Avenue
- Massachusetts Avenue south of Beech Street
- Somerville Avenue east of White Street
- Elm Street east of White Street
- Beach Street north of Massachusetts Avenue

COMPARISON OF PRE AND POST CONSTRUCTION

Traffic Volume Changes

Automatic Traffic Recorder (ATR) counts were conducted throughout the study area on June 25, 2008. These daily traffic levels have been compared to the daily traffic levels collected previously in November 2002 to assess any changes in traffic levels through the Porter Square area in the six (6) year period. Table 2 provides a comparison of Daily Traffic along the various roadways within the study area, and Figure 4 provides a graphical summary of the 2008 Daily Traffic levels while Daily Traffic networks depicting the pre-construction conditions are provided in the Appendix.

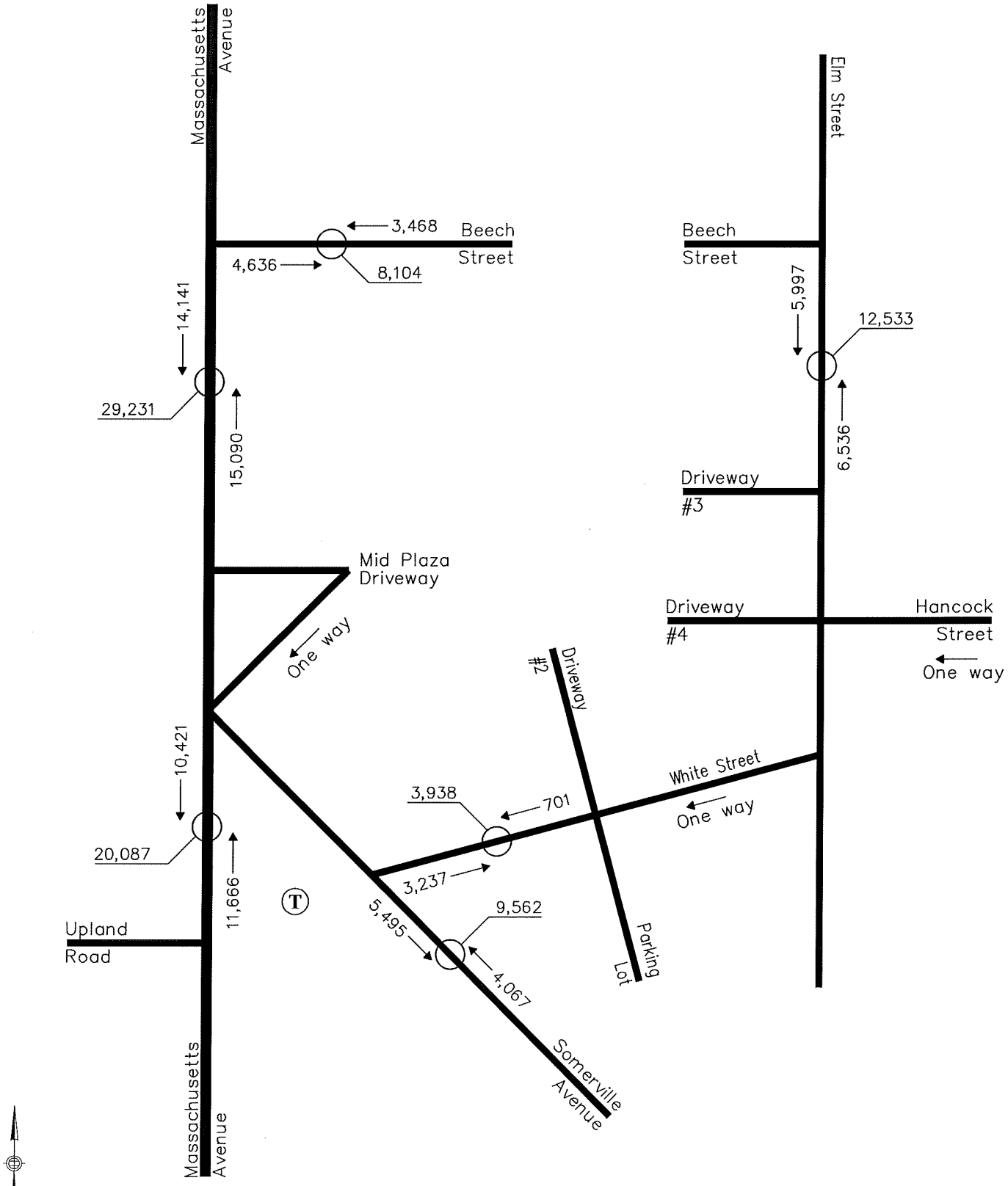


Figure 4
2008 Average Daily Traffic

Table 2
Average Daily Traffic Comparison

Location	2002 ADT[1]	2008 ADT[2]	% Change
Beech St east of Mass Ave	10,727	8,104	-24%
Mass Ave between Beech St & Somerville Ave	35,610	29,231	-18%
Mass Ave between Somerville Ave and Upland Rd	20,392	22,087	-10%
Somerville Ave south of White St	14,872	9,562	-36%
White St east of Somerville Ave	4,006	3,938	-2%
Elm St near Drive #3	16,669	18,530	-35%

[1] – November 2002 ADT Counts
[2] – June 2008 ADT Counts

As indicated in Table 2, traffic levels within the Porter Square have declined since 2002. This trend in declining traffic has been observed along other areas of Massachusetts Avenue. Recent traffic data collected by the Central Transportation Planning Staff (CTPS) along Massachusetts Avenue near the Harvard Bridge has shown a similar decline of approximately 15% between 2002 and 2008. This reduction in vehicle traffic is mostly the result of 10 years of major roadway reconstruction including detours and poor roadway conditions. Other lesser factors such as increased environmental awareness, movement to other modes of travel and economic factors including increased operating costs of motor vehicles may also contribute to the lower volume of vehicular traffic.

While the ADT volumes in Table 2 were conducted in June, the Peak Hour Turning Movement Counts (TMCs) were conducted at the key study intersections in May 2008. In order to asses the critical commuting peak hours and account for any vehicular traffic associated with schools, a comparison of the 2002 and 2008 TMCs was completed and is summarized in Table 3.

Table 3
Peak Hour Traffic Comparison

	2002 TMC[1]			2008 TMC[2]			% Change		
Location	**AM**	**PM**	**SAT**	**AM**	**PM**	**SAT**	**AM**	**PM**	**SAT**
Mass Ave north of Beech St	2457	2433	2392	1757	2011	1774	-28%	-17%	-26%
Mass Ave north of Somerville Ave	2555	2520	2546	2236	2288	2174	-12%	-9%	-15%
Mass Ave south of Somerville Ave	1725	1756	1704	1652	1674	1602	-4%	-5%	-6%
Mass Ave south of Upland Rd	1647	1606	1610	1299	1108	1411	-21%	-3%	-1%
Somerville Ave east of Mass Ave	929	976	1054	743	950	1040	-20%	-3%	-1%
Somerville Ave east of White Street	995	1091	1106	639	800	774	-36%	-27%	-30%
White Street east of Somerville Ave	188	328	390	139	292	336	-26%	-11%	-14%
Elm St north of Drive #3	990	1135	1201	685	1006	816	-31%	-11%	-32%
Elm St between Drive #3 and #4	970	1054	1171	804	936	785	-17%	-11%	-33%

[1] – November 2002 TMC Counts
[2] – May 2008 TMC Counts

As indicated in Table 3, all peak hour traffic levels have experienced decreased traffic levels. Again, this data is consistent with the CTPS study indicating an overall decrease in vehicular traffic along Massachusetts Avenue.

It should also be noted that soon after the completion of the Porter Square construction, Walden Street was closed by MassHighway due to the reconstruction of the Walden Bridge. The two detour routes are Rindge Avenue and Upland Road. The opening of the Bridge in December 2008 will have an impact on traffic in Porter Square. The most noticeable is likely to be a decrease in vehicles using Upland Road. The exact impacts to Porter Square are hard to predict as this will be the first time that Walden is open since the reconstruction of Porter Square.

Bicycle Ridership

As part of the traffic data collection, bicycle traffic was observed. Figures 5, 6 and 7 summarize the bicycle traffic through the area, while pre-construction bicycle volumes and movement are presented in the appendix. Figures 5A, 6A and 7A represent a comparison of the total bike traffic entering Porter Square in both 2002 and 2008.

