APPENDIX A

Participants of Study Advisory Meetings
April 13 October 21, 201

Participants of Study Advisory Meetings

Route 20 East Corridor in Marlborough

April 13, 2016

October 21, 2016

Name	Affiliation	Email
Dave Doucette	City Councilor, Marlborough	DPDOUCETTE@ME.COM
Meredith Harris	Executive Director, Marlborough Economic Development Corporation	MHarris@marlboroughedc.com
Tim Cummings	Former Executive Director, Marlborough Economic Development Corporation (attended April meeting)	
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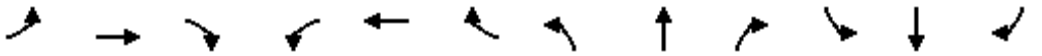
APPENDIX B

Intersection Capacity Analyses
Weekday AM Peak Hour
2016 Existing Conditions

Intersection Capacity Analysis
Route 20 at Route 85, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	43	318	231	210	246	5	180	333	97	19	439	22
Future Volume (vph)	43	318	231	210	246	5	180	333	97	19	439	22
Satd. Flow (prot)	1646	1733	1473	1678	1761	0	1631	1717	1459	0	3355	0
Flt Permitted	0.590			0.281			0.244				0.929	
Satd. Flow (perm)	1022	1733	1473	496	1761	0	419	1717	1459	0	3123	0
Satd. Flow (RTOR)			254		1				107		4	
Confl. Peds. (#/hr)							1					1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.93	0.93	0.93
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	6%	6%	6%	4%	4%	4%	7%	7%	7%	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)	47	349	254	231	275	0	198	366	107	0	516	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA	Perm	Perm	NA	
Protected Phases	5	2		1	6		3	8			4	
Permitted Phases	2		2	6			8		8	4		
Total Split (s)	15.0	31.0	31.0	15.0	31.0		15.0	44.0	44.0	29.0	29.0	
Total Lost Time (s)	3.0	5.0	5.0	3.0	5.0		3.0	5.0	5.0		5.0	
Act Effct Green (s)	32.9	23.6	23.6	40.8	33.0		36.0	33.9	33.9		19.5	
Actuated g/C Ratio	0.38	0.27	0.27	0.47	0.38		0.41	0.39	0.39		0.22	
v/c Ratio	0.11	0.74	0.43	0.58	0.41		0.60	0.55	0.17		0.73	
Control Delay	17.5	42.3	6.9	24.9	27.4		28.7	26.4	5.5		39.8	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	
Total Delay	17.5	42.3	6.9	24.9	27.4		28.7	26.4	5.5		39.8	
LOS	B	D	A	C	C		C	C	A		D	
Approach Delay		26.7			26.3			23.8			39.8	
Approach LOS		C			C			C			D	
Queue Length 50th (ft)	13	165	0	69	111		67	146	0		134	
Queue Length 95th (ft)	49	#426	68	#222	279		#191	335	39		#258	
Internal Link Dist (ft)		424			226			511			208	
Turn Bay Length (ft)	350						220					
Base Capacity (vph)	536	534	630	400	666		345	794	732		892	
Starvation Cap Reductn	0	0	0	0	0		0	0	0		0	
Spillback Cap Reductn	0	0	0	0	0		0	0	0		0	
Storage Cap Reductn	0	0	0	0	0		0	0	0		0	
Reduced v/c Ratio	0.09	0.65	0.40	0.58	0.41		0.57	0.46	0.15		0.58	

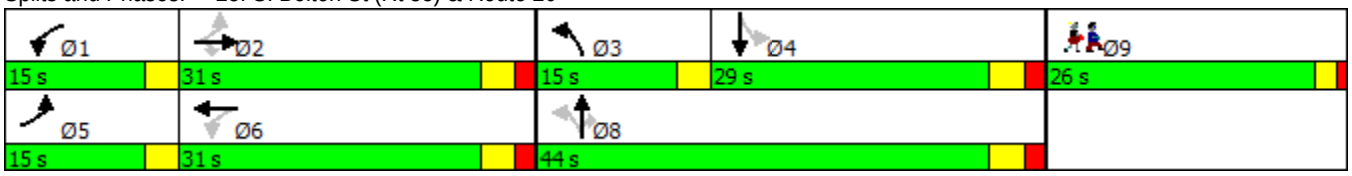
Intersection Summary			
Cycle Length: 116			
Actuated Cycle Length: 87.1			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.74			
Intersection Signal Delay: 28.6		Intersection LOS: C	
Intersection Capacity Utilization 75.1%		ICU Level of Service D	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	26.0
Total Lost Time (s)	
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

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

Splits and Phases: 25: S. Bolton St (Rt 85) & Route 20



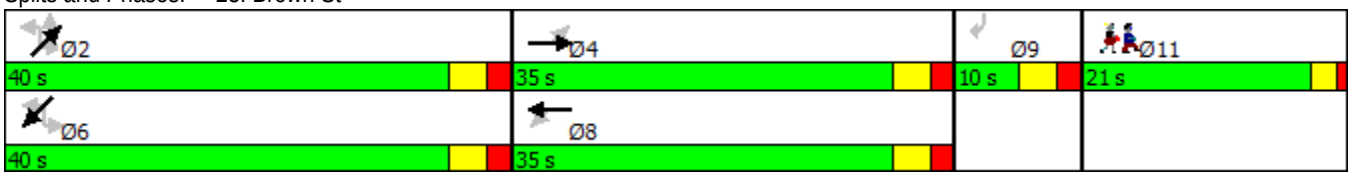
Intersection Capacity Analysis
Route 20 at Main Street, Marlborough

11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR2	SBR2	NEL2	NET	NER	SWL	SWT
Lane Configurations												
Traffic Volume (vph)	78	67	10	56	174	19	2	8	376	47	7	372
Future Volume (vph)	78	67	10	56	174	19	2	8	376	47	7	372
Satd. Flow (prot)	1678	1724	0	1711	1768	0	1589	0	1699	1446	0	1747
Flt Permitted	0.599			0.694					0.989			0.990
Satd. Flow (perm)	1050	1724	0	1242	1768	0	1589	0	1682	1406	0	1732
Satd. Flow (RTOR)		7			103		683			103		
Confl. Peds. (#/hr)	6		4	4		6				5	5	
Confl. Bikes (#/hr)												
Peak Hour Factor	0.80	0.80	0.80	0.92	0.92	0.92	0.92	0.80	0.80	0.80	0.88	0.88
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	2%	2%	2%	0%	8%	8%	8%	5%	5%
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	97	0	61	210	0	2	0	480	59	0	431
Turn Type	Perm	NA		Perm	NA		Perm	Perm	NA	Perm	Perm	NA
Protected Phases		4			8				2			6
Permitted Phases	4	4		8	8		9	2		2	6	
Total Split (s)	35.0	35.0		35.0	35.0		10.0	40.0	40.0	40.0	40.0	40.0
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0		5.0	5.0		5.0
Act Effct Green (s)	12.7	12.7		12.7	12.7		6.0		22.0	22.0		22.0
Actuated g/C Ratio	0.26	0.26		0.26	0.26		0.12		0.44	0.44		0.44
v/c Ratio	0.37	0.22		0.19	0.40		0.00		0.64	0.09		0.56
Control Delay	24.3	19.3		21.1	13.5		0.0		19.0	1.3		16.8
Queue Delay	0.0	0.0		0.0	0.0		0.0		0.0	0.0		0.0
Total Delay	24.3	19.3		21.1	13.5		0.0		19.0	1.3		16.8
LOS	C	B		C	B		A		B	A		B
Approach Delay		21.8			15.2				17.1			16.0
Approach LOS		C			B				B			B
Queue Length 50th (ft)	18	16		11	19		0		71	0		61
Queue Length 95th (ft)	88	78		66	120		0		327	2		325
Internal Link Dist (ft)		297			75				453			794
Turn Bay Length (ft)	150											
Base Capacity (vph)	745	1226		882	1285		791		1333	1136		1373
Starvation Cap Reductn	0	0		0	0		0		0	0		0
Spillback Cap Reductn	0	0		0	0		0		0	0		0
Storage Cap Reductn	0	0		0	0		0		0	0		0
Reduced v/c Ratio	0.13	0.08		0.07	0.16		0.00		0.36	0.05		0.31

Intersection Summary			
Cycle Length: 106			
Actuated Cycle Length: 49.6			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.64			
Intersection Signal Delay: 16.9		Intersection LOS: B	
Intersection Capacity Utilization 58.6%		ICU Level of Service B	
Analysis Period (min) 15			

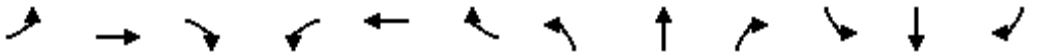
Splits and Phases: 23: Brown St



Lane Group	SWR	Ø11
Lane Configurations		
Traffic Volume (vph)	105	
Future Volume (vph)	105	
Satd. Flow (prot)	1487	
Flt Permitted		
Satd. Flow (perm)	1444	
Satd. Flow (RTOR)		
Confl. Peds. (#/hr)	6	
Confl. Bikes (#/hr)		
Peak Hour Factor	0.88	
Growth Factor	100%	
Heavy Vehicles (%)	5%	
Bus Blockages (#/hr)	0	
Parking (#/hr)		
Mid-Block Traffic (%)		
Shared Lane Traffic (%)		
Lane Group Flow (vph)	119	
Turn Type	Perm	
Protected Phases		11
Permitted Phases	6	
Total Split (s)	40.0	21.0
Total Lost Time (s)	5.0	
Act Effct Green (s)	22.0	
Actuated g/C Ratio	0.44	
v/c Ratio	0.19	
Control Delay	13.0	
Queue Delay	0.0	
Total Delay	13.0	
LOS	B	
Approach Delay		
Approach LOS		
Queue Length 50th (ft)	14	
Queue Length 95th (ft)	91	
Internal Link Dist (ft)		
Turn Bay Length (ft)	100	
Base Capacity (vph)	1145	
Starvation Cap Reductn	0	
Spillback Cap Reductn	0	
Storage Cap Reductn	0	
Reduced v/c Ratio	0.10	

Intersection Capacity Analysis
Route 20 at Lincoln Street, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	4	403	8	396	353	251	10	71	437	266	99	8
Future Volume (vph)	4	403	8	396	353	251	10	71	437	266	99	8
Satd. Flow (prot)	0	3445	0	1711	1689	0	0	1790	1531	0	1751	0
Flt Permitted		0.948		0.950				0.938			0.721	
Satd. Flow (perm)	0	3266	0	1711	1689	0	0	1689	1531	0	1307	0
Satd. Flow (RTOR)		2			64				68		1	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.93	0.93	0.93	0.75	0.75	0.75	0.84	0.84	0.84
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	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	451	0	426	650	0	0	108	583	0	445	0
Turn Type	Perm	NA		Prot	NA		Perm	NA	pm+ov	Perm	NA	
Protected Phases		2		1	6			4	1		8	
Permitted Phases	2						4		4	8		
Total Split (s)	25.0	25.0		35.0	60.0		35.0	35.0	35.0	35.0	35.0	
Total Lost Time (s)		5.0		5.0	5.0			5.0	5.0		5.0	
Act Effct Green (s)		15.8		24.8	45.7			30.3	60.2		30.3	
Actuated g/C Ratio		0.18		0.29	0.53			0.35	0.70		0.35	
v/c Ratio		0.75		0.87	0.70			0.18	0.53		0.97	
Control Delay		42.2		48.3	17.8			23.0	7.9		66.0	
Queue Delay		0.0		0.0	0.0			0.0	0.0		0.0	
Total Delay		42.2		48.3	17.8			23.0	7.9		66.0	
LOS		D		D	B			C	A		E	
Approach Delay		42.2			29.9			10.3			66.0	
Approach LOS		D			C			B			E	
Queue Length 50th (ft)		126		219	221			43	115		~254	
Queue Length 95th (ft)		184		#382	339			73	151		#443	
Internal Link Dist (ft)		289			228			617			398	
Turn Bay Length (ft)									150			
Base Capacity (vph)		768		602	1113			595	1184		461	
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		0.59		0.71	0.58			0.18	0.49		0.97	

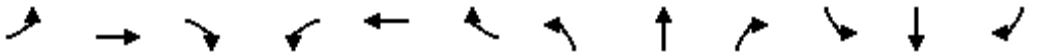
Intersection Summary	
Cycle Length: 95	
Actuated Cycle Length: 86.1	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.97	
Intersection Signal Delay: 32.9	Intersection LOS: C
Intersection Capacity Utilization 85.0%	ICU Level of Service E
Analysis Period (min) 15	

~ 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: 21:

Intersection Capacity Analysis
Route 20 at Curtis Avenue, Marlborough

11/7/2016

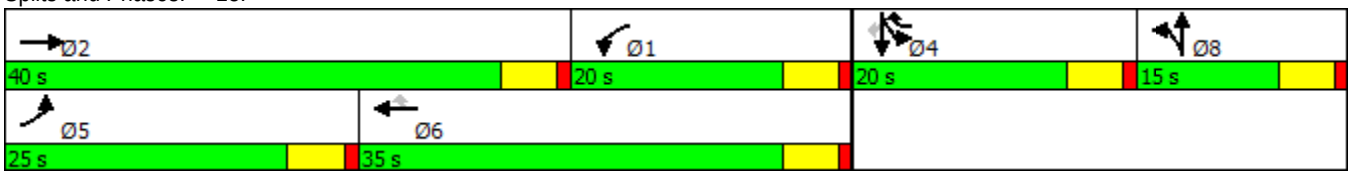


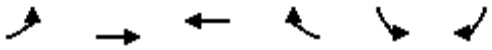
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	78	973	43	29	920	19	42	19	54	27	6	52
Future Volume (vph)	78	973	43	29	920	19	42	19	54	27	6	52
Satd. Flow (prot)	1662	3304	0	1678	3355	1501	0	1639	0	1535	1564	1446
Flt Permitted	0.950			0.950				0.982		0.950	0.968	
Satd. Flow (perm)	1662	3304	0	1678	3355	1501	0	1639	0	1535	1564	1446
Satd. Flow (RTOR)		5				80		38				195
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.82	0.82	0.82	0.71	0.71	0.71
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	5%	5%	5%	4%	4%	4%	3%	3%	3%	8%	8%	8%
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 (%)										40%		
Lane Group Flow (vph)	88	1141	0	30	939	19	0	140	0	23	23	73
Turn Type	Prot	NA		Prot	NA	pm+ov	Split	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4	8	8		4	4	
Permitted Phases						6						4
Total Split (s)	25.0	40.0		20.0	35.0	20.0	15.0	15.0		20.0	20.0	20.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	9.4	37.2		7.2	30.3	43.1		9.0		7.6	7.6	7.6
Actuated g/C Ratio	0.13	0.53		0.10	0.43	0.61		0.13		0.11	0.11	0.11
v/c Ratio	0.40	0.66		0.18	0.65	0.02		0.58		0.14	0.14	0.22
Control Delay	36.9	18.0		36.3	22.4	0.1		35.9		34.3	34.2	1.6
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	36.9	18.0		36.3	22.4	0.1		35.9		34.3	34.2	1.6
LOS	D	B		D	C	A		D		C	C	A
Approach Delay		19.3			22.4			35.9			14.2	
Approach LOS		B			C			D			B	
Queue Length 50th (ft)	37	158		13	187	0		42		10	10	0
Queue Length 95th (ft)	88	#392		42	325	0		101		27	27	0
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	488	1765		369	1538	1084		273		338	344	470
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.18	0.65		0.08	0.61	0.02		0.51		0.07	0.07	0.16

Intersection Summary			
Cycle Length: 95			
Actuated Cycle Length: 70.8			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.66			
Intersection Signal Delay: 21.2		Intersection LOS: C	
Intersection Capacity Utilization 59.1%		ICU Level of Service B	
Analysis Period (min) 15			

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

Splits and Phases: 18:





Lane Group	EBL	EBT	WBT	WBR	SBL	SBR	Ø9
Lane Configurations							
Traffic Volume (vph)	156	883	681	110	300	265	
Future Volume (vph)	156	883	681	110	300	265	
Satd. Flow (prot)	1662	3323	3355	1501	1694	1516	
Flt Permitted	0.950				0.950		
Satd. Flow (perm)	1662	3323	3355	1501	1694	1516	
Satd. Flow (RTOR)				91		177	
Confl. Peds. (#/hr)							
Confl. Bikes (#/hr)							
Peak Hour Factor	0.88	0.88	0.92	0.92	0.90	0.90	
Growth Factor	100%	100%	100%	100%	100%	100%	
Heavy Vehicles (%)	5%	5%	4%	4%	3%	3%	
Bus Blockages (#/hr)	0	0	0	0	0	0	
Parking (#/hr)							
Mid-Block Traffic (%)		0%	0%		0%		
Shared Lane Traffic (%)							
Lane Group Flow (vph)	177	1003	740	120	333	294	
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov	
Protected Phases	5	2	6		7	5	9
Permitted Phases				6		7	
Total Split (s)	25.0	75.0	50.0	50.0	25.0	25.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	
Act Effct Green (s)	14.5	46.2	26.4	26.4	21.4	40.7	
Actuated g/C Ratio	0.18	0.56	0.32	0.32	0.26	0.50	
v/c Ratio	0.60	0.54	0.69	0.22	0.76	0.35	
Control Delay	44.7	13.2	28.9	9.4	44.5	6.7	
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	
Total Delay	44.7	13.2	28.9	9.4	44.5	6.7	
LOS	D	B	C	A	D	A	
Approach Delay		17.9	26.2		26.8		
Approach LOS		B	C		C		
Queue Length 50th (ft)	74	126	149	9	137	25	
Queue Length 95th (ft)	#220	335	343	61	#544	92	
Internal Link Dist (ft)		235	318		492		
Turn Bay Length (ft)	300			150		100	
Base Capacity (vph)	433	2903	1969	918	441	952	
Starvation Cap Reductn	0	149	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	0.41	0.36	0.38	0.13	0.76	0.31	

Intersection Summary			
Cycle Length: 130			
Actuated Cycle Length: 82.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.76			
Intersection Signal Delay: 22.7		Intersection LOS: C	
Intersection Capacity Utilization 56.6%		ICU Level of Service B	
Analysis Period (min) 15			

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

Splits and Phases: 14:

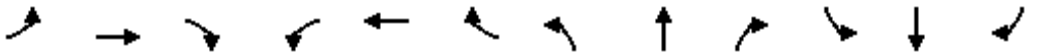
Movement	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (veh/h)	97	1050	621	19	40	191
Future Volume (Veh/h)	97	1050	621	19	40	191
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	105	1141	675	21	43	208
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						2
Median type		None	None			
Median storage veh)						
Upstream signal (ft)		773				
pX, platoon unblocked					0.66	
vC, conflicting volume	696				2026	675
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	696				2291	675
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	88				0	54
cM capacity (veh/h)	891				25	452

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	SW 1
Volume Total	105	1141	675	21	251
Volume Left	105	0	0	0	43
Volume Right	0	0	0	21	208
cSH	891	1700	1700	1700	122
Volume to Capacity	0.12	0.67	0.40	0.01	2.05
Queue Length 95th (ft)	10	0	0	0	516
Control Delay (s)	9.6	0.0	0.0	0.0	559.7
Lane LOS	A				F
Approach Delay (s)	0.8		0.0		559.7
Approach LOS					F

Intersection Summary			
Average Delay	64.5		
Intersection Capacity Utilization	65.3%	ICU Level of Service	C
Analysis Period (min)	15		

Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	37	859	82	198	400	15	91	44	444	62	82	58
Future Volume (vph)	37	859	82	198	400	15	91	44	444	62	82	58
Satd. Flow (prot)	1736	3471	1553	1703	3389	0	1752	1845	1568	0	1824	1583
Flt Permitted	0.950			0.950			0.950				0.979	
Satd. Flow (perm)	1736	3471	1553	1703	3389	0	1752	1845	1568	0	1824	1583
Satd. Flow (RTOR)			102		2							102
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.94	0.94	0.94	0.91	0.91	0.91	0.78	0.78	0.78
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	6%	6%	6%	3%	3%	3%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	39	895	85	211	442	0	100	48	488	0	184	74
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	30.0	45.0	45.0	30.0	45.0		30.0	30.0	30.0	30.0	30.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	8.4	40.8	40.8	25.5	63.0		12.4	12.4	42.2		17.1	17.1
Actuated g/C Ratio	0.07	0.34	0.34	0.21	0.52		0.10	0.10	0.35		0.14	0.14
v/c Ratio	0.32	0.76	0.14	0.58	0.25		0.55	0.25	0.89		0.71	0.24
Control Delay	64.9	42.1	5.4	53.1	20.8		65.5	56.0	54.5		66.3	5.6
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	64.9	42.1	5.4	53.1	20.8		65.5	56.0	54.5		66.3	5.6
LOS	E	D	A	D	C		E	E	D		E	A
Approach Delay		39.9			31.2			56.3			48.9	
Approach LOS		D			C			E			D	
Queue Length 50th (ft)	28	298	0	139	94		71	33	324		129	0
Queue Length 95th (ft)	79	#627	31	#324	227		159	88	#730		223	8
Internal Link Dist (ft)		394			534			205			111	
Turn Bay Length (ft)	350		50				75		150			
Base Capacity (vph)	368	1179	594	361	1780		371	391	551		387	416
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	0.11	0.76	0.14	0.58	0.25		0.27	0.12	0.89		0.48	0.18

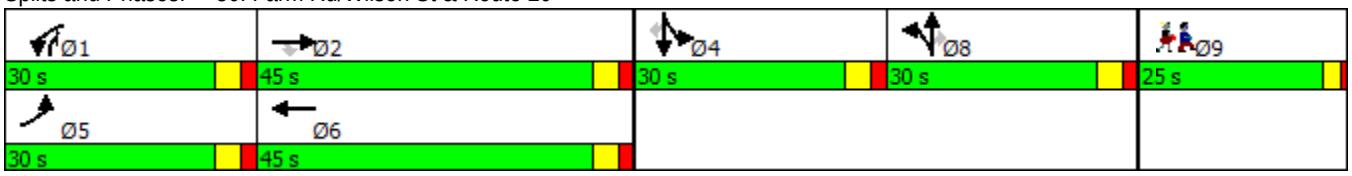
Intersection Summary		
Cycle Length: 160		
Actuated Cycle Length: 120		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.89		
Intersection Signal Delay: 42.7	Intersection LOS: D	
Intersection Capacity Utilization 71.5%	ICU Level of Service C	
Analysis Period (min) 15		

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
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

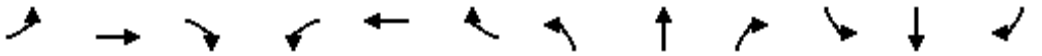
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicenzo Boulevard/Pomphrey Drive, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	24	1257	74	21	441	11	129	10	46	12	2	27
Future Volume (vph)	24	1257	74	21	441	11	129	10	46	12	2	27
Satd. Flow (prot)	1694	3361	0	1662	3310	0	3113	1479	0	1574	1425	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1694	3361	0	1662	3310	0	3113	1479	0	1574	1425	0
Satd. Flow (RTOR)		4			2			57			40	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.83	0.83	0.83	0.81	0.81	0.81	0.68	0.68	0.68
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	3%	3%	3%	5%	5%	5%	5%	5%	5%	7%	7%	7%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	25	1372	0	25	544	0	159	69	0	18	43	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	30.0	45.0		30.0	45.0		30.0	30.0		17.0	17.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	7.3	44.8		7.3	44.8		10.0	10.0		7.1	7.1	
Actuated g/C Ratio	0.09	0.56		0.09	0.56		0.12	0.12		0.09	0.09	
v/c Ratio	0.16	0.73		0.17	0.29		0.41	0.29		0.13	0.27	
Control Delay	44.5	22.1		44.6	15.4		39.4	18.6		45.2	20.9	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	44.5	22.1		44.6	15.4		39.4	18.6		45.2	20.9	
LOS	D	C		D	B		D	B		D	C	
Approach Delay		22.5			16.7			33.1			28.0	
Approach LOS		C			B			C			C	
Queue Length 50th (ft)	10	211		10	58		33	5		7	1	
Queue Length 95th (ft)	48	#832		44	208		85	43		28	22	
Internal Link Dist (ft)		536			775			209			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	563	1881		552	1852		1034	529		251	261	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.04	0.73		0.05	0.29		0.15	0.13		0.07	0.16	

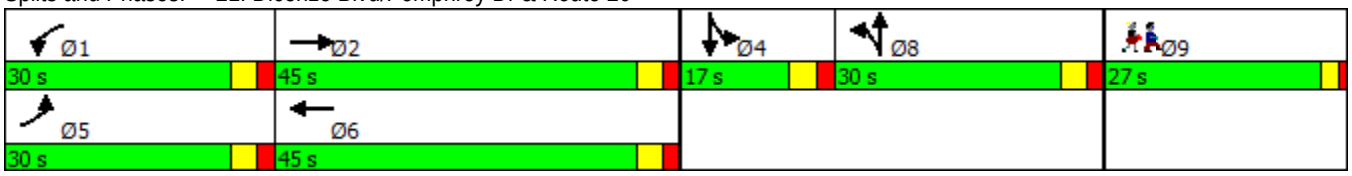
Intersection Summary			
Cycle Length: 149			
Actuated Cycle Length: 80.1			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.73			
Intersection Signal Delay: 22.2		Intersection LOS: C	
Intersection Capacity Utilization 55.8%		ICU Level of Service B	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
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

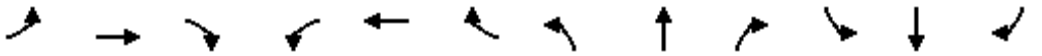
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



Intersection Capacity Analysis
Route 20 at Raytheon Driveway, Marlborough

11/7/2016

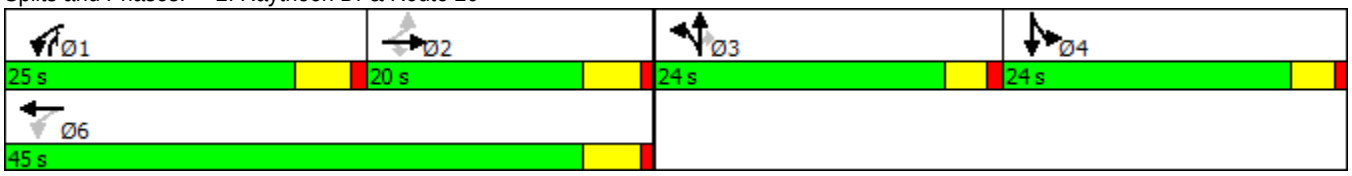


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	8	1085	247	159	459	5	3	2	5	3	0	3
Future Volume (vph)	8	1085	247	159	459	5	3	2	5	3	0	3
Satd. Flow (prot)	0	3355	1553	1662	1806	0	0	1537	1346	0	1152	0
Flt Permitted		0.951		0.155				0.971			0.976	
Satd. Flow (perm)	0	3191	1553	271	1806	0	0	1537	1346	0	1152	0
Satd. Flow (RTOR)			255		1				70		129	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.83	0.83	0.83	0.50	0.50	0.50	0.50	0.50	0.50
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	5%	5%	5%	20%	20%	20%	50%	50%	50%
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	1127	255	192	559	0	0	10	10	0	12	0
Turn Type	Perm	NA	Perm	pm+pt	NA		Split	NA	pm+ov	Split	NA	
Protected Phases		2		1	6		3	3	1	4	4	
Permitted Phases	2		2	6					3			
Total Split (s)	20.0	20.0	20.0	25.0	45.0		24.0	24.0	25.0	24.0	24.0	
Total Lost Time (s)		5.0	5.0	5.0	5.0			4.0	5.0		4.0	
Act Effct Green (s)		28.9	28.9	41.0	45.3			6.3	7.8		6.1	
Actuated g/C Ratio		0.59	0.59	0.83	0.92			0.13	0.16		0.12	
v/c Ratio		0.60	0.25	0.46	0.34			0.05	0.04		0.05	
Control Delay		12.2	2.6	7.1	3.1			23.0	0.2		0.3	
Queue Delay		0.0	0.0	0.0	0.0			0.0	0.0		0.0	
Total Delay		12.2	2.6	7.1	3.1			23.0	0.2		0.3	
LOS		B	A	A	A			C	A		A	
Approach Delay		10.4			4.1			11.6			0.3	
Approach LOS		B			A			B			A	
Queue Length 50th (ft)		63	0	0	0			2	0		0	
Queue Length 95th (ft)		#365	41	57	159			9	0		0	
Internal Link Dist (ft)		655			163			102			237	
Turn Bay Length (ft)			300									
Base Capacity (vph)		1874	1017	804	1664			640	624		554	
Starvation Cap Reductn		0	0	0	0			0	0		0	
Spillback Cap Reductn		0	0	0	0			0	0		0	
Storage Cap Reductn		0	0	0	0			0	0		0	
Reduced v/c Ratio		0.60	0.25	0.24	0.34			0.02	0.02		0.02	

