MEMORANDUM

To: **George J. Zambouras, Reading Town Engineer**   **July 8, 2010**
            Mike Karas, MassDOT Highway Division District 4

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

Re: **Boston Region MPO Congested and High-Crash Intersections Study:**
       Main Street (Route 28) at Franklin Street in Reading

This memorandum summarizes safety and operations analyses and proposes improvement strategies for the intersection of Main Street (Route 28) at Franklin Street in Reading. It contains the following sections:

- Intersection Layout and Traffic Control
- Issues and Concerns
- Crash Data Analysis
- Intersection Capacity Analysis
- Review of the "Yellow Trap" Situation
- Analyses of Improvement Alternatives
- Improvement Recommendations and Discussions

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

This signalized intersection is located in the northern section of Reading. Main Street, a four-lane roadway running in the north-south direction, is the major street of the intersection. It is part of state Route 28, which serves as a principal urban arterial for the region. Franklin Street, a two-lane roadway running in the east-west direction, is the minor street of the intersection. It mainly serves as a major collector for the town and is also used by crosstown traffic to connect Route 28 and other destinations.

Figure 1 shows the intersection layout and the area nearby. No exclusive right- or left-turn lanes are provided on any of the approaches. In both directions of Main Street, the outside lane is shared by the right-turn and through movements and the inside lane is shared by the left-turn and through movements. In both directions of Franklin Street, all movements share a single lane.

The traffic signal is currently operated in three traffic phases: (1) southbound all movements (left turns protected), (2) southbound/northbound all movements (left turns permitted), and (3)

FIGURE 1
Main Street (Route 28) at Franklin Street, Reading

Operational Improvements at Congested and High-Crash Intersections

CTPS

eastbound/westbound all movements. Right turns on red are allowed on all four approaches. The signal control also includes an exclusive pedestrian phase that lasts about 25 seconds. When manually activated, the on-call pedestrian phase takes place after the southbound/northbound traffic phase, and all traffic movements are prohibited.

The land use in the vicinity of the intersection is mainly commercial. Gas stations are located at the northeast and southwest corners of the intersection. There is a popular ice cream and flower store with parking at the southeast corner. A retailer, Home Goods, and its parking lot occupy the major area northwest of the intersection. The areas beyond the Route 28 corridor are mainly residential. A grade school, Wood End Elementary School, is located about a mile west of this intersection.

ISSUES AND CONCERNS

This intersection has moderately high traffic volumes but is not particularly congested during peak periods. Field observations indicated that most of the approaching traffic was able to pass the intersection within a single cycle in the AM peak hour. In the PM peak hour, traffic on both approaches of Franklin Street is more congested and backs up at times. Traffic on Route 28 is heavy but not congested during both peak hours.

Review of the intersection traffic volumes indicates that the intersection carries a relatively high number of southbound left turns and westbound right turns. A large portion of the traffic may be through-town traffic that uses Franklin Street and Haverhill Street to reach Route 28 in the north and Route 128/I-95 (Interstate 95) in the south. This traffic pattern is not easy to alter as long as the congested conditions at the I-93/I-95 interchange (Reading/Stoneham/Woburn) remain.

Safety is the main concern at this intersection. Review of recent crash data indicates that the intersection has a high number of crashes and a crash rate much higher than other signalized intersections in the area (see the next section for detailed analyses).

Lacking an exclusive turning lane, the southbound left turns operate in a lead-left protected/permissive mode so that they do not block the through traffic in the same lane. This operation preserves the intersection capacity but it frequently creates the "yellow trap" situation. The situation can happen at this intersection when the left turners use the yellow change interval but fail to pass the intersection before the opposite through traffic arrives or when they are confused about the green ball and fail to yield to the opposite through traffic. The situation can lead to angle (or "T-bone") collisions between the left turners and the opposite through traffic or cause collisions of/with other vehicles when they try to avoid the first conflict. Further discussions of this condition are included in a later section.

The available traffic counts indicate that Franklin Street carries a high percentage of left turns in both directions and heavy right turns in the westbound direction. Currently traffic operates in a concurrent eastbound/westbound phase that has higher potential for traffic conflicts than a split eastbound/westbound phase. The split phase is a safer operation but would consume more of the traffic signal cycle than the concurrent phase. This alternative is examined in a later section of this memorandum.

In summary, the issues and concerns for this intersection are:

- High number of crashes and high crash rate
- "Yellow trap" situation for the southbound left turns
- Traffic congestion on Franklin Street during the PM peak hour
- High percentage of turning movements on Franklin Street

CRASH DATA ANALYSIS

Based on the 2004–2006 MassDOT Registry Division crash data, Table 1 shows that on average 14 crashes occurred at the intersection each year. Although most of the crashes involved property damage only, nearly 30% of the total crashes resulted in personal injuries. The crash types consisted of nearly 70% angle collisions and 30% others. No crashes involved pedestrians or bicycles. About one-third of the total crashes occurred during peak periods.

TABLE 1
Summary of Crash Data (2004–2006)
Main Street at Franklin Street, Reading

Statistics Period		2004	2005	2006	2004–06	Average
Total number of crashes		12	18	13	43	14
Severity	Property damage only	9	11	9	29	10
	Personal injury	2	6	4	12	4
	Fatality	0	0	0	0	0
	Not reported	1	1	0	2	1
Collision Type	Angle	9	10	10	29	10
	Rear-end	2	1	1	4	1
	Sideswipe	0	3	1	4	1
	Head-on	0	2	1	3	1
	Single vehicle	0	0	0	0	0
	Not reported	1	2	0	3	1
Crashes involving pedestrian(s)		0	0	0	0	0
Crashes involving cyclist(s)		0	0	0	0	0
Occurred during weekday peak periods*		5	5	4	14	5
Wet or icy pavement conditions		1	4	2	7	2
Dark/lighted conditions		2	5	3	10	3

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

Crash rate[1] is another effective tool to examine 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 1.68 (see Appendix A for the calculation sheet). The rate is much

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[1] Crash rates are calculated from the combination of crash frequency (crashes per year) and vehicle exposure (traffic volumes or miles traveled). Crash rates are expressed as "crashes per million entering vehicles" for intersection locations and as "crashes per million miles traveled" for roadway segments.

higher than the average rate for the signalized locations in MassDOT Highway Division District 4, which is estimated to be 0.78.[2]

INTERSECTION CAPACITY ANALYSIS

CTPS collected turning movement counts at the intersection on May 27, 2009. 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 1,850 vehicles in the morning peak hour from 7:30 to 8:30 and about 2,100 vehicles in the evening peak hour from 5:00 to 6:00 (see Table 2). Two pedestrians and one pedestrian were observed during the AM and PM peak hours, respectively. No bicycles were observed entering the intersection in the AM or PM peak hour.

TABLE 2
AM and PM Peak Hour Traffic Volumes and Pedestrian Crossings
Main Street at Franklin Street, Reading

Street name		Main Street (Route 28)						Franklin Street					
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	35	334	20	235	578	83	78	49	50	85	124	167	1838
	Approach volume	389			896			177			376			
	Pedestrian crossings	0			2			0			0			2
PM peak hour	Turning volume	24	653	45	203	519	66	130	80	23	57	59	247	2106
	Approach volume	722			788			233			363			
	Pedestrian crossings	0			1			0			0			1

Based on the turning movement counts and the signal timings measured on the site, the intersection capacity was analyzed by using an intersection capacity analysis program, Synchro.[3] The intersection is evaluated to operate at level of service (LOS) C in the morning peak hour and at LOS D in the evening peak hour (see Table 3). Due to relatively high left turns, the eastbound approach endures more delays than the other approaches in the evening peak hour. It was evaluated as undesirable LOS F. The level of service criteria are based on the Highway Capacity Manual 2000.[4] Detailed analysis settings and results for both the AM and PM peak hour are included in Appendix B.

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

[3] 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.

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

TABLE 3
Intersection Capacity Analysis, Existing Conditions
Main Street at Franklin Street, Reading

Street name		Main Street (Route 28)						Franklin Street					Overall
Direction		Northbound			Southbound			Eastbound			Westbound		
Turning movement		LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT	
AM peak hour	LOS	B			B			D			D			C
	Delay (sec/veh)	18			20			37			47			27
PM peak hour	LOS	B			B			F			D			D
	Delay (sec/veh)	19			20			135			41			36

REVIEW OF THE "YELLOW TRAP" SITUATION

The "yellow trap" and similar situations for protected/permissive left turns (PPLT) have been a difficult issue, which is often different from one intersection to another. At this intersection, the southbound left turns operate in a lead-left protected/permissive mode so that they will not frequently block the through traffic due to lacking an exclusive turning lane. The "trap" can happen when the left turners use the yellow change interval but fail to pass out of the intersection before the opposite through traffic arrives or when they are confused about the green ball and fail to yield to the opposite through traffic. The situation can lead to angle (or "T-bone") collisions between the left turns and the opposite through traffic or cause collisions of/with other vehicles when they try to avoid the first conflict.

Two factors that potentially contribute to the "yellow trap" situation at this intersection were examined: (1) if the signal indication for the PPLT operation is appropriate and (2) if the yellow clearance interval for the left turns is sufficient.

Currently a typical MUTCD[5] five-section cluster signal head is installed over the southbound inside lane, with a regulatory sign indicating "Left turn yield on green ball" (see Figure 2). The allowable movements in the lane are indicated by three consecutive faces: (1) a green ball and a green arrow, indicating the through and the protected left-turn movements, (2) a green ball and a yellow arrow, indicating continuation of through movements and ending of the protected left-turn phase, and (3) a green ball only, indicating protected through movements and permissive left-turn movements.

The display sequence appears to be appropriate with the available equipment and has no conflicts with the displays on the opposite approach. The typical MUTCD five-section signal head is commonly used but is gradually challenged by practitioners in that left-turners sometimes incorrectly interpret the meaning of a green ball as a protected phase for them. A recent NCHRP study[6] found a flashing yellow arrow PPLT display to be equal or superior to the existing five-

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[5] Manual for Uniform Traffic Control Devices, Federal Highway Administration, U.S. Department of Transportation, *Chapter 4D. Traffic Control Signal Features*, 2003 edition with revision numbers 1 and 2 incorporated, December 2007.

