MEMORANDUM

To: **Jay Fink**   **July 8, 2010**
        Commissioner of Public Works, City of Lynn

From: **Chen-Yuan Wang**

Re: **Boston Region MPO Congested and High-Crash Intersections Study:**
        Western Avenue at Eastern Avenue/Stanwood Street and
        Western Avenue at Waitt Avenue/Maple Street in Lynn

This memorandum summarizes safety and operations analyses and proposes improvement strategies for the intersections of Western Avenue at Eastern Avenue/Stanwood Street and at Waitt Avenue/Maple Street in Lynn. The two intersections are located in close proximity and should therefore be examined together. The memorandum contains the following sections:

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

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

INTERSECTION LAYOUT AND TRAFFIC CONTROL

The two intersections are located in the northeast part of the city near its border with Swampscott and Salem. Western Avenue is a part of state Route 107, which reaches downtown Salem in the north and connects Revere Beach Parkway (Route 16) in the south. Route 107 functions as an urban principal arterial and carries a high proportion of the regional traffic. Eastern Avenue is a part of state Route 129A, which diverges from Route 129 near Flax Pond and rejoins Route 129 in the coastal area of Lynn and Swampscott. It basically functions as an urban collector for its adjacent neighborhoods.

As Figure 1 shows, the two intersections are located about 300 feet from each other. The northern intersection, Western Avenue at Eastern Avenue/Stanwood Street, is currently under a two-way stop control with stop signs installed on Eastern Avenue and Stanwood Street. The southern intersection, Western Avenue at Waitt Avenue/Maple Street, is currently under traffic

Labels on image:
- Western Avenue (Rt. 107)
- Stanwood Street
- Eastern Avenue (Rt. 129A)
- Maple Street
- Waitt Avenue
- Western Avenue (Rt. 107)
- N

FIGURE 1
Western Avenue (Rt. 107) at Eastern Avenue (Rt. 129A), Lynn

CTPS

*Operational Improvements
at Congested and
High-Crash Intersections*

signal control with pedestrian signal heads.[1] East of Western Avenue, Eastern Avenue and Waitt Avenue merge together, with a stop control on Waitt Avenue. West of Western Avenue, Stanwood Street and Maple Street also meet, at a recently constructed modern roundabout.

All of the streets running into the two intersections are two-lane roadways. All of the approaches have only a single travel lane shared by all movements, which flares somewhat near the intersection. On-street parking on Western Avenue is permitted in both directions between the two intersections. Crosswalks exist at all four approaches at the southern intersection. At the northern intersection, where Eastern Avenue and Stanwood Street are not aligned, crosswalks are installed only across Stanwood Street and on the northbound approach of Western Avenue.

The area is multi-family and single-family mixed residential, with commercial uses mainly along Western Avenue. At the northern intersection, a popular gas station is located on the northeastern corner, with curb cuts on Western Avenue and Eastern Avenue. Further north, Western Avenue is situated on a bridge over Floating Bridge Pond.

ISSUES AND CONCERNS

During peak periods, traffic is heavy on almost all of the approaches at the two intersections. Traffic is especially heavy on Route 107, which has four lanes north of the city border in Salem, but has only two lanes in this area. The area south of these two intersections is densely settled, with a number of signalized intersections located on Western Avenue. The two intersections essentially become a junction area where the southbound regional traffic diverges and the northbound regional traffic merges.

At the intersection of Western Avenue at Eastern Avenue/Stanwood Street, the southbound traffic is the heaviest among all approaches, with a high percentage of left and right turns. The left turns frequently back up due to heavy traffic in the opposite direction. Although the through and right-turn traffic sometimes can proceed around left turns, the entire approach can often be blocked when traffic is heavy from all approaches.

The right turns usually proceed without impedance if they are not blocked. The high volume of traffic includes a major portion of regional traffic seeking alternative paths to reach major highways in the west (such as Route 129 and Interstate 95) via local streets, such as Stanwood and Maple.

Under the two-way stop control, traffic on Eastern Avenue and Stanwood Street frequently forms extensive queues and experiences extensive delays. At times, aggressive drivers force themselves into the intersection, causing traffic blockages and near collisions. Crash data analysis indicates that this intersection has a much higher crash rate than similar intersections in the region (see the next section for details).

The intersection of Western Avenue at Waitt Avenue/Maple Street is under traffic signal control. Traffic on the minor streets (Waitt Avenue and Maple Street) moves fairly well, with reasonable delays. In order to prevent Maple Street traffic from spilling over to the roundabout upstream of

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[1] Although President Street is also located very close to the intersection, it is a one-way eastbound street that carries a relatively low volume of traffic. The intersection operates as a regular four-legged intersection.

this intersection, the signal currently allocates a higher portion of phase time for the minor streets than the major street. As a result, traffic on the major street (Western Avenue), especially in the northbound direction, experiences more delays than the minor streets.

Based on field observations and a quick review of the available crash and traffic data, the issues and concerns for these two intersections can be summarized as:

- High number of crashes at the intersection of Western Avenue at Eastern Avenue/Stanwood Street.
- Traffic congestion at the two intersections during the peak hours.
- Extensive traffic queues and delays on Eastern Avenue and Stanwood Street during the peak periods. Aggressive traffic from the two approaches causes intersection blockages and near collisions.
- Southbound left turns to Eastern Avenue at times block the through traffic.
- Noticeable delays for the northbound traffic at the intersection of Western Avenue at Waitt Avenue/Maple Street.
- East–west drivers prefer to use the signalized intersection in order to avoid crossing Western Avenue at the northern unsignalized intersection.

CRASH DATA ANALYSIS

Based on the 2004–2006 Massachusetts Registry of Motor Vehicle (RMV) crash data, Table 1 shows that on average, 10 crashes occurred annually at the intersection of Western Avenue at Eastern Avenue/Stanwood Street. About 20% of the crashes resulted in personal injuries. The crash types consist of about 70% angle collisions and about 20% rear-end collisions. The high proportion of angle-type collisions is likely due to the lack of signal control coupled with the offset design between Eastern Avenue and Stanwood Street.

The crash rate[2] is another effective tool for examining the relative safety of a particular location. Based on the crash data and the available recent traffic counts, the crash rate for this intersection is calculated as 1.07 (see Appendix A for the calculation). The rate is much higher than the average rate for the unsignalized locations in MassHighway District 4, which is estimated as 0.58.[3]

Table 2 shows that an average of five crashes occurred at the intersection of Western Avenue at Waitt Avenue/Maple Street each year. Most of the crashes (80%) resulted in property damage only. The crash types consist of about 60% angle collisions and about 40% rear-end collisions. Field observations indicate that traffic is congested at this intersection during the peak hours, with no major safety concerns. The crash rate for this intersection is calculated as 0.53 (see the Appendix A for the calculation). The rate is lower than the average rate for the signalized locations in MassHighway District 4, which is estimated as 0.78.

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

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

TABLE 1
Summary of RMV Crash Data (2004–2006)
Western Avenue at Eastern Avenue/Stanwood Street, Lynn

Statistics Period		2004	2005	2006	3-Year	Average
Total number of crashes		10	10	10	30	10
Severity	Property damage	7	7	9	23	8
	Personal injury	2	3	1	6	2
	Fatality	0	0	0	0	0
	Not reported	1	0	0	1	0
Collision Type	Angle	5	8	7	20	7
	Rear-end	4	1	2	7	2
	Sideswipe	1	0	0	1	0
	Head-on	0	1	0	1	0
	Single vehicle	0	0	0	0	0
	Not reported	0	0	1	1	0
Crashes involved pedestrian(s)		0	0	0	0	0
Crashes involved cyclist(s)		0	0	1	1	0
Occurred during weekday peak periods*		2	4	2	8	3
Wet or icy pavement conditions		2	4	4	10	3
Dark/lighted conditions		5	5	4	14	5

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

TABLE 2
Summary of RMV Crash Data (2004–2006)
Western Avenue at Waitt Avenue/Maple Street, Lynn

Statistics Period		2004	2005	2006	3-Year	Average
Total number of crashes		3	6	5	14	5
Severity	Property damage	3	5	4	12	4
	Personal injury	0	1	0	1	0
	Fatality	0	0	0	0	0
	Not reported	0	0	1	1	0
Collision Type	Angle	1	3	4	8	3
	Rear-end	1	3	1	5	2
	Sideswipe	1	0	0	1	0
	Head-on	0	0	0	0	0
	Single vehicle	0	0	0	0	0
	Not reported	0	0	0	0	0
Crashes involved pedestrian(s)		0	0	0	0	0
Crashes involved cyclist(s)		0	0	0	0	0
Occurred during weekday peak periods*		0	2	4	6	2
Wet or icy pavement conditions		0	0	2	2	1
Dark/lighted conditions		0	0	0	0	0

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

INTERSECTION CAPACITY ANALYSIS

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

As seen in Table 3, the intersection of Western Avenue at Eastern Avenue/Stanwood Street carried about 2,000 vehicles in the morning peak hour, from 7:45 to 8:45, and about 2,200 vehicles in the evening peak hour, from 4:45 to 5:45. About 2 and 20 pedestrians crossed the intersection during the AM and PM peak hour, respectively.