Intersection Summary			
Cycle Length: 93			
Actuated Cycle Length: 49.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.60			
Intersection Signal Delay: 8.2		Intersection LOS: A	
Intersection Capacity Utilization 71.4%		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: 2: Raytheon Dr & Route 20



Intersection Capacity Analysis
Route 20 at Wayside Inn Road/Hager Street, Marlborough

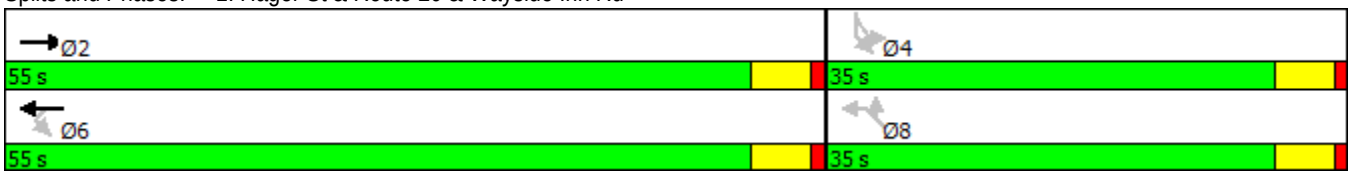
11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SBL2	SBL	SBR	NWL	NWR	NWR2
Lane Configurations												
Traffic Volume (vph)	0	879	0	7	401	1	34	55	120	107	75	2
Future Volume (vph)	0	879	0	7	401	1	34	55	120	107	75	2
Satd. Flow (prot)	0	1827	0	0	1791	0	0	1665	0	1736	1553	0
Flt Permitted					0.986			0.932		0.456		
Satd. Flow (perm)	0	1827	0	0	1767	0	0	1585	0	833	1553	0
Satd. Flow (RTOR)								81			24	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.91	0.91	0.91	0.84	0.84	0.84	0.83	0.83	0.83	0.88	0.88	0.88
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	4%	4%	4%	6%	6%	6%	3%	3%	3%	4%	4%	4%
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	966	0	0	486	0	0	252	0	122	87	0
Turn Type		NA		Perm	NA		Perm	Perm		Perm	Perm	
Protected Phases		2			6							
Permitted Phases				6			4	4		8	8	
Total Split (s)		55.0		55.0	55.0		35.0	35.0		35.0	35.0	
Total Lost Time (s)		5.0			5.0			5.0		5.0	5.0	
Act Effct Green (s)		42.2			42.2			13.3		13.3	13.3	
Actuated g/C Ratio		0.64			0.64			0.20		0.20	0.20	
v/c Ratio		0.83			0.43			0.66		0.73	0.26	
Control Delay		18.2			8.0			26.0		51.4	20.3	
Queue Delay		0.0			0.0			0.0		0.0	0.0	
Total Delay		18.2			8.0			26.0		51.4	20.3	
LOS		B			A			C		D	C	
Approach Delay		18.2			8.0			26.0		38.4		
Approach LOS		B			A			C		D		
Queue Length 50th (ft)		249			82			65		48	22	
Queue Length 95th (ft)		#672			169			127		107	59	
Internal Link Dist (ft)		190			594			403		33		
Turn Bay Length (ft)												
Base Capacity (vph)		1413			1367			795		395	750	
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		0.68			0.36			0.32		0.31	0.12	

Intersection Summary			
Cycle Length: 90			
Actuated Cycle Length: 66			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.83			
Intersection Signal Delay: 18.8		Intersection LOS: B	
Intersection Capacity Utilization 77.0%		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: Hager St & Route 20 & Wayside Inn Rd

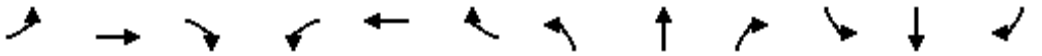


APPENDIX C

Intersection Capacity Analyses
Weekday PM Peak Hour
2016 Existing Conditions

Intersection Capacity Analysis
Route 20 @ Route 85, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	71	424	215	141	279	7	262	443	155	32	323	32
Future Volume (vph)	71	424	215	141	279	7	262	443	155	32	323	32
Satd. Flow (prot)	1728	1818	1546	1694	1776	0	1728	1818	1546	0	3359	0
Flt Permitted	0.471			0.167			0.299				0.872	
Satd. Flow (perm)	857	1818	1546	298	1776	0	544	1818	1546	0	2941	0
Satd. Flow (RTOR)			223		1				172		7	
Confl. Peds. (#/hr)							1					1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.93	0.93	0.93	0.91	0.91	0.91	0.90	0.90	0.90	0.85	0.85	0.85
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	3%	3%	3%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	76	456	231	155	315	0	291	492	172	0	456	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA	Perm	Perm	NA	
Protected Phases	5	2		1	6		3	8			4	
Permitted Phases	2		2	6			8		8	4		
Total Split (s)	15.0	31.0	31.0	15.0	31.0		15.0	44.0	44.0	29.0	29.0	
Total Lost Time (s)	3.0	5.0	5.0	3.0	5.0		3.0	5.0	5.0		5.0	
Act Effct Green (s)	36.6	26.6	26.6	40.9	30.6		37.6	35.6	35.6		20.2	
Actuated g/C Ratio	0.41	0.30	0.30	0.46	0.34		0.42	0.40	0.40		0.23	
v/c Ratio	0.18	0.84	0.38	0.53	0.52		0.74	0.68	0.24		0.68	
Control Delay	18.1	47.8	7.1	24.0	31.7		34.4	29.8	4.6		38.2	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	
Total Delay	18.1	47.8	7.1	24.0	31.7		34.4	29.8	4.6		38.2	
LOS	B	D	A	C	C		C	C	A		D	
Approach Delay		32.5			29.1			26.7			38.2	
Approach LOS		C			C			C			D	
Queue Length 50th (ft)	21	223	3	44	133		100	203	0		112	
Queue Length 95th (ft)	71	#596	70	132	#357		#335	#499	48		211	
Internal Link Dist (ft)		587			226			511			208	
Turn Bay Length (ft)	350						220					
Base Capacity (vph)	507	540	616	328	608		391	810	784		811	
Starvation Cap Reductn	0	0	0	0	0		0	0	0		0	
Spillback Cap Reductn	0	0	0	0	0		0	0	0		0	
Storage Cap Reductn	0	0	0	0	0		0	0	0		0	
Reduced v/c Ratio	0.15	0.84	0.38	0.47	0.52		0.74	0.61	0.22		0.56	

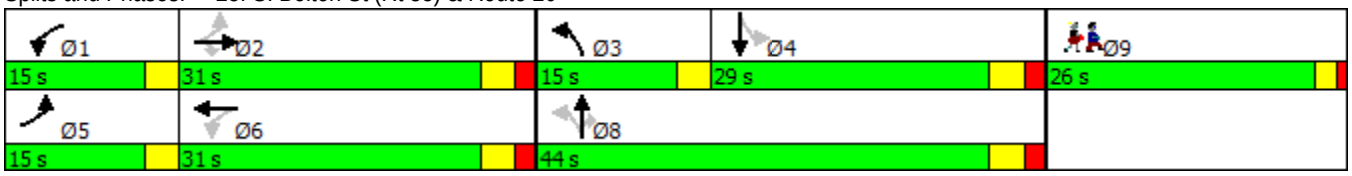
Intersection Summary	
Cycle Length: 116	
Actuated Cycle Length: 89.4	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.84	
Intersection Signal Delay: 30.8	Intersection LOS: C
Intersection Capacity Utilization 80.2%	ICU Level of Service D
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	26.0
Total Lost Time (s)	
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

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

Splits and Phases: 25: S. Bolton St (Rt 85) & Route 20



Intersection Capacity Analysis
Route 20 @ Main Street, Marlborough

11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR2	SBR2	NEL2	NET	NER	SWL	SWT
Lane Configurations												
Traffic Volume (vph)	111	98	9	79	178	36	2	8	460	92	6	312
Future Volume (vph)	111	98	9	79	178	36	2	8	460	92	6	312
Satd. Flow (prot)	1728	1791	0	1728	1764	0	1589	0	1817	1546	0	1799
Flt Permitted	0.556			0.682					0.992			0.990
Satd. Flow (perm)	1004	1791	0	1233	1764	0	1589	0	1804	1503	0	1783
Satd. Flow (RTOR)		4			103		655			103		
Confl. Peds. (#/hr)	6		4	4		6				5	5	
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.94	0.94	0.94	0.92	0.91	0.91	0.91	0.85	0.85
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	0%	1%	1%	1%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%				0%			0%
Shared Lane Traffic (%)												
Lane Group Flow (vph)	121	117	0	84	227	0	2	0	514	101	0	374
Turn Type	Perm	NA		Perm	NA		Perm	Perm	NA	Perm	Perm	NA
Protected Phases		4			8				2			6
Permitted Phases	4			8			9	2		2	6	
Total Split (s)	35.0	35.0		35.0	35.0		10.0	40.0	40.0	40.0	40.0	40.0
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0		5.0	5.0		5.0
Act Effct Green (s)	15.6	15.6		15.6	15.6		6.1		24.9	24.9		24.9
Actuated g/C Ratio	0.28	0.28		0.28	0.28		0.11		0.44	0.44		0.44
v/c Ratio	0.43	0.23		0.24	0.40		0.00		0.64	0.14		0.47
Control Delay	27.0	20.7		22.6	14.3		0.0		20.6	4.8		17.1
Queue Delay	0.0	0.0		0.0	0.0		0.0		0.0	0.0		0.0
Total Delay	27.0	20.7		22.6	14.3		0.0		20.6	4.8		17.1
LOS	C	C		C	B		A		C	A		B
Approach Delay		23.9			16.5				18.0			16.5
Approach LOS		C			B				B			B
Queue Length 50th (ft)	24	21		15	23		0		84	0		55
Queue Length 95th (ft)	125	107		86	134		0		#501	35		288
Internal Link Dist (ft)		301			90				453			794
Turn Bay Length (ft)	150											
Base Capacity (vph)	650	1162		799	1179		756		1304	1115		1288
Starvation Cap Reductn	0	0		0	0		0		0	0		0
Spillback Cap Reductn	0	0		0	0		0		0	0		0
Storage Cap Reductn	0	0		0	0		0		0	0		0
Reduced v/c Ratio	0.19	0.10		0.11	0.19		0.00		0.39	0.09		0.29

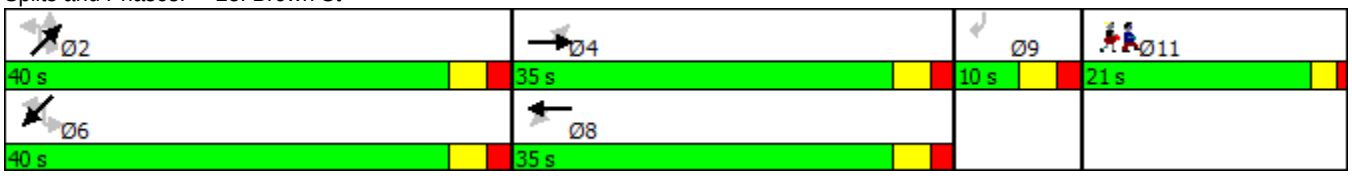
Intersection Summary			
Cycle Length: 106			
Actuated Cycle Length: 56			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.64			
Intersection Signal Delay: 18.1		Intersection LOS: B	
Intersection Capacity Utilization 65.5%		ICU Level of Service C	
Analysis Period (min) 15			

Lane Group	SWR	Ø11
Lane Configurations		
Traffic Volume (vph)	125	
Future Volume (vph)	125	
Satd. Flow (prot)	1531	
Flt Permitted		
Satd. Flow (perm)	1486	
Satd. Flow (RTOR)		
Confl. Peds. (#/hr)	6	
Confl. Bikes (#/hr)		
Peak Hour Factor	0.85	
Growth Factor	100%	
Heavy Vehicles (%)	2%	
Bus Blockages (#/hr)	0	
Parking (#/hr)		
Mid-Block Traffic (%)		
Shared Lane Traffic (%)		
Lane Group Flow (vph)	147	
Turn Type	Perm	
Protected Phases		11
Permitted Phases	6	
Total Split (s)	40.0	21.0
Total Lost Time (s)	5.0	
Act Effct Green (s)	24.9	
Actuated g/C Ratio	0.44	
v/c Ratio	0.22	
Control Delay	15.2	
Queue Delay	0.0	
Total Delay	15.2	
LOS	B	
Approach Delay		
Approach LOS		
Queue Length 50th (ft)	19	
Queue Length 95th (ft)	117	
Internal Link Dist (ft)		
Turn Bay Length (ft)	100	
Base Capacity (vph)	1074	
Starvation Cap Reductn	0	
Spillback Cap Reductn	0	
Storage Cap Reductn	0	
Reduced v/c Ratio	0.14	

Intersection Summary

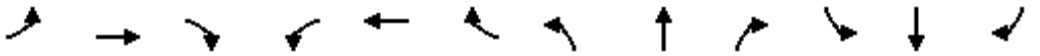
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 23: Brown St



Intersection Capacity Analysis
Route 20 @ Lincoln Street, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	10	359	14	408	330	322	15	77	475	211	51	5
Future Volume (vph)	10	359	14	408	330	322	15	77	475	211	51	5
Satd. Flow (prot)	0	3431	0	1711	1667	0	0	1786	1531	0	1746	0
Flt Permitted		0.926		0.950				0.924			0.702	
Satd. Flow (perm)	0	3180	0	1711	1667	0	0	1664	1531	0	1274	0
Satd. Flow (RTOR)		4			88				101		1	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.95	0.95	0.95	0.91	0.91	0.91	0.88	0.88	0.88	0.82	0.82	0.82
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	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	404	0	448	717	0	0	105	540	0	325	0
Turn Type	Perm	NA		Prot	NA		Perm	NA	pm+ov	Perm	NA	
Protected Phases		2		1	6			4	1		8	
Permitted Phases	2						4		4	8		
Total Split (s)	25.0	25.0		35.0	60.0		35.0	35.0	35.0	35.0	35.0	
Total Lost Time (s)		5.0		5.0	5.0			5.0	5.0		5.0	
Act Effct Green (s)		15.0		24.5	44.8			24.0	53.8		24.0	
Actuated g/C Ratio		0.19		0.31	0.56			0.30	0.68		0.30	
v/c Ratio		0.67		0.85	0.73			0.21	0.50		0.84	
Control Delay		37.4		43.5	17.0			23.6	6.8		47.9	
Queue Delay		0.0		0.0	0.0			0.0	0.0		0.0	
Total Delay		37.4		43.5	17.0			23.6	6.8		47.9	
LOS		D		D	B			C	A		D	
Approach Delay		37.4			27.2			9.5			47.9	
Approach LOS		D			C			A			D	
Queue Length 50th (ft)		107		219	235			41	85		158	
Queue Length 95th (ft)		165		#412	398			85	167		#272	
Internal Link Dist (ft)		289			228			617			398	
Turn Bay Length (ft)									150			
Base Capacity (vph)		843		678	1226			659	1196		505	
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		0.48		0.66	0.58			0.16	0.45		0.64	

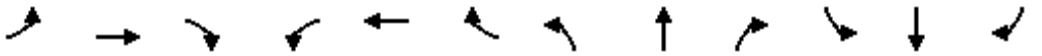
Intersection Summary	
Cycle Length: 95	
Actuated Cycle Length: 79.3	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.85	
Intersection Signal Delay: 27.0	Intersection LOS: C
Intersection Capacity Utilization 81.6%	ICU Level of Service D
Analysis Period (min) 15	

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

Splits and Phases: 21:

Intersection Capacity Analysis
Route 20 @ Curtis Avenue, Marlborough

11/7/2016

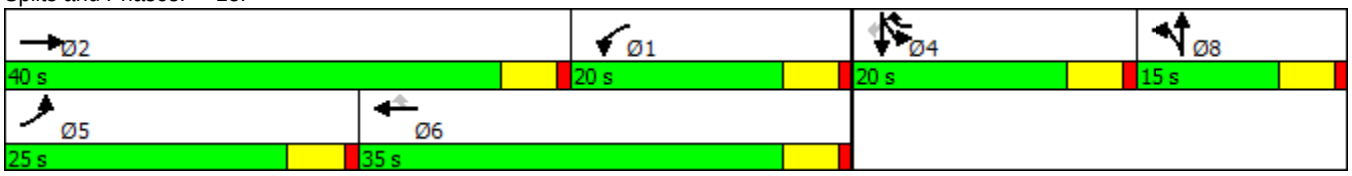


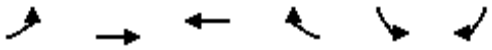
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	198	858	57	46	890	74	53	63	80	92	35	192
Future Volume (vph)	198	858	57	46	890	74	53	63	80	92	35	192
Satd. Flow (prot)	1728	3424	0	1728	3455	1546	0	1696	0	1625	1673	1546
Flt Permitted	0.950			0.950				0.987		0.950	0.978	
Satd. Flow (perm)	1728	3424	0	1728	3455	1546	0	1696	0	1625	1673	1546
Satd. Flow (RTOR)		8				82		29				204
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.90	0.90	0.90	0.85	0.85	0.85	0.94	0.94	0.94
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	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 (%)										32%		
Lane Group Flow (vph)	204	944	0	51	989	82	0	230	0	67	68	204
Turn Type	Prot	NA		Prot	NA	pm+ov	Split	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4	8	8		4	4	
Permitted Phases						6						4
Total Split (s)	25.0	40.0		20.0	35.0	20.0	15.0	15.0		20.0	20.0	20.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	14.5	36.1		10.9	27.3	40.7		10.2		8.4	8.4	8.4
Actuated g/C Ratio	0.18	0.45		0.14	0.34	0.50		0.13		0.10	0.10	0.10
v/c Ratio	0.66	0.61		0.22	0.85	0.10		0.97		0.40	0.39	0.59
Control Delay	42.4	21.4		34.8	33.8	3.1		85.7		43.1	42.8	13.5
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	42.4	21.4		34.8	33.8	3.1		85.7		43.1	42.8	13.5
LOS	D	C		C	C	A		F		D	D	B
Approach Delay		25.1			31.6			85.7			25.2	
Approach LOS		C			C			F			C	
Queue Length 50th (ft)	99	222		22	236	0		106		34	35	0
Queue Length 95th (ft)	179	318		60	#405	22		#262		80	81	62
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	435	1592		327	1305	946		238		307	316	457
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.47	0.59		0.16	0.76	0.09		0.97		0.22	0.22	0.45

Intersection Summary			
Cycle Length: 95			
Actuated Cycle Length: 80.6			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.97			
Intersection Signal Delay: 32.6		Intersection LOS: C	
Intersection Capacity Utilization 65.9%		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: 18:



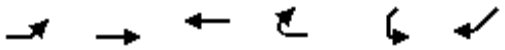


Lane Group	EBL	EBT	WBT	WBR	SBL	SBR	Ø9
Lane Configurations							
Traffic Volume (vph)	277	742	809	285	217	157	
Future Volume (vph)	277	742	809	285	217	157	
Satd. Flow (prot)	1728	3455	3455	1546	1711	1531	
Flt Permitted	0.950				0.950		
Satd. Flow (perm)	1728	3455	3455	1546	1711	1531	
Satd. Flow (RTOR)				198		145	
Confl. Peds. (#/hr)							
Confl. Bikes (#/hr)							
Peak Hour Factor	0.96	0.96	0.93	0.93	0.94	0.94	
Growth Factor	100%	100%	100%	100%	100%	100%	
Heavy Vehicles (%)	1%	1%	1%	1%	2%	2%	
Bus Blockages (#/hr)	0	0	0	0	0	0	
Parking (#/hr)							
Mid-Block Traffic (%)		0%	0%		0%		
Shared Lane Traffic (%)							
Lane Group Flow (vph)	289	773	870	306	231	167	
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov	
Protected Phases	5	2	6		7	5	9
Permitted Phases				6		7	
Total Split (s)	25.0	75.0	50.0	50.0	25.0	25.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	
Act Effct Green (s)	20.9	58.2	32.1	32.1	18.4	43.8	
Actuated g/C Ratio	0.23	0.64	0.35	0.35	0.20	0.48	
v/c Ratio	0.73	0.35	0.72	0.46	0.67	0.21	
Control Delay	48.5	9.8	30.4	11.4	47.5	4.2	
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	
Total Delay	48.5	9.8	30.4	11.4	47.5	4.2	
LOS	D	A	C	B	D	A	
Approach Delay		20.3	25.5		29.4		
Approach LOS		C	C		C		
Queue Length 50th (ft)	147	87	208	40	113	6	
Queue Length 95th (ft)	#454	245	413	148	#342	39	
Internal Link Dist (ft)		257	297		486		
Turn Bay Length (ft)	300			150		100	
Base Capacity (vph)	395	2765	1780	892	391	810	
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	0.73	0.28	0.49	0.34	0.59	0.21	

Intersection Summary	
Cycle Length: 130	
Actuated Cycle Length: 91.2	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.73	
Intersection Signal Delay: 24.0	Intersection LOS: C
Intersection Capacity Utilization 62.2%	ICU Level of Service B
Analysis Period (min) 15	

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

Splits and Phases: 14:



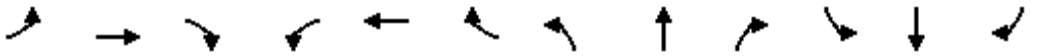
Movement	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (veh/h)	145	772	999	43	38	114
Future Volume (Veh/h)	145	772	999	43	38	114
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.98	0.98	0.95	0.95	0.81	0.81
Hourly flow rate (vph)	148	788	1052	45	47	141
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						2
Median type		None	None			
Median storage veh)						
Upstream signal (ft)		752				
pX, platoon unblocked					0.84	
vC, conflicting volume	1097				2136	1052
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	1097				2259	1052
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	77				0	49
cM capacity (veh/h)	640				29	275

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	SW 1
Volume Total	148	788	1052	45	188
Volume Left	148	0	0	0	47
Volume Right	0	0	0	45	141
cSH	640	1700	1700	1700	95
Volume to Capacity	0.23	0.46	0.62	0.03	1.99
Queue Length 95th (ft)	22	0	0	0	402
Control Delay (s)	12.3	0.0	0.0	0.0	554.0
Lane LOS	B				F
Approach Delay (s)	1.9		0.0		554.0
Approach LOS					F

Intersection Summary			
Average Delay	47.7		
Intersection Capacity Utilization	73.9%	ICU Level of Service	D
Analysis Period (min)	15		

Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	45	499	106	380	901	44	124	59	259	56	79	51
Future Volume (vph)	45	499	106	380	901	44	124	59	259	56	79	51
Satd. Flow (prot)	1770	3539	1583	1787	3549	0	1787	1881	1599	0	1844	1599
Flt Permitted	0.950			0.950			0.950				0.980	
Satd. Flow (perm)	1770	3539	1583	1787	3549	0	1787	1881	1599	0	1844	1599
Satd. Flow (RTOR)			102		3							102
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.90	0.90	0.90	0.95	0.95	0.95
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	47	520	110	396	985	0	138	66	288	0	142	54
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	30.0	45.0	45.0	30.0	45.0		30.0	30.0	30.0	30.0	30.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	8.6	23.0	23.0	26.3	43.7		13.8	13.8	44.7		13.8	13.8
Actuated g/C Ratio	0.08	0.23	0.23	0.26	0.43		0.14	0.14	0.44		0.14	0.14
v/c Ratio	0.31	0.65	0.25	0.86	0.64		0.57	0.26	0.41		0.57	0.18
Control Delay	56.1	41.4	10.8	57.3	29.5		54.3	46.7	21.1		54.1	1.3
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	56.1	41.4	10.8	57.3	29.5		54.3	46.7	21.1		54.1	1.3
LOS	E	D	B	E	C		D	D	C		D	A
Approach Delay		37.5			37.5			33.8			39.5	
Approach LOS		D			D			C			D	
Queue Length 50th (ft)	27	145	4	223	239		78	36	110		80	0
Queue Length 95th (ft)	88	308	59	#708	#601		199	106	229		203	0
Internal Link Dist (ft)		394			534			205			111	
Turn Bay Length (ft)	350		50				75		150			
Base Capacity (vph)	459	1469	717	463	1530		463	488	705		478	490
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	0.10	0.35	0.15	0.86	0.64		0.30	0.14	0.41		0.30	0.11

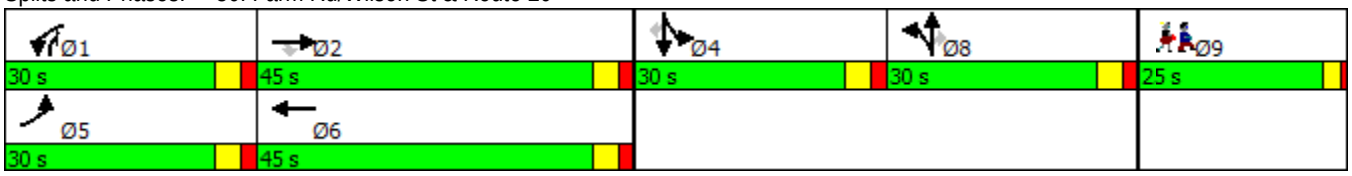
Intersection Summary	
Cycle Length: 160	
Actuated Cycle Length: 101.4	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.86	
Intersection Signal Delay: 37.0	Intersection LOS: D
Intersection Capacity Utilization 61.3%	ICU Level of Service B
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
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

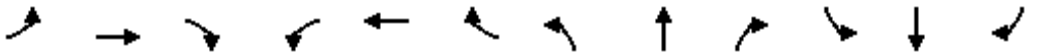
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicenzo Boulevard/Pomphrey Drive, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Future Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Satd. Flow (prot)	1728	3365	0	1711	3411	0	3173	1510	0	1636	1593	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1728	3365	0	1711	3411	0	3173	1510	0	1636	1593	0
Satd. Flow (RTOR)		16			2			27			9	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.94	0.94	0.94	0.70	0.70	0.70
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	3%	3%	3%	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)	33	807	0	63	1135	0	234	33	0	19	18	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	30.0	45.0		30.0	45.0		30.0	30.0		17.0	17.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	7.8	39.7		9.2	44.2		12.2	12.2		7.2	7.2	
Actuated g/C Ratio	0.09	0.47		0.11	0.52		0.14	0.14		0.09	0.09	
v/c Ratio	0.21	0.51		0.34	0.63		0.51	0.14		0.14	0.12	
Control Delay	47.7	22.0		47.1	22.6		41.3	20.2		48.8	36.1	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	47.7	22.0		47.1	22.6		41.3	20.2		48.8	36.1	
LOS	D	C		D	C		D	C		D	D	
Approach Delay		23.0			23.9			38.7			42.6	
Approach LOS		C			C			D			D	
Queue Length 50th (ft)	17	155		32	245		61	3		10	5	
Queue Length 95th (ft)	60	385		97	#647		137	36		32	24	
Internal Link Dist (ft)		536			775			209			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	556	1757		551	1792		1022	505		253	254	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.06	0.46		0.11	0.63		0.23	0.07		0.08	0.07	

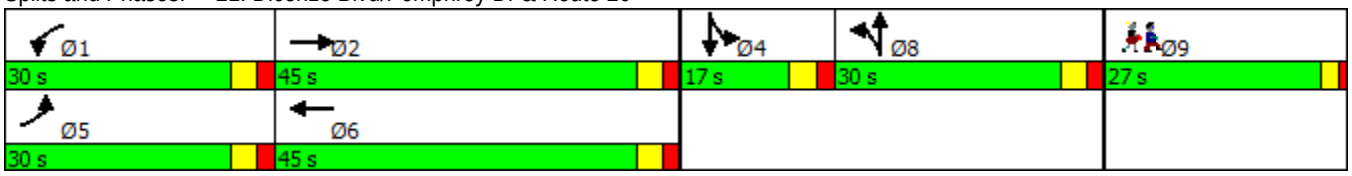
Intersection Summary	
Cycle Length: 149	
Actuated Cycle Length: 84.2	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.63	
Intersection Signal Delay: 25.5	Intersection LOS: C
Intersection Capacity Utilization 61.3%	ICU Level of Service B
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
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

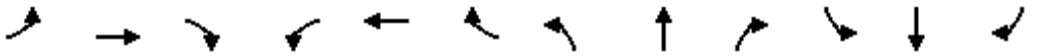
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



