BOSTON REGION METROPOLITAN PLANNING ORGANIZATION

State Transportation Building
Ten Park Plaza, Suite 2150
Boston, MA 02116-3968
Tel. (617) 973-7100
Fax (617) 973-8855
TTY (617) 973-7089
www.bostonmpo.org

DRAFT MEMORANDUM

DATE **February 22, 2012**

TO **City of Malden**

FROM **Steven P. Andrews and Chen-Yuan Wang, MPO Staff**

RE **FFY 2011 Safety and Operations Analyses at Selected Boston Region MPO Intersections: Main Street at Mountain Avenue**

INTRODUCTION

This memorandum summarizes safety and operations analyses and proposes improvement strategies for the intersection of Main Street at Mountain Avenue in Malden. It contains the following sections:

- Intersection Layout and Traffic Control
- Issues and Concerns
- Crash Data Analysis
- Intersection Capacity Analysis
- Analysis 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 analyses.

INTERSECTION LAYOUT AND TRAFFIC CONTROL

This signalized intersection is located less than half a mile northeast of downtown Malden. Main Street is a two-lane arterial that connects Route 16 in Everett to Route 128 in Wakefield. Mountain Avenue is a two-lane collector connecting Summer Street to the west to Mount Vernon Street to the east. Main Street is approximately 40 feet wide, and Mountain Avenue is approximately 30 feet wide. All the streets at the intersection are under the Town's jurisdiction.

Figure 1 shows the intersection layout and the area nearby. The intersection has a normal layout. Approaching the intersection, the Main Street northbound approach is one lane, which is shared by all movements. At the intersection, an MBTA bus stop abuts the northbound approach. When no bus is present, which is most of the time, vehicles use the bus stop to make right turns. Similarly, the Main Street southbound approach is one lane wide flanked by parking until just before the intersection, where an MBTA bus stop is often used as a right-turn lane. When vehicles on Main Street make left turns, through and right-turning vehicles swerve into the bus lane to bypass the turning vehicle. The Mountain Avenue eastbound approach is one lane wide until the intersection. One-hour parking is permitted along the south side of Mountain Avenue; however,

beginning approximately 150 feet to the west of the intersection, parking is not permitted. Some vehicles use this space to make right turns and bypass vehicles turning left. All of the vehicles traveling westbound on Mountain Avenue use a single lane to make all movements.

Crosswalks are installed across all of the approaches. The crosswalks are very worn out. This, coupled with a lack of standard pedestrian signals, makes the intersection not very pedestrian-friendly. Curb cuts are present at all approaches. The curb cuts do not have tactile strips. Each curb cut serves two crosswalks. Sidewalks are present and in good condition.

The two MBTA bus stops serve Routes 131, 136, and 137. Headways between buses are fairly long: five or fewer buses stop at each stop during the peak hours. Both bus stops are located on the near sides of the intersection. When buses are not present, vehicles use the bus stops as short right-turn lanes.

The traffic signal is pre-timed and operates in three traffic phases: northbound/southbound (NB/SB) all movements (left turns permitted), eastbound/westbound (EB/WB) all movements (left turns permitted), and an exclusive pedestrian phase, when traffic is stopped at all four approaches. Field measurements by a stopwatch indicated that each traffic signal cycle lasts 50 seconds (27 seconds for the NB/SB phases and 23 seconds for the EB/WB phase, including a 5-second clearance time for each phase), with a 13-second actuated pedestrian phase. A cycle with a pedestrian phase is 63 seconds long. Right-turns on red are allowed on all approaches.

Staff visited the intersection several times. During a visit in August 2010, the pedestrian push-button signal activated an on-call exclusive pedestrian phase. In subsequent visits in May and August 2011, using the pedestrian push buttons did not activate the phase. In August 2010, when the pedestrian buttons called for an exclusive phase, all of the traffic signals showed a flashing red and yellow light for 13 seconds. This type of indication can be confusing to the pedestrians and drivers who are not familiar with it. Pedestrian push buttons are attached to traffic signal posts at each of the corners of the intersection.

All of the signal heads are post-mounted and positioned about eight to nine feet high. They are located on the four corners of the intersection. Each approach receives two signal indications, but because the signal heads are low, they can be difficult to see from far away.

Although the land use in the vicinity of the intersection is mainly residential, there are a few businesses and other institutions in the area. At the northeast corner is a two-story apartment complex. West of the intersection are a community pool, a post office, and a YMCA building. The Malden Early Learning Center is about a quarter mile east of the intersection. To the south, Main Street passes through downtown Malden to Route 16 in Everett. To the north, Main Street is mostly flanked by residential areas and occasional businesses until it reaches Route 128 in Wakefield.

ISSUES AND CONCERNS

The intersection is congested during peak periods on Main Street. During the morning peak hour, westbound Mountain Avenue is fairly congested. Main Street is one of the main north-south arterials in the area and, as such, carries significant volumes in both directions. In general, the

BOSTON REGION MPO

FIGURE 1
Main Street at Mountain Avenue, Malden

Safety and Operations Improvements at Selected Intersections

peak direction is southbound in the morning and northbound in the evening. In the morning, traffic backs up on the northbound, southbound, and westbound approaches. Due to the large proportions of left turns, southbound traffic frequently backs up during the peak hours.

Recent turning movement counts (see Table 2 in the Intersection Capacity Analysis section) show significant eastbound, westbound, and southbound left-turn volumes. Left turns account for about 20% of the morning westbound volume, 20% of the afternoon eastbound volume, and 15% of the afternoon southbound volume. The northbound approach has few left- or right-turning vehicles.

Drivers park their vehicles too close to the intersection on the eastern side of Main Street north of the intersection. Unlike the other approaches, no signs are present reminding drivers that parking is not permitted within 20 feet of an intersection. When vehicles park too close to the intersection, right-turning vehicles must drive father out into the intersection to complete their maneuver.

A review of the recent crash data from 2006 to 2008 indicates a high number of crashes occurring at the intersection. The crash rate at this intersection is much higher than other signalized intersections in the area. Over half of the crashes were classified as angle crashes.

About 60 pedestrians use the intersection during each of the AM and PM peak hours. At worst, they could call for an exclusive pedestrian phase every cycle. More likely, these pedestrians arrive in groups and do not actuate the pedestrian phase every cycle. Regardless, the exclusive pedestrian phases cause significant delay to vehicles. It is conceivable that once vehicles are subjected to excessive delays, drivers could make riskier decisions while trying to cross oncoming traffic. However, during recent visits to the intersection, staff found that the pedestrian push buttons did not activate an exclusive pedestrian phase as they once did. While the absence of a pedestrian phase has certainly decreased vehicle delay at the intersection, it forces pedestrians to cross without any signals. Functionally, not providing an exclusive pedestrian phase is similar to giving the pedestrians a concurrent crossing phase, but it is much less safe. Pedestrians do not know if there is enough time to cross the street nor is there any indication of who has right of way. The inability to show pedestrian signals is largely a fault of the old signal system and its complete lack of pedestrian signal heads. With the addition of pedestrian signal heads, which a modern signal system would definitely have, the intersection would gain the ability to provide safe concurrent pedestrian phases.

The issues and concerns for this intersection can be summarized as follows:

- High number of crashes and high crash rate (see analysis below)
- Outdated traffic signal system
- Nonfunctioning pedestrian push buttons
- Severely faded crosswalk markings on all approaches
- Parking too close to the intersection
- Traffic congestion during peak hours

CRASH DATA ANALYSIS

Based on the 2006–08 Massachusetts Department of Transportation (MassDOT) Registry of Motor Vehicles Division crash data, Table 1 shows that, on average, about 12 crashes occurred at the intersection each year. About half of the crashes resulted in personal injuries or fatalities (the data include one fatality), and about a third of the total crashes involved property damage only. In a fifth of the cases, no severity was reported. The crash types, not including data that were not reported, consist of about 65% angle collisions, 10% sideswipe collisions, 10% rear-end collisions, 10% single-vehicle collisions, and 3% head-on collisions. One crash involved a pedestrian, and one crash involved a bicycle. About 23% of the total crashes occurred during weekday peak periods. About 20% of the total crashes happened when the roadway pavement was wet or icy. Nearly 40% of the crashes occurred in dark conditions (dawn, dusk, and nighttime). Currently, the only streetlight at the intersection is located on the northwest corner. Adding additional lighting at the intersection could potentially reduce the number of crashes in dark conditions.

TABLE 1
Summary of MassDOT Crash Data (2006–08)

Statistics Period		2006	2007	2008	3-Year	Annual
Total Number of Crashes		15	8	12	35	12
Severity	Property Damage Only	7	3	2	12	4
	Personal Injury	7	4	4	15	5
	Fatality	0	0	1	1	0
	Not Reported	1	1	5	7	2
Collision type	Angle	9	2	9	20	7
	Rear-end	2	1	1	4	1
	Sideswipe	2	1	0	3	1
	Head-on	0	1	0	1	0
	Single Vehicle	1	2	0	3	1
	Not Reported/Unknown	1	1	2	4	1
Involved pedestrian(s)		0	1	0	1	0
Involved cyclist(s)		0	1	0	1	0
Occurred during weekday peak periods*		4	1	3	8	3
Wet or icy pavement conditions		1	3	2	6	2
Dark/lighted conditions		3	5	4	12	4

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

Crash rates[1] are another effective metric for examining the relative safety of a particular location. Based on the 2006–08 crash data and the recently collected traffic volume data, the crash rate for this intersection is 1.87 crashes per million entering vehicles (see Appendix A for the calculation). This crash rate is more than double the average rate for the signalized locations in

[1] Crash rates are estimated based on crash frequency (crashes per year) and vehicle exposure (traffic volumes 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.

