



TECHNICAL MEMORANDUM

TO: Merrimack Valley Metropolitan Planning Organization
FROM: James Terlizzi, P.E., Transportation Planning Engineer
DATE: March 6, 2017
SUBJECT: Further analysis of the recommendations of the *Haverhill - River Street in the vicinity of Lowell Avenue Road Safety Audit* report

Staff has analyzed in further detail the impacts of the recommended improvements of the *Haverhill – River Street in the vicinity of Lowell Avenue Road Safety Audit* report and provided a summary of the results in this memorandum. Further conclusions and recommendations are drawn from the results of these analyses. The Road Safety Audit (RSA) for this location was conducted on December 20, 2016 and a final report was prepared and submitted to MassDOT on February 7, 2017.

Recommendations were made by the RSA participants and are summarized in the report within the Enhancements sections for all of the safety issues described in the “Audit Observations and Potential Safety Enhancements” section of the report. Table 4 of the report provides an Enhancements summary and shows the estimated safety payoff for each of the potential Enhancements.

Of particular concern to the audit participants, and supported by traffic volume and crash data, were: unsafe vehicular access to the McDonalds restaurant, unsafe vehicle exits from the Interstate Route 495 northbound ramps onto River Street, and congestion and delay along River Street and the Interstate Route 495 northbound off-ramp. The following presents an analysis of chiefly those recommendations that could be modeled by SYNCHRO software application. The SYNCHRO model follows the methodology presented in the Transportation Research Board’s (TRB’s) latest approved *Highway Capacity Manual*¹.

¹*Highway Capacity Manual*, HCM2010; Transportation Research Board; Washington, DC; 2010.

McDonalds driveway onto River Street

The greatest safety issue that presented itself to staff and the audit participants was vehicular access into the McDonalds via River Street from the west. Often, drivers wishing to enter the McDonalds must cross through opposing traffic in a congested lane and then through a free-flowing lane, however, on many occasions their vehicles are hidden from the view of drivers in the free-flowing lane by congestion in the other lane. Over the four-year study period, 21 crashes occurred at this location between vehicles turning left into the McDonalds and opposing vehicles in the curbside lane, with approximately half resulting in personal injury. This is perhaps the greatest contributor to the Equivalent Property Damage (EPDO) score for the River Street in the Lowell Avenue vicinity location.

To remove this safety issue, audit participants thought of prohibiting left-turns into the driveway by the long-term recommendation of either building a center median island on River Street or building a channelizing delta shaped island on the driveway that only allows right-turns in or out. The former of these two recommendations is the more expensive of the two. Alternatively, a more elegant recommendation was made for reconstruction in which the taper to full width of the curbside (free-flowing) lane begins after the driveway and there is only one lane passing the driveway with traffic in which drivers entering the McDonalds must pass through. This alternative preserves full access to and full egress from the McDonalds restaurant, while completely removing the safety issue.

In the interim, a recommendation was made to somehow make the vehicular access to the McDonalds restaurant more attractive via the Lowell Avenue driveway, rather than the River Street driveway, for those vehicles originating from Interstate Route 495 and River Street to the west. Thought was given by the RSA participants that if operations of traffic in the exclusive left-turn lane at the River Street and Lowell Avenue signalized intersection were safer, people would be more inclined to use it. Over the four-year study period, 8 crashes occurred at this location between a vehicle turning left onto Lowell Avenue and an opposing through vehicle on River Street, with three resulting in personal injury. The angle type collision at this location is the third greatest contributor to the EPDO score for the River Street in the Lowell Avenue vicinity location.

The traffic signal for the River Street and Lowell Avenue intersection currently allows traffic to proceed in the eastbound exclusive left-turn lane by protected/permissive

phasing; traffic is first allowed to turn left with no opposing traffic, with operators facing a green left arrow indication, and then traffic is then permitted to turn left after yielding the right-of way to opposing traffic. During the study period of the recorded crashes, the protected/permitted phasing was shown by the left green arrow/green ball indications in a dog-house signal face assembly. Last year, a vertical four faced assembly replaced it and the protected/permitted phasing is shown by the left green arrow/flashing yellow arrow indications. RSA participants recommended replacing the protected/permissive phasing with protected phasing only. This would completely remove the safety issue of traffic turning left against opposing through traffic and make travel in the lane more inviting to drivers, especially those destined to McDonalds. This will remove only some of the vehicles entering McDonalds by River Street. Table 1 summarizes this change.

Table 1. River Street at Lowell Avenue Operations Analysis Results

Pk Hr/Lane Mvmnt/Total ^a	Existing Conditions					LT Lane Protected Phase Only				
	V/C ^b	AD ^c	LOS ^d	Queue ^e	Length ^f	V/C	AD	LOS	Queue	Length
<i>Weekday Morning</i>										
River Street EB LT	0.65	15.8	B	4.3	108	0.87	41.8	D	8.8	220
River Street EB TH/RT	0.80	19.5	B	21.6	540	0.75	14.8	B	18.7	467
River Street EB RT	0.01	6.9	A	0.0	1	0.01	5.4	A	0.0	1
River Street WB LT	0.00	26.3	C	0.2	4	0.00	20.7	C	0.2	4
River Street WB TH	0.67	24.5	C	19.0	475 ^g	0.73	26.9	C	21.5	537 ^g
Lowell Avenue SB LT/TH	0.37	29.7	C	5.3	132	0.43	33.6	C	5.6	140
Lowell Avenue SB RT	0.93	49.7	D	9.4	236	0.85	35.3	D	9.3	232
Walgreens drive NB LT	0.03	33.0	C	0.6	14	0.04	37.1	D	0.6	15
Walgreens drive NB TH/RT	0.03	25.9	C	0.6	16	0.04	29.1	C	0.7	17
Intersection		27.2	C				26.9	C		
<i>Weekday Evening</i>										
River Street EB LT	0.93	40.9	D	13.5	338 ^g	0.92	49.6	D	14.5	362
River Street EB TH/RT	0.59	11.6	B	13.5	338	0.55	8.6	A	11.1	277
River Street EB RT	0.03	5.9	A	0.4	9	0.03	4.3	A	0.3	7
River Street WB LT	0.02	15.9	B	0.4	10	0.02	19.5	B	0.5	13
River Street WB TH	0.77	30.4	C	22.1	552 ^g	0.90	45.6	D	28.1	702 ^g
Lowell Avenue SB LT/TH	0.41	36.6	D	5.7	142	0.52	42.4	D	6.7	167 ^g
Lowell Avenue SB RT	0.88	43.6	D	12.0	300	0.76	28.3	C	10.5	263
Walgreens drive NB LT	0.14	41.4	D	1.4	35	0.21	47.4	D	1.5	37
Walgreens drive NB TH/RT	0.09	31.9	C	1.2	30	0.11	36.1	D	1.3	32
Intersection		29.8	C				31.5	C		

^aNB = Northbound; SB = Southbound; EB = Eastbound; WB = Westbound; LT = Left-Turn; TH = Through; RT = Right Turn. ^bVolume to Capacity ratio. ^cAverage Control Delay is in seconds per vehicle. ^dLevel of Service. ^e95th percentile queue is in vehicles. ^fLength of queue is in feet; assumes 25 feet per vehicle. ^g95th %ile volume exceeds capacity, queue may be longer. Max Q after 2 cycles.

As shown in Table 1, the change from protected/permmissive phasing to protected phasing only has only a slight impact to the overall operations of the signalized intersection. Traffic operations at the intersection remains at Level-of-Service (LOS) C during both the weekday morning and evening peak hours. Overall average vehicular delay is only increased an average of a couple of seconds during the evening.

However, during the weekday morning peak hour, operations of vehicles in the exclusive left-turn lane changes from LOS B, with an average vehicular delay 15.8 seconds per vehicle (sec/veh), to LOS D, 41.8 sec/veh. Operations of vehicles in the opposing through lane remains at LOS C, but changes in delay from 24.5 sec/veh to 26.9 sec/veh. During the weekday evening peak hour, operations of vehicles in the exclusive left-turn lane remains at LOS D, however, the average vehicular delay increases from 40.9 sec/veh to 49.6 sec/veh. Operations of vehicles in the opposing through lane changes from LOS C, 30.4 sec/veh, to LOS D, 45.6 sec/veh. More importantly, despite the maximum vehicle queue increasing only one vehicle in the exclusive left-turn lane, with this change, the maximum queue for the opposing through lane increases from 22 vehicles to 28 vehicles.