Intersection Capacity Analysis
Route 20 at Raytheon Driveway, Marlborough

11/7/2016

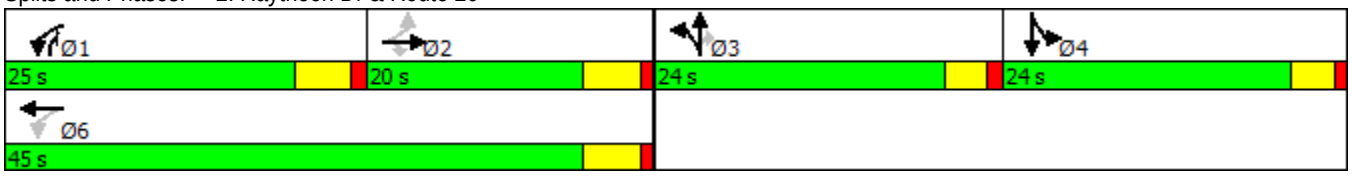


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	545	3	1	925	15	240	0	141	12	0	41
Future Volume (vph)	29	545	3	1	925	15	240	0	141	12	0	41
Satd. Flow (prot)	0	3411	1583	1728	1877	0	0	1787	1599	0	1649	0
Flt Permitted		0.719		0.299				0.950			0.989	
Satd. Flow (perm)	0	2460	1583	544	1877	0	0	1787	1599	0	1649	0
Satd. Flow (RTOR)			117		1				155		129	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.93	0.93	0.93	0.97	0.97	0.97	0.91	0.91	0.91	0.66	0.66	0.66
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	1%	1%	1%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	0	617	3	1	969	0	0	264	155	0	80	0
Turn Type	Perm	NA	Perm	pm+pt	NA		Split	NA	pm+ov	Split	NA	
Protected Phases		2		1	6		3	3	1	4	4	
Permitted Phases	2		2	6					3			
Total Split (s)	20.0	20.0	20.0	25.0	45.0		24.0	24.0	25.0	24.0	24.0	
Total Lost Time (s)		5.0	5.0	5.0	5.0			4.0	5.0		4.0	
Act Effct Green (s)		29.2	29.2	40.5	40.5			15.6	22.0		6.2	
Actuated g/C Ratio		0.40	0.40	0.56	0.56			0.21	0.30		0.09	
v/c Ratio		0.63	0.00	0.00	0.93			0.69	0.26		0.31	
Control Delay		22.6	0.0	10.0	34.7			37.2	3.4		5.5	
Queue Delay		0.0	0.0	0.0	0.0			0.0	0.0		0.0	
Total Delay		22.6	0.0	10.0	34.7			37.2	3.4		5.5	
LOS		C	A	A	C			D	A		A	
Approach Delay		22.5			34.6			24.7			5.5	
Approach LOS		C			C			C			A	
Queue Length 50th (ft)		121	0	0	408			114	0		0	
Queue Length 95th (ft)		196	0	3	#752			192	26		0	
Internal Link Dist (ft)		655			163			102			237	
Turn Bay Length (ft)			300									
Base Capacity (vph)		986	705	630	1042			495	868		551	
Starvation Cap Reductn		0	0	0	0			0	0		0	
Spillback Cap Reductn		0	0	0	0			0	0		0	
Storage Cap Reductn		0	0	0	0			0	0		0	
Reduced v/c Ratio		0.63	0.00	0.00	0.93			0.53	0.18		0.15	

Intersection Summary			
Cycle Length: 93			
Actuated Cycle Length: 72.9			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.93			
Intersection Signal Delay: 27.9		Intersection LOS: C	
Intersection Capacity Utilization 77.1%		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: 2: Raytheon Dr & Route 20



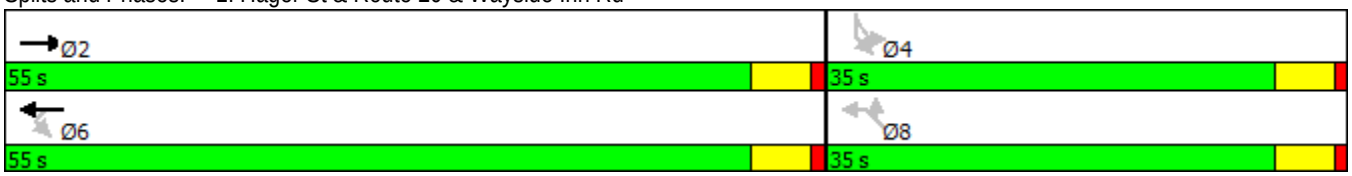
Intersection Capacity Analysis
Route 20 at Wayside Inn Road/Hager Street, Marlborough

11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SBL2	SBL	SBR	NWL	NWR	NWR2
Lane Configurations												
Traffic Volume (vph)	0	520	0	4	702	5	5	23	79	118	166	3
Future Volume (vph)	0	520	0	4	702	5	5	23	79	118	166	3
Satd. Flow (prot)	0	1881	0	0	1879	0	0	1657	0	1787	1599	0
Flt Permitted					0.998			0.980		0.841		
Satd. Flow (perm)	0	1881	0	0	1876	0	0	1645	0	1582	1599	0
Satd. Flow (RTOR)					1			92			24	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.91	0.91	0.91	0.86	0.86	0.86	0.94	0.94	0.94
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	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	536	0	0	780	0	0	125	0	126	180	0
Turn Type		NA		Perm	NA		Perm	Perm		Perm	Perm	
Protected Phases		2			6							
Permitted Phases				6			4	4		8	8	
Total Split (s)		55.0		55.0	55.0		35.0	35.0		35.0	35.0	
Total Lost Time (s)		5.0			5.0			5.0		5.0	5.0	
Act Effct Green (s)		25.6			25.6			10.4		10.4	10.4	
Actuated g/C Ratio		0.55			0.55			0.22		0.22	0.22	
v/c Ratio		0.52			0.76			0.29		0.36	0.48	
Control Delay		8.9			14.0			9.4		20.5	20.2	
Queue Delay		0.0			0.0			0.0		0.0	0.0	
Total Delay		8.9			14.0			9.4		20.5	20.2	
LOS		A			B			A		C	C	
Approach Delay		8.9			14.0			9.4		20.3		
Approach LOS		A			B			A		C		
Queue Length 50th (ft)		71			127			6		25	32	
Queue Length 95th (ft)		175			315			45		87	109	
Internal Link Dist (ft)		190			594			403		33		
Turn Bay Length (ft)												
Base Capacity (vph)		1766			1761			1159		1087	1106	
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		0.30			0.44			0.11		0.12	0.16	

Intersection Summary			
Cycle Length: 90			
Actuated Cycle Length: 46.6			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.76			
Intersection Signal Delay: 13.2		Intersection LOS: B	
Intersection Capacity Utilization 65.9%		ICU Level of Service C	
Analysis Period (min) 15			

Splits and Phases: 1: Hager St & Route 20 & Wayside Inn Rd



APPENDIX D

Preliminary Traffic Signal Warrants Analysis
Route 20 at Concord Road, Marlborough

Table D-1
Summary of Hourly Volumes and Warrant Analyses
Route 20 (East Main Street) at Concord Road, Marlborough

Hourly period starting	Route 20 (main street)		Concord Road (minor street)	Sum of main street	Maximum of minor street	Volumes above the required minimum on main/minor street		
	EB	WB	SB			Warrant 1	Warrant 2	Warrant 7
6:00	837	340	105	1177	105	√		√
7:00	986	618	225	1604	225	√	√	√
8:00	920	593	182	1513	182	√	√	√
9:00	753	558	131	1311	131	√	√	√
10:00	657	583	103	1240	103	√		√
11:00	604	681	112	1285	112	√		√
12:00	691	688	100	1379	100	√		√
13:00	663	680	107	1343	107	√		√
14:00	773	764	115	1537	115	√	√	√
15:00	746	857	130	1603	130	√	√	√
16:00	774	936	156	1710	156	√	√	√
17:00	870	951	157	1821	157	√	√	√
18:00	725	921	137	1646	137	√	√	√
19:00	625	718	85	1343	85	√		√

Warrants 1, 2, and 7 in MUTCD Chapter 4C were applied to this intersection.

Warrant 1 (8-Hour Volume) is fulfilled. It requires that the traffic conditions (observed vehicular volumes higher than the specified minimum volumes) exist for each of any 8 hours of an average day. The interruption of continuous traffic (Conditions B) was applied in this case. The volume threshold for a major street (assuming two lanes) is 900 vehicles per hour (vph) and for a minor street of one lane is 75 vph.

Warrant 2 (4-Hour Volume) is fulfilled. It requires that the traffic conditions (main street combined/minor street maximum volume falling above an applicable curve) exist for each of any 4 hours of an average day. The lower threshold volume for a minor street of one lane is 80 vph.

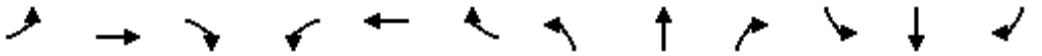
Warrant 7 (Crash Experience) is fulfilled. Traffic conditions in more than eight hours met the 80% threshold in Warrant 1. Meanwhile, there were five correctable crashes in the recent 12-month period.

APPENDIX E

Intersection Capacity Analyses
Saturday Midday Peak Hour
2016 Existing Conditions

Intersection Capacity Analysis
Route 20 at Lincoln Street, Marlborough

11/7/2016

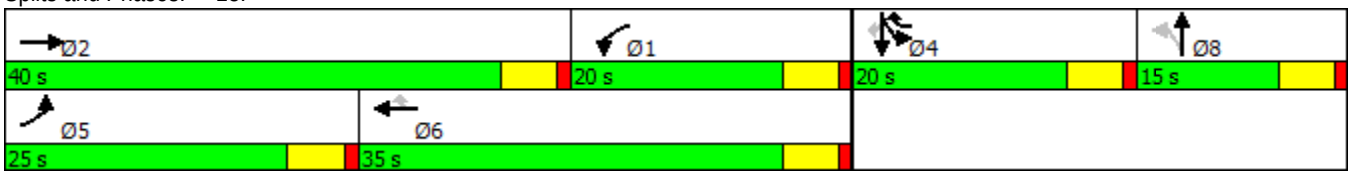


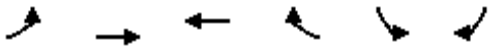
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	236	855	49	67	887	117	43	78	82	135	56	242
Future Volume (vph)	236	855	49	67	887	117	43	78	82	135	56	242
Satd. Flow (prot)	1728	3423	0	1728	3455	1546	0	1703	0	1658	1708	1561
Flt Permitted	0.950			0.950				0.895		0.950	0.979	
Satd. Flow (perm)	1725	3423	0	1723	3455	1500	0	1536	0	1658	1708	1521
Satd. Flow (RTOR)		7				127		29				272
Confl. Peds. (#/hr)	2		3	3		2	5					5
Confl. Bikes (#/hr)												
Peak Hour Factor	0.98	0.98	0.98	0.92	0.92	0.92	0.86	0.86	0.86	0.89	0.89	0.89
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%	0%	0%
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 (%)										30%		
Lane Group Flow (vph)	241	922	0	73	964	127	0	236	0	106	109	272
Turn Type	Prot	NA		Prot	NA	pm+ov	Perm	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4		8		4	4	
Permitted Phases						6	8					4
Total Split (s)	25.0	40.0		20.0	35.0	20.0	15.0	15.0		20.0	20.0	20.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	16.1	33.0		13.0	27.1	37.4		10.2		10.3	10.3	10.3
Actuated g/C Ratio	0.19	0.39		0.15	0.32	0.44		0.12		0.12	0.12	0.12
v/c Ratio	0.73	0.68		0.27	0.87	0.17		1.12		0.52	0.52	0.64
Control Delay	46.7	26.1		36.3	37.4	2.9		132.2		45.9	45.5	12.3
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	46.7	26.1		36.3	37.4	2.9		132.2		45.9	45.5	12.3
LOS	D	C		D	D	A		F		D	D	B
Approach Delay		30.4			33.5			132.2			27.1	
Approach LOS		C			C			F			C	
Queue Length 50th (ft)	126	234		35	255	0		~145		58	61	0
Queue Length 95th (ft)	216	320		81	#402	26		#295		113	116	67
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	418	1455		319	1256	826		211		301	310	499
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.58	0.63		0.23	0.77	0.15		1.12		0.35	0.35	0.55

Intersection Summary		
Cycle Length: 95		
Actuated Cycle Length: 84.1		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 1.12		
Intersection Signal Delay: 38.9	Intersection LOS: D	
Intersection Capacity Utilization 68.3%	ICU Level of Service C	
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: 18:



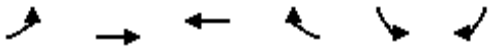


Lane Group	EBL	EBT	WBT	WBR	SBL	SBR	Ø9
Lane Configurations							
Traffic Volume (vph)	224	842	890	236	279	217	
Future Volume (vph)	224	842	890	236	279	217	
Satd. Flow (prot)	1728	3455	3455	1546	1728	1546	
Flt Permitted	0.950				0.950		
Satd. Flow (perm)	1726	3455	3455	1511	1728	1523	
Satd. Flow (RTOR)				149		155	
Confl. Peds. (#/hr)	1			1		3	
Confl. Bikes (#/hr)							
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	
Growth Factor	100%	100%	100%	100%	100%	100%	
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	
Bus Blockages (#/hr)	0	0	0	0	0	0	
Parking (#/hr)							
Mid-Block Traffic (%)		0%	0%		0%		
Shared Lane Traffic (%)							
Lane Group Flow (vph)	236	886	937	248	294	228	
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov	
Protected Phases	5	2	6		7	5	9
Permitted Phases				6		7	
Total Split (s)	25.0	75.0	50.0	50.0	25.0	25.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	
Act Effct Green (s)	18.6	57.7	33.9	33.9	20.8	39.4	
Actuated g/C Ratio	0.20	0.62	0.36	0.36	0.22	0.42	
v/c Ratio	0.69	0.41	0.75	0.39	0.76	0.31	
Control Delay	49.0	10.9	31.2	11.8	51.6	6.6	
Queue Delay	0.0	0.1	0.0	0.0	0.0	0.0	
Total Delay	49.0	11.0	31.2	11.8	51.6	6.6	
LOS	D	B	C	B	D	A	
Approach Delay		19.0	27.1		31.9		
Approach LOS		B	C		C		
Queue Length 50th (ft)	119	104	230	36	155	20	
Queue Length 95th (ft)	#349	289	455	132	#464	64	
Internal Link Dist (ft)		238	316		471		
Turn Bay Length (ft)	300			150		100	
Base Capacity (vph)	385	2698	1734	832	385	770	
Starvation Cap Reductn	0	502	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	0.61	0.40	0.54	0.30	0.76	0.30	

Intersection Summary			
Cycle Length: 130			
Actuated Cycle Length: 93.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.76			
Intersection Signal Delay: 24.8		Intersection LOS: C	
Intersection Capacity Utilization 65.0%		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: 14:

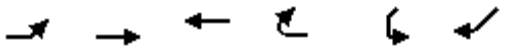


Lane Group	EBL	EBT	WBT	WBR	SBL	SBR	Ø9
Lane Configurations							
Traffic Volume (vph)	224	842	890	236	279	217	
Future Volume (vph)	224	842	890	236	279	217	
Satd. Flow (prot)	1728	3455	3455	1546	1728	1546	
Flt Permitted	0.950				0.950		
Satd. Flow (perm)	1726	3455	3455	1511	1728	1523	
Satd. Flow (RTOR)				149		155	
Confl. Peds. (#/hr)	1			1		3	
Confl. Bikes (#/hr)							
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95	
Growth Factor	100%	100%	100%	100%	100%	100%	
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	
Bus Blockages (#/hr)	0	0	0	0	0	0	
Parking (#/hr)							
Mid-Block Traffic (%)		0%	0%		0%		
Shared Lane Traffic (%)							
Lane Group Flow (vph)	236	886	937	248	294	228	
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov	
Protected Phases	5	2	6		7	5	9
Permitted Phases				6		7	
Total Split (s)	25.0	75.0	50.0	50.0	25.0	25.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0	
Act Effct Green (s)	18.6	57.7	33.9	33.9	20.8	39.4	
Actuated g/C Ratio	0.20	0.62	0.36	0.36	0.22	0.42	
v/c Ratio	0.69	0.41	0.75	0.39	0.76	0.31	
Control Delay	49.0	10.9	31.2	11.8	51.6	6.6	
Queue Delay	0.0	0.1	0.0	0.0	0.0	0.0	
Total Delay	49.0	11.0	31.2	11.8	51.6	6.6	
LOS	D	B	C	B	D	A	
Approach Delay		19.0	27.1		31.9		
Approach LOS		B	C		C		
Queue Length 50th (ft)	119	104	230	36	155	20	
Queue Length 95th (ft)	#349	289	455	132	#464	64	
Internal Link Dist (ft)		238	316		471		
Turn Bay Length (ft)	300			150		100	
Base Capacity (vph)	385	2698	1734	832	385	770	
Starvation Cap Reductn	0	502	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	0.61	0.40	0.54	0.30	0.76	0.30	

Intersection Summary			
Cycle Length: 130			
Actuated Cycle Length: 93.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.76			
Intersection Signal Delay: 24.8		Intersection LOS: C	
Intersection Capacity Utilization 65.0%		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: 14:



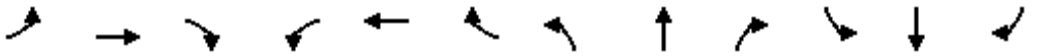
Movement	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (veh/h)	136	951	987	48	47	138
Future Volume (Veh/h)	136	951	987	48	47	138
Sign Control		Free	Free		Stop	
Grade		0%	0%		0%	
Peak Hour Factor	0.96	0.96	0.98	0.98	0.91	0.91
Hourly flow rate (vph)	142	991	1007	49	52	152
Pedestrians						
Lane Width (ft)						
Walking Speed (ft/s)						
Percent Blockage						
Right turn flare (veh)						4
Median type		None	None			
Median storage veh)						
Upstream signal (ft)		783				
pX, platoon unblocked					0.78	
vC, conflicting volume	1056				2282	1007
vC1, stage 1 conf vol						
vC2, stage 2 conf vol						
vCu, unblocked vol	1056				2502	1007
tC, single (s)	4.1				6.4	6.2
tC, 2 stage (s)						
tF (s)	2.2				3.5	3.3
p0 queue free %	79				0	48
cM capacity (veh/h)	663				20	294

Direction, Lane #	EB 1	EB 2	WB 1	WB 2	SW 1
Volume Total	142	991	1007	49	204
Volume Left	142	0	0	0	52
Volume Right	0	0	0	49	152
cSH	663	1700	1700	1700	67
Volume to Capacity	0.21	0.58	0.59	0.03	3.05
Queue Length 95th (ft)	20	0	0	0	Err
Control Delay (s)	11.9	0.0	0.0	0.0	Err
Lane LOS	B				F
Approach Delay (s)	1.5		0.0		Err
Approach LOS					F

Intersection Summary			
Average Delay	853.1		
Intersection Capacity Utilization	72.8%	ICU Level of Service	C
Analysis Period (min)	15		

Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	97	703	64	254	732	61	99	53	309	80	64	83
Future Volume (vph)	97	703	64	254	732	61	99	53	309	80	64	83
Satd. Flow (prot)	1787	3574	1599	1787	3528	0	1770	1863	1583	0	1830	1599
Flt Permitted	0.950			0.950			0.950				0.973	
Satd. Flow (perm)	1784	3574	1599	1787	3528	0	1767	1863	1563	0	1829	1577
Satd. Flow (RTOR)			102		5							102
Confl. Peds. (#/hr)	2					2	1		1	1		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.94	0.94	0.94	0.92	0.92	0.92	0.88	0.88	0.88	0.83	0.83	0.83
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	1%	1%	1%	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)	103	748	68	276	862	0	113	60	351	0	173	100
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	30.0	45.0	45.0	30.0	45.0		30.0	30.0	30.0	30.0	30.0	30.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	12.4	28.8	28.8	25.5	41.9		13.1	13.1	38.7		16.4	16.4
Actuated g/C Ratio	0.11	0.27	0.27	0.24	0.39		0.12	0.12	0.36		0.15	0.15
v/c Ratio	0.50	0.79	0.14	0.66	0.63		0.53	0.27	0.62		0.63	0.31
Control Delay	58.9	45.5	2.9	49.9	32.7		58.7	52.0	32.9		57.4	12.0
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	58.9	45.5	2.9	49.9	32.7		58.7	52.0	32.9		57.4	12.0
LOS	E	D	A	D	C		E	D	C		E	B
Approach Delay		43.8			36.9			40.6			40.8	
Approach LOS		D			D			D			D	
Queue Length 50th (ft)	64	234	0	162	226		70	36	168		106	0
Queue Length 95th (ft)	164	460	14	#470	518		172	101	312		228	42
Internal Link Dist (ft)		394			534			205			111	
Turn Bay Length (ft)	350		50				75		150			
Base Capacity (vph)	433	1387	683	433	1430		429	451	573		444	459
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	0.24	0.54	0.10	0.64	0.60		0.26	0.13	0.61		0.39	0.22

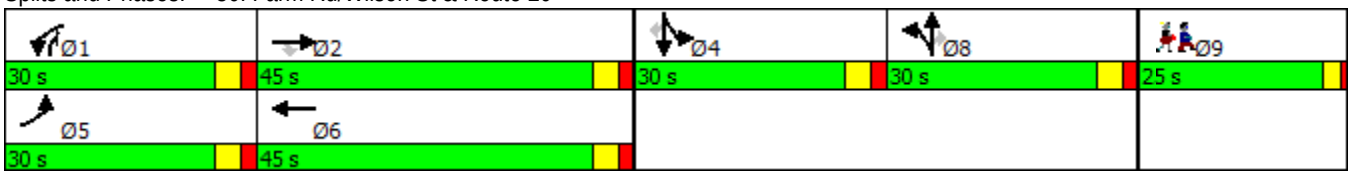
Intersection Summary		
Cycle Length: 160		
Actuated Cycle Length: 108.3		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.79		
Intersection Signal Delay: 40.2	Intersection LOS: D	
Intersection Capacity Utilization 60.5%	ICU Level of Service B	
Analysis Period (min) 15		

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
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

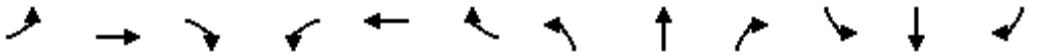
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicenzo Boulevard/Pomphrey Drive, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	726	214	109	645	27	347	12	64	8	13	27
Future Volume (vph)	29	726	214	109	645	27	347	12	64	8	13	27
Satd. Flow (prot)	1711	3305	0	1711	3401	0	3204	1520	0	1685	1594	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1711	3305	0	1711	3401	0	3204	1520	0	1685	1594	0
Satd. Flow (RTOR)		25			3			68			39	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.94	0.94	0.94	0.70	0.70	0.70
Growth Factor	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	2%	2%	2%	0%	0%	0%
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)	33	1056	0	111	686	0	369	81	0	11	58	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	30.0	45.0		30.0	45.0		30.0	30.0		17.0	17.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	7.9	42.0		12.3	52.0		17.1	17.1		7.6	7.6	
Actuated g/C Ratio	0.08	0.42		0.12	0.52		0.17	0.17		0.08	0.08	
v/c Ratio	0.25	0.76		0.53	0.39		0.68	0.26		0.09	0.37	
Control Delay	55.7	32.5		55.4	21.1		48.3	16.4		53.6	31.7	
Queue Delay	0.0	0.0		0.0	0.0		0.1	0.0		0.0	0.0	
Total Delay	55.7	32.5		55.4	21.1		48.4	16.4		53.6	31.7	
LOS	E	C		E	C		D	B		D	C	
Approach Delay		33.2			25.9			42.6			35.2	
Approach LOS		C			C			D			D	
Queue Length 50th (ft)	19	270		64	139		108	7		6	11	
Queue Length 95th (ft)	65	#716		162	344		224	59		24	41	
Internal Link Dist (ft)		391			775			209			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	445	1390		445	1755		833	445		210	233	
Starvation Cap Reductn	0	0		0	0		44	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.07	0.76		0.25	0.39		0.47	0.18		0.05	0.25	

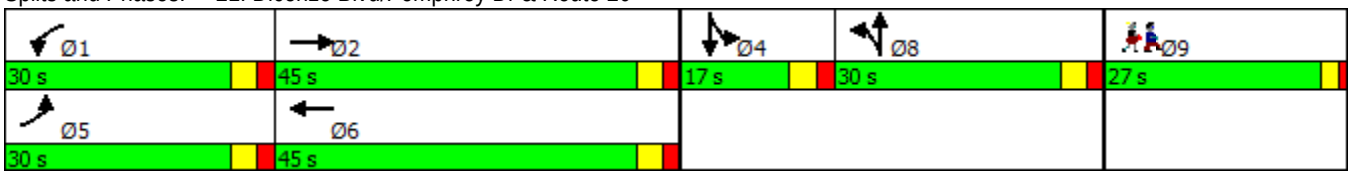
Intersection Summary		
Cycle Length: 149		
Actuated Cycle Length: 100.8		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.76		
Intersection Signal Delay: 32.6	Intersection LOS: C	
Intersection Capacity Utilization 62.0%	ICU Level of Service B	
Analysis Period (min) 15		

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
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

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

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



APPENDIX F

Corridor and Segment Crash Rate Worksheets

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : NA (2012)

DISTRICT : 3

~ SEGMENT DATA ~

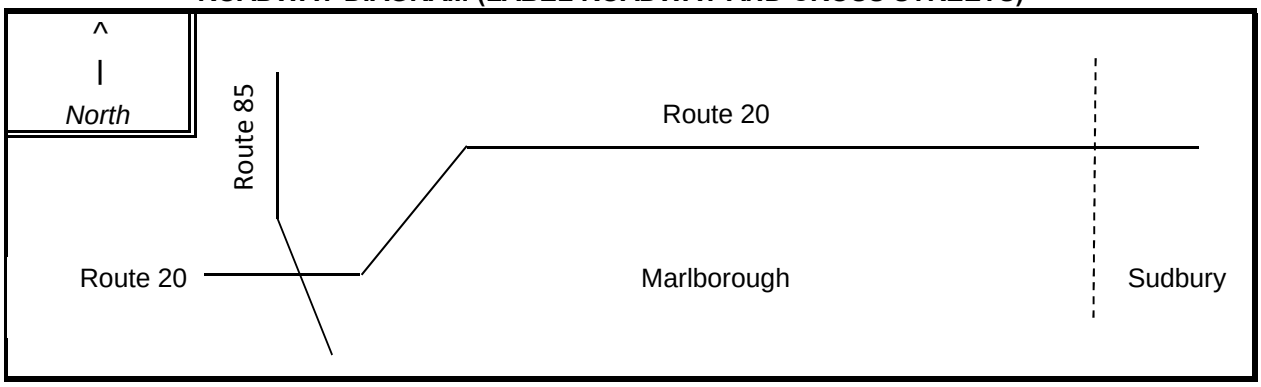
ROADWAY NAME: Route 20 Corridor

START POINT: West of Route 85 (South Bolton Street)

END POINT: Sudbury Town Line

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	**3.65**
AVERAGE DAILY TRAFFIC VOLUME (**V**):	20,500

TOTAL # OF CRASHES:	997	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**199.40**

CRASH RATE CALCULATION : **7.30**

$$\text{RATE} = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : 4/6-8/2016

DISTRICT : 3

~ SEGMENT DATA ~

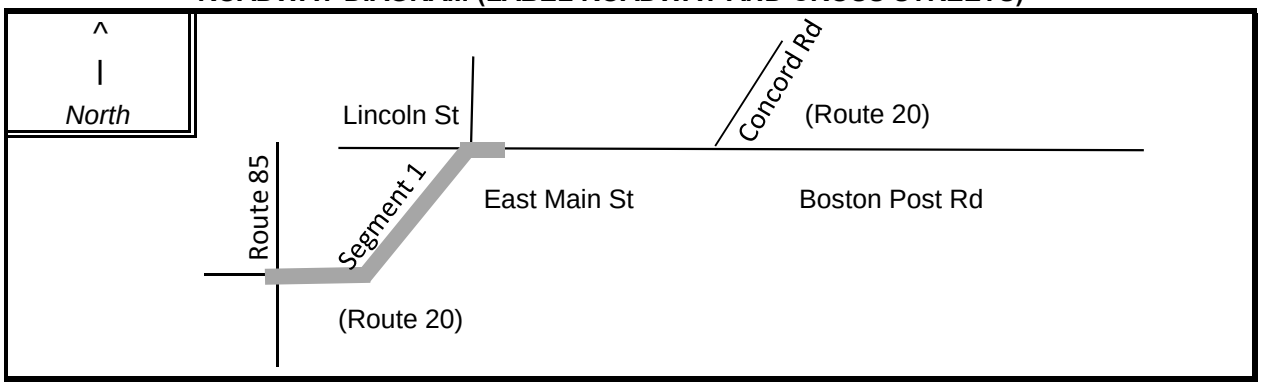
ROADWAY NAME: Route 20 Segment 1

START POINT: About 100 feet west of Route 85 (South Bolton Street)

END POINT: About 100 feet east of Lincoln Street

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	0.50
AVERAGE DAILY TRAFFIC VOLUME (**V**):	20,500

TOTAL # OF CRASHES:	152	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**30.40**

