MEMORANDUM

To: **Ben Fehan** **February 17, 2011**
Stoughton Town Engineer

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

Re: **Safety and Operations Analyses at Selected Boston Region MPO Intersections: Central Street at Pearl Street in Stoughton**

This memorandum summarizes safety and operations analyses and proposes improvement strategies for the intersection of Central Street at Pearl Street in Stoughton. 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 about half a mile north of Stoughton Town Center. Central Street is a two-lane roadway that connects Route 24 in the east and Route 27 in the west and intersects Route 138 in the middle. Although it is classified as a minor urban arterial, it is the principal east-west roadway in the northern section of the town. Pearl Street, a two-lane roadway running from the town center to the Canton/Stoughton border in the north-south direction, functions as a minor urban arterial and serves mainly the neighborhood between Washington Street (Route 138) and Canton Street (Route 27).

Figure 1 shows the intersection layout and the area nearby. The Central Street eastbound approach remains a single lane shared by all movements, with a slightly flared area near the intersection. The Central Street westbound approach widens to include an exclusive left-turn lane and a shared lane for through traffic and right turns. Both approaches of Pearl Street have a single lane shared by all movements. There is a small traffic median (about 6 feet by 20 feet) on Central Street west of the intersection, which bears a traffic light post with signal indications for traffic from both the east and west approaches. Crosswalks are installed across all approaches except the westbound approach. Sidewalks exist on all corners of the intersection. Away from the intersection, they exist only on the north side of Central Street and the west side of Pearl Street.

CTPS

FIGURE 1
Central Street at Pearl Street, Stoughton

Safety and Operations Improvements at Selected Intersections

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). Field measurements by a stopwatch indicated that each traffic signal cycle lasts about one minute (35 seconds for the EB/WB phase and 25 seconds for the NB/SB phase, including a 5-second clearance time for each phase). Right turns on red are allowed on all approaches. A regulatory sign of "Right Turn on Red after Full Stop" is installed for the southbound approach.

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 on the traffic median on Central Street. Although they provide each approach with two or more signal indications, they are not clearly visible from far away because of their low height.

The signal control also includes an on-call exclusive pedestrian phase that lasts about 20 seconds. There are pedestrian push buttons attached to the traffic signal post at the northwest corner and on a stand-alone low post at the other three corners. But there are no pedestrian signals and the pedestrian phase is indicated by the traffic signals. During the pedestrian phase, the traffic signals first show a steady yellow light and a steady red light lasting about 7 seconds (to indicate "Walk") and then show a steady red light lasting about 13 seconds to indicate ("Flashing Don't Walk"). This type of indication can be confusing to the pedestrians and drivers who are not familiar with it.

The land use in the vicinity of the intersection is mainly residential. There are also other uses, such as institutional, office, and commercial, on both streets. At the intersection, the southwest corner is an open lawn area own by the state (Stoughton District Court), while the other corners are occupied by private homes. West of the intersection, the district court main building and an elementary school (West Elementary School) are locate on Central Street. South of the intersection, Stoughton High School is located on Pearl Street about a quarter of a mile from the intersection. A middle school (O'Donnell Middle School) is also located just west of the high school, on Cushing Street. Because these schools are so close to this intersection, a school crossing guard is usually at the intersection to direct traffic during weekday school opening and closing hours.

Further away from the intersection, the east side of Central Street crossed Route 138, where many commercial developments are located, and reaches Route 24 in the east. The north side of Pearl Street becomes Pleasant Street in Canton, which connects with other streets and reaches Canton Center (and its commuter rail station) and Interstate 95 (I-95) in further west.

ISSUES AND CONCERNS

The intersection is congested during peak periods on almost all approaches, depending on the peak direction. Because Central Street is a major arterial in the north section of Stoughton, traffic there is heavy in both directions during peak periods. In general, the peak direction is eastbound in the morning and westbound in the evening. Traffic frequently backs up in both directions in the AM peak hour and mainly in the westbound direction in the PM peak hour. Pearl Street also has heavy traffic in both directions in the AM peak hour and mainly in the southbound direction in the PM peak hour. Due to the high proportion of left turns, southbound traffic frequently backs up during peak hours.

Recent turning movement counts (see Table 2 in the intersection capacity analysis section) indicate high westbound right-turn and southbound left-turn volumes at this intersection. The right turns are about 30% to 40% of the total westbound volume, and the left turns are about 50% to 60% of the total southbound volume. There is extensive traffic flowing from Central Street east of the intersection to Pearl Street north of the intersection, and vice versa. Drivers use the intersection and its north and east legs as an alternative path to reach Canton Center, I-95, Route 138 South, Route 24, and other major routes.

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. In addition, accident reports from the Stoughton Police Department show that several crashes involved a moving vehicle hitting the traffic median on Central Street or the nearby roadside light post. The collision diagram analysis indicates that the median and its adjacent light post form a narrow passage and appear to be hazardous to some drivers, especially those from the south making a left turn or those from the east traveling at a high speed (see the next section for further analysis).

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
- No standard pedestrian signal indications
- Questionable location of the traffic median on Central Street
- Traffic congestion during peak hours, especially on Central Street
- High proportion of WB right turns and SB left turns causing traffic queues

CRASH DATA ANALYSIS

Based on the 2006–2008 MassDOT Registry of Motor Vehicles Division crash data, Table 1 shows that on average 16 crashes occurred at the intersection each year. Nearly 30% of the total crashes resulted in personal injury. The crash types consist of about 30% angle collisions, 30% rear-end collisions, nearly 30% single-vehicle collisions, and about 10% other types, including "unknown." Two crashes out of the 48 total crashes in the three-year period involved pedestrians. No crashes involved bicyclists. About 10% of the total crashes occurred during weekday peak periods; about 25% of them occurred in wet or icy conditions; and about 30% of them occurred in dark conditions.

Crash rate[1] 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 1.70 (see Appendix A for the calculation sheet). The rate is much higher than the average rate for the signalized locations in MassDOT Highway Division's District 5, which is estimated to be 0.77.[2]

---

[1] 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.

[2] 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

TABLE 1
Summary of Crash Data (2006–2008)

Statistics Period		2006	2007	2008	2006–08	Average
Total number of crashes		20	15	13	48	16
Severity	**Property damage only**	13	9	6	28	9
	Personal injury	5	3	6	14	5
	Fatality	0	0	0	0	0
	Not reported	2	3	1	6	2
Collision Type	**Angle**	8	4	3	15	5
	Rear-end	3	8	4	15	5
	Sideswipe	1	0	0	1	0
	Head-on	2	0	0	2	1
	Single vehicle	4	3	6	13	4
	Not reported	2	0	0	2	1
Crashes involving pedestrian(s)		1	0	1	2	1
Crashes involving cyclist(s)		0	0	0	0	0
Occurred during weekday peak periods*		3	1	1	5	2
Wet or icy pavement conditions		4	5	3	12	4
Dark/lighted conditions		5	6	4	15	5

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

The Town of Stoughton also provided crash reports for the most recent three years, from 2007 to 2009.[3] Based on the reports, staff constructed the collision diagram for the intersection (see Figure 2). The diagram shows that various types of collisions occurred in and around the Intersection, and a relatively high number (over 30%) of crashes involved a moving vehicle hitting either the traffic median (and/or the light post dwelling on it) on Central Street or the adjacent light post on the north side of the street.

The two fixed objects in effect form a narrow passage that is difficult for westbound vehicles to enter, either from Central Street or from Pearl Street. It is especially difficult for the vehicles from Pearl Street turning left into Central Street, as the roadside light post is close to the left-turn path if the vehicles do not slow down and therefore make a wide-radius turn (in order to avoid hitting the median). The three crashes that involved hitting the roadside light post are very likely such a case. For large trucks or buses, it is even more difficult to make the left turn without hitting either object.