[6] National Cooperative Highway Research Program (NCHRP) Report 493, *Evaluation of Traffic Signal Displays for Protected/Permissive Left-Turn Control*, Transportation Research Board, Washington D.C., 2003.

section display based on traffic simulation tests of drivers' responses. Figure 3 shows the flashing yellow arrow indication in three- and four-section displays for an exclusive PPLT operation.

As the PPLT movements are not operated in an exclusive lane at this intersection, the flashing yellow arrow display has to be used alongside a typical three-ball signal head designated for the through traffic. However, we do not recommend this display for this intersection. The flashing yellow arrow display is still considered experimental by the MUTCD and by the state. Further studies are needed for the state to evaluate its effectiveness in terms of the overall intersection efficiency and safety and how it will work with the many existing signal controllers.

FIGURE 2
Traffic Signal Head over the Southbound Left-Turn/Through Lane
Main Street at Franklin Street, Reading
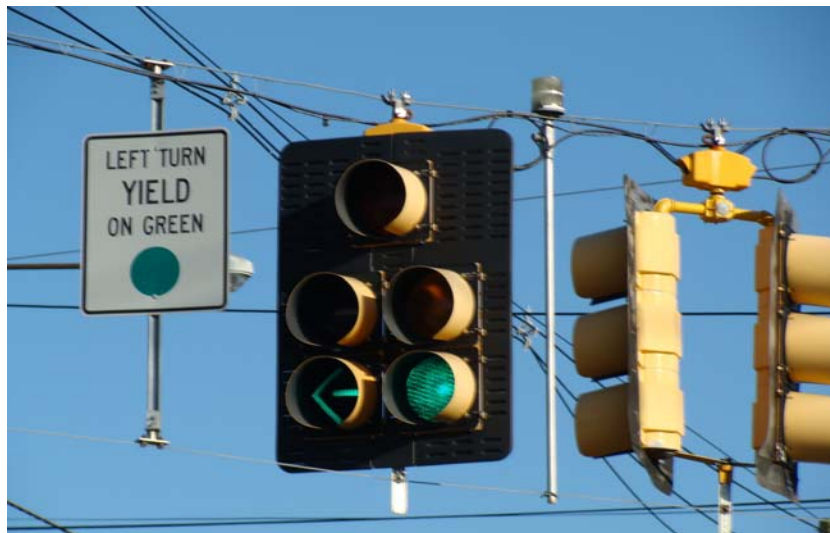
FIGURE 3
Exclusive Flashing Yellow Arrow Display Faces
(Source: NCHRP Report 493)
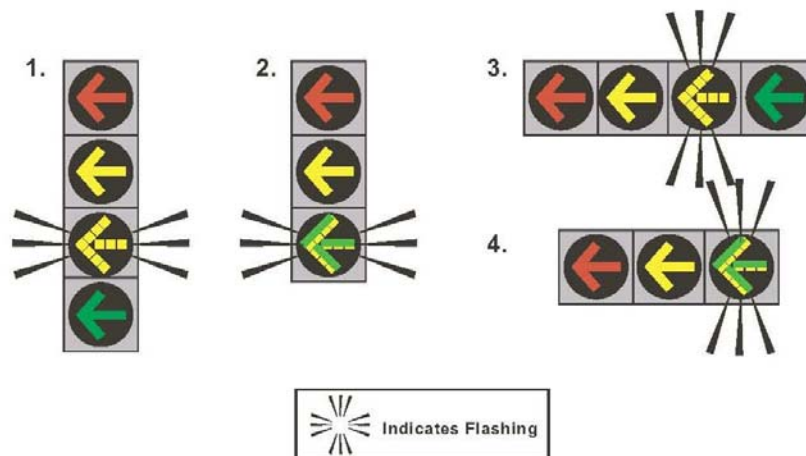
A review of the existing signal timing plan indicates that the yellow clearance time for the southbound left turns may need to be extended.

Based on the commonly used ITE (Institute of Traffic Engineers) formula, the yellow clearance interval consists of reaction time, deceleration time, and time to clear the intersection.[7] Table 4 shows estimation of the desirable yellow clearance time for the left turns under an average approaching speed ranging from 20 mph (miles per hour) to 50 mph[8] for the southbound left turn at this intersection. The assumptions for the calculation are:

- Reaction time = 1 second
- Average deceleration = between 10 feet/sec.^{2} and 15 feet/sec.^{2}
- Distance to clear the intersection = 60 feet (from the southbound stop line, passing a crosswalk and two northbound lanes in a curvature, to Franklin Street) + 20 feet (a vehicle length)

The estimation indicates that a total of 4.5 or 5 seconds of yellow clearance is desirable for the southbound left turns to safely clear or stop before the intersection. Currently the left turns have 2 seconds of yellow change interval (indicated by a steady yellow arrow) for reaction and deceleration but no time to clear the intersection because the opposite northbound green balls are shown as soon as the yellow arrow ends. We propose to extend the reaction and deceleration time from 2 seconds to 3 seconds and to add a time of 2 seconds to clear the intersection. The yellow arrow can indicate the yellow change interval but the time to clear the intersection can only be achieved by delaying the indication of the opposite northbound green balls for 2 seconds (as the typical five-section signal head does not have a red arrow).

TABLE 4
Estimation of Yellow Clearance Intervals with a Range of Approach Speeds
Main Street at Franklin Street, Reading

Approach speed (mph)	20	25	30	35	40	45	50
Reaction and deceleration time[1]	2.5	2.8	3.2	3.6	3.9	4.3	4.7
Reaction and deceleration time[2]	2.0	2.2	2.5	2.7	3.0	3.2	3.4
Time to clear the intersection	2.7	2.2	1.8	1.6	1.4	1.2	1.1
Total yellow clearance time[1]	5.2	5.0	5.0	5.1	5.3	5.5	5.8
Total yellow clearance time[2]	4.7	4.4	4.3	4.3	4.3	4.4	4.5

Note: 1. Average Deceleration = 10 feet/sec.^{2}
        2. Average Deceleration = 15 feet/sec.^{2}

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[7] "Traffic Signal Clearance Interval," Philip J. Tarnoff, *ITE Journal*, April 2004
[8] The posted speed on Route 28 in the area is 35 mph. The speed range represents different approaching conditions from "stop and go" to "fly through the intersection."

ANALYSES OF IMPROVEMENT ALTERNATIVES

This section examines four traffic signal and geometric design strategies to improve the safety and operation of this intersection. The analyses were performed progressively from simple to more involved modifications for the four improvement alternatives. The intersection capacity was evaluated using Synchro optimization and simulation software. Common to all four alternatives is the proposed modification of the southbound left-turn clearance time, extending the yellow change interval from 2 to 3 seconds and adding a 2-second clearance interval, and maintaining the existing total cycle length.

1. Retime Traffic Signal with Existing Phasing Sequence and Intersection Geometry

The unbalanced levels of service for the major street (Main Street: LOS B) and the minor street (Franklin Street: LOS D or F) in the existing conditions indicate that there may be room for improving the intersection operation by shifting some green time from Main Street to Franklin Street.

Synchro tests using the existing traffic volumes and intersection geometry indicate that the intersection is able to operate at acceptable levels of service at all approaches by shifting 2 seconds of green time from the northbound/southbound phase to the eastbound/westbound phase in the AM peak hour and shifting 6 seconds in the PM peak hour. This simple signal retiming alternative maintains the same overall intersection LOS and average delay in the AM peak hour and improves the overall LOS from D to C with reduced average delay by 6 seconds in the PM peak hour (see Table 5).

With the modified yellow change clearance time for the southbound left turns, the "yellow trap" situation is expected to be relieved somewhat. Details of the signal settings and analysis results for both peak hours are included in Appendix C.

2. Change EB/WB Operation to Split Phase under Existing Geometry

As mentioned, Franklin Street carries a high percentage of left turns in both directions. Under such conditions, an eastbound/westbound (EB/WB) split phase is a safer operation but would require an increased share of the overall traffic signal cycle compared to the existing concurrent phase.

Synchro tests of the EB/WB split phase with the existing signal cycle, traffic, and geometric conditions indicate that the intersection would operate at LOS C in the AM peak hour and LOS D in the PM peak hour (see Table 5). All the approaches under this alternative would endure more delays than under Alternative 1 (concurrent EB/WB traffic phase), especially in the PM peak hour.

The split phase operation would potentially reduce the through and turning traffic conflicts on Franklin Street. On the other hand, it would increase delays on all the approaches of the intersection. Especially in the PM peak hour, the approaches on Franklin Street would operate at undesirable LOS F and LOS E and both the approaches of Main Street would endure an increase of 15 to 20 seconds in delay. Details of the signal settings and analysis results for both peak hours are included in Appendix D.