MassDOT Highway Division District 4, which is estimated to be 0.78 crashes per million entering vehicles.[2]

INTERSECTION CAPACITY ANALYSIS

MPO staff collected turning-movement counts at the intersection on June 10, 2010. The data were recorded in 15-minute intervals for the peak traffic periods in the morning, from 7:00 to 9:00 AM, and in the evening, from 4:00 to 6:00 PM. The intersection carried about 1,563 vehicles in the morning peak hour, from 7:30 to 8:30 AM, and about 1,535 vehicles in the evening peak hour, from 5:00 to 6:00 PM (see Table 2). Staff observed nearly 60 pedestrians during the AM peak hour and almost 70 pedestrians during the PM peak hour. Four cyclists were observed in the AM peak hour, and seven cyclists were observed in the PM peak hour (the number of cyclists is not shown in Table 2).

TABLE 2
AM and PM Peak-Hour Traffic Volumes and Pedestrian Crossings, June 10, 2010

Street Name		Main Street						Mountain Avenue						Total
Direction		Northbound			Southbound			Eastbound			Westbound			
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM peak hour	Turning volume	27	303	43	46	475	51	26	137	34	79	283	59	
	Mvmt. percentage	7%	81%	12%	8%	83%	9%	13%	70%	17%	19%	67%	14%	1,563
	Approach volume	373			572			197			421			
	Ped. crossings	19			24			3			12			58
PM peak hour	Turning volume	17	467	49	71	368	48	60	189	51	34	131	50	
	Mvmt. percentage	3%	88%	9%	15%	76%	10%	20%	63%	17%	16%	61%	23%	1,535
	Approach volume	533			487			300			215			
	Ped. crossings	15			22			14			16			67

Based on the turning movement counts and the signal timings measured at the site, the intersection capacity was analyzed by using an intersection capacity analysis program, Synchro.[3] The intersection was modeled as a pretimed, signalized intersection with an actuated pedestrian phase. To replicate field conditions, short and narrow right-turn bays were added to the northbound and southbound approaches. As Table 3 shows, the approaches on Main Street were found to operate at level of service (LOS) F with an average delay of about a minute and half in the AM peak hour. Most of the delay is accrued on the left and through movements. During the afternoon peak hour, Main Street operates at LOS C in the northbound direction and LOS F in

[2] The average crash rates estimated by the MassDOT Highway Division are based upon a database that contains intersection crash rates submitted to MassDOT 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 annual basis, are based on all entries in the database, not just those entries made within the past year. The average crash rate for District 4 was calculated on July 7, 2011.

[3] Synchro Version 7 is developed and distributed by Trafficware Ltd. The software can perform capacity analysis and traffic simulation (when combined with SimTraffic) for an individual intersection or a series of intersections.

the southbound direction. Vehicles traveling southbound are, on average, delayed just over 100 seconds.

In general, vehicles traveling on Mountain Avenue suffer less delay. During the morning peak hour, Mountain Avenue operates at LOS B in the eastbound direction and LOS E in the westbound direction. Westbound vehicles are delayed, on average, 70 seconds. During the afternoon peak hour, Mountain Avenue operates at LOS C in the eastbound and westbound directions. Vehicles during the morning peak hour are delayed between 20 and 25 seconds. The criteria for the level of service ratings are based on the Highway Capacity Manual 2000.[4] Detailed analysis settings and results for both the AM and PM peak hour are included in Appendix B.

TABLE 3
Intersection Capacity Analysis, Existing Conditions

Street Name		Main Street					Mountain Avenue						Overall
Direction		Northbound			Southbound		Eastbound			Westbound			
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM peak hour	LOS	F		B	F		B	B			E			E
	Delay (sec/veh)	95.7		11.8	113.9		12.3	19.1			68.5			78.2
PM peak hour	LOS	D		B	F		B	C			C			F
	Delay (sec/veh)	35.1		12.2	224.2		11.9	24.2			20.5			82.0

ANALYSIS OF IMPROVEMENT ALTERNATIVES

To improve traffic operations at this intersection, staff examined a number of traffic and pedestrian signal strategies. The improvement alternatives progress from simple to more involved modifications. Because of the limited right-of-way available, staff did not examine any geometric modifications. As mentioned earlier, the intersection capacity was evaluated using the Synchro capacity analysis software.

All of the alternatives beyond Alternative 1 require a fully actuated traffic signal system, that is, a traffic signal system where each approach will have sensor for motor vehicles on all four approaches, and the presence of a vehicle may affect the green time each approach receives. The traffic signal system will also incorporate modern pedestrian signal heads and push buttons instead the current, outdated equipment. Alternative 1 assumes the current equipment remains in place and the exclusive pedestrian phase is lengthened to 19 seconds.[5] Signal timings for each of the alternatives are set to minimize the average delay per vehicle while maintaining the current amount of time given to vehicles (40 seconds of green time plus 10 seconds of clearance time). Right turns on red were prohibited when an alternative with an exclusive pedestrian phase was

[4] Transportation Research Board, National Research Council, *Highway Capacity Manual (HCM) 2000*, Washington, D. C., 2000.

[5] The pedestrian phase would need to be increased to 19 seconds from the existing 13 seconds in order to cover a crossing distance of at least 42 feet. The minimum crossing time is based on a walking speed of 3.5 feet per second (12 seconds) in addition to a "walk" indication time of 4 seconds and a steady upraised hand time of 3 seconds.

modeled. Right turns on red were permitted when analyzing alternatives with concurrent pedestrian phases. The alternatives tested for this intersection include:

Alternative 1	Extending the pedestrian time to allow pedestrians sufficient time to safely cross the intersection. Optimizing signal timings.
Alternative 2	Upgrading the intersection equipment, setting the equipment up to be fully actuated, and adding an actuated pedestrian phase. Optimizing signal timings.
Alternative 3	Changing the exclusive pedestrian phase to concurrent pedestrian phases.
Alternative 4	Adding a 3-second actuated leading pedestrian intervals before each phase for motor vehicles, and adding the improvements from Alternative 3.[6]

The signal timings for each alternative were optimized independently of the other alternatives. That is, just because one alternative builds on another does not mean the same signal timings were used for both alternatives. In some cases, the signal timings for different alternatives may be the same. Alternative 1, which uses the existing equipment, simply optimizes the signal timings while increasing the duration of the pedestrian phase. Alternative 2, which requires upgrading the intersection equipment, fully actuates the signals while still providing an exclusive pedestrian phase. Alternative 3 replaces the exclusive pedestrian phase with concurrent pedestrian phases. Alternative 4 adds a short leading pedestrian interval when called for.

Table 4 summarizes the intersection capacity analyses for both the AM and PM peak hours for the five alternatives, and the detailed analysis results for the alternatives are included in Appendices C to F). Table 3 provides measures of effectiveness for the existing conditions for each lane. Table 4 provides the measures of effectiveness for the existing conditions and the improvement alternatives analyzed for each roadway approach.

Alternative 1 significantly increases the intersection delay in the morning and decreases delay in the afternoon. In the morning, three more seconds of green time were taken from Mountain Avenue and given to Main Street. In the afternoon, five seconds of green time were transferred to Main Street. Alternative 1 is the least beneficial to vehicles, but, because it features an exclusive pedestrian phase, it would provide safe passage for pedestrians. Moving to a modern signal system, as required by Alternatives 2 through 4, would help solve problems for vehicles *and* pedestrians.

Alternative 2 uses a fully actuated traffic signal system to distribute green time. An exclusive, 19-second pedestrian phase is provided when called for. The exclusive pedestrian phase would cause lengthy delays at the intersection.

Alternative 3, switching from exclusive to concurrent pedestrian phases, significantly improves the operation of the intersection while providing permitted crossing time for pedestrians. This arrangement would be safer than the current field conditions (no pedestrian signals), but would be less safe than an exclusive phase because concurrent phases expose pedestrians to turning vehicles. Alternatives 4 uses a leading pedestrian interval to mitigate this problem.

[6] A leading pedestrian interval is a short "walk" phase given to pedestrians before vehicles receive a green light. It is generally long enough to allow pedestrians to cross one lane of traffic.

Synchro tests suggest that under Alternative 4, by adding a 3-second actuated leading pedestrian interval before each NB/SB and EB/WB phase, the intersection would operate at an acceptable level of service. The benefit to vehicles is only slightly less than in Alternative 3. The early interval would allow pedestrians to walk almost 11 feet into the intersection without competing with right-turning vehicles.

IMPROVEMENT RECOMMENDATIONS AND DISCUSSION

The intersection has a high number of crashes and a crash rate much higher than other signalized intersections in the area. The above safety and operations analyses found a number of deficiencies related to the existing signal system. When the pedestrian signal is turned on and functioning properly, there is significant congestion during the morning and afternoon peak hours. Given the large number of angle collisions, drivers may get frustrated and choose smaller gaps in opposing traffic. To improve traffic operations, the study examined four traffic signal alternatives.