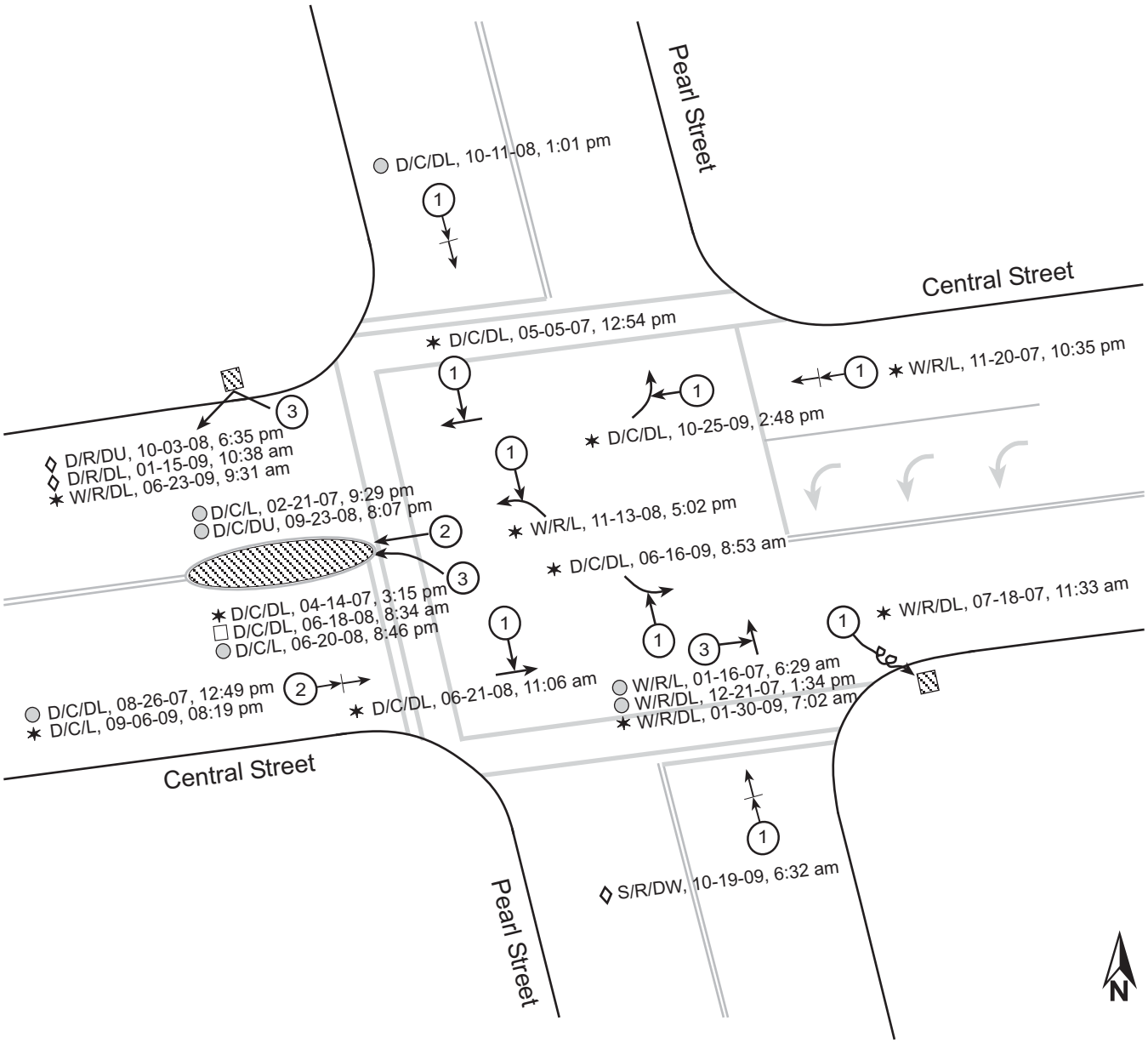
The analysis indicates that the traffic median (and its adjacent traffic light post) appears to be hazardous to drivers from the south or from the east of the intersection. It also hinders large trucks, buses, and emergency vehicles making turns at the intersection. The traffic median should be removed and replaced by pavement markings, if necessary. Meanwhile, the post-mounted traffic signals on the median and on the northwest corner should be hung from a cable system or a mast arm extended from the roadside.

---

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.

[3] These are reports filed by Stoughton Police Department. They do not include some of the crashes in the MassDOT Registry Division database, as some drivers might have notified the police and filed the reports only with the insurance companies.

FIGURE 2
Collision Diagram
January 1, 2007, through December 31, 2009
Central Street at Pearl Street, Stoughton



SYMBOLS	PAVEMENT/WEATHER/LIGHTING		TYPES OF COLLISIONS
Moving vehicle	D	Dry	Head-on
Backing vehicle	W	Wet	Angle
Pedestrian or bicycle	S	Snowy, icy	Rear-end
Out-of-control vehicle	--	Other	Sideswipe
Fixed object	C	Clear	Right angle
Property damage only	R	Rainy/foggy/cloudy	
Injury	S	Snow/sleet	
Fatality	--	Other	
No damage or injury	DL	Daylight	
Not reported	L	Dark, lights	
(#) Number of accidents	N	Dark, no lights	
	DU	Dusk	
	DW	Dawn	

CTPS

The MassDOT Registry Division's crash data show that there were two crashes involving pedestrians and that resulted in personal injuries. The first case was a westbound through vehicle that collided with a pedestrian at noontime on a raining Sunday (September 3, 2006). The second case was a vehicle going straight (direction unknown) colliding with a pedestrian at round 1:30 PM on a cloudless Wednesday (November 26, 2008). No further information can be found for these two cases, as no police reports were available. With no pedestrian signals at this intersection, the exclusive pedestrian phase indicated by traffic signals could be confusing for the pedestrians and drivers who are not familiar with the particular indications. As it is located in residential neighborhood and adjacent to school, the intersection should be equipped with standard pedestrian signals.

INTERSECTION CAPACITY ANALYSIS

Staff collected turning-movement counts at the intersection on May 18, 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 2,350 vehicles in the morning peak hour, from 7:15 to 8:15, and about 2,300 vehicles in the evening peak hour, from 5:00 to 6:00 (see Table 2). About 25 and 10 pedestrians were observed during the AM peak hour and the PM peak hour, respectively. About 5 bicyclists, who appeared to be high school students, went through the intersection in the AM peak hour. No bicyclists were observed in the PM peak hour.

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

Street name		**Central Street**						**Pearl 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	10	623	65	88	437	333	74	268	60	222	131	14	2325
	Approach volume	698			858			402			367			
	Pedestrian crossings	12			0			6			6			24
PM peak hour	Turning volume	13	472	55	45	545	251	60	203	54	306	246	23	2273
	Approach volume	540			841			317			575			
	Pedestrian crossings	6			0			2			1			9

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.[4] The program evaluates that it operates at an overall level of service (LOS) F with an average delay of over two minutes per vehicle in both the AM and PM peak hours (see Table 3). The level of service criteria are based on the Highway Capacity Manual 2000.[5] Detailed analysis settings and results for both the AM and PM peak hour are included in Appendix B.

[4] 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.

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

TABLE 3
Intersection Capacity Analysis, Existing Conditions

Street name		**Central Street**						**Pearl 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	**F**			**C**	**F**		**D**			**F**			**F**
	Delay (sec/veh)	151			24	81		42			> 180			124
PM peak hour	LOS	**E**			**B**	**E**		**C**			**F**			**F**
	Delay (sec/veh)	69			14	72		29			> 180			146

As the analysis shows, traffic on the EB/WB approaches endures extensive delays in the AM peak hour, especially the EB approach. Traffic on the SB approach endures significant delays due to the high proportion of left turns in the approach. The existing intersection capacity apparently is not sufficient in handling the existing traffic conditions.

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 system, the traffic signal cycle length would be extended from the existing 60 seconds to 80 seconds in order to reduce lost time due to signal changing during peak hours. An on-call exclusive pedestrian phase of 22 seconds[6] 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) Modify the WB approach to an LT(left-turn)/TH (through) shared lane and an exclusive RT (right-turn) lane, and operate the upgraded signal system under the existing phasing sequence
3) Modify the WB approach to an LT/TH shared lane and a TH/RT shared lane, and operate the upgraded signal system under the existing phasing sequence
4) Add an exclusive LT lane to the SB approach, and operate the upgraded signal system under the existing phasing sequence
5) Modify the WB approach to an LT/TH shared lane and an exclusive RT lane, add an exclusive LT lane to the SB approach, and operate the upgraded signal system under the existing phasing sequence

[6] The pedestrian phase would be increased to 22 seconds from the existing 20 seconds in order to cover a crossing distance of at least 60 feet, based on a walking speed of 3.5 feet per second in addition to a "walk" indication time of 4 seconds. The widest existing crossing distance is estimated as about 50 feet. The additional 10 feet would be considered for the potential modifications of the intersection layout.