TABLE 5
Intersection Capacity Analysis of Alternative Improvements
Existing Traffic Volumes
Main Street at Franklin Street, Reading

Street name		Main Street (Route 28)		Franklin Street		Overall
Approach		Northbound	Southbound	Eastbound	Westbound	
AM peak hour	Existing	B/18	B/20	D/37	D/47	C/27
	Alternative 1	C/22	C/21	C/34	D/42	C/27
	Alternative 2	C/23	C/30	D/41	E/56	C/35
	Alternative 3	B/16	B/16	D/48	C/26	C/21
	Alternative 4	C/22	C/21	D/47	D/35	C/27
PM peak hour	Existing	B/19	B/20	F/135	D/41	D/36
	Alternative 1	C/27	C/27	D/51	C/29	C/30
	Alternative 2	D/37	D/40	F/87	E/70	D/49
	Alternative 3	B/19	B/17	D/47	B/14	C/21
	Alternative 4	C/21	B/18	D/50	C/32	C/25

Note   Performance measures: Level of Service (A to F)/Average Delay (seconds per vehicle)
           Alternative 1: Retime Traffic Signal with Existing Phasing Sequence and Intersection Geometry
           Alternative 2: Change EB/WB Operation to Split Phase under Existing Geometry
           Alternative 3: Add a WB Right-Turn Lane and Retime Signal with Existing Phasing Sequence
           Alternative 4: Add a Lane on Both EB/WB Approaches and Change EB/WB Operation to Split Phase

    3.   Add a WB Right-Turn Lane and Retime Signal with Existing Phasing Sequence

The high percentage of right turns on the westbound approach (about 45% in the AM and 70% in the PM peak hour) indicates that adding an exclusive lane for that movement would significantly increase the capacity of the intersection. Based on the State Roadway Inventory file, Franklin Street has a right-of-way (ROW) of 40 feet in the intersection vicinity. Currently, the westbound approach pavement is about 23 feet wide; it may be feasible to construct a 10-foot turning lane within the ROW of the westbound approach.

With the addition of an exclusive lane, the existing signal phasing plan can overlap a protected westbound right-turn phase with the southbound-only phase. Synchro tests of the proposed modifications indicate that the intersection would operate at LOS C and all approaches would operate at an acceptable LOS with insignificant delays in both the AM and PM peak hours (see Table 5). Details of the signal settings and analysis results for both peak hours are included in Appendix E.

    4.   Add a Lane on Both EB/WB Approaches and Change EB/WB Operation to Split Phase

Tests of Alternative 2 show that the EB/WB split phase would operate at LOS E or F on Franklin Street. In order to maintain desirable LOS for all the approaches, the intersection would need to be expanded.

Different layouts of the expanded Franklin Street were tested. One of them, the combination of an exclusive right-turn lane with a through/left-turn shared lane for the westbound approach and an exclusive left-turn lane with a through/right-turn shared lane for the eastbound approach, yielded acceptable results. Synchro tests of the EB/WB split phase with the proposed modifications indicate that the intersection would operate at LOS C and all approaches would operate at an acceptable LOS in both the AM and PM peak hours (see Table 5). Details of the signal settings and analysis results for both peak hours are included in Appendix F.

In addition, a future-year scenario of 15% growth over a 20-year planning horizon was tested for each of the four alternatives. The growth assumption is based on a review of the traffic projections at the intersection from the recent Boston Region MPO transportation planning model. A higher number of pedestrian calls (five in each peak hour) than under existing conditions was assumed in the future-year analysis.

Results from Synchro tests of the alternatives with the projected traffic growth are summarized in Table 6. As shown, Alternative 1 would operate at acceptable LOS C in the AM peak hour and LOS D in PM peak hour. Alternative 2 would operate at an undesirable LOS F in both the AM and PM peak hours. Alternative 3 would operate at LOS C in both the AM and PM peak hours with insignificant delays. Alternative 4 would operate at LOS C in both the AM and PM peak hours with insignificant overall delays and noticeable delays on the eastbound approach. Details of the Synchro results for all the alternatives under the projected traffic conditions are included in Appendices G, H, I, and J.

TABLE 6
Intersection Capacity Analysis of Alternative Improvements
Projected 2030 Traffic Growth
Main Street at Franklin Street, Reading

Street name		Main Street (Route 28)		Franklin Street		Overall
Approach		Northbound	Southbound	Eastbound	Westbound	
AM peak hour	Existing	B/19	C/26	D/49	E/73	D/36
	Alternative 1	C/23	C/30	D/41	E/56	C/35
	Alternative 2	C/34	E/67	E/58	F/175	F/81
	Alternative 3	C/22	C/22	D/50	C/25	C/25
	Alternative 4	C/23	C/25	E/61	D/41	C/31
PM peak hour	Existing	C/21	C/29	F/261	E/60	E/57
	Alternative 1	D/37	D/37	E/78	C/33	D/41
	Alternative 2	E/60	F/82	E/71	F/131	F/82
	Alternative 3	C/25	C/25	D/50	B/14	C/26
	Alternative 4	C/22	C/22	E/62	D/38	C/29

Note   Performance measures: Level of Service (A to F)/Average Delay (seconds per vehicle)
        Alternative 1: Retime Traffic Signal with Existing Phasing Sequence and Intersection Geometry
        Alternative 2: Change EB/WB Operation to Split Phase under Existing Geometry
        Alternative 3: Add a WB Right-Turn Lane and Retime Signal with Existing Phasing Sequence
        Alternative 4: Add a Lane on Both EB/WB Approaches and Change EB/WB Operation to Split Phase

IMPROVEMENT RECOMMENDATIONS AND DISCUSSIONS

The above analyses indicate that the operation and safety of the intersection can be improved by signal retiming (Alternative 1). Changing EB/WB operation to split phase with the existing geometry (Alternative 2) is not effective as the intersection would operate at undesirable LOS F under the projected future traffic conditions. Adding a WB right-turn lane and retiming the signal with the existing phasing sequence (Alternative 3) is the most effective option as the intersection would operate at desirable levels of service with minimal delays even under the projected traffic conditions.

Alternative 4, adding a lane on both EB/WB approaches and changing EB/WB operation to split phase, would help the intersection operate at a desirable overall LOS but with noticeable delays on the eastbound approach (projected future traffic conditions). It would also cost more than other alternatives. The crash data do not indicate a high proportion of crashes involving EB/WB traffic. Therefore, we do not recommend Alternative 4 unless unforeseen major traffic growth or major changes in traffic patterns occur in the future.

We propose a two-stage improvement strategy for this intersection. In the short term, we propose retiming the signal with the existing intersection layout as follows:

- Extend the southbound yellow change interval from 2 seconds to 3 seconds
- Delay the indication of the northbound green for 2 seconds
- In the AM peak period, shift 2 seconds of green time from the northbound/southbound to the eastbound/westbound phase
- In the PM peak period, shift 6 seconds of green time from the northbound/southbound to the eastbound/westbound phase
- Retain the existing total cycle length

The proposed retiming is expected to relieve the "yellow trap" situation for the southbound left turns and to reduce delays for the eastbound/westbound traffic. As a result, the overall intersection safety and operations would be improved. However, the traffic conditions and crash data at the intersection should be monitored and reviewed after the signal retiming.

In the long term, if the intersection operations do not improve and the crash rates remain high, adding a WB right-turn lane and retiming the signal with the existing phasing sequence (Alternative 3) can be considered. The State Roadway Inventory file shows that Franklin Street has a ROW of about 40 feet, which is somewhat tight for an additional lane and sidewalks on both sides. The potential westbound reconfiguration could consist of two 10-foot approaching lanes, one 12-foot receiving lane, and two 4-foot sidewalks. In summary, the recommended improvement alternative includes the following modifications:

- Add an exclusive right-turn lane (desirable length: 200 feet) on the westbound approach
- Overlap a WB right-turn protected phase to the southbound-only phase
- Install a MUTCD five-section signal head containing right-turn green and yellow arrows over the additional westbound lane

Based on the projected future traffic conditions, this alternative is expected to improve operations and safety at the intersection. If this option is pursued, at the functional design stage the intersection should be reevaluated using updated traffic and crash data.

Appendix A

Intersection Crash Rate Calculation
Main Street at Franklin Street, Reading

MassHighway

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Reading   COUNT DATE :   5/27/09

DISTRICT :   4   UNSIGNALIZED : [   ]   SIGNALIZED : [**X**]

~ INTERSECTION DATA ~

MAJOR STREET :   Main Street (Rt. 28)

MINOR STREET(S) :   Frankin Street

INTERSECTION DIAGRAM
(Label Approaches)

North	Main Street
	Franklin Street
Franklin Street	
N (↑)	Main Street
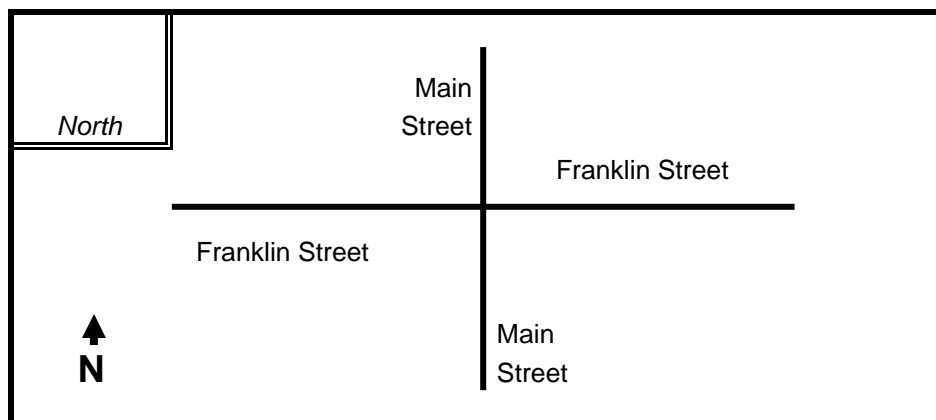
PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	NB	SB	EB	WB		
PEAK HOURLY VOLUMES (AM/PM) :	722	788	233	363		**2,106**

" K " FACTOR :	**0.090**	INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME :	**23,400**

TOTAL # OF CRASHES :	43	# OF YEARS :	3	AVERAGE # OF CRASHES PER YEAR (**A**) :	**14.33**

CRASH RATE CALCULATION : [**1.68**]   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
Main Street at Franklin Street, Reading