As Table 4 shows, the intersection of Western Avenue at Waitt Avenue/Maple Street carried about 2,000 vehicles in the morning peak hour, from 7:45 to 8:45, and about 2,150 vehicles in

TABLE 3
AM and PM Peak Hour Traffic Volumes and Pedestrian Crossings
Western Avenue at Eastern Avenue/Stanwood Street, Lynn

Street name		Western Avenue (Route 107)						Stanwood Street			Eastern Avenue			
Direction		Northbound			Southbound			Eastbound			Westbound			Total
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM peak hour	Turning volume	0	575	16	207	541	243	134	41	2	8	74	163	2004
	Approach volume	591			991			177			245			
	Ped. crossings	2			0			0			0			2
PM peak hour	Turning volume	1	637	30	175	546	287	147	70	5	17	51	241	2207
	Approach volume	668			1008			222			309			
	Ped. crossings	6			10			1			2			19

TABLE 4
AM and PM Peak Hour Traffic Volumes and Pedestrian Crossings
Western Avenue at Waitt Avenue/Maple Street, Lynn

Street name		Western Avenue (Route 107)						Maple Street			Waitt Avenue			
Direction		Northbound			Southbound			Eastbound			Westbound			Total
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM peak hour	Turning volume	10	485	100	2	540	9	113	280	9	109	334	3	1994
	Approach volume	595			551			402			446			
	Ped. crossings	3			1			2			2			8
PM peak hour	Turning volume	10	595	111	9	557	2	68	364	1	74	357	5	2153
	Approach volume	716			568			433			436			
	Ped. crossings	3			1			1			10			15

the evening peak hour, from 4:45 to 5:45. About 10 and 15 pedestrians crossed the intersection during the AM and PM peak hour, respectively. Fewer than five cyclists were observed in both peak hours combined (not shown in the table).

Based on the adjusted turning movement counts, staff performed capacity analyses for the two intersections using the computer program Synchro.[4] The intersection of Western Avenue at Eastern Avenue/Stanwood Street was analyzed according to the unsignalized intersection capacity analysis method of the Highway Capacity Manual.[5]

Analysis indicates that traffic on the stop-control approaches (Eastern Avenue and Stanwood Street) endures extensive delays (much more than 3 minutes) at level of service (LOS) F in both the AM and PM peak hours (see Table 5). Details of the analysis for both the AM and PM peak hours are included in Appendix B.

The intersection capacity analysis of Western Avenue at Waitt Avenue/Maple Street indicates that the intersection operates at LOS D in the AM peak hour and at LOS E in the PM peak hour (see Table 6). Analysis indicates a noticeably high average delay for traffic on Western Avenue,

TABLE 5
Existing Intersection Capacity Analysis
Western Avenue at Eastern Avenue/Stanwood Street, Lynn

Street name		Western Avenue (Route 107)						Stanwood Street			Eastern Avenue		
Direction		Northbound			Southbound			Eastbound			Westbound		
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
AM peak hour	LOS	A			A			F			F		
	Delay (sec/veh)	0			6			> 180			> 180		
PM peak hour	LOS	A			A			F			F		
	Delay (sec/veh)	0			8			> 180			> 180		

TABLE 6
Existing Intersection Capacity Analysis
Western Avenue at Waitt Avenue/Maple Street, Lynn

Street name		Western Avenue (Route 107)						Maple Street			Waitt Avenue			
Direction		Northbound			Southbound			Eastbound			Westbound			Overall
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM peak hour	LOS	E			D			C			C			D
	Delay (sec/veh)	70			44			25			26			44
PM peak hour	LOS	F			D			B			C			E
	Delay (sec/veh)	114			43			20			21			58

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

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

especially in the northbound direction. Details of the analysis for both the AM and PM peak hours are included in Appendix C.

PRELIMINARY ANALYSIS OF TRAFFIC SIGNAL WARRANTS

One of the potential improvements for the intersection of Western Avenue at Eastern Avenue/Stanwood Street is to introduce traffic signal control. According to the Manual for Uniform Traffic Control Devices (MUTCD),[6] an engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location must be performed to determine whether installation of a traffic signal is justified at a particular location. The investigation must include criteria related to the following traffic signal warrants and other factors related to existing operations and safety at the study location:

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

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

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

Analysis found that the intersection meets Warrants 1 and 2 at a relatively high satisfaction level. Although Warrant 7 is also satisfied according to the reported crashes (see Table 1), it was applied as a supportive reason, not as the principal reason, for the signalization.

ANALYSIS OF IMPROVEMENT ALTERNATIVES

Analysis of traffic signal warrants indicates that the intersection of Western Avenue at Eastern Avenue/Stanwood Street qualifies for the installation of a traffic signal. The traffic signal would reduce traffic flow conflicts, thus improving safety, delays, and queues. In addition, this signal should be coordinated with the adjacent signal at the intersection of Western Avenue at Waitt

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[6] Federal Highway Administration, U.S. Department of Transportation, *Chapter 4C. Traffic Control Signal Needs*, 2003 edition with revision numbers 1 and 2 incorporated, December 2007.

Avenue/Maple Street. The coordination would improve traffic movements and thus reduce delays and conflicts at both intersections.

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

In the first stage, a number of signal operation and geometric design strategies were tested for the intersection of Western Avenue at Eastern Avenue/Stanwood Street. The alternatives tested for this intersection include:

1) Two-phase permissive LT (left-turn)/ RT (right-turn) operation on all approaches, under the existing geometry
2) NB/SB (northbound/southbound) permissive phase and EB/WB (eastbound/westbound) split phase,[7] under the existing geometry
3) NB/SB permissive phase led by SB traffic with protected LT and EB/WB permissive phase, with the addition of an SB exclusive LT lane and a WB-RT exclusive lane

At this intersection, the SB traffic is the heaviest among all approaches and the SB left turns frequently back up. Although through and right-turn traffic sometimes can proceed around the left turns, the entire approach can be blocked when traffic is heavy from all approaches. Synchro analyses reflect these observations and show that only Alternative 3 can operate at acceptable levels of service for all approaches. The results from Alternative 3 are summarized and included in Table 7 (capacity analyses for selected alternatives in both stages), and detailed Synchro analyses are attached in Appendix D.

Based on the State Roadway Inventory file, Western Avenue has a right-of-way (ROW) of 56 feet and a pavement width of 45 feet for about 150 feet north of this intersection before the bridge section. It appears feasible to add an 11-foot SB LT lane within the existing pavement width. Analyses indicate that a storage length of about 240 feet is desirable for the LT lane.[8] As the space in the area is limited, we consider a storage length of 120 feet acceptable at this intersection.[9] Meanwhile, the WB approach has an ROW of 64 feet and a pavement width of 42 feet for about 800 feet east of this intersection. It is feasible to insert an RT exclusive lane on the approach, which would be beneficial for the intersection operation. Analysis indicates that a storage length of 80 feet would be sufficient for the RT lane.

A similar procedure was applied to the intersection of Western Avenue at Waitt Avenue/Maple Street. It was found that intersection operations could be improved by increasing slightly the cycle length under the existing signal phasing sequence and adding an exclusive RT lane on the

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[7] The split phase operation is considered helpful at this intersection, as Eastern Avenue and Stanwood Street are not aligned across each other. However, it was not evaluated as favorable due to heavy traffic on Western Avenue and limited space available for lane additions in desirable lengths for almost all approaches.
[8] The estimation is based on the 95th percentile queue from the worst case among alternatives under the future year traffic conditions.
[9] The estimation is based on one and a half times the 50th percentile queue from the worst case among alternatives under the future year traffic conditions.

NB approach (by removing two on-street parking spaces). The capacity analyses for this intersection are summarized and included in Table 8. Detailed analyses are in Appendix E.