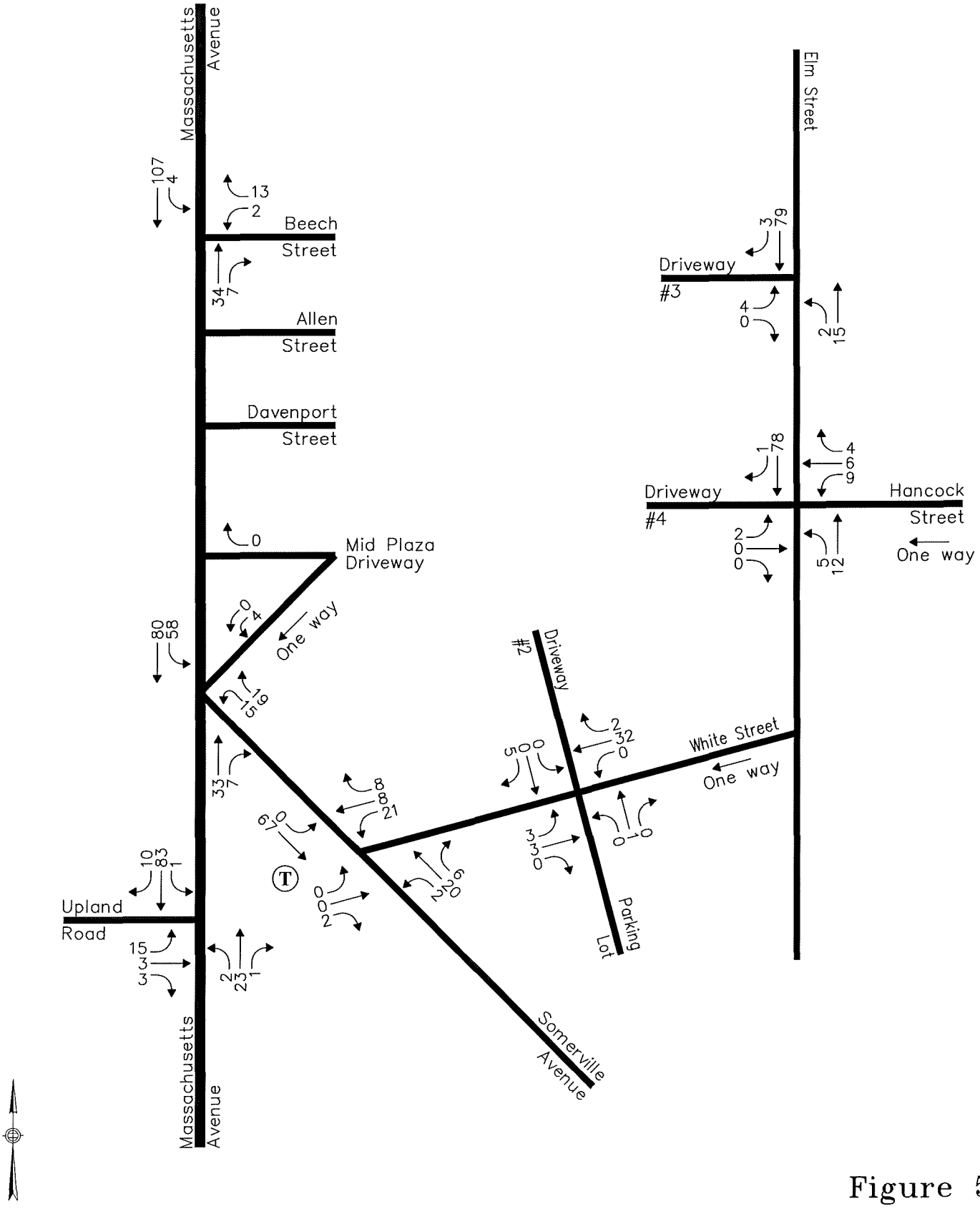


Figure 5
2008 Weekday AM Bicycles

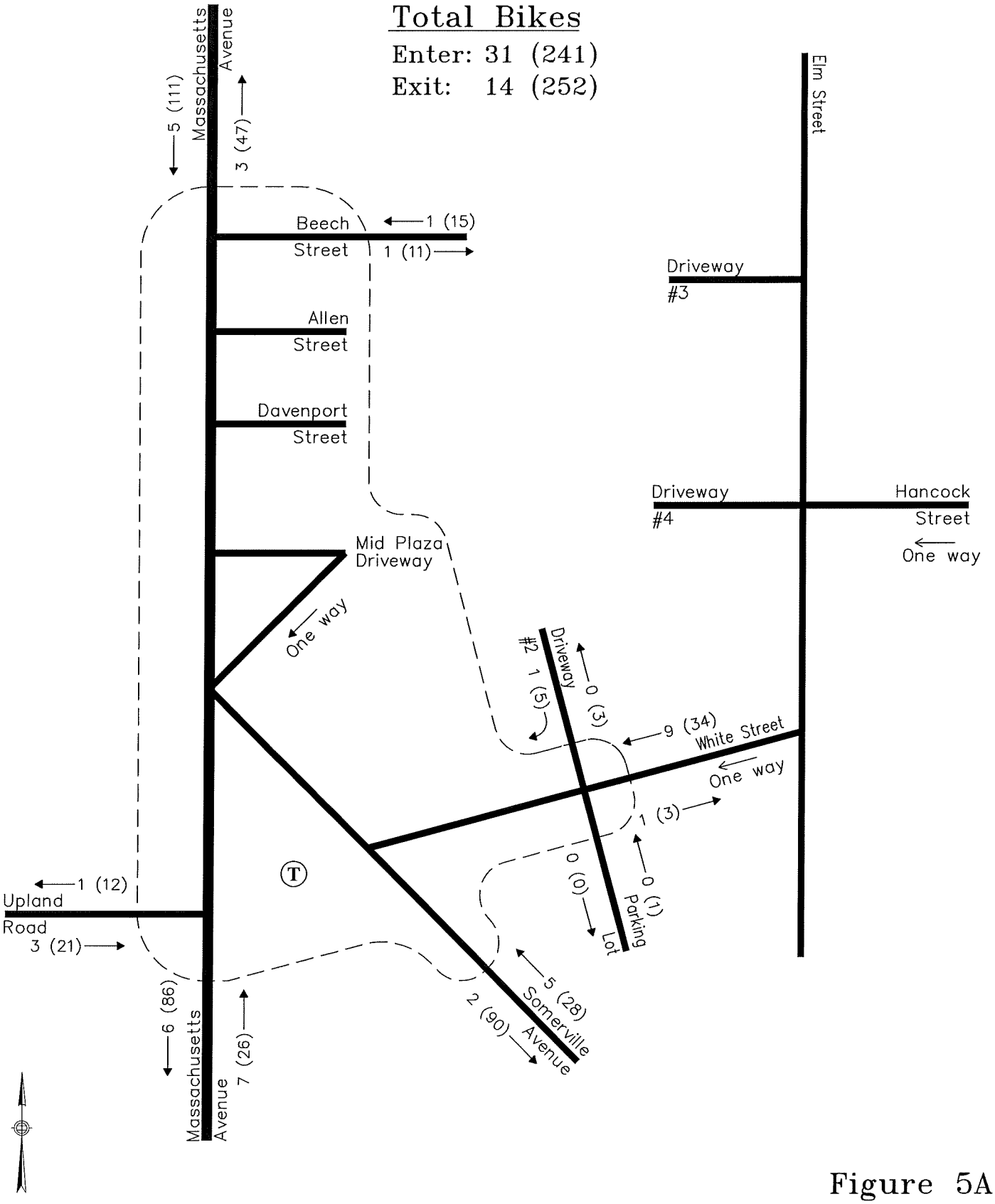


Figure 5A
2002 (2008) Weekday AM Bicycles

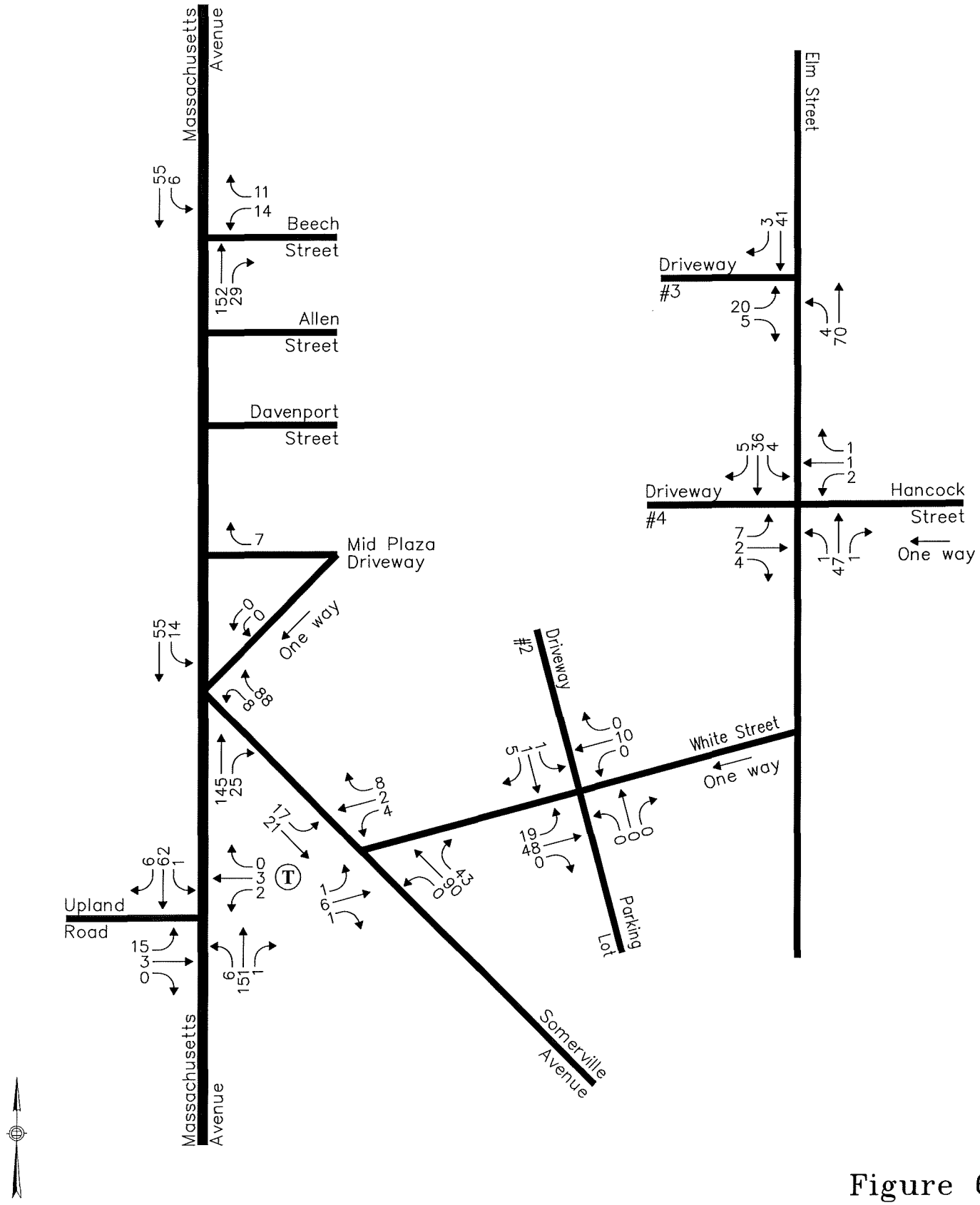


Figure 6
2008 Weekday PM Bicycles

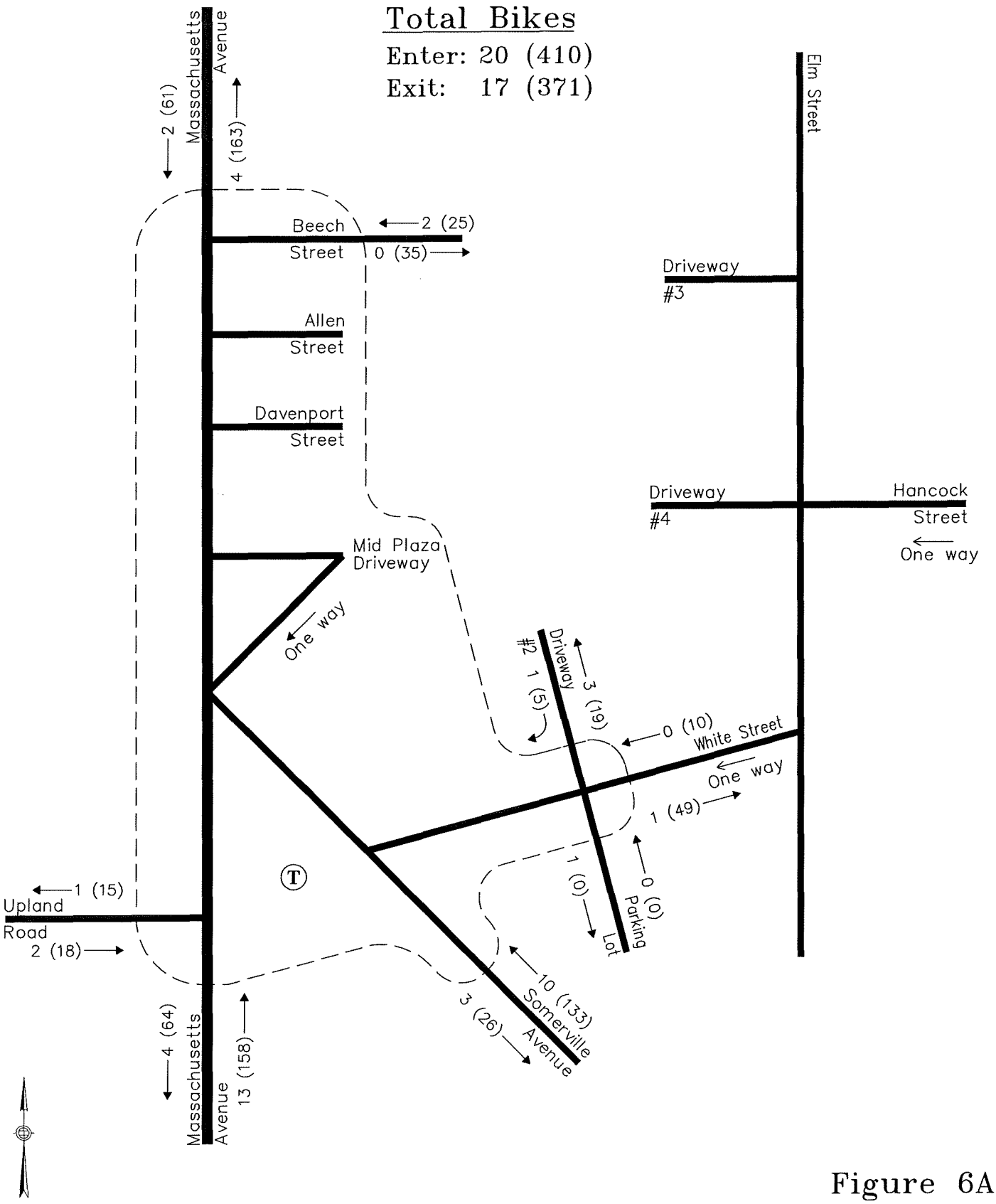


Figure 6A
2002 (2008) Weekday PM Bicycles

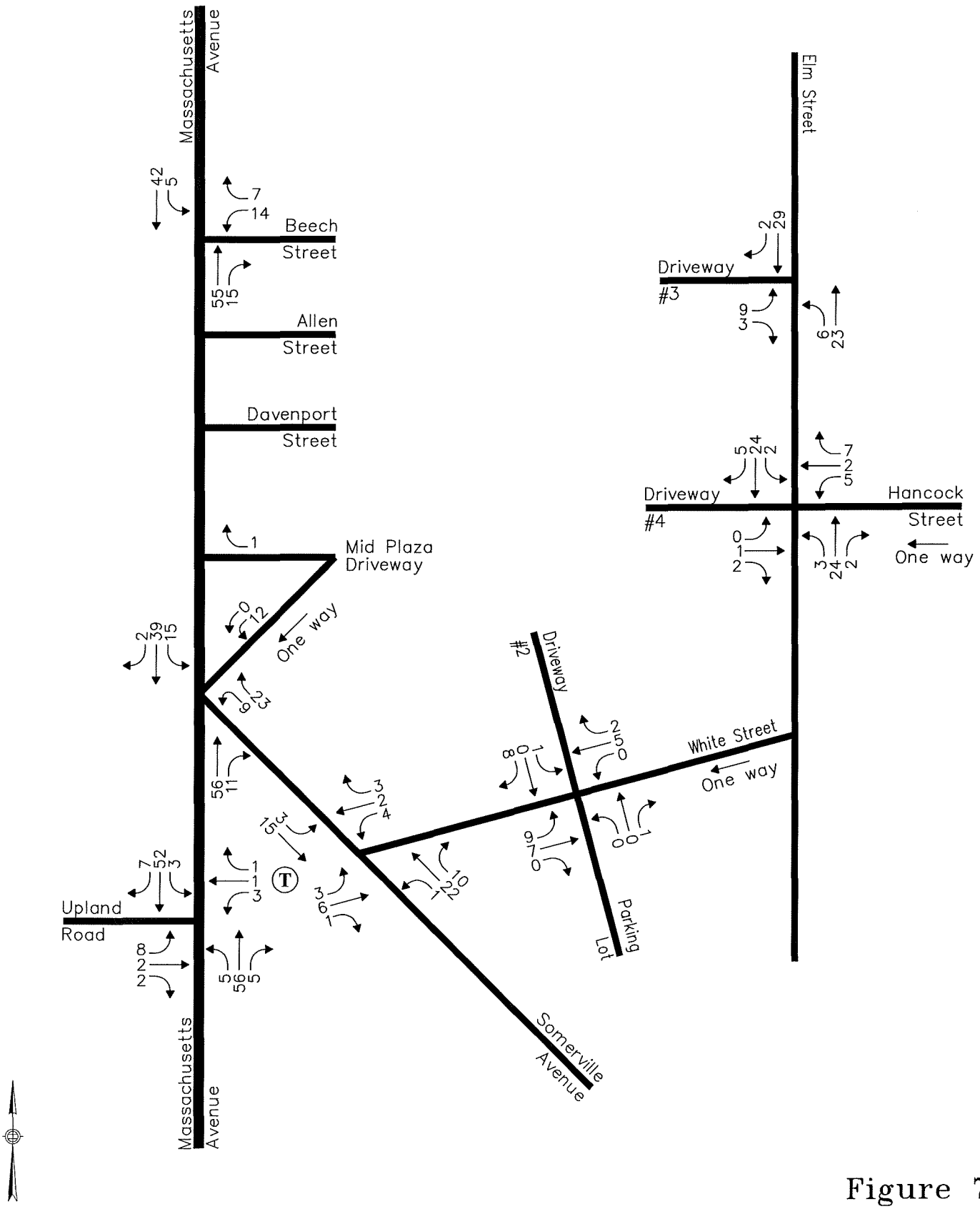


Figure 7
2008 Saturday Midday Bicycles

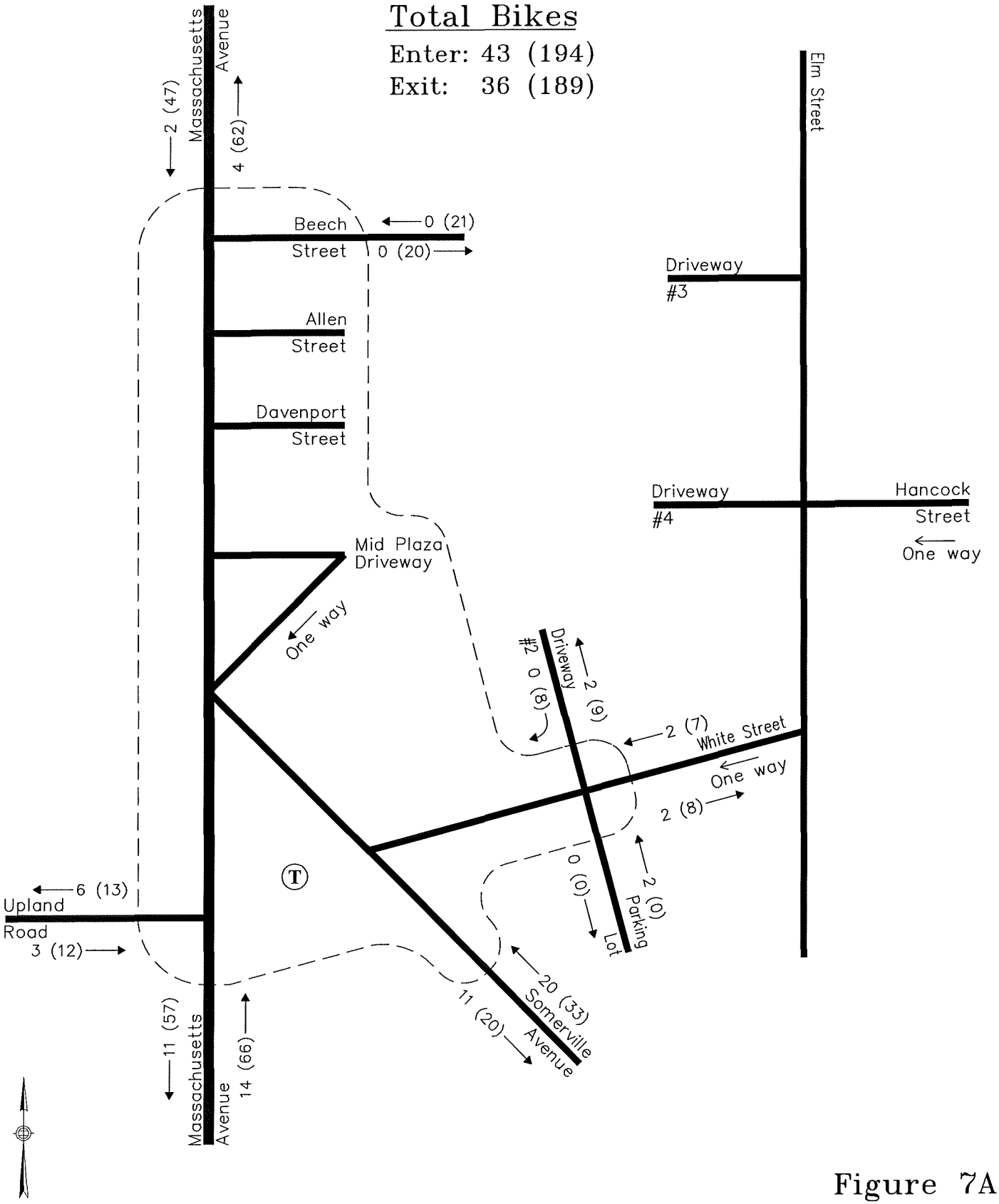


Figure 7A
2002 (2008) Saturday Midday Bicycles

In order to evaluate the changes in bicycle ridership through Porter Square, the total number of bikes entering and exiting the study area were examined during the three peak hours observed. This was accomplished by establishing boundaries and totaling the number of bicycles observed to cross the boundaries. These boundaries were established at the following borders of the study area:

- Massachusetts Avenue north of Beech Street
- Beech Street east of Massachusetts Avenue
- Upland Road west of Massachusetts Avenue
- Massachusetts Avenue south of Upland Road
- Somerville Avenue southeast of White Street
- White Street east of Parking Lot Entrance
- Parking Lot Entrance north of White Street
- Driveway south of White Street

Table 4 provides a comparison of the total number of bicycles entering and exiting the Porter Square study area during the three peak hours under 2002 and 2008 observations.

Table 4
Bicycle Ridership Increases (2002-2008)

	2002		2008		Change (2008/2002)	