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		✛			✛			◀↑▶			◀↑▶	
Volume (vph)	78	49	50	85	124	167	35	334	20	235	578	83
Confl. Peds. (#/hr)	2					2						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	1%	1%	1%	4%	4%	4%	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 (%)												
Lane Group Flow (vph)	0	192	0	0	409	0	0	423	0	0	973	0
Turn Type	Perm			Perm			Perm			pm+pt		
Protected Phases		2			6			8		7	4 7	
Permitted Phases	2			6			8			4 7		
Detector Phase	2	2		6	6		8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0		10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0		15.0	15.0		7.0		
Total Split (s)	34.0	34.0	0.0	34.0	34.0	0.0	49.0	49.0	0.0	9.0	67.0	0.0
Total Split (%)	29.1%	29.1%	0.0%	29.1%	29.1%	0.0%	41.9%	41.9%	0.0%	7.7%	57.3%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		2.0		
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		0.0		
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	2.0	5.0	4.0
Lead/Lag							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None		Max	Max		Max		
Act Effct Green (s)		29.2			29.2			44.3			53.4	
Actuated g/C Ratio		0.30			0.30			0.46			0.56	
v/c Ratio		0.61			0.84			0.33			0.71	
Control Delay		37.4			47.2			18.3			19.9	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		37.4			47.2			18.3			19.9	
LOS		D			D			B			B	
Approach Delay		37.4			47.2			18.3			19.9	
Approach LOS		D			D			B			B	
Queue Length 50th (ft)		85			202			75			162	
Queue Length 95th (ft)		#225			#483			157			332	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		316			485			1284			1368	
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		0.61			0.84			0.33			0.71	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	58.0	25.0
Total Split (%)	50%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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

Intersection Capacity Analysis
Main St @ Franklin St

Actuated Cycle Length: 96.2

Natural Cycle: 100

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.84

Intersection Signal Delay: 26.8   Intersection LOS: C

Intersection Capacity Utilization 72.2%   ICU Level of Service C

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
Main St @ Franklin St

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		⊕			⊕			⊕↟↟			⊕↟↟	
Volume (vph)	130	80	23	57	59	247	24	653	45	203	519	66
Confl. Peds. (#/hr)	1					1						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	1%	1%	1%	2%	2%	2%	1%	1%	1%
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 (%)												
Lane Group Flow (vph)	0	259	0	0	403	0	0	803	0	0	876	0
Turn Type	Perm			Perm			Perm			pm+pt		
Protected Phases		2			6			8		7	4 7	
Permitted Phases	2			6			8			4 7		
Detector Phase	2	2		6	6		8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0		10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0		15.0	15.0		7.0		
Total Split (s)	32.0	32.0	0.0	32.0	32.0	0.0	52.0	52.0	0.0	8.0	68.0	0.0
Total Split (%)	27.4%	27.4%	0.0%	27.4%	27.4%	0.0%	44.4%	44.4%	0.0%	6.8%	58.1%	0.0%
Yellow Time (s)	3.0	3.0		3.0	3.0		3.0	3.0		2.0		
All-Red Time (s)	2.0	2.0		2.0	2.0		2.0	2.0		0.0		
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	2.0	5.0	4.0
Lead/Lag							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None		Max	Max		Max		
Act Effct Green (s)		27.2			27.2			47.3			55.4	
Actuated g/C Ratio		0.28			0.28			0.49			0.58	
v/c Ratio		1.14			0.82			0.52			0.73	
Control Delay		134.5			41.1			19.0			20.0	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		134.5			41.1			19.0			20.0	
LOS		F			D			B			B	
Approach Delay		134.5			41.1			19.0			20.0	
Approach LOS		F			D			B			B	
Queue Length 50th (ft)		~171			172			152			130	
Queue Length 95th (ft)		#412			#429			299			#290	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		228			493			1558			1196	
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		1.14			0.82			0.52			0.73	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	60.0	25.0
Total Split (%)	51%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.2

Natural Cycle: 140

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 1.14

Intersection Signal Delay: 36.0   Intersection LOS: D
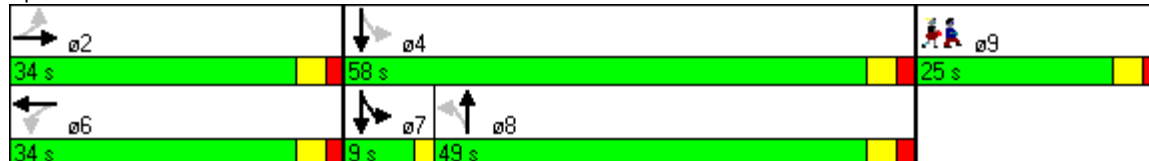
Intersection Capacity Utilization 89.9%   ICU Level of Service E

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: 1: Int

Appendix C

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 1: Retime Traffic Signal with Existing Phasing and Geometry
Under Existing Traffic Conditions
Main Street at Franklin Street, Reading

Intersection Capacity Analysis
Main St @ Franklin St

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		⟷			⟷			⟷			⟷	
Volume (vph)	78	49	50	85	124	167	35	334	20	235	578	83
Confl. Peds. (#/hr)	2					2						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	1%	1%	1%	4%	4%	4%	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 (%)												
Lane Group Flow (vph)	0	192	0	0	409	0	0	423	0	0	973	0
Turn Type	Perm			Perm			Perm			pm+pt		
Protected Phases		2			6			8		7	4 7	
Permitted Phases	2			6			8			4 7		
Detector Phase	2	2		6	6		8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0		10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0		15.0	15.0		10.0		
Total Split (s)	36.0	36.0	0.0	36.0	36.0	0.0	44.0	44.0	0.0	12.0	68.0	0.0
Total Split (%)	30.8%	30.8%	0.0%	30.8%	30.8%	0.0%	37.6%	37.6%	0.0%	10.3%	58.1%	0.0%
Yellow Time (s)	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		
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							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None		Max	Max		Max		
Act Effct Green (s)		30.3			30.3			39.3			51.4	
Actuated g/C Ratio		0.32			0.32			0.41			0.54	
v/c Ratio		0.56			0.81			0.37			0.74	
Control Delay		33.8			42.0			21.7			21.2	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		33.8			42.0			21.7			21.2	
LOS		C			D			C			C	
Approach Delay		33.8			42.0			21.7			21.2	
Approach LOS		C			D			C			C	
Queue Length 50th (ft)		82			194			84			172	
Queue Length 95th (ft)		199			#461			170			#364	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		351			524			1148			1320	
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		0.55			0.78			0.37			0.74	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	56.0	25.0
Total Split (%)	48%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 95.3
Natural Cycle: 100
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.81
Intersection Signal Delay: 26.8   Intersection LOS: C
Intersection Capacity Utilization 72.2%   ICU Level of Service C
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

ø2	ø4	ø9
36 s	56 s	25 s

ø6	ø7	ø8
36 s	12 s	44 s

Intersection Capacity Analysis
Main St @ Franklin St

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		⬥			⬥			◀↑▶			◀↑▶	
Volume (vph)	130	80	23	57	59	247	24	653	45	203	519	66
Confl. Peds. (#/hr)	1					1						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	1%	1%	1%	2%	2%	2%	1%	1%	1%
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 (%)												
Lane Group Flow (vph)	0	259	0	0	403	0	0	803	0	0	876	0
Turn Type	Perm			Perm			Perm			pm+pt		
Protected Phases		2			6			8		7	4 7	
Permitted Phases	2			6			8			4 7		
Detector Phase	2	2		6	6		8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0		10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0		15.0	15.0		10.0		
Total Split (s)	38.0	38.0	0.0	38.0	38.0	0.0	43.0	43.0	0.0	11.0	65.0	0.0
Total Split (%)	32.5%	32.5%	0.0%	32.5%	32.5%	0.0%	36.8%	36.8%	0.0%	9.4%	55.6%	0.0%
Yellow Time (s)	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		
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							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None		Max	Max		Max		
Act Effct Green (s)		33.2			33.2			38.3			49.3	
Actuated g/C Ratio		0.35			0.35			0.40			0.51	
v/c Ratio		0.81			0.68			0.64			0.82	
Control Delay		51.2			28.7			27.2			26.8	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		51.2			28.7			27.2			26.8	
LOS		D			C			C			C	
Approach Delay		51.2			28.7			27.2			26.8	
Approach LOS		D			C			C			C	
Queue Length 50th (ft)		130			151			187			156	
Queue Length 95th (ft)		#351			#363			345			#386	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		318			591			1258			1067	
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		0.81			0.68			0.64			0.82	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	54.0	25.0
Total Split (%)	46%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.2

Natural Cycle: 130

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.82

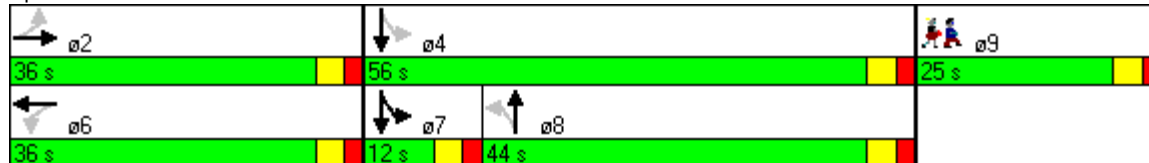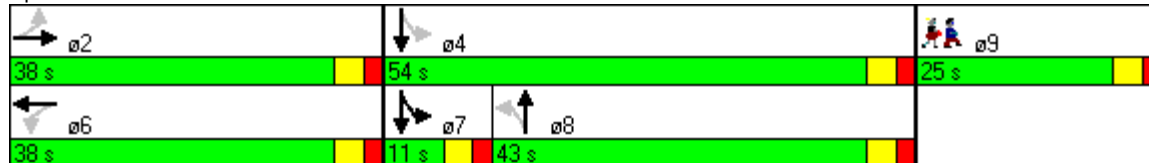|	
Intersection Signal Delay: 30.0	Intersection LOS: C
Intersection Capacity Utilization 89.9%	ICU Level of Service E

Analysis Period (min) 15

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

Queue shown is maximum after two cycles.

