MEMORANDUM

To: **Donald N. Onusseit** **February 17, 2011**
Wilmington Public Works Superintendent

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

Re: **Safety and Operations Analyses at Selected Boston Region MPO Intersections: Lowell Street (Route 129) at Woburn Street in Wilmington**

This memorandum summarizes safety and operations analyses and proposes improvement strategies for the intersection of Lowell Street (Route 129) at Woburn Street in Wilmington. It contains the following sections:

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

This signalized intersection is located in the southeastern section of Wilmington and about half a mile west of Interstate 93 (I-93) Exit 38. Lowell Street, a two-lane roadway running in the east-west direction, is the major street of the intersection. It is a part of State Route 129, a principal arterial in eastern Massachusetts that runs through several communities north of Boston from Marblehead in the east to Chelmsford in the west.[1] Woburn Street, the minor street of the intersection, is a two-lane urban minor arterial. It runs from the Wilmington/Woburn border, through this intersection, to the northern section of the town. It connects Route 38 (via Eames Street) in the south and I-93 (via Concord Street), Route 62, and Route 125 (via Andover Street) in the north.

Figure 1 shows the intersection layout and the area nearby. Both approaches of Lowell Street remain a single lane shared by all movements, with a slightly flared area near the intersection in the eastbound direction. Both approaches of Woburn Street also remain a single lane shared by all movements, with a slightly flared area near the intersection in the northbound direction.

[1] Along the way, Route 129 connects Route 1, Interstate 95 (I-95)/Route 128, Route 28, I-93, Route 38, Route 62, and Route 3.

CTPS

FIGURE 1
Lowell Street (Route 129) at Woburn Street, Wilmington

Safety and Operations Improvements at Selected Intersections

There are crosswalks, apparently newly installed and with appropriate curb ramps, across the westbound and the northbound approaches. Sidewalks exist on all corners of the intersection except the northwest corner. They continue on both sides of Lowell Street in the shopping area east of the intersection, but discontinue further east and west of the intersection. On the other hand, Woburn Street has a sidewalk continuously on its west side.

The traffic signal is pre-timed and operates in two traffic phases: (1) eastbound/westbound (EB/WB) all movements (left turns permitted), and (2) northbound/southbound (NB/SB) all movements (left turns permitted). Stopwatch measurements at the intersection indicate that the traffic signal cycle is fixed at about 72 seconds (41 seconds for the EB/WB phase and 31 seconds for the NB/SB phase, including a 6-second clearance time for each phase). The signal control also includes an on-call exclusive pedestrian phase that lasts about 24 seconds. Pedestrian signal heads with push buttons are located at both ends of the two existing crosswalks. Although there is a push button on the northwest corner, there are no pedestrian signal indications for crossing either street from the corner. Right turns on red are allowed on all approaches.

All the signal heads are post-mounted and positioned about 10 to 12 feet high. They are located on the four corners of the intersection and provide each approach with at least two signal indications. Recently the town added a third signal indication to the southbound approach to improve the drivers' view from the curving section of Woburn Street north of the intersection. In the same project (2008), the town upgraded the signal indications from 8-inch incandescent to 12-inch LED (light-emitting diode), and redirected and/or relocated several signal heads (see Appendix A). However, the upgrade was an interim improvement under a limited budget. The signal system is still not actuated by approaching traffic. The post-mounted signals are visible from the Woburn Street approaches, but they are not obvious from the wider and faster Lowell Street approaches because of their low height.

The land uses in the vicinity of the intersection are single-family residences mixed with commercial developments and office parks. At the intersection, the southwest corner is an open area own by the Town, and the northwest corner is a large parking lot for school buses. East of the intersection, both sides of Lowell Street are shopping plazas that consist of a supermarket and several retail shops and offices. Further east on Lowell Street there are mainly single-family houses just before Lowell Street reaches I-93. West of the intersection, a major corporation's office park is located on the south side and several commercial developments are on the north side of Lowell Street. Further west on Lowell Street are open parklands and scattered single-family houses just before its intersection with Route 38.

North of the intersection, both sides of Woburn Street are mainly residential areas. South of the intersection, there are single-family houses on both sides of Woburn Street for about half a mile. Further south, Woburn Street reaches a major industrial and office park area that spans the Wilmington/Woburn border between I-93 and Route 38.

Lowell Street (Route 129) in the vicinity of the intersection has a speed limit of 40 miles per hour (MPH). It is reduced to 25 MPH in both directions about 300 feet (EB) and 500 feet (WB) ahead of the intersection. Woburn Street in the vicinity of the intersection has a speed limit of 30 MPH. It is reduced to 20 MPH in both directions about 300 feet (NB) and 400 feet (SB) ahead of the intersection. There is a speed limit sign of 45 MPH in the WB direction just past the

intersection, which appears to be abrupt and inconsistent with other sections of Route 129 in the area.

ISSUES AND CONCERNS

A review of the recent crash data from 2006 to 2008 indicates that the intersection has a high number of crashes and a crash rate much higher than other signalized intersections in the area (see the next section for further analysis).

The intersection is congested during peak periods on almost all approaches, depending on the peak direction. As a principal arterial in the region, Lowell Street has heavy traffic in both directions during peak periods. Traffic frequently backs up in the westbound direction in the AM peak hour and in the eastbound direction in the PM peak hour. On Woburn Street, traffic is heavy on the SB approach in the AM peak hour and on the NB approach in the PM peak hour.

Given the incapability of adapting to traffic demand, the pre-timed signals appear to operate effectively during the peak periods. However, they may not operate effectively in the off-peak periods, as the signals would idle in green lights when the designated street is already clear.[2] Sometimes drivers waiting at the intersection may be confused by the late signal responses and behave aggressively. A fully actuated traffic signal system would operate effectively in all time periods.

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

- High number of crashes and high crash rate at the intersection
- Outdated traffic signal system, not actuated by traffic demand
- No crosswalk connecting the sidewalks on the west side of Woburn Street across the intersection
- Traffic congestion during peak hours, especially on Lowell Street

CRASH DATA ANALYSIS

Based on the 2006–2008 MassDOT Registry of Motor Vehicles Division crash data, Table 1 shows that on average nearly 20 crashes occurred at the intersection each year. About one-third (36%) of the total crashes resulted in personal injuries. The crash types consist of over 60% angle collisions, over 20% rear-end collisions, nearly 15% of single-vehicle collisions, and about 5% other types (one single vehicle crash and one unknown). About 20% of the total crashes occurred during weekday peak periods. About 15% of the total crashes occurred in wet or icy conditions. Over 15% of the total crashes occurred in dark conditions.

Crash rate[3] is another effective tool for examining the relative safety of a particular location. Based on the above data and the recently collected traffic volume data, the crash rate for this intersection is calculated as 2.12 (see Appendix B for the calculation sheet). The rate is much

[2] Field observations during off-peak periods on a Saturday and a Monday indicate quite a few such occasions.

[3] Crash rates normalize crash frequency (crashes per year) by 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.

higher than the average rate for the signalized locations in MassDOT Highway Division's District 4, which is estimated to be 0.78.[4]

TABLE 1
Summary of Crash Data (2006–2008)

Statistics Period		2006	2007	2008	2006–08	Average
Total number of crashes		22	16	21	59	20
Severity	Property damage only	8	9	13	30	10
	Personal injury	10	5	6	21	7
	Fatality	0	0	0	0	0
	Not reported	4	2	2	8	3
Collision Type	Angle	14	15	8	37	12
	Rear-end	3	1	9	13	4
	Sideswipe	4	1	3	8	3
	Head-on	0	0	0	0	0
	Single vehicle	1	0	0	1	0
	Not reported	0	0	1	1	0
Crashes involving pedestrian(s)		0	0	0	0	0
Crashes involving cyclist(s)		0	0	0	0	0
Occurred during weekday peak periods*		5	3	4	12	4
Wet or icy pavement conditions		4	1	3	8	3
Dark/lighted conditions		5	3	2	10	3

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

INTERSECTION CAPACITY ANALYSIS

Staff collected turning-movement counts at the intersection on May 19, 2010. The data were recorded in 15-minute intervals for the peak traffic periods in the morning, from 7:00 to 9:00, and in the evening, from 4:00 to 6:00. The intersection carried about 2,050 vehicles in the morning peak hour, from 7:00 to 8:00, and about 2,300 vehicles in the evening peak hour, from 5:00 to 6:00 (see Table 2). About 3 pedestrians and 1 pedestrian were observed during the AM peak hour and the PM peak hour, respectively. No bicyclists were observed in either the AM or the PM peak hour.[5]

Based on the turning-movement counts and the signal timings measured at the site, the intersection capacity was analyzed using an intersection capacity analysis program, Synchro.[6] The program indicated that the intersection operates at an overall level of service (LOS) E with an average delay of over one minute per vehicle in both the AM and PM peak hours (see Table

[4] The average crash rates estimated by the MassDOT Highway Division are based upon a database that contains intersection crash rates submitted to the Highway Division as part of a 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.