Peak Hour	**Entering**	**Exiting**	**Entering**	**Exiting**	**Entering**	**Exiting**
AM Peak	31	14	241	252	7.8	18.0
PM Peak	20	17	410	371	20.5	21.8
Sat Midday Peak	43	36	194	189	4.5	5.3

Based on a comparison of pre and post construction conditions, it appears that bicycle ridership through the area has increased significantly. Based on 2002 counts of bicycle movements through the area, the total number of cyclists observed within the study area was less than 50 cyclists in any of the peak hours. Under 2008 conditions, there are between approximately 200 and 400 bicycles within the Porter Square study area during the peak hours. This represents increases of 5 to more than 20 times the number of cyclists within the Porter Square area since the 2002 observations.

It should be noted that the observations in 2002 were conducted in November and the observations in 2008 were conducted in June. The warmer weather in June could explain some of the increased ridership; however, the magnitude of the increased presence of bicycles, compounded with the decreased vehicular volumes between 2002 and 2008 indicates a possible trend away from motor vehicle travel to bicycle travel. Additional surveys and studies would be required to confirm this trend, but the modifications to the Porter Square area have provided additional amenities for both bicycles and pedestrians. These modifications make the Porter

Square area more appealing to bicycle riders and pedestrian travel. In addition, the increased costs of auto usage could be a factor in increasing bicycle usage.

