MEMORANDUM

To: **John DePriest** **February 17, 2011**
Director of Planning and Development, City of Chelsea

From: **Chen-Yuan Wang and Efi Pagitsas**

Re: **Safety and Operations Analyses at Selected Boston Region MPO Intersections: Broadway at Congress Avenue/Third Street and Broadway at Everett Avenue/Cross Street in Chelsea**

This memorandum summarizes safety and operations analyses and proposes improvement strategies for the intersections of Broadway at Congress Avenue/Third Street and at Everett Avenue/Cross Street in Chelsea. The two intersections are located in close proximity and should therefore be examined together. The memorandum contains the following sections:

- Intersection Layout and Traffic Control
- Issues and Concerns
- Crash Data Analysis
- Intersection Capacity Analysis
- Preliminary Traffic Signal Warrants Analysis
- Analyses of Improvement Alternatives
- Improvement Recommendations and Discussion

The memorandum also includes a collection of technical appendices that contain methods and data applied in the study and detailed reports of the intersection capacity analysis.

INTERSECTION LAYOUT AND TRAFFIC CONTROL

The two intersections are located in the central area of Chelsea, just a few blocks west of the historic Bellingham Square. Broadway can be regarded as an extension of Route 107 from the Chelsea/Revere border to the Chelsea/East Boston border. It functions as an urban principal arterial and carries a high proportion of regional traffic. South of Bellingham Square, it operates in two lanes westbound only (inbound to Boston). Both sides of Broadway from Bellingham Square to its intersection with Everett Avenue/Cross Street are mostly commercial developments with on-street parking.

Figure 1 shows the intersection layout and the area nearby. The two intersections are about 200 feet from each other. The eastern intersection, Broadway at Congress Avenue/Third Street, is currently under a stop control on Congress Avenue. Congress Avenue and Third Street both operate one-way northbound only, with on-street parking on the west side. The western intersection, Broadway at Everett Avenue/Cross Street, is under a stop control on Everett

CTPS

FIGURE 1
Broadway at Congress Avenue/Third Street and at Everett Avenue/Cross Street, Chelsea

Safety and Operations Improvements at Selected Intersections

Avenue. Everett Avenue and Cross Street operate one-way southbound only, with on-street parking on both sides of Everett Avenue and on the east side of Cross Street.

Although there are no lane division markings on any of the streets at the two intersections, traffic generally progresses in two lanes (especially during peak periods). Traffic at the eastern intersection is controlled by two stop signs, one on each side of the Congress Avenue approach. Traffic at the western intersection is controlled by flashing beacons that indicate red to the Everett Street approach and yellow to the Broadway approach.

Crosswalks exist across all approaches at both intersections. Sidewalks exist on both sides of all the streets of the two intersections. There are no pedestrian crossing signals at the two intersections.

The intersection vicinity is thickly developed, with multi-family apartments and commercial developments. Pedestrian activity is heavy at the two intersections. Based on recent pedestrian counts, in June, each intersection carries about 200 to 250 in the AM peak traffic hour and over 400 pedestrians, in the PM peak traffic hour.. There are also bike activities in the area. Bicyclists from the North Shore area use Broadway to commute to Boston and its vicinity, and some local youths use bikes to get around the area in the afternoon hours. Recent counts indicate that each intersection carries about 5 bikes in the AM peak traffic hour and 15 bikes in the PM peak traffic hour.

The area has several Massachusetts Bay Transportation Authority (MBTA) bus routes in service, including Routes 111, 111C, 112, 114, 116, and 117. There are two bus stops, one on Broadway (with a shaded waiting area) and another on Everett Avenue, near the intersection of Broadway at Everett Avenue/Cross Street. Both locations appear to be appropriately located, at the near side of the intersection with on-street parking being prohibited.

ISSUES AND CONCERNS

A review of the recent crash data from 2006 to 2008 indicates that that the two intersections have a high number of crashes and a crash rate much higher than other unsignalized intersections in the area. Alarmingly, they both have a high pedestrian/bicyclist crash rate (see the next section for further analysis).

During peak periods, traffic is heavy on all approaches of the two intersections. Traffic is busy but not extremely congested on Broadway. Traffic on Broadway is free of controls but has to stop from time to time to yield to pedestrians. Traffic on Congress Avenue is heavy and congested due to the stop control. Congress Street is not only a major collector in the city but also a major access route to Route 1 (via the Tobin Bridge) to Boston. It becomes Third Street and merges into Everett Avenue just two blocks north of this intersection, where an entrance ramp to Route 1 Southbound is located.

Everett Avenue is a principal urban arterial in the city running from the Chelsea/Everett border to the intersection at Broadway. During peak hours, traffic on Everett Avenue is heavy. It is congested, and motorists sometimes experience extensive delay due to the stop control at the intersection.

As mentioned, the two intersections carry not only busy traffic but also heavy pedestrian movements, some bike traffic, and several MBTA bus routes. It is usually difficult to handle various transportation modes at a busy intersection, as their travel speed and behavior characteristics are quite different. These difficult situations may well be some of the causes of the high pedestrian and bike crash rates at the two intersections.

The issues and concerns for these two intersections can be summarized as:

- High number of crashes involving pedestrians or bicyclists
- High number of crashes and high crash rate of motor vehicles
- Traffic congestion during peak hours, with extensive delays for motorists on the Congress Avenue and Everett Avenue approaches

CRASH DATA ANALYSIS

Based on the 2006–2008 Massachusetts Department of Transportation (MassDOT) Registry of Motor Vehicles Division crash data, Table 1 shows that on average of about 20 crashes occurred annually at the intersection of Broadway at Congress Avenue/Third Street. About 35% of the crashes resulted in personal injuries. The crash types consist of about 60% angle collisions and 40% other collisions. The relatively high proportion of angle-type collisions is common for locations with two-way stop control. There were three head-on collisions in the 3-year period, which is unusual for one-way street operations.[1] During the 3-year period, one crash involved a pedestrian and three involved bicyclists.

The crash rate[2] is another effective tool for examining the relative safety of a particular location. Based on the crash data and the available recent traffic counts, the crash rate for this intersection is calculated as 3.88 (see Appendix A for the calculation). The rate is much higher than the average rate for the unsignalized locations in MassDOT Highway District 4, which is estimated as 0.59.[3]

Table 2 shows that an average of six crashes occurred at the intersection of Broadway at Everett Avenue/Cross Street each year. About 35% of the crashes resulted in personal injuries. The crash types consist of about 40% angle collisions, about 30% single-vehicle collisions, and about 30% other collisions. About half of the crashes occurred during weekday peak periods. This rate is

[1] The crashes might have been caused by insufficient signage in the area of the two intersections. Currently a "No Right Turn" plaque is mounted under the stop sign on the Congress Street approach. However, there is not any indication of "No Left Turn" on the Everett Avenue approach at its intersection with Broadway. Motorists could mistakenly turn left at the intersection and collide with others going in the proper direction on Broadway. The crash could happen near the upstream intersection at Congress Avenue, as there is no way to turn around in that section of Broadway.

[2] Crash rates are estimated based on crash frequency (crashes per year) and vehicle exposure (traffic volume or miles traveled). Crash rates are expressed as "crashes per million entering vehicles" for intersection locations and as "crashes per million miles traveled" for roadway segments.

[3] The average crash rates estimated by the MassDOT Highway Division are based on a database that contains intersection crash rates submitted to the Highway Division as part of the review process for an environmental impact report or functional design report. The most recent average crash rates, which are updated on a nearly yearly basis, are based on all entries in the database, not just those entries made within the past year.

TABLE 1
Summary of Crash Data (2006–2008)
Broadway at Congress Avenue/Third Street, Chelsea

Statistics Period		2006	2007	2008	3-Year	Average
Total number of crashes		28	17	12	57	19
Severity	Property damage only	11	10	7	28	9
	Personal injury	12	6	3	21	7
	Fatality	0	0	0	0	0
	Not reported	5	1	2	8	3
Collision Type	Angle	17	12	5	34	11
	Rear-end	4	2	0	6	2
	Sideswipe	2	0	5	7	2
	Head-on	2	1	0	3	1
	Single vehicle	2	2	2	6	2
	Not reported	1	0	0	1	0
Crashes involved pedestrian(s)		0	0	1	1	0
Crashes involved bicyclist(s)		2	1	0	3	1
Occurred during weekday peak periods*		3	1	1	5	2
Wet or icy pavement conditions		10	4	2	16	5
Dark/lighted conditions		7	9	3	19	6

* Peak periods are defined as 7:00–10:00 AM and 3:30–6:30 PM.

TABLE 2
Summary of Crash Data (2006–2008)
Broadway at Everett Avenue/Cross Street, Chelsea

Statistics Period		2006	2007	2008	3-Year	Average
Total number of crashes		7	5	5	17	6
Severity	Property damage only	5	1	4	10	3
	Personal injury	2	3	1	6	2
	Fatality	0	0	0	0	0
	Not reported	0	1	0	1	0
Collision Type	Angle	4	1	2	7	2
	Rear-end	0	1	0	1	0
	Sideswipe	0	1	1	2	1
	Head-on	0	0	0	0	0
	Single vehicle	3	2	0	5	2
	Not reported	0	0	2	2	1
Crashes involved pedestrian(s)		2	2	1	5	2
Crashes involved bicyclist(s)		1	0	0	1	0
Occurred during weekday peak periods*		3	3	3	9	3
Wet or icy pavement conditions		2	0	0	2	1
Dark/lighted conditions		1	0	1	2	1

* Peak periods are defined as 7:00–10:00 AM and 3:30–6:30 PM.

considered relatively high,[4] and it is an indication of congested conditions during peak periods. Most alarmingly, there were five crashes that involved pedestrians and one that involved a bicyclist during the 3-year period.

The crash rate for this intersection is calculated as 1.27 (see the Appendix A for the calculation). The rate is lower than the average rate for the unsignalized locations in MassDOT Highway District 4, which is estimated as 0.59.