CRASH RATE CALCULATION : **8.09**

$$\text{RATE} = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : 4/6-8/2016

DISTRICT : 3

~ SEGMENT DATA ~

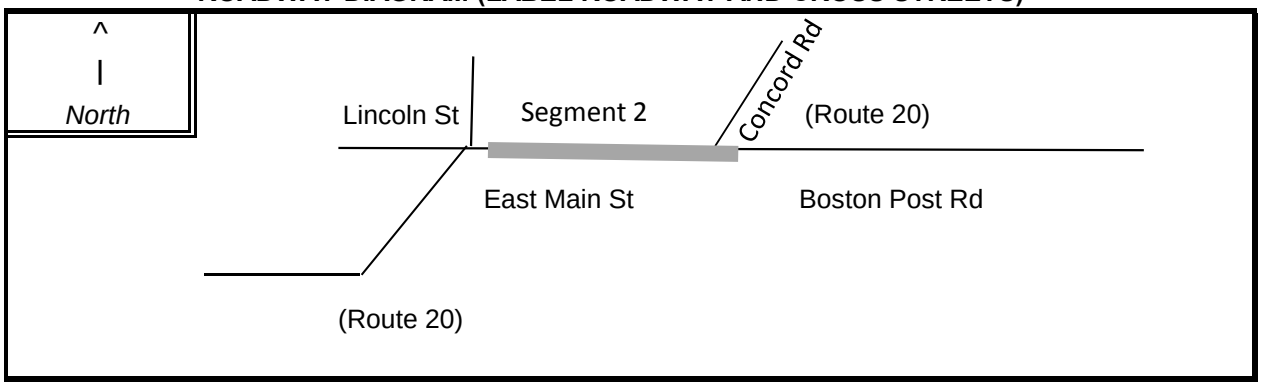
ROADWAY NAME: Route 20 Segment 2

START POINT: About 200 feet east of Lincoln Street

END POINT: About 200 feet east of Concord Road

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	0.55
AVERAGE DAILY TRAFFIC VOLUME (**V**):	26,000

TOTAL # OF CRASHES:	313	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**62.60**

CRASH RATE CALCULATION : **12.05**

$$\text{RATE} = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : 4/6-8/2016

DISTRICT : 3

~ SEGMENT DATA ~

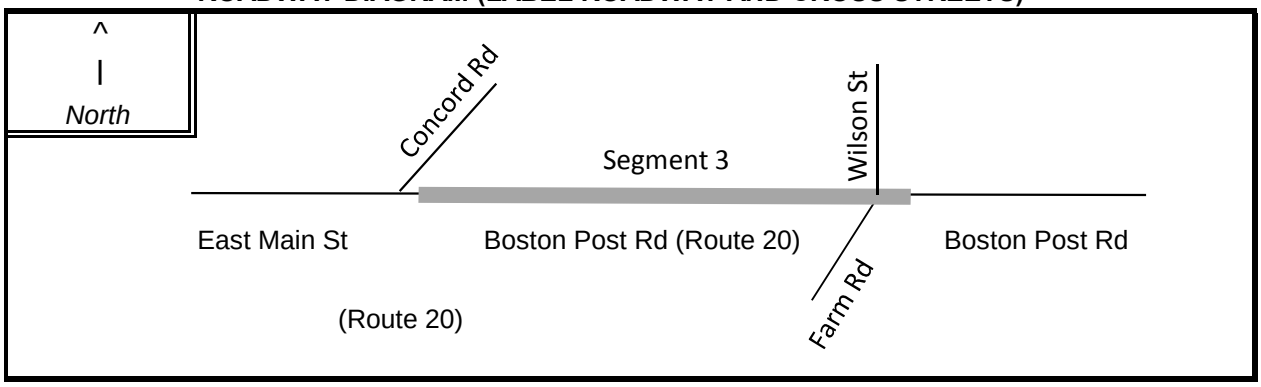
ROADWAY NAME: Route 20 Segment 3

START POINT: About 200 feet east of Concord Road

END POINT: About 300 feet east of Farm Road

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	1.30
AVERAGE DAILY TRAFFIC VOLUME (**V**):	21,000

TOTAL # OF CRASHES:	347	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**69.40**

CRASH RATE CALCULATION : **6.99**

$$RATE = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : 4/6-8/2016

DISTRICT : 3

~ SEGMENT DATA ~

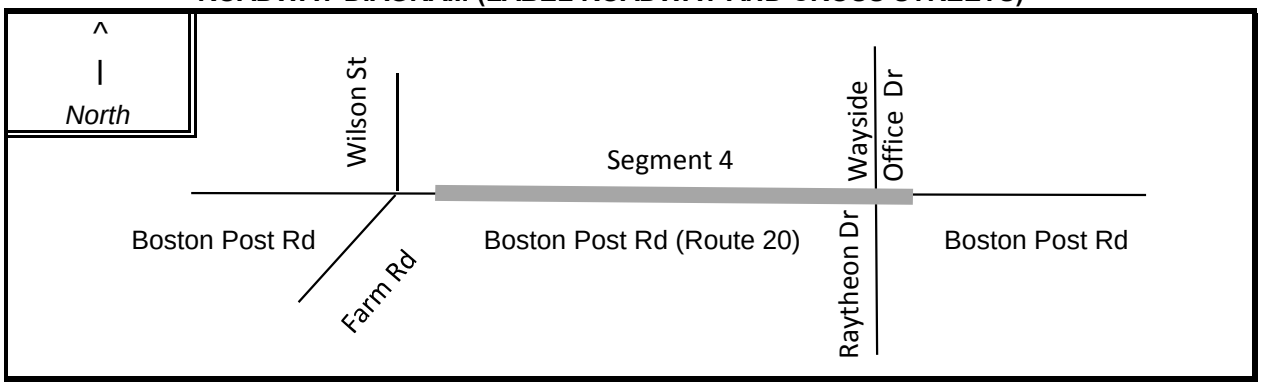
ROADWAY NAME: Route 20 Segment 4

START POINT: About 300 feet east of Farm Road

END POINT: About 100 feet east of Raytheon Driveway

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	0.80
AVERAGE DAILY TRAFFIC VOLUME (**V**):	18,200

TOTAL # OF CRASHES:	124	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**24.80**

CRASH RATE CALCULATION : **4.69**

$$\text{RATE} = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

SEGMENT CRASH RATE WORKSHEET

CITY/TOWN : Marlborough COUNT DATE : 4/6-8/2016

DISTRICT : 3

~ SEGMENT DATA ~

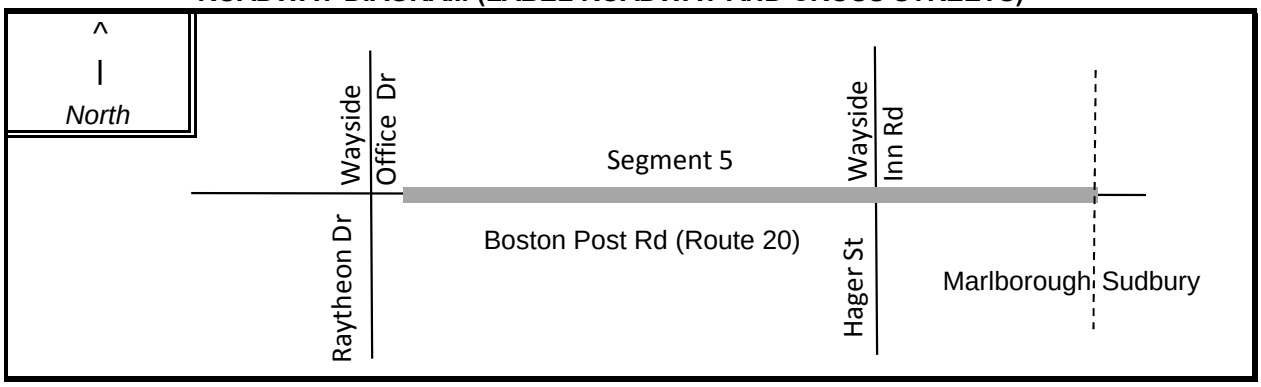
ROADWAY NAME: Route 20 Segment 5

START POINT: About 100 feet east of Raytheon Driveway

END POINT: Sudbury Town Line

FUNCTIONAL CLASSIFICATION OF ROADWAY: Urban Principal Arterial - Other

ROADWAY DIAGRAM (LABEL ROADWAY AND CROSS STREETS)



AVERAGE DAILY TRAFFIC

SEGMENT LENGTH IN MILES (**L**):	0.50
AVERAGE DAILY TRAFFIC VOLUME (**V**):	16,500

TOTAL # OF CRASHES:	61	# OF YEARS :	5	AVERAGE # OF CRASHES PER YEAR (**A**) :	**12.20**

CRASH RATE CALCULATION : **4.04**

$$\text{RATE} = \frac{(A * 1{,}000{,}000)}{(L * V * 365)}$$

Comments : 2013 State Average for Urban Principal Arterial (Other) = 3.49

Project Title & Date: Route 20 East Corridor Study

APPENDIX G

Intersection Crash Rate Worksheets

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

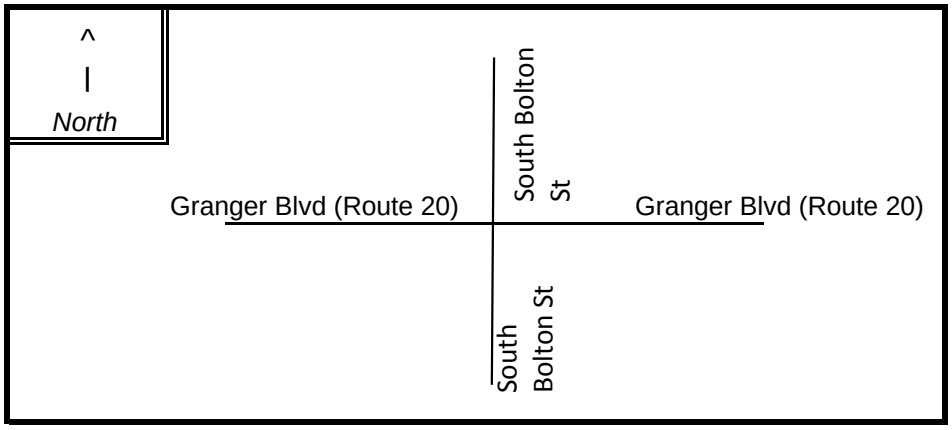
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Route 20 (Granger Boulevard)

MINOR STREET(S) : Route 85 (South Bolton Street)

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	EB	NB	SB	WB		
PEAK HOURLY VOLUMES (AM/PM) :	710	860	387	427		**2,384**

" K " FACTOR : **0.090** | INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **26,489**

TOTAL # OF CRASHES : 56 | # OF YEARS : 5 | AVERAGE # OF CRASHES PER YEAR (**A**) : **11.20**

CRASH RATE CALCULATION : **1.33**

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

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

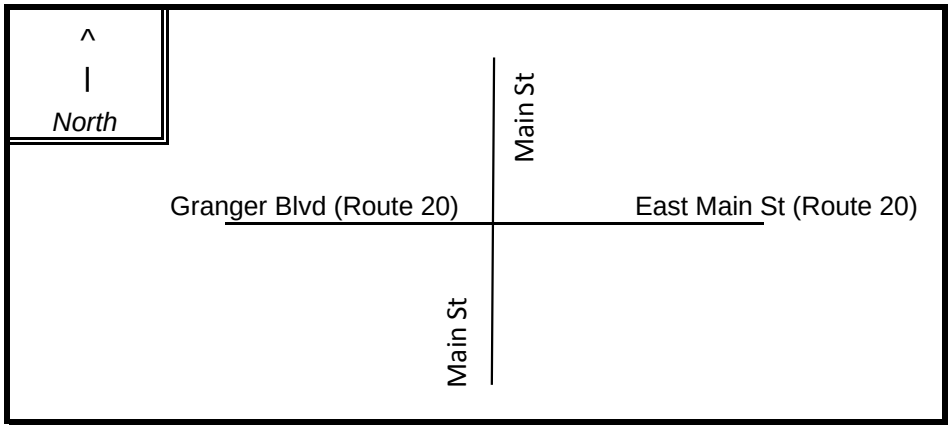
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Granger Boulevard/East Main Street

MINOR STREET(S) : Main Street

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	EB	NB	WB	SB		
PEAK HOURLY VOLUMES (AM/PM) :	560	293	443	218		**1,514**

" K " FACTOR : **0.090** | INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **16,822**

TOTAL # OF CRASHES : 20 | # OF YEARS : 5 | AVERAGE # OF CRASHES PER YEAR (**A**) : **4.00**

CRASH RATE CALCULATION : **0.75**

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

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

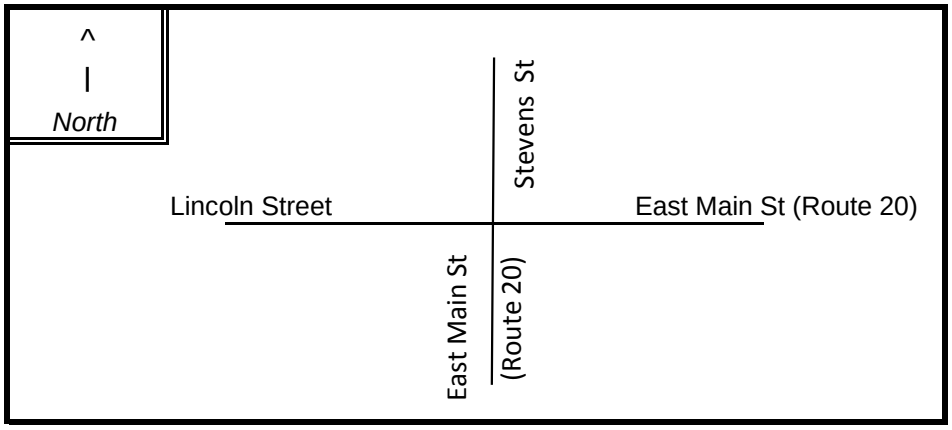
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : East Main Street

MINOR STREET(S) : Lincoln Street/Stevens Street

INTERSECTION DIAGRAM
(Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	EB	NB	WB	SB		
PEAK HOURLY VOLUMES (AM/PM) :	383	569	1,060	267		**2,279**

" K " FACTOR : **0.090** | INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **25,322**

TOTAL # OF CRASHES : 35 | # OF YEARS : 5 | AVERAGE # OF CRASHES PER YEAR (**A**) : **7.00**

CRASH RATE CALCULATION : **0.87**

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

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

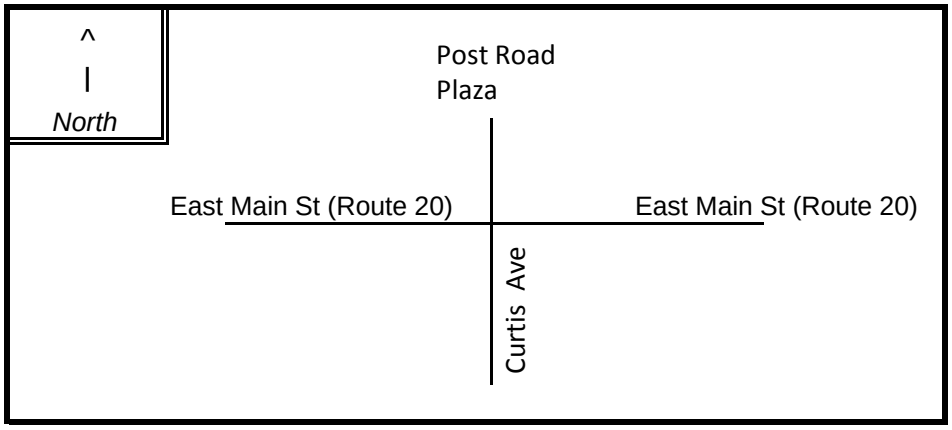
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : East Main Street (Route 20)

MINOR STREET(S) : Curtis Avenue/Post Road Plaza

INTERSECTION DIAGRAM
(Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						2,683

" K " FACTOR : 0.090

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : 29,811

TOTAL # OF CRASHES : 66

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : 13.20

CRASH RATE CALCULATION : 1.39

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

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

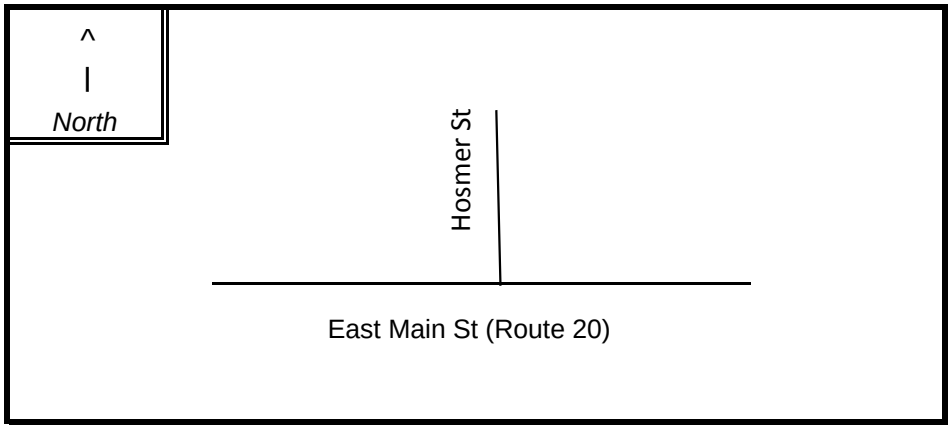
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : East Main Street (Route 20)

MINOR STREET(S) : Hosmer Street

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						2,487

" K " FACTOR : 0.090

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : 27,633

TOTAL # OF CRASHES : 40

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : 8.00

CRASH RATE CALCULATION : 0.91

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

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

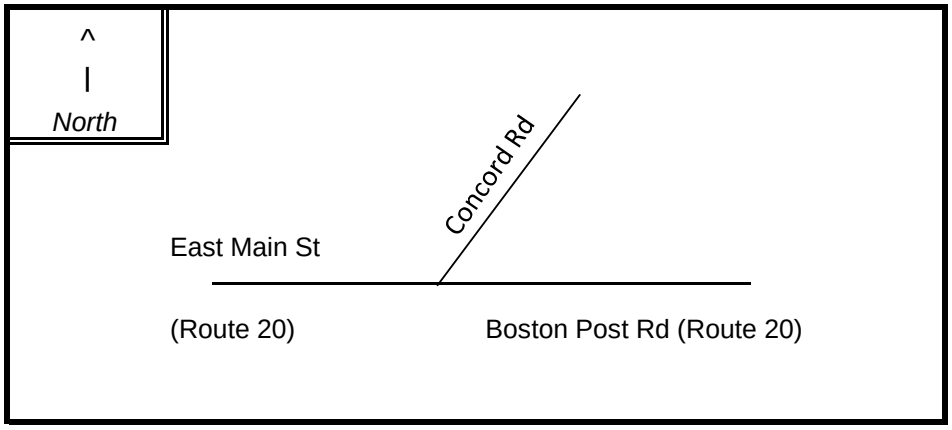
DISTRICT : 3 | UNSIGNALIZED : X | SIGNALIZED :

~ INTERSECTION DATA ~

MAJOR STREET : East Main Street/Boston Post Road (Route 20)

MINOR STREET(S) : Concord Road

INTERSECTION DIAGRAM
(Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :	EB	WB	SB			
PEAK HOURLY VOLUMES (AM/PM) :	917	1,042	179			**2,138**

" K " FACTOR : **0.090**

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **23,756**

TOTAL # OF CRASHES : 44

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : **8.80**

CRASH RATE CALCULATION : **1.17**

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

Comments : 2015 Average Crash Rate for MassDOT District 3 Unsignalized Intersections = 0.65

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

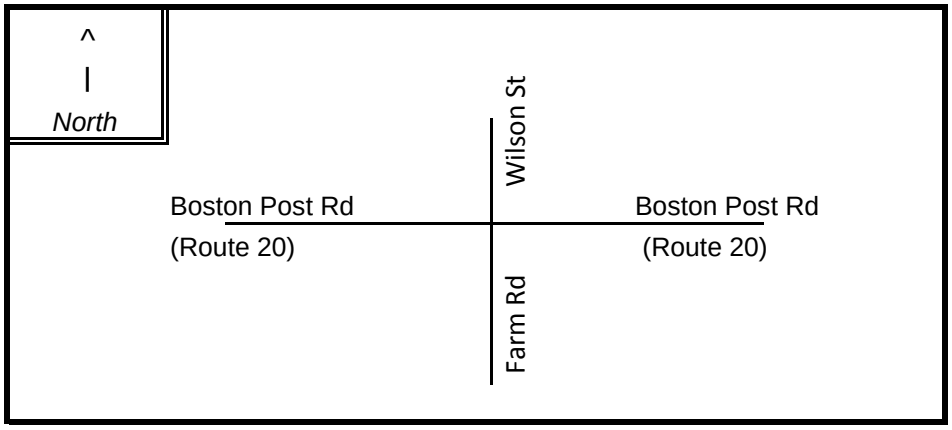
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Boston Post Road (Route 20)

MINOR STREET(S) : Farm Road/Wilson Street

INTERSECTION DIAGRAM
(Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						2,635

" K " FACTOR : **0.090**

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **29,278**

TOTAL # OF CRASHES : 48

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : **9.60**

CRASH RATE CALCULATION : **1.03**

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

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

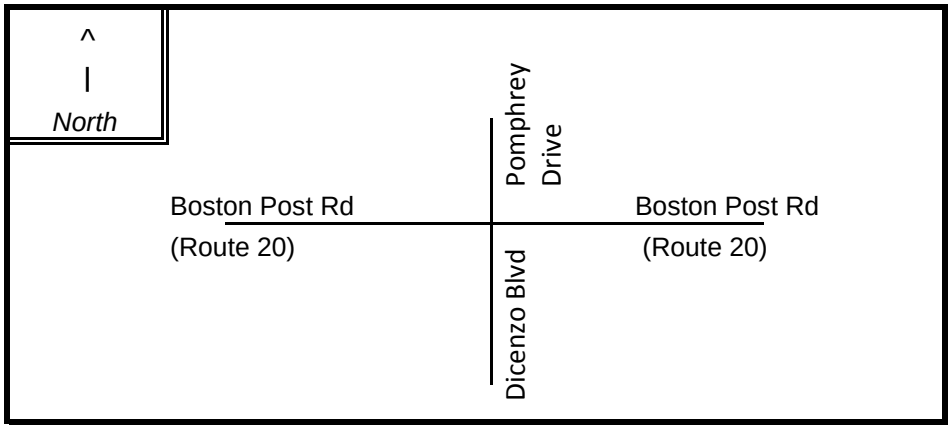
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Boston Post Road (Route 20)

MINOR STREET(S) : Dicenzo Boulevard/Pomphrey Drive

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						2,197

" K " FACTOR : 0.090

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : 24,411

TOTAL # OF CRASHES : 21 | # OF YEARS : 5 | AVERAGE # OF CRASHES PER YEAR (**A**) : 4.20

CRASH RATE CALCULATION : 0.54

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

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

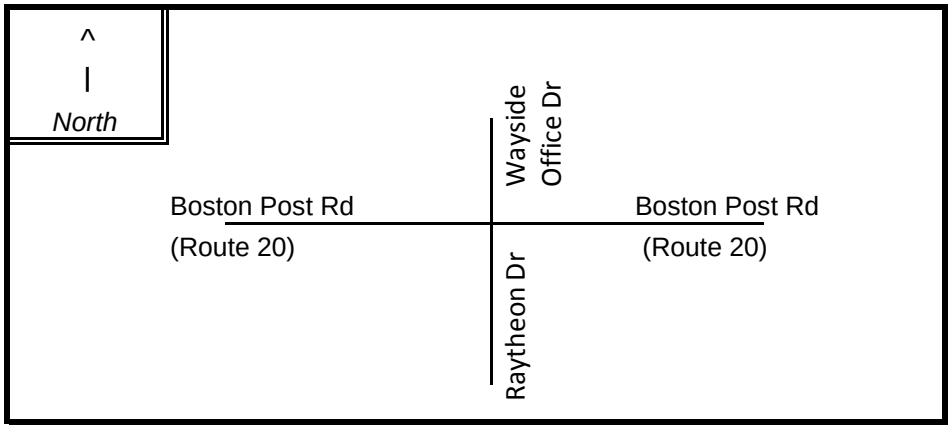
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Boston Post Road (Route 20)

MINOR STREET(S) : Raytheon Driveway/Wayside Office Driveway

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						1,952

" K " FACTOR : 0.090

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : 21,689

TOTAL # OF CRASHES : 10

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : 2.00

CRASH RATE CALCULATION : 0.29

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

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

INTERSECTION CRASH RATE WORKSHEET

CITY/TOWN : Marlborough | COUNT DATE : 4/7/2016

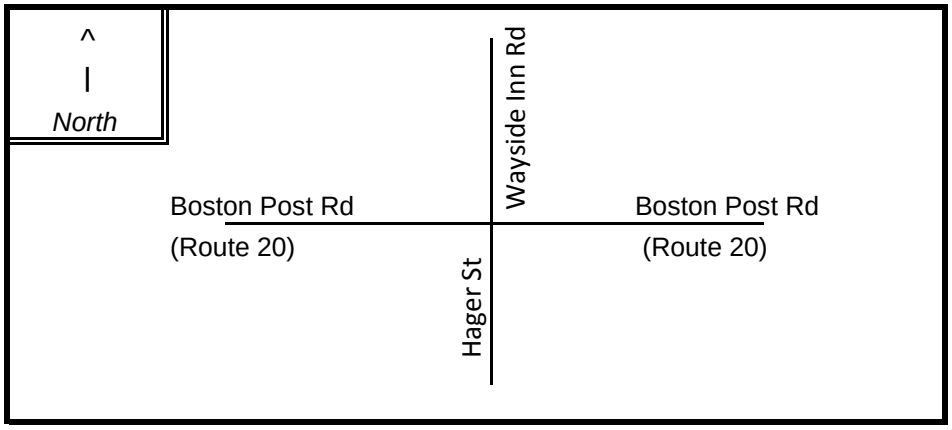
DISTRICT : 3 | UNSIGNALIZED : | SIGNALIZED : X

~ INTERSECTION DATA ~

MAJOR STREET : Boston Post Road (Route 20)

MINOR STREET(S) : Hager Street/Wayside Inn Road

INTERSECTION DIAGRAM (Label Approaches)



PEAK HOUR VOLUMES

APPROACH :	1	2	3	4	5	Total Peak Hourly Approach Volume
DIRECTION :						
PEAK HOURLY VOLUMES (AM/PM) :						1,814

" K " FACTOR : **0.090**

INTERSECTION ADT (**V**) = TOTAL DAILY APPROACH VOLUME : **20,156**

TOTAL # OF CRASHES : 27

OF YEARS : 5

AVERAGE # OF CRASHES PER YEAR (**A**) : **5.40**

CRASH RATE CALCULATION : **0.84**

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

Comments : 2015 Average Crash Rate for MassDOT District 3 Signalized Intersections = 0.90

Project Title & Date: Route 20 East Corridor Study

APPENDIX H

Collision Diagrams and Crash Statistics
Major Intersections and Segments in the Corridor

Figure H-1
Collision Diagram: Route 20 at Route 85
Marlborough Police Reports: January 2011–December 2015