TABLE 7
Intersection Capacity Analysis of Selected Alternatives
Existing Traffic Conditions
Western Avenue at Eastern Avenue/Stanwood Street, Lynn

Street Name		Western Ave. (Route 107)		Eastern Ave./Stanwood St.		Overall
Approach		**Northbound**	**Southbound**	**Eastbound**	**Westbound**	
AM peak hour	**Existing**	A/0	A/6	F/>180	F/>180	NA
	Stage 1	D/36	C/22	D/46	B/16	C/28
	Stage 2	B/13	C/22	D/54	B/17	C/21
PM peak hour	**Existing**	A/0	A/8	F/>180	F/>180	NA
	Stage 1	D/49	C/21	D/55	B/14	C/32
	Stage 2	A/9	C/25	D/47	B/14	C/21

Note: Performance Measures: Level of Service (A to F)/Average Delay (seconds per vehicle)
          Selected Alternative in Stage 1: NB/SB Permissive Phase Led by SB with a Protected LT and EB/WB Permissive Phase,
                  with the Addition of an SB-LT Lane and a WB-RT Lane
          Selected Alternative in Stage 2: Coordinated with the Signal at Waitt Avenue/Maple Street under the Same Signal Phasing
                  Sequence as in Stage 1

TABLE 8
Intersection Capacity Analysis of Selected Alternatives
Existing Traffic Conditions
Western Avenue at Waitt Avenue/Maple Street, Lynn

Street name		Western Ave. (Route 107)		Waitt Ave./Maple St.		Overall
Approach		**Northbound**	**Southbound**	**Eastbound**	**Westbound**	
AM peak hour	**Existing**	E/70	D/44	C/25	C/26	D/44
	Stage 1	C/31	E/58	C/31	C/31	D/39
	Stage 2	C/30	C/29	D/35	D/36	C/32
PM peak hour	**Existing**	E/114	D/43	B/20	C/21	E/58
	Stage 1	C/29	E/55	C/32	C/33	D/37
	Stage 2	C/29	C/20	C/34	D/35	C/29

Note: Performance Measures: Level of Service (A to F)/Average Delay (seconds per vehicle)
          Selected Alternative in Stage 1: Two-Phase Permissive Operation for All Approaches with the Addition of an NB RT Lane
          Selected Alternative in Stage 2: Coordinated with the Signal at Eastern Avenue/Stanwood Street under the Same Signal
                  Phasing Sequence as Stage 1

In the second stage, we tested different combinations of network cycle lengths and offsets for the two intersections through applications of the Synchro network optimization functions. To reduce the possibilities of traffic backing up to the upstream roundabout, we selected a relatively short cycle length of 90 seconds (including the pedestrian signal time) and assigned a higher percentage of green phase times for the EB/WB approaches at the intersection of Western Avenue at Waitt Avenue/Maple Street. The signal at Eastern Avenue is selected as the master intersection as it has a higher traffic volume than the other signal.

As Tables 7 and 8 show, with the coordination (Stage 2), both intersections would operate at a better overall level of service with less delay than the alternative without coordination (Stage 1). Detailed network settings and Synchro analyses of the two intersections in the second stage are in Appendices F and G.

With the installation of the new signal and its coordination with the existing one, traffic at the two intersections is expected to shift between the two intersections and rebalance. To reflect this phenomenon, this study also examined a scenario of a 50% shift of the left-turning traffic from Maple Street to Stanwood Street and found that the two intersections would still operate at the same level of service (LOS) as in the original case.

In addition, a future-year scenario of 8% growth over a 20-year planning horizon was tested for the selected alternatives. The growth assumption is based on a review of the traffic projections in the North Shore area from the recent Boston Region MPO transportation-planning model. Higher numbers (than in existing conditions) of pedestrian calls (20% growth) were assumed for both intersections in the future-year analysis.

Results from Synchro analyses with the projected traffic growth are summarized in Tables 9 and 10 for the two intersections separately. With the coordination (Stage 2), both intersections would still operate at an overall acceptable LOS D under the projected traffic conditions.

TABLE 9
Intersection Capacity Analysis of Selected Alternatives
2030 Projected Traffic Conditions
Western Avenue at Eastern Avenue/Stanwood Street, Lynn

Street Name		Western Ave. (Route 107)		Eastern Ave./Stanwood St.		Overall
Approach		Northbound	Southbound	Eastbound	Westbound	
AM peak hour	Existing	A/0	A/7	F/>180	F/>180	NA
	Stage 1	F/97	C/27	D/55	B/16	D/49
	Stage 2	C/33	D/41	D/51	B/16	D/36
PM peak hour	Existing	A/0	A/7	F/>180	F/>180	NA
	Stage 1	F/86	C/25	E/69	B/14	D/46
	Stage 2	D/43	B/13	E/68	B/18	D/43

Note: Performance measures: Level of Service (A to F)/Average Delay (seconds per vehicle)
Selected Alternative in Stage 1: NB/SB Permissive Phase led by SB with a Protected LT and EB/WB Permissive Phase, with the Addition of an SB-LT Lane and a WB-RT Lane
Selected Alternative in Stage 2: Coordinated with the Signal at Waitt Avenue/Maple Street under the Same Signal Phasing Sequence as Stage 1

TABLE 10
Intersection Capacity Analysis of Selected Alternatives
2030 Projected Traffic Conditions
Western Avenue at Waitt Avenue/Maple Street, Lynn

Street name		Western Ave. (Route 107)		Waitt Ave./Maple St.		Overall
Approach		Northbound	Southbound	Eastbound	Westbound	
AM peak hour	Existing	F/97	E/59	C/31	C/32	E/59
	Stage 1	C/30	E/66	D/51	D/51	D/49
	Stage 2	D/44	D/43	D/41	D/42	D/43
PM peak hour	Existing	F/155	E/60	C/22	C/23	E/76
	Stage 1	C/31	F/92	D/43	D/47	D/53
	Stage 2	D/40	E/66	D/35	D/36	D/45

Note: Performance Measures: Level of Service (A to F)/Average Delay (seconds per vehicle)
          Selected Alternative in Stage 1:   Two-Phase Permissive Operation for All Approaches with the Addition of an NB RT Lane
          Selected Alternative in Stage 2:   Coordinated with the Signal at Eastern Avenue/Stanwood Street under the Same Signal
                                       Phasing Sequence as Stage 1

IMPROVEMENT RECOMMENDATIONS

A series of analyses were conducted for the two intersections in this study. We first performed the signal warrant analysis for the intersection of Western Avenue at Eastern Avenue/Stanwood Street and made sure that the installation of a traffic signal control is justified. We then used Synchro to perform a two-stage traffic signal optimization analysis. In the first stage, the two intersections were analyzed and optimized as isolated intersections. Once the most suitable operation was selected for each of them, we performed the second stage analysis, in which the two intersections were coordinated and analyzed as one network system.

Based on the analyses, we propose the following improvements for the two intersections:

Western Avenue at Eastern Avenue/Stanwood Street

- Modify the southbound approach to include a left-turn exclusive lane.[10]
- Modify the westbound approach to include an exclusive right-turn exclusive lane.[11]
- Signalize the intersection.
- Coordinate this traffic signal with the signal at Waitt Avenue/Maple Street.

Western Avenue at Waitt Avenue/Maple Street

- Add a short northbound right-turn lane by removing two on-street parking spaces.
- Coordinate this traffic signal with the signal at Eastern Avenue/Stanwood Street.

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[10] As the space in the area is limited, the modifications have to be achieved by restriping travel lanes or slightly expanding the pavement surface under the existing right-of-way. Based on the Synchro queuing estimation, we consider a storage length of 120 feet to be acceptable.

[11] A storage length of 80 feet is sufficient based on Synchro queuing estimation.

As mentioned, the two intersections are essentially a junction area where the southbound regional traffic diverges and the northbound regional traffic merges. The coordination would synchronize and balance traffic movements at both intersections and thus improve operations and safety with reduced delays and conflicts.

With the installation of the new signal and its coordination with the existing one, traffic at the two intersections is expected to shift between the two intersections and rebalance. To reflect this phenomenon, this study also examined a scenario of a 50% shift of the left-turning traffic from Maple Street to Stanwood Street and found that the two intersections would still operate at the same LOS and with the same delays as in the original case. We recommend that traffic volumes at the two intersections and applicable signal timing parameters be monitored during the early stages of implementation until traffic volume shifts stabilize and the operation of the coordinated traffic signals is optimal.