The above analyses show that the two intersections have a high number of crashes and a crash rate much higher than other unsignalized intersections in the area. More alarmingly, they both have a high pedestrian/bicyclist crash rate.

INTERSECTION CAPACITY ANALYSIS

Staff collected turning movement counts at the two intersections on June 4, 2009. The data were recorded in 15-minute intervals for peak traffic periods in the morning, from 7:00 to 9:00, and in the evening, from 4:00 to 6:00. Meanwhile, 24-hour automatic traffic counts for 3 midweek days were collected by the MassDOT Highway Division in the week beginning May 11, 2009. Based on the 24-hour traffic counts, the turning movement counts at the two intersections were adjusted and balanced.

Table 3 shows that the intersection of Broadway at Congress Avenue/Third Street carried about 1,100 vehicles in the morning peak hour, from 7:30 to 8:30, and about 1,200 vehicles in the evening peak hour, from 4:00 to 5:00. About 250 and 450 pedestrians crossed the intersection during the AM and PM peak hour, respectively. About 5 cyclists in the AM peak hour (mainly traveling on Broadway and appearing to be commuters) and 15 cyclists in the PM peak hour (including commuters and some young residents using bikes recreationally) crossed the intersection (not shown in the table).

TABLE 3
AM and PM Peak-Hour Traffic Volumes and Pedestrian Crossings
Broadway at Congress Avenue/Third Street, Chelsea

Street name		**Broadway**						**Congress Ave.**			**Third St.**			**Total**
Direction		**Eastbound**			**Westbound**			**Northbound**			**Southbound**			
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM peak hour	Turning volume	NA			NA	474	139	87	402	NA	NA			1102
	Approach volume	0			613			489			0			
	Ped. crossings	50			50			70			75			245
PM peak hour	Turning volume	NA			NA	352	132	148	574	NA	NA			1204
	Approach volume	0			482			722			0			
	Ped. crossings	60			75			120			190			445

[4] We used one-third of total crashes as the threshold for the peak period crashes.

Table 4 shows that the intersection of Broadway at Everett Avenue/Third Street carried about 1,000 vehicles in the morning peak hour, from 7:30 to 8:30, and about 1,100 vehicles in the evening peak hour, from 4:00 to 5:00. About 200 and 460 pedestrians crossed the intersection during the AM and PM peak hour, respectively. About 5 and 15 cyclists crossed the intersection during the AM and PM peak hour, respectively (not shown in the table).

TABLE 4
AM and PM Peak Hour Traffic Volumes and Pedestrian Crossings
Broadway at Everett Avenue/Cross Street, Chelsea

Street name		**Broadway**						**Cross St.**			**Everett Ave.**			**Total**
Direction		**Eastbound**			**Westbound**			**Northbound**			**Southbound**			
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM peak hour	Turning volume	NA			296	257	NA	NA			NA	361	70	984
	Approach volume	0			553			0			431			
	Ped. crossings	60			45			20			70			195
PM peak hour	Turning volume	NA			235	266	NA	NA			NA	475	121	1097
	Approach volume	0			501			0			596			
	Ped. crossings	145			80			75			175			465

Based on the adjusted turning movement counts, staff performed capacity analyses for the two intersections using the computer program Synchro.[5] The analyses were performed according to the unsignalized intersection capacity analysis method of the Highway Capacity Manual.[6]

The analysis of the intersection of Broadway at Congress Avenue/Third Street indicates that traffic on the stop-control approach (Congress Avenue) operates at level of service (LOS) F and endures extensive delays in the PM peak hour (see Table 5). Details of the analysis for both the AM and PM peak hours are included in Appendix B.

The analysis of Broadway at Everett Avenue/Cross Street indicates that traffic on the stop-control approach (Everett Avenue) operates at LOS F and endures extensive delays in both the AM and PM peak hours (see Table 6). Details of the analysis for both the AM and PM peak hours are included in Appendix C.

It should be noted that delays on Broadway at the two intersections could actually be higher than the estimations shown in the tables. Due to heavy pedestrian crossings in the peak hours, vehicles on Broadway from time to time have to yield to crossing pedestrians.

[5] Synchro is intersection capacity analysis and traffic signal coordination software developed and distributed by Trafficware Ltd. It can be combined with SimTraffic to perform traffic simulation for an individual intersection or a series of intersections.

[6] Transportation Research Board, *Highway Capacity Manual 2000*, National Research Council, Washington D.C., 2000.

TABLE 5
Existing Intersection Capacity Analysis
Broadway at Congress Avenue/Third Street, Chelsea

Street name		**Broadway**						**Congress Ave.**			**Third St.**		
Direction		**Eastbound**			**Westbound**			**Northbound**			**Southbound**		
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
AM peak hour	LOS	NA			**A**			**F**			NA		
	Delay (sec/veh)	NA			0			79			NA		
PM peak hour	LOS	NA			**A**			**F**			NA		
	Delay (sec/veh)	NA			0			> 180			NA		

TABLE 6
Existing Intersection Capacity Analysis
Broadway at Everett Avenue/Cross Street, Chelsea

Street name		**Broadway**						**Cross St.**			**Everett Ave.**		
Direction		**Eastbound**			**Westbound**			**Northbound**			**Southbound**		
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
AM peak hour	LOS	NA			**A**			NA			**F**		
	Delay (sec/veh)	NA			5			NA			> 180		
PM peak hour	LOS	NA			**A**			NA			**F**		
	Delay (sec/veh)	NA			4			NA			> 180		

PRELIMINARY TRAFFIC SIGNAL WARRANTS ANALYSIS

One of the potential improvements for these intersections is to introduce traffic signal control. According to the Manual for Uniform Traffic Control Devices (MUTCD),[7] an engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location must be performed to determine whether installation of a traffic signal is justified at a particular location. The investigation must include criteria related to the following traffic signal warrants and other factors related to existing operations and safety at the study location:

1. Eight-Hour Vehicular Volume Warrant
2. Four-Hour Vehicular Volume Warrant
3. Peak-Hour Warrant
4. Pedestrian Volume Warrant
5. School Crossing Warrant
6. Coordinated Signal System Warrant
7. Crash Experience Warrant
8. Roadway Network Warrant
9. Intersection Near a Grade Crossing

[7] Federal Highway Administration, U.S. Department of Transportation, *Chapter 4C. Traffic Control Signal Needs*, 2009 Edition, December 2009.

A traffic control signal should not be installed unless two or more of the factors contained in these warrants are met. Moreover, the satisfaction of a warrant or warrants in itself does not justify the installation of a signal unless an engineering study indicates that the installation will improve the overall safety and/or operation of the intersection.

In this study, we performed a preliminary analysis of the applicable traffic signal warrants based on the hourly volumes averaged from the available 24-hour traffic counts. The applicable factors are contained in Warrants 1, 2, 4, and 7, assuming that each of the two intersections operates as an isolated location. Warrant 3 is intended for unusual cases, such as office complexes or manufacturing plants that attract or discharge large numbers of vehicles over a short time, the intersection is not close to any schools. Because of the lack of such buildings, factors related to Warrants 3, 5, 8, and 9 were not considered.

The examination of Warrants 1, 2, and 7 was based on hourly traffic volumes of an average day, which were derived from three mid-week days' traffic counts collected by the MassDOT Highway Division in the week of May 11, 2009. The counts were considered seasonal or slightly higher than the average (see Appendix D for the detailed summary of hourly volumes for all of the approaches at the intersection). Analyses of the traffic counts indicate that the intersection of Broadway at Congress Avenue/Third Street meets the traffic conditions required by Warrant 1, 2, and 7. The intersection of Broadway at Everett Avenue/Cross Street meets only the traffic conditions required by Warrant 2 (Four-Hour Vehicular Volume Warrant).

Warrant 4, the pedestrian volume warrant, is intended for application where traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street. The examination, based on the hourly traffic volumes from the MassDOT counts and the pedestrian volumes from the staff's turning movement counts, indicates that neither of the intersections meets the required intensive traffic conditions (using both the four-hour and the one-hour criteria), even though the pedestrian volumes are high at the two intersections.

The analysis finds that the two intersections meet at least one or more signal warrants under separate examinations. Detailed analysis of the hourly traffic volumes and pedestrian volumes for Warrants 1, 2, 4, and 7 are summarized in Appendix E for both intersections.

ANALYSIS OF IMPROVEMENT ALTERNATIVES

The above analyses show that the stop controls at the two intersections are insufficient to handle the existing traffic conditions. Common improvement alternatives to stop controls include modern roundabouts and traffic signals. Modern roundabouts were not considered in this study, as they are difficult to fit into the intersections' tight space and are not compatible with the existing street system.

Analysis of traffic signal warrants indicates that both of the two intersections justify the installation of a traffic signal. The traffic signal would interrupt traffic on Broadway to permit traffic from Congress Avenue (and from Everett Avenue) to proceed and reduce the its congested conditions of the minor streets. Properly designed, it would be expected to reduce the frequency and severity of certain types of crashes, especially right-angle collisions.

More significantly, it would potentially reduce conflicts between pedestrians or bicycles and vehicles. Currently the two intersections are somewhat chaotic during peak hours, when both the vehicular and pedestrian traffic are heavy and frequently crossing each other. Properly designed and combined with pedestrian signals, the signal system can provide exclusive or concurrent pedestrian phases for pedestrians to cross the intersections more comfortably and safely.

On the other hand, the traffic signal would potentially increase delays for motorists traveling on parts of Broadway that currently are free of signal controls. As they are located in close proximity along a principal arterial, the traffic signals at the two intersections should be coordinated. The signal coordination would potentially expedite traffic flow and reduce delays for motorists on Broadway.

To evaluate the improvement alternatives, staff used Synchro to perform a two-stage traffic signal optimization analysis. In the first stage, the two intersections were analyzed and optimized separately as individual locations. Once the most suitable operation was identified for each of the two intersections, staff conducted the second-stage analysis, in which the two intersections were coordinated and analyzed as one network system.