TABLE 4
Intersection Capacity Analyses of Improvement Alternatives

Street Name		Main Street				Mountain Avenue				Overall	
Direction		Northbound		Southbound		Eastbound		Westbound			
Measurement		LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay	LOS	Delay
AM peak hour	**Existing**	**F**	**87.2**	**F**	**101.8**	**B**	**19.1**	**E**	**68.5**	**E**	**78.2**
	Alternative 1	D	52.4	E	70.4	C	31.2	F	>180.0	F	103.5
	Alternative 2	D	51.3	E	70.4	C	25.6	F	>180.0	F	102.5
	Alternative 3	B	13.9	C	27.3	B	12.1	C	34.1	C	23.5
	Alternative 4	B	17.6	C	31.7	B	14.1	D	49.4	C	30.2
PM peak hour	**Existing**	**C**	**32.0**	**F**	**>180.0**	**C**	**24.2**	**C**	**20.5**	**F**	**82.0**
	Alternative 1	C	22.0	E	70.9	F	124.5	E	62.4	E	64.2
	Alternative 2	C	19.0	E	70.9	F	124.5	E	58.7	E	62.7
	Alternative 3	B	12.4	C	22.8	B	15.1	B	12.6	B	16.3
	Alternative 4	B	11.6	B	17.6	C	25.3	B	17.5	B	17.1

Note: Alternative 1: Increase the duration of the exclusive pedestrian phase from 13 seconds to 19 seconds.
Alternative 2: Actuate signal. Increase duration of the exclusive pedestrian phase to 19 seconds.
Alternative 3: Change exclusive pedestrian phase to concurrent pedestrian phases. Pedestrian phases are actuated.
Alternative 4: Alternative 3 plus adding an actuated leading pedestrian interval before each phase.

Alternative 1 essentially shows how the intersection should operate to accommodate pedestrians. In its current state, this intersection does not provide an adequate environment for pedestrians to cross. If no other alternative is implemented, the intersection needs to have an exclusive pedestrian phase.

Upgrading the traffic signal makes Alternatives 2 through 4 possible. Under Alternative 2, given the high traffic volumes at this intersection, each approach usually receives the maximum

allowable green time that is allocated for its traffic signal phase. Some phases may end before their maximum allotted time. While there will not be a significant reduction in vehicle delay during the peak hours, there should be some gains during the off-peak hours. Adding concurrent pedestrian phases dramatically decreases delay while providing a safe environment for pedestrians.

Alternative 4 allows more than the required amount of time for pedestrians to safely cross the street. Vehicle delays are generally still acceptable, although in the morning peak-hour, the delay for westbound vehicles is noticeably higher than in other alternatives. Most pedestrians will not have to compete with turning vehicles.

At this preliminary planning stage, the staff recommends Alternative 4 for this intersection. Overall, Alternative 4 would significantly decrease delay while providing most pedestrians with enough dedicated time to avoid turning vehicles.

Upgrading the outdated signal system is critically important for this intersection. The current situation for pedestrians is less than ideal and should be improved. An updated signal system would solve many of the problems at this intersection by both improving vehicle flow and accommodating pedestrians.

Currently, bus stops are located on the near sides of the intersection. Moving these stops to the far side of the intersection should help bus drivers access the stop, while allowing right-turning vehicles more clearance to make their maneuvers. One parking space would need to be taken to move the southbound (inbound) bus stop; there are several driveways and a fire hydrant currently preventing drivers from parking. Three to four parking spaces would need to be taken to move the northbound (outbound) bus stop. If the bus stops are moved, parking should not be recovered from the original bus stop locations. Right-turning vehicles currently use this space when it is available. The extra space also helps vehicles see waiting pedestrians and other vehicles.

If the bus stops remain in their current locations, the staff expects that it would be beneficial to the efficient operation of the intersection to paint the location of the bus stops on the pavement. This would help prevent people from parking in the bus stop, while still allowing people to make right turns from this area when it is not in use.

No sign indicates that parking is prohibited along the eastern side of Main Street north of the intersection. Malden prohibits parking within 20 feet of the intersection. Adding a sign might help remind drivers where they are allowed to park. Prohibiting vehicles from parking on this portion of the intersection will give more space to right-turning vehicles and will give drivers better sightlines, even it that space is not used as a bus stop.

Recommendations:

- Implement Alternative 4—actuated concurrent pedestrian phases along with an actuated leading pedestrian interval.
- Install a modern traffic signal system with functioning pedestrian push buttons and countdown signals.
- Install overhead signal heads that are clearly visible from all approaches.

- Add a left-turn lane and a shared through/right-turn lane on eastbound Mountain Avenue.
- Add shared right-turn lanes/bus stops on Main Street.
- Repaint and maintain the crosswalks.
- Add tactile strips to curb cuts.
- Improve lighting conditions at the intersection by adding one more streetlight.
- Enforce the current "no parking" signs.
- On the eastern side of Main Street, prohibit parking from the north crosswalk to approximately 20–30 feet north of the intersection. Twenty feet is the minimum distance per the city's ordinances.
- Consider moving bus stops to the far sides of the intersection.

The total cost of the signal installation (including its support system) is roughly estimated to be $750,000. Both streets and the intersection are under the jurisdiction of the City of Malden. The city can seek funding support from Chapter 90 Program[7] or Public Works Economic Development (PWED) Program,[8] and can consult with MassDOT Highway District 4 staff beginning with the initial signal design stage of the project.

In the interim, before the intersection is upgraded, staff suggest that additional signage at the intersection might help pedestrians cross safely. The 2009 Manual on Uniform Traffic Control Devices (MUTCD) lists sign R10-15 as an acceptable sign to "remind drivers who are making turns to yield to pedestrians." Figure 2, taken from the MUTCD, shows the R10-15 sign. In its current state, this sign seems to suggest that right turning vehicles should yield to pedestrians. In order to remind vehicles turning left and right to yield, staff suggest removing the right-turn arrow. The text "TURNING VEHICLES," on a fluorescent yellow-green background, would fill the top portion of the sign. If modifying the sign is not feasible, the original version is also acceptable. One sign would be mounted at each corner of the intersection. Each vehicle sees two signal heads: one on the near side of the intersection on the left, and another on the far side of the intersection on the right. Placing the sign underneath signal housing on the far-side signal post would likely be the most visible location for the sign. The cost of these signs would be relatively minimal, likely costing less than a few thousand dollars. The signs could be reused if the intersection is upgraded.

[7] The Chapter 90 Program was enacted in 1973 to entitle municipalities to reimbursement of documented expenditures under the provisions of MGL Chapter 90, Section 34, Clause 2 (a), on approved projects.

[8] The PWED Program, which was designed to fund transportation infrastructure projects that stimulate economic development, has now been consolidated into the MassWorks Infrastructure Program. This new program is a one-stop shop at the Executive Office of Housing and Economic Development (EOHED) for municipalities and other eligible applicants to seek public infrastructure funding that supports these and other economic development projects. More information about the program is described on an EOHED webpage, www.mass.gov/eohed/infrastructure.

FIGURE 2
MUTCD Sign R10-15: Turning Vehicles Must Yield to Pedestrians

A sign prohibiting parking to the northern crosswalk on the eastern side of Main Street would help right-turning vehicles make their maneuvers easier while helping drivers determine whether they are legally parked. Malden already prohibits parking within 20 feet of the intersection, but drivers are more likely to look for a sign to confirm whether they can park. The sign should be located about 20–30 feet north of the intersection. Parking should remain prohibited if the intersection is upgraded.

SPA/CW/spa

APPENDIX A

Existing Conditions

Intersection Crash Rate Calculation:
Main Street at Mountain Avenue, Malden

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Malden | COUNT DATE : 6/4/2010

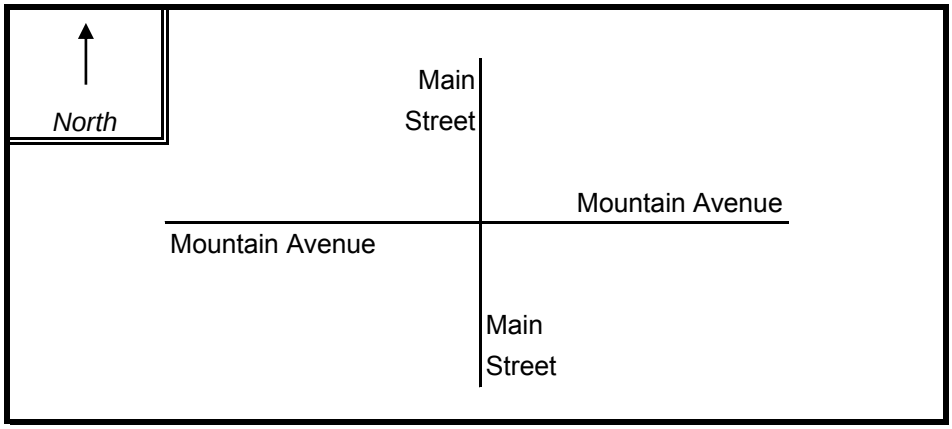
DISTRICT : 4 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Main Street

MINOR STREET(S) : Mountain Avenue

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	EB	WB	NB	SB		
PEAK HOURLY VOLUMES (AM/**PM**) :	533	487	300	215		**1,535**

" K " FACTOR : **0.090**

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **17,056**

TOTAL # OF CRASHES : 35

OF YEARS : 3

AVERAGE # OF CRASHES PER YEAR (**A**) : **11.67**

CRASH RATE CALCULATION : **1.874**

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

Comments : MassDOT District 4 Average Rate = 0.78 (July 7, 2011)

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

APPENDIX B

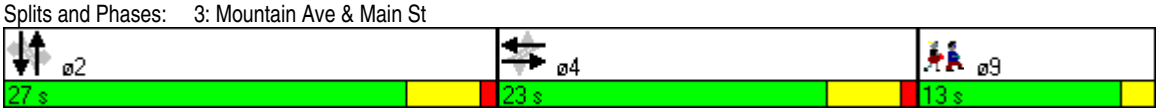
Existing Conditions

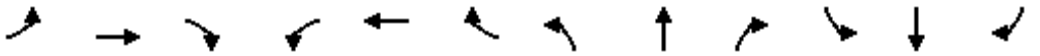
AM/PM Peak-Hour Intersection Capacity Analysis:
Main Street at Mountain Avenue, Malden

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR	ø9
Lane Configurations											
Volume (vph)	26	137	79	283	27	303	43	46	475	51	
Turn Type	Perm		Perm		Perm		Perm	Perm		Perm	
Protected Phases		4		4		2			2		9
Permitted Phases	4		4		2		2	2		2	
Detector Phase	4	4	4	4	2	2	2	2	2	2	
Switch Phase											
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	21.0	21.0	21.0	21.0	19.0	19.0	19.0	19.0	19.0	19.0	13.0
Total Split (s)	23.0	23.0	23.0	23.0	27.0	27.0	27.0	27.0	27.0	27.0	13.0
Total Split (%)	36.5%	36.5%	36.5%	36.5%	42.9%	42.9%	42.9%	42.9%	42.9%	42.9%	21%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Lead/Lag											
Lead-Lag Optimize?											
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max	Max	Max	None

Intersection Summary
Cycle Length: 63
Actuated Cycle Length: 57.8
Natural Cycle: 100
Control Type: Semi Act-Uncoord
Description: Main Street at Mountain Avenue in Malden, MA.