River Street at the Interstate Route 495 northbound off-ramp

The second greatest safety issue for the River Street study area is the problem with Interstate Route 495 northbound off-ramp right-turning vehicles colliding with one another at the ramp's intersection with River Street, as shown in the collision diagrams. From the crash report narratives, it was found that many of the rear-end collisions occurred because a leading vehicle would move from the STOP line and upon gaining sight distance and noticing oncoming traffic would suddenly stop. The operator of a trailing vehicle would not notice this sudden stop, by focusing attention on oncoming traffic while advancing the vehicle at the same time. The assumption by the trailing vehicle operator that the leading vehicle had departed leads to a rear-end collision. As shown in the collision diagram, over the four-year study period, 34 crashes occurred at this location between vehicles turning right off of the ramp, with five resulting in personal injury. This is the second greatest contributor to the EPDO score for the River Street in the Lowell Avenue vicinity location.

Audit participants thought of different ways to remove the issues that currently restrict the sight distance to operators of vehicles turning right off of the ramp. The most

significant restriction to sight distance for the right-turning vehicle operators is the adjacent vehicles turning left off of the ramp, as identified during the RSA. Audit participants thought that the best way to reduce the issue would be to install a traffic signal at the ramp intersection, with the current lane geometry. With a traffic signal, the operators of vehicles turning right off of the ramp will only have the single task of viewing the green signal indications for proceeding as opposed to the existing dual task of viewing the oncoming traffic on River Street, while paying attention to the vehicles in front. Table 2 summarizes the change in operations with the installation of a traffic signal at the intersection.

Table 2. River Street at I495NB off-ramp Operations Analysis Results

Pk Hr/Lane Mvmnt/Total ^a	Existing Conditions - Unsignalized					Proposed - Signalized				
	V/C ^b	AD ^c	LOS ^d	Queue ^e	Length ^f	V/C	AD	LOS	Queue	Length
<i>Weekday Morning</i>										
River Street EB TH	0.00	00.0	NA	0.0	0	0.81	21.4	C	17.4	436
River Street WB TH	0.00	00.0	NA	0.0	0	0.65	7.5	A	6.0	150
I495 NB ramp LT	0.58	48.7	E	3.1	78	0.39	38.8	D	5.7	142 ^g
I495 NB ramp RT	1.05	94.1	F	13.8	345	0.48	25.8	C	8.4	210
Intersection	NA	20.0	NA			0.76	17.4	B		
<i>Weekday Evening</i>										
River Street EB TH	0.00	00.0	NA	0.0	0	0.82	30.7	C	17.8	444
River Street WB TH	0.00	00.0	NA	0.0	0	0.61	6.1	A	6.8	170
I495 NB ramp LT	0.43	32.0	D	1.9	48	0.36	42.3	D	6.5	163 ^g
I495 NB ramp RT	1.15	119	F	19.6	490	0.61	24.0	C	14.5	363
Intersection	NA	31.5	NA			0.75	19.5	B		

^aNB = Northbound; EB = Eastbound; WB = Westbound; LT = Left-Turn; TH = Through; RT = Right Turn. ^bVolume to Capacity ratio. ^cAverage Control Delay is in sec per vehicle. ^dLevel of Service. ^e95th percentile queue is in vehicles. ^fLength of queue is in feet; assumes 25 feet per vehicle. NA= Not Applicable. ^g95th %ile volume exceeds capacity, queue may be longer. Max Q after 2 cycles.

As shown in Table 2, installation of a traffic signal will actually decrease the overall average vehicular delay to traffic entering the intersection, despite vehicles at times being stopped on River Street. Overall average intersection delay decreases from approximately 20 sec/veh to 17 sec/veh during the weekday morning peak hour and from approximately 32 sec/veh to 20 sec/veh during the weekday evening peak hour.

Despite traffic being stopped at times on River Street with a new signal, the maximum queue for westbound traffic will never be more than approximately 6 to 7 vehicles, as shown in the Table. This is well within the stacking distance between this signalized intersection and the existing signalized intersection of River Street and Lowell Avenue.

The new signal will share the burden of delay and vehicle stacking between the River Street eastbound approach and the Interstate Route 495 northbound off-ramp approach. Where there was no delay prior to the signal installation, there will be an average delay of approximately 21 to 31 sec/veh, operating at LOS C, for River Street eastbound traffic with the signal installed. Also, where there was no vehicle stacking prior to the signal installation, there will be a maximum queue of approximately 17 to 18 vehicles for River Street eastbound traffic with the signal installed.

With signal installation at this intersection, the turning movement that will notice the largest benefit will be the vehicles turning right off of the ramp. Traffic in this movement currently operates over capacity and operates at LOS F during both of the weekday commuter peak hours. Average vehicular delay is approximately 94 to 119 sec/veh and the maximum queues are approximately 14 and 20 vehicles during the weekday morning and evening peak hours, respectively, according to the analysis. A 20 vehicle queue is more than halfway down the ramp. However, these delays and queues are understated. The operations analysis neglects the influence of the operations of the adjacent signalized intersection upon the operations of this intersection. For instance, the vehicles stacking from the River Street eastbound approach to the Lowell Avenue signalized intersection will at times extend past the Interstate Route 495 northbound off-ramp. This prevents vehicles turning right off of the ramp from entering River Street and further exacerbates the vehicular delay and stacking on the ramp. Observations during the RSA and at other times show the vehicle queue extending the 900 feet of the ramp length to the trunk line of the interstate highway.

With the signal installed, traffic turning right off of the ramp is forecasted to operate at LOS C, with an average delay of approximately 24 to 26 sec/veh, during both weekday commuter peak hours. Additionally, the maximum queues will be reduced to approximately 8 to 15 vehicles during the weekday morning and evening peak hours, respectively. Therefore, it is not necessary to widen the ramp for two right-turn lanes, as was recommended within the RSA report.

As shown in the appendix of the RSA report, with the 4 hours of turning movement traffic volume data that was collected, the intersection easily meets the 4-hour and very likely meets the 8-hour traffic volume warrants for the installation of a traffic signal, according to the *Manual on Uniform Traffic Control Devices (MUTCD)*².

²*Manual on Uniform Traffic Control Devices (MUTCD)*; U.S. DOT, FHWA; Washington, DC; December, 2009.

River Street corridor delay

One of the safety issues that came up during the RSA was that the traffic congestion on the Interstate Route 495 northbound off-ramp and on River Street within the vicinity of Lowell Avenue causes much aggravation and drivers get “fed up”, which leads to them making aggressive and unsafe moves. This is hard to quantify, however, aggressive maneuvers were observed during the RSA. The aforementioned analysis results, confirmed by RSA participant observations, show that there is much vehicle congestion and delay experienced by drivers traveling through the study area.

To reduce congestion, in the short-term, one of the audit participants recommended programming the existing traffic signal controller at the River Street and Lowell Avenue intersection for “Dynamic Maximum Green” settings to step up more green time for River Street with increasing traffic. MassDOT engineers confirmed that the controller at this location has this capability. This will increase vehicular delay and stacking on Lowell Avenue, however, the critical congestion on River Street, past the McDonalds driveway and past the Interstate Route 495 northbound ramps will be reduced.

In the mid-term, it was recommended by audit participants that adaptive traffic signal control be installed at the River Street and Lowell Avenue intersection. This provides a slightly more responsive traffic control, by relying on vehicle queues, rather than vehicle volume and frequency that the “Dynamic Maximum Green” settings detects. Additional in-road vehicle detection will be placed near the ramp intersection to monitor vehicle queues and make adjustments to the signal control accordingly. A queue detector placed on River Street at the Interstate Route 495 northbound ramp will extend the River Street eastbound signal phase at Lowell Avenue to keep River Street clear for a short time, so that vehicles turning right off of the ramp may enter the roadway.