An essential factor in timing the signals for the two intersections is the time required for pedestrians to safely cross each of them. We examined the crossing distances of all the approaches at the two intersections and found that a 24-second pedestrian signal phase should be sufficient for pedestrians to cross either of them safely without any unexpected conditions. The estimation applied a 3-foot-per-second pedestrian walking speed in considering the elderly and children living in the area (see Appendix F for detailed estimations at all the approaches).

In the first stage, two alternatives were examined for the two intersections under the existing layouts: (1) a simple two-phase traffic signal operation allowing concurrent pedestrian crossings, and (2) a two-phase traffic operation combined with an on-call exclusive pedestrian signal phase for all pedestrian crossings. Synchro tests show that traffic at both intersections would operate at desirable level of service (LOS) B in the first alternative and would operate at desirable LOS C or acceptable LOS D in the second alternative. However, the second alternative is considered safer for pedestrians than the first alternative, as in the current operation pedestrians still encounter potential conflicts with turning vehicles.[8] We therefore selected the second alternative (signal operations with exclusive pedestrian phases) at this stage. Detailed Synchro analyses and results for both intersections are included in Appendices G and H, respectively.

In the second stage, we tested different combinations of network cycle lengths and offsets for the two intersections through applications of the Synchro network optimization functions. The tests show that the coordinated signals would operate at a better level of service than the uncoordinated signals for almost all the approaches. Although the optimized coordination would increase the average signal cycle length by about a quarter minute, both signals would still operate in a relatively short cycle of under 90 seconds (including the exclusive pedestrian phases). In the PM peak hour, the pedestrian phase would occur in almost every cycle. The signal at Congress Avenue is selected as the master intersection as it has a higher traffic volume

[8] The conflicts can be reduced by providing an exclusive signal phase and travel lane for turning vehicles so that only through traffic would be concurrent with pedestrians on the same street. However, expansion of either of the intersections does not appear feasible, as the area is fully developed, with limited space available.

than the other signal. Detailed Synchro analyses and results for both intersections are included in Appendices I and J, respectively.

Tables 7 and 8 summarize the capacity analyses and approach delays at the two stages for the two intersections. Under the coordinated signal system, the intersection of Broadway at Congress Avenue/Third Street would operate at desirable LOS C in the AM peak hour and at acceptable LOS D in the PM peak hour in the coordinated scenario (see Table 7); the intersection of Broadway at Everett Avenue/Cross Street would operate at desirable LOS B and LOS C in the AM and PM peak hours, respectively, with minimal delays (see Table 8). Synchro traffic simulations show that traffic on Broadway flows smoothly with the coordinated signal system, with minimal delays in the peak hours at the Everett Avenue/Cross Street intersection.

TABLE 7
Intersection Capacity Analysis of Selected Alternatives
Broadway at Congress Avenue/Third Street, Chelsea

Street Name		**Broadway**	**Congress Avenue**	**Overall**
Approach		**Westbound**	**Northbound**	
AM peak hour	**Existing**	A/0	F/79	NA
	Stage 1	C/34	D/39	D/37
	Stage 2	C/27	D/42	C/33
PM peak hour	**Existing**	A/0	F/>180	NA
	Stage 1	E/56	D/42	D/48
	Stage 2	C/33	D/39	D/37

Note: Performance Measures: Level of Service (A to F)/Average Delay (seconds per vehicle)
Selected alternative in Stage 1: Uncoordinated Two-Phase (NB/WB) Traffic Signal with Exclusive Pedestrian Phase under the Existing Intersection Layout
Selected alternative in Stage 2: Coordinated Two-Phase (NB/WB) Traffic Signal with Exclusive Pedestrian Phase under the Existing Intersection Layout

TABLE 8
Intersection Capacity Analysis of Selected Alternatives
Broadway at Everett Avenue/Cross Street, Chelsea

Street Name		**Broadway**	**Everett Avenue**	**Overall**
Approach		**Westbound**	**Southbound**	
AM peak hour	**Existing**	A/5	F/>180	NA
	Stage 1	C/32	C/32	C/32
	Stage 2	A/4	D/38	B/19
PM peak hour	**Existing**	A/4	F/>180	NA
	Stage 1	D/49	D/37	D/42
	Stage 2	A/9	D/37	C/24

Note: Performance Measures: Level of Service (A to F)/Average Delay (seconds per vehicle)
Selected alternative in Stage 1: Uncoordinated Two-Phase (NB/WB) Traffic Signal with Exclusive Pedestrian Phase under the Existing Intersection Layout
Selected alternative in Stage 2: Coordinated Two-Phase (NB/WB) Traffic Signal with Exclusive Pedestrian Phase under the Existing Intersection Layout

In addition, a future-year scenario of 10% growth over a 20-year planning horizon was tested for the coordinated signal system.[9] Synchro tests show that the intersection of Broadway at Congress Avenue/Third Street would operate at acceptable LOS D in both the AM and PM peak hours; the intersection of Broadway at Everett Avenue/Cross Street would still operate at desirable LOS B and LOS C in the AM and PM peak hours.

IMPROVEMENT RECOMMENDATIONS AND DISCUSSION

The two intersections have a high number of crashes and a crash rate much higher than other unsignalized intersections in the area. More alarmingly, they both have a high pedestrian/bicyclist crash rate. To improve the existing conditions, we conducted a series of safety and operations analyses for the two intersections.

The crash data analysis indicates that traffic congestion during peak periods, a high number of pedestrian crossings, and conflicts between motorists and non-motorists might have been some of the causes of crashes at the two intersections. The capacity analysis ascertains that traffic on Congress Avenue and Everett Avenue endures extensive delays during peak hours. The preliminary signal warrant analysis finds that the two intersections both warrant the installation of traffic signals.

To evaluate potential long-term improvement alternatives, we used Synchro to perform a two-stage traffic signal optimization analysis. In the first stage, the two intersections were analyzed and optimized individually. In the second stage, the two intersections were coordinated and analyzed as one network system. The analysis finds that a coordinated traffic signal system with exclusive pedestrian signal phases would be most beneficial for the two intersections. The coordinated signal system would potentially expedite traffic flow on Broadway. Meanwhile, by including actuated exclusive pedestrian signal phases, the system would improve pedestrian safety at the two intersections.

We therefore recommend that in the long term the two intersections be signalized and coordinated. The two intersections carry heavy pedestrian volumes. The proposed traffic signals are essential more for the pedestrians than for the vehicular traffic, especially at the Everett Avenue/Cross Street intersection.[10] The signals would provide exclusive phases to stop all the traffic for pedestrians to cross the intersections safely and comfortably.

The signal system for the two intersections should include the following features:

- Install a fully actuated and coordinated traffic signal system with pedestrian signals.
- Install pedestrian signal heads with push buttons and accessible (audible) signals at all corners of the intersections.
- Include on-call exclusive pedestrian phases in the signal cycles.
- Install overhead signal indications supported by mast arms, which can be clearly viewed from all approaches.

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[9] The growth assumption is based on a quick review of the traffic projections in the area from the recent Boston Region MPO transportation-planning model.

[10] The proposed Congress Avenue/Third Street intersection signal alone would create traffic gaps for users of this intersection. However, without the proposed traffic signal to stop traffic at intervals, pedestrians at the Everett Avenue/Cross Street intersection would still encounter delays and conflicts with vehicular traffic.

In addition, the following geometric elements should be considered in the functional design stage of the signalization:

- Maintain the existing crosswalks and sidewalks.
- Consider installing pedestrian bulb-outs at the corners of the two intersections where there is on-street parking.

The bulb-out has several advantages: (a) it shortens the distances for pedestrians to cross Broadway and Everett Avenue/Congress Avenue, (b) it narrows the width of Broadway and Everett Avenue/Congress Avenue and slows down the traffic, and (c) it allows pedestrians to have a better view of the street conditions. At this preliminary planning stage, we identified the northeastern corner at the intersection of Broadway at Everett Avenue/Cross Street as an appropriate location to install the bulb-out. At the functional design stage, other potential locations should be further examined.

As the future traffic signals can operate under the existing intersection layouts, the main cost for this recommended improvement would be the new traffic/pedestrian signal system and the installation of any proposed bulb-outs. The total cost of the traffic and pedestrian signals and the coordination system is roughly estimated as $500,000 to $750,000. Each pedestrian bulb-out would cost about $25,000 to $50,000, depending on its size and materials. More precise costs can be estimated at the functional design stage. Currently all the streets and the two intersections are under the jurisdiction of the City of Chelsea. The implementation would require the City to work closely with MassDOT through the project implantation process (see Appendix K).

In the short term, we propose the following improvements for the two intersections:

Broadway at Congress Avenue/Third Street

- Regularly maintain pavement markings to make them prominent to motorists.[11]
- Install a series (at least three) of “SLOW” pavement markings on the WB Broadway approach.
- Install the “Share the Road with Bicyclists” assembly (W11-1/W16-1 in the Manual on Uniform Traffic Control Devices) at appropriate locations along Broadway in the area.
- Install “sharrow” (see Figure 2) pavement makings on Broadway to provide an additional reminder that bicycles use this roadway.

Broadway at Everett Avenue/Cross Street

- Regularly maintain pavement markings to make them prominent to motorists.
- Add a stop sign on each side of the Everett Avenue approach to supplement the flashing beacons.
- Install “No left Turn” regulatory signs on both sides of Everett Avenue ahead of the intersection or mount a “No Left Turn” plaque below the future stop sign on the east side of Everett Avenue.

[11] If necessary, the crosswalks can be painted with a red or green background with white striped lines to provide a contrast and prominent appearance. The color of maroon seems to match the surrounding brick buildings.

- Remove the first parking space on the east side of Everett Avenue.[12]
- Extend the sidewalk on the northeast corner as a pedestrian bulb-out.[13]

Figure 2

Example of "Sharrow" Pavement Marking

The Everett Avenue/Cross Street intersection had five crashes involving pedestrians from 2006 to 2008. Although these short-term improvements would not be as effective as the proposed traffic/pedestrian signal system, they would potentially improve the safety of the two intersections by reducing the conflicts between motorists and non-motorists. Not including the proposed pedestrian bulb-out, they should cost about several thousand dollars and could be implemented in a relatively short time. They are also compatible with the future signal system.