The increased bicycle usage is consistent with trends throughout the City. The City of Cambridge conducts citywide annual bike counts each September. The 2008 counts were recently completed and have indicated that throughout the City, bike usage has doubled since 2002. In addition, bike counts were completed at the Porter Square intersection in 2006 and 2008 as part of the citywide bike count program. Between 2006 and 2008, bicycle ridership through Porter Square during the afternoon peak period has increased by a factor of 1.5, while volumes in the morning have remained consistent since 2006.

Survey of Left Turning Bicyclists

In addition to observing and collecting data on bicycle volumes and movements, the City of Cambridge conducted interviews with cyclists in the Porter Square area on Thursday June 5, 2008 between 4:50 and 5:50 PM; Friday June 6, 2008 between 7:50 and 8:50 AM; Tuesday June 10, 2008 between 8:27 and 9:27 AM; and Thursday June 12, 2008 between 8:30 and 9:30 AM. The interviews were conducted to obtain cyclists' opinions of the newly constructed bike jug-handle designed to provide a signalized crossing for the southbound left turn from Massachusetts Avenue to Somerville Avenue. A total of 15 interviews were conducted.

New Bike "Jug-Handle"

Figure 8 presents a graphical summary of the observed trends for southbound left turning cyclists. Based on the observation of 120 cyclists making the southbound left turn from Massachusetts Avenue to Somerville Avenue approximately 75%, or 90 cyclists were observed to continue to follow the vehicular movements and ride with traffic in the left turn lane. Twenty two percent (22%) of the cyclists used the new jug handle configuration while the remaining 8% utilized the pedestrian crosswalk.

As mentioned, bicycle observations were conducted at the Porter Square intersection in September 2008 as part of the City's annual bike count program. Based on the 2008 counts 32% of the total bicycles observed in the AM Peak Hour were observed to be running red lights, while 16% of the cyclists in the PM Peak Hour were running the red lights. None of the red light runners were observed to be utilizing the new jug handle configuration.

Figure 8
Left Turn Movement Summary

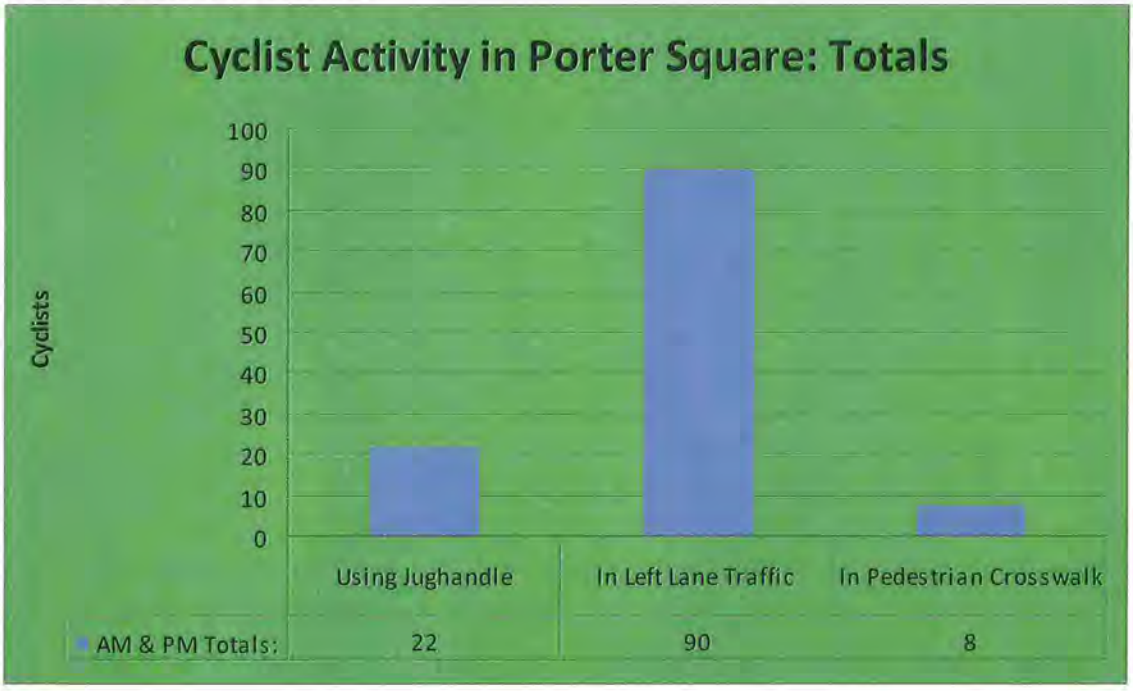
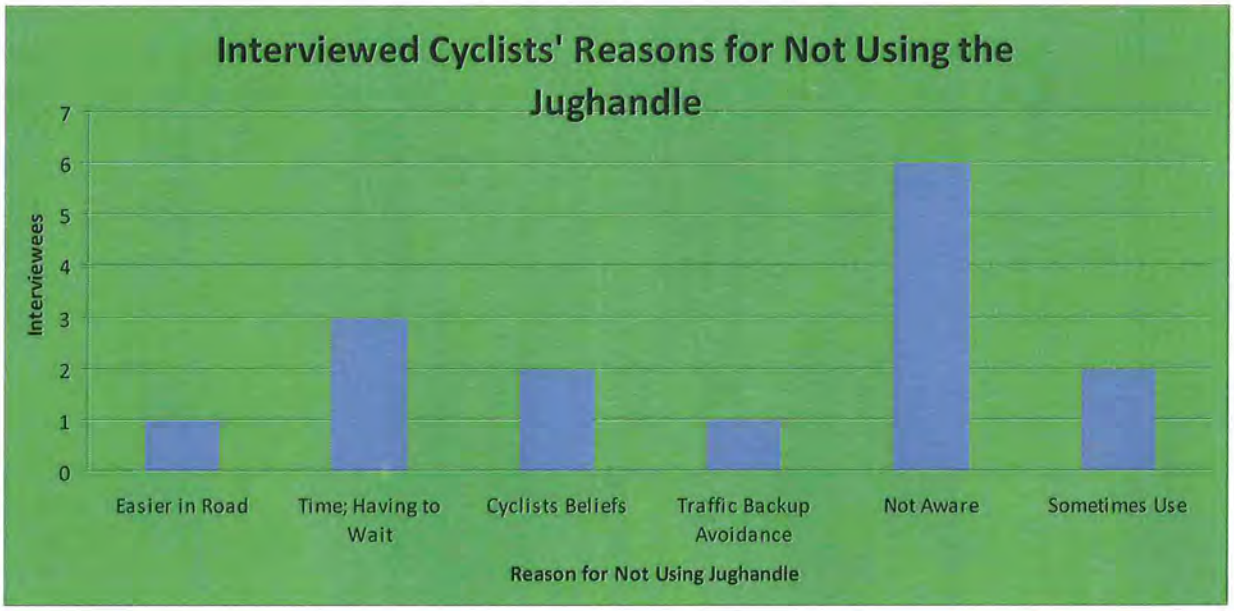


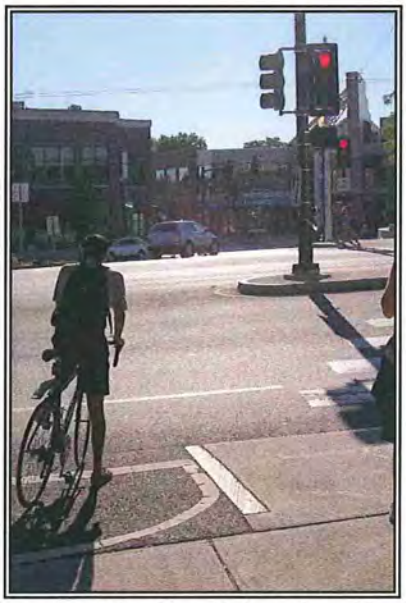
Figure 9 presents a graphical representation of the results of the interviews with the cyclists. As indicated in Figure 9, 15 cyclists were interviewed regarding the effectiveness of the constructed jug handle. Of the 15, 9 of the cyclists were aware of the jug handle but chose to use the left turn lane for a variety of reasons including the left turn lane use is easier and/or faster to use than the

jug handle, preference and the sentiment that bikes should be in the road. Forty percent, or 6 of the 15 interviewed cyclists, were not aware of the jug handle.

Figure 9
Results of Cyclist Interviews



Left Turning Cyclist in Travel Lane



Left Turning Cyclist Using Jug Handle

Pedestrian Volumes/Patterns

Based on an overall comparison of pedestrian movements throughout the Porter Square area during the three peak hours observed (weekday morning and evening as well as Saturday midday) it appears that the total number of pedestrian crossings have declined. During the morning peak hours there are approximately 25% fewer pedestrian movements, and during the evening and Saturday peak hours the number of pedestrian crossing has declined by approximately 11% and 17% This overall reduction may be a result of the new construction and reconfigured crosswalk locations. Under the pre construction configuration, a single pedestrian may have crossed several locations, particularly in the vicinity of the Massachusetts Avenue/Somerville Avenue intersection. However, under the post construction conditions more direct crossing are provided eliminating or reducing the need for multiple crossing locations.

It should also be noted that the highest pedestrian volumes under both 2002 and 2008 conditions occur in the evening peak hour. In 2002, the weekday morning peak hour pedestrian volumes were greater than the Saturday volumes. However, in 2008, the Saturday midday pedestrian volumes were heavier than the weekday morning peak hour. It should be noted again that the 2002 pedestrian volumes were counted in November, while the 2008 volumes were counted in May. Weather and temperature may partially account for the increased pedestrian volumes during the Saturday peak hour in 2008. While the weekday pedestrian movements are likely commuting movements, and not greatly impacted by weather conditions, the Saturday volumes may be more discretionary trips with increased activity with warmer weather conditions in May.

The new pedestrian crosswalks in the vicinity of Massachusetts Avenue at Somerville Avenue and Somerville Avenue at White Street have clarified the pedestrian movements and enhanced the crossings by providing marked crosswalks in the desired pedestrian line of travel. Prior to the construction, between 300 and 750 pedestrians (depending on peak hour) were observed to be crossing through the Massachusetts Avenue at Somerville Avenue in unmarked crosswalk areas. The desired path led pedestrians from the easterly side of Massachusetts Avenue towards the shopping center area; however there was no marked crosswalk in this area.

The current configuration provides a dedicated crosswalk on the westbound Somerville Avenue approach to Massachusetts Avenue as well as along both the northbound and southbound Massachusetts Avenue approaches to Somerville Avenue. The pedestrian facilities were further enhanced with crosswalks on both the eastbound and westbound Somerville Avenue approaches to White Street. These crosswalks combine to move between 600 and 900 pedestrians across both Massachusetts Avenue and Somerville Avenue in protected pedestrian crosswalks. Figures 10, 11 and 12 depict the 2008 pedestrian movements based on the constructed crosswalk locations. Pre construction pedestrian networks were shown in Figure 2 and the corresponding pedestrian volumes are provided in the Appendix.