Splits and Phases: 1: Int

Appendix D

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 2: Change EB/WB Operation to Split Phase under Existing Geometry
Under Existing Traffic Conditions
Main Street at Franklin Street, Reading

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		✛			✛			✛			✛	
Volume (vph)	78	49	50	85	124	167	35	334	20	235	578	83
Confl. Peds. (#/hr)	2					2						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	1%	1%	1%	4%	4%	4%	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 (%)												
Lane Group Flow (vph)	0	192	0	0	409	0	0	423	0	0	973	0
Turn Type	Split			Split			Perm			pm+pt		
Protected Phases	2	2		6	6			8		7	4 7	
Permitted Phases							8			4 7		
Detector Phase	2	2		6	6		8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0		10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0		15.0	15.0		10.0		
Total Split (s)	17.0	17.0	0.0	27.0	27.0	0.0	36.0	36.0	0.0	12.0	60.0	0.0
Total Split (%)	14.5%	14.5%	0.0%	23.1%	23.1%	0.0%	30.8%	30.8%	0.0%	10.3%	51.3%	0.0%
Yellow Time (s)	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		
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							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None		Max	Max		Max		
Act Effct Green (s)		12.1			22.1			31.2			43.3	
Actuated g/C Ratio		0.13			0.23			0.32			0.45	
v/c Ratio		0.84			0.97			0.47			0.90	
Control Delay		70.5			72.3			28.9			35.8	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		70.5			72.3			28.9			35.8	
LOS		E			E			C			D	
Approach Delay		70.5			72.3			28.9			35.8	
Approach LOS		E			E			C			D	
Queue Length 50th (ft)		103			219			98			211	
Queue Length 95th (ft)		#284			#525			190			#540	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		228			423			896			1087	
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		0.84			0.97			0.47			0.90	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	48.0	25.0
Total Split (%)	41%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.2

Natural Cycle: 140

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.97

Intersection Signal Delay: 45.2   Intersection LOS: D

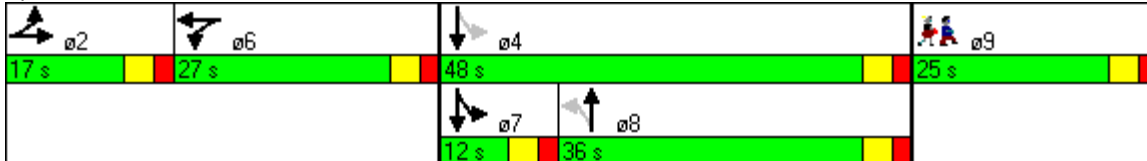Intersection Capacity Utilization 72.2%   ICU Level of Service C

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

ø2	ø6	ø4		ø9
17 s	27 s	48 s		25 s

		ø7	ø8	
		12 s	36 s	

Intersection Capacity Analysis
Main St @ Franklin St

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		⊕			⊕			⟷↑⟷			⟷↑⟷	
Volume (vph)	130	80	23	57	59	247	24	653	45	203	519	66
Confl. Peds. (#/hr)	1				1							
Confl. Bikes (#/hr)												
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	1%	1%	1%	2%	2%	2%	1%	1%	1%
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 (%)												
Lane Group Flow (vph)	0	259	0	0	403	0	0	803	0	0	876	0
Turn Type	Split			Split			Perm			pm+pt		
Protected Phases	2	2		6	6			8		7	4 7	
Permitted Phases							8			4 7		
Detector Phase	2	2		6	6		8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0		10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0		15.0	15.0		10.0		
Total Split (s)	19.0	19.0	0.0	25.0	25.0	0.0	36.0	36.0	0.0	12.0	60.0	0.0
Total Split (%)	16.2%	16.2%	0.0%	21.4%	21.4%	0.0%	30.8%	30.8%	0.0%	10.3%	51.3%	0.0%
Yellow Time (s)	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		
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							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None		Max	Max		Max		
Act Effct Green (s)		14.1			20.1			31.2			43.3	
Actuated g/C Ratio		0.15			0.21			0.32			0.45	
v/c Ratio		0.96			0.97			0.78			0.95dl	
Control Delay		87.1			70.4			36.8			39.9	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		87.1			70.4			36.8			39.9	
LOS		F			E			D			D	
Approach Delay		87.1			70.4			36.8			39.9	
Approach LOS		F			E			D			D	
Queue Length 50th (ft)		149			191			215			181	
Queue Length 95th (ft)		#383			#482			#418			#477	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		271			414			1025			950	
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		0.96			0.97			0.78			0.92	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	48.0	25.0
Total Split (%)	41%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.2
Natural Cycle: 150
Control Type: Actuated-Uncoordinated
Maximum v/c Ratio: 0.97

Intersection Signal Delay: 49.3   Intersection LOS: D
Intersection Capacity Utilization 89.9%   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.

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

Splits and Phases: 1: Int

Appendix E

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 3: Add a WB Right-Turn Lane
and Retime Signal with Existing Phasing Sequence
Under Existing Traffic Conditions
Main Street at Franklin Street, Reading

Intersection Capacity Analysis
Main St @ Franklin St

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		⊕			⬱	⬏		⬱⬐			⬱⬐	
Volume (vph)	78	49	50	85	124	167	35	334	20	235	578	83
Confl. Peds. (#/hr)	2					2						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	1%	1%	1%	4%	4%	4%	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 (%)												
Lane Group Flow (vph)	0	192	0	0	227	182	0	423	0	0	973	0
Turn Type	Perm			Perm		pm+ov	Perm			pm+pt		
Protected Phases		2			6	7		8		7	4 7	
Permitted Phases	2			6		6	8			4 7		
Detector Phase	2	2		6	6	7	8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0	5.0	10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0	10.0	15.0	15.0		10.0		
Total Split (s)	32.0	32.0	0.0	32.0	32.0	10.0	50.0	50.0	0.0	10.0	70.0	0.0
Total Split (%)	27.4%	27.4%	0.0%	27.4%	27.4%	8.5%	42.7%	42.7%	0.0%	8.5%	59.8%	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag						Lead	Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None	Max	Max	Max		Max		
Act Effct Green (s)		22.4			22.4	27.4		45.6			55.8	
Actuated g/C Ratio		0.24			0.24	0.30		0.50			0.61	
v/c Ratio		0.74			0.66	0.30		0.30			0.66	
Control Delay		48.4			42.1	5.2		16.3			15.9	
Queue Delay		0.0			0.0	0.0		0.0			0.0	
Total Delay		48.4			42.1	5.2		16.3			15.9	
LOS		D			D	A		B			B	
Approach Delay		48.4			25.6			16.3			15.9	
Approach LOS		D			C			B			B	
Queue Length 50th (ft)		88			111	0		68			138	
Queue Length 95th (ft)		#236			239	49		154			320	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		314			424	601		1394			1483	
Starvation Cap Reductn		0			0	0		0			0	
Spillback Cap Reductn		0			0	0		0			0	
Storage Cap Reductn		0			0	0		0			0	
Reduced v/c Ratio		0.61			0.54	0.30		0.30			0.66	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	60.0	25.0
Total Split (%)	51%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 91.7

Natural Cycle: 90

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.74

Intersection Signal Delay: 21.1   Intersection LOS: C

Intersection Capacity Utilization 74.3%   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: 1: Int

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		↔			↰	↱		↔↱			↔↱	
Volume (vph)	130	80	23	57	59	247	24	653	45	203	519	66
Confl. Peds. (#/hr)	1					1						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	1%	1%	1%	2%	2%	2%	1%	1%	1%
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 (%)												
Lane Group Flow (vph)	0	259	0	0	129	274	0	803	0	0	876	0
Turn Type	Perm			Perm		pm+ov	Perm			pm+pt		
Protected Phases		2			6	7		8		7	4 7	
Permitted Phases	2			6		6	8			4 7		
Detector Phase	2	2		6	6	7	8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0	5.0	10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0	10.0	15.0	15.0		10.0		
Total Split (s)	32.0	32.0	0.0	32.0	32.0	10.0	50.0	50.0	0.0	10.0	70.0	0.0
Total Split (%)	27.4%	27.4%	0.0%	27.4%	27.4%	8.5%	42.7%	42.7%	0.0%	8.5%	59.8%	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag						Lead	Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None	Max	Max	Max		Max		
Act Effct Green (s)		22.8			22.8	27.9		45.6			55.7	
Actuated g/C Ratio		0.25			0.25	0.30		0.50			0.60	
v/c Ratio		0.75			0.37	0.41		0.51			0.69	
Control Delay		47.4			33.3	5.1		18.9			16.9	
Queue Delay		0.0			0.0	0.0		0.0			0.0	
Total Delay		47.4			33.3	5.1		18.9			16.9	
LOS		D			C	A		B			B	
Approach Delay		47.4			14.1			18.9			16.9	
Approach LOS		D			B			B			B	
Queue Length 50th (ft)		129			58	0		148			118	
Queue Length 95th (ft)		#303			138	58		309			#282	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		411			417	670		1569			1274	
Starvation Cap Reductn		0			0	0		0			0	
Spillback Cap Reductn		0			0	0		0			0	
Storage Cap Reductn		0			0	0		0			0	
Reduced v/c Ratio		0.63			0.31	0.41		0.51			0.69	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	60.0	25.0
Total Split (%)	51%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 92.1

Natural Cycle: 90

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.75

Intersection Signal Delay: 20.5   Intersection LOS: C

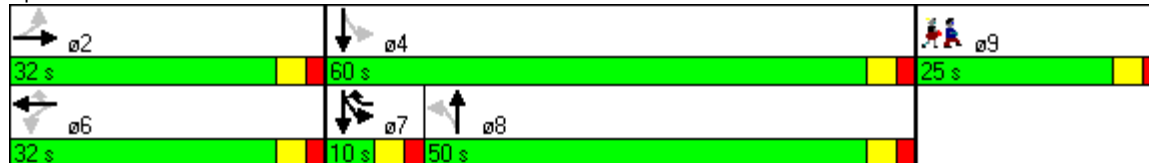Intersection Capacity Utilization 74.5%   ICU Level of Service D

Analysis Period (min) 15

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

     Queue shown is maximum after two cycles.