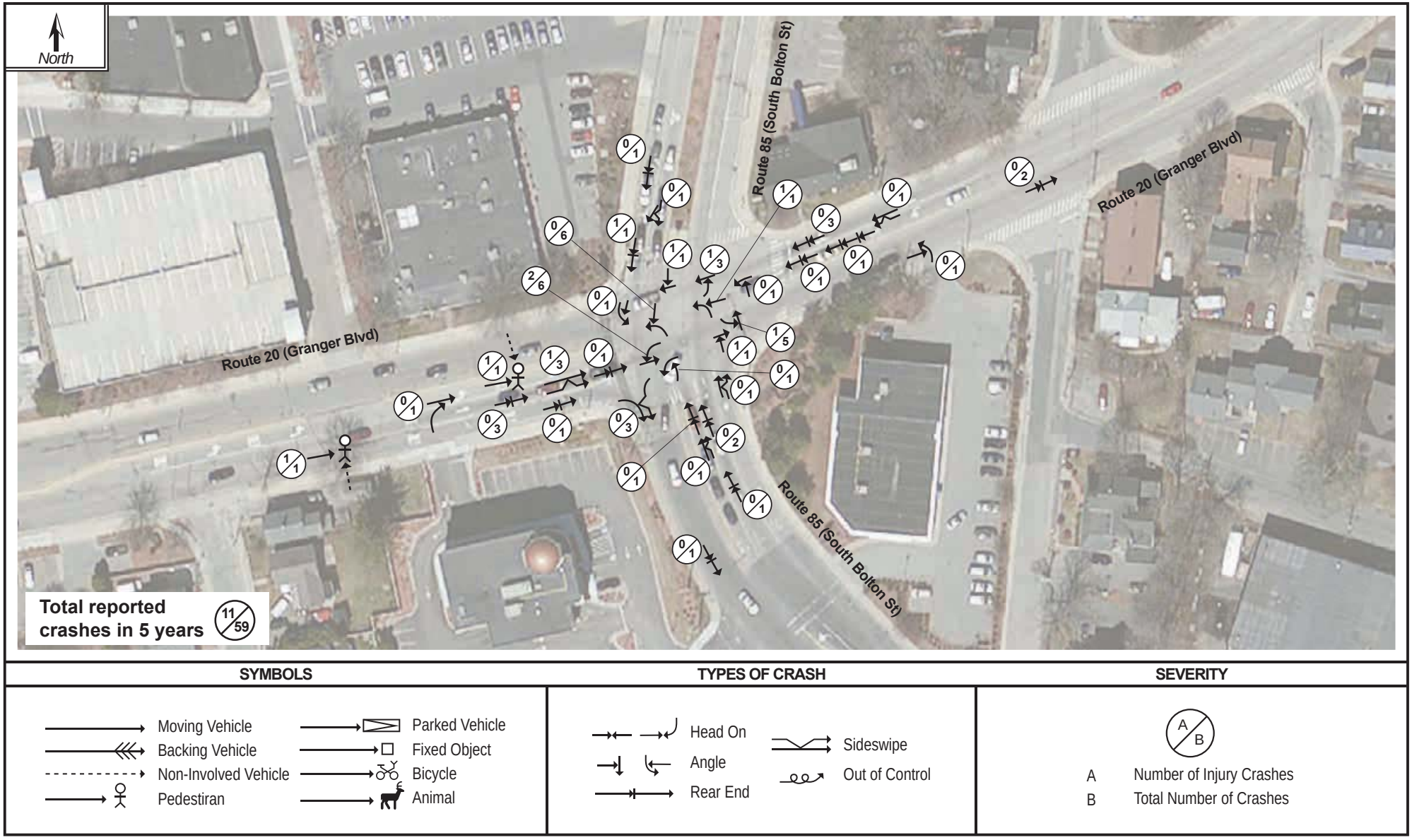
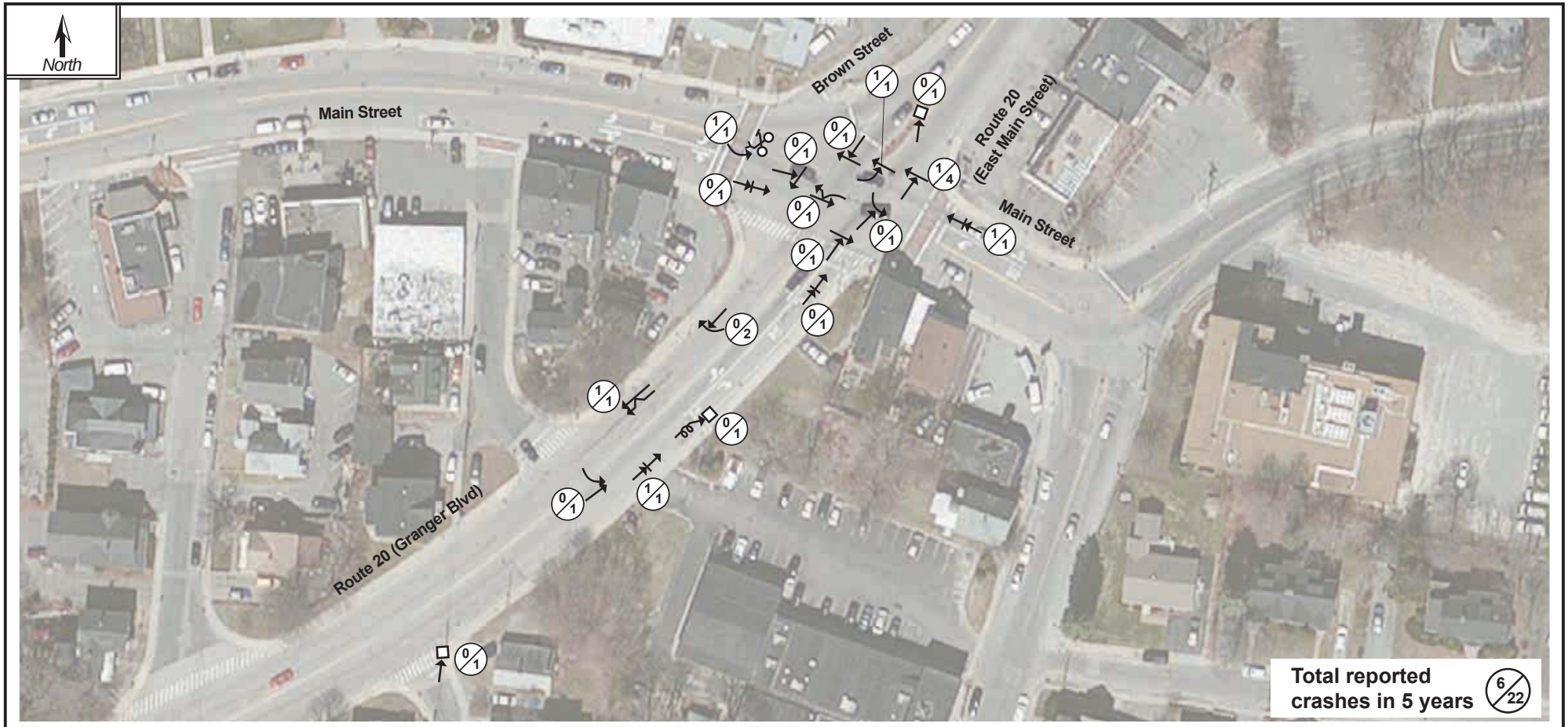


Table H-1
Crash Statistics: Route 20 at Route 85
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		13	8	10	11	17	59	11.8
Severity	Property damage only	10	7	9	10	12	48	9.6
	Non-fatal injury	3	1	1	1	5	11	2.2
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	1	0	0	1	2	0.4
	Rear-end	4	2	4	4	5	19	3.8
	Angle	7	3	3	6	8	27	5.4
	Sideswipe, same direction	0	2	2	0	3	7	1.4
	Sideswipe, opposite direction	1	0	1	1	0	3	0.6
	Head-on	1	0	0	0	0	1	0.2
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	1	0	0	1	2	0.4
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		4	4	1	0	0	9	1.8
Wet or icy pavement conditions		4	1	2	1	3	11	2.2
Dark conditions (lit or unlit)		5	1	2	2	2	12	2.4

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

Figure H-2
Collision Diagram: Route 20 at Main Street
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

- Moving Vehicle
- Backing Vehicle
- Non-Involved Vehicle
- Pedestiran
- Parked Vehicle
- Fixed Object
- Bicycle
- Animal

TYPES OF CRASH

- Head On
- Angle
- Rear End
- Sideswipe
- Out of Control

SEVERITY

A/B

A Number of Injury Crashes
B Total Number of Crashes

Table H-2
Crash Statistics: Route 20 at Main Street
Marlborough Police Crash Data 2011-15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		5	5	1	6	5	22	4.4
Severity	Property damage only	4	3	0	3	5	15	3.0
	Non-fatal injury	1	1	1	3	0	6	1.2
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	1	0	0	0	1	0.2
Collision type	Single vehicle	0	2	0	1	0	3	0.6
	Rear-end	1	1	1	0	1	4	0.8
	Angle	2	2	0	4	4	12	2.4
	Sideswipe, same direction	1	0	0	1	0	2	0.4
	Sideswipe, opposite direction	1	0	0	0	0	1	0.2
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	1	0	1	0.2
Occurred during weekday peak periods*		1	3	0	0	0	4	0.8
Wet or icy pavement conditions		1	1	0	2	0	4	0.8
Dark conditions (lit or unlit)		3	1	0	2	1	7	1.4

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

Figure H-3
Collision Diagram: Route 20 between Main Street and Lincoln Street
Marlborough Police Reports: January 2011–December 2015

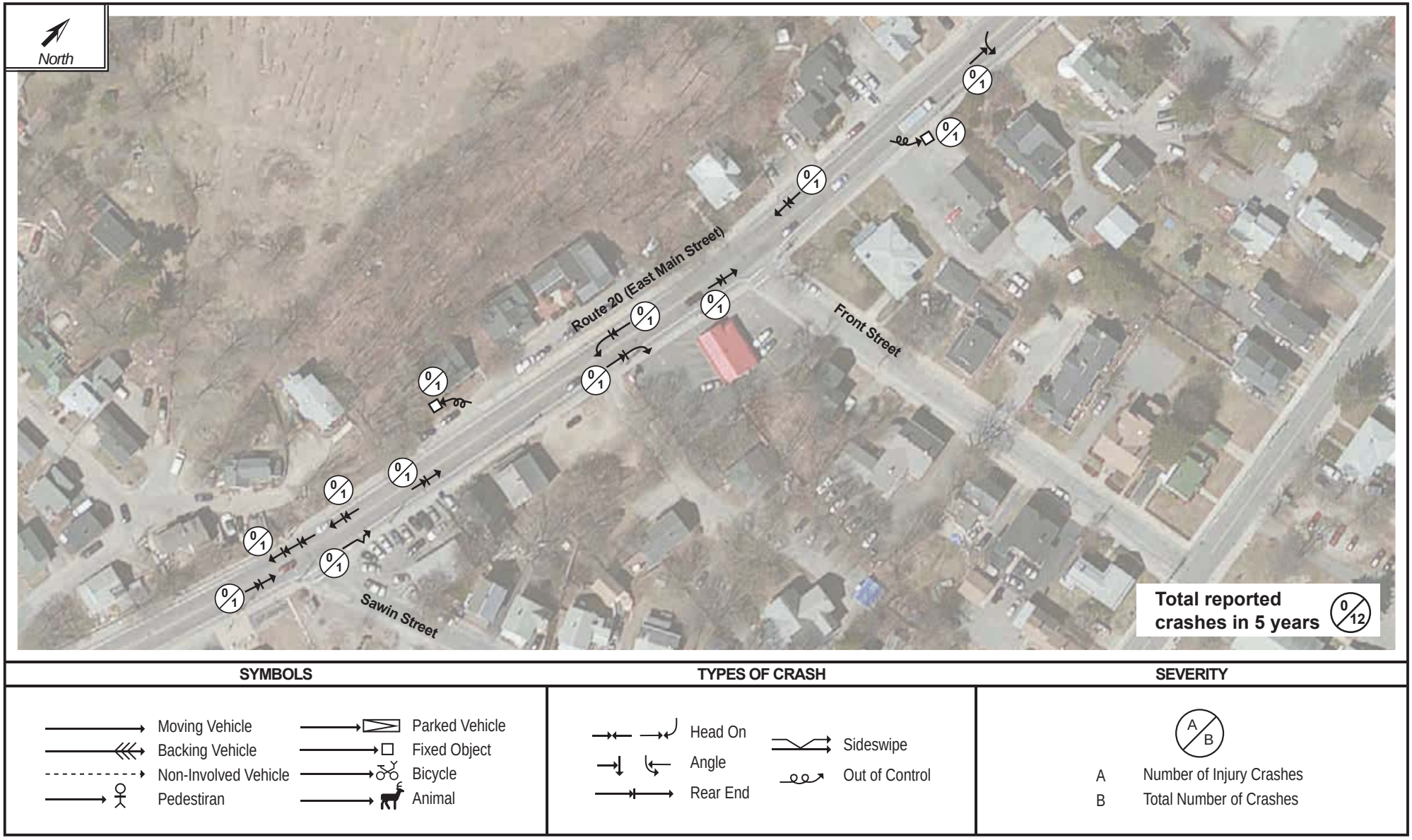
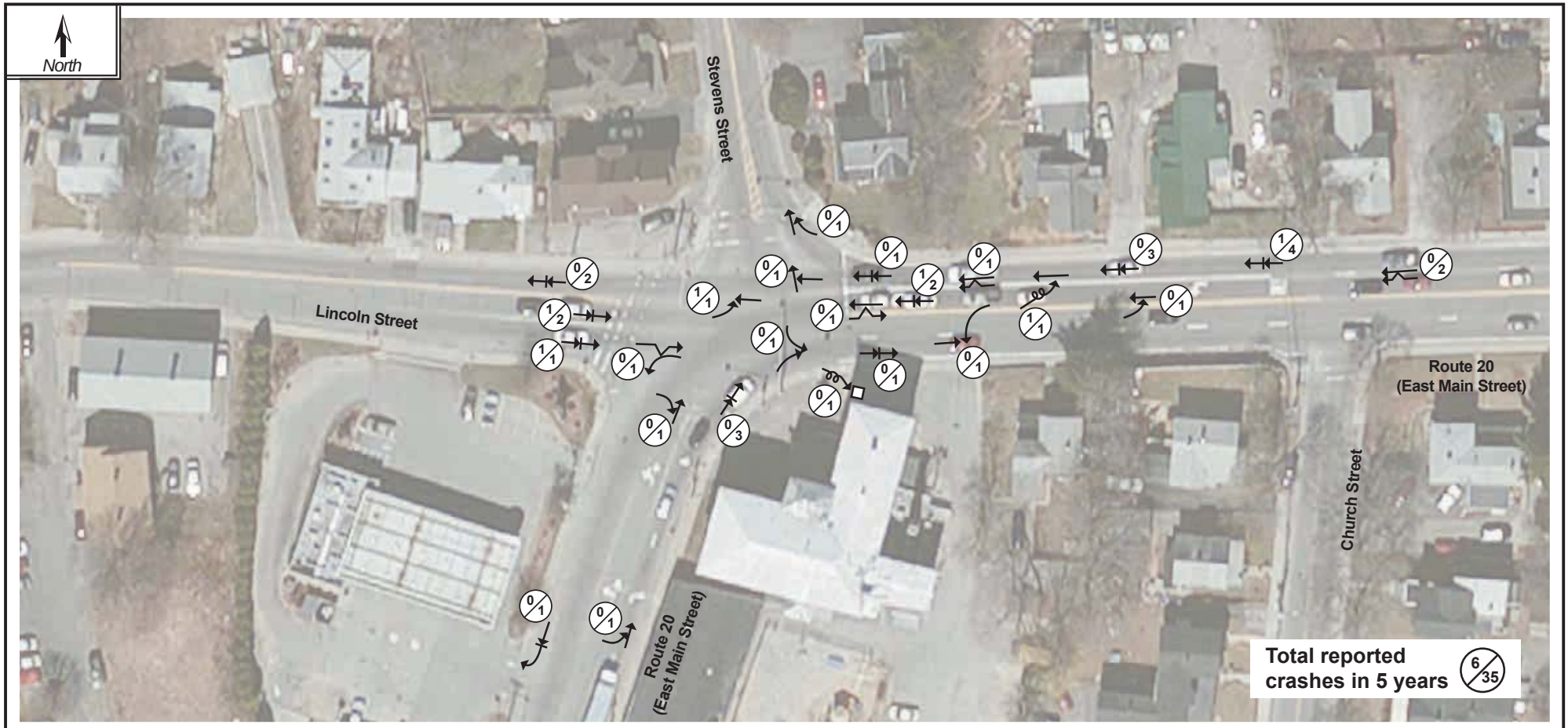


Table H-3
Crash Statistics: Route 20 between Main Street and Lincoln Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		1	1	2	4	4	12	2.4
Severity	Property damage only	1	1	2	4	4	12	2.4
	Non-fatal injury	0	0	0	0	0	0	0.0
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	0	0	1	1	2	0.4
	Rear-end	1	1	2	3	1	8	1.6
	Angle	0	0	0	0	2	2	0.4
	Sideswipe, same direction	0	0	0	0	0	0	0.0
	Sideswipe, opposite direction	0	0	0	0	0	0	0.0
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		1	1	2	3	3	10	2.0
Wet or icy pavement conditions		0	0	1	1	2	4	0.8
Dark conditions (lit or unlit)		0	0	0	2	3	5	1.0

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

Figure H-4
Collision Diagram: Route 20 at Lincoln Street/Stevens Street
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

- Moving Vehicle
- Backing Vehicle
- Non-Involved Vehicle
- Pedestiran
- Parked Vehicle
- Fixed Object
- Bicycle
- Animal

TYPES OF CRASH

- Head On
- Angle
- Rear End
- Sideswipe
- Out of Control

SEVERITY

A/B

A Number of Injury Crashes
B Total Number of Crashes

Table H-4
Crash Statistics: Route 20 at Lincoln/Stevens Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		4	9	7	4	11	35	7.0
Severity	Property damage only	3	7	6	4	9	29	5.8
	Non-fatal injury	1	2	1	0	2	6	1.2
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	0	1	0	0	1	0.2
	Rear-end	3	3	3	4	7	20	4.0
	Angle	0	4	2	0	3	9	1.8
	Sideswipe, same direction	0	1	0	0	0	1	0.2
	Sideswipe, opposite direction	1	0	1	0	0	2	0.4
	Head-on	0	1	0	0	1	2	0.4
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		1	3	1	0	0	5	1.0
Wet or icy pavement conditions		0	3	3	2	4	12	2.4
Dark conditions (lit or unlit)		0	2	3	0	1	6	1.2

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

Figure H-5
Collision Diagram: Route 20 between Lincoln Street and Curtis Avenue
Marlborough Police Reports: January 2011–December 2015

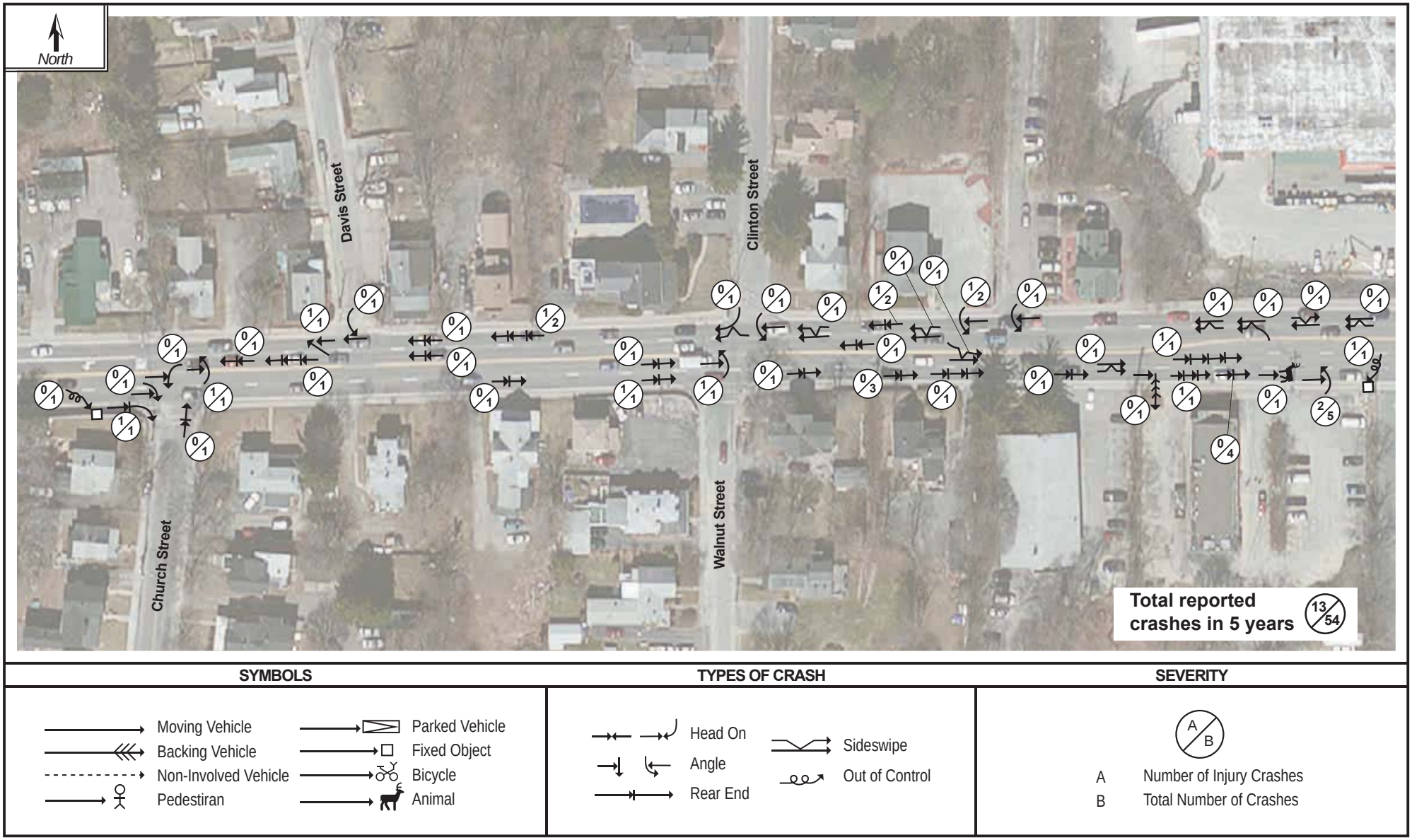
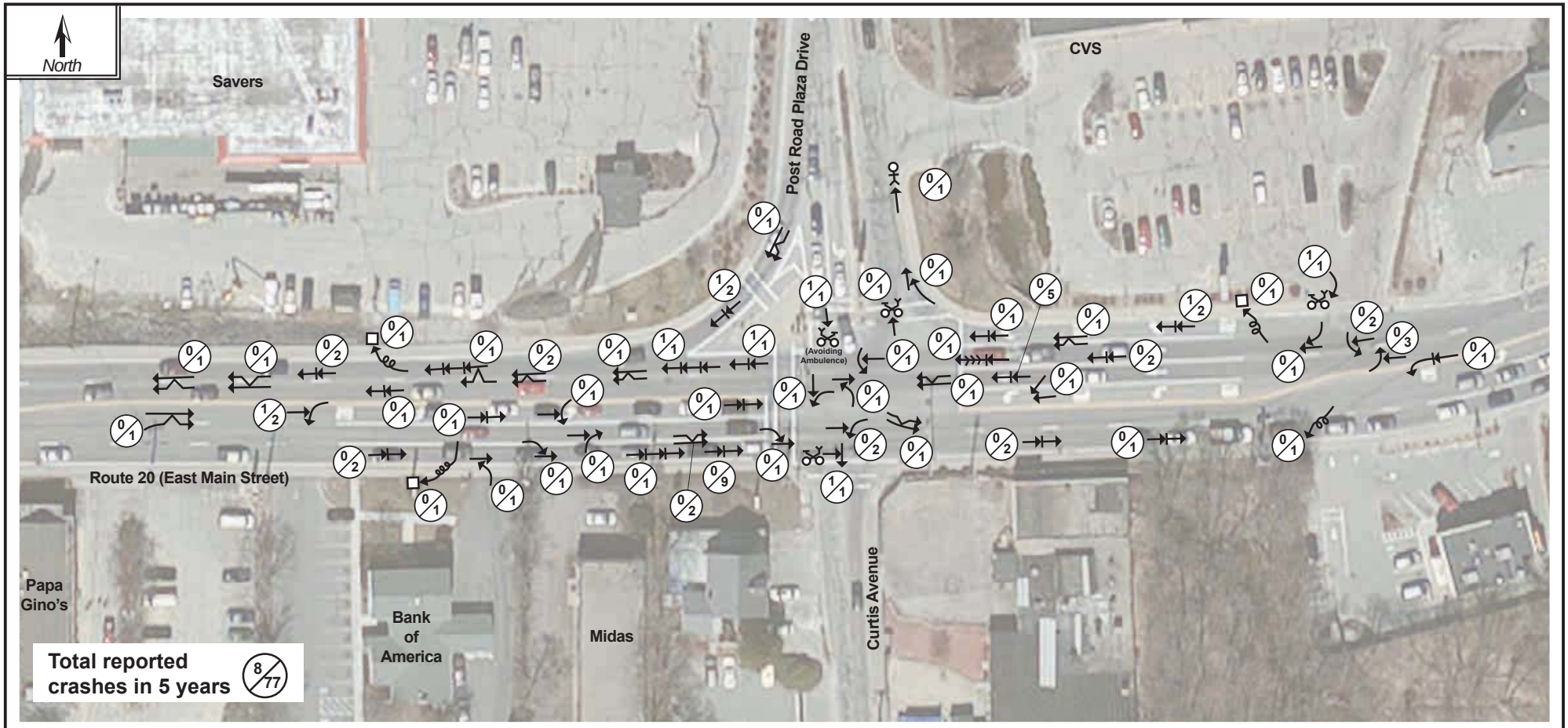


Table H-5
Crash Statistics: Route 20 between Lincoln Street and Curtis Avenue
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		14	4	11	9	16	54	10.8
Severity	Property damage only	12	2	7	7	13	41	8.2
	Non-fatal injury	2	2	4	2	3	13	2.6
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	1	0	1	1	0	3	0.6
	Rear-end	5	2	3	7	8	25	5.0
	Angle	4	2	6	1	4	17	3.4
	Sideswipe, same direction	4	0	1	0	4	9	1.8
	Sideswipe, opposite direction	0	0	0	0	0	0	0.0
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		4	1	4	0	0	9	1.8
Wet or icy pavement conditions		10	2	3	3	3	21	4.2
Dark conditions (lit or unlit)		4	0	1	3	3	11	2.2

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

Figure H-6
Collision Diagram: Route 20 at Curtis Avenue
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

- Moving Vehicle
- Backing Vehicle
- Non-Involved Vehicle
- Pedestiran
- Parked Vehicle
- Fixed Object
- Bicycle
- Animal

TYPES OF CRASH

- Head On
- Angle
- Rear End
- Sideswipe
- Out of Control

SEVERITY

A/B

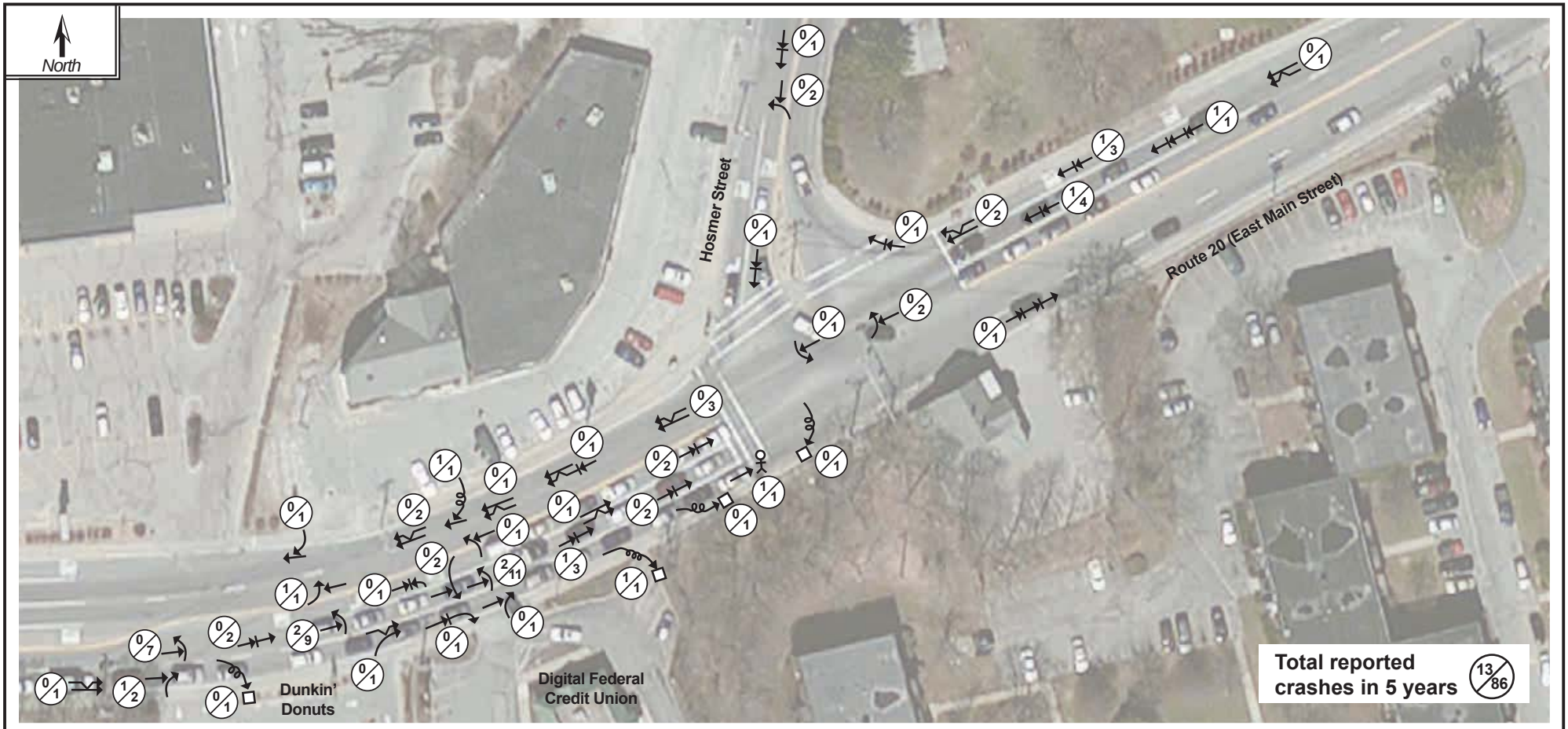
A Number of Injury Crashes
B Total Number of Crashes