The coordinated signals would also provide an exclusive pedestrian signal phase separately for pedestrians to safely cross either intersection. Sidewalks and crosswalks should be considered for all approaches when the intersection at Eastern Avenue/Stanwood Street is reconstructed for the installation of a traffic signal. The signal system should include pedestrian signal heads with an accessible (audible) pedestrian signal.

Appendix A

Intersection Crash Rate Calculation

Western Avenue at Eastern Avenue/Stanwood Street, Lynn
Western Avenue at Waitt Avenue/Maple Street, Lynn

MassHighway

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Lynn   COUNT DATE :   5/26/09

DISTRICT :   4   UNSIGNALIZED :   X   SIGNALIZED :

~ INTERSECTION DATA ~

MAJOR STREET :   Western Avenue

MINOR STREET(S) :   Eastern Avenue

                   Stanwood Street

INTERSECTION DIAGRAM
(Label Approaches)
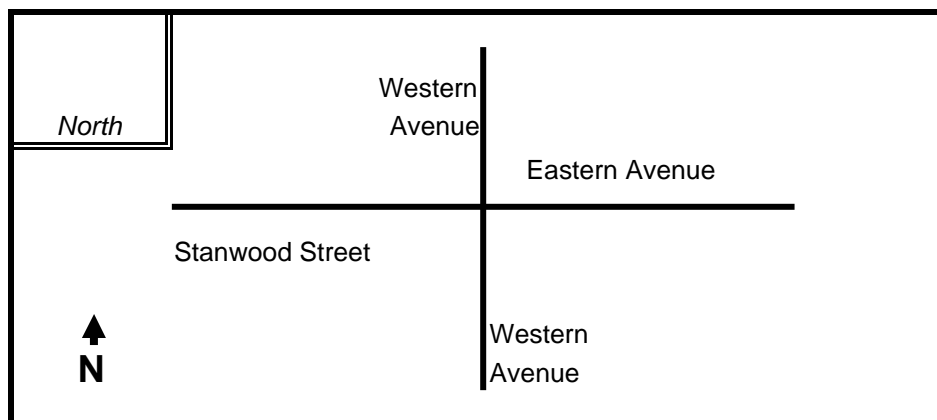
North	Western Avenue	
		Eastern Avenue
Stanwood Street		
↑ N	Western Avenue	

PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	NB	SB	EB	WB		
PEAK HOURLY VOLUMES (AM/PM) :	668	1108	222	309		**2,307**

" K " FACTOR :	**0.090**	INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME :		**25,633**
TOTAL # OF CRASHES :	30	# OF YEARS :	3	AVERAGE # OF CRASHES PER YEAR (**A**) :	**10.00**

CRASH RATE CALCULATION :   **1.07**   RATE = $\dfrac{(A * 1{,}000{,}000)}{(V * 365)}$

Comments : _____

Project Title & Date: Boston MPO Congested and High-Crash Intersections Study

MassHighway

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Lynn   COUNT DATE :   5/26/09

DISTRICT :   4   UNSIGNALIZED :   X   SIGNALIZED :

~ INTERSECTION DATA ~

MAJOR STREET :   Western Avenue

MINOR STREET(S) :   Waitt Avenue

                        Maple Street

INTERSECTION DIAGRAM
(Label Approaches)
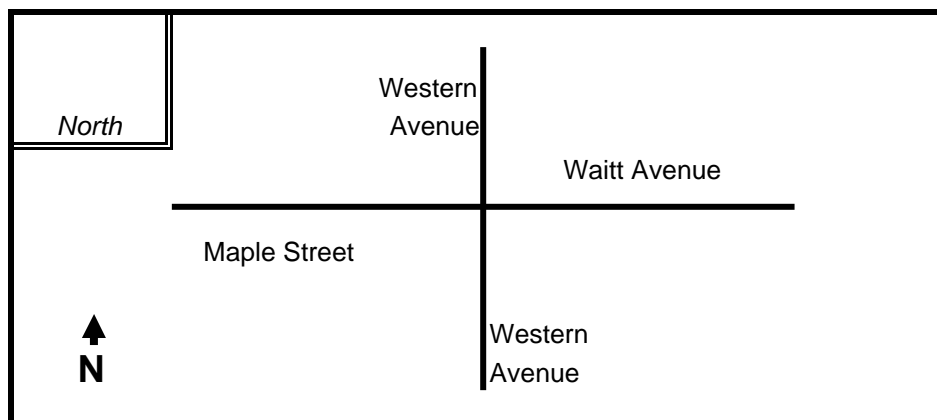
North	Western Avenue	
		Waitt Avenue
	Maple Street	
↑ N	Western Avenue	

PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	NB	SB	EB	WB		
PEAK HOURLY VOLUMES (AM/PM) :	716	568	433	436		**2,153**

" K " FACTOR :	**0.090**	INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME :		**23,922**
TOTAL # OF CRASHES :	14	# OF YEARS :	3	AVERAGE # OF CRASHES PER YEAR (**A**) :	**4.67**

CRASH RATE CALCULATION :   **0.53**   RATE = $\dfrac{(A * 1,000,000)}{(V * 365)}$

Comments :

Project Title & Date: Boston MPO Congested and High-Crash Intersections Study

Appendix B

**AM/PM Peak Hour Intersection Capacity Analysis
Existing Traffic Conditions
Western Avenue at Eastern Avenue/Stanwood Street, Lynn**

Movement	EBL	EBR	EBR2	NWL2	NWL	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	⍦				⍦			✛			✛	
Volume (veh/h)	134	41	2	8	74	163	0	575	16	207	541	243
Sign Control	Stop				Stop			Free			Free	
Grade	0%				0%			0%			0%	
Peak Hour Factor	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Hourly flow rate (vph)	143	44	2	9	79	173	0	612	17	220	576	259
Pedestrians								2				
Lane Width (ft)								16.0				
Walking Speed (ft/s)								4.0				
Percent Blockage								0				
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)								302				
pX, platoon unblocked	0.70	0.70		0.70	0.70	0.70				0.70		
vC, conflicting volume	1978	1774	707	1791	1895	620	834			629		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	2179	1889	707	1914	2061	250	834			262		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	0	0	100	0	0	69	100			76		
cM capacity (veh/h)	0	37	433	0	29	552	791			912		

Direction, Lane #	EB 1	NW 1	NE 1	SW 1
Volume Total	188	261	629	1054
Volume Left	143	9	0	220
Volume Right	2	173	17	259
cSH	0	0	791	912
Volume to Capacity	Err	Err	0.00	0.24
Queue Length 95th (ft)	Err	Err	0	24
Control Delay (s)	Err	Err	0.0	6.0
Lane LOS	F	F		A
Approach Delay (s)	Err	Err	0.0	6.0
Approach LOS	F	F		

Intersection Summary				
Average Delay		Err		
Intersection Capacity Utilization		136.4%	ICU Level of Service	H
Analysis Period (min)		15		

Movement	EBL	EBR	EBR2	NWL2	NWL	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations	⍓				⍓			⊕			⊕	
Volume (veh/h)	147	70	5	17	51	241	1	637	30	175	546	287
Sign Control	Stop				Stop			Free			Free	
Grade	0%				0%			0%			0%	
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Hourly flow rate (vph)	152	72	5	18	53	248	1	657	31	180	563	296
Pedestrians	1				2			10			10	
Lane Width (ft)	15.0				15.0			16.0			16.0	
Walking Speed (ft/s)	4.0				4.0			4.0			4.0	
Percent Blockage	0				0			1			1	
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)								302				
pX, platoon unblocked	0.69	0.69		0.69	0.69	0.69				0.69		
vC, conflicting volume	2032	1764	722	1799	1897	684	860			690		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	2272	1884	722	1935	2077	315	860			323		
tC, single (s)	7.1	6.5	6.2	7.1	6.5	6.2	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	0	0	99	0	0	50	100			79		
cM capacity (veh/h)	0	38	423	0	29	495	789			854		

Direction, Lane #	EB 1	NW 1	NE 1	SW 1
Volume Total	229	319	689	1039
Volume Left	152	18	1	180
Volume Right	5	248	31	296
cSH	0	0	789	854
Volume to Capacity	Err	Err	0.00	0.21
Queue Length 95th (ft)	Err	Err	0	20
Control Delay (s)	Err	Err	0.0	5.4
Lane LOS	F	F	A	A
Approach Delay (s)	Err	Err	0.0	5.4
Approach LOS	F	F		

Intersection Summary				
Average Delay		Err		
Intersection Capacity Utilization		150.0%	ICU Level of Service	H
Analysis Period (min)		15		