In the long-term, it was recommended that a traffic signal be installed at the Interstate Route 495 northbound ramp intersection with River Street and the signal controller should be coordinated with the existing controller at the River Street at Lowell Avenue intersection. The existing controller should be the master controller and there should be little to no offset in time between the phases at the two intersections where traffic is to be progressed. Traffic should be progressed from the Interstate Route 495 northbound off-ramp to and through the River Street eastbound approach to the Lowell Avenue intersection.

Conclusions and Recommendations

There is much congestion and delay in the study area during the weekday commuter peak hours and at other times, as shown by the operations analysis and as observed by the Road Safety Audit participants. Congestion and delay experienced by the traffic control at the River Street and Lowell Avenue intersection contributes to operational and safety problems not only at this location, but at nearby locations that come under the influence of traffic control and operations at the signalized location. For example, vehicle stacking from the signal on the River Street westbound approach, past the McDonalds driveway, contributes to the delay and decreased safety of vehicles entering the driveway from River Street to the west. Also, vehicle stacking from the signal on the River Street eastbound approach, past the ramp, contributes to the delay and decreased safety of vehicles turning right off of the ramp onto River Street.

The greatest safety benefit that can be provided to this study area is the shortening of the River Street exclusive right-turn lane on the westbound approach to Lowell Avenue, so that vehicles turning left into the McDonalds driveway from River Street must cross only one opposing lane, instead of two.

Reducing congestion and delay will greatly improve safety for this study area. Traffic signal installation at the Interstate Route 495 northbound ramp and its controller's coordination with the existing controller will provide the largest benefit to reducing traffic congestion within the study area. Signalized control of vehicles turning right off of the off-ramp will significantly reduce, but not eliminate, the large number of rear-end collisions occurring between vehicles in this movement. This will provide the second greatest safety benefit to safety in this study area.

Protecting traffic turning left from River Street onto Lowell Avenue from opposing traffic by altering the existing signal control at the intersection will provide third greatest safety benefit to this study area.

Appendix A. Intersection Operations Analysis Results

River Street at the Interstate Route 495 northbound ramps

Intersection

Int Delay, s/veh 20

Movement	EBT	EBR	WBL	WBT	NEL	NER
Vol, veh/h	791	0	0	876	105	408
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	Stop
Storage Length	-	-	-	-	0	100
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	100	100	100	100	100	100
Heavy Vehicles, %	2	2	2	1	3	3
Mvmt Flow	791	0	0	876	105	408

Major/Minor	Major1	Major2	Minor1
Conflicting Flow All	0	0	791
Stage 1	-	-	-
Stage 2	-	-	-
Critical Hdwy	-	-	4.12
Critical Hdwy Stg 1	-	-	-
Critical Hdwy Stg 2	-	-	-
Follow-up Hdwy	-	-	2.218
Pot Cap-1 Maneuver	-	-	829
Stage 1	-	-	-
Stage 2	-	-	-
Platoon blocked, %	-	-	-
Mov Cap-1 Maneuver	-	-	829
Mov Cap-2 Maneuver	-	-	-
Stage 1	-	-	-
Stage 2	-	-	-

Approach	EB	WB	NE
HCM Control Delay, s	0	0	84.8
HCM LOS			F

Minor Lane/Major Mvmt	NELn1	NELn2	EBT	EBR	WBL	WBT
Capacity (veh/h)	182	387	-	-	829	-
HCM Lane V/C Ratio	0.577	1.054	-	-	-	-
HCM Control Delay (s)	48.7	94.1	-	-	0	-
HCM Lane LOS	E	F	-	-	A	-
HCM 95th %tile Q(veh)	3.1	13.8	-	-	0	-

Notes

-: Volume exceeds capacity \$: Delay exceeds 300s +: Computation Not Defined *: All major volume in platoon

Intersection

Int Delay, s/veh 31.5

Movement	EBT	EBR	WBL	WBT	NEL	NER
Vol, veh/h	640	0	0	881	94	547
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	Stop
Storage Length	-	-	-	-	0	100
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	100	100	100	100	100	100
Heavy Vehicles, %	1	2	2	1	3	2
Mvmt Flow	640	0	0	881	94	547

Major/Minor	Major1	Major2	Minor1
Conflicting Flow All	0	640	1081
Stage 1	-	-	640
Stage 2	-	-	441
Critical Hdwy	-	4.12	6.645
Critical Hdwy Stg 1	-	-	5.445
Critical Hdwy Stg 2	-	-	5.845
Follow-up Hdwy	-	2.218	3.5285
Pot Cap-1 Maneuver	-	944	225
Stage 1	-	-	522
Stage 2	-	-	614
Platoon blocked, %	-	-	-
Mov Cap-1 Maneuver	-	944	225
Mov Cap-2 Maneuver	-	-	225
Stage 1	-	-	522
Stage 2	-	-	614

Approach	EB	WB	NE
HCM Control Delay, s	0	0	106.2
HCM LOS			F

Minor Lane/Major Mvmt	NELn1	NELn2	EBT	EBR	WBL	WBT
Capacity (veh/h)	225	474	-	-	944	-
HCM Lane V/C Ratio	0.418	1.154	-	-	-	-
HCM Control Delay (s)	32	119	-	-	0	-
HCM Lane LOS	D	F	-	-	A	-
HCM 95th %tile Q(veh)	1.9	19.6	-	-	0	-

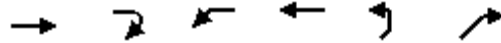
Notes

~: Volume exceeds capacity \$: Delay exceeds 300s +: Computation Not Defined *: All major volume in platoon

HCM Signalized Intersection Capacity Analysis

13: I495 NB off-ramp

3/3/2017



Movement	EBT	EBR	WBL	WBT	NEL	NER
Lane Configurations	↑			↑	↘	↗
Volume (vph)	791	0	0	876	105	408
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	12	15	15
Total Lost time (s)	5.0			5.0	5.0	5.0
Lane Util. Factor	1.00			1.00	1.00	1.00
Frt	1.00			1.00	1.00	0.85
Flt Protected	1.00			1.00	0.95	1.00
Satd. Flow (prot)	1863			1881	1928	1725
Flt Permitted	1.00			1.00	0.95	1.00
Satd. Flow (perm)	1863			1881	1928	1725
Peak-hour factor, PHF	0.97	0.97	0.97	0.97	0.97	1.00
Adj. Flow (vph)	815	0	0	903	108	408
RTOR Reduction (vph)	0	0	0	0	0	124
Lane Group Flow (vph)	815	0	0	903	108	284
Heavy Vehicles (%)	2%	2%	2%	1%	3%	3%
Turn Type	NA			NA	Prot	Perm
Protected Phases	4			8	2	
Permitted Phases						2 3
Actuated Green, G (s)	48.9			66.9	13.1	31.1
Effective Green, g (s)	48.9			66.9	13.1	31.1
Actuated g/C Ratio	0.54			0.74	0.15	0.35
Clearance Time (s)	5.0			5.0	5.0	
Vehicle Extension (s)	3.0			3.0	3.0	
Lane Grp Cap (vph)	1012			1398	280	596
v/s Ratio Prot	c0.44			c0.48	0.06	
v/s Ratio Perm						c0.16
v/c Ratio	0.81			0.65	0.39	0.48
Uniform Delay, d1	16.7			5.7	34.8	23.1
Progression Factor	1.00			1.17	1.00	1.00
Incremental Delay, d2	4.7			0.8	4.0	2.7
Delay (s)	21.4			7.5	38.8	25.8
Level of Service	C			A	D	C
Approach Delay (s)	21.4			7.5	28.5	
Approach LOS	C			A	C	

Intersection Summary

HCM 2000 Control Delay	17.4	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.76		
Actuated Cycle Length (s)	90.0	Sum of lost time (s)	15.0
Intersection Capacity Utilization	75.2%	ICU Level of Service	D
Analysis Period (min)	15		
c Critical Lane Group			