Splits and Phases: 1: Int

Appendix F

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 4: Add a Lane on EB/WB Approaches
and Change EB/WB Operation to Split Phase
Under Existing Traffic Conditions
Main Street at Franklin Street, Reading

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↱	↟			↰	↱		↔↟			↔↟	
Volume (vph)	78	49	50	85	124	167	35	334	20	235	578	83
Confl. Peds. (#/hr)	2					2						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	1%	1%	1%	4%	4%	4%	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 (%)												
Lane Group Flow (vph)	85	107	0	0	227	182	0	423	0	0	973	0
Turn Type	Split			Split		Perm	Perm			pm+pt		
Protected Phases	2	2		6	6			8		7	4 7	
Permitted Phases						6	8			4 7		
Detector Phase	2	2		6	6	6	8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	7.0	7.0		7.0	7.0	7.0	10.0	10.0		5.0		
Minimum Split (s)	12.0	12.0		12.0	12.0	12.0	15.0	15.0		10.0		
Total Split (s)	15.0	15.0	0.0	21.0	21.0	21.0	44.0	44.0	0.0	12.0	68.0	0.0
Total Split (%)	12.8%	12.8%	0.0%	17.9%	17.9%	17.9%	37.6%	37.6%	0.0%	10.3%	58.1%	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None	None	Max	Max		Max		
Act Effct Green (s)	9.1	9.1			15.5	15.5		39.3			51.4	
Actuated g/C Ratio	0.10	0.10			0.16	0.16		0.41			0.54	
v/c Ratio	0.51	0.56			0.75	0.44		0.37			0.73	
Control Delay	54.1	41.8			55.7	9.9		21.5			20.9	
Queue Delay	0.0	0.0			0.0	0.0		0.0			0.0	
Total Delay	54.1	41.8			55.7	9.9		21.5			20.9	
LOS	D	D			E	A		C			C	
Approach Delay		47.2			35.3			21.5			20.9	
Approach LOS		D			D			C			C	
Queue Length 50th (ft)	47	40			126	0		84			171	
Queue Length 95th (ft)	#114	#113			#302	63		170			#363	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)	185	210			314	419		1157			1330	
Starvation Cap Reductn	0	0			0	0		0			0	
Spillback Cap Reductn	0	0			0	0		0			0	
Storage Cap Reductn	0	0			0	0		0			0	
Reduced v/c Ratio	0.46	0.51			0.72	0.43		0.37			0.73	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	56.0	25.0
Total Split (%)	48%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 94.7

Natural Cycle: 90

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.75

Intersection Signal Delay: 26.5   Intersection LOS: C
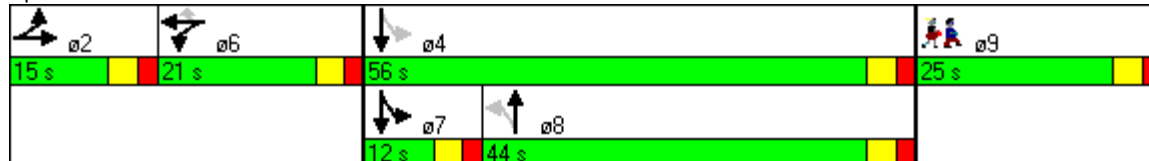
Intersection Capacity Utilization 70.2%   ICU Level of Service C

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
Main St @ Franklin St

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↱	↟			↰	↱		↟↟			↰↟	
Volume (vph)	130	80	23	57	59	247	24	653	45	203	519	66
Confl. Peds. (#/hr)	1					1						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	0%	0%	0%	1%	1%	1%	2%	2%	2%	1%	1%	1%
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 (%)												
Lane Group Flow (vph)	144	115	0	0	129	274	0	803	0	0	876	0
Turn Type	Split			Split		Perm	Perm			pm+pt		
Protected Phases	2	2		6	6			8		7	4 7	
Permitted Phases						6	8			4 7		
Detector Phase	2	2		6	6	6	8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	7.0	7.0		7.0	7.0	7.0	10.0	10.0		5.0		
Minimum Split (s)	12.0	12.0		12.0	12.0	12.0	15.0	15.0		10.0		
Total Split (s)	18.0	18.0	0.0	14.0	14.0	14.0	49.0	49.0	0.0	11.0	71.0	0.0
Total Split (%)	15.4%	15.4%	0.0%	12.0%	12.0%	12.0%	41.9%	41.9%	0.0%	9.4%	60.7%	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None	None	Max	Max		Max		
Act Effct Green (s)	11.8	11.8		9.1	9.1		44.4			55.5		
Actuated g/C Ratio	0.12	0.12		0.10	0.10		0.47			0.58		
v/c Ratio	0.64	0.49		0.74	0.69		0.54			0.71		
Control Delay	55.0	44.2		68.5	15.6		21.0			18.1		
Queue Delay	0.0	0.0		0.0	0.0		0.0			0.0		
Total Delay	55.0	44.2		68.5	15.6		21.0			18.1		
LOS	D	D		E	B		C			B		
Approach Delay		50.2		32.5			21.0			18.1		
Approach LOS		D		C			C			B		
Queue Length 50th (ft)	79	57		74	0		163			130		
Queue Length 95th (ft)	#191	134		#209	#100		314			#279		
Internal Link Dist (ft)		642		631			407			422		
Turn Bay Length (ft)												
Base Capacity (vph)	249	262		175	398		1480			1235		
Starvation Cap Reductn	0	0		0	0		0			0		
Spillback Cap Reductn	0	0		0	0		0			0		
Storage Cap Reductn	0	0		0	0		0			0		
Reduced v/c Ratio	0.58	0.44		0.74	0.69		0.54			0.71		

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	60.0	25.0
Total Split (%)	51%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 95

Natural Cycle: 90

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.74

Intersection Signal Delay: 25.1   Intersection LOS: C

Intersection Capacity Utilization 68.9%   ICU Level of Service C

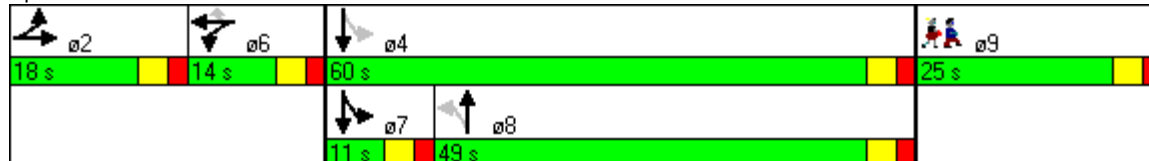Analysis Period (min) 15

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

   Queue shown is maximum after two cycles.

Splits and Phases: 1: Int

Appendix G

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 1: Retime Traffic Signal with Existing Phasing and Geometry
Under Projected Future Traffic Conditions
Main Street at Franklin Street, Reading

Intersection Capacity Analysis
Main St @ Franklin St

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		⟷			⟷			⟸⟰⟹			⟸⟰⟹	
Volume (vph)	78	49	50	85	124	167	35	334	20	235	578	83
Confl. Peds. (#/hr)	2					2						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Heavy Vehicles (%)	4%	4%	4%	1%	1%	1%	4%	4%	4%	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 (%)												
Lane Group Flow (vph)	0	221	0	0	470	0	0	487	0	0	1120	0
Turn Type	Perm			Perm			Perm			pm+pt		
Protected Phases		2			6			8		7	4 7	
Permitted Phases	2			6			8			4 7		
Detector Phase	2	2		6	6		8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0		10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0		15.0	15.0		10.0		
Total Split (s)	36.0	36.0	0.0	36.0	36.0	0.0	44.0	44.0	0.0	12.0	68.0	0.0
Total Split (%)	30.8%	30.8%	0.0%	30.8%	30.8%	0.0%	37.6%	37.6%	0.0%	10.3%	58.1%	0.0%
Yellow Time (s)	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		
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							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None		Max	Max		Max		
Act Effct Green (s)		31.2			31.2			39.3			51.3	
Actuated g/C Ratio		0.32			0.32			0.41			0.53	
v/c Ratio		0.69			0.93			0.45			0.89	
Control Delay		40.9			56.3			23.2			29.6	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		40.9			56.3			23.2			29.6	
LOS		D			E			C			C	
Approach Delay		40.9			56.3			23.2			29.6	
Approach LOS		D			E			C			C	
Queue Length 50th (ft)		101			241			101			211	
Queue Length 95th (ft)		#275			#571			200			#564	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		319			508			1088			1263	
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		0.69			0.93			0.45			0.89	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	56.0	25.0
Total Split (%)	48%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.2

Natural Cycle: 150

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.93

Intersection Signal Delay: 34.8   Intersection LOS: C
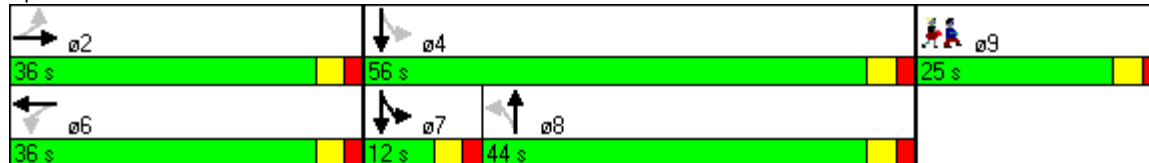
Intersection Capacity Utilization 81.2%   ICU Level of Service D

Analysis Period (min) 15

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

    Queue shown is maximum after two cycles.