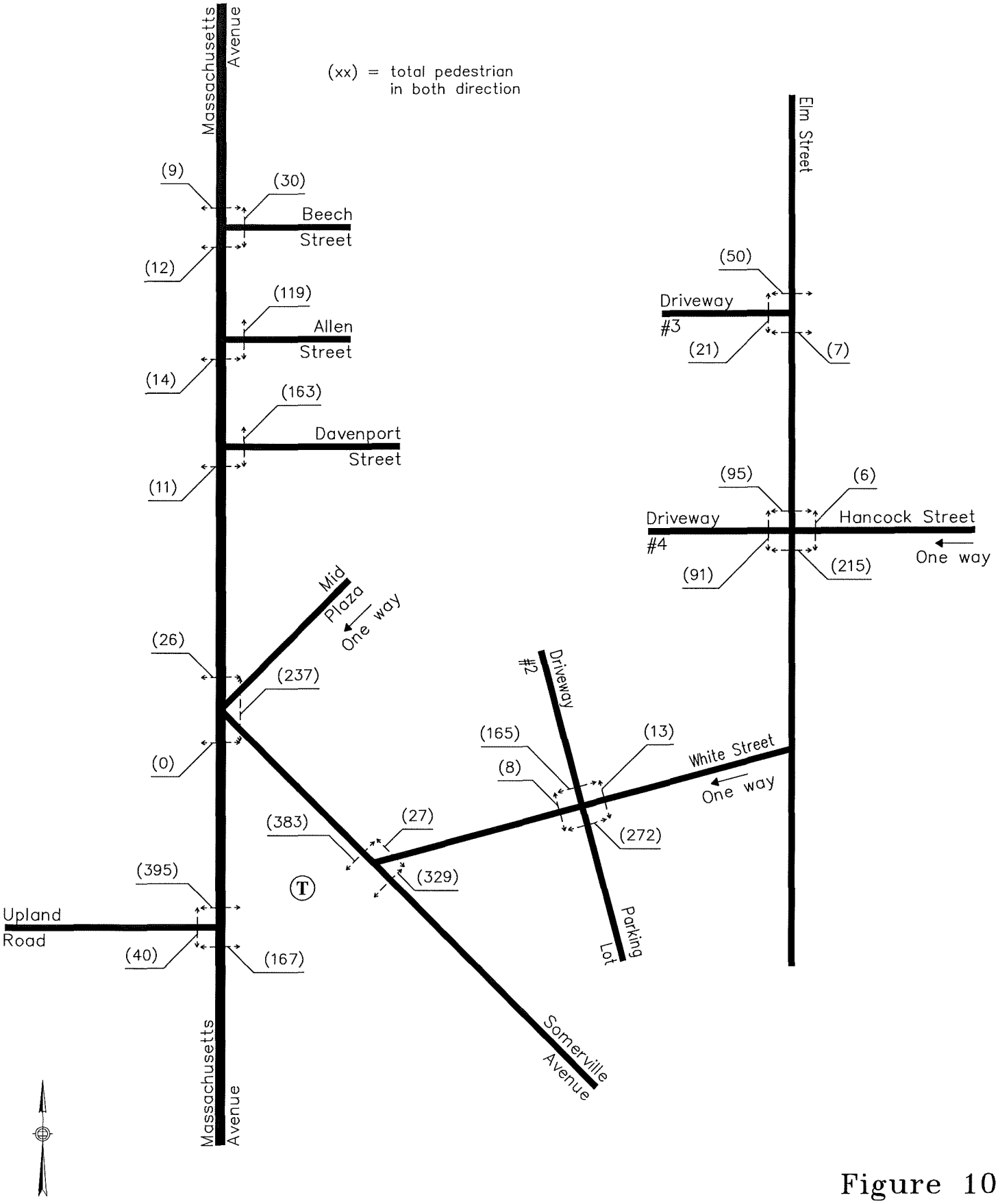


Figure 10
2008 Weekday AM Pedestrians

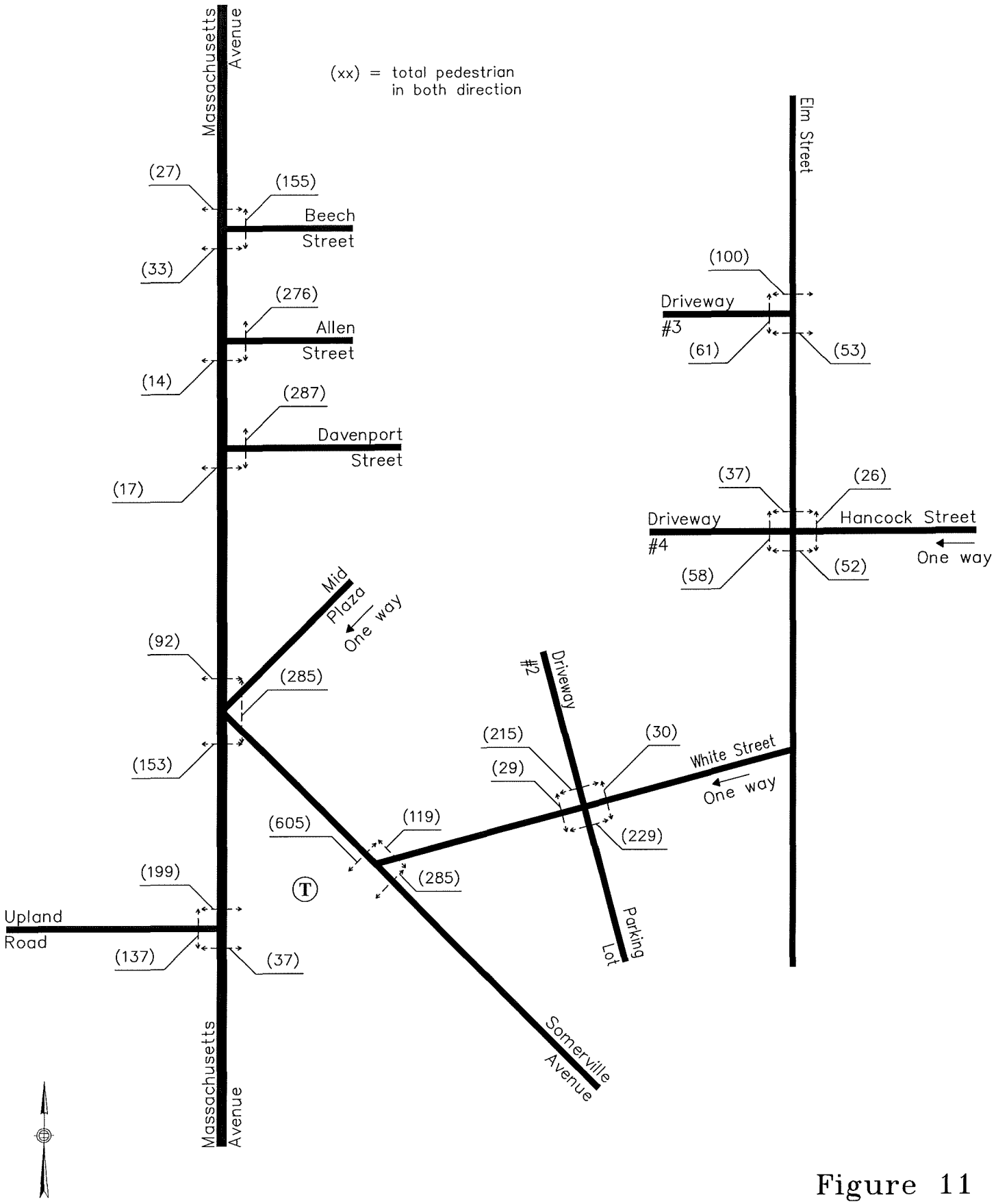


Figure 11
2008 Weekday PM Pedestrians

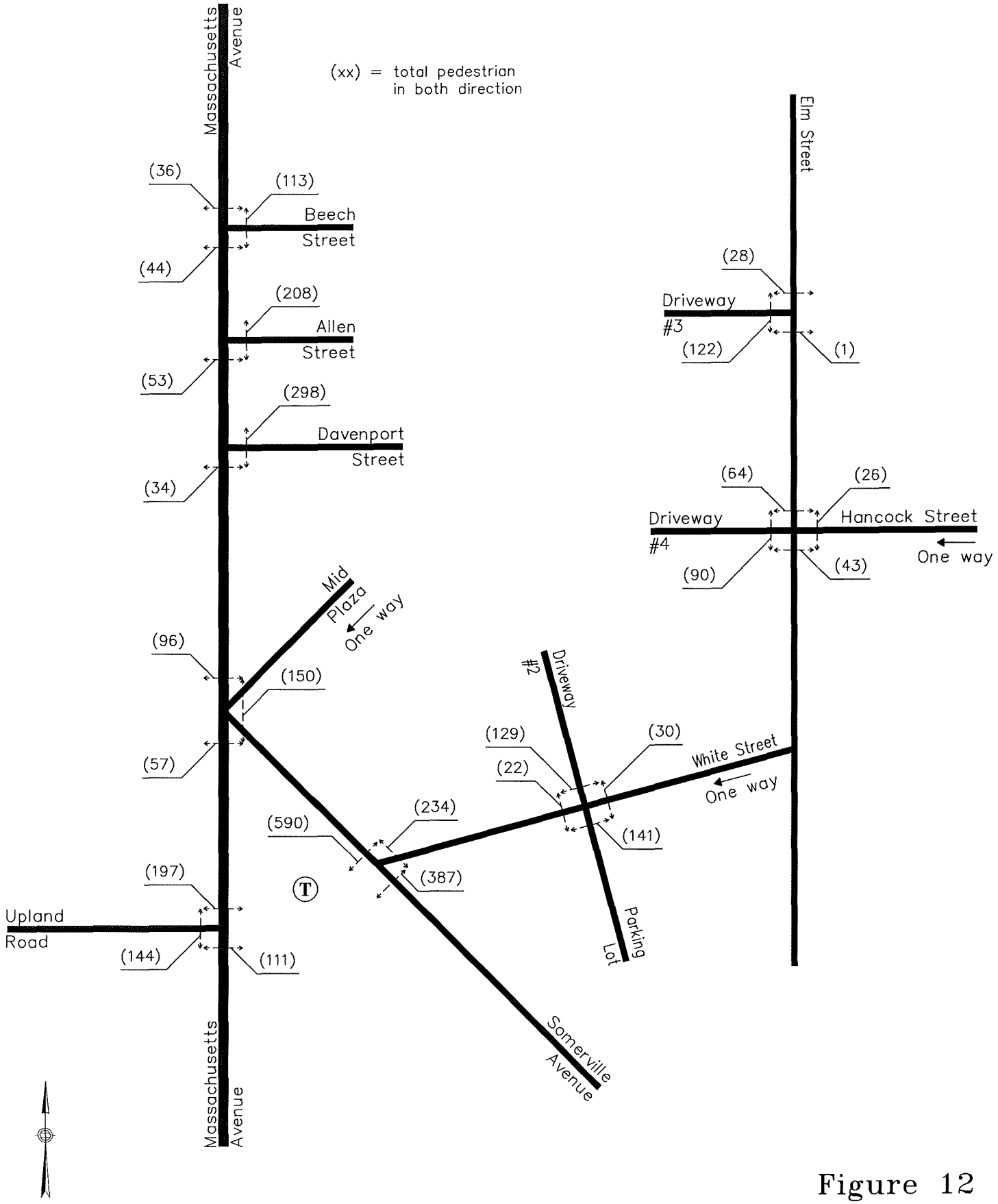


Figure 12
2008 Saturday Midday Pedestrians

The provisions of new crosswalks crossing Massachusetts Avenue at Allen Street and Davenport Street appear to be servicing a demand. The Allen Street crossing was used by 14 pedestrians during both the morning and evening peak periods and over 50 pedestrians during the Saturday period. Similarly the Davenport Street crossing was used by 11 and 17 pedestrians respectively during the morning and evening peak periods and 34 pedestrians during the Saturday peak period.