Timings
13: I495 NB off-ramp

3/3/2017

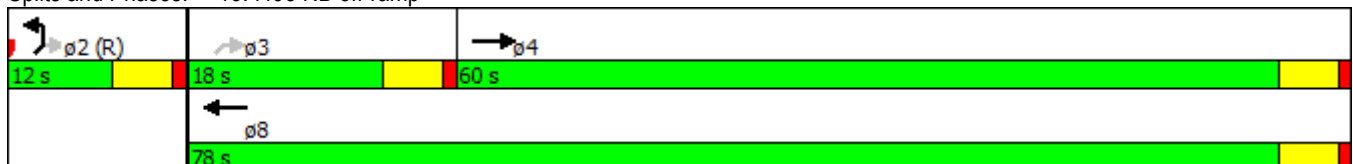


Lane Group	EBT	WBT	NEL	NER	ø3
Lane Configurations	↑	↑	↙	↗	
Volume (vph)	791	876	105	408	
Turn Type	NA	NA	Prot	Perm	
Protected Phases	4	8	2		3
Permitted Phases				2 3	
Detector Phase	4	8	2	2 3	
Switch Phase					
Minimum Initial (s)	4.0	4.0	4.0		4.0
Minimum Split (s)	21.0	21.0	21.0		21.0
Total Split (s)	60.0	78.0	12.0		18.0
Total Split (%)	66.7%	86.7%	13.3%		20%
Yellow Time (s)	4.0	4.0	4.0		4.0
All-Red Time (s)	1.0	1.0	1.0		1.0
Lost Time Adjust (s)	0.0	0.0	0.0		
Total Lost Time (s)	5.0	5.0	5.0		
Lead/Lag	Lag			Lead	
Lead-Lag Optimize?	Yes			Yes	
Recall Mode	None	None	C-Max		Max
Act Effct Green (s)	48.9	66.9	13.1	31.1	
Actuated g/C Ratio	0.54	0.74	0.15	0.35	
v/c Ratio	0.81	0.65	0.39	0.57	
Control Delay	23.1	8.1	43.8	17.4	
Queue Delay	0.2	0.7	0.0	0.7	
Total Delay	23.2	8.8	43.8	18.1	
LOS	C	A	D	B	
Approach Delay	23.2	8.8	23.4		
Approach LOS	C	A	C		

Intersection Summary

Cycle Length: 90
 Actuated Cycle Length: 90
 Offset: 0 (0%), Referenced to phase 2:NEL and 6:, Start of Green
 Natural Cycle: 90
 Control Type: Actuated-Coordinated
 Maximum v/c Ratio: 0.81
 Intersection Signal Delay: 17.4
 Intersection Capacity Utilization 75.2%
 Analysis Period (min) 15
 Intersection LOS: B
 ICU Level of Service D

Splits and Phases: 13: I495 NB off-ramp



Queues

13: I495 NB off-ramp

3/3/2017



Lane Group	EBT	WBT	NEL	NER
Lane Group Flow (vph)	815	903	108	408
v/c Ratio	0.81	0.65	0.39	0.57
Control Delay	23.1	8.1	43.8	17.4
Queue Delay	0.2	0.7	0.0	0.7
Total Delay	23.2	8.8	43.8	18.1
Queue Length 50th (ft)	331	144	58	99
Queue Length 95th (ft)	436	150	#142	210
Internal Link Dist (ft)	12	1	594	
Turn Bay Length (ft)				100
Base Capacity (vph)	1138	1525	280	720
Starvation Cap Reductn	0	293	0	0
Spillback Cap Reductn	33	0	0	98
Storage Cap Reductn	0	0	0	0
Reduced v/c Ratio	0.74	0.73	0.39	0.66

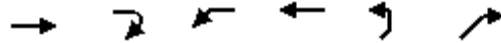
Intersection Summary

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

HCM Signalized Intersection Capacity Analysis

13: I495 NB off-ramp

3/6/2017



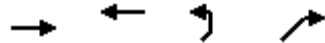
Movement	EBT	EBR	WBL	WBT	NEL	NER
Lane Configurations	↑			↑	↘	↗
Volume (vph)	640	0	0	881	94	547
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width	12	12	12	15	15	15
Total Lost time (s)	5.0			5.0	5.0	5.0
Lane Util. Factor	1.00			1.00	1.00	1.00
Frt	1.00			1.00	1.00	0.85
Flt Protected	1.00			1.00	0.95	1.00
Satd. Flow (prot)	1881			2069	1928	1742
Flt Permitted	1.00			1.00	0.95	1.00
Satd. Flow (perm)	1881			2069	1928	1742
Peak-hour factor, PHF	0.93	0.93	0.93	0.93	0.93	0.93
Adj. Flow (vph)	688	0	0	947	101	588
RTOR Reduction (vph)	0	0	0	0	0	109
Lane Group Flow (vph)	688	0	0	947	101	479
Heavy Vehicles (%)	1%	2%	2%	1%	3%	2%
Turn Type	NA			NA	Prot	Perm
Protected Phases	4			8	2	
Permitted Phases						2 3
Actuated Green, G (s)	44.6			75.6	14.4	45.4
Effective Green, g (s)	44.6			75.6	14.4	45.4
Actuated g/C Ratio	0.45			0.76	0.14	0.45
Clearance Time (s)	5.0			5.0	5.0	
Vehicle Extension (s)	3.0			3.0	3.0	
Lane Grp Cap (vph)	838			1564	277	790
v/s Ratio Prot	c0.37			0.46	0.05	
v/s Ratio Perm						c0.28
v/c Ratio	0.82			0.61	0.36	0.61
Uniform Delay, d1	24.2			5.5	38.7	20.6
Progression Factor	1.00			1.03	1.00	1.00
Incremental Delay, d2	6.5			0.5	3.7	3.4
Delay (s)	30.7			6.1	42.3	24.0
Level of Service	C			A	D	C
Approach Delay (s)	30.7			6.1	26.7	
Approach LOS	C			A	C	

Intersection Summary

HCM 2000 Control Delay	19.5	HCM 2000 Level of Service	B
HCM 2000 Volume to Capacity ratio	0.75		
Actuated Cycle Length (s)	100.0	Sum of lost time (s)	15.0
Intersection Capacity Utilization	75.9%	ICU Level of Service	D
Analysis Period (min)	15		
c Critical Lane Group			

Timings
13: I495 NB off-ramp

3/6/2017



Lane Group	EBT	WBT	NEL	NER	ø3
Lane Configurations	↑	↑	↙	↗	
Volume (vph)	640	881	94	547	
Lane Group Flow (vph)	688	947	101	588	
Turn Type	NA	NA	Prot	Perm	
Protected Phases	4	8	2		3
Permitted Phases				2 3	
Detector Phase	4	8	2	2 3	
Switch Phase					
Minimum Initial (s)	4.0	4.0	4.0		4.0
Minimum Split (s)	21.0	21.0	21.0		21.0
Total Split (s)	58.0	89.0	11.0		31.0
Total Split (%)	58.0%	89.0%	11.0%		31%
Yellow Time (s)	4.0	4.0	4.0		4.0
All-Red Time (s)	1.0	1.0	1.0		1.0
Lost Time Adjust (s)	0.0	0.0	0.0		
Total Lost Time (s)	5.0	5.0	5.0		
Lead/Lag	Lag				Lead
Lead-Lag Optimize?	Yes				Yes
Recall Mode	None	None	C-Max		Max
Act Effct Green (s)	44.6	75.6	14.4	45.4	
Actuated g/C Ratio	0.45	0.76	0.14	0.45	
v/c Ratio	0.82	0.61	0.37	0.65	
Control Delay	32.4	6.6	47.5	19.2	
Queue Delay	0.0	0.7	0.0	0.2	
Total Delay	32.4	7.3	47.5	19.4	
LOS	C	A	D	B	
Approach Delay	32.4	7.3	23.5		
Approach LOS	C	A	C		
Queue Length 50th (ft)	363	167	60	191	
Queue Length 95th (ft)	444	170	#163	363	
Internal Link Dist (ft)	12	1	594		
Turn Bay Length (ft)				100	
Base Capacity (vph)	996	1737	276	898	
Starvation Cap Reductn	0	440	0	0	
Spillback Cap Reductn	0	0	0	31	
Storage Cap Reductn	0	0	0	0	
Reduced v/c Ratio	0.69	0.73	0.37	0.68	

Intersection Summary

Cycle Length: 100
 Actuated Cycle Length: 100
 Offset: 0 (0%), Referenced to phase 2:NEL and 6:, Start of Green
 Natural Cycle: 75
 Control Type: Actuated-Coordinated
 Maximum v/c Ratio: 0.82
 Intersection Signal Delay: 19.5
 Intersection LOS: B
 Intersection Capacity Utilization 75.9%
 ICU Level of Service D
 Analysis Period (min) 15
 # 95th percentile volume exceeds capacity, queue may be longer.