Appendix C

AM/PM Peak Hour Intersection Capacity Analysis
Existing Traffic Conditions
Western Avenue at Waitt Avenue/Maple Street, Lynn

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		⟳			⟳			⟳			⟳	
Volume (vph)	113	280	9	109	334	3	10	485	100	2	540	9
Confl. Peds. (#/hr)	1		3	3		1	1		2	2		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	4%	4%	4%	4%	4%	4%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)									0			0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	428	0	0	474	0	0	633	0	0	586	0
Turn Type	Perm			Perm			Perm			Perm		
Protected Phases		2			6			4			8	
Permitted Phases	2			6			4			8		
Detector Phase	2	2		6	6		4	4		8	8	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	16.0	16.0		16.0	16.0		20.0	20.0		20.0	20.0	
Total Split (s)	29.0	29.0	0.0	29.0	29.0	0.0	24.0	24.0	0.0	24.0	24.0	0.0
Total Split (%)	41.4%	41.4%	0.0%	41.4%	41.4%	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		None	None		Max	Max		None	None	
Act Effct Green (s)		24.3			24.3			19.2			19.2	
Actuated g/C Ratio		0.43			0.43			0.34			0.34	
v/c Ratio		0.73			0.76			1.04			0.92	
Control Delay		25.4			25.9			69.5			43.8	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		25.4			25.9			69.5			43.8	
LOS		C			C			E			D	
Approach Delay		25.4			25.9			69.5			43.8	
Approach LOS		C			C			E			D	
Queue Length 50th (ft)		100			112			191			167	
Queue Length 95th (ft)		#342			#375			#545			#489	
Internal Link Dist (ft)		236			49			618			222	
Turn Bay Length (ft)												
Base Capacity (vph)		584			627			611			634	
Starvation Cap Reductn		0			0			0			0	
Spillback Cap Reductn		0			0			0			0	
Storage Cap Reductn		0			0			0			0	
Reduced v/c Ratio		0.73			0.76			1.04			0.92	

Intersection Summary

Cycle Length: 70

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	24%
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	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 56.4

Natural Cycle: 90

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 1.04

Intersection Signal Delay: 43.8 Intersection LOS: D
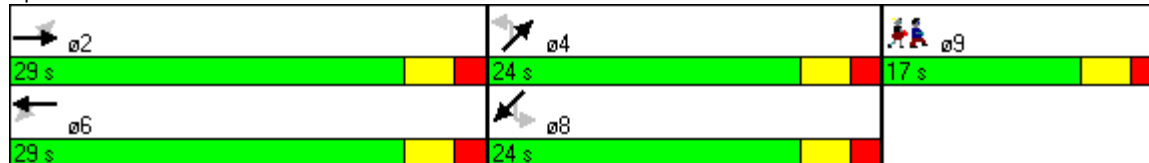
Intersection Capacity Utilization 85.3% ICU Level of Service E

Analysis Period (min) 15

\#   95th percentile volume exceeds capacity, queue may be longer.

Queue shown is maximum after two cycles.

Splits and Phases: 5: Int

Intersection Capacity Analysis
Western Ave @ Waitt Ave/Maple St

2/16/2010

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		⟠			⟠			⟠			⟠	
Volume (vph)	68	364	1	74	357	5	10	595	111	9	557	2
Confl. Peds. (#/hr)	1		3	3		1	1		10	10		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)									0			0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	446	0	0	449	0	0	737	0	0	585	0
Turn Type	Perm			Perm			Perm			Perm		
Protected Phases		2			6			4			8	
Permitted Phases	2			6			4			8		
Detector Phase	2	2		6	6		4	4		8	8	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	16.0	16.0		16.0	16.0		20.0	20.0		20.0	20.0	
Total Split (s)	29.0	29.0	0.0	29.0	29.0	0.0	24.0	24.0	0.0	24.0	24.0	0.0
Total Split (%)	41.4%	41.4%	0.0%	41.4%	41.4%	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		None	None		Max	Max		None	None	
Act Effct Green (s)		24.3			24.3			19.2			19.2	
Actuated g/C Ratio		0.43			0.43			0.34			0.34	
v/c Ratio		0.63			0.65			1.17			0.92	
Control Delay		19.9			20.6			114.2			43.0	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		19.9			20.6			114.2			43.0	
LOS		B			C			F			D	
Approach Delay		19.9			20.6			114.2			43.0	
Approach LOS		B			C			F			D	
Queue Length 50th (ft)		98			99			~276			166	
Queue Length 95th (ft)		#317			#326			#642			#486	
Internal Link Dist (ft)		236			45			618			222	
Turn Bay Length (ft)												
Base Capacity (vph)		705			693			632			636	
Starvation Cap Reductn		0			0			0			0	
Spillback Cap Reductn		0			0			0			0	
Storage Cap Reductn		0			0			0			0	
Reduced v/c Ratio		0.63			0.65			1.17			0.92	

Intersection Summary

Cycle Length: 70

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	24%
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	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 56.4

Natural Cycle: 90

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 1.17

Intersection Signal Delay: 57.5   Intersection LOS: E

Intersection Capacity Utilization 92.3%   ICU Level of Service F

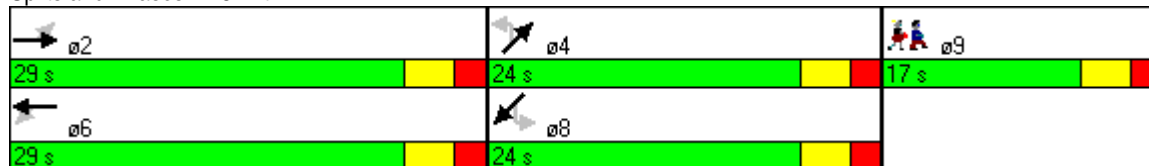Analysis Period (min) 15

~   Volume exceeds capacity, queue is theoretically infinite.

     Queue shown is maximum after two cycles.

\#   95th percentile volume exceeds capacity, queue may be longer.

     Queue shown is maximum after two cycles.

Splits and Phases: 5: Int

ø2	ø4	ø9
29 s	24 s	17 s
ø6	ø8	
29 s	24 s	

Appendix D

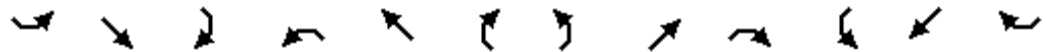**AM/PM Peak Hour Intersection Capacity Analysis**

Stage 1 Selected Alternative:
NB/SB Permissive Phase Led by SB with Protected LT and EB/WB Permissive Phase, with the Additions of a SB-LT Lane and a WB-RT Exclusive Lane

Western Avenue at Eastern Avenue/Stanwood Street, Lynn

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		⊕			↰	↱		⊕		↰	↳	
Volume (vph)	134	41	2	8	74	163	0	575	16	207	541	243
Confl. Peds. (#/hr)			2	2								
Confl. Bikes (#/hr)												
Peak Hour Factor	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	3%	3%	3%	4%	4%	4%	4%	4%	4%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)						0						0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	189	0	0	88	173	0	629	0	220	835	0
Turn Type	Perm			Perm		Perm	Perm			pm+pt		
Protected Phases		2			6			8		7	4	
Permitted Phases	2			6		6	8			4		
Detector Phase	2	2		6	6	6	8	8		7	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		8.0	29.0	
Total Split (s)	20.0	20.0	0.0	20.0	20.0	20.0	41.0	41.0	0.0	12.0	53.0	0.0
Total Split (%)	22.2%	22.2%	0.0%	22.2%	22.2%	22.2%	45.6%	45.6%	0.0%	13.3%	58.9%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0		3.5	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0	2.0	2.0	2.0		0.5	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	5.0	5.0	5.0	4.0	4.0	5.0	4.0
Lead/Lag							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes		Yes		
Recall Mode	None	None		None	None	None	Min	Min		None	Min	
Act Effct Green (s)		14.4			14.4	14.4		31.9		45.2	44.2	
Actuated g/C Ratio		0.20			0.20	0.20		0.45		0.63	0.62	
v/c Ratio		0.71			0.25	0.41		0.76		0.69	0.84	
Control Delay		46.4			29.7	8.8		25.1		22.1	22.0	
Queue Delay		0.0			0.0	0.0		11.1		0.0	0.0	
Total Delay		46.4			29.7	8.8		36.2		22.1	22.0	
LOS		D			C	A		D		C	C	
Approach Delay		46.4			15.8			36.2			22.0	
Approach LOS		D			B			D			C	
Queue Length 50th (ft)		79			33	0		205		32	220	
Queue Length 95th (ft)		#228			89	55		#514		#155	#699	
Internal Link Dist (ft)		1			441			223			733	
Turn Bay Length (ft)										200		
Base Capacity (vph)		284			376	434		960		319	1102	
Starvation Cap Reductn		0			0	0		306		0	0	
Spillback Cap Reductn		0			0	0		0		0	0	
Storage Cap Reductn		0			0	0		0		0	0	
Reduced v/c Ratio		0.67			0.23	0.40		0.96		0.69	0.76	