[5] It was raining lightly in the AM peak hour and heavily in the PM peak hour.

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

3). The level-of-service criteria are based on the Highway Capacity Manual 2000.[7] Detailed analysis settings and results for both the AM and PM peak hour are included in Appendix C.

TABLE 2
AM and PM Peak-Hour Traffic Volumes and Pedestrian Crossings

Street name		**Lowell Street**						**Woburn Street**						**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	24	606	140	123	378	33	39	59	52	134	392	72	2050
	Approach volume	770			532			150			598			
	Pedestrian crossings	0			0			1			2			3
PM peak hour	Turning volume	85	665	82	52	470	124	101	342	138	75	92	65	2291
	Approach volume	832			646			581			232			
	Pedestrian crossings	0			0			0			1			1

TABLE 3
Intersection Capacity Analysis, Existing Conditions

Street name		**Lowell Street**						**Woburn Street**						**Overall**
Direction		**Eastbound**			**Westbound**			**Northbound**			**Southbound**			
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM peak hour	LOS	**D**			**F**			**C**			**F**			**E**
	Delay (sec/veh)	41			117			21			91			74
PM peak hour	LOS	**F**			**C**			**F**			**C**			**E**
	Delay (sec/veh)	103			34			83			33			71

As the analysis shows, traffic on the WB approach endures extensive delays in the AM peak hour, as the WB left turns were frequently deterred by the heavy EB through traffic and block the entire approach. In the PM peak, the same situation occurs in the opposite direction and traffic on the EB approach endures extensive delays. On Woburn Street, traffic on the SB approach endures noticeable delays in the AM peak hour and traffic on the NB approach endures noticeable delays in the PM peak hour.

ANALYSES OF IMPROVEMENT ALTERNATIVES

To improve traffic operations at this intersection, we examined a number of traffic signal and geometric design strategies. The analyses were performed progressively, from simple to more involved modifications in the improvement alternatives. As mentioned earlier, the intersection capacity was evaluated using the Synchro optimization and simulation software.

A basic assumption for all the alternatives is a fully actuated traffic signal system with pedestrian signal heads and push buttons in place of the existing outdated system. With the actuated signal

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

system, the traffic signal cycle length was extended from the existing 72 seconds to 80 seconds in order to reduce the time lost to signal changing during peak hours. An on-call exclusive pedestrian phase of 24 seconds was also assumed for all the alternatives. The alternatives tested for this intersection include:

1) Operate the upgraded signal system under the existing intersection layout and phasing sequence (two-phase EB/WB and NB/SB operation with left turns permitted)
2) Add an exclusive RT (right-turn) lane on the EB approach, and operate the upgraded signal system under the existing phasing sequence
3) Add an exclusive LT (left-turn) lane on both EB/WB approaches, and put in a protected/permissive LT phase prior to the existing EB/WB phase
4) Add an exclusive RT (right-turn) lane on the EB approach and an exclusive LT (left-turn) lane on both EB/WB approaches, and incorporate a protected/permissive EB/WB LT phase
5) Add an exclusive LT (left-turn) lane on both NB/SB approaches, and put in a protected/permissive LT phase prior to the existing NB/SB phase

Table 4 summarizes the intersection capacity analyses for the six alternatives. Detailed analysis settings and results for both the AM and PM peak hours for the alternatives are included in Appendices D to H separately. As Table 4 shows, traffic operations at the intersection would be improved noticeably by simply upgrading the signal system (Alternative 1), especially the operations on Lowell Street.

Alternative 2 was developed in an attempt to utilize the open space in the southwest quadrant to address the relatively high EB right-turn volume in the peak hours. However, Synchro tests show that it would not improve, but rather deteriorate, traffic operations on all other approaches, except the EB approach itself. Ironically, adding the EB-RT lane would facilitate traffic flow on the EB approach, which it in turn would seriously deter the WB left turns and consequently impede traffic on the entire WB approach.

Adding an LT lane on both the EB and WB approaches (Alternative 3) would improve the intersection traffic operations significantly in the PM peak hour, but only marginally in the AM peak hour. The EB approach in the AM peak hour would inversely deteriorate because the high EB through and right-turn traffic would still share a lane, with limited green time (less than the simple two-phase operation in Alternative 1) in each traffic cycle.

With the available space in the southwest quadrant, Alternative 4 (adding an EB-LT lane on top of Alternative 3) was a logical next option to pursue. Synchro tests show that it would significantly improve traffic operations at the intersection in both the AM and PM peak hours. All the approaches would operate at a desirable LOS C or LOS D in the peak hours, except the SB approach in the AM peak hour (acceptable LOS E).

Alternative 5 (adding a LT lane on the NB and SB approaches) was developed to test if it can shift some NB/SB phase time to the EB/WB phase and maintain the existing EB/WB layout. The expansion appears to be feasible by using the open space/parking lot in the southwest/northwest quadrant and realigning Woburn Street slightly to the west. Synchro tests show that it would achieve similar but slightly less significant improvement than Alternative 4. Especially in the PM peak hour, it would not improve the congested EB and NB approaches to a desirable LOS C or

LOS D as Alternative 4 would. In terms of safety benefits, Alternative 4 would be more beneficial than Alternative 5, as the LT pockets are placed on the higher volume and higher speed Lowell Street.

TABLE 4
Intersection Capacity Analyses of Improvement Alternatives

Street name		**Lowell Street**		**Woburn Street**		**Overall**
Approach		**Eastbound**	**Westbound**	**Northbound**	**Southbound**	
AM peak hour	Existing	D/41	F/117	C/21	F/91	E/74
	Alternative 1	C/29	D/50	C/23	F/110	E/58
	Alternative 2	B/15	F/91	C/27	F/170	F/81
	Alternative 3	E/70	C/32	C/22	F/95	E/64
	Alternative 4	D/37	C/35	B/19	E/60	D/42
	Alternative 5	C/26	D/40	C/24	E/78	D/45
PM peak hour	Existing	F/103	C/34	F/83	C/33	E/71
	Alternative 1	E/63	C/27	F/81	C/33	D/54
	Alternative 2	C/25	E/66	F/158	E/57	E/73
	Alternative 3	D/48	C/33	E/64	C/30	D/46
	Alternative 4	C/34	C/35	D/55	C/28	D/39
	Alternative 5	E/56	C/26	E/78	C/29	D/50

Note Performance measures: Level of Service (A to F)/Average Delay (seconds per vehicle)
Alternative 1: Operate the upgraded signal system under the existing intersection layout and phasing sequence
Alternative 2: Add an EB-RT, and operate the upgraded signal system under the existing phasing sequence
Alternative 3: Add a LT lane on EB/WB approaches, and add a protected/permissive EB/WB LT phase in each traffic cycle
Alternative 4: Add an EB-RT lane and add a LT lane on EB/WB approaches, and add a protected/permissive EB/WB LT phase in each traffic cycle
Alternative 5: Add a LT lane on NB/SB approaches, and add a protected/permissive NB/SB LT phase in the traffic cycle

The above analyses indicate that simply upgrading to a fully actuated signal system with no major geometry modifications (Alternative 1) would noticeably improve traffic operations at the intersection. Alternative 4 would be most beneficial among the alternatives with intersection layout modifications. At this preliminary planning stage, it appears that Alternative 4 is potential by using the open space in the southwest quadrant and rearranging and realigning Lowell Street layout within its right-of-way or with a slight expansion.[8]

In addition, a future-year scenario of 10% growth over a 20-year planning horizon was tested for the two alternatives.[9] Synchro tests show that under the 2030 projected traffic conditions Alternative 1 would deteriorate to LOS F with an average delay of about one and half minutes in both the AM and PM peak hours. With the expanded intersection capacity, Alternative 4 would operate at acceptable LOS E with an average delay of slightly less than a minute in both the AM and PM peak hours under the projected traffic conditions. Meanwhile, not shown in the capacity

[8] The State Road Inventory File indicates that Lowell Street in the intersection vicinity has a surface width of 26 feet with a right-of-way (ROW) width of 60 feet. Adding an 11-foot wide LT lane appears to be potential within the ROW. If it requires some land takings, it would be minimal and would not affect private homes.