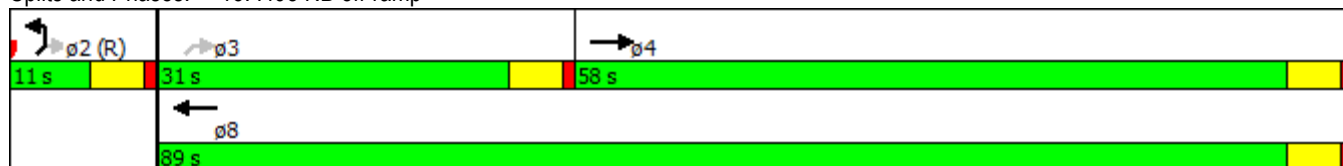
Timings

13: I495 NB off-ramp

3/6/2017

Queue shown is maximum after two cycles.

Splits and Phases: 13: I495 NB off-ramp



Queues
13: I495 NB off-ramp

3/6/2017



Lane Group	EBT	WBT	NEL	NER
Lane Group Flow (vph)	688	947	101	588
v/c Ratio	0.82	0.61	0.37	0.65
Control Delay	32.4	6.6	47.5	19.2
Queue Delay	0.0	0.7	0.0	0.2
Total Delay	32.4	7.3	47.5	19.4
Queue Length 50th (ft)	363	167	60	191
Queue Length 95th (ft)	444	170	#163	363
Internal Link Dist (ft)	12	1	594	
Turn Bay Length (ft)				100
Base Capacity (vph)	996	1737	276	898
Starvation Cap Reductn	0	440	0	0
Spillback Cap Reductn	0	0	0	31
Storage Cap Reductn	0	0	0	0
Reduced v/c Ratio	0.69	0.73	0.37	0.68

Intersection Summary























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

River Street at Lowell Avenue

HCM 2010 Signalized Intersection Summary

2: Walgreens drive/Lowell Avenue & River Street

10/5/2016

												
Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (veh/h)	299	888	12	1	534	111	7	4	9	140	7	515
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1827	1900	1900	1827	1863	1900	1900	1900	1900	1797	1827
Adj Flow Rate, veh/h	302	897	12	1	539	0	7	4	9	141	7	520
Adj No. of Lanes	1	1	1	1	1	1	1	1	0	0	1	1
Peak Hour Factor	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Percent Heavy Veh, %	2	4	0	0	4	2	0	0	0	0	0	4
Cap, veh/h	463	1116	987	227	803	696	211	127	287	388	17	560
Arrive On Green	0.12	0.61	0.61	0.44	0.44	0.00	0.24	0.24	0.24	0.24	0.24	0.24
Sat Flow, veh/h	1774	1827	1615	623	1827	1583	890	521	1172	1267	71	1553
Grp Volume(v), veh/h	302	897	12	1	539	0	7	0	13	148	0	520
Grp Sat Flow(s),veh/h/ln	1774	1827	1615	623	1827	1583	890	0	1693	1338	0	1553
Q Serve(g_s), s	7.8	33.8	0.3	0.1	21.1	0.0	0.6	0.0	0.5	8.2	0.0	22.0
Cycle Q Clear(g_c), s	7.8	33.8	0.3	18.4	21.1	0.0	9.3	0.0	0.5	8.7	0.0	22.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		0.69	0.95		1.00
Lane Grp Cap(c), veh/h	463	1116	987	227	803	696	211	0	414	405	0	560
V/C Ratio(X)	0.65	0.80	0.01	0.00	0.67	0.00	0.03	0.00	0.03	0.37	0.00	0.93
Avail Cap(c_a), veh/h	651	1116	987	227	803	696	211	0	414	405	0	560
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	14.2	13.4	6.9	26.3	20.1	0.0	33.0	0.0	25.9	29.2	0.0	27.7
Incr Delay (d2), s/veh	1.6	6.2	0.0	0.0	4.4	0.0	0.1	0.0	0.0	0.6	0.0	22.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	4.0	18.6	0.1	0.0	11.6	0.0	0.2	0.0	0.2	3.2	0.0	15.8
LnGrp Delay(d),s/veh	15.8	19.5	6.9	26.3	24.5	0.0	33.0	0.0	25.9	29.7	0.0	49.7
LnGrp LOS	B	B	A	C	C		C		C	C		D
Approach Vol, veh/h		1211			540			20			668	
Approach Delay, s/veh		18.5			24.5			28.4			45.3	
Approach LOS		B			C			C			D	
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2		4		6		8				
Phs Duration (G+Y+Rc), s	15.5	46.5		28.0		62.0		28.0				
Change Period (Y+Rc), s	5.0	7.0		6.0		7.0		6.0				
Max Green Setting (Gmax), s	20.0	30.0		22.0		55.0		22.0				
Max Q Clear Time (g_c+I1), s	9.8	23.1		11.3		35.8		24.0				
Green Ext Time (p_c), s	0.7	4.9		2.3		10.6		0.0				
Intersection Summary												
HCM 2010 Ctrl Delay			27.2									
HCM 2010 LOS			C									

Timings

2: Walgreens drive/Lowell Avenue & River Street

10/5/2016



Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	SWL	SWT	SWR
Lane Configurations											
Volume (vph)	299	888	12	1	534	111	7	4	140	7	515
Turn Type	pm+pt	NA	Perm	Perm	NA	Perm	Perm	NA	Perm	NA	pm+ov
Protected Phases	1	6			2			4		8	1
Permitted Phases	6		6	2		2	4		8		8
Detector Phase	1	6	6	2	2	2	4	4	8	8	1
Switch Phase											
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	9.0	23.0	23.0	23.0	23.0	23.0	22.0	22.0	22.0	22.0	9.0
Total Split (s)	25.0	62.0	62.0	37.0	37.0	37.0	28.0	28.0	28.0	28.0	25.0
Total Split (%)	27.8%	68.9%	68.9%	41.1%	41.1%	41.1%	31.1%	31.1%	31.1%	31.1%	27.8%
Yellow Time (s)	3.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	3.0	3.0	3.0
All-Red Time (s)	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	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
Total Lost Time (s)	5.0	7.0	7.0	7.0	7.0	7.0	6.0	6.0		6.0	5.0
Lead/Lag	Lead			Lag	Lag	Lag					Lead
Lead-Lag Optimize?	Yes			Yes	Yes	Yes					Yes
Recall Mode	None	Max	Max	Max	Max	Max	None	None	None	None	None
Act Effect Green (s)	57.2	55.1	55.1	37.3	37.3	37.3	14.5	14.5		14.5	33.4
Actuated g/C Ratio	0.69	0.67	0.67	0.45	0.45	0.45	0.18	0.18		0.18	0.40
v/c Ratio	0.55	0.74	0.01	0.00	0.65	0.15	0.03	0.04		0.65	0.74
Control Delay	9.6	15.0	0.3	18.0	25.7	6.1	27.1	17.9		44.9	21.3
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
Total Delay	9.6	15.0	0.3	18.0	25.7	6.1	27.1	17.9		44.9	21.3
LOS	A	B	A	B	C	A	C	B		D	C
Approach Delay		13.5			22.3			21.1		26.5	
Approach LOS		B			C			C		C	

Intersection Summary

Cycle Length: 90	
Actuated Cycle Length: 82.7	
Natural Cycle: 60	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.74	
Intersection Signal Delay: 19.2	Intersection LOS: B
Intersection Capacity Utilization 81.5%	ICU Level of Service D
Analysis Period (min) 15	