Both the Allen Street and Davenport Street crosswalks have been constructed with advance yield markings painted on the roadway approaches to the crosswalks to provide motorists with a visual indication of where to stop or yield when pedestrians are present. The yield markings are meant to enhance the compliance with the state law requiring motorists to yield to pedestrians. The behavior of drivers at the Allen Street crossing of Massachusetts Avenue was observed in October of 2007 and June of 2008. Based on the studies prepared by the City of Cambridge Traffic Parking and Transportation Department, an average of twenty-seven percent (27%) of the drivers were observed to yield to pedestrians in the crosswalk at this location.

The City recently completed a study of yielding at 11 crosswalks throughout the city. Five locations had advance yield markings and six did not. The overall average yield compliance at the 11 observed crosswalks was approximately 35%. Of the 5 locations with the marked advanced yield lines the average compliance was slightly higher at 39% while at the 6 locations without the markings the average compliance fell slightly to 31%. Along Massachusetts Avenue, 4 locations were studied, two with the yield markings and two without. Along Massachusetts Avenue the average compliance, regardless of markings was approximately 23%. Again a similar trend was observed that with the markings, the compliance increased slightly to 26% while without the markings the compliance was slightly lower at 21%.

Based on this relatively small sample size to date; it appears that the yield markings do provide some improvements in drivers yielding to pedestrians at crosswalks. However, further studies and evaluation, including before and after studies will be required to fully determine the effectiveness of the yield markings.

It should be noted that along the southbound Massachusetts Avenue approach to Davenport Street, the Dashed White Center line was not removed between the yield line and the crosswalk. The combination of the yield line and dashed line combine to form a directional arrow northbound in the southbound travel lane which should be avoided in future installations.

The upgraded traffic signals at Beech Street, Somerville Avenue and Upland Road provide pedestrian signal phasing that is automatically activated each signal cycle, regardless of the presence of pedestrians. This operation was implemented before the construction phase and brought the two signals into compliance with the City signal policy and reduces the delay for pedestrians waiting to cross.

Intersection Capacity Analysis

Two of the critical concerns throughout Porter Square are increased traffic congestion and queues on Mass Ave and conflicts between motor vehicles, pedestrians and cyclists. The reconfiguration of Porter Square provided new traffic signal equipment at the four major intersections of Massachusetts Avenue and Beech Street, Massachusetts Avenue at Somerville Avenue, Massachusetts Avenue at Upland Road and Somerville Avenue at White Street At the intersection of Massachusetts Avenue and Somerville Avenue, additional concurrent pedestrian phasing is provided where pedestrian crossing can occur without conflicts with vehicles. These crossings include; the shopping center left turn exit drive and the northerly and the southerly Massachusetts Avenue crossings. In addition, the three traffic signals are running in coordination. Using the Porter Square signal as the control, the city is running time based coordination and progression for the entire Mass Ave corridor from Harvard Square to the Arlington town line.

In order to provide an accurate pre and post construction evaluation of vehicle traffic operations the capacity or Level of Service (LOS) at each of the intersections was computed. LOS calculations were completed based on peak hour traffic volumes collected at the intersections in May 2008 Figures 13, 14 and 15 provide a summary of the vehicle counts and movements.