[12] Because the parking space is very close to the intersection, a parked car there usually blocks the view between the motorists on Everett Avenue and on Broadway.

[13] The bulb-out can take the place of a parking space on Everett Avenue that could be removed, and could extend to the existing bus bay on Broadway.

Appendix A

Intersection Crash Rate Calculation
Broadway at Congress Avenue/Third Street, Chelsea
Broadway at Everett Avenue/Cross Street, Chelsea

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Chelsea COUNT DATE : 6/4/09

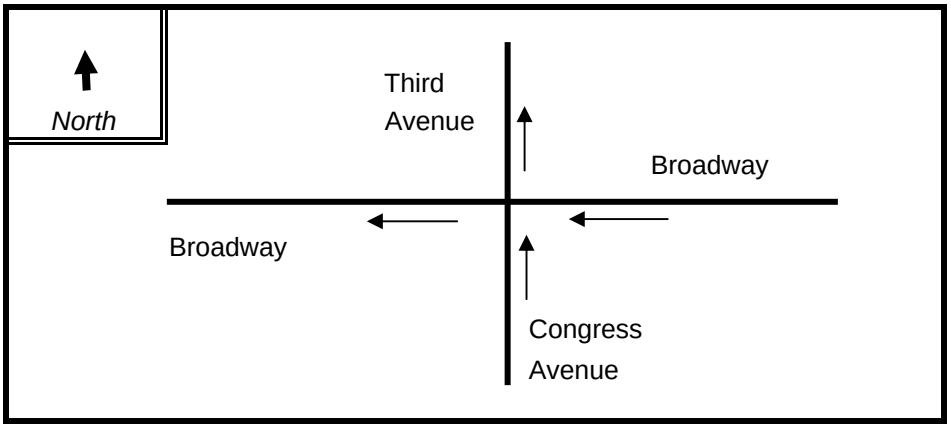
DISTRICT : 4 UNSIGNALIZED : X SIGNALIZED :

~ INTERSECTION DATA ~

MAJOR STREET : Broadway

MINOR STREET(S) : Congress Avenue/Third Avenue

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	WB	NB				
PEAK HOURLY VOLUMES (AM/PM) :	484	722				**1,206**

" K " FACTOR : **0.090** INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **13,400**

TOTAL # OF CRASHES : 57 # OF YEARS : 3 AVERAGE # OF CRASHES PER YEAR (**A**) : **19.00**

CRASH RATE CALCULATION : **3.88** RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : MassDOT District 4 Average Rate = 0.59

Project Title & Date: Safety and Operations Analyses at Selceted Intersections

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Chelsea COUNT DATE : 6/4/09

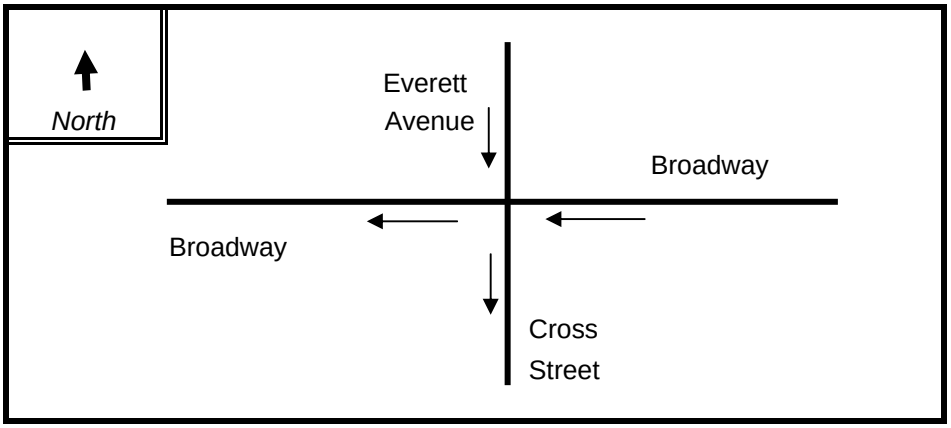
DISTRICT : 4 UNSIGNALIZED : X SIGNALIZED :

~ INTERSECTION DATA ~

MAJOR STREET : Broadway

MINOR STREET(S) : Everett Avenue/Cross Street

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	WB	SB				
PEAK HOURLY VOLUMES (AM/PM) :	501	596				**1,097**

" K " FACTOR : **0.090** INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **12,189**

TOTAL # OF CRASHES : 17 # OF YEARS : 3 AVERAGE # OF CRASHES PER YEAR (**A**) : **5.67**

CRASH RATE CALCULATION : **1.27** RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : MassDOT District 4 Average Rate = 0.59

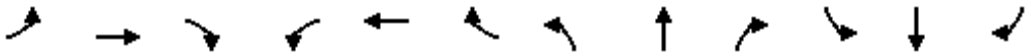
Project Title & Date: Safety and Operations Analyses at Selceted Intersections

Appendix B

AM/PM Peak Hour Intersection Capacity Analysis
Existing Traffic Conditions
Broadway at Congress Avenue/Third Street, Chelsea

HCM Unsignalized Intersection Capacity Analysis
Broadway @ Congress Ave, Chelsea

7/22/2010



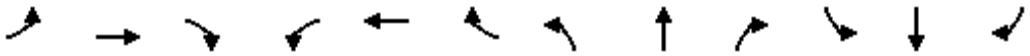
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	0	0	0	474	139	87	402	0	0	0	0
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Hourly flow rate (vph)	0	0	0	0	533	156	98	452	0	0	0	0
Pedestrians		50			50			70			75	
Lane Width (ft)		0.0			11.0			10.0			0.0	
Walking Speed (ft/s)		3.0			3.0			3.0			3.0	
Percent Blockage		0			5			6			0	
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	764			70			386	834	120	962	756	469
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	764			70			386	834	120	962	756	469
tC, single (s)	4.1			4.1			7.5	6.5	6.9	7.5	6.5	6.9
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	100			100			80	0	100	0	100	100
cM capacity (veh/h)	858			1443			486	283	812	0	318	546

Direction, Lane #	WB 1	WB 2	NB 1	NB 2
Volume Total	355	334	248	301
Volume Left	0	0	98	0
Volume Right	0	156	0	0
cSH	1700	1700	339	283
Volume to Capacity	0.21	0.20	0.73	1.06
Queue Length 95th (ft)	0	0	138	296
Control Delay (s)	0.0	0.0	39.9	111.5
Lane LOS			E	F
Approach Delay (s)	0.0		79.2	
Approach LOS			F	

Intersection Summary			
Average Delay	35.1		
Intersection Capacity Utilization	45.8%	ICU Level of Service	A
Analysis Period (min)	15		

HCM Unsignalized Intersection Capacity Analysis
Broadway @ Congress Ave, Chelsea

7/22/2010



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	0	0	0	352	132	148	574	0	0	0	0
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Hourly flow rate (vph)	0	0	0	0	371	139	156	604	0	0	0	0
Pedestrians		60			75			120			190	
Lane Width (ft)		0.0			11.0			10.0			0.0	
Walking Speed (ft/s)		3.0			3.0			3.0			3.0	
Percent Blockage		0			8			11			0	
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	699			120			365	819	195	1007	750	505
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	699			120			365	819	195	1007	750	505
tC, single (s)	4.1			4.1			7.5	6.5	6.9	7.5	6.5	6.9
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	100			100			66	0	100	0	100	100
cM capacity (veh/h)	907			1316			462	276	673	0	304	518

Direction, Lane #	WB 1	WB 2	NB 1	NB 2
Volume Total	247	262	357	403
Volume Left	0	0	156	0
Volume Right	0	139	0	0
cSH	1700	1700	335	276
Volume to Capacity	0.15	0.15	1.07	1.46
Queue Length 95th (ft)	0	0	327	564
Control Delay (s)	0.0	0.0	104.3	260.5
Lane LOS			F	F
Approach Delay (s)	0.0		187.1	
Approach LOS			F	

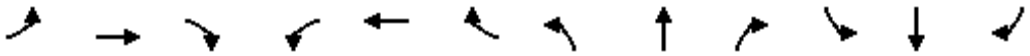
Intersection Summary				
Average Delay	112.0			
Intersection Capacity Utilization	50.0%	ICU Level of Service	A	
Analysis Period (min)	15			

Appendix C

AM/PM Peak Hour Intersection Capacity Analysis
Existing Traffic Conditions
Broadway at Everett Avenue/Cross Street, Chelsea

HCM Unsignalized Intersection Capacity Analysis
Broadway @ Everett Ave, Chelsea

7/22/2010



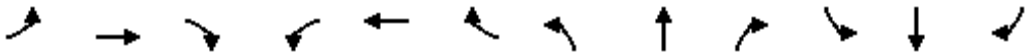
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	0	0	296	257	0	0	0	0	0	361	70
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Hourly flow rate (vph)	0	0	0	333	289	0	0	0	0	0	406	79
Pedestrians		60			45			70			70	
Lane Width (ft)		0.0			11.0			0.0			10.0	
Walking Speed (ft/s)		3.0			3.0			3.0			3.0	
Percent Blockage		0			5			0			6	
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	359			70			1221	1094	115	1069	1094	274
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	359			70			1221	1094	115	1069	1094	274
tC, single (s)	4.1			4.3			7.5	6.5	6.9	7.5	6.6	7.0
tC, 2 stage (s)												
tF (s)	2.2			2.3			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	100			78			0	100	100	100	0	88
cM capacity (veh/h)	1133			1479			0	156	880	125	152	673

Direction, Lane #	WB 1	WB 2	SB 1	SB 2
Volume Total	429	193	270	214
Volume Left	333	0	0	0
Volume Right	0	0	0	79
cSH	1479	1700	152	212
Volume to Capacity	0.22	0.11	1.78	1.01
Queue Length 95th (ft)	22	0	498	226
Control Delay (s)	6.7	0.0	427.6	111.2
Lane LOS	A		F	F
Approach Delay (s)	4.7		287.9	
Approach LOS			F	