Intersection Summary

Cycle Length: 90

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	19%
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	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 71.6

Natural Cycle: 90

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.84

Intersection Signal Delay: 27.6   Intersection LOS: C
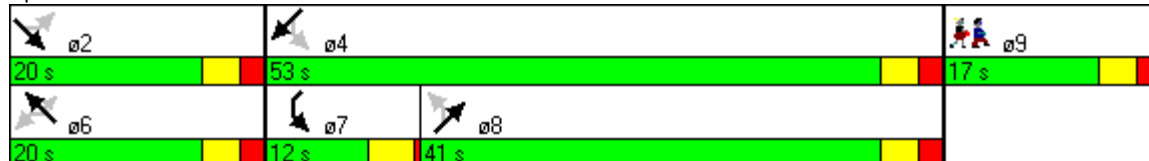
Intersection Capacity Utilization 112.7%   ICU Level of Service H

Analysis Period (min) 15

\#   95th percentile volume exceeds capacity, queue may be longer.

    Queue shown is maximum after two cycles.

Splits and Phases: 1: Int

Intersection Capacity Analysis
Western Ave @ Eastern Ave/Stanwood St

2/16/2010

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		⊕			⊣	↱		⊕		↰	⇂	
Volume (vph)	147	70	5	17	51	241	1	637	30	175	546	287
Confl. Peds. (#/hr)	10		6	10		2	1		2	2		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)						0						0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	229	0	0	71	248	0	689	0	180	859	0
Turn Type	Perm			Perm			Perm	Perm		pm+pt		
Protected Phases		2			6			8		7	4	
Permitted Phases	2			6		6	8			4		
Detector Phase	2	2		6	6	6	8	8		7	4	
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0	4.0	4.0	4.0		3.5	4.0	
Minimum Split (s)	20.0	20.0		20.0	20.0	20.0	20.0	20.0		7.0	29.0	
Total Split (s)	20.0	20.0	0.0	20.0	20.0	20.0	45.0	45.0	0.0	8.0	53.0	0.0
Total Split (%)	22.2%	22.2%	0.0%	22.2%	22.2%	22.2%	50.0%	50.0%	0.0%	8.9%	58.9%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0		2.5	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0	2.0	2.0	2.0		1.0	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	3.5	5.0	4.0
Lead/Lag							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes		Yes		
Recall Mode	None	None		None	None	None	Min	Min		None	Min	
Act Effct Green (s)		15.2			15.2	15.2		38.5		48.1	46.6	
Actuated g/C Ratio		0.20			0.20	0.20		0.52		0.64	0.62	
v/c Ratio		0.81			0.23	0.55		0.70		0.48	0.85	
Control Delay		55.0			29.9	9.6		19.8		11.8	22.4	
Queue Delay		0.0			0.0	0.0		29.2		0.0	0.0	
Total Delay		55.0			29.9	9.6		49.0		11.8	22.4	
LOS		D			C	A		D		B	C	
Approach Delay		55.0			14.1			49.0			20.6	
Approach LOS		D			B			D			C	
Queue Length 50th (ft)		99			27	0		201		25	230	
Queue Length 95th (ft)		#280			76	69		#506		84	#724	
Internal Link Dist (ft)		1			441			223			733	
Turn Bay Length (ft)										200		
Base Capacity (vph)		281			311	454		1031		376	1050	
Starvation Cap Reductn		0			0	0		368		0	0	
Spillback Cap Reductn		0			0	0		0		0	0	
Storage Cap Reductn		0			0	0		0		0	0	
Reduced v/c Ratio		0.81			0.23	0.55		1.04		0.48	0.82	

Intersection Summary

Cycle Length: 90

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	19%
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	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 74.7

Natural Cycle: 90

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.85

Intersection Signal Delay: 31.8   Intersection LOS: C

Intersection Capacity Utilization 123.4%   ICU Level of Service H

Analysis Period (min) 15

\#   95th percentile volume exceeds capacity, queue may be longer.

   Queue shown is maximum after two cycles.
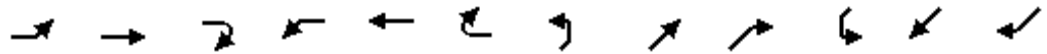

Splits and Phases: 1: Int

Appendix E

AM/PM Peak Hour Intersection Capacity Analysis

Stage 1 Selected Alternative:
Two-Phase Permissive Operation for All Approaches,
with the Addition of a NB RT Lane

Western Avenue at Waitt Avenue/Maple Street, Lynn

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		⊕			⊕			◁	↱		⊕	
Volume (vph)	113	280	9	109	334	3	10	485	100	2	540	9
Confl. Peds. (#/hr)	1		3	3		1	1		2	2		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	4%	4%	4%	4%	4%	4%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)									0			0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	428	0	0	474	0	0	527	106	0	586	0
Turn Type	Perm			Perm			Perm		Perm	Perm		
Protected Phases		2			6			8			4	
Permitted Phases	2			6			8		8	4		
Detector Phase	2	2		6	6		8	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	29.0	29.0	
Total Split (s)	36.0	36.0	0.0	36.0	36.0	0.0	37.0	37.0	37.0	37.0	37.0	0.0
Total Split (%)	40.0%	40.0%	0.0%	40.0%	40.0%	0.0%	41.1%	41.1%	41.1%	41.1%	41.1%	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	4.0	5.0	5.0	5.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None	None		None	None		Min	Min	Min	Min	Min	
Act Effct Green (s)		31.5			31.5			28.8	28.8		28.8	
Actuated g/C Ratio		0.43			0.43			0.39	0.39		0.39	
v/c Ratio		0.75			0.77			0.82	0.22		0.80	
Control Delay		30.9			31.3			33.8	17.3		30.7	
Queue Delay		0.0			0.0			0.0	0.0		27.2	
Total Delay		30.9			31.3			33.8	17.3		57.8	
LOS		C			C			C	B		E	
Approach Delay		30.9			31.3			31.1			57.8	
Approach LOS		C			C			C			E	
Queue Length 50th (ft)		157			177			190	28		209	
Queue Length 95th (ft)		#420			#461			#479	82		#507	
Internal Link Dist (ft)		236			49			618			223	
Turn Bay Length (ft)									40			
Base Capacity (vph)		569			612			719	545		824	
Starvation Cap Reductn		0			0			0	0		255	
Spillback Cap Reductn		0			0			0	0		0	
Storage Cap Reductn		0			0			0	0		0	
Reduced v/c Ratio		0.75			0.77			0.73	0.19		1.03	

Intersection Summary

Cycle Length: 90

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	19%
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	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 73.2

Natural Cycle: 90

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.82

Intersection Signal Delay: 38.5   Intersection LOS: D

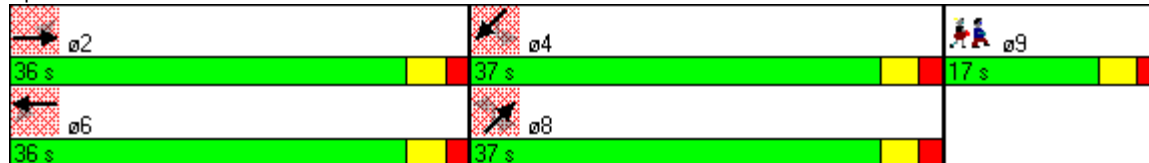Intersection Capacity Utilization 78.4%   ICU Level of Service D

Analysis Period (min) 15

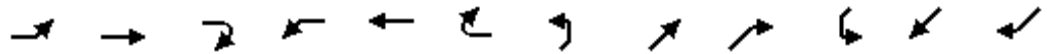\#   95th percentile volume exceeds capacity, queue may be longer.

Queue shown is maximum after two cycles.