Splits and Phases: 3: Mountain Ave & Main St





Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	26	137	34	79	283	59	27	303	43	46	475	51
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	14	12	12	12	12	10	10	9	9	10	8
Total Lost time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Lane Util. Factor		1.00			1.00			1.00	1.00		1.00	1.00
Frpb, ped/bikes		0.99			0.99			1.00	0.96		1.00	0.98
Flpb, ped/bikes		1.00			1.00			1.00	1.00		1.00	1.00
Frt		0.98			0.98			1.00	0.85		1.00	0.85
Flt Protected		0.99			0.99			0.99	1.00		0.99	1.00
Satd. Flow (prot)		1901			1628			1466	1331		1500	1311
Flt Permitted		0.88			0.88			0.69	1.00		0.84	1.00
Satd. Flow (perm)		1690			1451			1018	1331		1271	1311
Peak-hour factor, PHF	0.72	0.80	0.77	0.90	0.91	0.82	0.61	0.79	0.90	0.77	0.94	0.67
Adj. Flow (vph)	36	171	44	88	311	72	44	384	48	60	505	76
RTOR Reduction (vph)	0	12	0	0	10	0	0	0	14	0	0	16
Lane Group Flow (vph)	0	239	0	0	461	0	0	428	34	0	565	60
Confl. Peds. (#/hr)	24		19	19		24	3		12	12		3
Confl. Bikes (#/hr)						1			2			1
Heavy Vehicles (%)	5%	2%	1%	1%	0%	3%	2%	9%	3%	4%	6%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	5	0	0	5
Parking (#/hr)					0			0			0	
Turn Type	Perm			Perm			Perm		Perm	Perm		Perm
Protected Phases		4			4			2			2	
Permitted Phases	4			4			2		2	2		2
Actuated Green, G (s)		18.2			18.2			22.3	22.3		22.3	22.3
Effective Green, g (s)		18.2			18.2			22.3	22.3		22.3	22.3
Actuated g/C Ratio		0.31			0.31			0.38	0.38		0.38	0.38
Clearance Time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Vehicle Extension (s)		2.0			2.0			2.0	2.0		2.0	2.0
Lane Grp Cap (vph)		525			451			387	507		484	499
v/s Ratio Prot												
v/s Ratio Perm		0.14			c0.32			0.42	0.03		c0.44	0.05
v/c Ratio		0.46			1.02			1.11	0.07		1.17	0.12
Uniform Delay, d1		16.2			20.2			18.2	11.5		18.2	11.8
Progression Factor		1.00			1.00			1.00	1.00		1.00	1.00
Incremental Delay, d2		2.8			48.3			77.5	0.3		95.7	0.5
Delay (s)		19.1			68.5			95.7	11.8		113.9	12.3
Level of Service		B			E			F	B		F	B
Approach Delay (s)		19.1			68.5			87.2			101.8	
Approach LOS		B			E			F			F	

Intersection Summary			
HCM Average Control Delay	78.2	HCM Level of Service	E
HCM Volume to Capacity ratio	1.10		
Actuated Cycle Length (s)	58.6	Sum of lost time (s)	18.1
Intersection Capacity Utilization	92.3%	ICU Level of Service	F
Analysis Period (min)	15		

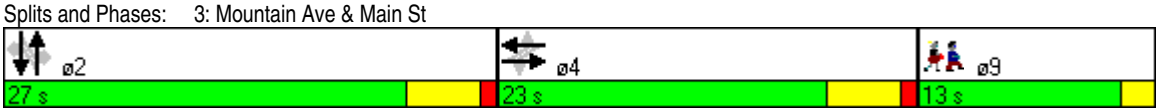
Description: Main Street at Mountain Avenue in Malden, MA.

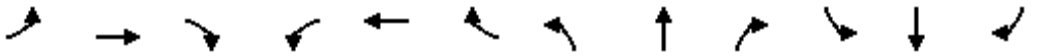
c Critical Lane Group

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR	ø9
Lane Configurations											
Volume (vph)	60	189	34	131	17	467	49	71	368	48	
Turn Type	Perm		Perm		Perm		Perm	Perm		Perm	
Protected Phases		4		4		2			2		9
Permitted Phases	4		4		2		2	2		2	
Detector Phase	4	4	4	4	2	2	2	2	2	2	
Switch Phase											
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	13.0
Total Split (s)	23.0	23.0	23.0	23.0	27.0	27.0	27.0	27.0	27.0	27.0	13.0
Total Split (%)	36.5%	36.5%	36.5%	36.5%	42.9%	42.9%	42.9%	42.9%	42.9%	42.9%	21%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Lead/Lag											
Lead-Lag Optimize?											
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max	Max	Max	None

Intersection Summary
Cycle Length: 63
Actuated Cycle Length: 57.8
Natural Cycle: 90
Control Type: Semi Act-Uncoord
Description: Main Street at Mountain Avenue in Malden, MA.

Splits and Phases: 3: Mountain Ave & Main St





Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	60	189	51	34	131	50	17	467	49	71	368	48
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	14	12	12	12	12	10	10	9	10	10	9
Total Lost time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Lane Util. Factor		1.00			1.00			1.00	1.00		1.00	1.00
Frpb, ped/bikes		0.99			0.99			1.00	0.96		1.00	0.96
Flpb, ped/bikes		1.00			1.00			1.00	1.00		1.00	1.00
Frt		0.98			0.96			1.00	0.85		1.00	0.85
Flt Protected		0.99			0.99			1.00	1.00		0.99	1.00
Satd. Flow (prot)		1909			1611			1562	1367		1536	1387
Flt Permitted		0.87			0.91			0.97	1.00		0.59	1.00
Satd. Flow (perm)		1683			1473			1512	1367		908	1387
Peak-hour factor, PHF	0.75	0.86	0.85	0.85	0.91	0.74	0.71	0.96	0.61	0.81	0.91	0.81
Adj. Flow (vph)	80	220	60	40	144	68	24	486	80	88	404	59
RTOR Reduction (vph)	0	11	0	0	21	0	0	0	19	0	0	14
Lane Group Flow (vph)	0	349	0	0	231	0	0	510	61	0	492	45
Confl. Peds. (#/hr)	15		22	22		15	14		16	16		14
Confl. Bikes (#/hr)			1						4			
Heavy Vehicles (%)	1%	1%	3%	0%	0%	0%	0%	2%	0%	2%	3%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	4	0	0	2
Parking (#/hr)					0			0			0	
Turn Type	Perm			Perm			Perm		Perm	Perm		Perm
Protected Phases		4			4			2			2	
Permitted Phases	4			4			2		2	2		2
Actuated Green, G (s)		18.2			18.2			22.3	22.3		22.3	22.3
Effective Green, g (s)		18.2			18.2			22.3	22.3		22.3	22.3
Actuated g/C Ratio		0.31			0.31			0.38	0.38		0.38	0.38
Clearance Time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Vehicle Extension (s)		2.0			2.0			2.0	2.0		2.0	2.0
Lane Grp Cap (vph)		523			457			575	520		346	528
v/s Ratio Prot												
v/s Ratio Perm		c0.21			0.16			0.34	0.04		c0.54	0.03
v/c Ratio		0.67			0.51			0.89	0.12		1.42	0.08
Uniform Delay, d1		17.6			16.5			17.0	11.8		18.2	11.6
Progression Factor		1.00			1.00			1.00	1.00		1.00	1.00
Incremental Delay, d2		6.6			4.0			18.1	0.5		206.0	0.3
Delay (s)		24.2			20.5			35.1	12.2		224.2	11.9
Level of Service		C			C			D	B		F	B
Approach Delay (s)		24.2			20.5			32.0			201.5	
Approach LOS		C			C			C			F	

Intersection Summary			
HCM Average Control Delay	82.0	HCM Level of Service	F
HCM Volume to Capacity ratio	1.08		
Actuated Cycle Length (s)	58.6	Sum of lost time (s)	18.1
Intersection Capacity Utilization	85.5%	ICU Level of Service	E
Analysis Period (min)	15		

Description: Main Street at Mountain Avenue in Malden, MA.

c Critical Lane Group

APPENDIX C

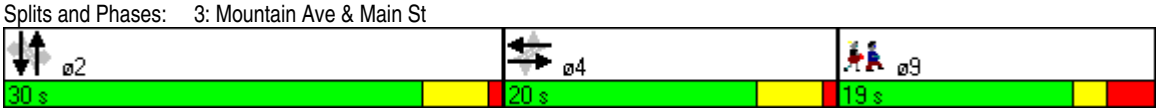
Alternative 1:
Increase Exclusive Pedestrian Time and Optimize Signal Timing

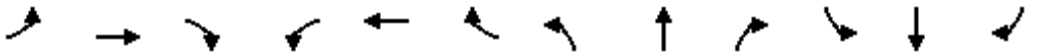
AM/PM Peak-Hour Intersection Capacity Analysis:
Main Street at Mountain Avenue, Malden

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR	ø9
Lane Configurations											
Volume (vph)	26	137	79	283	27	303	43	46	475	51	
Turn Type	Perm		Perm		Perm		Perm	Perm		Perm	
Protected Phases		4		4		2			2		9
Permitted Phases	4		4		2		2	2		2	
Detector Phase	4	4	4	4	2	2	2	2	2	2	
Switch Phase											
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	19.0
Total Split (s)	20.0	20.0	20.0	20.0	30.0	30.0	30.0	30.0	30.0	30.0	19.0
Total Split (%)	29.0%	29.0%	29.0%	29.0%	43.5%	43.5%	43.5%	43.5%	43.5%	43.5%	28%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Lead/Lag											
Lead-Lag Optimize?											
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max	Max	Max	None

Intersection Summary
Cycle Length: 69
Actuated Cycle Length: 61.4
Natural Cycle: 150
Control Type: Semi Act-Uncoord
Description: Main Street at Mountain Avenue in Malden, MA.