6) Modify the WB approach to an LT/TH shared lane and a TH/RT shared lane, add an exclusive LT lane to the SB approach, and operate the upgraded signal system under the existing phasing sequence

Alternatives 4, 5, and 6 basically are Alternatives 1, 2, and 3 with the addition of an SB-LT exclusive lane to each. We also tested other alternatives. They are not included, as they would expand the intersection to a large extent and are much less feasible than the above six alternatives.

Table 4 summarizes the intersection capacity analyses for both the AM and PM peak hours for the six alternatives (detailed analysis settings and results for the alternatives are included in Appendices C to H separately). Alternative 1 shows that the intersection operations would be improved by simply upgrading the signal system, especially the operations on Central Street. Changing the WB approach to accommodate its high right-turn volume (Alternative 2) would improve Central Street traffic operations and the overall intersection operation noticeably. Changing the WB approach to two shared lanes (Alternative 3) would also improve Central Street traffic operations and the overall intersection operation, especially in the PM peak hour.

TABLE 4
Intersection Capacity Analyses of Improvement Alternatives

Street name		**Central Street**		**Pearl Street**		**Overall**
Approach		**Eastbound**	**Westbound**	**Northbound**	**Southbound**	
AM peak hour	Existing	F/151	F/81	D/42	F/ >180	F/124
	Alternative 1	E/62	E/58	D/44	F/ >180	F/91
	Alternative 2	D/52	D/40	D/35	F/179	E/65
	Alternative 3	D/53	C/26	D/35	F/179	E/60
	Alternative 4	D/45	D/52	D/45	F/151	E/65
	Alternative 5	D/52	D/40	C/33	E/80	D/49
	Alternative 6	D/53	C/26	C/33	E/80	D/44
PM peak hour	Existing	E/68	E/72	C/29	F/ >180	F/146
	Alternative 1	D/52	E/64	C/30	F/ >180	F/125
	Alternative 2	D/46	D/37	C/23	F/178	E/73
	Alternative 3	D/54	C/35	B/19	F/108	E/56
	Alternative 4	D/52	E/64	C/29	F/107	E/67
	Alternative 5	C/33	C/29	C/24	E/62	D/38
	Alternative 6	D/36	C/27	C/22	D/48	C/34

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: Modify the WB approach to an LT/TH lane and an RT lane, with the upgraded signal system
Alternative 3: Modify the WB approach to an LT/TH lane and a TH/RT lane, with the upgraded signal system
Alternative 4: Add an LT lane on the SB approach, with the improvements of Alternative 1
Alternative 5: Add an LT lane on the SB Approach, with the improvements of Alternative 2
Alternative 6: Add an LT lane on the SB Approach, with the improvements of Alternative 3

Alternative 2 would likely be constructed within the existing WB approach layout with no major intersection modifications. Alternative 3 would potentially require some land takings, as it calls for two receiving lanes on the WB departure approach and a slight realignment of Central Street. Currently the section of Central Street west of the intersection appears to have space (the lawn area belongs to Stoughton District Court) available on the south side. The State Road Inventory File indicates that this section of Central Street has a surface width of 24 feet with a right-of-way (ROW) width of 40 feet. To maintain the existing sidewalk on the south side and a 2-foot shoulder on each side, this alternative would very likely require some land takings. The feasibility of Alternative 3 should be further examined in the functional design stage.

The Synchro tests indicate that the SB approach in the first three alternatives would still operate at an unacceptable LOS F with extensive delays. Adding an LT exclusive lane on the SB approach without other modifications (Alternative 4) would improve traffic operations mainly on the SB approach and somewhat on the EB and WB approaches. Adding an LT lane on the SB approach and changing the WB approach lane configuration (Alternatives 5 and 6) would improve traffic operations significantly on all the approaches. Based on the Synchro tests' queue length estimation, this modification would require at least 250 feet of left turn storage space on the SB approach. That would require an expansion of the entire section of Pearl Street from McEvoy Circle to the intersection.

From the aerial photograph of the vicinity, there appears to be little room for the expansion, as both sides of Pearl Street are occupied by private homes. The State Road Inventory File indicates that this section of Pearl Street (owned by the town) has a surface width of 28 feet with a right-of-way (ROW) width of 50 feet. Given the existing 6-foot-wide sidewalk on the west side and a 2-foot shoulder on each side, there may be room for an additional lane with the configuration of two 10-foot lanes approaching the intersection. The feasibility of adding the LT lane should be carefully examined in the future functional design stage, as it could have some impacts on the residential areas north of the intersection.

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 and the intersection layout that might have been the causes of some crashes in recent years. The traffic median on Central Street is found to be hazardous for drivers from the south and from the east. However, it houses major signal indications for Central Street traffic and can not be removed unless the signals are converted to overhead signal indications.

Meanwhile, the intersection is highly 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 alternatives tested for this intersection include:

1) Operate the upgraded signal system under the existing intersection layout
2) Modify the WB approach to an LT/TH shared lane and an exclusive RT lane, and operate the upgraded signal system under the existing phasing sequence
3) Modify the WB approach to an LT/TH shared lane and a TH/RT shared lane, and operate the upgraded signal system under the existing phasing sequence

4) Add an exclusive LT lane to the SB approach, and operate the upgraded signal system under the existing phasing sequence
5) Modify the WB approach to an LT/TH shared lane and an exclusive RT lane, add an exclusive LT lane to the SB approach, and operate the upgraded signal system under the existing phasing sequence
6) Modify the WB approach to an LT/TH shared lane and a TH/RT shared lane, add an exclusive LT lane to the SB approach, and operate the upgraded signal system under the existing phasing sequence

The study found that Alternatives 3, 4, 5, and 6 would likely require land takings and have some impacts on the surrounding areas. Alternatives 1 and 2 are more feasible than the other alternatives. Alternative 2 is operationally more favorable than Alternative 1, as it would noticeably improve traffic operations, with reduced delays on all approaches. In terms of traffic safety, Alternative 1 is more favorable than Alternative 2, as the WB left turns in Alternative 2 would be under more pressure with the lost waiting (storage) space. Meanwhile, Alternative 2 could potentially induce somewhat more traffic bound for Canton Center/I-95 traffic with the increase of EB-RT capacity.

At this preliminary planning stage, we recommend Alternative 1 for this intersection. It is essential to upgrade the outdated signal system. Although the intersection would likely still operate at an undesirable LOS F during peak hours, its operations and safety would improve noticeably from the existing conditions. The new signal system should include the following major features:

- Install a fully actuated traffic signal system with standard pedestrian signals and push buttons
- Replace the existing post-mounted signals with overhead signal indications supported by a cable system or mast arms, which can be clearly viewed on all approaches from a distance
- Remove the traffic median on Central Street, and replace it with hatched pavement markings if necessary
- Maintain the existing crosswalks and sidewalks at the intersection
- Include a pre-emption function for emergency vehicles[7]
- Install wheelchair ramps with ADA (American with Disabilities Act)/AAB(Massachusetts Architectural Access Board) standards at all corners of the intersection
- Install accessible (audible) countdown pedestrian signals
- Improve lighting conditions at the intersection[8]

Meanwhile, we recommend including Alternatives 2 to 6 for further examination in the future functional design stage for the intersection. Based on the Town's suggestions (see Appendix I), the following issues should be included in the design scope:

---

[7] Most of the major intersections in the town are already equipped with this function in connection with fire engines and other emergency vehicles. The upgraded signals at this intersection should be incorporated into the system.

[8] The crash data for recent years show that 30% of the intersection crashes occurred in dark conditions. Currently the intersection has only one street light, over its southeast corner. Additional lighting would potentially reduce the number of crashes in darkness.