Splits and Phases: 5: Int

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		⊕			⊕			↤	↱		⊕	
Volume (vph)	68	364	1	74	357	5	10	595	111	9	557	2
Confl. Peds. (#/hr)	1		3	3		1	1		10	10		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)									0			0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	446	0	0	449	0	0	623	114	0	585	0
Turn Type	Perm			Perm			Perm		Perm	Perm		
Protected Phases		2			6			8			4	
Permitted Phases	2			6			8		8	4		
Detector Phase	2	2		6	6		8	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	29.0	29.0	
Total Split (s)	34.0	34.0	0.0	34.0	34.0	0.0	39.0	39.0	39.0	39.0	39.0	0.0
Total Split (%)	37.8%	37.8%	0.0%	37.8%	37.8%	0.0%	43.3%	43.3%	43.3%	43.3%	43.3%	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	4.0	5.0	5.0	5.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None	None		None	None		Min	Min	Min	Min	Min	
Act Effct Green (s)		28.6			28.6			33.7	33.7		33.7	
Actuated g/C Ratio		0.38			0.38			0.45	0.45		0.45	
v/c Ratio		0.75			0.78			0.83	0.20		0.69	
Control Delay		31.8			33.4			31.5	15.6		23.7	
Queue Delay		0.0			0.0			0.0	0.0		31.6	
Total Delay		31.8			33.4			31.5	15.6		55.4	
LOS		C			C			C	B		E	
Approach Delay		31.8			33.4			29.0			55.4	
Approach LOS		C			C			C			E	
Queue Length 50th (ft)		165			168			227	29		195	
Queue Length 95th (ft)		#416			#429			#572	84		#475	
Internal Link Dist (ft)		236			49			618			223	
Turn Bay Length (ft)									40			
Base Capacity (vph)		606			592			765	571		858	
Starvation Cap Reductn		0			0			0	0		297	
Spillback Cap Reductn		0			0			0	0		0	
Storage Cap Reductn		0			0			0	0		0	
Reduced v/c Ratio		0.74			0.76			0.81	0.20		1.04	

Intersection Summary

Cycle Length: 90

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	19%
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	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 75.2
Natural Cycle: 90
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.83
Intersection Signal Delay: 37.4   Intersection LOS: D
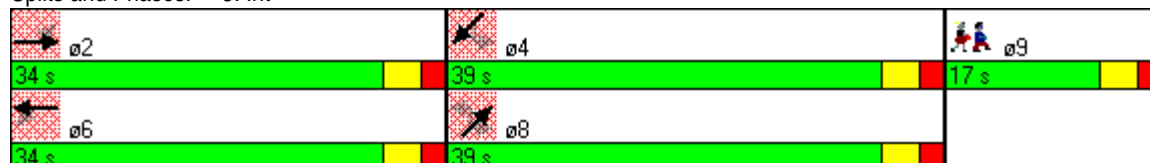Intersection Capacity Utilization 84.6%   ICU Level of Service E
Analysis Period (min) 15
\#   95th percentile volume exceeds capacity, queue may be longer.
    Queue shown is maximum after two cycles.
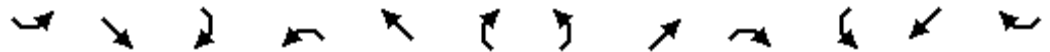

Splits and Phases: 5: Int

Appendix F

AM/PM Peak Hour Intersection Capacity Analysis

Stage 2 Selected Alternative:
Coordinated with the Signal at Waitt Avenue/Maple Street
under the Same Signal Phasing Sequence as Stage 1

Western Avenue at Eastern Avenue/Stanwood Street, Lynn

Intersection Capacity Analysis
Western Ave @ Eastern Ave/Stanwood St

2/16/2010

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		⬧			⬧	⬧		⬧			⬧	⬧
Volume (vph)	134	41	2	8	74	163	0	575	16	207	541	243
Confl. Peds. (#/hr)			2	2								
Confl. Bikes (#/hr)												
Peak Hour Factor	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	3%	3%	3%	4%	4%	4%	4%	4%	4%	3%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)						0						0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	189	0	0	88	173	0	629	0	220	835	0
Turn Type	Perm			Perm		Perm	Perm			pm+pt		
Protected Phases		2			6			8		7	4	
Permitted Phases	2			6		6	8			4		
Detector Phase	2	2		6	6	6	8	8		7	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		8.0	29.0	
Total Split (s)	20.0	20.0	0.0	20.0	20.0	20.0	40.0	40.0	0.0	13.0	53.0	0.0
Total Split (%)	22.2%	22.2%	0.0%	22.2%	22.2%	22.2%	44.4%	44.4%	0.0%	14.4%	58.9%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0		3.5	3.0	
All-Red Time (s)	2.0	2.0		2.0	2.0	2.0	2.0	2.0		0.5	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	5.0	5.0	5.0	4.0	4.0	5.0	4.0
Lead/Lag							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes		Yes		
Recall Mode	None	None		None	None	None	C-Min	C-Min		None	C-Min	
Act Effct Green (s)		17.3			17.3	17.3		43.0		60.3	59.3	
Actuated g/C Ratio		0.19			0.19	0.19		0.48		0.67	0.66	
v/c Ratio		0.74			0.26	0.43		0.71		0.61	0.79	
Control Delay		53.5			32.8	8.8		12.0		17.2	19.9	
Queue Delay		0.0			0.0	0.0		0.8		0.0	2.9	
Total Delay		53.5			32.8	8.8		12.9		17.2	22.8	
LOS		D			C	A		B		B	C	
Approach Delay		53.5			16.9			12.9			21.6	
Approach LOS		D			B			B			C	
Queue Length 50th (ft)		98			41	0		77		41	277	
Queue Length 95th (ft)		#228			89	55		#499		#160	#699	
Internal Link Dist (ft)		1			441			223			733	
Turn Bay Length (ft)										200		
Base Capacity (vph)		261			345	412		888		362	1055	
Starvation Cap Reductn		0			0	0		80		0	0	
Spillback Cap Reductn		0			0	0		0		0	129	
Storage Cap Reductn		0			0	0		0		0	0	
Reduced v/c Ratio		0.72			0.26	0.42		0.78		0.61	0.90	

Intersection Summary

Cycle Length: 90

Stage 2 Selected Alternative (AM)
CTPS

Synchro 7 - Report
Page 1

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	19%
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	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 90

Offset: 0 (0%), Referenced to phase 4:SWTL and 8:NETL, Start of Green, Master Intersection

Natural Cycle: 90

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.79

Intersection Signal Delay: 21.3   Intersection LOS: C

Intersection Capacity Utilization 112.7%   ICU Level of Service H

Analysis Period (min) 15

\# 95th percentile volume exceeds capacity, queue may be longer.

   Queue shown is maximum after two cycles.

Splits and Phases: 1: Int

Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		⊕			⊣	↾		⊕		↾	↳	
Volume (vph)	147	70	5	17	51	241	1	637	30	175	546	287
Confl. Peds. (#/hr)	10		6	10		2	1		2	2		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)						0						0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	229	0	0	71	248	0	689	0	180	859	0
Turn Type	Perm			Perm			Perm	Perm		pm+pt		
Protected Phases		2			6				8		7	4
Permitted Phases	2			6			6	8			4	
Detector Phase	2	2		6	6	6	8	8			7	4
Switch Phase												
Minimum Initial (s)	4.0	4.0		4.0	4.0	4.0	4.0	4.0			3.5	4.0
Minimum Split (s)	20.0	20.0		20.0	20.0	20.0	20.0	20.0			7.0	29.0
Total Split (s)	20.0	20.0	0.0	20.0	20.0	20.0	45.0	45.0	0.0	8.0	53.0	0.0
Total Split (%)	22.2%	22.2%	0.0%	22.2%	22.2%	22.2%	50.0%	50.0%	0.0%	8.9%	58.9%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0	3.0	3.0	3.0			2.5	3.0
All-Red Time (s)	2.0	2.0		2.0	2.0	2.0	2.0	2.0			1.0	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		3.5	5.0	4.0
Lead/Lag							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes		Yes		
Recall Mode	None	None		None	None	None	C-Min	C-Min		None	C-Min	
Act Effct Green (s)		20.8			20.8	20.8		44.3		57.3	55.8	
Actuated g/C Ratio		0.23			0.23	0.23		0.49		0.64	0.62	
v/c Ratio		0.72			0.20	0.51		0.73		0.48	0.86	
Control Delay		47.2			30.4	8.6		7.9		13.5	25.1	
Queue Delay		0.0			0.0	0.0		0.9		0.0	2.3	
Total Delay		47.2			30.4	8.6		8.8		13.5	27.4	
LOS		D			C	A		A		B	C	
Approach Delay		47.2			13.5			8.8			25.0	
Approach LOS		D			B			A			C	
Queue Length 50th (ft)		115			31	0		49		36	331	
Queue Length 95th (ft)		#280			76	69		m#77		84	#724	
Internal Link Dist (ft)		1			441			223			733	
Turn Bay Length (ft)										200		
Base Capacity (vph)		320			356	483		939		375	1004	
Starvation Cap Reductn		0			0	0		77		0	0	
Spillback Cap Reductn		0			0	0		0		0	63	
Storage Cap Reductn		0			0	0		0		0	0	
Reduced v/c Ratio		0.72			0.20	0.51		0.80		0.48	0.91	

Intersection Summary

Cycle Length: 90

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	19%
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	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 90

Offset: 0 (0%), Referenced to phase 4:SWTL and 8:NETL, Start of Green, Master Intersection

Natural Cycle: 90

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.86

Intersection Signal Delay: 20.7   Intersection LOS: C

Intersection Capacity Utilization 123.4%   ICU Level of Service H

Analysis Period (min) 15

\#   95th percentile volume exceeds capacity, queue may be longer.