Table H-6
Crash Statistics: Route 20 at Curtis Avenue
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		14	18	17	16	12	77	15.4
Severity	Property damage only	13	17	17	13	9	69	13.8
	Non-fatal injury	1	1	0	3	3	8	1.6
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	1	2	1	2	6	1.2
	Rear-end	6	7	8	8	6	35	7.0
	Angle	4	7	5	4	4	24	4.8
	Sideswipe, same direction	2	1	2	3	0	8	1.6
	Sideswipe, opposite direction	1	2	0	0	0	3	0.6
	Head-on	1	0	0	0	0	1	0.2
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	1	0	0	1	0.2
Involved cyclist(s)		0	0	0	1	2	3	0.6
Occurred during weekday peak periods*		2	5	5	0	0	12	2.4
Wet or icy pavement conditions		5	7	9	7	2	30	6.0
Dark conditions (lit or unlit)		3	8	2	0	2	15	3.0

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

Figure H-7
Collision Diagram: Route 20 at Hosmer Street
Marlborough Police Reports: January 2011–December 2015



SYMBOLS	TYPES OF CRASH	SEVERITY
Moving Vehicle Backing Vehicle Non-Involved Vehicle Pedestiran Parked Vehicle Fixed Object Bicycle Animal	Head On Angle Rear End Sideswipe Out of Control	A/B A Number of Injury Crashes B Total Number of Crashes

Table H-1
Crash Statistics: Route 20 at Hosmer Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		26	21	13	13	13	86	17.2
Severity	Property damage only	21	18	13	9	11	72	14.4
	Non-fatal injury	4	3	0	4	2	13	2.6
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	1	0	0	0	0	1	0.2
Collision type	Single vehicle	1	0	0	1	3	5	1.0
	Rear-end	6	6	5	4	2	23	4.6
	Angle	14	9	4	6	4	37	7.4
	Sideswipe, same direction	4	4	3	0	3	14	2.8
	Sideswipe, opposite direction	0	1	1	2	0	4	0.8
	Head-on	1	1	0	0	1	3	0.6
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	1	0	1	0.2
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		8	8	5	0	0	21	4.2
Wet or icy pavement conditions		12	3	3	5	4	27	5.4
Dark conditions (lit or unlit)		5	3	2	2	3	15	3.0

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

Figure H-8
Collision Diagram: Route 20 at Concord Road
Marlborough Police Reports: January 2011–December 2015

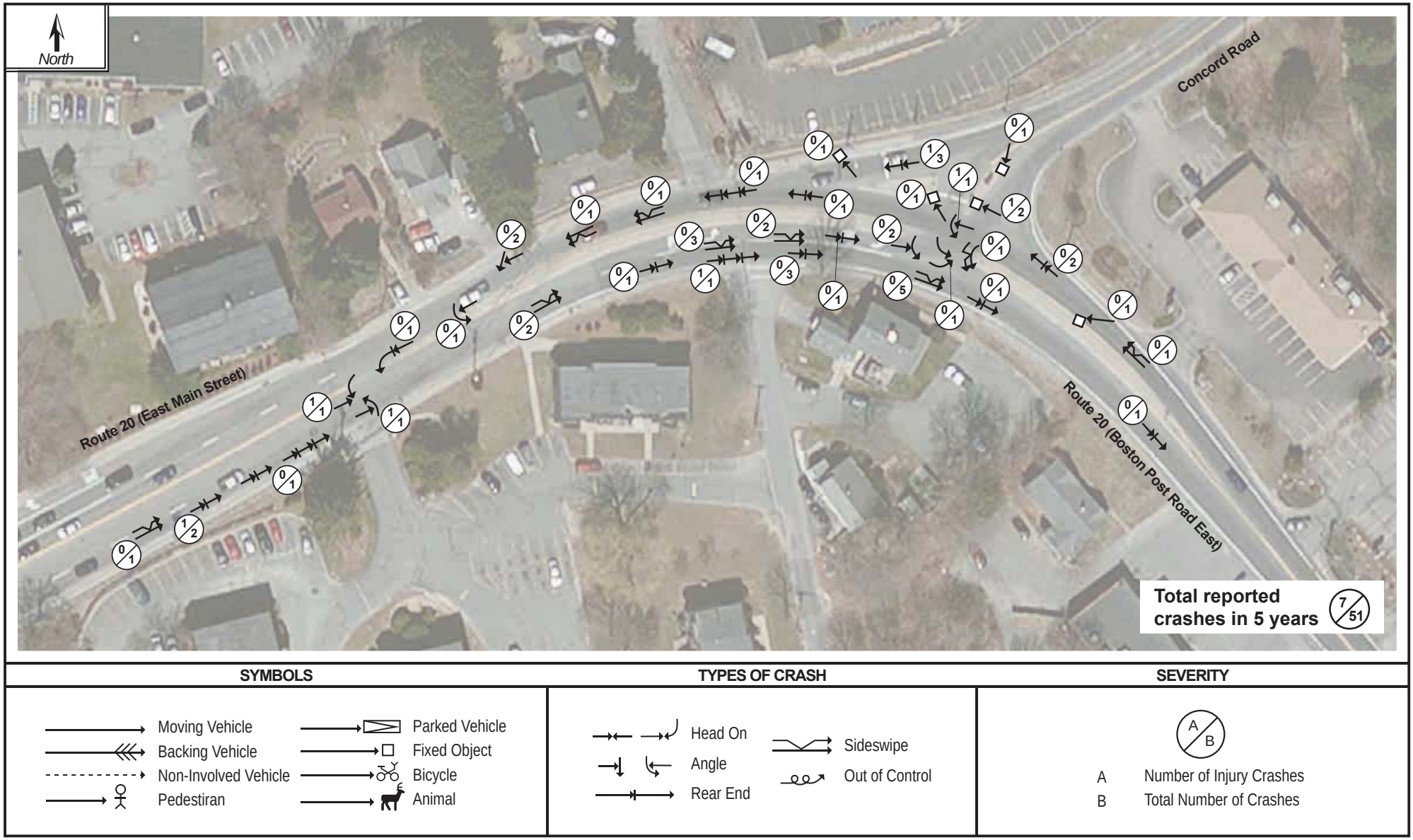
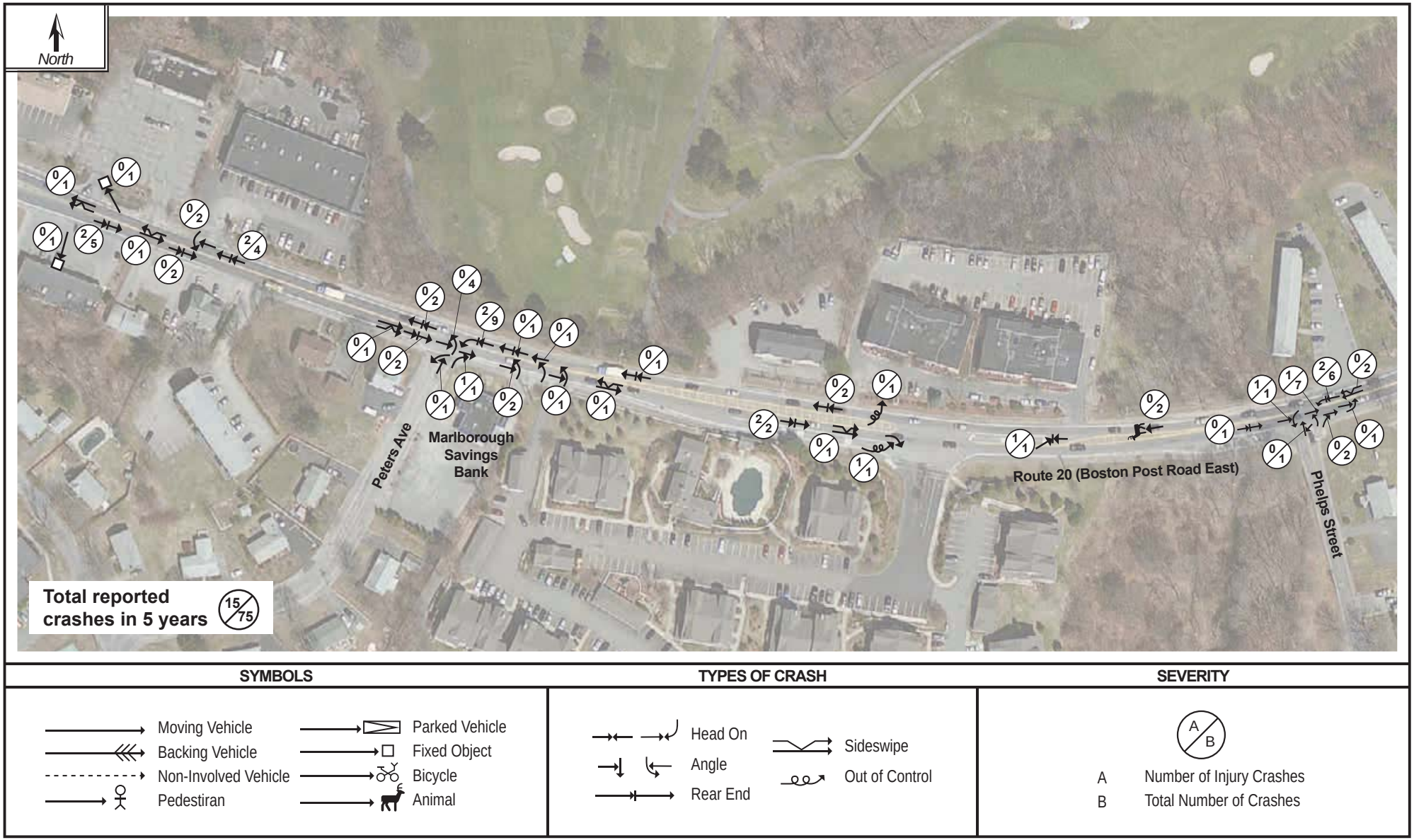


Table H-8
Crash Statistics: Route 20 at Concord Road
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		12	9	18	5	7	51	10.2
Severity	Property damage only	12	6	16	4	6	44	8.8
	Non-fatal injury	0	3	2	1	1	7	1.4
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	1	2	1	0	2	6	1.2
	Rear-end	5	2	5	4	1	17	3.4
	Angle	3	2	5	0	1	11	2.2
	Sideswipe, same direction	3	3	7	1	2	16	3.2
	Sideswipe, opposite direction	0	0	0	0	0	0	0.0
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	1	1	0.2
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		2	4	8	5	6	25	5.0
Wet or icy pavement conditions		5	2	2	1	3	13	2.6
Dark conditions (lit or unlit)		3	0	1	0	2	6	1.2

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

Figure H-9
Collision Diagram: Route 20 between Concord Road and Phelps Street
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

- Moving Vehicle
- Backing Vehicle
- Non-Involved Vehicle
- Pedestiran
- Parked Vehicle
- Fixed Object
- Bicycle
- Animal

TYPES OF CRASH

- Head On
- Angle
- Rear End
- Sideswipe
- Out of Control

SEVERITY

A/B

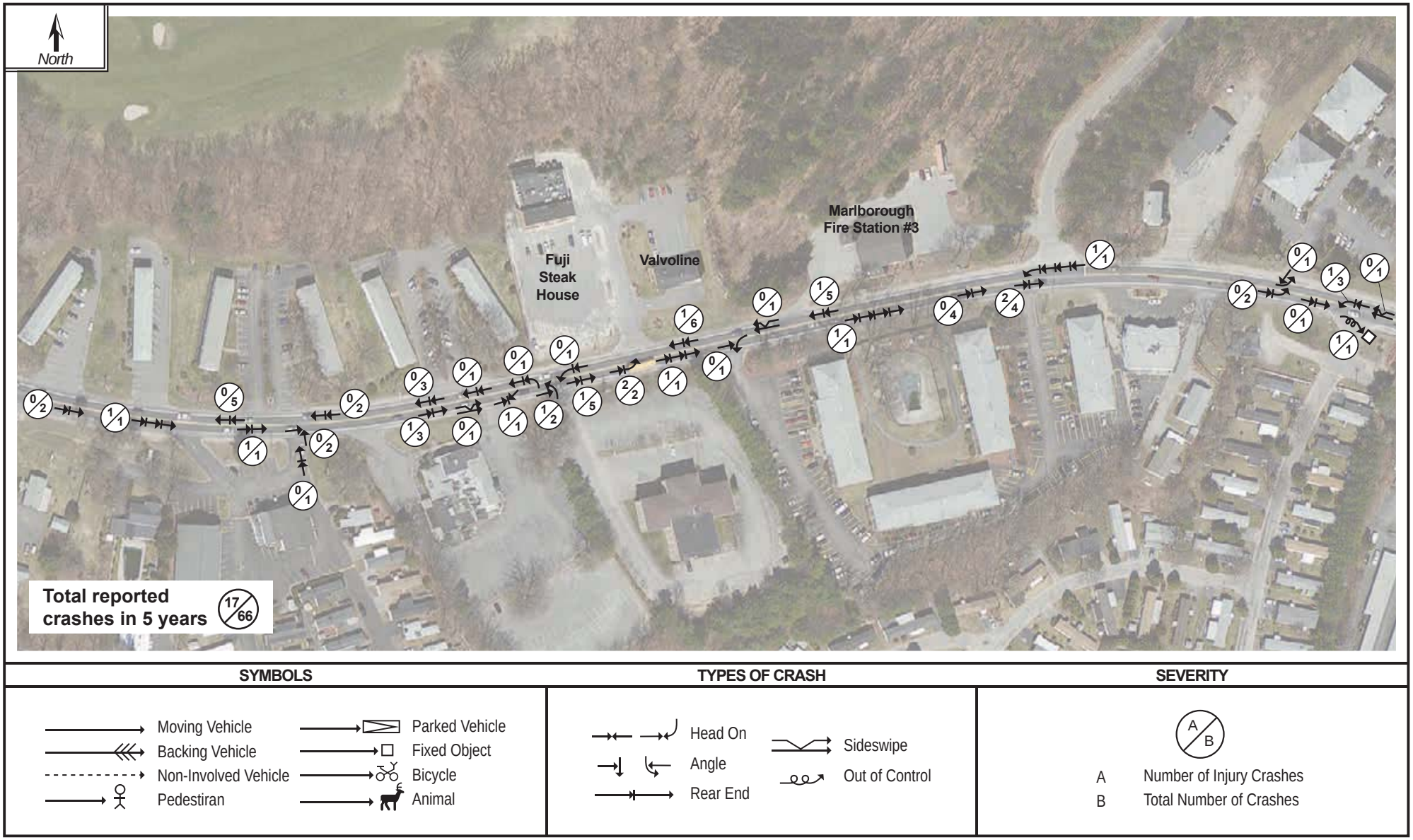
A Number of Injury Crashes
B Total Number of Crashes

Table H-9
Crash Statistics: Route 20 between Concord Road and Phelps Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		18	11	7	14	25	75	15.0
Severity	Property damage only	11	10	7	11	21	60	12.0
	Non-fatal injury	7	1	0	3	4	15	3.0
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	1	2	1	2	1	7	1.4
	Rear-end	12	4	5	4	10	35	7.0
	Angle	5	4	1	3	10	23	4.6
	Sideswipe, same direction	0	1	0	2	2	5	1.0
	Sideswipe, opposite direction	0	0	0	1	2	3	0.6
	Head-on	0	0	0	2	0	2	0.4
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		6	4	3	0	0	13	2.6
Wet or icy pavement conditions		7	0	2	4	11	24	4.8
Dark conditions (lit or unlit)		6	1	2	2	4	15	3.0

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

Figure H-10
Collision Diagram: Route 20 between Phelps Street and Victoria Lane
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

- Moving Vehicle
- Backing Vehicle
- Non-Involved Vehicle
- Pedestiran
- Parked Vehicle
- Fixed Object
- Bicycle
- Animal

TYPES OF CRASH

- Head On
- Angle
- Rear End
- Sideswipe
- Out of Control

SEVERITY

A/B

A Number of Injury Crashes
B Total Number of Crashes

Table H-10
Crash Statistics: Route 20 between Phelps Street and Victoria Lane
Marlboro Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		16	17	13	15	5	66	13.2
Severity	Property damage only	12	11	11	11	4	49	9.8
	Non-fatal injury	4	6	2	4	1	17	3.4
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	1	0	0	0	1	0.2
	Rear-end	13	14	10	14	3	54	10.8
	Angle	2	0	2	0	1	5	1.0
	Sideswipe, same direction	1	0	0	1	0	2	0.4
	Sideswipe, opposite direction	0	0	0	0	0	0	0.0
	Head-on	0	2	1	0	1	4	0.8
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		6	6	8	0	0	20	4.0
Wet or icy pavement conditions		4	4	4	6	2	20	4.0
Dark conditions (lit or unlit)		2	4	1	6	0	13	2.6

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

Figure H-11
Collision Diagram: Route 20 between Victoria Lane and Farm Road
Marlborough Police Reports: January 2011–December 2015

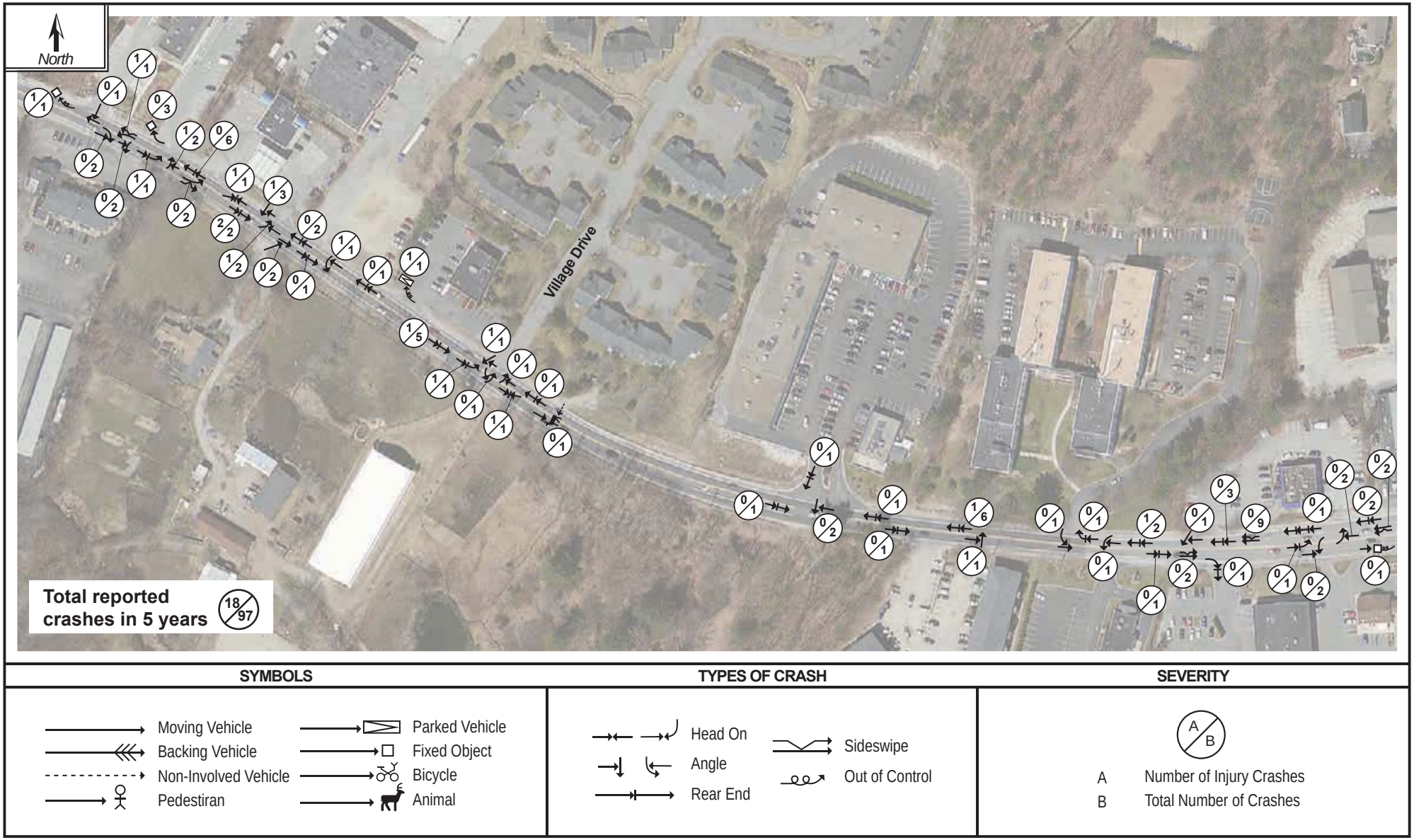
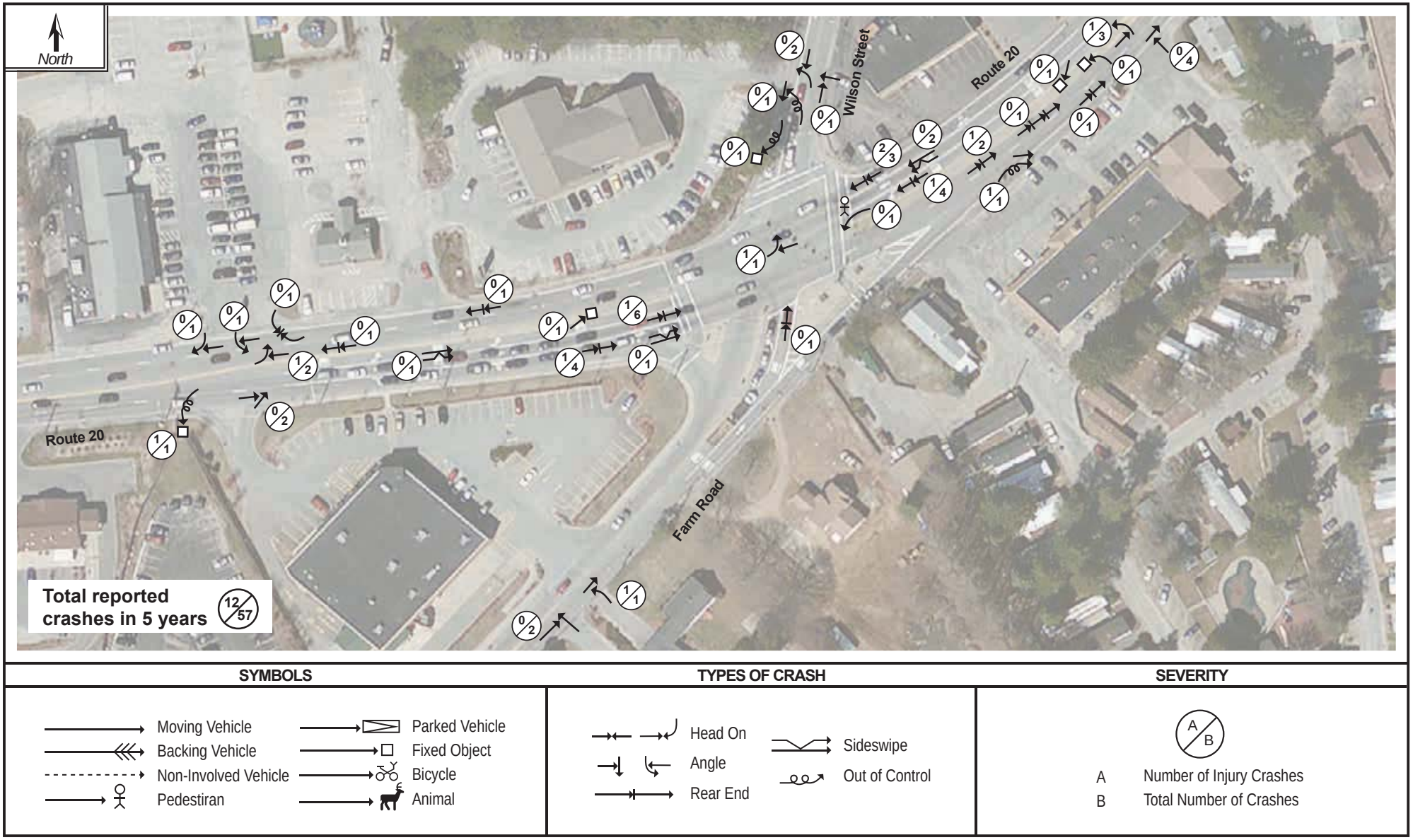


Table H-11
Crash Statistics: Route 20 between Victoria Lane and Farm Road
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		21	14	19	20	23	97	19.4
Severity	Property damage only	16	9	19	20	15	79	15.8
	Non-fatal injury	5	5	0	0	8	18	3.6
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	1	2	2	1	1	7	1.4
	Rear-end	8	8	8	8	7	39	7.8
	Angle	5	2	4	5	11	27	5.4
	Sideswipe, same direction	5	1	5	6	2	19	3.8
	Sideswipe, opposite direction	1	0	0	0	0	1	0.2
	Head-on	1	0	0	0	2	3	0.6
	Rear-to-rear	0	1	0	0	0	1	0.2
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		3	5	8	0	0	16	3.2
Wet or icy pavement conditions		3	3	5	4	7	22	4.4
Dark conditions (lit or unlit)		4	3	3	3	6	19	3.8

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

Figure H-12
Collision Diagram: Route 20 at Farm Road/Wilson Street
Marlborough Police Reports: January 2011–December 2015



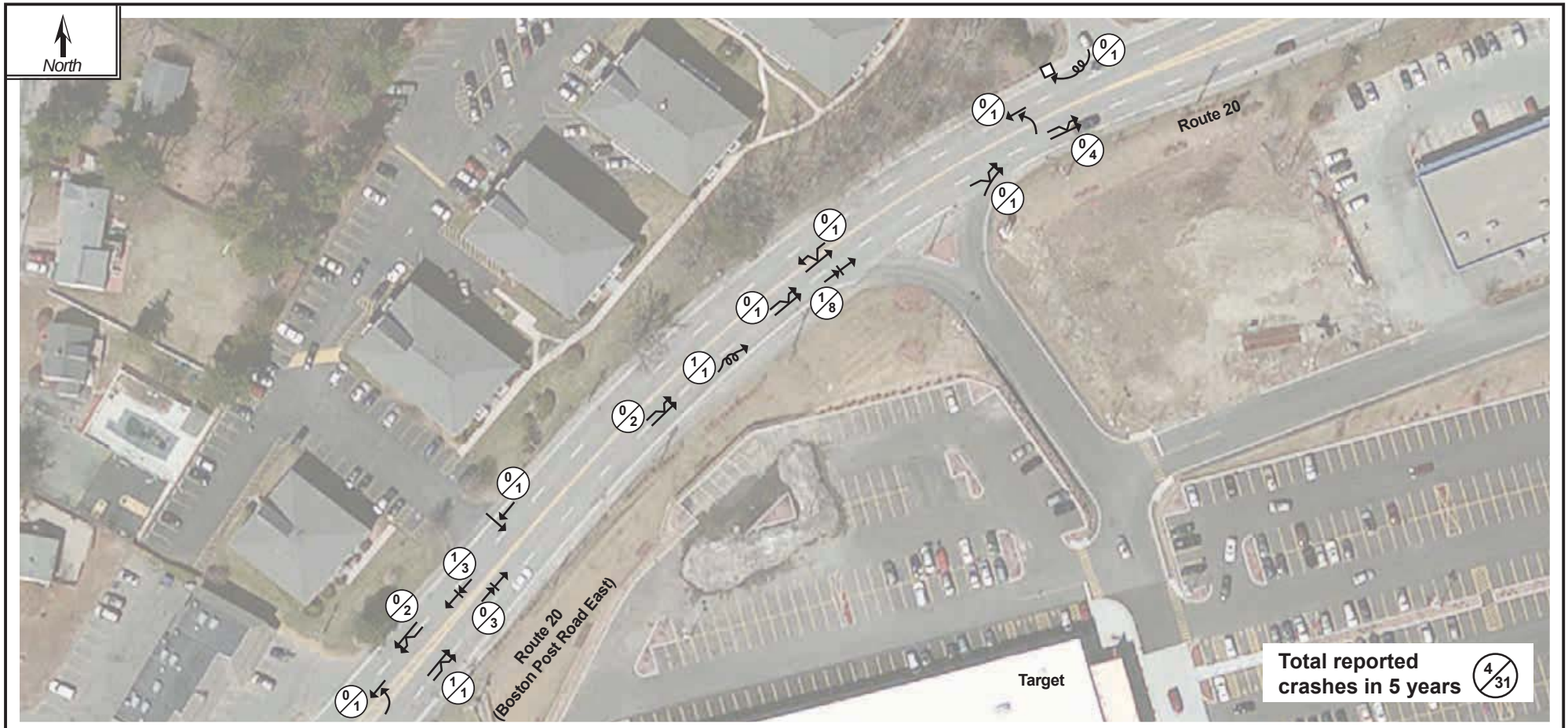
SYMBOLS		TYPES OF CRASH		SEVERITY	
Moving Vehicle	Parked Vehicle	Head On	Sideswipe	A/B	
Backing Vehicle	Fixed Object	Angle	Out of Control	A	Number of Injury Crashes
Non-Involved Vehicle	Bicycle	Rear End		B	Total Number of Crashes
Pedestiran	Animal				