Splits and Phases: 2: Walgreens drive/Lowell Avenue & River Street



Queues

2: Walgreens drive/Lowell Avenue & River Street

10/5/2016


























Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	SWT	SWR
Lane Group Flow (vph)	302	897	12	1	539	112	7	13	148	520
v/c Ratio	0.55	0.74	0.01	0.00	0.65	0.15	0.03	0.04	0.65	0.74
Control Delay	9.6	15.0	0.3	18.0	25.7	6.1	27.1	17.9	44.9	21.3
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	9.6	15.0	0.3	18.0	25.7	6.1	27.1	17.9	44.9	21.3
Queue Length 50th (ft)	49	264	0	0	206	4	3	2	72	170
Queue Length 95th (ft)	108	540	1	4	#475	41	14	16	132	236
Internal Link Dist (ft)		245			91			109	41	
Turn Bay Length (ft)			125			110	50			
Base Capacity (vph)	658	1218	1089	264	823	767	333	460	348	827
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.46	0.74	0.01	0.00	0.65	0.15	0.02	0.03	0.43	0.63

Intersection Summary

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

HCM 2010 Signalized Intersection Summary
 2: Walgreens drive/Lowell Avenue & River Street

10/5/2016

												
Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (veh/h)	446	709	30	6	616	145	23	11	19	128	9	517
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1881	1863	1900	1900	1863	1881	1900	1900	1900	1900	1865	1881
Adj Flow Rate, veh/h	460	731	31	6	635	0	24	11	20	132	9	533
Adj No. of Lanes	1	1	1	1	1	1	1	1	0	0	1	1
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Percent Heavy Veh, %	1	2	0	0	2	1	0	0	0	0	0	1
Cap, veh/h	495	1229	1066	387	825	708	166	127	231	325	20	603
Arrive On Green	0.17	0.66	0.66	0.44	0.44	0.00	0.21	0.21	0.21	0.21	0.21	0.21
Sat Flow, veh/h	1792	1863	1615	715	1863	1599	878	605	1101	1218	95	1599
Grp Volume(v), veh/h	460	731	31	6	635	0	24	0	31	141	0	533
Grp Sat Flow(s),veh/h/ln	1792	1863	1615	715	1863	1599	878	0	1706	1313	0	1599
Q Serve(g_s), s	14.1	22.0	0.7	0.5	28.8	0.0	2.5	0.0	1.5	8.8	0.0	21.0
Cycle Q Clear(g_c), s	14.1	22.0	0.7	0.7	28.8	0.0	12.8	0.0	1.5	10.3	0.0	21.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		0.65	0.94		1.00
Lane Grp Cap(c), veh/h	495	1229	1066	387	825	708	166	0	358	345	0	603
V/C Ratio(X)	0.93	0.59	0.03	0.02	0.77	0.00	0.14	0.00	0.09	0.41	0.00	0.88
Avail Cap(c_a), veh/h	554	1229	1066	387	825	708	166	0	358	345	0	603
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	19.8	9.5	5.9	15.8	23.6	0.0	41.0	0.0	31.8	35.8	0.0	29.1
Incr Delay (d2), s/veh	21.2	2.1	0.1	0.1	6.9	0.0	0.4	0.0	0.1	0.8	0.0	14.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	15.3	11.9	0.3	0.1	16.4	0.0	0.6	0.0	0.7	3.6	0.0	16.1
LnGrp Delay(d),s/veh	40.9	11.6	5.9	15.9	30.4	0.0	41.4	0.0	31.9	36.6	0.0	43.6
LnGrp LOS	D	B	A	B	C		D		C	D		D
Approach Vol, veh/h		1222			641			55				674
Approach Delay, s/veh		22.5			30.3			36.0				42.1
Approach LOS		C			C			D				D
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2		4		6		8				
Phs Duration (G+Y+Rc), s	21.7	51.3		27.0		73.0		27.0				
Change Period (Y+Rc), s	5.0	7.0		6.0		7.0		6.0				
Max Green Setting (Gmax), s	20.0	41.0		21.0		66.0		21.0				
Max Q Clear Time (g_c+I1), s	16.1	30.8		14.8		24.0		23.0				
Green Ext Time (p_c), s	0.6	6.4		1.8		13.6		0.0				
Intersection Summary												
HCM 2010 Ctrl Delay			29.8									
HCM 2010 LOS			C									

Timings

2: Walgreens drive/Lowell Avenue & River Street

10/5/2016



Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	SWL	SWT	SWR
Lane Configurations											
Volume (vph)	446	709	30	6	616	145	23	11	128	9	517
Lane Group Flow (vph)	460	731	31	6	635	149	24	31	0	141	533
Turn Type	pm+pt	NA	Perm	Perm	NA	Perm	Perm	NA	Perm	NA	pm+ov
Protected Phases	1	6			2			4		8	1
Permitted Phases	6		6	2		2	4		8		8
Detector Phase	1	6	6	2	2	2	4	4	8	8	1
Switch Phase											
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	9.0	23.0	23.0	23.0	23.0	23.0	22.0	22.0	22.0	22.0	9.0
Total Split (s)	25.0	73.0	73.0	48.0	48.0	48.0	27.0	27.0	27.0	27.0	25.0
Total Split (%)	25.0%	73.0%	73.0%	48.0%	48.0%	48.0%	27.0%	27.0%	27.0%	27.0%	25.0%
Yellow Time (s)	3.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	3.0	3.0	3.0
All-Red Time (s)	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	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
Total Lost Time (s)	5.0	7.0	7.0	7.0	7.0	7.0	6.0	6.0		6.0	5.0
Lead/Lag	Lead			Lag	Lag	Lag					Lead
Lead-Lag Optimize?	Yes			Yes	Yes	Yes					Yes
Recall Mode	None	Max	Max	Max	Max	Max	None	None	None	None	None
Act Effect Green (s)	68.1	66.1	66.1	42.2	42.2	42.2	14.8	14.8		14.8	39.8
Actuated g/C Ratio	0.72	0.70	0.70	0.45	0.45	0.45	0.16	0.16		0.16	0.42
v/c Ratio	0.84	0.56	0.03	0.02	0.76	0.19	0.13	0.11		0.67	0.70
Control Delay	29.2	9.5	2.0	17.2	30.5	8.8	34.6	19.0		52.9	21.1
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
Total Delay	29.2	9.5	2.0	17.2	30.5	8.8	34.6	19.0		52.9	21.1
LOS	C	A	A	B	C	A	C	B		D	C
Approach Delay		16.8			26.3			25.8		27.8	
Approach LOS		B			C			C		C	
Queue Length 50th (ft)	133	185	0	2	315	21	12	6		80	183
Queue Length 95th (ft)	#338	338	9	10	#552	63	35	30		142	300
Internal Link Dist (ft)		245			91			109		41	
Turn Bay Length (ft)			125			110	50				
Base Capacity (vph)	563	1310	1146	330	835	765	269	399		299	775
Starvation Cap Reductn	0	0	0	0	0	0	0	0		0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0		0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0		0	0
Reduced v/c Ratio	0.82	0.56	0.03	0.02	0.76	0.19	0.09	0.08		0.47	0.69

Intersection Summary

Cycle Length: 100

Actuated Cycle Length: 94

Natural Cycle: 90

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.84

Intersection Signal Delay: 22.4

Intersection LOS: C

Intersection Capacity Utilization 86.4%

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.