- Scheduling public hearings to receive public input
- Consideration of private parking needs and access
- Drainage improvements
- Potential coordination with nearby traffic signals
- Pavement marking coordination with the nearby roadways

Assuming no land takings, the total cost of the signal installation (including its support system) and the necessary intersection modifications can be roughly estimated as $500,000 to $750,000. Both streets and the intersection are under the jurisdiction of the Town of Stoughton. The Town can seek funding support from the state by working closely with MassDOT Highway District 5 through the project implementation process (see Appendix J).

In the immediate term, before the signal system is updated, the safety at this intersection can be enhanced by (1) making sure a comprehensive school crossing guard protection is always in place at this location during school hours, and (2) placing pedestrian crossing warning signs on both of the Central Street approaches.

Appendix A

Intersection Crash Rate Calculation
Central Street at Pearl Street, Stoughton

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Stoughton COUNT DATE : 6/3/10

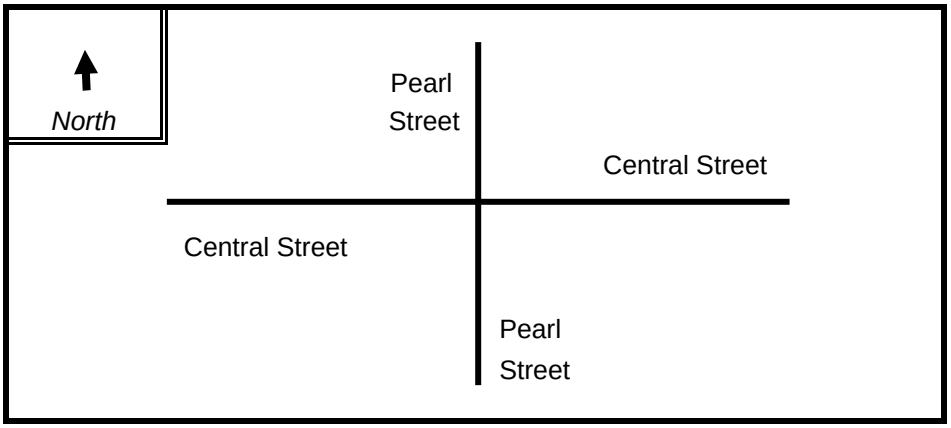
DISTRICT : 5 UNSIGNALIZED : SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Central Street

MINOR STREET(S) : Pearl 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) :	698	858	402	367		**2,325**

" K " FACTOR : **0.090** INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **25,833**

TOTAL # OF CRASHES : 48 # OF YEARS : 3 AVERAGE # OF CRASHES PER YEAR (**A**) : **16.00**

CRASH RATE CALCULATION : **1.70** RATE = $\frac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : MassDOT District 5 Average Rate = 0.77

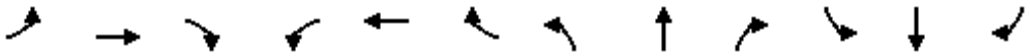
Project Title & Date: Safety and Operations Analyses at Selceted Intersections

Appendix B

AM/PM Peak Hour Intersection Capacity Analysis
Existing Traffic Conditions
Central Street at Pearl Street, Stoughton

Intersection Capacity Analysis
Central St @ Pearl St, Stoughton

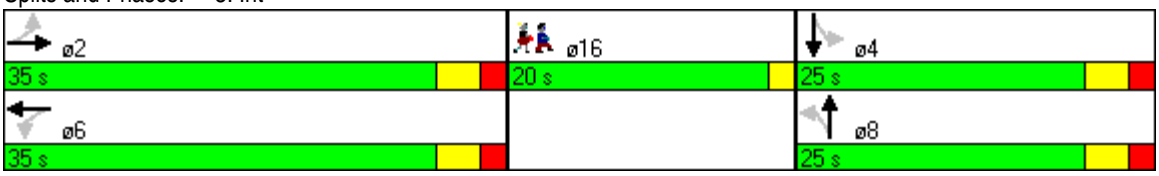
7/20/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	10	623	65	88	437	333	74	268	60	222	131	14
Confl. Peds. (#/hr)	6		6	6		6	12					12
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 (%)	7%	7%	7%	7%	7%	7%	2%	2%	2%	7%	7%	7%
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)	35.0	35.0		35.0	35.0		25.0	25.0		25.0	25.0	
Total Split (s)	35.0	35.0	0.0	35.0	35.0	0.0	25.0	25.0	0.0	25.0	25.0	0.0
Total Split (%)	43.8%	43.8%	0.0%	43.8%	43.8%	0.0%	31.3%	31.3%	0.0%	31.3%	31.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		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)	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	Max	Max		Max	Max		Max	Max		Max	Max	
Act Effct Green (s)		30.4		30.4	30.4			20.3			20.3	
Actuated g/C Ratio		0.48		0.48	0.48			0.32			0.32	
v/c Ratio		1.26		0.45	1.11			0.86			1.48	
Control Delay		151.2		23.5	87.8			41.5			259.4	
Queue Delay		0.0		0.0	0.0			0.0			0.0	
Total Delay		151.2		23.5	87.8			41.5			259.4	
LOS		F		C	F			D			F	
Approach Delay		151.2			81.2			41.5			259.4	
Approach LOS		F			F			D			F	

Intersection Summary			
Cycle Length: 80			
Actuated Cycle Length: 64			
Natural Cycle: 140			
Control Type: Semi Act-Uncoord			
Maximum v/c Ratio: 1.48			
Intersection Signal Delay: 123.5		Intersection LOS: F	
Intersection Capacity Utilization 126.0%		ICU Level of Service H	
Analysis Period (min) 15			

Splits and Phases: 3: Int

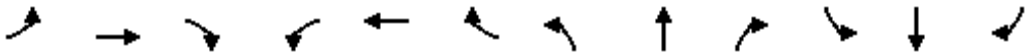


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	20.0
Total Split (s)	20.0
Total Split (%)	25%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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
Central St @ Pearl St, Stoughton

7/20/2010

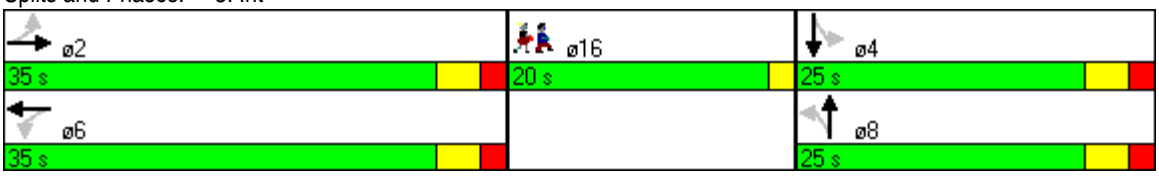


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	13	472	55	45	545	251	60	203	54	306	246	23
Confl. Peds. (#/hr)	2		1	1		2	6					6
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	3%	3%	3%	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)	35.0	35.0		35.0	35.0		25.0	25.0		25.0	25.0	
Total Split (s)	35.0	35.0	0.0	35.0	35.0	0.0	25.0	25.0	0.0	25.0	25.0	0.0
Total Split (%)	43.8%	43.8%	0.0%	43.8%	43.8%	0.0%	31.3%	31.3%	0.0%	31.3%	31.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		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)	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	Max	Max		Max	Max		Max	Max		Max	Max	
Act Effct Green (s)		30.4		30.4	30.4			20.3			20.3	
Actuated g/C Ratio		0.48		0.48	0.48			0.32			0.32	
v/c Ratio		1.03		0.16	1.08			0.67			1.80	
Control Delay		68.9		14.1	74.8			29.0			393.5	
Queue Delay		0.0		0.0	0.0			0.0			0.0	
Total Delay		68.9		14.1	74.8			29.0			393.5	
LOS		E		B	E			C			F	
Approach Delay		68.9			71.6			29.0			393.5	
Approach LOS		E			E			C			F	

Intersection Summary

Cycle Length: 80
Actuated Cycle Length: 64
Natural Cycle: 150
Control Type: Semi Act-Uncoord
Maximum v/c Ratio: 1.80
Intersection Signal Delay: 146.5 Intersection LOS: F
Intersection Capacity Utilization 115.4% ICU Level of Service H
Analysis Period (min) 15

Splits and Phases: 3: Int

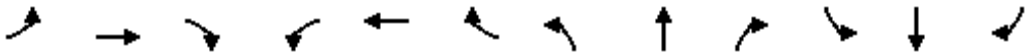


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	20.0
Total Split (s)	20.0
Total Split (%)	25%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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 C