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

analyses, Alternative 4 would be more beneficial than Alternative 1 in terms of traffic safety as it reduces traffic congestion and provides waiting space for left turns on Lowell Street.

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 identified a number of deficiencies related to the existing signal system and the intersection layout. Meanwhile, the intersection is congested during the AM and PM peak hours. To improve traffic operations, the study examined a number of traffic signal and geometric design strategies.

The improvement alternatives were developed and analyzed progressively from simple to more involved modifications of the intersection layout. The alternatives tested for this intersection include:

1) Operate the upgraded signal system under the existing intersection layout and phasing sequence
2) Add an exclusive RT lane on the EB approach, and operate the upgraded signal system under the existing phasing sequence
3) Add an exclusive LT lane on both EB/WB approaches, and put in a protected/permissive LT phase prior to the existing EB/WB phase
4) Add an exclusive EB-RT lane and an exclusive LT lane on both EB/WB approaches, and incorporate a protected/permissive EB/WB LT phase
5) Add an exclusive LT lane on both NB/SB approaches, and put in a protected/permissive LT phase prior to the existing NB/SB phase

The analyses found that simply upgrading to a fully actuated signal system (Alternative 1) would noticeably improve traffic operations at the intersection. Adding an EB-RT lane and adding a LT lane on both the EB and WB approaches (Alternative 4) would be most beneficial in terms of traffic operations and safety among all the alternatives. At this preliminary planning stage, it appears that the expansion is feasible by using the open space in the southwest quadrant and rearranging and realigning the Lowell Street layout within its right-of-way or with a slight expansion.

The study also examined the two alternatives under projected traffic conditions in 2030 and found that in Alternative 1 the level of service would deteriorate to LOS F, with extensive delays on almost all the approaches in peak hours. In Alternative 4, traffic would operate at acceptable LOS E, with acceptable delays (as an urban intersection) under the projected traffic conditions.

The choice of Alternative 1 or Alternative 4 depends on the feasibility of the intersection expansion, which should be further examined in the functional design stage. At this preliminary planning stage, it appears that Alternative 4 could potentially be implemented, by using the open space (owned by the town) in the southwest quadrant and rearranging and realigning the Lowell Street layout within its right-of-way or with a slight expansion.

The most essential improvement for this intersection is to upgrade the outdated signal system. The new signal system should include the following major features:

- Install a fully actuated traffic signal system with necessary equipment update

- Replace the existing post-mounted signals with overhead signal indications supported by mast arms, which can be clearly viewed on all approaches from a distance
- Install crosswalks and curb cuts/ramps on the eastbound and the southbound approaches
- Install a staging area for pedestrians at the northwest corner of the intersection[10]
- Include pre-emption function for emergency vehicles to pass through the intersection
- Install accessible (audible) countdown pedestrian signals

If Alternative 4 is found feasible in the functional design stage, the following features should be considered:

- Install sufficient storage space, at least 150 feet, for EB/WB left turns
- Channelize EB-RT lane to reduce traffic conflicts and shorten pedestrian crossing distance
- Provide sufficient shoulders on both streets for bikes

The entire section of Route 129 from Route 38 to Woburn Street (not including this intersection) was recently rehabilitated. The intersection of Route 129 at Route 38 and a few other locations in the section were reconstructed and upgraded with new overhead signals. As a major intersection on Route 129 in the area, this intersection should also be reconstructed and upgraded with a fully actuated signal system and overhead signal indications. Currently the intersection and its adjacent streets are under the jurisdiction of the Town of Wilmington. This study provides a basis for the Town to proceed with functional designs for this intersection. The Town should also work closely with MassDOT Highway District 4 for the implementation of the proposed improvements (see Appendix I for the MassDOT project implantation process).

In the immediate term, three minor improvements can be considered for the intersection. First, the speed limit sign of 45 MPH in the WB direction just past the intersection should be changed to 40 MPH and moved somewhat further away from the intersection. Second, the 25 MPH speed limit sign on the eastbound approach is too close to the intersection and should be moved about 200 feet further west.

Third, a traffic speed study for all the approaches at the intersection should be performed to examine the potential of reducing the signal clearance (yellow plus all-red time) interval from 6 seconds to 5 seconds. Synchro tests show that the clearance interval reduction would noticeably improve the intersection capacity even under the existing pretimed operation. However, it is essential to make certain that the 5-second clearance interval is sufficient for vehicles to stop or pass through the intersection safely from all approaches.

This study performed calculations with the assumption of a prevailing traffic speed 10 MPH higher than the posted speed limit on both streets and found that a 5-second clearance interval should be sufficient for this intersection under the assumed approaching speeds (see Appendix I for further discussion and detailed calculations). Most importantly, before adopting the change the Town should perform a traffic speed study (or hire a certified consultant) to validate that the prevailing speed (85th percentile speed) is not higher than 35 MPH on Lowell Street and is not higher than 30 MPH on Woburn Street.

[10] The installation of the crosswalks and the staging area would provide pedestrians a direct connection between the sidewalks on Woburn Street across the intersection and increase pedestrian safety.

Appendix A

Intersection Signal Improvements Project (Proposed May 2008)
Lowell Street at Woburn Street, Wilmington