Intersection Summary				
Average Delay	128.7			
Intersection Capacity Utilization	43.0%	ICU Level of Service	A	
Analysis Period (min)	15			

HCM Unsignalized Intersection Capacity Analysis
Broadway @ Everett Ave, Chelsea

7/22/2010



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	0	0	235	266	0	0	0	0	0	475	121
Sign Control		Free			Free			Stop			Stop	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Hourly flow rate (vph)	0	0	0	247	280	0	0	0	0	0	500	127
Pedestrians		145			80			75			175	
Lane Width (ft)		0.0			11.0			0.0			10.0	
Walking Speed (ft/s)		3.0			3.0			3.0			3.0	
Percent Blockage		0			8			0			16	
Right turn flare (veh)												
Median type		None			None							
Median storage veh)												
Upstream signal (ft)												
pX, platoon unblocked												
vC, conflicting volume	455			75			1232	1025	155	1030	1025	460
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	455			75			1232	1025	155	1030	1025	460
tC, single (s)	4.1			4.2			7.5	6.5	6.9	7.5	6.5	6.9
tC, 2 stage (s)												
tF (s)	2.2			2.2			3.5	4.0	3.3	3.5	4.0	3.3
p0 queue free %	100			84			0	100	100	100	0	72
cM capacity (veh/h)	935			1515			0	166	799	111	164	459

Direction, Lane #	WB 1	WB 2	SB 1	SB 2
Volume Total	341	187	333	294
Volume Left	247	0	0	0
Volume Right	0	0	0	127
cSH	1515	1700	164	227
Volume to Capacity	0.16	0.11	2.03	1.29
Queue Length 95th (ft)	15	0	650	387
Control Delay (s)	6.1	0.0	532.3	203.8
Lane LOS	A		F	F
Approach Delay (s)	3.9		378.3	
Approach LOS			F	

Intersection Summary				
Average Delay	207.3			
Intersection Capacity Utilization	44.8%	ICU Level of Service	A	
Analysis Period (min)	15			

Appendix D

Summary of hourly traffic volumes
May/June, 2009
Broadway at Congress Avenue/Third Street, Chelsea
Broadway at Everett Avenue/Cross Street, Chelsea

Mass Highway Department
WEEKLY SUMMARY FOR LANE 1
Starting: 5/11/2009

STA. 1 WB
1-WAY

Site Reference: 000000000526
Site ID: 090150000104
Location: BROADWAY, EAST OF CONGRESS AVE/3RD ST.
Direction: WEST

File: 104.prn
City: CHELSEA
County: VOL ONE-WAY

TIME	MON 11	TUE 12	WED 13	THU 14	FRI	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00		99	140	106		115			115	345
02:00		62	91	77		76			76	230
03:00		55	55	76		62			62	186
04:00		54	65	97		72			72	216
05:00		93	113	124		110			110	330
06:00		270	292	303		288			288	865
07:00		485	483	512		493			493	1480
08:00		535	562	570		555			555	1667
09:00		623	686	685		664			664	1994
10:00		624	593	612		609			609	1829
11:00		585	635			610			610	1220
12:00		681	682			681			681	1363
13:00		594	672			633			633	1266
14:00		662	630			646			646	1292
15:00		654	601			627			627	1255
16:00	694	778	595			689			689	2067
17:00	669	685	658			670			670	2012
18:00	669	603	626			632			632	1898
19:00	559	580	565			568			568	1704
20:00	503	523	521			515			515	1547
21:00	426	439	483			449			449	1348
22:00	347	354	385			362			362	1086
23:00	252	260	256			256			256	768
24:00	156	166	173			165			165	495
TOTALS	4275	10464	10562	3162	0	10547	0	0	10547	28463
AVG WKDY	40.5	99.2	100.1	29.9						
AVG WEEK	40.5	99.2	100.1	29.9						
AM Times		12:00	09:00	09:00		12:00			12:00	
AM Peaks		681	686	685		681			681	
PM Times	16:00	16:00	13:00			16:00			16:00	
PM Peaks	694	778	672			689			689	

43

AWD 10547
FAC .90 (.96)
ADT 9,100

Mass Highway Department
WEEKLY SUMMARY FOR LANE 1 Page: 1
Starting: 5/11/2009

STA. 2 NB
1-WAY

Site Reference: 000000000885
Site ID: 090150000201
Location: CONGRESS AVE., SOUTH OF BROADWAY
Direction: NORTH

File: 201.prn
City: CHELSEA
County: VOL ONE-WAY

TIME	MON 11	TUE 12	WED 13	THU 14	FRI	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00		87	118	103		102			102	308
02:00		71	100	89		86			86	260
03:00		84	61	83		76			76	228
04:00		67	67	64		66			66	198
05:00		108	132	133		124			124	373
06:00		275	316	340		310			310	931
07:00		508	457	485		483			483	1450
08:00		529	538	548		538			538	1615
09:00		507	535	504		515			515	1546
10:00		480	534	500		504			504	1514
11:00		426	449			437			437	875
12:00		507	545			526			526	1052
13:00		559	610			584			584	1169
14:00		611	585			598			598	1196
15:00		651	656			653			653	1307
16:00	764	702	641			702			702	2107
17:00	651	655	626			644			644	1932
18:00	630	648	586			621			621	1864
19:00	530	578	551			553			553	1659
20:00	466	417	462			448			448	1345
21:00	417	378	398			397			397	1193
22:00	284	324	351			319			319	959
23:00	216	230	211			219			219	657
24:00	142	170	178			163			163	490
TOTALS	4100	9572	9707	2849	0	9668	0	0	9668	26228
AVG WKDY	42.4	99	100.4	29.4						
AVG WEEK	42.4	99	100.4	29.4						
AM Times		08:00	12:00	08:00		08:00			08:00	
AM Peaks		529	545	548		538			538	
PM Times	16:00	16:00	15:00			16:00			16:00	
PM Peaks	764	702	656			702			702	

u6

AWD 9668
FAC .90 (.98)
ADT 8,500

Broadway @ Everett Ave.

Mass Highway Department
WEEKLY SUMMARY FOR LANE
Starting: 6/16/2009

STA. 1

Site Reference: 000000000714
Site ID: 090200000104
Location: BROADWAY WB, BTWN EVERETT AVE & 3rd ST.
Direction: ROAD TOTAL

1 - WAY

File: 104-R.prn
City: CHELSEA
County: VOL

TIME	MON 22	TUE 16	WED 17	THU 18	FRI 19	WKDAY AVG	SAT 20	SUN 21	WEEK AVG	TOTAL
01:00	117		71	78	78	86	178	176	116	698
02:00	92		45	51	64	63	146	190	98	588
03:00	76		54	50	62	60	123	130	82	495
04:00	81		50	49	65	61	95	102	73	442
05:00	120		74	81	86	90	66	65	82	492
06:00	234		183	162	152	182	108	56	149	895
07:00	237		260	267	272	259	168	91	215	1295
08:00	343		288	384	383	349	200	136	289	1734
09:00	419		296	463	446	406	252	173	341	2049
10:00	395		291	413	374	368	345	241	343	2059
11:00	417		318	353	400	372	463	304	375	2255
12:00	493		328	403	432	414	475	372	417	2503
13:00	468		414	443	492	454	541	393	458	2751
14:00	457	466	415	424	508	454	478	479	461	3227
15:00	511	465	365	477	541	471	439	408	458	3206
16:00	457	486	457	488	497	477	478	403	466	3266
17:00	472	515	483	516	534	504	517	347	483	3384
18:00	472	506	466	468	507	483	465	371	465	3255
19:00	356	391	450	459	456	422	517	345	424	2974
20:00	334	459	402	391	463	409	507	345	414	2901
21:00	272	368	315	296	394	329	434	350	347	2429
22:00	282	314	298	271	404	313	395	334	328	2298
23:00	187	217	183	194	318	219	385	268	250	1752
24:00	158	140	149	132	246	165	248	195	181	1268
TOTALS	7450	4327	6655	7313	8174	7410	8023	6274	7315	48216
% AVG WKDY	100.5	58.3	89.8	98.6	110.3		108.2	84.6		
% AVG WEEK	101.8	59.1	90.9	99.9	111.7		109.6	85.7		
AM Times	12:00		12:00	09:00	09:00	12:00	12:00	12:00	12:00	
AM Peaks	493		328	463	446	414	475	372	417	
PM Times	15:00	17:00	17:00	17:00	15:00	17:00	13:00	14:00	17:00	
PM Peaks	511	515	483	516	541	504	541	479	483	

U3

AWD 7410

FAC .90 (.96)

ADT 6,400

Mass Highway Department
WEEKLY SUMMARY FOR LANE
Starting: 6/1/2009

STA. 2

Site Reference: 000000000684
Site ID: 090200000201
Location: EVERETT AVE NB, BTWN CHERRY ST & BROADWY
Direction: ROAD TOTAL SB

File: 201.prn
City: CHELSEA
County: VOL

1-WAY

TIME	MON 1	TUE 2	WED 3	THU 4	FRI 5	WKDAY AVG	SAT	SUN	WEEK AVG	TOTAL
01:00		112	109	122	147	122			122	490
02:00		75	82	98	112	91			91	367
03:00		68	69	79	97	78			78	313
04:00		86	113	80	91	92			92	370
05:00		98	93	78	91	90			90	360
06:00		142	152	146	147	146			146	587
07:00		246	231	218	248	235			235	943
08:00		383	357	382	330	363			363	1452
09:00		437	417	425	430	427			427	1709
10:00		448	396	421	411	419			419	1676
11:00		472	434	438		448			448	1344
12:00		430	458	482		456			456	1370
13:00		511	495	525		510			510	1531
14:00	525	520	516	481		510			510	2042
15:00	525	500	525	547		524			524	2097
16:00	571	565	580	575		572			572	2291
17:00	609	545	561	601		579			579	2316
18:00	529	588	504	542		540			540	2163
19:00	542	483	533	535		523			523	2093
20:00	433	454	453	471		452			452	1811
21:00	434	438	392	422		421			421	1686
22:00	373	361	361	401		374			374	1496
23:00	256	245	238	289		257			257	1028
24:00	165	184	177	202		182			182	728
TOTALS	4962	8391	8246	8560	2104	8411	0	0	8411	32263
% AVG WKDY	58.9	99.7	98	101.7	25					
% AVG WEEK	58.9	99.7	98	101.7	25					
AM Times		11:00	12:00	12:00	09:00	12:00			12:00	
AM Peaks		472	458	482	430	456			456	
PM Times	17:00	18:00	16:00	17:00		17:00			17:00	
PM Peaks	609	588	580	601		579			579	