Splits and Phases: 1: Int

Intersection Capacity Analysis
Main St @ Franklin St

12/21/2009

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		⟐			⟐			⟐⟐			⟐⟐	
Volume (vph)	130	80	23	57	59	247	24	653	45	203	519	66
Confl. Peds. (#/hr)	1				1							
Confl. Bikes (#/hr)												
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Growth Factor	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Heavy Vehicles (%)	0%	0%	0%	1%	1%	1%	2%	2%	2%	1%	1%	1%
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 (%)												
Lane Group Flow (vph)	0	297	0	0	464	0	0	923	0	0	1006	0
Turn Type	Perm			Perm			Perm			pm+pt		
Protected Phases		2			6			8			7	4 7	
Permitted Phases	2			6			8			4 7		
Detector Phase	2	2		6	6		8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0		10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0		15.0	15.0		10.0		
Total Split (s)	39.0	39.0	0.0	39.0	39.0	0.0	39.0	39.0	0.0	14.0	67.0	0.0
Total Split (%)	33.3%	33.3%	0.0%	33.3%	33.3%	0.0%	33.3%	33.3%	0.0%	12.0%	57.3%	0.0%
Yellow Time (s)	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		
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							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None		Max	Max		Max		
Act Effct Green (s)		34.2			34.2			34.2			48.3	
Actuated g/C Ratio		0.36			0.36			0.36			0.50	
v/c Ratio		0.97			0.77			0.83			0.98dl	
Control Delay		78.0			33.1			37.2			36.8	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		78.0			33.1			37.2			36.8	
LOS		E			C			D			D	
Approach Delay		78.0			33.1			37.2			36.8	
Approach LOS		E			C			D			D	
Queue Length 50th (ft)		162			187			248			194	
Queue Length 95th (ft)		#428			#461			#492			#536	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		305			600			1106			1079	
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		0.97			0.77			0.83			0.93	

Intersection Summary

Cycle Length: 117

PM Improvement Alternative 1 (Future Year)
Boston MPO Intersections Study
Synchro 7 - Report
Page 1

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	53.0	25.0
Total Split (%)	45%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.2

Natural Cycle: 150

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.97

Intersection Signal Delay: 40.9 | Intersection LOS: D

Intersection Capacity Utilization 101.5% | ICU Level of Service G

Analysis Period (min) 15

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

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

Splits and Phases: 1: Int

ø2	ø4	ø9
39 s	53 s	25 s

ø6	ø7	ø8	
39 s	14 s	39 s	

Appendix H

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 2: Change EB/WB Operation to Split Phase with Existing Geometry
Under Projected Future Traffic Conditions
Main Street at Franklin Street, Reading

Intersection Capacity Analysis
Main St @ Franklin St

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		⭖			⭖			⭖↟↟			⭖↟↟	
Volume (vph)	78	49	50	85	124	167	35	334	20	235	578	83
Confl. Peds. (#/hr)	2					2						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Heavy Vehicles (%)	4%	4%	4%	1%	1%	1%	4%	4%	4%	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 (%)												
Lane Group Flow (vph)	0	221	0	0	470	0	0	487	0	0	1120	0
Turn Type	Split			Split			Perm			pm+pt		
Protected Phases	2	2		6	6			8		7	4 7	
Permitted Phases							8			4 7		
Detector Phase	2	2		6	6		8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0		10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0		15.0	15.0		10.0		
Total Split (s)	20.0	20.0	0.0	24.0	24.0	0.0	34.0	34.0	0.0	14.0	62.0	0.0
Total Split (%)	17.1%	17.1%	0.0%	20.5%	20.5%	0.0%	29.1%	29.1%	0.0%	12.0%	53.0%	0.0%
Yellow Time (s)	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		
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							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None		Max	Max		Max		
Act Effct Green (s)		15.0			19.1			29.2			43.3	
Actuated g/C Ratio		0.16			0.20			0.30			0.45	
v/c Ratio		0.79			1.27			0.63			1.05	
Control Delay		58.4			175.0			34.2			66.6	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		58.4			175.0			34.2			66.6	
LOS		E			F			C			E	
Approach Delay		58.4			175.0			34.2			66.6	
Approach LOS		E			F			C			E	
Queue Length 50th (ft)		116			~329			124			~264	
Queue Length 95th (ft)		#300			#664			234			#668	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		282			369			769			1069	
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		0.78			1.27			0.63			1.05	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	48.0	25.0
Total Split (%)	41%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.1

Natural Cycle: 150

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 1.27

Intersection Signal Delay: 81.1   Intersection LOS: F

Intersection Capacity Utilization 81.2%   ICU Level of Service D

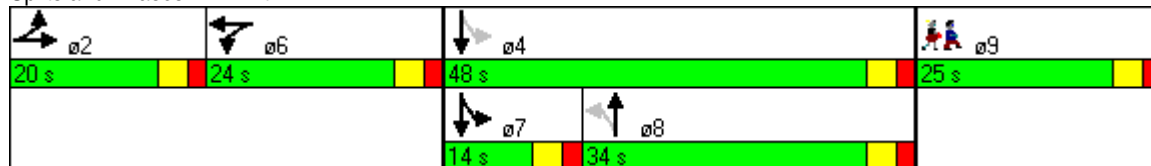Analysis Period (min) 15

~   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: 1: Int

Intersection Capacity Analysis
Main St @ Franklin St

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		✛			✛			↟↟			↟↟	
Volume (vph)	130	80	23	57	59	247	24	653	45	203	519	66
Confl. Peds. (#/hr)	1					1						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Growth Factor	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Heavy Vehicles (%)	0%	0%	0%	1%	1%	1%	2%	2%	2%	1%	1%	1%
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 (%)												
Lane Group Flow (vph)	0	297	0	0	464	0	0	923	0	0	1006	0
Turn Type	Split			Split			Perm			pm+pt		
Protected Phases	2	2		6	6			8		7	4 7	
Permitted Phases							8			4 7		
Detector Phase	2	2		6	6		8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0		10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0		15.0	15.0		10.0		
Total Split (s)	22.0	22.0	0.0	24.0	24.0	0.0	34.0	34.0	0.0	12.0	58.0	0.0
Total Split (%)	18.8%	18.8%	0.0%	20.5%	20.5%	0.0%	29.1%	29.1%	0.0%	10.3%	49.6%	0.0%
Yellow Time (s)	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		
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							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None		Max	Max		Max		
Act Effct Green (s)		17.1			19.1			29.2			41.3	
Actuated g/C Ratio		0.18			0.20			0.30			0.43	
v/c Ratio		0.91			1.17			0.98			1.21dl	
Control Delay		71.1			130.9			59.5			82.0	
Queue Delay		0.0			0.0			0.0			0.0	
Total Delay		71.1			130.9			59.5			82.0	
LOS		E			F			E			F	
Approach Delay		71.1			130.9			59.5			82.0	
Approach LOS		E			F			E			F	
Queue Length 50th (ft)		168			~280			272			~251	
Queue Length 95th (ft)		#413			#599			#550			#623	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		328			397			941			927	
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		0.91			1.17			0.98			1.09	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	46.0	25.0
Total Split (%)	39%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.2

Natural Cycle: 150

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 1.17

Intersection Signal Delay: 81.5   Intersection LOS: F

Intersection Capacity Utilization 101.5%   ICU Level of Service G

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.

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

Splits and Phases: 1: Int
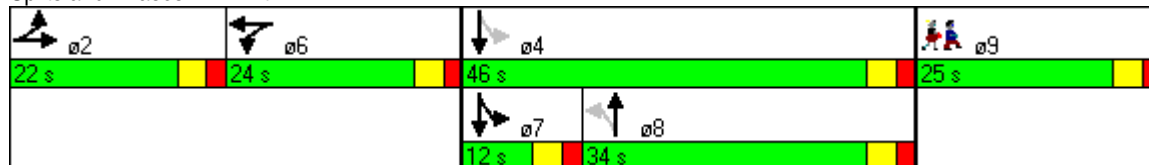
Appendix I

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 3: Add a WB Right-Turn Lane
and Retime Signal with Existing Phasing Sequence
Under Projected Future Traffic Conditions
Main Street at Franklin Street, Reading

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		⬥			⬦	⬧		⬨			⬨	
Volume (vph)	78	49	50	85	124	167	35	334	20	235	578	83
Confl. Peds. (#/hr)	2					2						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Heavy Vehicles (%)	4%	4%	4%	1%	1%	1%	4%	4%	4%	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 (%)												
Lane Group Flow (vph)	0	221	0	0	261	209	0	487	0	0	1120	0
Turn Type	Perm			Perm		pm+ov	Perm			pm+pt		
Protected Phases		2			6	7		8		7	4 7	
Permitted Phases	2			6		6	8			4 7		
Detector Phase	2	2		6	6	7	8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0	5.0	10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0	10.0	15.0	15.0		10.0		
Total Split (s)	32.0	32.0	0.0	32.0	32.0	14.0	46.0	46.0	0.0	14.0	74.0	0.0
Total Split (%)	27.4%	27.4%	0.0%	27.4%	27.4%	12.0%	39.3%	39.3%	0.0%	12.0%	63.2%	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag						Lead	Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None	Max	Max	Max		Max		
Act Effct Green (s)		27.2			27.2	36.2		41.3			55.4	
Actuated g/C Ratio		0.28			0.28	0.38		0.43			0.58	
v/c Ratio		0.78			0.66	0.29		0.42			0.81	
Control Delay		50.8			41.3	4.2		21.6			21.6	
Queue Delay		0.0			0.0	0.0		0.0			0.0	
Total Delay		50.8			41.3	4.2		21.6			21.6	
LOS		D			D	A		C			C	
Approach Delay		50.8			24.8			21.6			21.6	
Approach LOS		D			C			C			C	
Queue Length 50th (ft)		108			131	0		96			186	
Queue Length 95th (ft)		#298			#307	49		194			#464	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		285			396	726		1146			1388	
Starvation Cap Reductn		0			0	0		0			0	
Spillback Cap Reductn		0			0	0		0			0	
Storage Cap Reductn		0			0	0		0			0	
Reduced v/c Ratio		0.78			0.66	0.29		0.42			0.81	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	60.0	25.0
Total Split (%)	51%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.2

Natural Cycle: 130

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.81

Intersection Signal Delay: 25.0   Intersection LOS: C

Intersection Capacity Utilization 82.8%   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: 1: Int