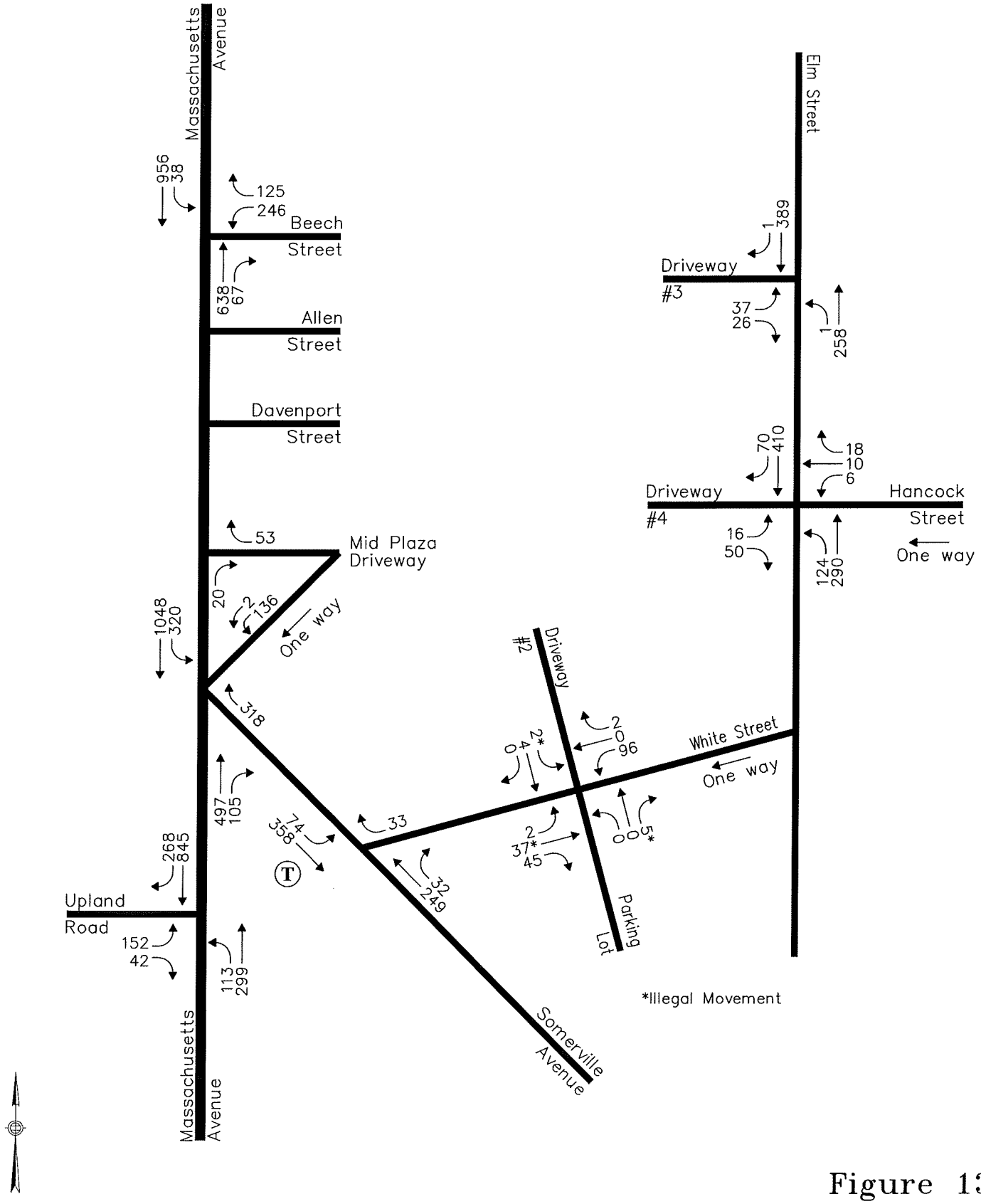


Figure 13
2008 Weekday AM Vehicles

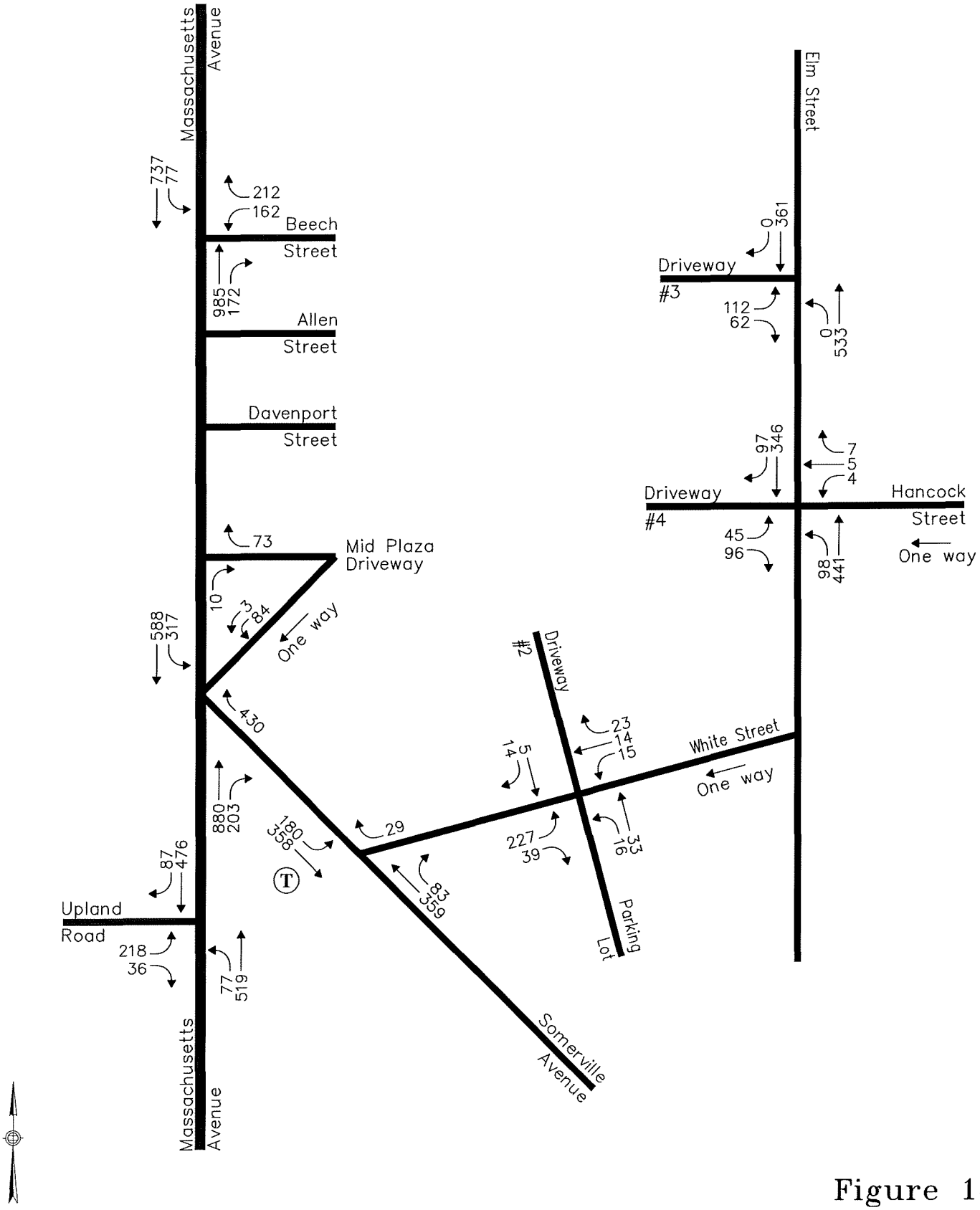


Figure 14
2008 Weekday PM Vehicles

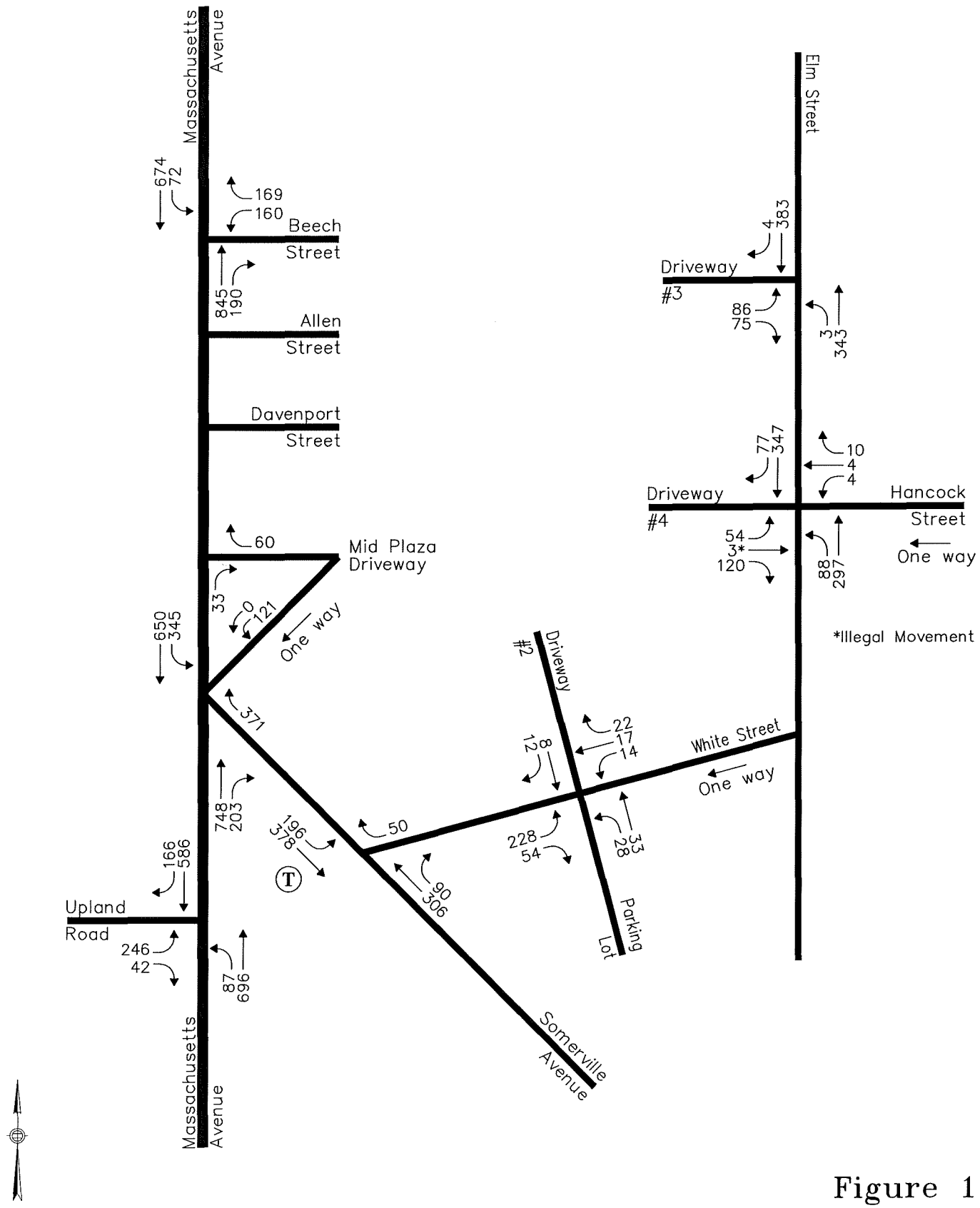


Figure 15
2008 Saturday Midday Vehicles

Similar networks depicting the pre construction peak hour turning movement counts are presented in the Appendix.

In order to provide an accurate representation of the operations of the current traffic signals, the timing plans were recorded directly from the traffic signal controllers in June 2008. Tables 5 through 8 provide a comparison of the pre and post construction LOS operations for each of the four signalized intersections.

Table 5
Capacity Analysis Summary
Massachusetts Avenue at Beech Street

	2002 (Pre Construction)				2008 (Post Construction)			
Intersection/Peak Hour/Lane	V/C[a]	g/C[b]	Del.[c]	LOS[d]	V/C	g/C	Del.	LOS
Massachusetts Avenue at Beech Street								
Weekday AM:								
Mass Ave SB Left/Thru	2.10	0.43	282.2	F	0.72	0.49	26.9	C
Mass Ave NB Thru/Right	0.95	0.38	50.6	D	0.51	0.45	23.5	C
Beech St WB Left					0.77	0.22	58.6	E
Beech St WB Right					0.44	0.22	44.8	D
Beech St WB Approach	1.17	0.28	117.9	F			53.9	D
OVERALL INTERSECTION			**168.1**	**F**	**0.73**		**31.0**	**C**
Weekday PM:								
Mass Ave SB Left/Thru	2.36	0.47	121.2	F	0.79	0.53	28.0	C
Mass Ave NB Thru/Right	1.19	0.43	114.1	F	0.87	0.47	24.2	C
Beech St WB Left					0.58	0.18	53.2	D
Beech St WB Right					0.83	0.18	71.9	E
Beech St WB Approach	1.11	0.24	101.5	F			63.8	E
OVERALL INTERSECTION			**21.0**	**F**	**0.85**		**31.6**	**C**
Saturday Midday:								
Mass Ave SB Left/Thru	1.73	0.47	234.3	F	0.70	0.52	25.0	C
Mass Ave NB Thru/Right	1.33	0.43	151.8	F	0.72	0.48	26.1	C
Beech St WB Left					0.60	0.18	53.1	D
Beech St WB Right					0.71	0.18	60.1	E
Beech St WB Approach	1.19	0.24	117.2	F			56.7	E
OVERALL INTERSECTION			**178.5**	**F**	**0.72**		**30.8**	**C**

[a]Volume-to-capacity ratio.
[b]Actuated effective green time to cycle length ratio.
[c]Average control delay in seconds per vehicle.
[d]Level of service.

Table 6
Capacity Analysis Summary
Massachusetts Avenue at Somerville Avenue

Intersection/Peak Hour/Lane	2002 (Pre Construction) V/C[a]	g/C[b]	Del.[c]	LOS[d]	2008 (Post Construction) V/C	g/C	Del.	LOS
Massachusetts Avenue at Somerville Avenue								
Weekday AM:								
Mass Ave SB Left	0.77	0.24	63.3	E	0.62	0.35	29.9	C
Mass Ave SB (Thru) Left/Thru	0.97	0.70	44.0	D	0.58	0.55	14.2	B
Mass Ave SB Approach			47.0	D			17.9	B
Mass Ave NB Thru					0.81	0.20	44.9	D
Mass Ave NB Right					0.39	0.20	34.8	C
Mass Ave NB Approach	0.49	0.46	20.5	C			43.1	D
Somerville Ave WB Right	0.41	0.48	2.2	A	0.29	0.46	5.5	A
Shopping Drive SWB Left					1.06	0.09	142.0	F
OVERALL INTERSECTION			**32.4**	**C**	**0.57**		**30.0**	**C**
Weekday PM:								
Mass Ave SB Left	0.68	0.23	32.8	C	0.60	0.20	43.0	D
Mass Ave SB (Thru) Left/Thru	0.61	0.70	4.2	A	0.55	0.62	9.1	A
Mass Ave SB Approach			9.8	A			15.9	B
Mass Ave NB Thru					0.67	0.42	26.8	C
Mass Ave NB Right					0.34	0.42	20.4	C
Mass Ave NB Approach	0.83	0.47	9.8	A			25.6	C
Somerville Ave WB Right	0.51	0.47	3.6	A	0.61	0.29	10.8	B
Shopping Drive SWB All Movements					1.75	0.06	432.1	F
OVERALL INTERSECTION			**8.5**	**A**	**0.73**		**48.1**	**D**
Saturday Midday:								
Mass Ave SB Left	0.93	0.18	70.4	E	0.67	0.20	45.8	D
Mass Ave SB (Thru) Left/Thru	0.72	0.64	14.7	B	0.60	0.62	10.4	B
Mass Ave SB Approach			25.9	C			17.3	B
Mass Ave NB Thru					0.56	0.42	19.4	B
Mass Ave NB Right					0.34	0.42	15.6	B
Mass Ave NB Approach	0.77	0.46	22.1	C			18.6	B
Somerville Ave WB Right	0.55	0.46	2.6	A	0.56	0.29	14.8	B
Shopping Drive SWB All Movements					2.07	0.06	572.2	F
OVERALL INTERSECTION			**19.0**	**C**	**0.71**		**61.5**	**E**

[a]Volume-to-capacity ratio.
[b]Actuated effective green time to cycle length ratio.
[c]Average control delay in seconds per vehicle.
[d]Level of service.

Table 7
Capacity Analysis Summary
Somerville Avenue at White Street

Intersection/Peak Hour/Lane	2002 (Pre Construction) V/C[a]	g/C[a]	Del.[b]	LOS[c]	2008 (Post Construction) V/C	g/C	Del.	LOS
Somerville Avenue at White Street								
Weekday AM:								
Somerville Ave EB Left	0.73	0.24	26.3	C	0.10	0.62	3.0	A
Somerville Ave EB Thru	0.60	0.29	15.0	B	0.16	0.69	2.4	A
Somerville Ave EB Approach			16.4	B			2.5	A
Somerville Ave WB Thru/Right	0.77	0.24	41.6	D	0.26	0.35	28.4	C
White St SB Right	0.05	0.46	0.0	A	0.19	0.20	41.2	D
OVERALL INTERSECTION			**27.0**	**C**	**0.22**		**15.1**	**B**
Weekday PM:								
Somerville Ave EB Left	1.70	0.28	246.7	F	0.21	0.68	3.5	A
Somerville Ave EB Thru	0.56	0.28	21.2	C	0.15	0.74	0.8	A
Somerville Ave EB Approach			78.7	E			1.7	A
Somerville Ave WB Thru/Right	0.88	0.23	49.2	D	0.71	0.20	51.2	D
White St SB Right	0.07	0.47	0.0	A	0.07	0.42	21.2	C
OVERALL INTERSECTION			**61.4**	**E**	**0.36**		**23.9**	**C**
Saturday Midday:								
Somerville Ave EB Left	2.87	0.24	320.7	F	0.21	0.68	2.3	A
Somerville Ave EB Thru	0.71	0.24	19.4	B	0.15	0.74	1.1	A
Somerville Ave EB Approach			98.2	F			1.5	A
Somerville Ave WB Thru/Right	1.28	0.18	139.0	F	0.59	0.20	47.1	D
White St SB Right	0.16	0.46	0.0	A	0.09	0.42	21.4	C
OVERALL INTERSECTION			**106.4**	**F**	**0.32**		**20.6**	**C**

[a]Volume-to-capacity ratio.
[b]Actuated effective green time to cycle length ratio.
[c]Average control delay in seconds per vehicle.
[d]Level of service.