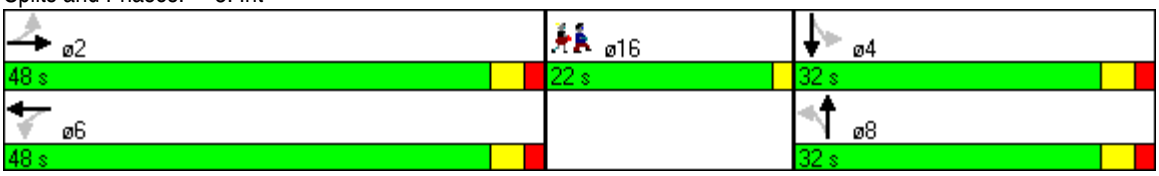
AM/PM Peak Hour Intersection Capacity Analysis
Alternative 1
Upgrade Signal System and Maintain Existing Intersection Layout
Central Street at Pearl Street, Stoughton



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	10	623	65	88	437	333	74	268	60	222	131	14
Confl. Peds. (#/hr)	6		6	6		6	12					12
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 (%)	7%	7%	7%	7%	7%	7%	2%	2%	2%	7%	7%	7%
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)	21.0	21.0		21.0	21.0		15.0	15.0		15.0	15.0	
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 (%)	47.1%	47.1%	0.0%	47.1%	47.1%	0.0%	31.4%	31.4%	0.0%	31.4%	31.4%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		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)	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	Max	Max		Max	Max		None	None		None	None	
Act Effct Green (s)		43.3		43.3	43.3			27.2			27.2	
Actuated g/C Ratio		0.52		0.52	0.52			0.32			0.32	
v/c Ratio		1.02		0.40	1.03			0.84			1.51	
Control Delay		62.2		21.3	62.8			44.4			274.4	
Queue Delay		0.0		0.0	0.0			0.0			0.0	
Total Delay		62.2		21.3	62.8			44.4			274.4	
LOS		E		C	E			D			F	
Approach Delay		62.2			58.5			44.4			274.4	
Approach LOS		E			E			D			F	

Intersection Summary			
Cycle Length: 102			
Actuated Cycle Length: 84			
Natural Cycle: 140			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 1.51			
Intersection Signal Delay: 91.3		Intersection LOS: F	
Intersection Capacity Utilization 126.0%		ICU Level of Service H	
Analysis Period (min) 15			

Splits and Phases: 3: Int



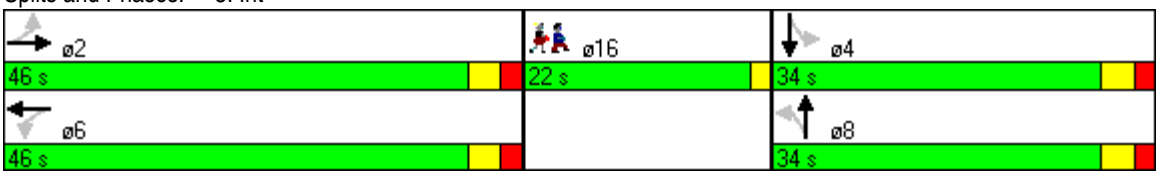
Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

Intersection Summary

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	13	472	55	45	545	251	60	203	54	306	246	23
Confl. Peds. (#/hr)	2		1	1		2	6					6
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 (%)	3%	3%	3%	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)	21.0	21.0		21.0	21.0		15.0	15.0		15.0	15.0	
Total Split (s)	46.0	46.0	0.0	46.0	46.0	0.0	34.0	34.0	0.0	34.0	34.0	0.0
Total Split (%)	45.1%	45.1%	0.0%	45.1%	45.1%	0.0%	33.3%	33.3%	0.0%	33.3%	33.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		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)	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	Max	Max		Max	Max		None	None		None	None	
Act Effct Green (s)		41.3		41.3	41.3			29.2			29.2	
Actuated g/C Ratio		0.49		0.49	0.49			0.35			0.35	
v/c Ratio		0.96		0.16	1.04			0.62			1.66	
Control Delay		51.9		16.0	67.2			29.8			334.9	
Queue Delay		0.0		0.0	0.0			0.0			0.0	
Total Delay		51.9		16.0	67.2			29.8			334.9	
LOS		D		B	E			C			F	
Approach Delay		51.9			64.5			29.8			334.9	
Approach LOS		D			E			C			F	

Intersection Summary	
Cycle Length: 102	
Actuated Cycle Length: 84	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.66	
Intersection Signal Delay: 125.1	Intersection LOS: F
Intersection Capacity Utilization 115.4%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 3: Int

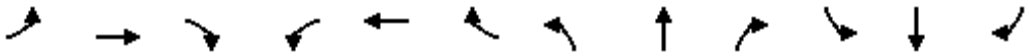


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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

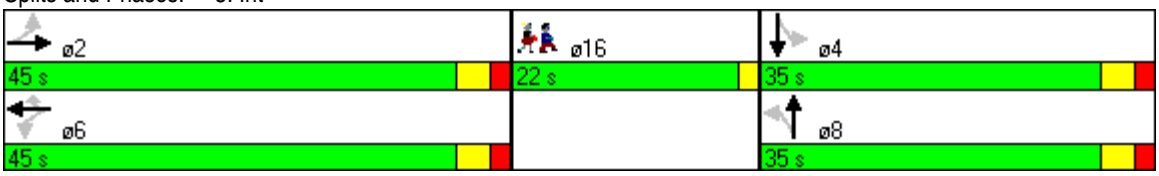
AM/PM Peak Hour Intersection Capacity Analysis
Alternative 2
Upgrade Signal System and
Change WB to a LT/TH Shared Lane and a RT Exclusive Lane
Central Street at Pearl Street, Stoughton



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	10	623	65	88	437	333	74	268	60	222	131	14
Confl. Peds. (#/hr)	6		6	6		6	12					12
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 (%)	7%	7%	7%	7%	7%	7%	2%	2%	2%	7%	7%	7%
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			6		6	8			4		
Detector Phase	2	2		6	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)	21.0	21.0		21.0	21.0	21.0	15.0	15.0		15.0	15.0	
Total Split (s)	45.0	45.0	0.0	45.0	45.0	45.0	35.0	35.0	0.0	35.0	35.0	0.0
Total Split (%)	44.1%	44.1%	0.0%	44.1%	44.1%	44.1%	34.3%	34.3%	0.0%	34.3%	34.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0		3.0	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0	2.0	2.0	2.0		2.0	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Max	Max		Max	Max	Max	None	None		None	None	
Act Effct Green (s)		40.3			40.3	40.3		30.2			30.2	
Actuated g/C Ratio		0.48			0.48	0.48		0.36			0.36	
v/c Ratio		0.98			1.00	0.43		0.76			1.29	
Control Delay		51.5			63.4	3.8		35.4			179.3	
Queue Delay		0.0			0.0	0.0		0.0			0.0	
Total Delay		51.5			63.4	3.8		35.4			179.3	
LOS		D			E	A		D			F	
Approach Delay		51.5			40.3			35.4			179.3	
Approach LOS		D			D			D			F	

Intersection Summary			
Cycle Length: 102			
Actuated Cycle Length: 84			
Natural Cycle: 150			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 1.29			
Intersection Signal Delay: 64.8		Intersection LOS: E	
Intersection Capacity Utilization 135.7%		ICU Level of Service H	
Analysis Period (min) 15			

Splits and Phases: 3: Int

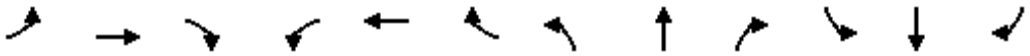


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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
Central St @ Pearl St, Stoughton