Splits and Phases: 3: Mountain Ave & Main St





Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	26	137	34	79	283	59	27	303	43	46	475	51
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	14	12	12	12	12	10	10	9	9	10	8
Total Lost time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Lane Util. Factor		1.00			1.00			1.00	1.00		1.00	1.00
Frpb, ped/bikes		0.99			0.99			1.00	0.96		1.00	0.98
Flpb, ped/bikes		1.00			1.00			1.00	1.00		1.00	1.00
Frt		0.98			0.98			1.00	0.85		1.00	0.85
Flt Protected		0.99			0.99			0.99	1.00		0.99	1.00
Satd. Flow (prot)		1898			1624			1466	1333		1500	1312
Flt Permitted		0.80			0.82			0.74	1.00		0.87	1.00
Satd. Flow (perm)		1532			1349			1084	1333		1310	1312
Peak-hour factor, PHF	0.72	0.80	0.77	0.90	0.91	0.82	0.61	0.79	0.90	0.77	0.94	0.67
Adj. Flow (vph)	36	171	44	88	311	72	44	384	48	60	505	76
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	251	0	0	471	0	0	428	48	0	565	76
Confl. Peds. (#/hr)	24		19	19		24	3		12	12		3
Confl. Bikes (#/hr)						1			2			1
Heavy Vehicles (%)	5%	2%	1%	1%	0%	3%	2%	9%	3%	4%	6%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	5	0	0	5
Parking (#/hr)					0			0			0	
Turn Type	Perm			Perm			Perm		Perm	Perm		Perm
Protected Phases		4			4			2			2	
Permitted Phases	4			4			2		2	2		2
Actuated Green, G (s)		15.4			15.4			25.6	25.6		25.6	25.6
Effective Green, g (s)		15.4			15.4			25.6	25.6		25.6	25.6
Actuated g/C Ratio		0.24			0.24			0.40	0.40		0.40	0.40
Clearance Time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Vehicle Extension (s)		2.0			2.0			2.0	2.0		2.0	2.0
Lane Grp Cap (vph)		372			327			437	537		528	529
v/s Ratio Prot												
v/s Ratio Perm		0.16			c0.35			0.39	0.04		c0.43	0.06
v/c Ratio		0.67			1.44			0.98	0.09		1.07	0.14
Uniform Delay, d1		21.8			24.0			18.7	11.7		19.0	12.0
Progression Factor		1.00			1.00			1.00	1.00		1.00	1.00
Incremental Delay, d2		9.4			214.8			38.2	0.3		59.2	0.6
Delay (s)		31.2			238.8			56.9	12.1		78.2	12.6
Level of Service		C			F			E	B		E	B
Approach Delay (s)		31.2			238.8			52.4			70.4	
Approach LOS		C			F			D			E	

Intersection Summary			
HCM Average Control Delay	103.5	HCM Level of Service	F
HCM Volume to Capacity ratio	1.21		
Actuated Cycle Length (s)	63.5	Sum of lost time (s)	22.5
Intersection Capacity Utilization	92.3%	ICU Level of Service	F
Analysis Period (min)	15		

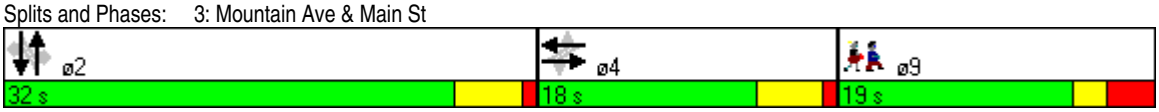
Description: Main Street at Mountain Avenue in Malden, MA.

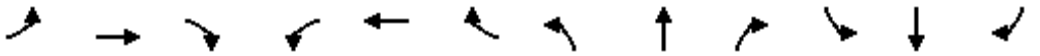
c Critical Lane Group

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR	ø9
Lane Configurations											
Volume (vph)	60	189	34	131	17	467	49	71	368	48	
Turn Type	Perm		Perm		Perm		Perm	Perm		Perm	
Protected Phases		4		4		2			2		9
Permitted Phases	4		4		2		2	2		2	
Detector Phase	4	4	4	4	2	2	2	2	2	2	
Switch Phase											
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	19.0
Total Split (s)	18.0	18.0	18.0	18.0	32.0	32.0	32.0	32.0	32.0	32.0	19.0
Total Split (%)	26.1%	26.1%	26.1%	26.1%	46.4%	46.4%	46.4%	46.4%	46.4%	46.4%	28%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Lead/Lag											
Lead-Lag Optimize?											
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max	Max	Max	None

Intersection Summary
Cycle Length: 69
Actuated Cycle Length: 61.4
Natural Cycle: 100
Control Type: Semi Act-Uncoord
Description: Main Street at Mountain Avenue in Malden, MA.

Splits and Phases: 3: Mountain Ave & Main St





Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	60	189	51	34	131	50	17	467	49	71	368	48
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	14	12	12	12	12	10	10	9	10	10	9
Total Lost time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Lane Util. Factor		1.00			1.00			1.00	1.00		1.00	1.00
Frpb, ped/bikes		0.99			0.99			1.00	0.96		1.00	0.96
Flpb, ped/bikes		1.00			1.00			1.00	1.00		1.00	1.00
Frt		0.98			0.96			1.00	0.85		1.00	0.85
Flt Protected		0.99			0.99			1.00	1.00		0.99	1.00
Satd. Flow (prot)		1902			1606			1562	1371		1536	1390
Flt Permitted		0.78			0.81			0.97	1.00		0.68	1.00
Satd. Flow (perm)		1491			1303			1515	1371		1058	1390
Peak-hour factor, PHF	0.75	0.86	0.85	0.85	0.91	0.74	0.71	0.96	0.61	0.81	0.91	0.81
Adj. Flow (vph)	80	220	60	40	144	68	24	486	80	88	404	59
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	360	0	0	252	0	0	510	80	0	492	59
Confl. Peds. (#/hr)	15		22	22		15	14		16	16		14
Confl. Bikes (#/hr)			1						4			
Heavy Vehicles (%)	1%	1%	3%	0%	0%	0%	0%	2%	0%	2%	3%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	4	0	0	2
Parking (#/hr)					0			0			0	
Turn Type	Perm			Perm			Perm		Perm	Perm		Perm
Protected Phases		4			4			2			2	
Permitted Phases	4			4			2		2	2		2
Actuated Green, G (s)		13.3			13.3			27.7	27.7		27.7	27.7
Effective Green, g (s)		13.3			13.3			27.7	27.7		27.7	27.7
Actuated g/C Ratio		0.21			0.21			0.44	0.44		0.44	0.44
Clearance Time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Vehicle Extension (s)		2.0			2.0			2.0	2.0		2.0	2.0
Lane Grp Cap (vph)		312			273			661	598		462	606
v/s Ratio Prot												
v/s Ratio Perm		c0.24			0.19			0.34	0.06		c0.46	0.04
v/c Ratio		1.15			0.92			0.77	0.13		1.06	0.10
Uniform Delay, d1		25.1			24.6			15.2	10.7		17.9	10.5
Progression Factor		1.00			1.00			1.00	1.00		1.00	1.00
Incremental Delay, d2		99.4			37.8			8.5	0.5		60.2	0.3
Delay (s)		124.5			62.4			23.7	11.2		78.1	10.9
Level of Service		F			E			C	B		E	B
Approach Delay (s)		124.5			62.4			22.0			70.9	
Approach LOS		F			E			C			E	

Intersection Summary			
HCM Average Control Delay	64.2	HCM Level of Service	E
HCM Volume to Capacity ratio	1.09		
Actuated Cycle Length (s)	63.5	Sum of lost time (s)	22.5
Intersection Capacity Utilization	85.5%	ICU Level of Service	E
Analysis Period (min)	15		

Description: Main Street at Mountain Avenue in Malden, MA.

c Critical Lane Group

APPENDIX D

Alternative 2:
Install a Fully Actuated Traffic Signal with an Actuated, Exclusive Pedestrian Phase

AM/PM Peak-Hour Intersection Capacity Analysis:
Main Street at Mountain Avenue, Malden

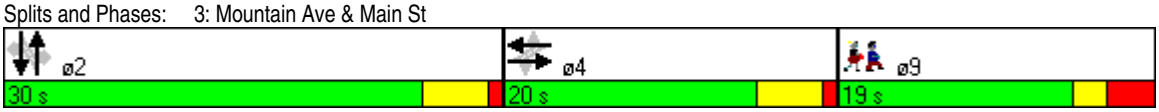
Timings
3: Mountain Ave & Main St

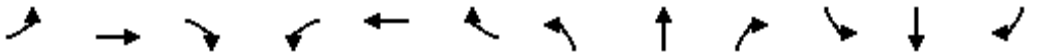
8/26/2011

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR	ø9
Lane Configurations											
Volume (vph)	26	137	79	283	27	303	43	46	475	51	
Turn Type	Perm		Perm		Perm		Perm	Perm		Perm	
Protected Phases		4		4		2			2		9
Permitted Phases	4		4		2		2	2		2	
Detector Phase	4	4	4	4	2	2	2	2	2	2	
Switch Phase											
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	19.0
Total Split (s)	20.0	20.0	20.0	20.0	30.0	30.0	30.0	30.0	30.0	30.0	19.0
Total Split (%)	29.0%	29.0%	29.0%	29.0%	43.5%	43.5%	43.5%	43.5%	43.5%	43.5%	28%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Lead/Lag											
Lead-Lag Optimize?											
Recall Mode	None	None	None	None	None	None	None	None	None	None	None

Intersection Summary
Cycle Length: 69
Actuated Cycle Length: 61.4
Natural Cycle: 150
Control Type: Actuated-Uncoordinated
Description: Main Street at Mountain Avenue in Malden, MA.