Timings

2: Walgreens drive/Lowell Avenue & River Street

10/5/2016

Splits and Phases: 2: Walgreens drive/Lowell Avenue & River Street



Queues

2: Walgreens drive/Lowell Avenue & River Street

10/5/2016

























Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	SWT	SWR
Lane Group Flow (vph)	460	731	31	6	635	149	24	31	141	533
v/c Ratio	0.84	0.56	0.03	0.02	0.76	0.19	0.13	0.11	0.67	0.70
Control Delay	29.2	9.5	2.0	17.2	30.5	8.8	34.6	19.0	52.9	21.1
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	29.2	9.5	2.0	17.2	30.5	8.8	34.6	19.0	52.9	21.1
Queue Length 50th (ft)	133	185	0	2	315	21	12	6	80	183
Queue Length 95th (ft)	#338	338	9	10	#552	63	35	30	142	300
Internal Link Dist (ft)		245			91			109	41	
Turn Bay Length (ft)			125			110	50			
Base Capacity (vph)	563	1310	1146	330	835	765	269	399	299	775
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.82	0.56	0.03	0.02	0.76	0.19	0.09	0.08	0.47	0.69

Intersection Summary

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

HCM 2010 Signalized Intersection Summary
 2: Walgreens drive/Lowell Avenue & River Street

3/6/2017

												
Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (veh/h)	299	888	12	1	534	111	7	4	9	140	7	515
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1827	1900	1900	1827	1863	1900	1900	1900	1900	1797	1827
Adj Flow Rate, veh/h	302	897	12	1	539	0	7	4	9	141	7	520
Adj No. of Lanes	1	1	1	1	1	1	1	1	0	0	1	1
Peak Hour Factor	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Percent Heavy Veh, %	2	4	0	0	4	2	0	0	0	0	0	4
Cap, veh/h	347	1198	1059	282	739	640	166	104	234	330	13	614
Arrive On Green	0.20	0.66	0.66	0.40	0.40	0.00	0.20	0.20	0.20	0.20	0.20	0.20
Sat Flow, veh/h	1774	1827	1615	623	1827	1583	890	521	1172	1258	67	1553
Grp Volume(v), veh/h	302	897	12	1	539	0	7	0	13	148	0	520
Grp Sat Flow(s),veh/h/ln	1774	1827	1615	623	1827	1583	890	0	1693	1324	0	1553
Q Serve(g_s), s	14.9	29.9	0.2	0.1	22.4	0.0	0.6	0.0	0.6	8.8	0.0	18.0
Cycle Q Clear(g_c), s	14.9	29.9	0.2	7.4	22.4	0.0	10.0	0.0	0.6	9.3	0.0	18.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		0.69	0.95		1.00
Lane Grp Cap(c), veh/h	347	1198	1059	282	739	640	166	0	339	343	0	614
V/C Ratio(X)	0.87	0.75	0.01	0.00	0.73	0.00	0.04	0.00	0.04	0.43	0.00	0.85
Avail Cap(c_a), veh/h	611	1198	1059	282	739	640	166	0	339	343	0	614
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	35.1	10.5	5.4	20.6	22.6	0.0	37.0	0.0	29.0	32.8	0.0	24.7
Incr Delay (d2), s/veh	6.7	4.3	0.0	0.0	6.3	0.0	0.1	0.0	0.0	0.9	0.0	10.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	7.9	16.1	0.1	0.0	12.5	0.0	0.2	0.0	0.3	3.4	0.0	13.4
LnGrp Delay(d),s/veh	41.8	14.8	5.4	20.7	28.9	0.0	37.1	0.0	29.1	33.6	0.0	35.3
LnGrp LOS	D	B	A	C	C		D		C	C		D
Approach Vol, veh/h		1211			540			20			668	
Approach Delay, s/veh		21.4			28.9			31.9			34.9	
Approach LOS		C			C			C			C	
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2		4		6		8				
Phs Duration (G+Y+Rc), s	22.6	43.4		24.0		66.0		24.0				
Change Period (Y+Rc), s	5.0	7.0		6.0		7.0		6.0				
Max Green Setting (Gmax), s	31.0	23.0		18.0		59.0		18.0				
Max Q Clear Time (g_c+I1), s	16.9	24.4		12.0		31.9		20.0				
Green Ext Time (p_c), s	0.8	0.0		1.7		12.8		0.0				
Intersection Summary												
HCM 2010 Ctrl Delay			26.9									
HCM 2010 LOS			C									

Timings

2: Walgreens drive/Lowell Avenue & River Street

3/6/2017



Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	SWL	SWT	SWR
Lane Configurations											
Volume (vph)	299	888	12	1	534	111	7	4	140	7	515
Turn Type	Prot	NA	Perm	Perm	NA	Perm	Perm	NA	Perm	NA	pm+ov
Protected Phases	1	6			2			4		8	1
Permitted Phases			6	2		2	4		8		8
Detector Phase	1	6	6	2	2	2	4	4	8	8	1
Switch Phase											
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	9.0	23.0	23.0	23.0	23.0	23.0	22.0	22.0	22.0	22.0	9.0
Total Split (s)	36.0	66.0	66.0	30.0	30.0	30.0	24.0	24.0	24.0	24.0	36.0
Total Split (%)	40.0%	73.3%	73.3%	33.3%	33.3%	33.3%	26.7%	26.7%	26.7%	26.7%	40.0%
Yellow Time (s)	3.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	3.0	3.0	3.0
All-Red Time (s)	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	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
Total Lost Time (s)	5.0	7.0	7.0	7.0	7.0	7.0	6.0	6.0		6.0	5.0
Lead/Lag	Lead			Lag	Lag	Lag					Lead
Lead-Lag Optimize?	Yes			Yes	Yes	Yes					Yes
Recall Mode	None	Max	Max	Max	Max	Max	None	None	None	None	None
Act Effct Green (s)	20.6	59.1	59.1	33.5	33.5	33.5	14.2	14.2		14.2	40.8
Actuated g/C Ratio	0.24	0.68	0.68	0.39	0.39	0.39	0.16	0.16		0.16	0.47
v/c Ratio	0.72	0.72	0.01	0.00	0.76	0.17	0.04	0.05		0.69	0.68
Control Delay	39.7	13.4	0.3	22.0	34.9	7.5	29.7	19.5		50.9	19.0
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
Total Delay	39.7	13.4	0.3	22.0	34.9	7.5	29.7	19.5		50.9	19.0
LOS	D	B	A	C	C	A	C	B		D	B
Approach Delay		19.8			30.2			23.1		26.1	
Approach LOS		B			C			C		C	

Intersection Summary

Cycle Length: 90

Actuated Cycle Length: 86.3

Natural Cycle: 70

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.76

Intersection Signal Delay: 24.1

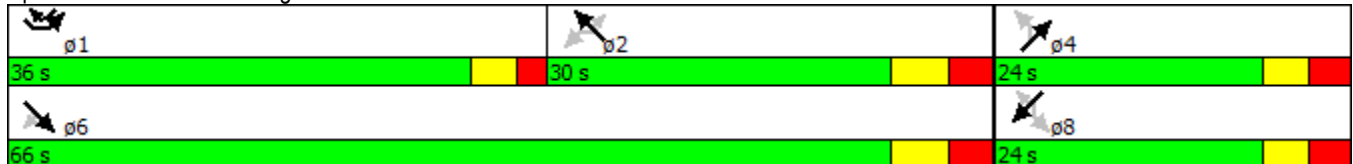
Intersection LOS: C

Intersection Capacity Utilization 81.5%

ICU Level of Service D

Analysis Period (min) 15

Splits and Phases: 2: Walgreens drive/Lowell Avenue & River Street



Queues

2: Walgreens drive/Lowell Avenue & River Street

3/6/2017


























Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	SWT	SWR
Lane Group Flow (vph)	302	897	12	1	539	112	7	13	148	520
v/c Ratio	0.72	0.72	0.01	0.00	0.76	0.17	0.04	0.05	0.69	0.68
Control Delay	39.7	13.4	0.3	22.0	34.9	7.5	29.7	19.5	50.9	19.0
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	39.7	13.4	0.3	22.0	34.9	7.5	29.7	19.5	50.9	19.0
Queue Length 50th (ft)	152	270	0	0	254	5	3	2	76	182
Queue Length 95th (ft)	220	467	1	4	#537	45	15	17	140	232
Internal Link Dist (ft)		245			91			109	41	
Turn Bay Length (ft)			125			110	50			
Base Capacity (vph)	636	1251	1117	245	709	674	254	362	273	948
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.47	0.72	0.01	0.00	0.76	0.17	0.03	0.04	0.54	0.55

Intersection Summary

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

HCM 2010 Signalized Intersection Summary
 2: Walgreens drive/Lowell Avenue & River Street