   Queue shown is maximum after two cycles.

m   Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 1: Int

ø2	ø4		👫 ø9
20 s	53 s		17 s
ø6	ø7	ø8	
20 s	8 s	45 s	

Appendix G

AM/PM Peak Hour Intersection Capacity Analysis

Stage 2 Selected Alternative:
Coordinated with the Signal at Eastern Avenue/Stanwood Street
under the Same Signal Phasing Sequence as Stage 1

Western Avenue at Waitt Avenue/Maple Street, Lynn

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		✛			✛			⬐	↱		✛	
Volume (vph)	113	280	9	109	334	3	10	485	100	2	540	9
Confl. Peds. (#/hr)	1		3	3		1	1		2	2		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	4%	4%	4%	4%	4%	4%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)									0			0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	428	0	0	474	0	0	527	106	0	586	0
Turn Type	Perm			Perm			Perm		Perm	Perm		
Protected Phases		2			6			8			4	
Permitted Phases	2			6			8		8	4		
Detector Phase	2	2		6	6		8	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	29.0	29.0	
Total Split (s)	36.0	36.0	0.0	36.0	36.0	0.0	37.0	37.0	37.0	37.0	37.0	0.0
Total Split (%)	40.0%	40.0%	0.0%	40.0%	40.0%	0.0%	41.1%	41.1%	41.1%	41.1%	41.1%	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	4.0	5.0	5.0	5.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None	None		None	None		C-Min	C-Min	C-Min	C-Min	C-Min	
Act Effct Green (s)		37.7			37.7			38.9	38.9		38.9	
Actuated g/C Ratio		0.42			0.42			0.43	0.43		0.43	
v/c Ratio		0.78			0.80			0.75	0.20		0.73	
Control Delay		35.4			36.0			31.4	18.5		18.4	
Queue Delay		0.0			0.0			0.5	0.0		10.1	
Total Delay		35.4			36.0			31.9	18.5		28.6	
LOS		D			D			C	B		C	
Approach Delay		35.4			36.0			29.6			28.6	
Approach LOS		D			D			C			C	
Queue Length 50th (ft)		199			223			233	35		174	
Queue Length 95th (ft)		#422			#463			#479	82		m#478	
Internal Link Dist (ft)		236			49			618			223	
Turn Bay Length (ft)									40			
Base Capacity (vph)		550			594			700	531		802	
Starvation Cap Reductn		0			0			0	0		189	
Spillback Cap Reductn		0			0			27	0		0	
Storage Cap Reductn		0			0			0	0		0	
Reduced v/c Ratio		0.78			0.80			0.78	0.20		0.96	

Intersection Summary

Cycle Length: 90

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	19%
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	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 90

Offset: 88 (98%), Referenced to phase 4:SWTL and 8:NETL, Start of Green

Natural Cycle: 90

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.80

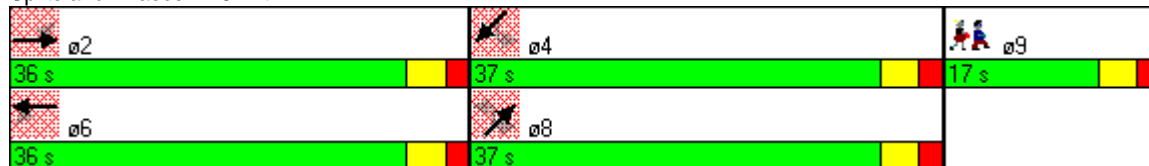|	
Intersection Signal Delay: 31.9	Intersection LOS: C
Intersection Capacity Utilization 82.1%	ICU Level of Service E

Analysis Period (min) 15

\#   95th percentile volume exceeds capacity, queue may be longer.
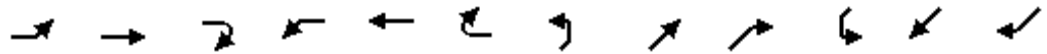
    Queue shown is maximum after two cycles.

m   Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 5: Int

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations		✛			✛			⬸	⬈		✛	
Volume (vph)	68	364	1	74	357	5	10	595	111	9	557	2
Confl. Peds. (#/hr)	1		3	3		1	1		10	10		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)									0			0
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	446	0	0	449	0	0	623	114	0	585	0
Turn Type	Perm			Perm			Perm		Perm	Perm		
Protected Phases		2			6			8			4	
Permitted Phases	2			6			8		8	4		
Detector Phase	2	2		6	6		8	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	29.0	29.0	
Total Split (s)	33.0	33.0	0.0	33.0	33.0	0.0	40.0	40.0	40.0	40.0	40.0	0.0
Total Split (%)	36.7%	36.7%	0.0%	36.7%	36.7%	0.0%	44.4%	44.4%	44.4%	44.4%	44.4%	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	4.0	5.0	5.0	5.0	5.0	5.0	4.0
Lead/Lag												
Lead-Lag Optimize?												
Recall Mode	None	None		None	None		C-Min	C-Min	C-Min	C-Min	C-Min	
Act Effct Green (s)		34.8			34.8			41.8	41.8		41.8	
Actuated g/C Ratio		0.39			0.39			0.46	0.46		0.46	
v/c Ratio		0.73			0.76			0.80	0.20		0.68	
Control Delay		33.7			35.0			31.4	16.5		14.1	
Queue Delay		0.0			0.0			0.2	0.0		6.3	
Total Delay		33.7			35.0			31.6	16.5		20.4	
LOS		C			D			C	B		C	
Approach Delay		33.7			35.0			29.2			20.4	
Approach LOS		C			D			C			C	
Queue Length 50th (ft)		206			210			278	35		82	
Queue Length 95th (ft)		#424			#437			#561	82		m244	
Internal Link Dist (ft)		236			49			618			223	
Turn Bay Length (ft)									40			
Base Capacity (vph)		607			593			779	582		860	
Starvation Cap Reductn		0			0			0	0		221	
Spillback Cap Reductn		0			0			8	0		0	
Storage Cap Reductn		0			0			0	0		0	
Reduced v/c Ratio		0.73			0.76			0.81	0.20		0.92	

Intersection Summary

Cycle Length: 90

Lane Group	ø9
Lane Configurations	
Volume (vph)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Detector Phase	
Switch Phase	
Minimum Initial (s)	4.0
Minimum Split (s)	17.0
Total Split (s)	17.0
Total Split (%)	19%
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	
Queue Length 50th (ft)	
Queue Length 95th (ft)	
Internal Link Dist (ft)	
Turn Bay Length (ft)	
Base Capacity (vph)	
Starvation Cap Reductn	
Spillback Cap Reductn	
Storage Cap Reductn	
Reduced v/c Ratio	

Intersection Summary

Actuated Cycle Length: 90

Offset: 0 (0%), Referenced to phase 4:SWTL and 8:NETL, Start of Green

Natural Cycle: 90

Control Type: Actuated-Coordinated

Maximum v/c Ratio: 0.80

Intersection Signal Delay: 29.0   Intersection LOS: C

Intersection Capacity Utilization 84.6%   ICU Level of Service E

Analysis Period (min) 15

\#   95th percentile volume exceeds capacity, queue may be longer.

    Queue shown is maximum after two cycles.

m   Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 5: Int

ø2	ø4	ø9
33 s	40 s	17 s

ø6	ø8
33 s	40 s