Splits and Phases: 3: Mountain Ave & Main St





Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	26	137	34	79	283	59	27	303	43	46	475	51
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	14	12	12	12	12	10	10	9	9	10	8
Total Lost time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Lane Util. Factor		1.00			1.00			1.00	1.00		1.00	1.00
Frpb, ped/bikes		0.99			0.99			1.00	0.96		1.00	0.98
Flpb, ped/bikes		1.00			1.00			1.00	1.00		1.00	1.00
Frt		0.98			0.98			1.00	0.85		1.00	0.85
Flt Protected		0.99			0.99			0.99	1.00		0.99	1.00
Satd. Flow (prot)		1898			1624			1466	1333		1500	1312
Flt Permitted		0.80			0.82			0.74	1.00		0.87	1.00
Satd. Flow (perm)		1532			1349			1084	1333		1310	1312
Peak-hour factor, PHF	0.72	0.80	0.77	0.90	0.91	0.82	0.61	0.79	0.90	0.77	0.94	0.67
Adj. Flow (vph)	36	171	44	88	311	72	44	384	48	60	505	76
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	251	0	0	471	0	0	428	48	0	565	76
Confl. Peds. (#/hr)	24		19	19		24	3		12	12		3
Confl. Bikes (#/hr)						1			2			1
Heavy Vehicles (%)	5%	2%	1%	1%	0%	3%	2%	9%	3%	4%	6%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	5	0	0	5
Parking (#/hr)					0			0			0	
Turn Type	Perm			Perm			Perm		Perm	Perm		Perm
Protected Phases		4			4			2			2	
Permitted Phases	4			4			2		2	2		2
Actuated Green, G (s)		15.4			15.4			25.6	25.6		25.6	25.6
Effective Green, g (s)		15.4			15.4			25.6	25.6		25.6	25.6
Actuated g/C Ratio		0.24			0.24			0.40	0.40		0.40	0.40
Clearance Time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Vehicle Extension (s)		2.0			2.0			2.0	2.0		2.0	2.0
Lane Grp Cap (vph)		372			327			437	537		528	529
v/s Ratio Prot												
v/s Ratio Perm		0.16			c0.35			0.39	0.04		c0.43	0.06
v/c Ratio		0.67			1.44			0.98	0.09		1.07	0.14
Uniform Delay, d1		21.8			24.0			18.7	11.7		19.0	12.0
Progression Factor		1.00			1.00			1.00	1.00		1.00	1.00
Incremental Delay, d2		3.8			214.8			37.1	0.0		59.2	0.0
Delay (s)		25.6			238.8			55.8	11.8		78.2	12.1
Level of Service		C			F			E	B		E	B
Approach Delay (s)		25.6			238.8			51.3			70.4	
Approach LOS		C			F			D			E	

Intersection Summary			
HCM Average Control Delay	102.5	HCM Level of Service	F
HCM Volume to Capacity ratio	1.21		
Actuated Cycle Length (s)	63.5	Sum of lost time (s)	22.5
Intersection Capacity Utilization	92.3%	ICU Level of Service	F
Analysis Period (min)	15		

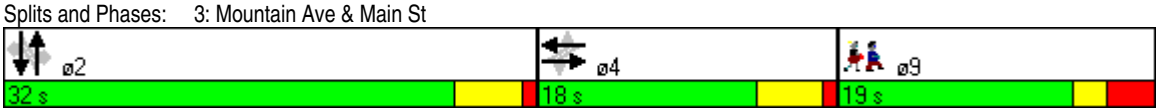
Description: Main Street at Mountain Avenue in Malden, MA.

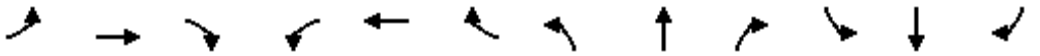
c Critical Lane Group

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR	ø9
Lane Configurations											
Volume (vph)	60	189	34	131	17	467	49	71	368	48	
Turn Type	Perm		Perm		Perm		Perm	Perm		Perm	
Protected Phases		4		4		2			2		9
Permitted Phases	4		4		2		2	2		2	
Detector Phase	4	4	4	4	2	2	2	2	2	2	
Switch Phase											
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	19.0
Total Split (s)	18.0	18.0	18.0	18.0	32.0	32.0	32.0	32.0	32.0	32.0	19.0
Total Split (%)	26.1%	26.1%	26.1%	26.1%	46.4%	46.4%	46.4%	46.4%	46.4%	46.4%	28%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
Lead/Lag											
Lead-Lag Optimize?											
Recall Mode	None	None	None	None	None	None	None	None	None	None	None

Intersection Summary
Cycle Length: 69
Actuated Cycle Length: 61.4
Natural Cycle: 100
Control Type: Actuated-Uncoordinated
Description: Main Street at Mountain Avenue in Malden, MA.

Splits and Phases: 3: Mountain Ave & Main St





Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	60	189	51	34	131	50	17	467	49	71	368	48
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	14	12	12	12	12	10	10	9	10	10	9
Total Lost time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Lane Util. Factor		1.00			1.00			1.00	1.00		1.00	1.00
Frpb, ped/bikes		0.99			0.99			1.00	0.96		1.00	0.96
Flpb, ped/bikes		1.00			1.00			1.00	1.00		1.00	1.00
Frt		0.98			0.96			1.00	0.85		1.00	0.85
Flt Protected		0.99			0.99			1.00	1.00		0.99	1.00
Satd. Flow (prot)		1902			1606			1562	1371		1536	1390
Flt Permitted		0.78			0.81			0.97	1.00		0.68	1.00
Satd. Flow (perm)		1491			1303			1515	1371		1058	1390
Peak-hour factor, PHF	0.75	0.86	0.85	0.85	0.91	0.74	0.71	0.96	0.61	0.81	0.91	0.81
Adj. Flow (vph)	80	220	60	40	144	68	24	486	80	88	404	59
RTOR Reduction (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group Flow (vph)	0	360	0	0	252	0	0	510	80	0	492	59
Confl. Peds. (#/hr)	15		22	22		15	14		16	16		14
Confl. Bikes (#/hr)			1						4			
Heavy Vehicles (%)	1%	1%	3%	0%	0%	0%	0%	2%	0%	2%	3%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	4	0	0	2
Parking (#/hr)					0			0			0	
Turn Type	Perm			Perm			Perm		Perm	Perm		Perm
Protected Phases		4			4			2			2	
Permitted Phases	4			4			2		2	2		2
Actuated Green, G (s)		13.3			13.3			27.7	27.7		27.7	27.7
Effective Green, g (s)		13.3			13.3			27.7	27.7		27.7	27.7
Actuated g/C Ratio		0.21			0.21			0.44	0.44		0.44	0.44
Clearance Time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Vehicle Extension (s)		2.0			2.0			2.0	2.0		2.0	2.0
Lane Grp Cap (vph)		312			273			661	598		462	606
v/s Ratio Prot												
v/s Ratio Perm		c0.24			0.19			0.34	0.06		c0.46	0.04
v/c Ratio		1.15			0.92			0.77	0.13		1.06	0.10
Uniform Delay, d1		25.1			24.6			15.2	10.7		17.9	10.5
Progression Factor		1.00			1.00			1.00	1.00		1.00	1.00
Incremental Delay, d2		99.4			34.1			5.1	0.0		60.2	0.0
Delay (s)		124.5			58.7			20.3	10.8		78.1	10.6
Level of Service		F			E			C	B		E	B
Approach Delay (s)		124.5			58.7			19.0			70.9	
Approach LOS		F			E			B			E	

Intersection Summary			
HCM Average Control Delay	62.7	HCM Level of Service	E
HCM Volume to Capacity ratio	1.09		
Actuated Cycle Length (s)	63.5	Sum of lost time (s)	22.5
Intersection Capacity Utilization	85.5%	ICU Level of Service	E
Analysis Period (min)	15		

Description: Main Street at Mountain Avenue in Malden, MA.

c Critical Lane Group

APPENDIX E

Alternative 3:
Replace the Exclusive Pedestrian Phase with Concurrent Pedestrian Phases

AM/PM Peak-Hour Intersection Capacity Analysis:
Main Street at Mountain Avenue, Malden

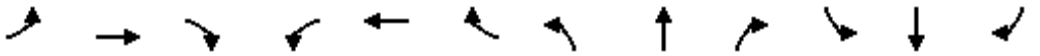
Timings
3: Mountain Ave & Main St

8/26/2011

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations										
Volume (vph)	26	137	79	283	27	303	43	46	475	51
Turn Type	Perm		Perm		Perm		Perm	Perm		Perm
Protected Phases		4		4		2			2	
Permitted Phases	4		4		2		2	2		2
Detector Phase	4	4	4	4	2	2	2	2	2	2
Switch Phase										
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	19.0	19.0	19.0	19.0	17.0	17.0	17.0	17.0	17.0	17.0
Total Split (s)	22.0	22.0	22.0	22.0	28.0	28.0	28.0	28.0	28.0	28.0
Total Split (%)	44.0%	44.0%	44.0%	44.0%	56.0%	56.0%	56.0%	56.0%	56.0%	56.0%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Lead/Lag										
Lead-Lag Optimize?										
Recall Mode	Ped	Ped	Ped	Ped	Ped	Ped	Ped	Ped	Ped	Ped

Intersection Summary
Cycle Length: 50
Actuated Cycle Length: 47.9
Natural Cycle: 60
Control Type: Actuated-Uncoordinated
Description: Main Street at Mountain Avenue in Malden, MA.