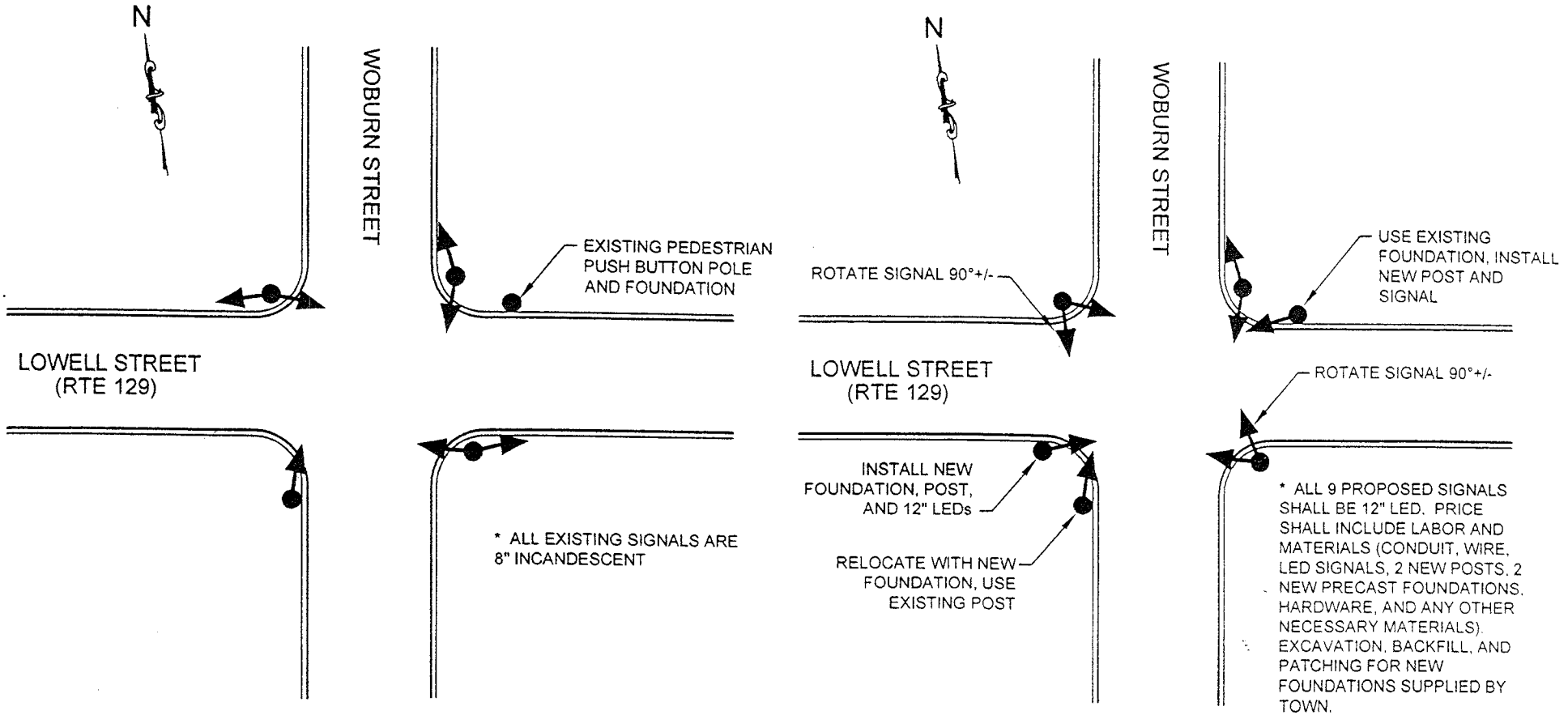


FIGURE 1 - INTERSECTION CONFIGURATION

Appendix B

Intersection Crash Rate Calculation
Lowell Street at Woburn Street, Wilmington

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Wilmington COUNT DATE : 5/19/10

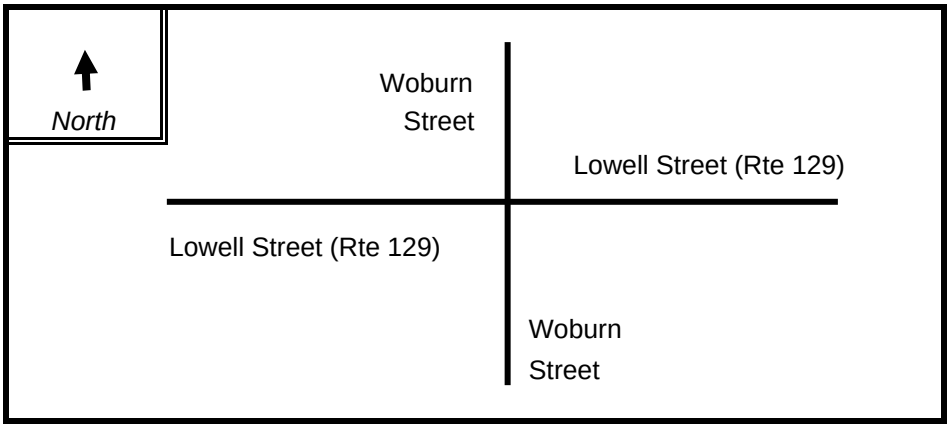
DISTRICT : 4 UNSIGNALIZED : SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Lowell Street (Route 129)

MINOR STREET(S) : Woburn Street

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) :	832	646	581	232		**2,291**

" K " FACTOR : **0.090** INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **25,456**

TOTAL # OF CRASHES : 59 # OF YEARS : 3 AVERAGE # OF CRASHES PER YEAR (**A**) : **19.67**

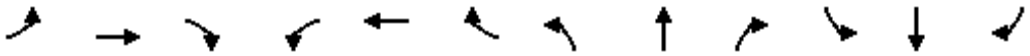
CRASH RATE CALCULATION : **2.12** RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : MassDOT District 4 Average Rate = 0.78

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

Appendix C

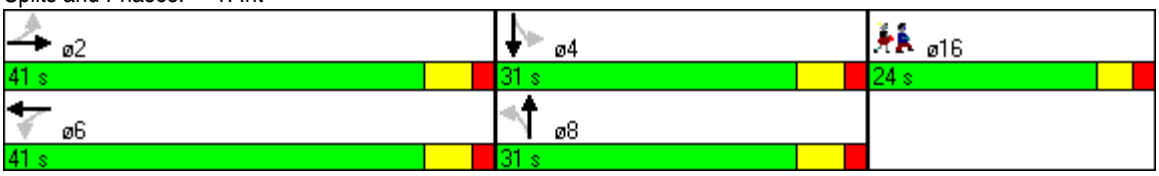
AM/PM Peak Hour Intersection Capacity Analysis
Existing Traffic Conditions
Lowell Street at Woburn Street, Wilmington



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	24	641	147	130	405	33	41	63	55	142	415	76
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
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 (%)	4%	4%	4%	5%	5%	5%	9%	9%	9%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	Perm			Perm			Perm			Perm		
Protected Phases		2			6			8			4	
Permitted Phases	2			6			8			4		
Detector Phase	2	2		6	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	20.0	20.0		20.0	20.0		20.0	20.0		20.0	20.0	
Total Split (s)	41.0	41.0	0.0	41.0	41.0	0.0	31.0	31.0	0.0	31.0	31.0	0.0
Total Split (%)	42.7%	42.7%	0.0%	42.7%	42.7%	0.0%	32.3%	32.3%	0.0%	32.3%	32.3%	0.0%
Yellow Time (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	6.0	6.0	4.0	6.0	6.0	4.0	6.0	6.0	4.0	6.0	6.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Max	Max		Max	Max		Max	Max		Max	Max	
Act Effct Green (s)		35.3			35.3			25.2			25.2	
Actuated g/C Ratio		0.46			0.46			0.33			0.33	
v/c Ratio		0.99			1.32			0.40			1.16	
Control Delay		50.8			181.2			21.3			115.5	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		50.8			181.2			21.3			115.5	
LOS		D			F			C			F	
Approach Delay		50.8			181.2			21.3			115.5	
Approach LOS		D			F			C			F	

Intersection Summary	
Cycle Length: 96	
Actuated Cycle Length: 76	
Natural Cycle: 150	
Control Type: Semi Act-Uncoord	
Maximum v/c Ratio: 1.32	
Intersection Signal Delay: 101.6	Intersection LOS: F
Intersection Capacity Utilization 130.5%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 1: Int

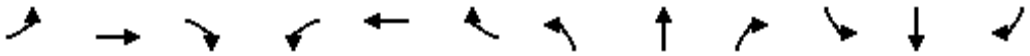


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	25%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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
Lowell St @ Woburn St, Wilmington

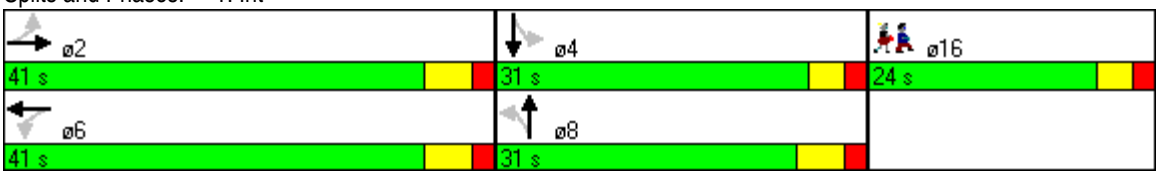
9/30/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	89	691	85	54	488	129	105	356	144	79	96	68
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	1%	1%	1%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	Perm			Perm			Perm			Perm		
Protected Phases		2			6			8			4	
Permitted Phases	2			6			8			4		
Detector Phase	2	2		6	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	20.0	20.0		20.0	20.0		20.0	20.0		20.0	20.0	
Total Split (s)	41.0	41.0	0.0	41.0	41.0	0.0	31.0	31.0	0.0	31.0	31.0	0.0
Total Split (%)	42.7%	42.7%	0.0%	42.7%	42.7%	0.0%	32.3%	32.3%	0.0%	32.3%	32.3%	0.0%
Yellow Time (s)	4.0	4.0		4.0	4.0		4.0	4.0		3.0	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	6.0	6.0	4.0	6.0	6.0	4.0	6.0	6.0	4.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Max	Max		Max	Max		Max	Max		Max	Max	
Act Effct Green (s)		35.3			35.3			25.2			26.3	
Actuated g/C Ratio		0.46			0.46			0.33			0.35	
v/c Ratio		1.21			0.92			1.12			0.66	
Control Delay		129.7			39.2			101.7			31.1	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		129.7			39.2			101.7			31.1	
LOS		F			D			F			C	
Approach Delay		129.7			39.2			101.7			31.1	
Approach LOS		F			D			F			C	