43

AWD 8411
FAC .90 (.96)
ADT 7,300

Appendix E

Analysis of Traffic Signal Warrants 1, 2, 4, and 7
Based on 2009 Traffic Counts
Broadway at Congress Avenue/Third Street, Chelsea
Broadway at Everett Avenue/Cross Street, Chelsea

Traffic Signal Warrents Analysis:
Broadway @ Congress/Third Ave, Chelsea

Court	Hourly Traffic Vol.		Intersection Ped. Vol.		Examination of Signal Warrants:			
Period	Main St.	Minor St.	Total	50%	**Warrant 1**	**Warrant 2**	**Warrant 4**	**Warrant 7**
7:00	493	483	184	92				X
8:00	555	538	264	132		X		X
9:00	664	515			X	X		X
10:00	609	504			X	X		X
11:00	610	437			X	X		X
12:00	681	526			X	X		X
13:00	633	584			X	X		X
14:00	646	598			X	X		X
15:00	627	653			X	X		X
16:00	689	702	445	223	X	X	X	X
17:00	670	644	470	235	X	X	X	X
18:00	632	621			X	X		X
19:00	568	553				X		X
20:00	515	448						X
Criteria:								
Warrant 1	> 600	> 200						
Warrant 2	Figure 4C-1							
Warrant 7	> 480	> 160						
Warrant 4	Figures 4C-5 and 4C-7							
Results:					**Satisfied**	**Satisfied**	**No**	**Satisfied**

Note: For Warrant 4, the main street (Broadway) traffic volumes and 50% pedestrian crossings were used.
The check marks in the warrant examination are for the 4-hour criterion.
As shown, only two hours in the afternoon meet the criterion.

Traffic Signal Warrents Analysis:
Broadway @ Everett Ave, Chelsea

Court	Hourly Traffic Vol.		Intersection Ped. Vol.			Examination of Signal Warrants:			
Period	Main St.	Minor St.	Total	50%		**Warrant 1**	**Warrant 2**	**Warrant 4**	**Warrant 7**
7:00	259	235	123	62					
8:00	370	363	170	85					
9:00	443	427							
10:00	394	419							
11:00	390	448							
12:00	443	456							
13:00	468	510					X		
14:00	463	510					X		
15:00	510	524					X		X
16:00	481	572	472	236			X		X
17:00	507	579	470	235			X		X
18:00	482	540					X		X
19:00	424	523							
20:00	376	452							
Criteria:									
Warrant 1	> 600	> 200							
Warrant 2	Figure 4C-1								
Warrant 7	> 480	> 160							
Warrant 4	Figures 4C-5 and 4C-7								
Results:						**No**	**Satisfied**	**No**	**No**

Note: For Warrant 4, the main street (Broadway) traffic volumes and 50% pedestrian crossings were used.

Appendix F

Pedestrian Signal Time Estimations
Broadway at Congress Avenue/Third Street, Chelsea
Broadway at Everett Avenue/Cross Street, Chelsea

Broadway @ Congress Avenue/Third Street, Chelsea

Crossing location	Broadway WB	Broadway EB	Congress Ave.	Third St.
Crossing distance (feet)	45	45	30	30
Walk indication interval	7.0	7.0	7.0	7.0
Pedestrian clearance time (ped. walk speed = 3.5 ft/sec.)	12.9	12.9	8.6	8.6
Pedestrian clearance time (ped. walk speed = 3 ft/sec.)	15.0	15.0	10.0	10.0
Total pedestrain phase time (ped. walk speed = 3.5 ft/sec.)	19.9	19.9	15.6	15.6
Total pedestrain phase time (ped. walk speed = 3 ft/sec.)	22.0	22.0	17.0	17.0

Broadway @ Everett Avenue/Cross Street, Chelsea

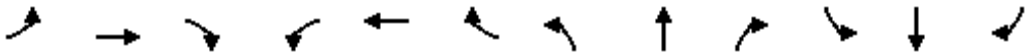
Crossing location	Broadway WB	Broadway EB	Everett Ave.	Cross St.
Crossing distance (feet)	50	40	45	30
Walk indication interval	7.0	7.0	7.0	7.0
Pedestrian clearance time (ped. walk speed = 3.5 ft/sec.)	14.3	11.4	12.9	8.6
Pedestrian clearance time (ped. walk speed = 3 ft/sec.)	16.7	13.3	15.0	10.0
Total pedestrain phase time (ped. walk speed = 3.5 ft/sec.)	21.3	18.4	19.9	15.6
Total pedestrain phase time (ped. walk speed = 3 ft/sec.)	23.7	20.3	22.0	17.0

Note:

1. Crossing Distnaces were estimated from aerial photography in the vicinity.
2. Pedestrian walk speed 3 ft/sec. is used for this study, while estimations of MUTCD's satndard speed (3.5 ft/sec.) also are listed for reference.

Appendix G

AM/PM Peak Hour Intersection Capacity Analysis
Stage 1: Uncoordinated Traffic Signal Alternative
Broadway at Congress Avenue/Third Street, Chelsea



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	0	0	0	474	139	87	402	0	0	0	0
Confl. Peds. (#/hr)	75		70	70		75	50		50	50		50
Confl. Bikes (#/hr)						1			3			
Peak Hour Factor	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	0%	8%	20%	2%	2%	0%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	10	0	0	0	0	0	0
Parking (#/hr)	0	0	0	0	0	10	5	0	0	0	0	0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type							Perm					
Protected Phases					8			2				
Permitted Phases							2					
Detector Phase					8		2	2				
Switch Phase												
Minimum Initial (s)					4.0		4.0	4.0				
Minimum Split (s)					11.0		11.0	11.0				
Total Split (s)	0.0	0.0	0.0	0.0	25.0	0.0	21.0	21.0	0.0	0.0	0.0	0.0
Total Split (%)	0.0%	0.0%	0.0%	0.0%	35.7%	0.0%	30.0%	30.0%	0.0%	0.0%	0.0%	0.0%
Yellow Time (s)					3.5		3.5	3.5				
All-Red Time (s)					1.5		1.5	1.5				
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0	4.0	5.0	4.0	5.0	5.0	4.0	4.0	4.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode					Max		None	None				
Act Effct Green (s)					20.9			15.3				
Actuated g/C Ratio					0.33			0.24				
v/c Ratio					0.83			0.84				
Control Delay					34.6			38.7				
Queue Delay					0.0			0.0				
Total Delay					34.6			38.7				
LOS					C			D				
Approach Delay					34.6			38.7				
Approach LOS					C			D				

Intersection Summary	
Cycle Length: 70	
Actuated Cycle Length: 64.3	
Natural Cycle: 70	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.84	
Intersection Signal Delay: 36.5	Intersection LOS: D
Intersection Capacity Utilization 47.4%	ICU Level of Service A
Analysis Period (min) 15	

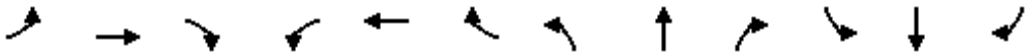
Splits and Phases: 1: Int

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	34%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

Intersection Summary

Intersection Capacity Analysis
Broadway @ Congress Ave, Chelsea

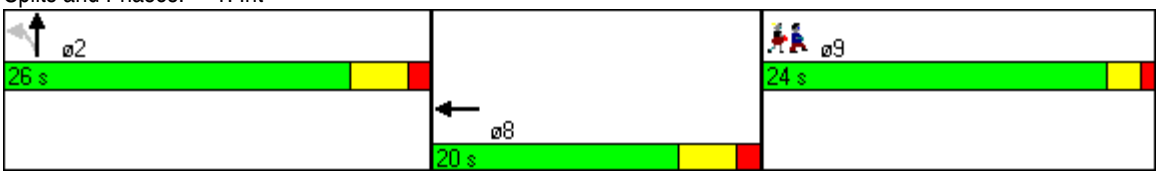
10/28/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	0	0	0	352	132	148	574	0	0	0	0
Confl. Peds. (#/hr)	190		120	120		190	60		75	75		60
Confl. Bikes (#/hr)						1			3			
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	0%	3%	11%	1%	1%	0%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	10	0	0	0	0	0	0
Parking (#/hr)	0	0	0	0	0	20	0	0	10	0	0	0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type							Perm					
Protected Phases					8			2				
Permitted Phases							2					
Detector Phase					8		2	2				
Switch Phase												
Minimum Initial (s)					4.0		4.0	4.0				
Minimum Split (s)					11.0		11.0	11.0				
Total Split (s)	0.0	0.0	0.0	0.0	20.0	0.0	26.0	26.0	0.0	0.0	0.0	0.0
Total Split (%)	0.0%	0.0%	0.0%	0.0%	28.6%	0.0%	37.1%	37.1%	0.0%	0.0%	0.0%	0.0%
Yellow Time (s)					3.5		3.5	3.5				
All-Red Time (s)					1.5		1.5	1.5				
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0	4.0	5.0	4.0	5.0	5.0	4.0	4.0	4.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode					Max		None	None				
Act Effct Green (s)					15.0			20.8				
Actuated g/C Ratio					0.21			0.30				
v/c Ratio					0.94			0.91				
Control Delay					56.4			41.7				
Queue Delay					0.0			0.0				
Total Delay					56.4			41.7				
LOS					E			D				
Approach Delay					56.4			41.7				
Approach LOS					E			D				