Table H-12
Crash Statistics: Route 20 at Farm Road/Wilson Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		16	13	9	13	6	57	11.4
Severity	Property damage only	14	8	6	12	5	45	9.0
	Non-fatal injury	2	5	3	1	1	12	2.4
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	2	2	2	0	6	1.2
	Rear-end	8	6	3	5	2	24	4.8
	Angle	4	3	3	4	3	17	3.4
	Sideswipe, same direction	1	1	1	1	1	5	1.0
	Sideswipe, opposite direction	0	0	0	1	0	1	0.2
	Head-on	2	1	0	0	0	3	0.6
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	1	0	0	0	0	1	0.2
Involved pedestrian(s)		1	0	0	0	0	1	0.2
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		5	10	2	9	5	31	6.2
Wet or icy pavement conditions		4	1	0	2	0	7	1.4
Dark conditions (lit or unlit)		2	1	0	3	0	6	1.2

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

Figure H-13
Collision Diagram: Route 20 between Farm Road and Dicenzo Boulevard
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

- Moving Vehicle
- Backing Vehicle
- Non-Involved Vehicle
- Pedestiran
- Parked Vehicle
- Fixed Object
- Bicycle
- Animal

TYPES OF CRASH

- Head On
- Angle
- Rear End
- Sideswipe
- Out of Control

SEVERITY

A/B

A Number of Injury Crashes
B Total Number of Crashes

Table H-13
Crash Statistics: Route 20 between Farm Road and Dicenzo Boulevard
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		9	6	4	6	6	31	6.2
Severity	Property damage only	9	5	3	4	6	27	5.4
	Non-fatal injury	0	1	1	2	0	4	0.8
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	2	0	0	0	2	0.4
	Rear-end	5	1	2	3	3	14	2.8
	Angle	0	2	0	1	1	4	0.8
	Sideswipe, same direction	4	1	2	2	1	10	2.0
	Sideswipe, opposite direction	0	0	0	0	1	1	0.2
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		2	4	2	6	2	16	3.2
Wet or icy pavement conditions		1	1	0	0	2	4	0.8
Dark conditions (lit or unlit)		0	0	0	0	1	1	0.2

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

Figure H-14
Collision Diagram: Route 20 at Dicenzo Boulevard
Marlborough Police Reports: January 2011–December 2015

SYMBOLS

- Moving Vehicle
- Backing Vehicle
- Non-Involved Vehicle
- Pedestiran
- Parked Vehicle
- Fixed Object
- Bicycle
- Animal

TYPES OF CRASH

- Head On
- Angle
- Rear End
- Sideswipe
- Out of Control

SEVERITY

A/B

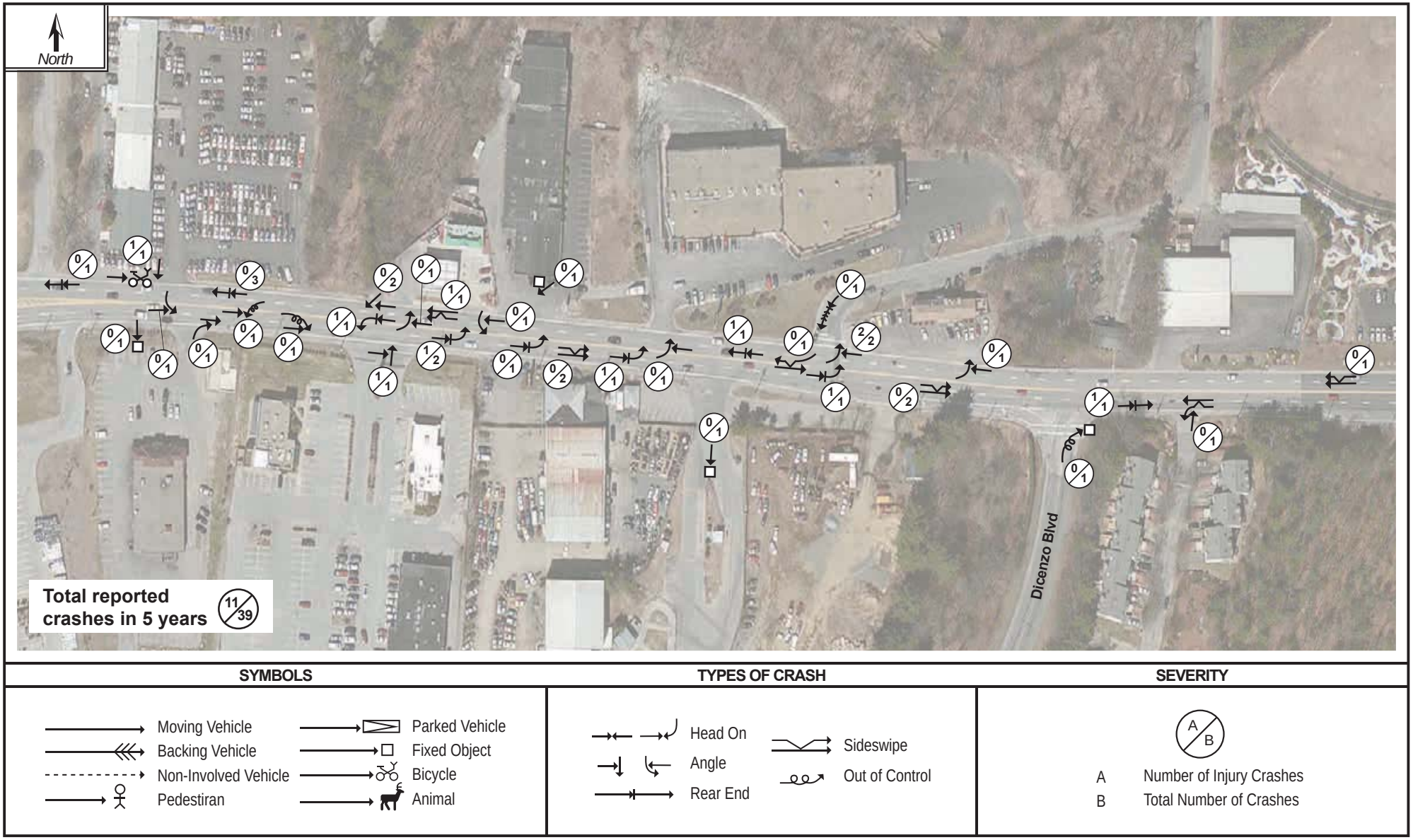
A Number of Injury Crashes
B Total Number of Crashes

Table H-14
Crash Statistics: Route 20 at Dicenzo Boulevard
Marlborough Police Department Crash Data 2011-15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		4	4	4	8	8	28	5.6
Severity	Property damage only	3	3	3	7	7	23	4.6
	Non-fatal injury	1	1	1	1	1	5	1.0
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	0	0	0	0	0	0.0
	Rear-end	2	1	0	4	3	10	2.0
	Angle	2	2	0	2	5	11	2.2
	Sideswipe, same direction	0	1	2	2	0	5	1.0
	Sideswipe, opposite direction	0	0	1	0	0	1	0.2
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	1	0	0	1	0.2
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		1	1	4	7	6	19	3.8
Wet or icy pavement conditions		3	1	1	2	2	9	1.8
Dark conditions (lit or unlit)		0	0	1	2	0	3	0.6

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

Figure H-15
Collision Diagram: Route 20 between Dicenzo Boulevard and Raytheon Driveway
Marlborough Police Reports: January 2011–December 2015



SYMBOLS

- Moving Vehicle
- Backing Vehicle
- Non-Involved Vehicle
- Pedestiran
- Parked Vehicle
- Fixed Object
- Bicycle
- Animal

TYPES OF CRASH

- Head On
- Angle
- Rear End
- Sideswipe
- Out of Control

SEVERITY

A/B

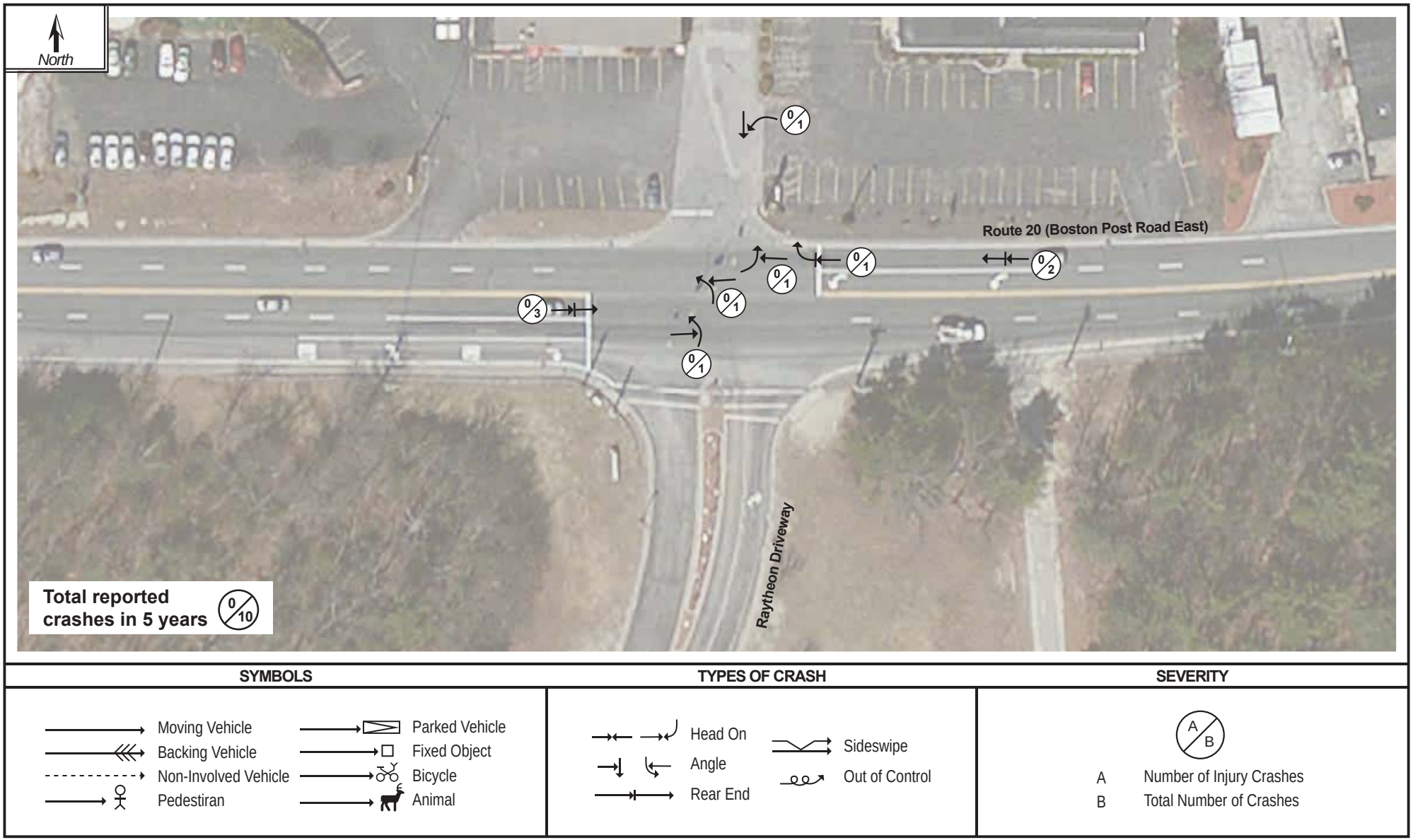
A Number of Injury Crashes
B Total Number of Crashes

Table H-15
Crash Statistics: Route 20 between Dicenzo Boulevard and Raytheon Driveway
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		10	5	8	9	7	39	7.8
Severity	Property damage only	5	4	7	4	7	27	5.4
	Non-fatal injury	5	1	0	5	0	11	2.2
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	1	0	0	1	0.2
Collision type	Single vehicle	1	1	1	0	1	4	0.8
	Rear-end	4	2	1	4	1	12	2.4
	Angle	2	1	3	3	1	10	2.0
	Sideswipe, same direction	1	1	3	1	2	8	1.6
	Sideswipe, opposite direction	1	0	0	0	2	3	0.6
	Head-on	1	0	0	0	0	1	0.2
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	1	0	1	0.2
Occurred during weekday peak periods*		3	2	4	9	5	23	4.6
Wet or icy pavement conditions		1	2	3	2	3	11	2.2
Dark conditions (lit or unlit)		0	2	0	1	3	6	1.2

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

Figure H-16
Collision Diagram: Route 20 at Raytheon Driveway
Marlborough Police Reports: January 2011–December 2015



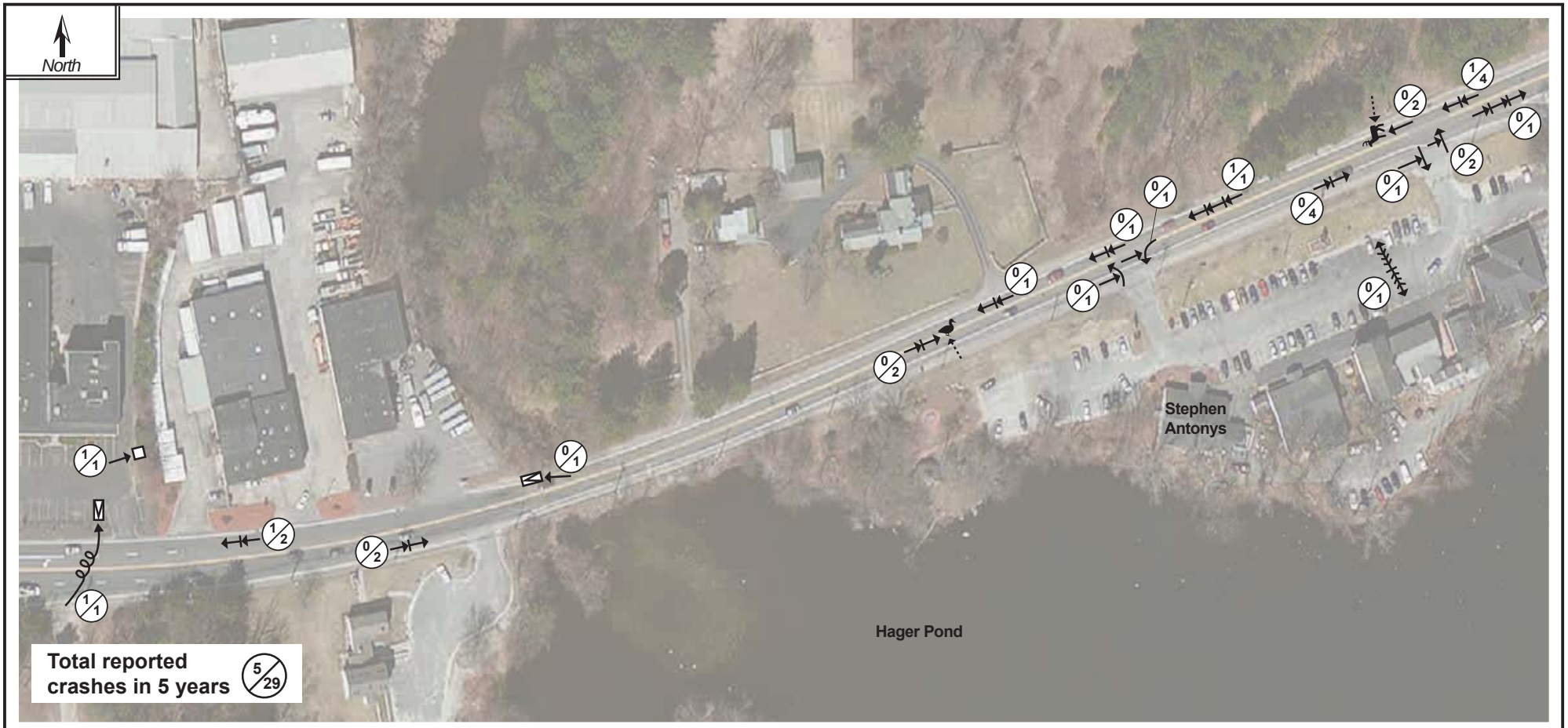
SYMBOLS	TYPES OF CRASH	SEVERITY
Moving Vehicle Backing Vehicle Non-Involved Vehicle Pedestiran Parked Vehicle Fixed Object Bicycle Animal	Head On Angle Rear End Sideswipe Out of Control	A/B A Number of Injury Crashes B Total Number of Crashes

Table H-16
Crash Statistics: Route 20 at Raytheon Driveway
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		2	0	3	2	3	10	2.0
Severity	Property damage only	2	0	3	2	3	10	2.0
	Non-fatal injury	0	0	0	0	0	0	0.0
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	0	0	0	0	0	0.0
	Rear-end	1	0	3	1	1	6	1.2
	Angle	1	0	0	1	2	4	0.8
	Sideswipe, same direction	0	0	0	0	0	0	0.0
	Sideswipe, opposite direction	0	0	0	0	0	0	0.0
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		2	0	3	1	3	9	1.8
Wet or icy pavement conditions		1	0	2	1	1	5	1.0
Dark conditions (lit or unlit)		0	0	1	0	0	1	0.2

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

Figure H-17
Collision Diagram: Route 20 between Raytheon Driveway and Wayside Inn Road
Marlborough Police Reports: January 2011–December 2015



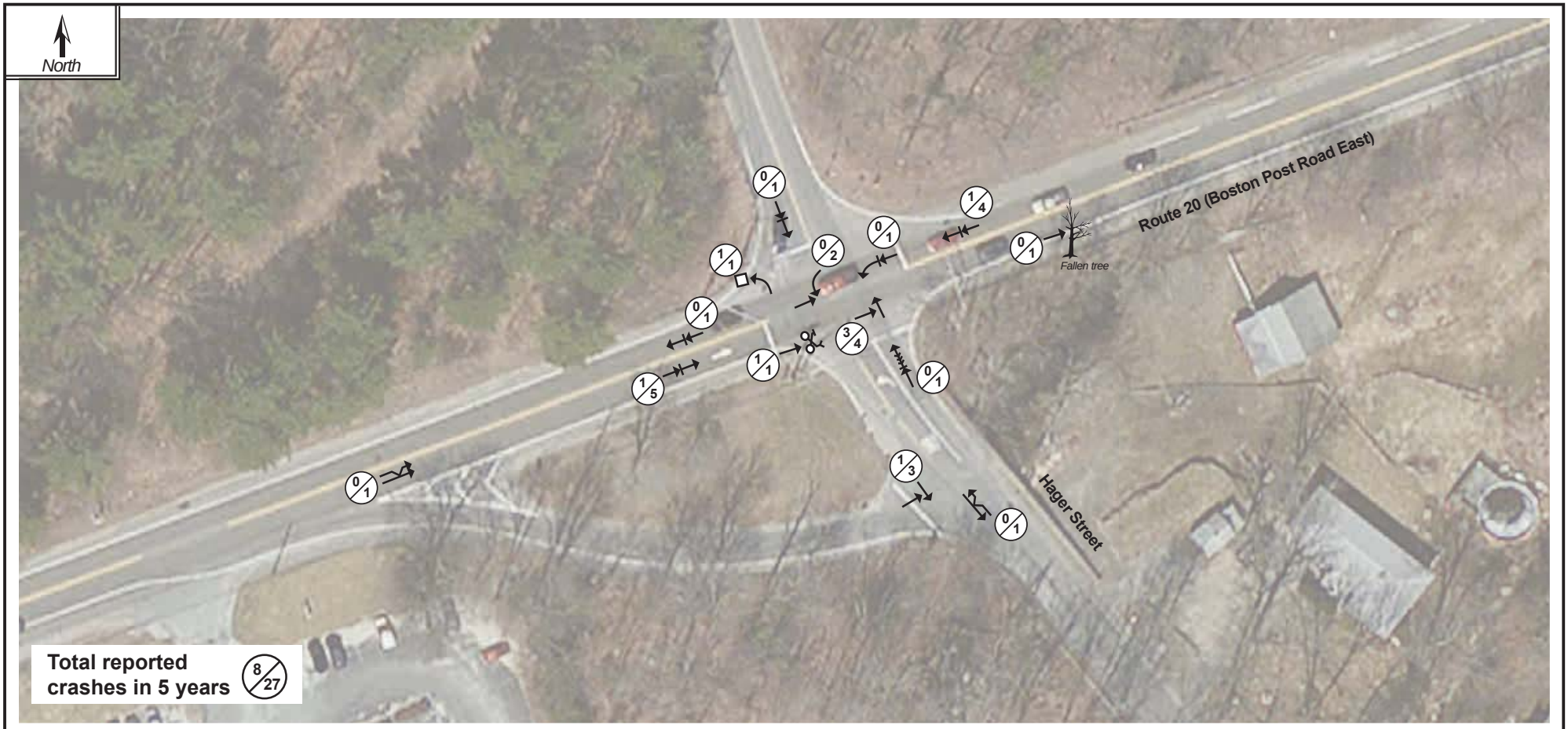
SYMBOLS		TYPES OF CRASH		SEVERITY	
Moving Vehicle	Parked Vehicle	Head On	Sideswipe	A/B	
Backing Vehicle	Fixed Object	Angle	Out of Control	A	Number of Injury Crashes
Non-Involved Vehicle	Bicycle	Rear End		B	Total Number of Crashes
Pedestiran	Animal				

Table H-17
Crash Statistics: Route 20 between Raytheon Driveway and Wayside Inn Road
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		8	7	3	6	5	29	5.8
Severity	Property damage only	6	7	3	5	3	24	4.8
	Non-fatal injury	2	0	0	1	2	5	1.0
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	1	0	0	1	2	0.4
	Rear-end	7	3	1	5	3	19	3.8
	Angle	0	1	2	0	1	4	0.8
	Sideswipe, same direction	0	0	0	0	0	0	0.0
	Sideswipe, opposite direction	0	1	0	1	0	2	0.4
	Head-on	1	0	0	0	0	1	0.2
	Rear-to-rear	0	1	0	0	0	1	0.2
	Not reported/unknown	0	0	0	0	0	0	0.0
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	0	0	0.0
Occurred during weekday peak periods*		5	2	0	0	0	7	1.4
Wet or icy pavement conditions		1	2	0	1	0	4	0.8
Dark conditions (lit or unlit)		0	1	0	0	1	2	0.4

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

Figure H-18
Collision Diagram: Route 20 at Wayside Inn Road/Hager Street
Marlborough Police Reports: January 2011–December 2015



SYMBOLS	TYPES OF CRASH	SEVERITY
Moving Vehicle	Head On	A/B
Backing Vehicle	Angle	A Number of Injury Crashes
Non-Involved Vehicle	Rear End	B Total Number of Crashes
Pedestiran	Sideswipe	
Parked Vehicle	Out of Control	
Fixed Object		
Bicycle		
Animal		

Table H-18
Crash Statistics: Route 20 at Wayside Inn Road/Hager Street
Marlborough Police Crash Data 2011–15

Statistics Period		2011	2012	2013	2014	2015	5-Yr. Total	Annual Avg.
Total number of crashes		8	4	3	6	6	27	5.4
Severity	Property damage only	7	2	1	5	4	19	3.8
	Non-fatal injury	1	2	2	1	2	8	1.6
	Fatality	0	0	0	0	0	0	0.0
	Not reported/unknown	0	0	0	0	0	0	0.0
Collision type	Single vehicle	0	0	0	0	1	1	0.2
	Rear-end	2	3	1	3	4	13	2.6
	Angle	4	1	2	2	1	10	2.0
	Sideswipe, same direction	0	0	0	1	0	1	0.2
	Sideswipe, opposite direction	1	0	0	0	0	1	0.2
	Head-on	0	0	0	0	0	0	0.0
	Rear-to-rear	0	0	0	0	0	0	0.0
	Not reported/unknown	1	0	0	0	0	1	0.2
Involved pedestrian(s)		0	0	0	0	0	0	0.0
Involved cyclist(s)		0	0	0	0	1	1	0.2
Occurred during weekday peak periods*		4	0	1	6	4	15	3.0
Wet or icy pavement conditions		2	0	1	1	1	5	1.0
Dark conditions (lit or unlit)		2	0	1	0	0	3	0.6

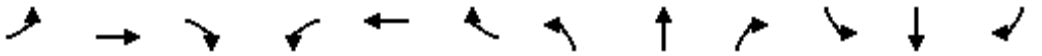
* Peak periods are defined as 7:00–10:00 AM and 3:30–6:30 PM.

APPENDIX I

Intersection Capacity Analyses
Weekday AM Peak Hour
Projected 2040 Traffic Conditions with Proposed Improvements

Intersection Capacity Analysis
Route 20 at Route 85, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	43	318	231	210	246	5	180	333	97	19	439	22
Future Volume (vph)	43	318	231	210	246	5	180	333	97	19	439	22
Satd. Flow (prot)	1646	1733	1473	1678	1761	0	1631	1717	1459	1694	3362	0
Flt Permitted	0.578			0.241			0.241			0.416		
Satd. Flow (perm)	1002	1733	1473	426	1761	0	414	1717	1459	742	3362	0
Satd. Flow (RTOR)			272		1				142		4	
Confl. Peds. (#/hr)							1					1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.93	0.93	0.93
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	6%	6%	6%	4%	4%	4%	7%	7%	7%	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)	51	374	272	247	295	0	212	392	114	22	530	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA	Perm	pm+pt	NA	
Protected Phases	5	2		1	6		3	8		7	4	
Permitted Phases	2		2	6			8		8	4		
Total Split (s)	8.0	26.0	26.0	12.0	30.0		13.0	26.0	26.0	10.0	23.0	
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0		4.0	5.0	5.0	4.0	5.0	
Act Effct Green (s)	26.5	21.4	21.4	34.6	29.0		30.6	26.3	26.3	23.7	16.8	
Actuated g/C Ratio	0.34	0.28	0.28	0.44	0.37		0.39	0.34	0.34	0.30	0.22	
v/c Ratio	0.14	0.79	0.45	0.77	0.45		0.69	0.67	0.19	0.07	0.73	
Control Delay	17.5	42.0	6.7	36.6	25.0		33.3	33.1	4.3	18.4	36.4	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	17.5	42.0	6.7	36.6	25.0		33.3	33.1	4.3	18.4	36.4	
LOS	B	D	A	D	C		C	C	A	B	D	
Approach Delay		26.4			30.3			28.6			35.7	
Approach LOS		C			C			C			D	
Queue Length 50th (ft)	12	156	0	69	106		61	131	0	6	114	
Queue Length 95th (ft)	49	#436	68	#287	263		#205	#464	29	27	#264	
Internal Link Dist (ft)		424			226			511			208	
Turn Bay Length (ft)	350						220			50		
Base Capacity (vph)	374	475	601	320	656		306	581	587	302	794	
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	0.14	0.79	0.45	0.77	0.45		0.69	0.67	0.19	0.07	0.67	

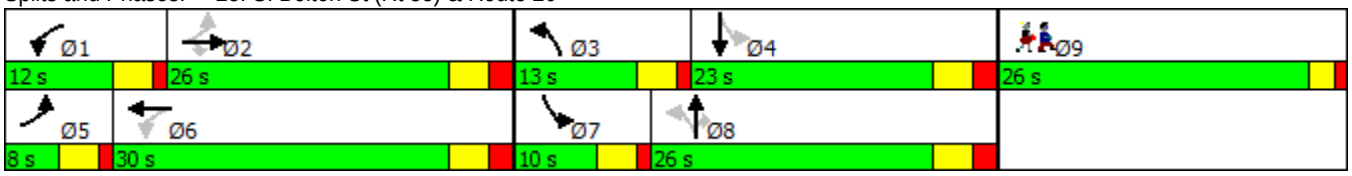
Intersection Summary		
Cycle Length: 100		
Actuated Cycle Length: 77.8		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.79		
Intersection Signal Delay: 29.9	Intersection LOS: C	
Intersection Capacity Utilization 69.8%	ICU Level of Service C	
Analysis Period (min) 15		

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	26.0
Total Lost Time (s)	
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

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

Splits and Phases: 25: S. Bolton St (Rt 85) & Route 20



Intersection Capacity Analysis
Route 20 at Main Street, Marlborough

11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	78	67	10	56	174	19	8	376	47	7	372	105
Future Volume (vph)	78	67	10	56	174	19	8	376	47	7	372	105
Satd. Flow (prot)	1678	1726	0	1711	1767	0	1616	1667	0	0	1747	1487
Flt Permitted	0.593			0.690			0.385				0.988	
Satd. Flow (perm)	1037	1726	0	1231	1767	0	655	1667	0	0	1728	1447
Satd. Flow (RTOR)		7			5			9				96
Confl. Peds. (#/hr)	6		4	4		6			5	5		6
Confl. Bikes (#/hr)												
Peak Hour Factor	0.80	0.80	0.80	0.92	0.92	0.92	0.80	0.80	0.80	0.88	0.88	0.88
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	4%	4%	4%	2%	2%	2%	8%	8%	8%	5%	5%	5%
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)	104	103	0	65	224	0	11	566	0	0	461	128
Turn Type	Perm	NA		Perm	NA		Perm	NA		Perm	NA	Perm
Protected Phases		4			8			2			6	
Permitted Phases	4			8			2			6		6
Total Split (s)	22.0	22.0		22.0	22.0		43.0	43.0		43.0	43.0	43.0
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0			5.0	5.0
Act Effct Green (s)	14.7	14.7		14.7	14.7		23.8	23.8			23.8	23.8
Actuated g/C Ratio	0.28	0.28		0.28	0.28		0.45	0.45			0.45	0.45
v/c Ratio	0.36	0.21		0.19	0.45		0.04	0.75			0.59	0.18
Control Delay	25.3	20.2		22.1	23.5		11.8	21.2			16.3	5.3
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0			0.0	0.0
Total Delay	25.3	20.2		22.1	23.5		11.8	21.2			16.3	5.3
LOS	C	C		C	C		B	C			B	A
Approach Delay		22.8			23.2			21.0			13.9	
Approach LOS		C			C			C			B	
Queue Length 50th (ft)	21	19		13	46		2	113			85	4
Queue Length 95th (ft)	93	82		70	#198		13	336			295	42
Internal Link Dist (ft)		297			75			453			795	
Turn Bay Length (ft)	150											100
Base Capacity (vph)	378	635		449	648		505	1288			1333	1138
Starvation Cap Reductn	0	0		0	0		0	0			0	0
Spillback Cap Reductn	0	0		0	0		0	0			0	0
Storage Cap Reductn	0	0		0	0		0	0			0	0
Reduced v/c Ratio	0.28	0.16		0.14	0.35		0.02	0.44			0.35	0.11