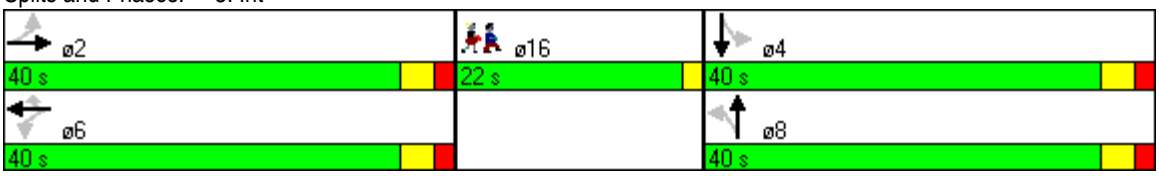
9/23/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	13	472	55	45	545	251	60	203	54	306	246	23
Confl. Peds. (#/hr)	2		1	1		2	6					6
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 (%)	3%	3%	3%	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			6		6	8			4		
Detector Phase	2	2		6	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)	21.0	21.0		21.0	21.0	21.0	15.0	15.0		15.0	15.0	
Total Split (s)	40.0	40.0	0.0	40.0	40.0	40.0	40.0	40.0	0.0	40.0	40.0	0.0
Total Split (%)	39.2%	39.2%	0.0%	39.2%	39.2%	39.2%	39.2%	39.2%	0.0%	39.2%	39.2%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0		3.0	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0	2.0	2.0	2.0		2.0	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Max	Max		Max	Max	Max	None	None		None	None	
Act Effct Green (s)		35.3			35.3	35.3		35.3			35.3	
Actuated g/C Ratio		0.42			0.42	0.42		0.42			0.42	
v/c Ratio		0.91			0.95	0.35		0.52			1.31	
Control Delay		45.5			51.1	4.2		22.6			177.6	
Queue Delay		0.0			0.0	0.0		0.0			0.0	
Total Delay		45.5			51.1	4.2		22.6			177.6	
LOS		D			D	A		C			F	
Approach Delay		45.5			37.2			22.6			177.6	
Approach LOS		D			D			C			F	

Intersection Summary	
Cycle Length: 102	
Actuated Cycle Length: 84	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.31	
Intersection Signal Delay: 72.7	Intersection LOS: E
Intersection Capacity Utilization 123.1%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 3: 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)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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	

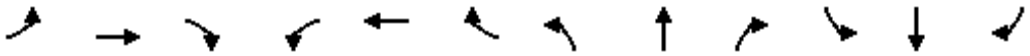
Intersection Summary

Appendix E

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 3
Upgrade Signal System and
Change WB to a LT/TH Shared Lane and a TH/RT Shared Lane
Central Street at Pearl Street, Stoughton

Intersection Capacity Analysis
Central St @ Pearl St, Stoughton

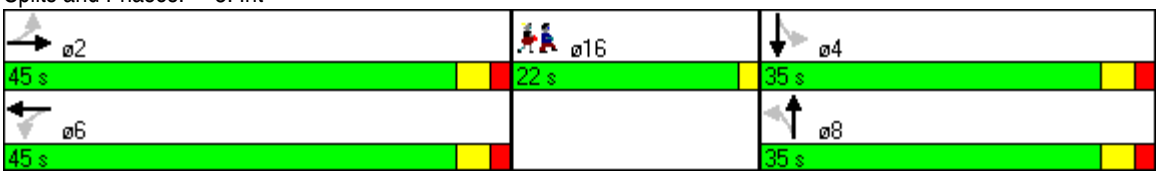
9/23/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	10	623	65	88	437	333	74	268	60	222	131	14
Confl. Peds. (#/hr)	6		6	6		6	12					12
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 (%)	7%	7%	7%	7%	7%	7%	2%	2%	2%	7%	7%	7%
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)	21.0	21.0		21.0	21.0		15.0	15.0		15.0	15.0	
Total Split (s)	45.0	45.0	0.0	45.0	45.0	0.0	35.0	35.0	0.0	35.0	35.0	0.0
Total Split (%)	44.1%	44.1%	0.0%	44.1%	44.1%	0.0%	34.3%	34.3%	0.0%	34.3%	34.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		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)	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	Max	Max		Max	Max		None	None		None	None	
Act Effct Green (s)		40.3			40.3			30.2			30.2	
Actuated g/C Ratio		0.48			0.48			0.36			0.36	
v/c Ratio		0.98			0.85			0.76			1.29	
Control Delay		53.3			26.0			35.3			179.3	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		53.3			26.0			35.3			179.3	
LOS		D			C			D			F	
Approach Delay		53.3			26.0			35.3			179.3	
Approach LOS		D			C			D			F	

Intersection Summary	
Cycle Length: 102	
Actuated Cycle Length: 84	
Natural Cycle: 140	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.29	
Intersection Signal Delay: 60.0	Intersection LOS: E
Intersection Capacity Utilization 133.1%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 3: Int

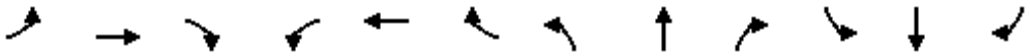


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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
Central St @ Pearl St, Stoughton

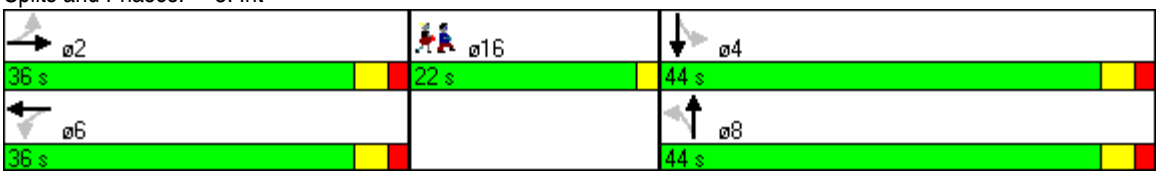
9/23/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	13	472	55	45	545	251	60	203	54	306	246	23
Confl. Peds. (#/hr)	2		1	1		2	6					6
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 (%)	3%	3%	3%	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)	21.0	21.0		21.0	21.0		15.0	15.0		15.0	15.0	
Total Split (s)	36.0	36.0	0.0	36.0	36.0	0.0	44.0	44.0	0.0	44.0	44.0	0.0
Total Split (%)	35.3%	35.3%	0.0%	35.3%	35.3%	0.0%	43.1%	43.1%	0.0%	43.1%	43.1%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		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)	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	Max	Max		Max	Max		None	None		None	None	
Act Effct Green (s)		31.2			31.2			39.3			39.3	
Actuated g/C Ratio		0.37			0.37			0.47			0.47	
v/c Ratio		0.95			0.87			0.47			1.14	
Control Delay		54.3			35.0			18.9			108.1	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		54.3			35.0			18.9			108.1	
LOS		D			D			B			F	
Approach Delay		54.3			35.0			18.9			108.1	
Approach LOS		D			D			B			F	

Intersection Summary	
Cycle Length: 102	
Actuated Cycle Length: 84	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.14	
Intersection Signal Delay: 55.8	Intersection LOS: E
Intersection Capacity Utilization 113.2%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 3: Int

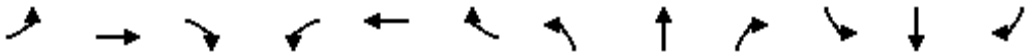


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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

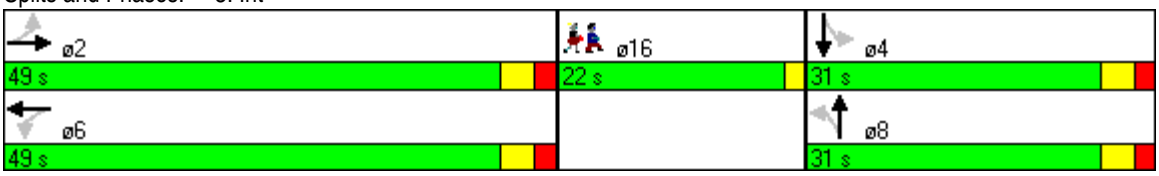
AM/PM Peak Hour Intersection Capacity Analysis
Alternative 4
Upgrade Signal System and Add a SB-LT Exclusive Lane
Central Street at Pearl Street, Stoughton