Splits and Phases: 3: Mountain Ave & Main St



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	26	137	34	79	283	59	27	303	43	46	475	51
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	14	12	12	12	12	10	10	9	9	10	8
Total Lost time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Lane Util. Factor		1.00			1.00			1.00	1.00		1.00	1.00
Frpb, ped/bikes		0.99			0.99			1.00	0.95		1.00	0.97
Flpb, ped/bikes		1.00			1.00			1.00	1.00		1.00	1.00
Frt		0.98			0.98			1.00	0.85		1.00	0.85
Flt Protected		0.99			0.99			0.99	1.00		0.99	1.00
Satd. Flow (prot)		1900			1627			1466	1321		1499	1309
Flt Permitted		0.91			0.90			0.89	1.00		0.92	1.00
Satd. Flow (perm)		1736			1475			1312	1321		1383	1309
Peak-hour factor, PHF	0.72	0.80	0.77	0.90	0.91	0.82	0.61	0.79	0.90	0.77	0.94	0.67
Adj. Flow (vph)	36	171	44	88	311	72	44	384	48	60	505	76
RTOR Reduction (vph)	0	15	0	0	13	0	0	0	18	0	0	22
Lane Group Flow (vph)	0	236	0	0	458	0	0	428	30	0	565	54
Confl. Peds. (#/hr)	24		19	19		24	3		12	12		3
Confl. Bikes (#/hr)						1			2			1
Heavy Vehicles (%)	5%	2%	1%	1%	0%	3%	2%	9%	3%	4%	6%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	5	0	0	5
Parking (#/hr)					0			0			0	
Turn Type	Perm			Perm			Perm		Perm	Perm		Perm
Protected Phases		4			4			2			2	
Permitted Phases	4			4			2		2	2		2
Actuated Green, G (s)		16.4			16.4			21.4	21.4		21.4	21.4
Effective Green, g (s)		16.4			16.4			21.4	21.4		21.4	21.4
Actuated g/C Ratio		0.34			0.34			0.45	0.45		0.45	0.45
Clearance Time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Vehicle Extension (s)		2.0			2.0			2.0	2.0		2.0	2.0
Lane Grp Cap (vph)		596			506			587	591		619	586
v/s Ratio Prot												
v/s Ratio Perm		0.14			c0.31			0.33	0.02		c0.41	0.04
v/c Ratio		0.40			0.90			0.73	0.05		0.91	0.09
Uniform Delay, d1		11.9			15.0			10.8	7.5		12.3	7.6
Progression Factor		1.00			1.00			1.00	1.00		1.00	1.00
Incremental Delay, d2		0.2			19.2			3.8	0.0		17.6	0.0
Delay (s)		12.1			34.1			14.7	7.5		29.9	7.6
Level of Service		B			C			B	A		C	A
Approach Delay (s)		12.1			34.1			13.9			27.3	
Approach LOS		B			C			B			C	

Intersection Summary			
HCM Average Control Delay	23.5	HCM Level of Service	C
HCM Volume to Capacity ratio	0.91		
Actuated Cycle Length (s)	47.8	Sum of lost time (s)	10.0
Intersection Capacity Utilization	92.3%	ICU Level of Service	F
Analysis Period (min)	15		

Description: Main Street at Mountain Avenue in Malden, MA.

c Critical Lane Group

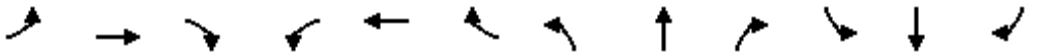
Timings
3: Mountain Ave & Main St

8/26/2011

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations										
Volume (vph)	60	189	34	131	17	467	49	71	368	48
Turn Type	Perm		Perm		Perm		Perm	Perm		Perm
Protected Phases		4		4		2			2	
Permitted Phases	4		4		2		2	2		2
Detector Phase	4	4	4	4	2	2	2	2	2	2
Switch Phase										
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	19.0	19.0	19.0	19.0	17.0	17.0	17.0	17.0	17.0	17.0
Total Split (s)	19.0	19.0	19.0	19.0	31.0	31.0	31.0	31.0	31.0	31.0
Total Split (%)	38.0%	38.0%	38.0%	38.0%	62.0%	62.0%	62.0%	62.0%	62.0%	62.0%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Lead/Lag										
Lead-Lag Optimize?										
Recall Mode	Ped	Ped	Ped	Ped	Ped	Ped	Ped	Ped	Ped	Ped

Intersection Summary
Cycle Length: 50
Actuated Cycle Length: 45
Natural Cycle: 55
Control Type: Actuated-Uncoordinated
Description: Main Street at Mountain Avenue in Malden, MA.

Splits and Phases: 3: Mountain Ave & Main St



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	60	189	51	34	131	50	17	467	49	71	368	48
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	14	12	12	12	12	10	10	9	10	10	9
Total Lost time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Lane Util. Factor		1.00			1.00			1.00	1.00		1.00	1.00
Frpb, ped/bikes		0.99			0.99			1.00	0.95		1.00	0.95
Flpb, ped/bikes		1.00			1.00			1.00	1.00		1.00	1.00
Frt		0.98			0.96			1.00	0.85		1.00	0.85
Flt Protected		0.99			0.99			1.00	1.00		0.99	1.00
Satd. Flow (prot)		1909			1611			1562	1355		1535	1376
Flt Permitted		0.88			0.91			0.97	1.00		0.79	1.00
Satd. Flow (perm)		1704			1482			1514	1355		1222	1376
Peak-hour factor, PHF	0.75	0.86	0.85	0.85	0.91	0.74	0.71	0.96	0.61	0.81	0.91	0.81
Adj. Flow (vph)	80	220	60	40	144	68	24	486	80	88	404	59
RTOR Reduction (vph)	0	14	0	0	25	0	0	0	28	0	0	22
Lane Group Flow (vph)	0	346	0	0	227	0	0	510	52	0	492	37
Confl. Peds. (#/hr)	15		22	22		15	14		16	16		14
Confl. Bikes (#/hr)			1						4			
Heavy Vehicles (%)	1%	1%	3%	0%	0%	0%	0%	2%	0%	2%	3%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	4	0	0	2
Parking (#/hr)					0			0			0	
Turn Type	Perm			Perm			Perm		Perm	Perm		Perm
Protected Phases		4			4			2			2	
Permitted Phases	4			4			2		2	2		2
Actuated Green, G (s)		14.2			14.2			20.6	20.6		20.6	20.6
Effective Green, g (s)		14.2			14.2			20.6	20.6		20.6	20.6
Actuated g/C Ratio		0.32			0.32			0.46	0.46		0.46	0.46
Clearance Time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Vehicle Extension (s)		2.0			2.0			2.0	2.0		2.0	2.0
Lane Grp Cap (vph)		540			470			696	623		562	633
v/s Ratio Prot												
v/s Ratio Perm		c0.20			0.15			0.34	0.04		c0.40	0.03
v/c Ratio		0.64			0.48			0.73	0.08		0.88	0.06
Uniform Delay, d1		13.1			12.3			9.9	6.8		10.9	6.7
Progression Factor		1.00			1.00			1.00	1.00		1.00	1.00
Incremental Delay, d2		2.0			0.3			3.4	0.0		13.8	0.0
Delay (s)		15.1			12.6			13.3	6.8		24.8	6.7
Level of Service		B			B			B	A		C	A
Approach Delay (s)		15.1			12.6			12.4			22.8	
Approach LOS		B			B			B			C	

Intersection Summary			
HCM Average Control Delay	16.3	HCM Level of Service	B
HCM Volume to Capacity ratio	0.78		
Actuated Cycle Length (s)	44.8	Sum of lost time (s)	10.0
Intersection Capacity Utilization	85.5%	ICU Level of Service	E
Analysis Period (min)	15		

Description: Main Street at Mountain Avenue in Malden, MA.

c Critical Lane Group

APPENDIX F

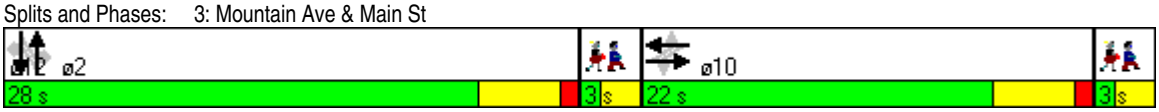
Alternative 4:
Add an Actuated, Leading Pedestrian Interval before the NB/SB and EB/WB Phases

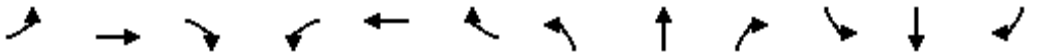
AM/PM Peak-Hour Intersection Capacity Analysis:
Main Street at Mountain Avenue, Malden

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR	ø4	ø12
Lane Configurations												
Volume (vph)	26	137	79	283	27	303	43	46	475	51		
Turn Type	Perm		Perm		Perm		Perm	Perm		Perm		
Protected Phases		10		10		2			2		4	12
Permitted Phases	10		10		2		2	2		2		
Detector Phase	10	10	10	10	2	2	2	2	2	2		
Switch Phase												
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	1.0	1.0
Minimum Split (s)	19.0	19.0	19.0	19.0	17.0	17.0	17.0	17.0	17.0	17.0	3.0	3.0
Total Split (s)	22.0	22.0	22.0	22.0	28.0	28.0	28.0	28.0	28.0	28.0	3.0	3.0
Total Split (%)	39.3%	39.3%	39.3%	39.3%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	5%	5%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0	2.0
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0		
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None	None	None	None	None	None	None	None	None	None	None	None

Intersection Summary
Cycle Length: 56
Actual Cycle Length: 51.8
Natural Cycle: 90
Control Type: Semi Act-Uncoord
Description: Main Street at Mountain Avenue in Malden, MA.