Intersection Summary	
Cycle Length: 70	
Actuated Cycle Length: 69.8	
Natural Cycle: 70	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.94	
Intersection Signal Delay: 47.6	Intersection LOS: D
Intersection Capacity Utilization 51.6%	ICU Level of Service A
Analysis Period (min) 15	

Splits and Phases: 1: Int



Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	34%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

Intersection Summary

Appendix H

AM/PM Peak Hour Intersection Capacity Analysis
Stage 1: Uncoordinated Traffic Signal Alternative
Broadway at Everett Avenue/Cross Street, Chelsea

Intersection Capacity Analysis
Broadway @ Everett Ave, Chelsea

10/28/2010

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	0	0	296	257	0	0	0	0	0	361	70
Confl. Peds. (#/hr)	70		20	20		70	60		45	45		60
Confl. Bikes (#/hr)						3						
Peak Hour Factor	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	9%	5%	0%	0%	0%	0%	0%	4%	3%
Bus Blockages (#/hr)	0	0	0	0	0	10	0	0	0	0	0	5
Parking (#/hr)				0	0	0				0	0	0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type				Perm								
Protected Phases					8							
Permitted Phases				8							6	
Detector Phase				8	8						6	
Switch Phase												
Minimum Initial (s)				4.0	4.0						4.0	
Minimum Split (s)				11.0	11.0						11.0	
Total Split (s)	0.0	0.0	0.0	19.0	19.0	0.0	0.0	0.0	0.0	0.0	17.0	0.0
Total Split (%)	0.0%	0.0%	0.0%	31.7%	31.7%	0.0%	0.0%	0.0%	0.0%	0.0%	28.3%	0.0%
Yellow Time (s)				3.5	3.5						3.5	
All-Red Time (s)				1.5	1.5						1.5	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode				Max	Max						None	
Act Effct Green (s)					14.9						11.7	
Actuated g/C Ratio					0.27						0.21	
v/c Ratio					0.86dl						0.77	
Control Delay					30.3						32.4	
Queue Delay					1.6						0.0	
Total Delay					31.8						32.4	
LOS					C						C	
Approach Delay					31.8						32.4	
Approach LOS					C						C	

Intersection Summary	
Cycle Length: 60	
Actuated Cycle Length: 54.6	
Natural Cycle: 60	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.77	
Intersection Signal Delay: 32.1	Intersection LOS: C
Intersection Capacity Utilization 44.7%	ICU Level of Service A
Analysis Period (min) 15	

dl Defacto Left Lane. Recode with 1 though lane as a left lane.

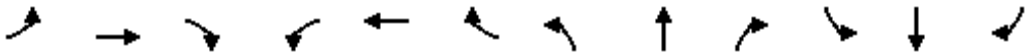
Splits and Phases: 3: Int

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	40%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

Intersection Summary

Intersection Capacity Analysis
Broadway @ Everett Ave, Chelsea

10/28/2010

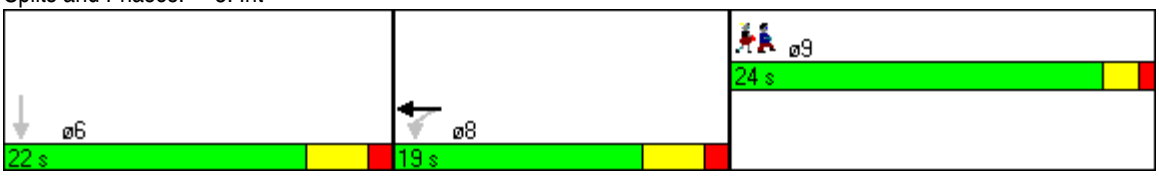


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	0	0	235	266	0	0	0	0	0	475	121
Confl. Peds. (#/hr)	175		75	75		175	145		80	80		145
Confl. Bikes (#/hr)						3						
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	3%	3%	3%	0%	0%	0%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	20	0	0	0	0	0	0	10
Parking (#/hr)				0	20	0				0	10	10
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type				Perm								
Protected Phases					8							
Permitted Phases				8							6	
Detector Phase				8	8						6	
Switch Phase												
Minimum Initial (s)				4.0	4.0						4.0	
Minimum Split (s)				11.0	11.0						11.0	
Total Split (s)	0.0	0.0	0.0	19.0	19.0	0.0	0.0	0.0	0.0	0.0	22.0	0.0
Total Split (%)	0.0%	0.0%	0.0%	29.2%	29.2%	0.0%	0.0%	0.0%	0.0%	0.0%	33.8%	0.0%
Yellow Time (s)				3.5	3.5						3.5	
All-Red Time (s)				1.5	1.5						1.5	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode				Max	Max						None	
Act Effct Green (s)					14.0						16.4	
Actuated g/C Ratio					0.22						0.25	
v/c Ratio					0.96dl						0.86	
Control Delay					45.3						37.0	
Queue Delay					3.3						0.0	
Total Delay					48.6						37.0	
LOS					D						D	
Approach Delay					48.6						37.0	
Approach LOS					D						D	

Intersection Summary	
Cycle Length: 65	
Actuated Cycle Length: 64.4	
Natural Cycle: 65	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.89	
Intersection Signal Delay: 42.3	Intersection LOS: D
Intersection Capacity Utilization 46.4%	ICU Level of Service A
Analysis Period (min) 15	

dl Defacto Left Lane. Recode with 1 though lane as a left lane.

Splits and Phases: 3: Int



Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	37%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

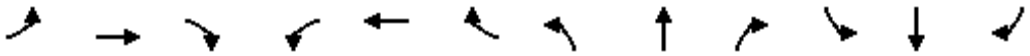
Intersection Summary

Appendix I

AM/PM Peak Hour Intersection Capacity Analysis
Stage 2: Coordinated Traffic Signal Alternative
Broadway at Congress Avenue/Third Street, Chelsea

Intersection Capacity Analysis
Broadway @ Everett Ave, Chelsea

10/25/2010



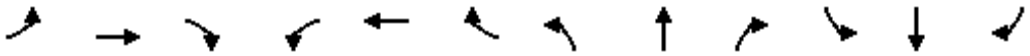
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	0	0	296	257	0	0	0	0	0	361	70
Confl. Peds. (#/hr)	70		20	20		70	60		45	45		60
Confl. Bikes (#/hr)						3						
Peak Hour Factor	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	9%	5%	0%	0%	0%	0%	0%	4%	3%
Bus Blockages (#/hr)	0	0	0	0	0	10	0	0	0	0	0	5
Parking (#/hr)				0	0	0				0	0	0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type				Perm								
Protected Phases					8							
Permitted Phases				8							6	
Detector Phase				8	8						6	
Switch Phase												
Minimum Initial (s)				4.0	4.0						4.0	
Minimum Split (s)				11.0	11.0						11.0	
Total Split (s)	0.0	0.0	0.0	33.0	33.0	0.0	0.0	0.0	0.0	0.0	26.0	0.0
Total Split (%)	0.0%	0.0%	0.0%	39.8%	39.8%	0.0%	0.0%	0.0%	0.0%	0.0%	31.3%	0.0%
Yellow Time (s)				3.5	3.5						3.5	
All-Red Time (s)				1.5	1.5						1.5	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode				C-Max	C-Max						None	
Act Effct Green (s)					35.7						18.1	
Actuated g/C Ratio					0.43						0.22	
v/c Ratio					0.48						0.75	
Control Delay					3.8						37.9	
Queue Delay					0.3						0.0	
Total Delay					4.1						37.9	
LOS					A						D	
Approach Delay					4.1						37.9	
Approach LOS					A						D	

Intersection Summary	
Cycle Length: 83	
Actuated Cycle Length: 83	
Offset: 5 (6%), Referenced to phase 8:WBTL, Start of Green	
Natural Cycle: 60	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.75	
Intersection Signal Delay: 18.9	Intersection LOS: B
Intersection Capacity Utilization 44.7%	ICU Level of Service A
Analysis Period (min) 15	

Splits and Phases: 3: Int

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	29%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

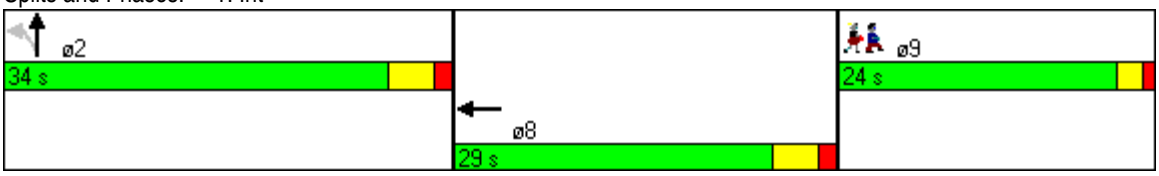
Intersection Summary



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	0	0	0	352	132	148	574	0	0	0	0
Confl. Peds. (#/hr)	190		120	120		190	60		75	75		60
Confl. Bikes (#/hr)						1			3			
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	0%	3%	11%	1%	1%	0%	0%	0%	0%
Bus Blockages (#/hr)	0	0	0	0	0	10	0	0	0	0	0	0
Parking (#/hr)	0	0	0	0	0	20	0	0	10	0	0	0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type							Perm					
Protected Phases					8			2				
Permitted Phases							2					
Detector Phase					8		2	2				
Switch Phase												
Minimum Initial (s)					4.0		4.0	4.0				
Minimum Split (s)					11.0		11.0	11.0				
Total Split (s)	0.0	0.0	0.0	0.0	29.0	0.0	34.0	34.0	0.0	0.0	0.0	0.0
Total Split (%)	0.0%	0.0%	0.0%	0.0%	33.3%	0.0%	39.1%	39.1%	0.0%	0.0%	0.0%	0.0%
Yellow Time (s)					3.5		3.5	3.5				
All-Red Time (s)					1.5		1.5	1.5				
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0	4.0	5.0	4.0	5.0	5.0	4.0	4.0	4.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode					C-Max		None	None				
Act Effct Green (s)					25.5			27.5				
Actuated g/C Ratio					0.29			0.32				
v/c Ratio					0.68			0.86				
Control Delay					33.2			39.0				
Queue Delay					0.1			0.0				
Total Delay					33.3			39.0				
LOS					C			D				
Approach Delay					33.3			39.0				
Approach LOS					C			D				