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	10	623	65	88	437	333	74	268	60	222	131	14
Confl. Peds. (#/hr)	6		6	6		6	12					12
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 (%)	7%	7%	7%	7%	7%	7%	2%	2%	2%	7%	7%	7%
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)	21.0	21.0		21.0	21.0		15.0	15.0		15.0	15.0	
Total Split (s)	49.0	49.0	0.0	49.0	49.0	0.0	31.0	31.0	0.0	31.0	31.0	0.0
Total Split (%)	48.0%	48.0%	0.0%	48.0%	48.0%	0.0%	30.4%	30.4%	0.0%	30.4%	30.4%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		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)	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	Max	Max		Max	Max		None	None		None	None	
Act Effct Green (s)		44.4		44.4	44.4			26.2		26.2	26.2	
Actuated g/C Ratio		0.53		0.53	0.53			0.31		0.31	0.31	
v/c Ratio		0.96		0.38	1.01			0.85		1.38	0.33	
Control Delay		45.5		19.9	55.9			45.3		233.4	25.6	
Queue Delay		0.0		0.0	0.0			0.0		0.0	0.0	
Total Delay		45.5		19.9	55.9			45.3		233.4	25.6	
LOS		D		B	E			D		F	C	
Approach Delay		45.5			52.2			45.3			151.3	
Approach LOS		D			D			D			F	

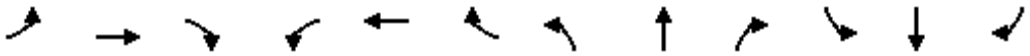
Intersection Summary	
Cycle Length: 102	
Actuated Cycle Length: 84	
Natural Cycle: 140	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.38	
Intersection Signal Delay: 64.7	Intersection LOS: E
Intersection Capacity Utilization 117.3%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 3: 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)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
Lost Time Adjust (s)	
Total Lost Time (s)	
Lead/Lag	
Lead-Lag Optimize?	
Recall Mode	None
Act Effct Green (s)	
Actuated g/C Ratio	
v/c Ratio	
Control Delay	
Queue Delay	
Total Delay	
LOS	
Approach Delay	
Approach LOS	

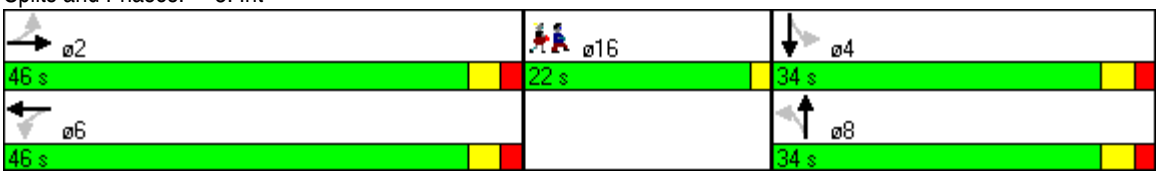
Intersection Summary



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	13	472	55	45	545	251	60	203	54	306	246	23
Confl. Peds. (#/hr)	2		1	1		2	6					6
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 (%)	3%	3%	3%	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)	21.0	21.0		21.0	21.0		15.0	15.0		15.0	15.0	
Total Split (s)	46.0	46.0	0.0	46.0	46.0	0.0	34.0	34.0	0.0	34.0	34.0	0.0
Total Split (%)	45.1%	45.1%	0.0%	45.1%	45.1%	0.0%	33.3%	33.3%	0.0%	33.3%	33.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		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)	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	Max	Max		Max	Max		None	None		None	None	
Act Effct Green (s)		41.3		41.3	41.3			29.2		29.2	29.2	
Actuated g/C Ratio		0.49		0.49	0.49			0.35		0.35	0.35	
v/c Ratio		0.96		0.16	1.04			0.61		1.27	0.52	
Control Delay		51.9		16.0	67.2			29.4		176.6	27.3	
Queue Delay		0.0		0.0	0.0			0.0		0.0	0.0	
Total Delay		51.9		16.0	67.2			29.4		176.6	27.3	
LOS		D		B	E			C		F	C	
Approach Delay		51.9			64.5			29.4			106.8	
Approach LOS		D			E			C			F	

Intersection Summary			
Cycle Length: 102			
Actuated Cycle Length: 84			
Natural Cycle: 150			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 1.27			
Intersection Signal Delay: 67.3		Intersection LOS: E	
Intersection Capacity Utilization 99.5%		ICU Level of Service F	
Analysis Period (min) 15			

Splits and Phases: 3: Int

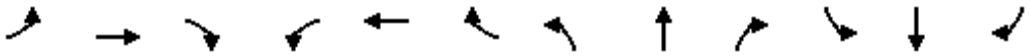


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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

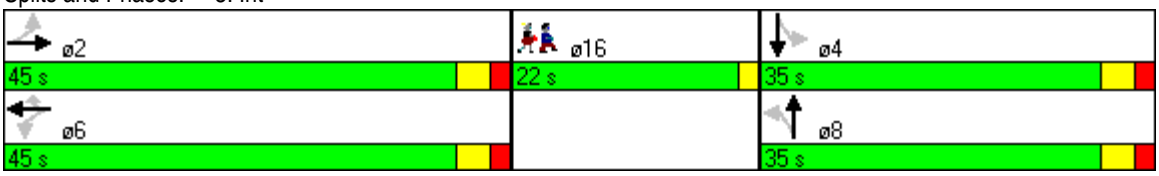
AM/PM Peak Hour Intersection Capacity Analysis
Alternative 5
Upgrade Signal System,
Add a SB-LT Exclusive Lane, and
Change WB to a LT/TH Shared Lane and a RT Exclusive Lane
Central Street at Pearl Street, Stoughton



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	10	623	65	88	437	333	74	268	60	222	131	14
Confl. Peds. (#/hr)	6		6	6		6	12					12
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 (%)	7%	7%	7%	7%	7%	7%	2%	2%	2%	7%	7%	7%
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			6		6	8			4		
Detector Phase	2	2		6	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)	21.0	21.0		21.0	21.0	21.0	15.0	15.0		15.0	15.0	
Total Split (s)	45.0	45.0	0.0	45.0	45.0	45.0	35.0	35.0	0.0	35.0	35.0	0.0
Total Split (%)	44.1%	44.1%	0.0%	44.1%	44.1%	44.1%	34.3%	34.3%	0.0%	34.3%	34.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0		3.0	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0	2.0	2.0	2.0		2.0	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Max	Max		Max	Max	Max	None	None		None	None	
Act Effct Green (s)		40.3			40.3	40.3		30.2		30.2	30.2	
Actuated g/C Ratio		0.48			0.48	0.48		0.36		0.36	0.36	
v/c Ratio		0.98			1.00	0.43		0.73		1.09	0.29	
Control Delay		51.5			63.4	3.8		33.4		117.3	22.0	
Queue Delay		0.0			0.0	0.0		0.0		0.0	0.0	
Total Delay		51.5			63.4	3.8		33.4		117.3	22.0	
LOS		D			E	A		C		F	C	
Approach Delay		51.5			40.3			33.4			79.6	
Approach LOS		D			D			C			E	

Intersection Summary	
Cycle Length: 102	
Actuated Cycle Length: 84	
Natural Cycle: 140	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.09	
Intersection Signal Delay: 48.7	Intersection LOS: D
Intersection Capacity Utilization 127.1%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 3: Int

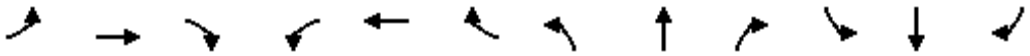


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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
Central St @ Pearl St, Stoughton

9/24/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	13	472	55	45	545	251	60	203	54	306	246	23
Confl. Peds. (#/hr)	2		1	1		2	6					6
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 (%)	3%	3%	3%	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			6		6	8			4		
Detector Phase	2	2		6	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)	21.0	21.0		21.0	21.0	21.0	15.0	15.0		15.0	15.0	
Total Split (s)	42.0	42.0	0.0	42.0	42.0	42.0	38.0	38.0	0.0	38.0	38.0	0.0
Total Split (%)	41.2%	41.2%	0.0%	41.2%	41.2%	41.2%	37.3%	37.3%	0.0%	37.3%	37.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0		3.0	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0	2.0	2.0	2.0		2.0	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	Max	Max		Max	Max	Max	None	None		None	None	
Act Effct Green (s)		37.3			37.3	37.3		33.3		33.3	33.3	
Actuated g/C Ratio		0.44			0.44	0.44		0.40		0.40	0.40	
v/c Ratio		0.80			0.89	0.34		0.53		1.06	0.46	
Control Delay		32.3			40.1	4.0		23.8		95.7	23.0	
Queue Delay		0.0			0.0	0.0		0.0		0.0	0.0	
Total Delay		32.3			40.1	4.0		23.8		95.7	23.0	
LOS		C			D	A		C		F	C	
Approach Delay		32.3			29.4			23.8			61.7	
Approach LOS		C			C			C			E	