Table 8
Capacity Analysis Summary
Massachusetts Avenue at Upland Road

Intersection/Peak Hour/Lane	2002 (Pre Construction) V/C[a]	g/C[a]	Del.[b]	LOS[c]	2008 (Post Construction) V/C	g/C	Del.	LOS
Massachusetts Avenue at Upland Road								
Weekday AM:								
Mass Ave NB Left/Thru	0.90	0.51	23.4	C	0.43	0.57	16.2	B
Mass Ave SB Thru/Right	0.72	0.47	33.6	C	0.76	0.51	12.7	B
Upland Rd EB Left					0.85	0.13	**83.1**	**F**
Upland Rd EB Right					0.04	0.13	45.6	D
Upland Rd EB Approach	0.55	0.28	35.2	D			75.0	E
OVERALL INTERSECTION			**30.5**	**C**	**0.75**		**21.3**	**C**
Weekday PM:								
Mass Ave NB Left/Thru	1.15	0.43	103.7	F	0.52	0.49	22.2	C
Mass Ave SB Thru/Right	0.59	0.36	31.7	C	0.50	0.37	26.6	C
Upland Rd EB Left					0.69	0.20	55.8	E
Upland Rd EB Right					0.03	0.20	38.8	D
Upland Rd EB Approach	0.62	0.32	34.2	C			53.4	D
OVERALL INTERSECTION			**69.0**	**E**	**0.57**		**29.3**	**C**
Saturday Midday:								
Mass Ave NB Left/Thru	0.98	0.48	40.4	D	0.72	0.49	27.7	C
Mass Ave SB Thru/Right	0.52	0.42	18.9	B	0.67	0.37	34.8	C
Upland Rd EB Left					0.91	0.20	79.1	E
Upland Rd EB Right					0.03	0.20	38.9	D
Upland Rd EB Approach	0.65	0.23	29.7	C			73.2	E
OVERALL INTERSECTION			**31.4**	**C**	**0.78**		**38.3**	**D**

[a]Volume-to-capacity ratio.
[b]Actuated effective green time to cycle length ratio.
[c]Average control delay in seconds per vehicle.
[d]Level of service.

As illustrated in Tables 5 through 8, the new geometry and upgraded traffic signals have achieved one of the goals of providing LOS 'D' or better the goal at the majority of the intersections with the exception of the Massachusetts Avenue at Somerville Avenue intersection, where the overall level of service has declined to a LOS 'E" during the Saturday midday peak period.

Several observations were noted in the field that may contribute to lower LOS ratings at individual vehicle approaches or intersections along the corridor and are noted below:

1. The signals are designed to "call" exclusive pedestrian phases, which stop all vehicle traffic through the intersections, each cycle and therefore no pedestrian push buttons are provided. This eliminates the need for pedestrians to manually activate the pedestrian phase, and forces all vehicular traffic to stop each cycle regardless of the presence of any pedestrian demand. As mentioned previously, this has been done to provide a high level of service to pedestrians but it involves a tradeoff since vehicles cannot take advantage of un-used signal time when no pedestrians are present.

2. The southbound Massachusetts Avenue approach is striped as a dedicated left turn lane with a shared left/through lane and a dedicated through lane. This type of lane configuration requires "Split" signal phasing to be effective, where the southbound approach needs to run exclusively and independent of the northbound approach. However, the southbound approach currently has a lead phase but then runs concurrently with the northbound approach. During this concurrent period the left turn movement is stopped with a RED LEFT ARROW. However, because the middle lane is a shared left and through lane, any vehicle in the lane making a left turn is required to stop, thereby blocking the through movement. During the field visit, this was observed several times with through vehicles trapped behind a left turning vehicle becoming frustrated, blowing horns, and aggressively changing lanes to bypass the stopped left turning vehicle.

   It is recommended that the operations of the left turn movement be reexamined once the Walden Bridge reopens and the construction along Somerville Avenue is completed. This will ensure more representative traffic volumes to fully investigate the impacts of potential lane usage of or phasing modifications.

3. Along the southbound Massachusetts Avenue approach the signing indicates a dedicated left turn lane, a shared left and through lane and a dedicated right turn lane. The pavement markings along the southbound approach differ from the sign and indicate a dedicated left turn lane, a shared left/through lane and a dedicated through lane. In reality there is no right turn lane, rather a second, dedicated through lane. This can exacerbate the condition in item 2 above as drivers unfamiliar with the area may feel like they have to be in the middle lane to continue southbound along Massachusetts Avenue and then are trapped behind a left turning vehicle.

4. The signal display along the southbound Massachusetts Avenue approach to Somerville Avenue is not consistent with the MUTCD. The overhead signal above the middle lane displays a Vertical Green Arrow. However, the lane is dedicated as a shared through/left lane. Therefore a mixed message is being provided to motorists. The signal indicates that this is an *exclusive* through lane, while the signing and pavement markings indicate a *shared* through/left lane. Either the lane markings and signs should be revised to indicate a dedicated left lane and two dedicated through lanes, or the signal indication should be changed to a Green Ball. As noted in item 2, this lane configuration and signal phasing should be studied further by the City to analyze which changes should be recommended.

5. With the current signal operations, the shopping center drive exits onto Massachusetts Avenue southbound on its own protected signal phase. However, southbound Massachusetts Avenue traffic is typically queued from the Upland Road intersection through Somerville Avenue when this phase occurs. Therefore, the traffic exiting the shopping center is not be able to progress along Massachusetts Avenue southbound and occasionally blocks the opposing northbound travel lanes.

6. The pre-construction signal plans for Upland Road indicate that there was to be a lagging southbound movement, however this phase created a "Left Turn Trap" situation, in which a northbound left turning vehicle assumes the southbound movement is stopping at the same time as the northbound traffic, and proceeds to make a left turn on the yellow or red clearance. However, with a southbound lagging phase in operation, the southbound traffic is still progressing through the intersection on a green display. While this phase appears to have been designed to provide the necessary relief at the Somerville Avenue intersection to accommodate the shopping center traffic (as discussed above), the operation of this phase created a hazardous situation and was removed from the signal operations by the City. As discussed earlier, the operations of the southbound left turn movement to Somerville Avenue should be examined in the future in more detail. At that time, consideration should be given to exploring the potential to provide a southbound "lead" phase at the Upland Street intersection in conjunction with the left turn movement from the Shopping Center at Somerville Avenue. The northbound left turn movement at the Upland Street intersection could potentially operate as a "lag" phase without the introduction of a left turn trap.

7. At the Beech Street intersection, a new traffic controller was installed, however the remainder of the pre-construction on-street hardware was retained. New count down pedestrian signal indications were provided for the new crossing on the northerly leg of Massachusetts Avenue, however all other crossings retained the older non-count down pedestrian displays. These should be changed to consistent displays as budget allows.

8. The eastbound White Street approach to the shopping center driveway is confusing. As indicated by the traffic counts, 37 vehicles during the morning peak hour were observed to travel the wrong direction along White Street east of the shopping center drive. This may be due to confusing signing along the approach. The Do Not Enter Sign is on the left side of eastbound drivers and the right side of the shopping center entrance. It appears that the Do Not Enter is prohibiting the entrance to the shopping center rather than White Street. An additional Do Not Enter Sign should be installed on the right side of White Street to clearly indicate that the roadway is one-way westbound.

It should also be noted that the 2002 study projected volumes through the study area for the peak hours, based on the proposed modifications of the area. In general, the turning movement projections and reassignments were higher than the volumes observed in 2008. The areas of interest, where the observed 2008 volumes were greater than those anticipated include the right turn movement out of the Porter Square Shopping Area in the morning peak hour and the southbound right turns from Massachusetts Avenue to Upland Road in the morning and Saturday midday peak hours. The increased traffic exiting the Shopping Center in the morning may be due to drivers utilizing the shopping center as a "cut-through" from Elm Street to Massachusetts Avenue southbound. During field observations a number of vehicles were observed to enter the Elm Street shopping center drive and turn left onto Massachusetts Avenue via the new driveway without stopping in the shopping center. The right turn movement to Upland Road is approximately twice as high as anticipated. In addition, occasional drivers were observed to enter Driveway #3 along Elm Street from both the north and south, particularly during the morning and Saturday midday peak hours.

CONCLUSIONS AND RECOMMENDATIONS

This study has been prepared to evaluate how the recently completed reconstruction of Porter Square addressed the original goals of the project and has impacted pedestrians, bicyclists and motor vehicle operators in the study area. This study included an analysis of pedestrian and bicycle movements and trends as well as an evaluation of the operations of the newly reconstructed traffic signals. The following is a summary of the original project goals:

- Reduce vehicular domination of Porter Square
- Improve conditions for pedestrians, bicyclists and transit users, particularly for pedestrians crossing Somerville Avenue at the MBTA Stop
- Reduce cut-through and shopping center related vehicular traffic on neighboring residential streets
- Improve streetscape and create a sense of place in Porter Square
- Improve traffic safety
- Maintain traffic level-of-service (LOS) at or near existing conditions or LOS D, whichever is lower.

With the exception of the traffic level-of-service (LOS D or better), the goals of the project have been achieved. The overall project provides enhanced facilities for pedestrians and bicyclists by providing better additional and better defined pedestrian crossings, improved pedestrian phasing at the signals and bike lanes and a bike "jug-handle" to accommodate cycle traffic. In addition, the creation of the pedestrian plaza and provision for bike storage adjacent to the shopping center has increased the focus of the Porter Square area as a pedestrian and bicycle friendly area. The

increased presence of bicycles during the critical peak hours is an indication that the enhanced facilities have been successful.

Additional observations and recommendations are noted below:

- Overall traffic levels throughout the area have generally decreased. The most significant reductions are noted along Somerville Avenue south of White Street (36%), Beech Street east of Massachusetts Avenue (24%) and Massachusetts Avenue south of Beech Street (18%).

- Pedestrian crossings have been enhanced resulting in pedestrians crossing within marked crosswalks particularly at the Massachusetts Avenue/Somerville Avenue intersection.

- The installation of new crosswalks crossing Massachusetts Avenue at Allen Street and Davenport Street are being utilized by pedestrians.

- The installation of YIELD lines at crosswalks appears to provide slightly better compliance of motorists to yield for pedestrians within the crosswalk. However, additional studies are could further substantiate these findings

- Bicycle volumes throughout the area have dramatically increased between 2002 and 2008. While an increase in bike usage would be expected due to the seasonal variation between November and June observations, the dramatic increases of between 5 to 20 times the number of bikes observed during the peak hours between 2002 and 2008, would indicate a general trend towards increased bike ridership through the Porter Square area. This has been confirmed by the recent completion of the citywide bike count program. Between 2006 and 2008, bicycle volumes through the Porter Square area during the evening peak hour have increased by a factor of 1.5 while morning peak hour volumes have remained constant. Furthermore, citywide bike usage has more than doubled since 2002.

- While the Bicycle Jug-Handle is being utilized by approximately 20% of cyclists turning left from Massachusetts Avenue to Somerville Avenue, it appears that the majority of cyclists continue to use the left turn vehicle lane. The City has recently added additional pavement markings better identify the jug-handle in hopes of capturing a portion of the 40% of cyclists that were not aware of the presence of the jug-handle.

- To address the trapping of through vehicles in the shared left/through lane along the southbound Massachusetts Avenue approach to Somerville Avenue, the approach could be restriped to a single dedicated left turn lane and two dedicated through lanes. Further study of the operations of the movement, lane configuration and signal operations should

be undertaken once the Walden Bridge reopens and construction on Somerville Avenue is completed.

- The signing along the southbound Massachusetts Avenue approach to Somerville Avenue depicting the lane configuration should be consistent with the lane striping along the approach.