Splits and Phases: 3: Mountain Ave & Main St





Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	26	137	34	79	283	59	27	303	43	46	475	51
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	14	12	12	12	12	10	10	9	9	10	8
Total Lost time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Lane Util. Factor		1.00			1.00			1.00	1.00		1.00	1.00
Frpb, ped/bikes		0.99			0.99			1.00	0.95		1.00	0.97
Flpb, ped/bikes		1.00			1.00			1.00	1.00		1.00	1.00
Frt		0.98			0.98			1.00	0.85		1.00	0.85
Flt Protected		0.99			0.99			0.99	1.00		0.99	1.00
Satd. Flow (prot)		1899			1626			1466	1318		1499	1308
Flt Permitted		0.90			0.89			0.86	1.00		0.92	1.00
Satd. Flow (perm)		1714			1466			1260	1318		1382	1308
Peak-hour factor, PHF	0.72	0.80	0.77	0.90	0.91	0.82	0.61	0.79	0.90	0.77	0.94	0.67
Adj. Flow (vph)	36	171	44	88	311	72	44	384	48	60	505	76
RTOR Reduction (vph)	0	14	0	0	11	0	0	0	15	0	0	18
Lane Group Flow (vph)	0	237	0	0	460	0	0	428	33	0	565	58
Confl. Peds. (#/hr)	24		19	19		24	3		12	12		3
Confl. Bikes (#/hr)						1			2			1
Heavy Vehicles (%)	5%	2%	1%	1%	0%	3%	2%	9%	3%	4%	6%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	5	0	0	5
Parking (#/hr)					0			0			0	
Turn Type	Perm			Perm			Perm		Perm	Perm		Perm
Protected Phases		10			10			2			2	
Permitted Phases	10			10			2		2	2		2
Actuated Green, G (s)		17.0			17.0			23.0	23.0		23.0	23.0
Effective Green, g (s)		17.0			17.0			23.0	23.0		23.0	23.0
Actuated g/C Ratio		0.32			0.32			0.44	0.44		0.44	0.44
Clearance Time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Vehicle Extension (s)		2.0			2.0			2.0	2.0		2.0	2.0
Lane Grp Cap (vph)		556			476			553	579		607	574
v/s Ratio Prot												
v/s Ratio Perm		0.14			c0.31			0.34	0.02		c0.41	0.04
v/c Ratio		0.43			0.97			0.77	0.06		0.93	0.10
Uniform Delay, d1		13.9			17.4			12.5	8.5		13.9	8.6
Progression Factor		1.00			1.00			1.00	1.00		1.00	1.00
Incremental Delay, d2		0.2			32.0			6.1	0.0		20.9	0.0
Delay (s)		14.1			49.4			18.6	8.5		34.8	8.7
Level of Service		B			D			B	A		C	A
Approach Delay (s)		14.1			49.4			17.6			31.7	
Approach LOS		B			D			B			C	

Intersection Summary			
HCM Average Control Delay	30.2	HCM Level of Service	C
HCM Volume to Capacity ratio	0.89		
Actuated Cycle Length (s)	52.4	Sum of lost time (s)	10.0
Intersection Capacity Utilization	92.3%	ICU Level of Service	F
Analysis Period (min)	15		

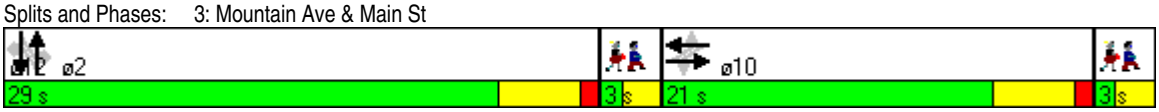
Description: Main Street at Mountain Avenue in Malden, MA.

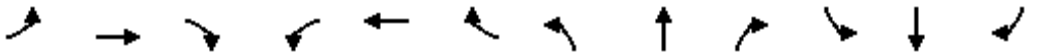
c Critical Lane Group

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR	ø4	ø12
Lane Configurations												
Volume (vph)	60	189	34	131	17	467	49	71	368	48		
Turn Type	Perm		Perm		Perm		Perm	Perm		Perm		
Protected Phases		10		10		2			2		4	12
Permitted Phases	10		10		2		2	2		2		
Detector Phase	10	10	10	10	2	2	2	2	2	2		
Switch Phase												
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	1.0	1.0
Minimum Split (s)	21.0	21.0	21.0	21.0	17.0	17.0	17.0	17.0	17.0	17.0	3.0	3.0
Total Split (s)	21.0	21.0	21.0	21.0	29.0	29.0	29.0	29.0	29.0	29.0	3.0	3.0
Total Split (%)	37.5%	37.5%	37.5%	37.5%	51.8%	51.8%	51.8%	51.8%	51.8%	51.8%	5%	5%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0	2.0
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0		
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None	None	None	None	None	None	None	None	None	None	None	None

Intersection Summary
Cycle Length: 56
Actual Cycle Length: 49.3
Natural Cycle: 60
Control Type: Semi Act-Uncoord
Description: Main Street at Mountain Avenue in Malden, MA.

Splits and Phases: 3: Mountain Ave & Main St





Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	60	189	51	34	131	50	17	467	49	71	368	48
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width	12	14	12	12	12	12	10	10	9	10	10	9
Total Lost time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Lane Util. Factor		1.00			1.00			1.00	1.00		1.00	1.00
Frpb, ped/bikes		0.99			0.99			1.00	0.94		1.00	0.95
Flpb, ped/bikes		1.00			1.00			1.00	1.00		1.00	1.00
Frt		0.98			0.96			1.00	0.85		1.00	0.85
Flt Protected		0.99			0.99			1.00	1.00		0.99	1.00
Satd. Flow (prot)		1907			1610			1562	1351		1535	1372
Flt Permitted		0.85			0.89			0.97	1.00		0.81	1.00
Satd. Flow (perm)		1647			1440			1516	1351		1247	1372
Peak-hour factor, PHF	0.75	0.86	0.85	0.85	0.91	0.74	0.71	0.96	0.61	0.81	0.91	0.81
Adj. Flow (vph)	80	220	60	40	144	68	24	486	80	88	404	59
RTOR Reduction (vph)	0	13	0	0	24	0	0	0	20	0	0	15
Lane Group Flow (vph)	0	347	0	0	228	0	0	510	60	0	492	44
Confl. Peds. (#/hr)	15		22	22		15	14		16	16		14
Confl. Bikes (#/hr)			1						4			
Heavy Vehicles (%)	1%	1%	3%	0%	0%	0%	0%	2%	0%	2%	3%	0%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	4	0	0	2
Parking (#/hr)					0			0			0	
Turn Type	Perm			Perm			Perm		Perm	Perm		Perm
Protected Phases		10			10			2			2	
Permitted Phases	10			10			2		2	2		2
Actuated Green, G (s)		13.4			13.4			24.2	24.2		24.2	24.2
Effective Green, g (s)		13.4			13.4			24.2	24.2		24.2	24.2
Actuated g/C Ratio		0.27			0.27			0.48	0.48		0.48	0.48
Clearance Time (s)		5.0			5.0			5.0	5.0		5.0	5.0
Vehicle Extension (s)		2.0			2.0			2.0	2.0		2.0	2.0
Lane Grp Cap (vph)		441			386			734	654		604	664
v/s Ratio Prot												
v/s Ratio Perm		c0.21			0.16			0.34	0.04		c0.39	0.03
v/c Ratio		0.79			0.59			0.69	0.09		0.81	0.07
Uniform Delay, d1		17.0			15.9			10.0	7.0		11.0	6.9
Progression Factor		1.00			1.00			1.00	1.00		1.00	1.00
Incremental Delay, d2		8.3			1.6			2.3	0.0		7.9	0.0
Delay (s)		25.3			17.5			12.3	7.0		18.9	6.9
Level of Service		C			B			B	A		B	A
Approach Delay (s)		25.3			17.5			11.6			17.6	
Approach LOS		C			B			B			B	

Intersection Summary			
HCM Average Control Delay	17.1	HCM Level of Service	B
HCM Volume to Capacity ratio	0.76		
Actuated Cycle Length (s)	50.0	Sum of lost time (s)	10.0
Intersection Capacity Utilization	85.5%	ICU Level of Service	E
Analysis Period (min)	15		
Description: Main Street at Mountain Avenue in Malden, MA.			

c Critical Lane Group