Intersection Summary	
Cycle Length: 96	
Actuated Cycle Length: 76	
Natural Cycle: 150	
Control Type: Semi Act-Uncoord	
Maximum v/c Ratio: 1.21	
Intersection Signal Delay: 87.1	Intersection LOS: F
Intersection Capacity Utilization 112.8%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 1: Int



Lane Group	ø16
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	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	25%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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 D

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 1
Upgrade Signal System with Existing Layout and Phasing Sequence
Lowell Street at Woburn Street, Wilmington

Intersection Capacity Analysis
Lowell St @ Woburn St, Wilmington

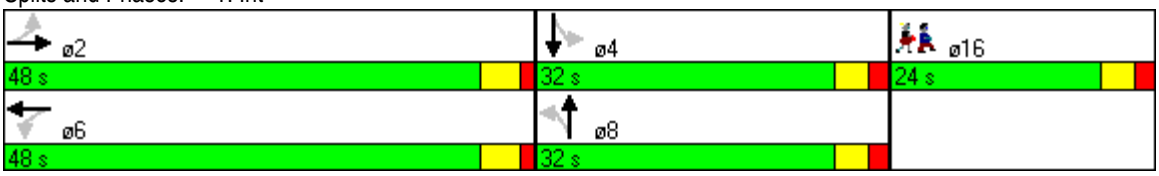
10/6/2010

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	24	606	140	123	378	31	39	59	52	134	392	72
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
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 (%)	4%	4%	4%	5%	5%	5%	9%	9%	9%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	Perm			Perm			Perm			Perm		
Protected Phases		2			6			8			4	
Permitted Phases	2			6			8			4		
Detector Phase	2	2		6	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	20.0	20.0		20.0	20.0		20.0	20.0		20.0	20.0	
Total Split (s)	48.0	48.0	0.0	48.0	48.0	0.0	32.0	32.0	0.0	32.0	32.0	0.0
Total Split (%)	46.2%	46.2%	0.0%	46.2%	46.2%	0.0%	30.8%	30.8%	0.0%	30.8%	30.8%	0.0%
Yellow Time (s)	3.5	3.5		3.5	3.5		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.5	1.5		1.5	1.5		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Min	Min		Min	Min		None	None		None	None	
Act Effct Green (s)		43.3			43.3			27.2			27.2	
Actuated g/C Ratio		0.52			0.52			0.32			0.32	
v/c Ratio		0.84			0.95			0.38			1.14	
Control Delay		28.8			49.7			23.1			110.1	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		28.8			49.7			23.1			110.1	
LOS		C			D			C			F	
Approach Delay		28.8			49.7			23.1			110.1	
Approach LOS		C			D			C			F	

Intersection Summary

Cycle Length: 104
Actuated Cycle Length: 84
Natural Cycle: 150
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 1.14
Intersection Signal Delay: 57.6 Intersection LOS: E
Intersection Capacity Utilization 121.9% ICU Level of Service H
Analysis Period (min) 15

Splits and Phases: 1: Int

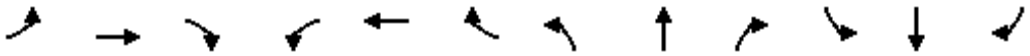


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	23%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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
Lowell St @ Woburn St, Wilmington

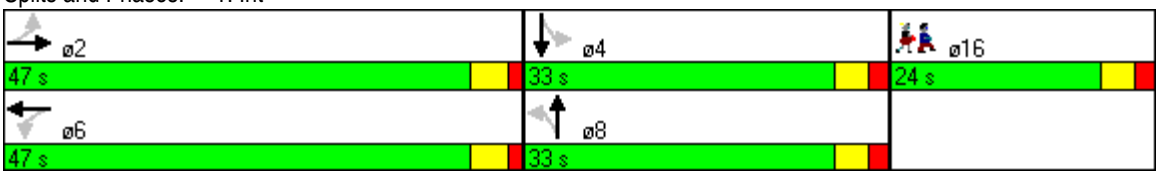
10/6/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	85	665	82	52	470	129	101	342	138	75	92	65
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	1%	1%	1%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	Perm			Perm			Perm			Perm		
Protected Phases		2			6			8			4	
Permitted Phases	2			6			8			4		
Detector Phase	2	2		6	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	20.0	20.0		20.0	20.0		20.0	20.0		20.0	20.0	
Total Split (s)	47.0	47.0	0.0	47.0	47.0	0.0	33.0	33.0	0.0	33.0	33.0	0.0
Total Split (%)	45.2%	45.2%	0.0%	45.2%	45.2%	0.0%	31.7%	31.7%	0.0%	31.7%	31.7%	0.0%
Yellow Time (s)	3.5	3.5		3.5	3.5		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.5	1.5		1.5	1.5		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Min	Min		Min	Min		None	None		None	None	
Act Effct Green (s)		42.3			42.3			28.2			28.2	
Actuated g/C Ratio		0.50			0.50			0.34			0.34	
v/c Ratio		1.03			0.79			1.05			0.65	
Control Delay		62.7			27.1			80.9			33.3	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		62.7			27.1			80.9			33.3	
LOS		E			C			F			C	
Approach Delay		62.7			27.1			80.9			33.3	
Approach LOS		E			C			F			C	

Intersection Summary	
Cycle Length: 104	
Actuated Cycle Length: 84	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.05	
Intersection Signal Delay: 54.2	Intersection LOS: D
Intersection Capacity Utilization 107.2%	ICU Level of Service G
Analysis Period (min) 15	

Splits and Phases: 1: Int



Lane Group	ø16
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	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	23%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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 E

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 2
Add an EB-RT Lane and Operate Traffic Signals with Existing Phasing Sequence
Lowell Street at Woburn Street, Wilmington

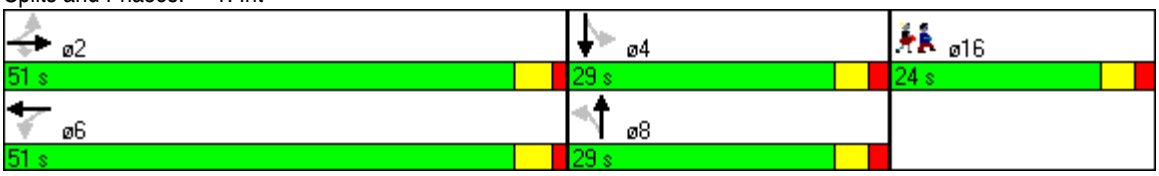
Intersection Capacity Analysis
Lowell St @ Woburn St, Wilmington

10/6/2010

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	24	606	140	123	378	31	39	59	52	134	392	72
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
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 (%)	4%	4%	4%	5%	5%	5%	9%	9%	9%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	Perm		Perm	Perm			Perm			Perm		
Protected Phases		2			6			8			4	
Permitted Phases	2		2	6			8			4		
Detector Phase	2	2	2	6	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	20.0	20.0	20.0	20.0	20.0		20.0	20.0		20.0	20.0	
Total Split (s)	51.0	51.0	51.0	51.0	51.0	0.0	29.0	29.0	0.0	29.0	29.0	0.0
Total Split (%)	49.0%	49.0%	49.0%	49.0%	49.0%	0.0%	27.9%	27.9%	0.0%	27.9%	27.9%	0.0%
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.5	1.5	1.5	1.5	1.5		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Min	Min	Min	Min	Min		None	None		None	None	
Act Effct Green (s)		46.4	46.4		46.4			24.2			24.2	
Actuated g/C Ratio		0.55	0.55		0.55			0.29			0.29	
v/c Ratio		0.64	0.16		1.10			0.45			1.28	
Control Delay		18.0	2.8		90.9			27.1			170.2	
Queue Delay		0.0	0.0		0.0			0.0			0.0	
Total Delay		18.0	2.8		90.9			27.1			170.2	
LOS		B	A		F			C			F	
Approach Delay		15.2			90.9			27.1			170.2	
Approach LOS		B			F			C			F	

Intersection Summary	
Cycle Length: 104	
Actuated Cycle Length: 84	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.28	
Intersection Signal Delay: 81.0	Intersection LOS: F
Intersection Capacity Utilization 113.4%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 1: Int