Intersection Summary	
Cycle Length: 87	
Actuated Cycle Length: 87	
Offset: 0 (0%), Referenced to phase 8:WBT, Start of Green, Master Intersection	
Natural Cycle: 70	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.86	
Intersection Signal Delay: 36.7	Intersection LOS: D
Intersection Capacity Utilization 51.6%	ICU Level of Service A
Analysis Period (min) 15	

Splits and Phases: 1: Int



Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	28%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

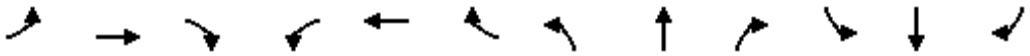
Intersection Summary

Appendix J

AM/PM Peak Hour Intersection Capacity Analysis
Stage 2: Coordinated Traffic Signal Alternative
Broadway at Everett Avenue/Cross Street, Chelsea

Intersection Capacity Analysis
Broadway @ Everett Ave, Chelsea

10/25/2010



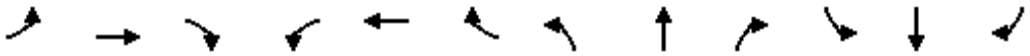
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	0	0	296	257	0	0	0	0	0	361	70
Confl. Peds. (#/hr)	70		20	20		70	60		45	45		60
Confl. Bikes (#/hr)						3						
Peak Hour Factor	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	9%	5%	0%	0%	0%	0%	0%	4%	3%
Bus Blockages (#/hr)	0	0	0	0	0	10	0	0	0	0	0	5
Parking (#/hr)				0	0	0				0	0	0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type				Perm								
Protected Phases					8							
Permitted Phases				8							6	
Detector Phase				8	8						6	
Switch Phase												
Minimum Initial (s)				4.0	4.0						4.0	
Minimum Split (s)				11.0	11.0						11.0	
Total Split (s)	0.0	0.0	0.0	33.0	33.0	0.0	0.0	0.0	0.0	0.0	26.0	0.0
Total Split (%)	0.0%	0.0%	0.0%	39.8%	39.8%	0.0%	0.0%	0.0%	0.0%	0.0%	31.3%	0.0%
Yellow Time (s)				3.5	3.5						3.5	
All-Red Time (s)				1.5	1.5						1.5	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode				C-Max	C-Max						None	
Act Effct Green (s)					35.7						18.1	
Actuated g/C Ratio					0.43						0.22	
v/c Ratio					0.48						0.75	
Control Delay					3.8						37.9	
Queue Delay					0.3						0.0	
Total Delay					4.1						37.9	
LOS					A						D	
Approach Delay					4.1						37.9	
Approach LOS					A						D	

Intersection Summary	
Cycle Length: 83	
Actuated Cycle Length: 83	
Offset: 5 (6%), Referenced to phase 8:WBTL, Start of Green	
Natural Cycle: 60	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.75	
Intersection Signal Delay: 18.9	Intersection LOS: B
Intersection Capacity Utilization 44.7%	ICU Level of Service A
Analysis Period (min) 15	

Splits and Phases: 3: Int

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	29%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

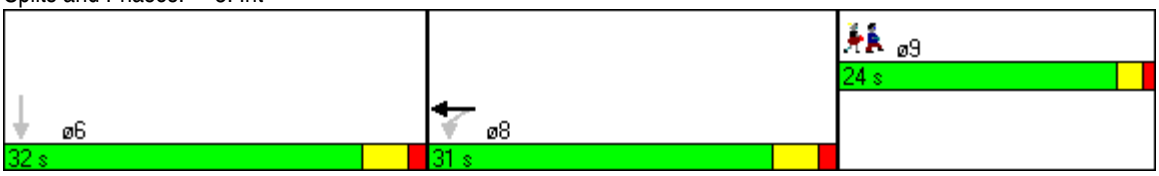
Intersection Summary



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	0	0	235	266	0	0	0	0	0	475	121
Confl. Peds. (#/hr)	175		75	75		175	145		80	80		145
Confl. Bikes (#/hr)						3						
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	3%	3%	3%	0%	0%	0%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	20	0	0	0	0	0	0	10
Parking (#/hr)				0	20	0				0	10	10
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type				Perm								
Protected Phases					8							
Permitted Phases				8							6	
Detector Phase				8	8						6	
Switch Phase												
Minimum Initial (s)				4.0	4.0						4.0	
Minimum Split (s)				11.0	11.0						11.0	
Total Split (s)	0.0	0.0	0.0	31.0	31.0	0.0	0.0	0.0	0.0	0.0	32.0	0.0
Total Split (%)	0.0%	0.0%	0.0%	35.6%	35.6%	0.0%	0.0%	0.0%	0.0%	0.0%	36.8%	0.0%
Yellow Time (s)				3.5	3.5						3.5	
All-Red Time (s)				1.5	1.5						1.5	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	4.0	4.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode				C-Max	C-Max						None	
Act Effct Green (s)					29.3						23.7	
Actuated g/C Ratio					0.34						0.27	
v/c Ratio					0.57						0.80	
Control Delay					8.0						37.7	
Queue Delay					0.7						0.0	
Total Delay					8.6						37.7	
LOS					A						D	
Approach Delay					8.6						37.7	
Approach LOS					A						D	

Intersection Summary	
Cycle Length: 87	
Actuated Cycle Length: 87	
Offset: 3 (3%), Referenced to phase 8:WBTL, Start of Green	
Natural Cycle: 60	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.80	
Intersection Signal Delay: 24.4	Intersection LOS: C
Intersection Capacity Utilization 46.4%	ICU Level of Service A
Analysis Period (min) 15	

Splits and Phases: 3: Int



Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	28%
Yellow Time (s)	2.0
All-Red Time (s)	1.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

Intersection Summary

Appendix K

MassDOT Project Implementation Process

The following description of the implementation process is based on Chapter 2 of the *MassDOT Highway Division's Project Development and Design Guide (2005).* The text below borrows heavily from that document.

1 NEEDS IDENTIFICATION

For each of the locations at which an improvement is to be implemented, MassDOT Highway Division leads an effort to define the problem, establishes project goals and objectives, and defines the scope of the planning needed for implementation. To that end, it has to complete a Project Need Form (PNF), which states in general terms the deficiencies or needs related to the transportation facility or location. The PNF documents the problems and explains why corrective action is needed. For this study, the information defining the need for the project will be drawn primarily, perhaps exclusively, from the present report. Also, at this point in the process, MassDOT Highway Division meets with potential participants, such as the Boston Region Metropolitan Planning Organization (MPO) and community members, to allow for an informal review of the project.

The PNF is reviewed by the MassDOT Highway Division district office whose jurisdiction includes the location of the proposed project. MassDOT Highway Division also sends the PNF to the MPO, for informational purposes. The outcome of this step determines whether the project requires further planning, whether it is already well supported by prior planning studies, and, therefore, whether it is ready to move forward into the design phase, or whether it should be dismissed from further consideration.

2 PLANNING

This phase will likely not be required for the implementation of the improvements proposed in this planning study, as this planning report should constitute the outcome of this step. However, in general, the purpose of this implementation step is for the project proponent to identify issues, impacts, and approvals that may need to be obtained, so that the subsequent design and permitting processes are understood.

The level of planning needed will vary widely, based on the complexity of the project. Typical tasks include: define the existing context, confirm project need, establish goals and objectives, initiate public outreach, define the project, collect data, develop and analyze alternatives, make recommendations, and provide documentation. Likely outcomes include consensus on the project definition to enable it to move forward into environmental documentation (if needed) and design, or a recommendation to delay the project or dismiss it from further consideration.

3 PROJECT INITIATION

At this point in the process, the proponent, MassDOT Highway Division, fills out, for each improvement, a Project Initiation Form (PIF), which is reviewed by its Project Review Committee (PRC) and the MPO. The PRC is composed of the Chief

Engineer, each District Highway Director, and representatives of the Project Management, Environmental, Planning, Right-of-Way, Traffic, and Bridge departments, and the Capital Expenditure Program Office (CEPO). The PIF documents the project type and description, summarizes the project planning process, identifies likely funding and project management responsibility, and defines a plan for interagency and public participation. First the PRC reviews and evaluates the proposed project based on the Executive Office of Transportation and Public Works's statewide priorities and criteria. If the result is positive, MassDOT Highway Division moves the project forward to the design phase, and to programming review by the MPO. The PRC may provide a Project Management Plan to define roles and responsibilities for subsequent steps. The MPO review includes project evaluation based on the MPO's regional priorities and criteria. The MPO may assign project evaluation criteria score, a Transportation Improvement Program (TIP) year, a tentative project category, and a tentative funding category.

4 ENVIRONMENTAL, DESIGN, AND RIGHT-OF-WAY PROCESS

This step has four distinct but closely integrated elements: public outreach, environmental documentation and permitting (if required), design, and right-of-way acquisition (if required). The outcome of this step is a fully designed and permitted project ready for construction. However, a project does not have to be fully designed in order for the MPO to program it in the TIP.

5 PROGRAMMING

Programming, which typically begins during the design phase, can actually occur at any time during the process, from planning to design. In this step, which is distinct from project initiation, where the MPO receives preliminary information on the proposed project, the proponent requests that the MPO place the project in the region's TIP. The MPO considers the project in terms of regional needs, evaluation criteria, and compliance with the regional Transportation Plan and decides whether to place it in the draft TIP for public review and then in the final TIP.

6 PROCUREMENT

Following project design and programming, MassDOT Highway Division publishes a request for proposals. It then reviews the bids and awards the contract to the qualified bidder with the lowest bid.

7 CONSTRUCTION

After a construction contract is awarded, MassDOT Highway Division and the contractor develop a public participation plan and a management plan for the construction process.

8 PROJECT ASSESSMENT

The purpose of this step is to receive constituents' comments on the project development process and the project's design elements. MassDOT Highway Division can apply what is learned in this process to future projects.