3/2/2017

												
Movement	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Volume (veh/h)	446	709	30	6	616	145	23	11	19	128	9	517
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1881	1863	1900	1900	1863	1881	1900	1900	1900	1900	1865	1881
Adj Flow Rate, veh/h	460	731	31	6	635	0	24	11	20	132	9	533
Adj No. of Lanes	1	1	1	1	1	1	1	1	0	0	1	1
Peak Hour Factor	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Percent Heavy Veh, %	1	2	0	0	2	1	0	0	0	0	0	1
Cap, veh/h	502	1323	1147	344	708	608	115	97	176	259	13	704
Arrive On Green	0.28	0.71	0.71	0.38	0.38	0.00	0.16	0.16	0.16	0.16	0.16	0.16
Sat Flow, veh/h	1792	1863	1615	715	1863	1599	878	605	1101	1182	81	1599
Grp Volume(v), veh/h	460	731	31	6	635	0	24	0	31	141	0	533
Grp Sat Flow(s),veh/h/ln	1792	1863	1615	715	1863	1599	878	0	1706	1262	0	1599
Q Serve(g_s), s	24.9	18.7	0.6	0.5	32.1	0.0	2.7	0.0	1.6	9.6	0.0	16.0
Cycle Q Clear(g_c), s	24.9	18.7	0.6	0.5	32.1	0.0	13.8	0.0	1.6	11.2	0.0	16.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		0.65	0.94		1.00
Lane Grp Cap(c), veh/h	502	1323	1147	344	708	608	115	0	273	272	0	704
V/C Ratio(X)	0.92	0.55	0.03	0.02	0.90	0.00	0.21	0.00	0.11	0.52	0.00	0.76
Avail Cap(c_a), veh/h	663	1323	1147	344	708	608	115	0	273	272	0	704
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	34.9	6.9	4.3	19.4	29.2	0.0	46.5	0.0	35.9	40.7	0.0	23.5
Incr Delay (d2), s/veh	14.8	1.7	0.0	0.1	16.4	0.0	0.9	0.0	0.2	1.7	0.0	4.7
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	14.3	10.2	0.3	0.1	19.6	0.0	0.7	0.0	0.7	3.9	0.0	13.2
LnGrp Delay(d),s/veh	49.6	8.6	4.3	19.5	45.6	0.0	47.4	0.0	36.1	42.4	0.0	28.3
LnGrp LOS	D	A	A	B	D		D		D	D		C
Approach Vol, veh/h		1222			641			55				674
Approach Delay, s/veh		23.9			45.3			41.1				31.2
Approach LOS		C			D			D				C
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2		4		6		8				
Phs Duration (G+Y+Rc), s	33.0	45.0		22.0		78.0		22.0				
Change Period (Y+Rc), s	5.0	7.0		6.0		7.0		6.0				
Max Green Setting (Gmax), s	37.0	29.0		16.0		71.0		16.0				
Max Q Clear Time (g_c+I1), s	26.9	34.1		15.8		20.7		18.0				
Green Ext Time (p_c), s	1.1	0.0		0.1		14.2		0.0				
Intersection Summary												
HCM 2010 Ctrl Delay			31.5									
HCM 2010 LOS			C									

Timings

2: Walgreens drive/Lowell Avenue & River Street

3/2/2017



Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	SWL	SWT	SWR
Lane Configurations											
Volume (vph)	446	709	30	6	616	145	23	11	128	9	517
Lane Group Flow (vph)	460	731	31	6	635	149	24	31	0	141	533
Turn Type	Prot	NA	Perm	Perm	NA	Perm	Perm	NA	Perm	NA	pm+ov
Protected Phases	1	6			2			4		8	1
Permitted Phases			6	2		2	4		8		8
Detector Phase	1	6	6	2	2	2	4	4	8	8	1
Switch Phase											
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Minimum Split (s)	9.0	23.0	23.0	23.0	23.0	23.0	22.0	22.0	22.0	22.0	9.0
Total Split (s)	42.0	78.0	78.0	36.0	36.0	36.0	22.0	22.0	22.0	22.0	42.0
Total Split (%)	42.0%	78.0%	78.0%	36.0%	36.0%	36.0%	22.0%	22.0%	22.0%	22.0%	42.0%
Yellow Time (s)	3.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	3.0	3.0	3.0
All-Red Time (s)	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	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
Total Lost Time (s)	5.0	7.0	7.0	7.0	7.0	7.0	6.0	6.0		6.0	5.0
Lead/Lag	Lead			Lag	Lag	Lag					Lead
Lead-Lag Optimize?	Yes			Yes	Yes	Yes					Yes
Recall Mode	None	Max	Max	Max	Max	Max	None	None	None	None	None
Act Effct Green (s)	30.6	71.1	71.1	35.5	35.5	35.5	14.0	14.0		14.0	50.6
Actuated g/C Ratio	0.31	0.72	0.72	0.36	0.36	0.36	0.14	0.14		0.14	0.52
v/c Ratio	0.83	0.54	0.03	0.02	0.94	0.24	0.14	0.12		0.74	0.63
Control Delay	44.1	8.3	1.5	25.3	56.9	12.8	38.6	21.3		63.8	17.6
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
Total Delay	44.1	8.3	1.5	25.3	56.9	12.8	38.6	21.3		63.8	17.6
LOS	D	A	A	C	E	B	D	C		E	B
Approach Delay		21.6			48.4			28.8		27.3	
Approach LOS		C			D			C		C	
Queue Length 50th (ft)	264	192	0	3	~416	27	13	6		85	192
Queue Length 95th (ft)	362	277	7	13	#702	78	37	32		#167	263
Internal Link Dist (ft)		245			91			109		41	
Turn Bay Length (ft)			125			110	50				
Base Capacity (vph)	674	1349	1179	266	674	634	190	297		218	954
Starvation Cap Reductn	0	0	0	0	0	0	0	0		0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0		0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0		0	0
Reduced v/c Ratio	0.68	0.54	0.03	0.02	0.94	0.24	0.13	0.10		0.65	0.56

Intersection Summary

Cycle Length: 100

Actuated Cycle Length: 98.1

Natural Cycle: 90

Control Type: Actuated-Uncoordinated

Maximum v/c Ratio: 0.94

Intersection Signal Delay: 30.9

Intersection LOS: C

Intersection Capacity Utilization 86.4%

ICU Level of Service E

Analysis Period (min) 15

~ Volume exceeds capacity, queue is theoretically infinite.

Queue shown is maximum after two cycles.

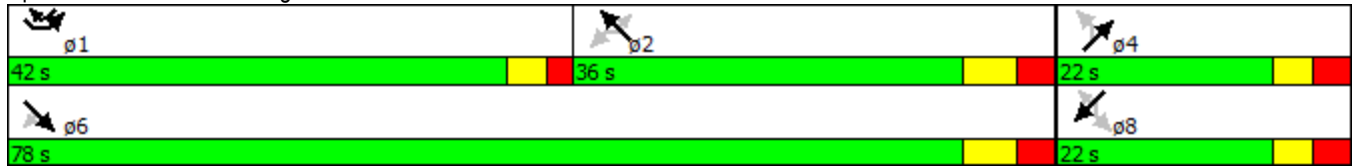
Timings

2: Walgreens drive/Lowell Avenue & River Street

3/2/2017

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

Splits and Phases: 2: Walgreens drive/Lowell Avenue & River Street



Queues

2: Walgreens drive/Lowell Avenue & River Street

3/2/2017



Lane Group	SEL	SET	SER	NWL	NWT	NWR	NEL	NET	SWT	SWR
Lane Group Flow (vph)	460	731	31	6	635	149	24	31	141	533
v/c Ratio	0.83	0.54	0.03	0.02	0.94	0.24	0.14	0.12	0.74	0.63
Control Delay	44.1	8.3	1.5	25.3	56.9	12.8	38.6	21.3	63.8	17.6
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	44.1	8.3	1.5	25.3	56.9	12.8	38.6	21.3	63.8	17.6
Queue Length 50th (ft)	264	192	0	3	~416	27	13	6	85	192
Queue Length 95th (ft)	362	277	7	13	#702	78	37	32	#167	263
Internal Link Dist (ft)		245			91			109	41	
Turn Bay Length (ft)			125			110	50			
Base Capacity (vph)	674	1349	1179	266	674	634	190	297	218	954
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.68	0.54	0.03	0.02	0.94	0.24	0.13	0.10	0.65	0.56

Intersection Summary

~ 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.