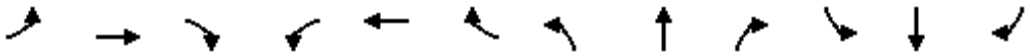


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	23%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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
Lowell St @ Woburn St, Wilmington

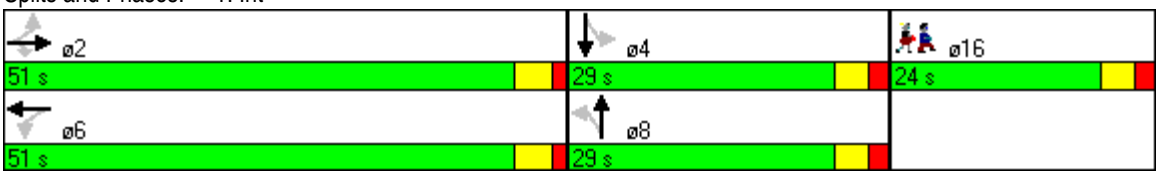
10/6/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	85	665	82	52	470	129	101	342	138	75	92	65
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	1%	1%	1%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	Perm		Perm	Perm			Perm			Perm		
Protected Phases		2			6			8			4	
Permitted Phases	2		2	6			8			4		
Detector Phase	2	2	2	6	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	20.0	20.0	20.0	20.0	20.0		20.0	20.0		20.0	20.0	
Total Split (s)	51.0	51.0	51.0	51.0	51.0	0.0	29.0	29.0	0.0	29.0	29.0	0.0
Total Split (%)	49.0%	49.0%	49.0%	49.0%	49.0%	0.0%	27.9%	27.9%	0.0%	27.9%	27.9%	0.0%
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.5	1.5	1.5	1.5	1.5		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Min	Min	Min	Min	Min		None	None		None	None	
Act Effct Green (s)		46.4	46.4		46.4			24.2			24.2	
Actuated g/C Ratio		0.55	0.55		0.55			0.29			0.29	
v/c Ratio		0.83	0.09		1.04			1.25			0.86	
Control Delay		26.8	4.2		66.4			158.0			56.8	
Queue Delay		0.0	0.0		0.0			0.0			0.0	
Total Delay		26.8	4.2		66.4			158.0			56.8	
LOS		C	A		E			F			E	
Approach Delay		24.6			66.4			158.0			56.8	
Approach LOS		C			E			F			E	

Intersection Summary	
Cycle Length: 104	
Actuated Cycle Length: 84	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.25	
Intersection Signal Delay: 73.4	Intersection LOS: E
Intersection Capacity Utilization 121.3%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 1: Int



Lane Group	ø16
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	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	23%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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	

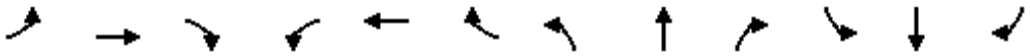
Intersection Summary

Appendix F

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 3
Add a LT Lane on EB/WB Approaches,
and Add a Protected/Permissive EB/WB LT Phase in Each Traffic Cycle
Lowell Street at Woburn Street, Wilmington

Intersection Capacity Analysis
Lowell St @ Woburn St, Wilmington

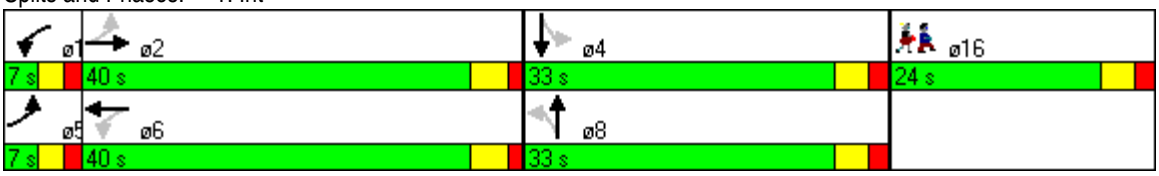
10/6/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	24	606	140	123	378	31	39	59	52	134	392	72
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
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 (%)	4%	4%	4%	5%	5%	5%	9%	9%	9%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	pm+pt			pm+pt			Perm			Perm		
Protected Phases	5	2		1	6			8			4	
Permitted Phases	2			6			8			4		
Detector Phase	5	2		1	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	2.0	4.0		2.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	7.0	20.0		7.0	20.0		20.0	20.0		20.0	20.0	
Total Split (s)	7.0	40.0	0.0	7.0	40.0	0.0	33.0	33.0	0.0	33.0	33.0	0.0
Total Split (%)	6.7%	38.5%	0.0%	6.7%	38.5%	0.0%	31.7%	31.7%	0.0%	31.7%	31.7%	0.0%
Yellow Time (s)	2.5	3.5		2.5	3.5		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.5	1.5		1.5	1.5		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	5.0	4.0	4.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag	Lead	Lag		Lead	Lag							
Lead-Lag Optimize?	Yes	Yes		Yes	Yes							
Recall Mode	None	Min		None	Min		None	None		None	None	
Act Effct Green (s)	39.3	35.3		41.8	39.7			28.2			28.2	
Actuated g/C Ratio	0.47	0.42		0.50	0.47			0.34			0.34	
v/c Ratio	0.07	1.05		0.88	0.51			0.36			1.10	
Control Delay	12.9	71.8		69.7	20.4			22.2			95.3	
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	
Total Delay	12.9	71.8		69.7	20.4			22.2			95.3	
LOS	B	E		E	C			C			F	
Approach Delay		70.0			31.8			22.2			95.3	
Approach LOS		E			C			C			F	

Intersection Summary			
Cycle Length: 104			
Actuated Cycle Length: 84			
Natural Cycle: 150			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 1.10			
Intersection Signal Delay: 64.0		Intersection LOS: E	
Intersection Capacity Utilization 98.0%		ICU Level of Service F	
Analysis Period (min) 15			

Splits and Phases: 1: Int

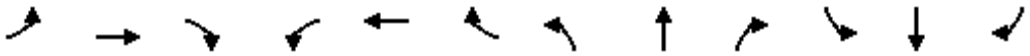


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	23%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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
Lowell St @ Woburn St, Wilmington

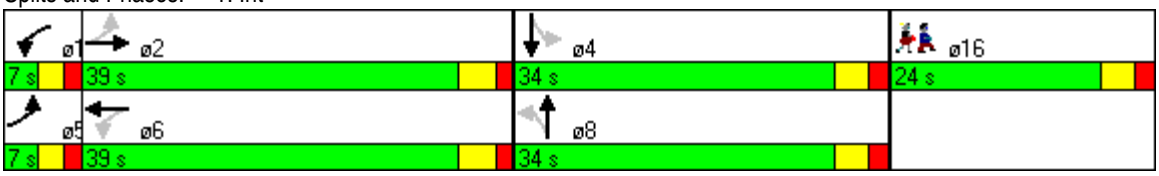
10/6/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	85	665	82	52	470	129	101	342	138	75	92	65
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	1%	1%	1%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	pm+pt			pm+pt			Perm			Perm		
Protected Phases	5	2		1	6			8			4	
Permitted Phases	2			6			8			4		
Detector Phase	5	2		1	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	2.0	4.0		2.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	7.0	20.0		7.0	20.0		20.0	20.0		20.0	20.0	
Total Split (s)	7.0	39.0	0.0	7.0	39.0	0.0	34.0	34.0	0.0	34.0	34.0	0.0
Total Split (%)	6.7%	37.5%	0.0%	6.7%	37.5%	0.0%	32.7%	32.7%	0.0%	32.7%	32.7%	0.0%
Yellow Time (s)	2.5	3.5		2.5	3.5		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.5	1.5		1.5	1.5		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	5.0	4.0	4.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag	Lead	Lag		Lead	Lag							
Lead-Lag Optimize?	Yes	Yes		Yes	Yes							
Recall Mode	None	Min		None	Min		None	None		None	None	
Act Effct Green (s)	38.6	35.8		37.7	34.4			29.3			29.3	
Actuated g/C Ratio	0.47	0.43		0.46	0.42			0.35			0.35	
v/c Ratio	0.49	0.97		0.35	0.83			0.99			0.60	
Control Delay	25.6	50.9		20.0	34.0			63.6			30.0	
Queue Delay	0.0	0.0		0.0	0.0			0.0			0.0	
Total Delay	25.6	50.9		20.0	34.0			63.6			30.0	
LOS	C	D		B	C			E			C	
Approach Delay		48.3			32.9			63.6			30.0	
Approach LOS		D			C			E			C	