Intersection Capacity Analysis
Main St @ Franklin St

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		✛			◁	↱		◁↟↟			◁↟↟	
Volume (vph)	130	80	23	57	59	247	24	653	45	203	519	66
Confl. Peds. (#/hr)	1						1					
Confl. Bikes (#/hr)												
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Growth Factor	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Heavy Vehicles (%)	0%	0%	0%	1%	1%	1%	2%	2%	2%	1%	1%	1%
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 (%)												
Lane Group Flow (vph)	0	297	0	0	148	316	0	923	0	0	1006	0
Turn Type	Perm			Perm		pm+ov	Perm			pm+pt		
Protected Phases		2			6	7		8		7	4 7	
Permitted Phases	2			6		6	8			4 7		
Detector Phase	2	2		6	6	7	8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	10.0	10.0		10.0	10.0	5.0	10.0	10.0		5.0		
Minimum Split (s)	15.0	15.0		15.0	15.0	10.0	15.0	15.0		10.0		
Total Split (s)	32.0	32.0	0.0	32.0	32.0	12.0	48.0	48.0	0.0	12.0	72.0	0.0
Total Split (%)	27.4%	27.4%	0.0%	27.4%	27.4%	10.3%	41.0%	41.0%	0.0%	10.3%	61.5%	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag						Lead	Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None	Max	Max	Max		Max		
Act Effct Green (s)		27.2			27.2	34.2		43.3			55.4	
Actuated g/C Ratio		0.28			0.28	0.36		0.45			0.58	
v/c Ratio		0.79			0.38	0.41		0.66			0.85	
Control Delay		49.5			32.9	4.5		24.5			24.9	
Queue Delay		0.0			0.0	0.0		0.0			0.0	
Total Delay		49.5			32.9	4.5		24.5			24.9	
LOS		D			C	A		C			C	
Approach Delay		49.5			13.5			24.5			24.9	
Approach LOS		D			B			C			C	
Queue Length 50th (ft)		155			68	0		204			158	
Queue Length 95th (ft)		#382			157	60		387			#438	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)		376			389	767		1402			1178	
Starvation Cap Reductn		0			0	0		0			0	
Spillback Cap Reductn		0			0	0		0			0	
Storage Cap Reductn		0			0	0		0			0	
Reduced v/c Ratio		0.79			0.38	0.41		0.66			0.85	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	60.0	25.0
Total Split (%)	51%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.2

Natural Cycle: 130

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.85

Intersection Signal Delay: 25.5   Intersection LOS: C

Intersection Capacity Utilization 82.8%   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: 1: Int

ø2	ø4	ø9
32 s	60 s	25 s

ø6	ø7	ø8
32 s	12 s	48 s
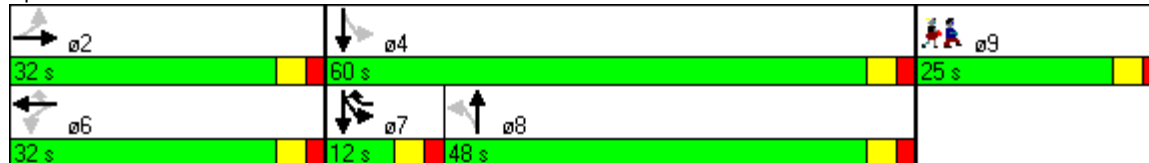
Appendix J

AM/PM Peak Hour Intersection Capacity Analysis
Alternative 4: Add a Lane on EB/WB Approaches
and Change EB/WB Operation to Split Phase
Under Projected Future Traffic Conditions
Main Street at Franklin Street, Reading

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↱			↰	↱		↔↑↔			↔↑↔	
Volume (vph)	78	49	50	85	124	167	35	334	20	235	578	83
Confl. Peds. (#/hr)	2					2						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Heavy Vehicles (%)	4%	4%	4%	1%	1%	1%	4%	4%	4%	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 (%)												
Lane Group Flow (vph)	98	123	0	0	261	209	0	487	0	0	1120	0
Turn Type	Split			Split		Perm	Perm			pm+pt		
Protected Phases	2	2		6	6			8		7	4 7	
Permitted Phases						6	8			4 7		
Detector Phase	2	2		6	6	6	8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	7.0	7.0		7.0	7.0	7.0	10.0	10.0		5.0		
Minimum Split (s)	12.0	12.0		12.0	12.0	12.0	15.0	15.0		10.0		
Total Split (s)	13.0	13.0	0.0	21.0	21.0	21.0	44.0	44.0	0.0	14.0	72.0	0.0
Total Split (%)	11.1%	11.1%	0.0%	17.9%	17.9%	17.9%	37.6%	37.6%	0.0%	12.0%	61.5%	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None	None	Max	Max		Max		
Act Effct Green (s)	8.1	8.1			16.1	16.1		39.3			53.4	
Actuated g/C Ratio	0.08	0.08			0.17	0.17		0.41			0.56	
v/c Ratio	0.68	0.71			0.84	0.48		0.45			0.84	
Control Delay	67.8	55.3			64.6	9.8		23.2			24.5	
Queue Delay	0.0	0.0			0.0	0.0		0.0			0.0	
Total Delay	67.8	55.3			64.6	9.8		23.2			24.5	
LOS	E	E			E	A		C			C	
Approach Delay		60.9			40.2			23.2			24.5	
Approach LOS		E			D			C			C	
Queue Length 50th (ft)	56	51			148	0		101			198	
Queue Length 95th (ft)	#166	#170			#363	68		200			#508	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)	145	173			309	437		1088			1334	
Starvation Cap Reductn	0	0			0	0		0			0	
Spillback Cap Reductn	0	0			0	0		0			0	
Storage Cap Reductn	0	0			0	0		0			0	
Reduced v/c Ratio	0.68	0.71			0.84	0.48		0.45			0.84	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	58.0	25.0
Total Split (%)	50%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.2

Natural Cycle: 120

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.84

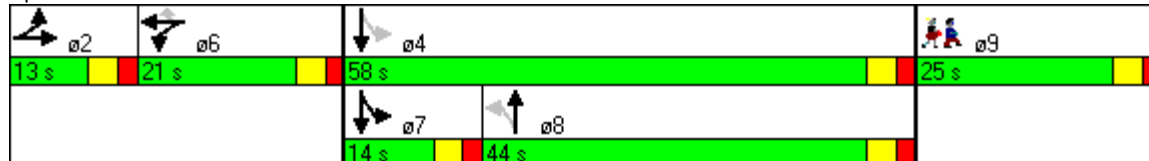| Intersection Signal Delay: 30.9	Intersection LOS: C
Intersection Capacity Utilization 77.9%	ICU Level of Service D

Analysis Period (min) 15

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

   Queue shown is maximum after two cycles.

Splits and Phases: 1: Int

ø2	ø6	ø4		ø9
13 s	21 s	58 s		25 s
		ø7	ø8	
		14 s	44 s	

Intersection Capacity Analysis
Main St @ Franklin St

12/23/2009

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	⬆			⬱	↱		⬱⬆			⬱⬆	
Volume (vph)	130	80	23	57	59	247	24	653	45	203	519	66
Confl. Peds. (#/hr)	1					1						
Confl. Bikes (#/hr)												
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Growth Factor	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%	115%
Heavy Vehicles (%)	0%	0%	0%	1%	1%	1%	2%	2%	2%	1%	1%	1%
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 (%)												
Lane Group Flow (vph)	166	131	0	0	148	316	0	923	0	0	1006	0
Turn Type	Split			Split		Perm	Perm			pm+pt		
Protected Phases	2	2		6	6			8		7	4 7	
Permitted Phases						6	8			4 7		
Detector Phase	2	2		6	6	6	8	8		7	4 7	
Switch Phase												
Minimum Initial (s)	7.0	7.0		7.0	7.0	7.0	10.0	10.0		5.0		
Minimum Split (s)	12.0	12.0		12.0	12.0	12.0	15.0	15.0		10.0		
Total Split (s)	16.0	16.0	0.0	14.0	14.0	14.0	51.0	51.0	0.0	11.0	73.0	0.0
Total Split (%)	13.7%	13.7%	0.0%	12.0%	12.0%	12.0%	43.6%	43.6%	0.0%	9.4%	62.4%	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	5.0	5.0	5.0	4.0	5.0	5.0	4.0
Lead/Lag							Lag	Lag		Lead		
Lead-Lag Optimize?							Yes	Yes				
Recall Mode	None	None		None	None	None	Max	Max		Max		
Act Effct Green (s)	11.1	11.1			9.1	9.1		46.3			57.4	
Actuated g/C Ratio	0.12	0.12			0.09	0.09		0.48			0.60	
v/c Ratio	0.80	0.60			0.86	0.73		0.61			0.83	
Control Delay	70.3	51.0			83.9	16.1		21.6			22.4	
Queue Delay	0.0	0.0			0.0	0.0		0.0			0.0	
Total Delay	70.3	51.0			83.9	16.1		21.6			22.4	
LOS	E	D			F	B		C			C	
Approach Delay		61.8			37.7			21.6			22.4	
Approach LOS		E			D			C			C	
Queue Length 50th (ft)	95	68			86	0		190			147	
Queue Length 95th (ft)	#256	#174			#245	#113		368			#408	
Internal Link Dist (ft)		642			631			407			422	
Turn Bay Length (ft)												
Base Capacity (vph)	208	220			173	434		1501			1212	
Starvation Cap Reductn	0	0			0	0		0			0	
Spillback Cap Reductn	0	0			0	0		0			0	
Storage Cap Reductn	0	0			0	0		0			0	
Reduced v/c Ratio	0.80	0.60			0.86	0.73		0.61			0.83	

Intersection Summary

Cycle Length: 117

Lane Group	ø4	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	4	9
Permitted Phases		
Detector Phase		
Switch Phase		
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	21.0	25.0
Total Split (s)	62.0	25.0
Total Split (%)	53%	21%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lost Time Adjust (s)		
Total Lost Time (s)		
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	None	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: 96.2

Natural Cycle: 120

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.86

Intersection Signal Delay: 29.1   Intersection LOS: C

Intersection Capacity Utilization 76.4%   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: 1: Int

ø2	ø6	ø4		ø9
16 s	14 s	62 s		25 s
		ø7	ø8	
		11 s	51 s	