Intersection Summary	
Cycle Length: 102	
Actuated Cycle Length: 84	
Natural Cycle: 140	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.06	
Intersection Signal Delay: 37.5	Intersection LOS: D
Intersection Capacity Utilization 107.2%	ICU Level of Service G
Analysis Period (min) 15	

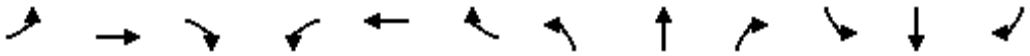
Splits and Phases: 3: Int

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)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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

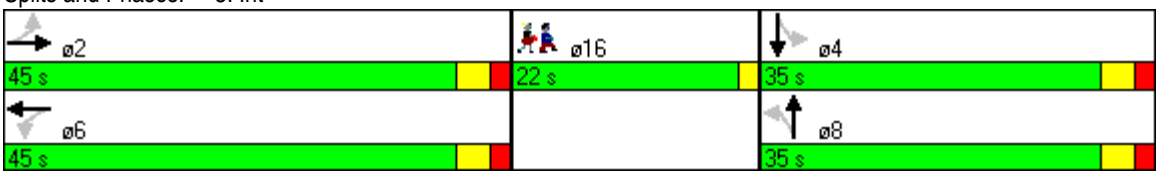
AM/PM Peak Hour Intersection Capacity Analysis
Alternative 6
Upgrade Signal System,
Add a SB-LT Exclusive Lane, and
Change WB to a LT/TH Shared Lane and a TH/RT Shared Lane
Central Street at Pearl Street, Stoughton



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	10	623	65	88	437	333	74	268	60	222	131	14
Confl. Peds. (#/hr)	6		6	6		6	12					12
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 (%)	7%	7%	7%	7%	7%	7%	2%	2%	2%	7%	7%	7%
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)	21.0	21.0		21.0	21.0		15.0	15.0		15.0	15.0	
Total Split (s)	45.0	45.0	0.0	45.0	45.0	0.0	35.0	35.0	0.0	35.0	35.0	0.0
Total Split (%)	44.1%	44.1%	0.0%	44.1%	44.1%	0.0%	34.3%	34.3%	0.0%	34.3%	34.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		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)	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	Max	Max		Max	Max		None	None		None	None	
Act Effct Green (s)		40.3			40.3			30.2		30.2	30.2	
Actuated g/C Ratio		0.48			0.48			0.36		0.36	0.36	
v/c Ratio		0.98			0.85			0.73		1.09	0.29	
Control Delay		53.3			26.0			33.3		117.3	22.0	
Queue Delay		0.0			0.0			0.0		0.0	0.0	
Total Delay		53.3			26.0			33.3		117.3	22.0	
LOS		D			C			C		F	C	
Approach Delay		53.3			26.0			33.3			79.6	
Approach LOS		D			C			C			E	

Intersection Summary	
Cycle Length: 102	
Actuated Cycle Length: 84	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.09	
Intersection Signal Delay: 43.9	Intersection LOS: D
Intersection Capacity Utilization 124.5%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 3: Int

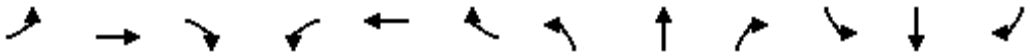


Lane Group	ø16
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Turn Type	
Protected Phases	16
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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
Central St @ Pearl St, Stoughton

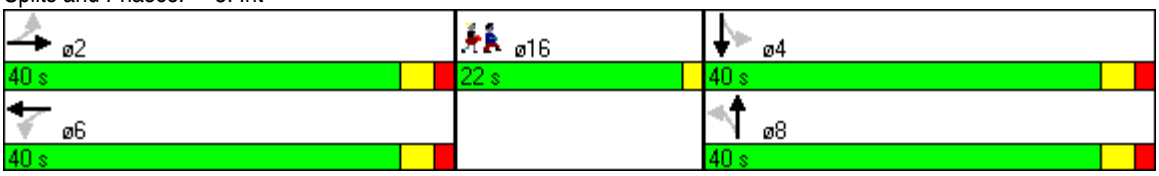
9/24/2010



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	13	472	55	45	545	251	60	203	54	306	246	23
Confl. Peds. (#/hr)	2		1	1		2	6					6
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 (%)	3%	3%	3%	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)	21.0	21.0		21.0	21.0		15.0	15.0		15.0	15.0	
Total Split (s)	40.0	40.0	0.0	40.0	40.0	0.0	40.0	40.0	0.0	40.0	40.0	0.0
Total Split (%)	39.2%	39.2%	0.0%	39.2%	39.2%	0.0%	39.2%	39.2%	0.0%	39.2%	39.2%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		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)	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	Max	Max		Max	Max		None	None		None	None	
Act Effct Green (s)		35.3			35.3			35.3		35.3	35.3	
Actuated g/C Ratio		0.42			0.42			0.42		0.42	0.42	
v/c Ratio		0.84			0.78			0.49		0.97	0.43	
Control Delay		36.4			26.5			21.8		71.1	21.1	
Queue Delay		0.0			0.0			0.0		0.0	0.0	
Total Delay		36.4			26.5			21.8		71.1	21.1	
LOS		D			C			C		E	C	
Approach Delay		36.4			26.5			21.8			47.7	
Approach LOS		D			C			C			D	

Intersection Summary	
Cycle Length: 102	
Actuated Cycle Length: 84	
Natural Cycle: 150	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.97	
Intersection Signal Delay: 33.6	Intersection LOS: C
Intersection Capacity Utilization 97.3%	ICU Level of Service F
Analysis Period (min) 15	

Splits and Phases: 3: 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)	4.0
Minimum Split (s)	22.0
Total Split (s)	22.0
Total Split (%)	22%
Yellow Time (s)	2.0
All-Red Time (s)	0.0
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

Letter from Stoughton
January 18, 2011

TOWN OF STOUGHTON
10 PEARL STREET
STOUGHTON, MA 02072
ENGINEERING DEPARTMENT

DATE: January 18, 2011

TO: Chen-Yuan Wang
Staff Planner

FROM: Ben Fehan
Town Engineer

SUBJECT: Intersection of Central and Pearl Streets
Stoughton, MA

CC: Francis T. Crimmins, Jr., Town Manager; John Batchelder, Superintendent of Public Works

We have completed our review of the Safety and Operations Analysis of the Intersection of Central and Pearl Streets in Stoughton. We thank you for the opportunity to comment as this intersection is a major one in the town and serves as the gateway for traffic flowing north into Canton.

GENERAL

The Report contains the following:

- Accident data with some analysis
- Aerial photographs
- A description of the traffic signal operation
- Peak period-level of service analysis

The Report is targeted at documenting the safety issues which exist at the intersection. It is not intended to document all the issues which would have to be addressed in the redesign of the intersection such as:

- Roadway widths
- Parking needs of abutters
- Traffic Signal coordination
- Intersection redesign
- Pedestrian access

REPORT FINDINGS/IMPROVEMENTS NEEDED

We concur with the following report findings:

- The existing traffic signals are antiquated and not clearly visible.
- Modern post mounted traffic signals should be installed w/std. pedestrian signals.
- The existing traffic island should be removed.
- Land acquisition should be investigated to facilitate proper lane design.

RELATED DESIGN ISSUES

In addition to the report findings, we have identified other criteria which should be included in the design scope. They include:

- Consideration of private parking needs.
- Scheduling of a Public Hearing to receive citizen input.
- Drainage improvements.
- Traffic light coordination with nearby intersections.
- Pavement marking coordination.

Once again we thank you for the time and effort that you and your staff have placed in this report. We assume that you will be issuing a final version soon with the conclusion that traffic improvements are needed and we look forward to receiving that report. We also trust that you will provide MADOT District 5 office with copies of the final document. We would appreciate receiving three copies of the final report.

Appendix J

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.