Intersection Summary			
Cycle Length: 104			
Actuated Cycle Length: 82.6			
Natural Cycle: 150			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.99			
Intersection Signal Delay: 45.9		Intersection LOS: D	
Intersection Capacity Utilization 91.1%		ICU Level of Service F	
Analysis Period (min) 15			

Splits and Phases: 1: Int



Lane Group	ø16
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	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	23%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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 G

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 4
Add An EB-RT Lane and a LT Lane on EB/WB Approaches, and Add a Protected/Permissive EB/WB LT Phase in Each Traffic Cycle
Lowell Street at Woburn Street, Wilmington

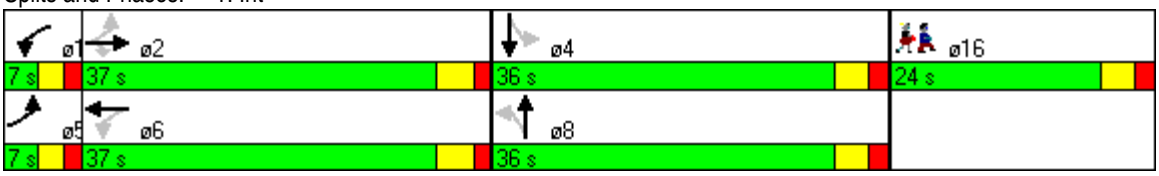
Intersection Capacity Analysis
Lowell St @ Woburn St, Wilmington

10/6/2010

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	24	606	140	123	378	31	39	59	52	134	392	72
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
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 (%)	4%	4%	4%	5%	5%	5%	9%	9%	9%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	pm+pt		Perm	pm+pt			Perm			Perm		
Protected Phases	5	2		1	6			8			4	
Permitted Phases	2		2	6			8			4		
Detector Phase	5	2	2	1	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	2.0	4.0	4.0	2.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	7.0	20.0	20.0	7.0	20.0		20.0	20.0		20.0	20.0	
Total Split (s)	7.0	37.0	37.0	7.0	37.0	0.0	36.0	36.0	0.0	36.0	36.0	0.0
Total Split (%)	6.7%	35.6%	35.6%	6.7%	35.6%	0.0%	34.6%	34.6%	0.0%	34.6%	34.6%	0.0%
Yellow Time (s)	2.5	3.5	3.5	2.5	3.5		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.5	1.5	1.5	1.5	1.5		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag	Lead	Lag	Lag	Lead	Lag							
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes							
Recall Mode	None	Min	Min	None	Min		None	None		None	None	
Act Effct Green (s)	36.3	32.3	32.3	38.8	36.7			31.2			31.2	
Actuated g/C Ratio	0.43	0.38	0.38	0.46	0.44			0.37			0.37	
v/c Ratio	0.08	0.91	0.22	0.88	0.55			0.32			0.98	
Control Delay	14.6	44.8	6.4	71.6	23.4			19.3			60.6	
Queue Delay	0.0	0.0	0.0	0.0	0.0			0.0			0.0	
Total Delay	14.6	44.8	6.4	71.6	23.4			19.3			60.6	
LOS	B	D	A	E	C			B			E	
Approach Delay		36.9			34.5			19.3			60.6	
Approach LOS		D			C			B			E	

Intersection Summary			
Cycle Length: 104			
Actuated Cycle Length: 84			
Natural Cycle: 150			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.98			
Intersection Signal Delay: 41.9		Intersection LOS: D	
Intersection Capacity Utilization 89.5%		ICU Level of Service E	
Analysis Period (min) 15			

Splits and Phases: 1: Int



Lane Group	ø16
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	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	23%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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

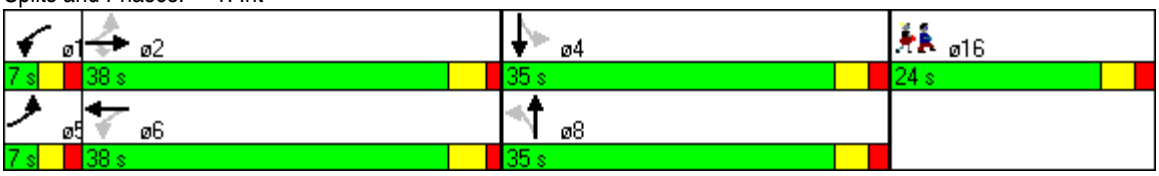
Intersection Capacity Analysis
Lowell St @ Woburn St, Wilmington

10/6/2010

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	85	665	82	52	470	129	101	342	138	75	92	65
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	1%	1%	1%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	pm+pt		Perm	pm+pt			Perm			Perm		
Protected Phases	5	2		1	6			8			4	
Permitted Phases	2		2	6			8			4		
Detector Phase	5	2	2	1	6		8	8		4	4	
Switch Phase												
Minimum Initial (s)	2.0	4.0	4.0	2.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	7.0	20.0	20.0	7.0	20.0		20.0	20.0		20.0	20.0	
Total Split (s)	7.0	38.0	38.0	7.0	38.0	0.0	35.0	35.0	0.0	35.0	35.0	0.0
Total Split (%)	6.7%	36.5%	36.5%	6.7%	36.5%	0.0%	33.7%	33.7%	0.0%	33.7%	33.7%	0.0%
Yellow Time (s)	2.5	3.5	3.5	2.5	3.5		3.0	3.0		3.0	3.0	
All-Red Time (s)	1.5	1.5	1.5	1.5	1.5		2.0	2.0		2.0	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0	4.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag	Lead	Lag	Lag	Lead	Lag							
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes							
Recall Mode	None	Min	Min	None	Min		None	None		None	None	
Act Effct Green (s)	37.6	34.8	34.8	36.7	33.4			30.3			30.3	
Actuated g/C Ratio	0.46	0.42	0.42	0.44	0.40			0.37			0.37	
v/c Ratio	0.54	0.87	0.12	0.35	0.85			0.96			0.57	
Control Delay	29.5	38.1	7.7	20.6	36.7			54.5			27.8	
Queue Delay	0.0	0.0	0.0	0.0	0.0			0.0			0.0	
Total Delay	29.5	38.1	7.7	20.6	36.7			54.5			27.8	
LOS	C	D	A	C	D			D			C	
Approach Delay		34.2			35.4			54.5			27.8	
Approach LOS		C			D			D			C	

Intersection Summary		
Cycle Length: 104		
Actuated Cycle Length: 82.6		
Natural Cycle: 140		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.96		
Intersection Signal Delay: 39.1	Intersection LOS: D	
Intersection Capacity Utilization 86.1%	ICU Level of Service E	
Analysis Period (min) 15		

Splits and Phases: 1: Int



Lane Group	ø16
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	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	23%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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	

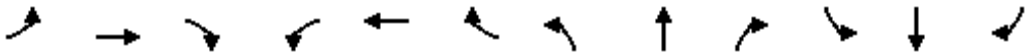
Intersection Summary

Appendix H

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 5
Add a LT Lane on NB/SB Approaches,
and Add a Protected/Permissive NB/SB LT Phase in Each Traffic Cycle
Lowell Street at Woburn Street, Wilmington

Intersection Capacity Analysis
Lowell St @ Woburn St, Wilmington

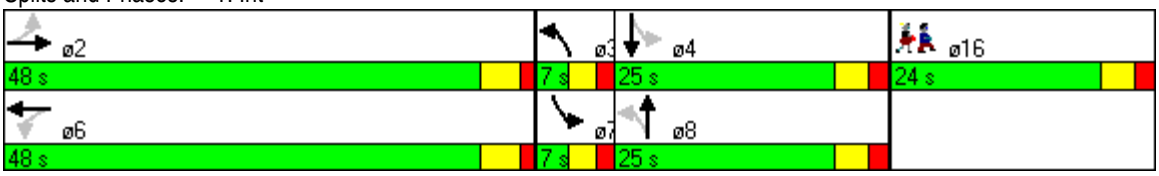
10/6/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	24	606	140	123	378	31	39	59	52	134	392	72
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
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 (%)	4%	4%	4%	5%	5%	5%	9%	9%	9%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	Perm			Perm			pm+pt			pm+pt		
Protected Phases		2			6		3	8		7	4	
Permitted Phases	2			6			8			4		
Detector Phase	2	2		6	6		3	8		7	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		3.0	4.0		3.0	4.0	
Minimum Split (s)	20.0	20.0		20.0	20.0		7.0	20.0		7.0	20.0	
Total Split (s)	48.0	48.0	0.0	48.0	48.0	0.0	7.0	25.0	0.0	7.0	25.0	0.0
Total Split (%)	46.2%	46.2%	0.0%	46.2%	46.2%	0.0%	6.7%	24.0%	0.0%	6.7%	24.0%	0.0%
Yellow Time (s)	3.5	3.5		3.5	3.5		2.5	3.0		2.5	3.0	
All-Red Time (s)	1.5	1.5		1.5	1.5		1.5	2.0		1.5	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	4.0	5.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0
Lead/Lag							Lead	Lag		Lead	Lag	
Lead-Lag Optimize?							Yes	Yes		Yes	Yes	
Recall Mode	Min	Min		Min	Min		None	None		None	None	
Act Effct Green (s)		43.6			43.6		18.1	15.5		23.0	20.3	
Actuated g/C Ratio		0.54			0.54		0.22	0.19		0.28	0.25	
v/c Ratio		0.81			0.90		0.29	0.35		0.42	1.06	
Control Delay		25.9			39.7		27.5	23.0		29.0	92.2	
Queue Delay		0.0			0.0		0.0	0.0		0.0	0.0	
Total Delay		25.9			39.7		27.5	23.0		29.0	92.2	
LOS		C			D		C	C		C	F	
Approach Delay		25.9			39.7			24.2			78.1	
Approach LOS		C			D			C			E	

Intersection Summary	
Cycle Length: 104	
Actuated Cycle Length: 81.2	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.06	
Intersection Signal Delay: 44.6	Intersection LOS: D
Intersection Capacity Utilization 114.5%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 1: Int

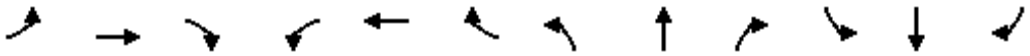


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	23%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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
Lowell St @ Woburn St, Wilmington

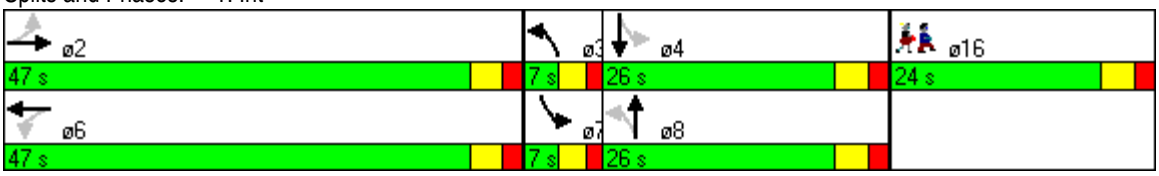
10/6/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	85	665	82	52	470	129	101	342	138	75	92	65
Confl. Peds. (#/hr)	1		1	1		1			1	1		
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	1%	1%	1%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Turn Type	Perm			Perm			pm+pt			pm+pt		
Protected Phases		2			6		3	8		7	4	
Permitted Phases	2			6			8			4		
Detector Phase	2	2		6	6		3	8		7	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		3.0	4.0		3.0	4.0	
Minimum Split (s)	20.0	20.0		20.0	20.0		7.0	20.0		7.0	20.0	
Total Split (s)	47.0	47.0	0.0	47.0	47.0	0.0	7.0	26.0	0.0	7.0	26.0	0.0
Total Split (%)	45.2%	45.2%	0.0%	45.2%	45.2%	0.0%	6.7%	25.0%	0.0%	6.7%	25.0%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		2.5	3.0		2.5	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0		1.5	2.0		1.5	2.0	
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	5.0	4.0	5.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	4.0
Lead/Lag							Lead	Lag		Lead	Lag	
Lead-Lag Optimize?							Yes	Yes		Yes	Yes	
Recall Mode	Min	Min		Min	Min		None	None		None	None	
Act Effct Green (s)		42.5			42.5		24.6	21.2		24.6	21.2	
Actuated g/C Ratio		0.51			0.51		0.30	0.26		0.30	0.26	
v/c Ratio		1.01			0.78		0.30	1.06		0.52	0.35	
Control Delay		56.0			25.8		25.0	89.1		37.1	24.7	
Queue Delay		0.0			0.0		0.0	0.0		0.0	0.0	
Total Delay		56.0			25.8		25.0	89.1		37.1	24.7	
LOS		E			C		C	F		D	C	
Approach Delay		56.0			25.8			78.0			28.7	
Approach LOS		E			C			E			C	

Intersection Summary	
Cycle Length: 104	
Actuated Cycle Length: 82.6	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.06	
Intersection Signal Delay: 50.3	Intersection LOS: D
Intersection Capacity Utilization 105.0%	ICU Level of Service G
Analysis Period (min) 15	

Splits and Phases: 1: Int



Lane Group	ø16
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	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	1.0
Minimum Split (s)	24.0
Total Split (s)	24.0
Total Split (%)	23%
Yellow Time (s)	3.0
All-Red Time (s)	2.0
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

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.

Appendix J

Review of Traffic Signal Clearance Interval
Lowell Street at Woburn Street, Wilmington

The clearance interval is the time following a green signal indication during which a yellow signal indication is displayed to warn motorists of the impending change in right of way assignment (so called the yellow change interval) and followed by an all-red interval for vehicles to clear the intersection. Yellow change intervals inconsistent with normal operating speeds create a dilemma zone in which drivers can neither stop safely nor reach the intersection before the signal turns red. Lengthening the yellow interval, within appropriate guidelines, has been shown to significantly reduce the number of inadvertent red-light violations. On the other hand, too long of a yellow interval decreases capacity of the intersection and increases delay to motorists. This in turn can cause driver frustration and may result in motorists intentionally violating the red-light and entering the intersection later.

All the existing signal phases at this intersection include a clearance (yellow change + all-red) interval of 6 seconds. Based on the commonly used ITE (Institute of Traffic Engineers) formula, the yellow clearance interval consists of reaction time, deceleration time, and time to clear the intersection.[1] The calculation for both streets of the intersection shows that a total of 5 seconds clearance time is applicable for safe operations.

The components and assumptions for the clearance time desirable for the Lowell Street approaches are:

- Reaction time = 1 second
- Deceleration time = 2.6 seconds, assuming average vehicle speed = 35 MPH (posted speed limit: 25 MPH) and average deceleration = 10 feet/sec.^{2}
- All-red time= 1.4 seconds, assuming distance to clear the intersection = 60 feet = 40 feet (Woburn Street width) + 20 feet (a vehicle length to clear the intersection)

Stopwatch measurements at the intersection estimate the existing 6-second clearance interval consists of 4-second yellow time and 2-second all-red time. The calculation indicates that a 5-second clearance interval consisting of 3.5 seconds of yellow time (reaction time plus deceleration time) and 1.5 seconds of all-red time is applicable for the Lowell Street approaches if the prevailing speed (85th percentile speed) approaching the intersection is 35 MPH or lower.

The components and assumptions for the clearance time desirable for the Woburn Street approaches are:

- Reaction time = 1 second
- Deceleration time = 2.2 seconds, assuming average vehicle speed = 30 MPH (posted speed limit: 20 MPH) and average deceleration = 10 feet/sec.^{2}
- All-red time= 1.8 seconds, assuming distance to clear the intersection = 80 feet = 60 feet (Lowell Street width) + 20 feet (a vehicle length to clear the intersection)

The calculation indicates that a 5-second clearance interval consisting of 3 seconds of yellow time (reaction time plus deceleration time) and 2 seconds of all-red time is applicable for the Woburn Street approaches if the prevailing speed approaching the intersection is 30 MPH or lower.

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[1] *Traffic Signal Clearance Interval*, Philip J. Tarnoff, ITE Journal, April 2004

The above calculation indicate that a 5-second clearance interval should be sufficient and effective if the prevailing speed is 35 MPH or lower on Lowell Street and 30 MPH or lower on Woburn Street. It is essential to validate the prevailing speed assumptions through a traffic speed study at the intersection before adopting the changes.