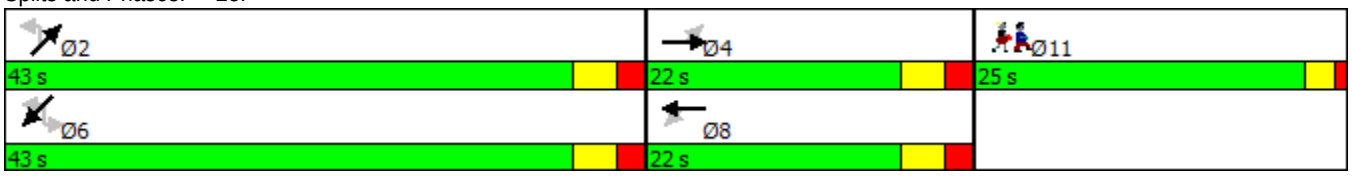
Intersection Summary			
Cycle Length: 90			
Actuated Cycle Length: 52.7			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.75			
Intersection Signal Delay: 19.1		Intersection LOS: B	
Intersection Capacity Utilization 55.5%		ICU Level of Service B	
Analysis Period (min) 15			

Lane Group	Ø11
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
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	11
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
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

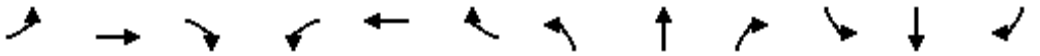
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 23:



Intersection Capacity Analysis
Route 20 at Lincoln Street, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	4	403	8	396	353	251	10	71	437	266	99	8
Future Volume (vph)	4	403	8	396	353	251	10	71	437	266	99	8
Satd. Flow (prot)	0	3441	0	1711	1689	0	0	1790	1531	0	1751	0
Flt Permitted		0.946		0.950				0.938			0.717	
Satd. Flow (perm)	0	3259	0	1711	1689	0	0	1689	1531	0	1300	0
Satd. Flow (RTOR)		2			64				55		1	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.93	0.93	0.93	0.75	0.75	0.75	0.84	0.84	0.84
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	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	483	0	456	695	0	0	115	623	0	475	0
Turn Type	Perm	NA		Prot	NA		Perm	NA	pm+ov	Perm	NA	
Protected Phases		2		1	6			4	1		8	
Permitted Phases	2						4		4	8		
Total Split (s)	25.0	25.0		35.0	60.0		35.0	35.0	35.0	35.0	35.0	
Total Lost Time (s)		5.0		5.0	5.0			5.0	5.0		5.0	
Act Effct Green (s)		16.7		26.3	48.1			30.3	61.6		30.3	
Actuated g/C Ratio		0.19		0.30	0.54			0.34	0.70		0.34	
v/c Ratio		0.78		0.90	0.73			0.20	0.58		1.07	
Control Delay		44.1		52.1	18.8			23.9	9.0		93.6	
Queue Delay		0.0		0.0	0.0			0.0	0.0		0.0	
Total Delay		44.1		52.1	18.8			23.9	9.0		93.6	
LOS		D		D	B			C	A		F	
Approach Delay		44.1			32.0			11.3			93.6	
Approach LOS		D			C			B			F	
Queue Length 50th (ft)		142		246	249			49	142		~328	
Queue Length 95th (ft)		198		#423	383			76	172		#484	
Internal Link Dist (ft)		289			228			617			398	
Turn Bay Length (ft)									150			
Base Capacity (vph)		745		585	1083			578	1149		445	
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		0.65		0.78	0.64			0.20	0.54		1.07	

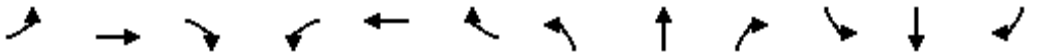
Intersection Summary	
Cycle Length: 95	
Actuated Cycle Length: 88.4	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 1.07	
Intersection Signal Delay: 39.0	Intersection LOS: D
Intersection Capacity Utilization 89.6%	ICU Level of Service E
Analysis Period (min) 15	

~ 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: 21:

Intersection Capacity Analysis
Route 20 at Curtis Avenue, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	78	973	43	29	920	19	42	19	54	27	6	52
Future Volume (vph)	78	973	43	29	920	19	42	19	54	27	6	52
Satd. Flow (prot)	1662	3304	0	1678	3355	1501	0	1641	0	1535	1566	1446
Flt Permitted	0.950			0.950				0.982		0.950	0.969	
Satd. Flow (perm)	1662	3304	0	1678	3355	1501	0	1641	0	1535	1566	1446
Satd. Flow (RTOR)		6				85		39				206
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.82	0.82	0.82	0.71	0.71	0.71
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	5%	5%	5%	4%	4%	4%	3%	3%	3%	8%	8%	8%
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 (%)										40%		
Lane Group Flow (vph)	94	1222	0	32	1004	21	0	150	0	25	25	78
Turn Type	Prot	NA		Prot	NA	pm+ov	Split	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4	8	8		4	4	
Permitted Phases						6						4
Total Split (s)	15.0	44.0		11.0	40.0	21.0	14.0	14.0		21.0	21.0	21.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	9.5	51.9		6.0	46.3	59.5		10.5		8.2	8.2	8.2
Actuated g/C Ratio	0.11	0.58		0.07	0.51	0.66		0.12		0.09	0.09	0.09
v/c Ratio	0.54	0.64		0.29	0.58	0.02		0.66		0.18	0.18	0.25
Control Delay	49.6	18.1		33.2	10.1	0.0		43.6		38.7	38.6	1.8
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	49.6	18.1		33.2	10.1	0.0		43.6		38.7	38.6	1.8
LOS	D	B		C	B	A		D		D	D	A
Approach Delay		20.3			10.6			43.6			16.2	
Approach LOS		C			B			D			B	
Queue Length 50th (ft)	51	270		18	88	0		59		14	14	0
Queue Length 95th (ft)	100	403		m29	118	m0		#131		28	28	0
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	193	1907		111	1725	1130		233		272	278	426
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.49	0.64		0.29	0.58	0.02		0.64		0.09	0.09	0.18

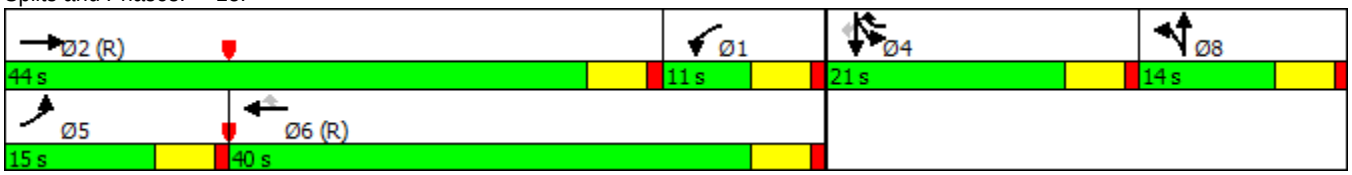
Intersection Summary		
Cycle Length: 90		
Actuated Cycle Length: 90		
Offset: 0 (0%), Referenced to phase 2:EBT and 6:WBT, Start of Green, Master Intersection		
Control Type: Actuated-Coordinated		
Maximum v/c Ratio: 0.66		
Intersection Signal Delay: 17.6	Intersection LOS: B	
Intersection Capacity Utilization 61.5%	ICU Level of Service B	

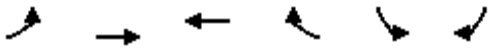
Analysis Period (min) 15

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

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

Splits and Phases: 18:



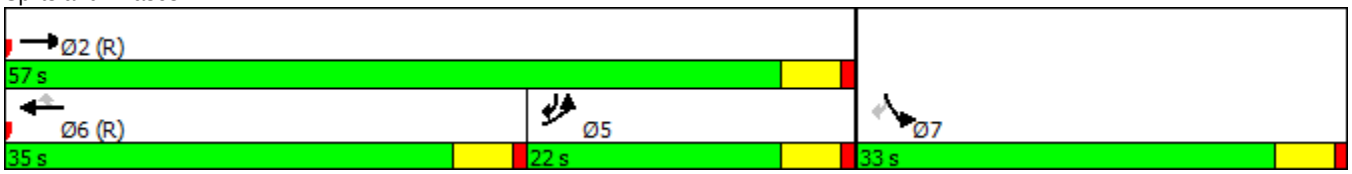


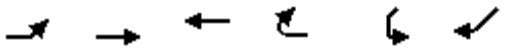
Lane Group	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Traffic Volume (vph)	156	883	681	110	300	265
Future Volume (vph)	156	883	681	110	300	265
Satd. Flow (prot)	1662	3323	3355	1501	1694	1516
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1662	3323	3355	1501	1694	1516
Satd. Flow (RTOR)				128		45
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.88	0.88	0.92	0.92	0.90	0.90
Growth Factor	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	5%	5%	4%	4%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	190	1074	792	128	357	315
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov
Protected Phases	5	2	6		7	5
Permitted Phases				6		7
Total Split (s)	22.0	57.0	35.0	35.0	33.0	22.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0
Act Effct Green (s)	14.8	56.7	36.9	36.9	23.3	43.1
Actuated g/C Ratio	0.16	0.63	0.41	0.41	0.26	0.48
v/c Ratio	0.70	0.51	0.58	0.19	0.82	0.42
Control Delay	37.6	2.7	14.5	1.4	46.3	13.7
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	37.6	2.7	14.5	1.4	46.3	13.7
LOS	D	A	B	A	D	B
Approach Delay		7.9	12.6		31.0	
Approach LOS		A	B		C	
Queue Length 50th (ft)	110	27	187	7	188	91
Queue Length 95th (ft)	183	30	92	2	275	133
Internal Link Dist (ft)		239	315		492	
Turn Bay Length (ft)	300			150		100
Base Capacity (vph)	313	2094	1376	691	527	731
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	0.61	0.51	0.58	0.19	0.68	0.43

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 85 (94%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.82	
Intersection Signal Delay: 14.9	Intersection LOS: B
Intersection Capacity Utilization 59.7%	ICU Level of Service B

Analysis Period (min) 15

Splits and Phases: 14:





Lane Group	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (vph)	97	1050	621	19	40	191
Future Volume (vph)	97	1050	621	19	40	191
Satd. Flow (prot)	1678	1949	3424	0	1752	1672
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1678	1949	3424	0	1752	1672
Satd. Flow (RTOR)			5			185
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	4%	4%	5%	5%	3%	3%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	113	1221	744	0	47	222
Turn Type	Prot	NA	NA		Prot	pm+ov
Protected Phases	5	2	6		7	5
Permitted Phases						7
Total Split (s)	16.0	69.0	53.0		21.0	16.0
Total Lost Time (s)	4.0	5.0	5.0		5.0	4.0
Act Effct Green (s)	18.4	77.5	53.0		9.1	28.0
Actuated g/C Ratio	0.20	0.86	0.59		0.10	0.31
v/c Ratio	0.33	0.73	0.37		0.27	0.34
Control Delay	21.0	9.3	14.5		39.5	4.7
Queue Delay	0.0	0.0	0.0		0.0	0.0
Total Delay	21.0	9.3	14.5		39.5	4.7
LOS	C	A	B		D	A
Approach Delay		10.2	14.5		10.8	
Approach LOS		B	B		B	
Queue Length 50th (ft)	36	207	125		26	13
Queue Length 95th (ft)	m68	#654	225		53	45
Internal Link Dist (ft)		53	224		402	
Turn Bay Length (ft)						50
Base Capacity (vph)	376	1677	2215		311	676
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	0.30	0.73	0.34		0.15	0.33

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 73 (81%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.73	
Intersection Signal Delay: 11.6	Intersection LOS: B
Intersection Capacity Utilization 72.5%	ICU Level of Service C

Analysis Period (min) 15

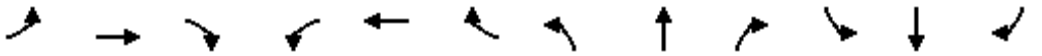
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

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

Splits and Phases: 11:

Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	37	859	82	198	400	15	91	44	444	62	82	58
Future Volume (vph)	37	859	82	198	400	15	91	44	444	62	82	58
Satd. Flow (prot)	1736	3471	1553	1703	3389	0	1752	1845	1568	0	1824	1583
Flt Permitted	0.950			0.950			0.950				0.979	
Satd. Flow (perm)	1736	3471	1553	1703	3389	0	1752	1845	1568	0	1824	1583
Satd. Flow (RTOR)			136		3							136
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.94	0.94	0.94	0.91	0.91	0.91	0.78	0.78	0.78
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	4%	4%	4%	6%	6%	6%	3%	3%	3%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	41	957	91	225	472	0	107	52	522	0	197	80
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	25.0	39.0	39.0	25.0	39.0		14.0	14.0	25.0	17.0	17.0	17.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	8.0	32.7	32.7	20.2	49.9		9.0	9.0	33.4		12.1	12.1
Actuated g/C Ratio	0.08	0.33	0.33	0.21	0.51		0.09	0.09	0.34		0.12	0.12
v/c Ratio	0.29	0.83	0.15	0.64	0.27		0.67	0.31	0.98		0.88	0.25
Control Delay	50.6	38.5	2.1	47.5	17.3		66.9	50.5	67.6		80.1	2.8
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	50.6	38.5	2.1	47.5	17.3		66.9	50.5	67.6		80.1	2.8
LOS	D	D	A	D	B		E	D	E		F	A
Approach Delay		36.0			27.0			66.2			57.8	
Approach LOS		D			C			E			E	
Queue Length 50th (ft)	24	265	0	124	84		63	30	299		118	0
Queue Length 95th (ft)	67	#526	13	#294	189		#184	81	#750		#259	0
Internal Link Dist (ft)		394			914			205			111	
Turn Bay Length (ft)	200			300			75		150			
Base Capacity (vph)	356	1212	631	349	1720		161	170	532		225	314
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	0.12	0.79	0.14	0.64	0.27		0.66	0.31	0.98		0.88	0.25

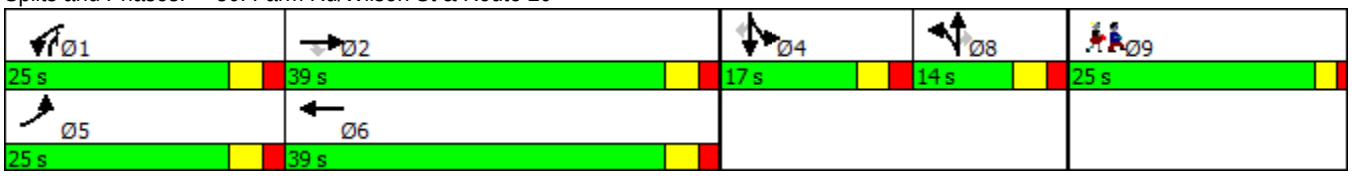
Intersection Summary		
Cycle Length: 120		
Actuated Cycle Length: 98.4		
Control Type: Actuated-Uncoordinated		
Maximum v/c Ratio: 0.98		
Intersection Signal Delay: 43.4	Intersection LOS: D	
Intersection Capacity Utilization 75.6%	ICU Level of Service D	
Analysis Period (min) 15		

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
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

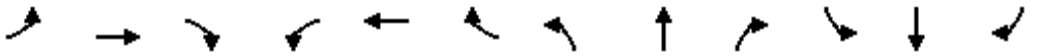
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicenzo Boulevard/Pomphrey Drive, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	24	1257	74	21	441	11	129	10	46	12	2	27
Future Volume (vph)	24	1257	74	21	441	11	129	10	46	12	2	27
Satd. Flow (prot)	1694	3361	0	1662	3310	0	3113	1479	0	1574	1425	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1694	3361	0	1662	3310	0	3113	1479	0	1574	1425	0
Satd. Flow (RTOR)		7			3			61			42	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.83	0.83	0.83	0.81	0.81	0.81	0.68	0.68	0.68
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	3%	3%	3%	5%	5%	5%	5%	5%	5%	7%	7%	7%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	26	1469	0	27	583	0	170	74	0	19	45	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	11.0	55.0		11.0	55.0		12.0	12.0		10.0	10.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	6.4	49.7		6.4	49.7		7.4	7.4		5.3	5.3	
Actuated g/C Ratio	0.08	0.62		0.08	0.62		0.09	0.09		0.07	0.07	
v/c Ratio	0.19	0.71		0.21	0.28		0.59	0.39		0.18	0.34	
Control Delay	47.4	17.3		47.6	11.0		49.2	23.0		49.5	24.4	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	47.4	17.3		47.6	11.0		49.2	23.0		49.5	24.4	
LOS	D	B		D	B		D	C		D	C	
Approach Delay		17.8			12.6			41.3			31.9	
Approach LOS		B			B			D			C	
Queue Length 50th (ft)	12	199		12	54		41	6		9	1	
Queue Length 95th (ft)	49	#737		46	179		#111	47		30	23	
Internal Link Dist (ft)		528			1696			203			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	134	2219		131	2184		287	191		103	133	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.19	0.66		0.21	0.27		0.59	0.39		0.18	0.34	

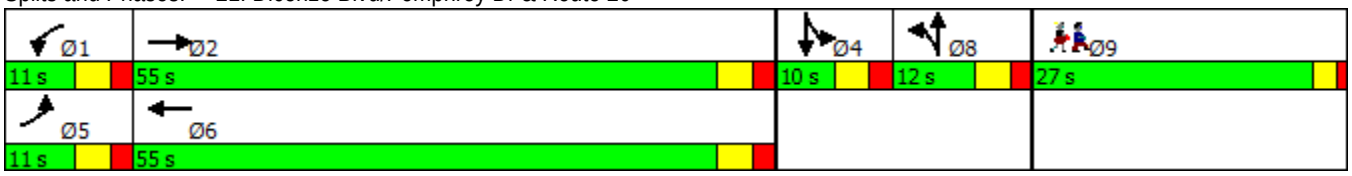
Intersection Summary			
Cycle Length: 115			
Actuated Cycle Length: 80.4			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.71			
Intersection Signal Delay: 19.3		Intersection LOS: B	
Intersection Capacity Utilization 58.6%		ICU Level of Service B	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
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

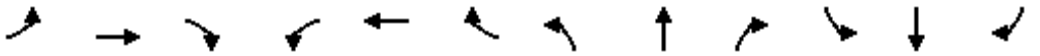
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



Intersection Capacity Analysis
Route 20 at Raytheon Driveway, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	8	1085	247	159	459	5	3	2	5	3	0	3
Future Volume (vph)	8	1085	247	159	459	5	3	2	5	3	0	3
Satd. Flow (prot)	1678	1766	1553	1662	1806	0	0	1537	1346	0	1152	0
Flt Permitted	0.439			0.067				0.971			0.976	
Satd. Flow (perm)	775	1766	1553	117	1806	0	0	1537	1346	0	1152	0
Satd. Flow (RTOR)			180		1				89		129	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.83	0.83	0.83	0.50	0.50	0.50	0.50	0.50	0.50
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	4%	4%	4%	5%	5%	5%	20%	20%	20%	50%	50%	50%
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)	9	1197	272	205	598	0	0	10	11	0	12	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		Split	NA	pm+ov	Split	NA	
Protected Phases	5	2		1	6		3	3	1	4	4	
Permitted Phases	2		2	6					3			
Total Split (s)	9.0	56.0	56.0	11.0	58.0		11.0	11.0	11.0	11.0	11.0	
Total Lost Time (s)	4.0	5.0	5.0	5.0	5.0			4.0	5.0		4.0	
Act Effct Green (s)	57.7	51.6	51.6	62.3	65.5			6.3	7.0		6.1	
Actuated g/C Ratio	0.81	0.72	0.72	0.88	0.92			0.09	0.10		0.09	
v/c Ratio	0.01	0.94	0.23	0.88	0.36			0.07	0.05		0.06	
Control Delay	2.2	25.9	2.5	54.5	4.0			34.4	0.5		0.5	
Queue Delay	0.0	0.0	0.0	0.0	0.0			0.0	0.0		0.0	
Total Delay	2.2	25.9	2.5	54.5	4.0			34.4	0.5		0.5	
LOS	A	C	A	D	A			C	A		A	
Approach Delay		21.5			16.9			16.6			0.5	
Approach LOS		C			B			B			A	
Queue Length 50th (ft)	0	258	7	37	0			4	0		0	
Queue Length 95th (ft)	5	#1043	56	#197	236			12	0		0	
Internal Link Dist (ft)		655			458			102			237	
Turn Bay Length (ft)	100		300	150								
Base Capacity (vph)	691	1280	1175	233	1662			152	213		230	
Starvation Cap Reductn	0	0	0	0	0			0	0		0	
Spillback Cap Reductn	0	0	0	0	0			0	0		0	
Storage Cap Reductn	0	0	0	0	0			0	0		0	
Reduced v/c Ratio	0.01	0.94	0.23	0.88	0.36			0.07	0.05		0.05	

Intersection Summary			
Cycle Length: 110			
Actuated Cycle Length: 71.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.94			
Intersection Signal Delay: 19.7		Intersection LOS: B	
Intersection Capacity Utilization 87.2%		ICU Level of Service E	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	21.0
Total Lost Time (s)	
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

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

Splits and Phases: 2: Raytheon Dr & Route 20

Intersection Capacity Analysis
Route 20 at Wayside Inn Road/Hager Street, Marlborough

11/7/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SBL2	SBL	SBR	NWL	NWR	NWR2
Lane Configurations												
Traffic Volume (vph)	58	879	152	7	401	1	34	55	120	107	20	2
Future Volume (vph)	58	879	152	7	401	1	34	55	120	107	20	2
Satd. Flow (prot)	1736	1827	1553	1703	1792	0	0	1723	1490	1736	1553	0
Flt Permitted	0.950			0.950				0.961		0.950		
Satd. Flow (perm)	1736	1827	1553	1703	1792	0	0	1723	1490	1736	1553	0
Satd. Flow (RTOR)			145					182	182		182	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.91	0.91	0.91	0.84	0.84	0.84	0.83	0.83	0.83	0.88	0.88	0.88
Growth Factor	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%	107%
Heavy Vehicles (%)	4%	4%	4%	6%	6%	6%	3%	3%	3%	4%	4%	4%
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 (%)									17%			
Lane Group Flow (vph)	68	1034	179	9	512	0	0	141	129	130	26	0
Turn Type	Prot	NA	Perm	Prot	NA		Prot	Prot	Perm	Prot	Prot	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases			2						8			
Total Split (s)	14.0	65.0	65.0	9.0	60.0		10.0	10.0	10.0	15.0	15.0	
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0			5.0	5.0	5.0	5.0	
Act Effct Green (s)	8.5	60.9	60.9	5.1	51.9			5.1	5.1	10.0	10.0	
Actuated g/C Ratio	0.09	0.63	0.63	0.05	0.54			0.05	0.05	0.10	0.10	
v/c Ratio	0.44	0.89	0.17	0.10	0.53			0.54	0.52	0.72	0.08	
Control Delay	53.3	28.3	3.4	50.8	19.0			11.1	9.8	66.4	0.5	
Queue Delay	0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	
Total Delay	53.3	28.3	3.4	50.8	19.0			11.1	9.8	66.4	0.5	
LOS	D	C	A	D	B			B	A	E	A	
Approach Delay		26.1			19.6			10.5		55.4		
Approach LOS		C			B			B		E		
Queue Length 50th (ft)	37	397	6	5	183			0	0	72	0	
Queue Length 95th (ft)	100	#1185	51	23	371			18	8	#214	0	
Internal Link Dist (ft)		190			594			403		273		
Turn Bay Length (ft)	150		100	50					50		100	
Base Capacity (vph)	182	1159	1038	89	1062			263	250	182	326	
Starvation Cap Reductn	0	0	0	0	0			0	0	0	0	
Spillback Cap Reductn	0	0	0	0	0			0	0	0	0	
Storage Cap Reductn	0	0	0	0	0			0	0	0	0	
Reduced v/c Ratio	0.37	0.89	0.17	0.10	0.48			0.54	0.52	0.71	0.08	

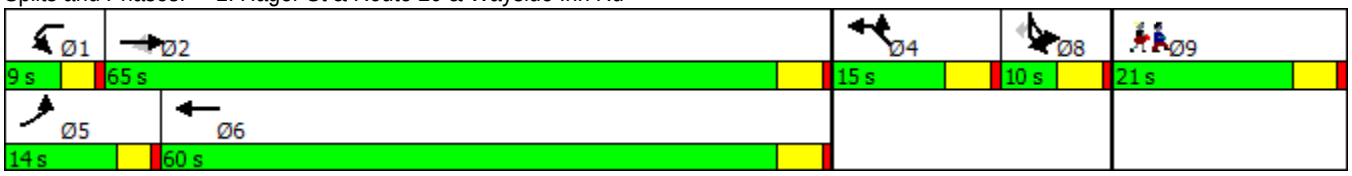
Intersection Summary			
Cycle Length: 120			
Actuated Cycle Length: 96			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.89			
Intersection Signal Delay: 24.7		Intersection LOS: C	
Intersection Capacity Utilization 78.3%		ICU Level of Service D	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	21.0
Total Lost Time (s)	
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

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

Splits and Phases: 1: Hager St & Route 20 & Wayside Inn Rd

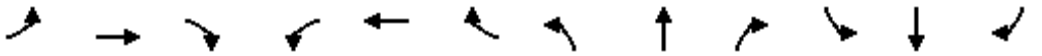


APPENDIX J

Intersection Capacity Analyses
Weekday PM Peak Hour
Projected 2040 Traffic Conditions with Proposed Improvements

Intersection Capacity Analysis
Route 20 at Route 85, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	71	424	215	141	279	7	262	443	155	32	323	32
Future Volume (vph)	71	424	215	141	279	7	262	443	155	32	323	32
Satd. Flow (prot)	1728	1818	1546	1694	1776	0	1728	1818	1546	1711	3369	0
Flt Permitted	0.394			0.155			0.268			0.247		
Satd. Flow (perm)	716	1818	1546	276	1776	0	487	1818	1546	445	3369	0
Satd. Flow (RTOR)			250		1				182		9	
Confl. Peds. (#/hr)							1					1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.93	0.93	0.93	0.91	0.91	0.91	0.90	0.90	0.90	0.85	0.85	0.85
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	3%	3%	3%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	82	492	250	167	339	0	314	532	186	41	451	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA	Perm	pm+pt	NA	
Protected Phases	5	2		1	6		3	8		7	4	
Permitted Phases	2		2	6			8		8	4		
Total Split (s)	8.0	29.0	29.0	8.0	29.0		17.0	29.0	29.0	8.0	20.0	
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0		4.0	5.0	5.0	4.0	5.0	
Act Effct Green (s)	29.5	24.4	24.4	30.3	26.1		32.8	27.1	27.1	19.6	14.5	
Actuated g/C Ratio	0.38	0.31	0.31	0.39	0.33		0.42	0.35	0.35	0.25	0.18	
v/c Ratio	0.26	0.87	0.38	0.93	0.57		0.76	0.85	0.28	0.23	0.72	
Control Delay	19.5	45.6	5.7	76.2	29.6		33.3	41.5	6.0	21.1	38.4	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	
Total Delay	19.5	45.6	5.7	76.2	29.6		33.3	41.5	6.0	21.1	38.4	
LOS	B	D	A	E	C		C	D	A	C	D	
Approach Delay		30.9			45.0			32.6			37.0	
Approach LOS		C			D			C			D	
Queue Length 50th (ft)	21	206	0	45	128		93	230	1	10	98	
Queue Length 95th (ft)	72	#563	60	#231	#341		#304	#621	56	39	#212	
Internal Link Dist (ft)		424			226			511			208	
Turn Bay Length (ft)	350						220			50		
Base Capacity (vph)	321	564	652	179	592		412	627	653	176	661	
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	0.26	0.87	0.38	0.93	0.57		0.76	0.85	0.28	0.23	0.68	

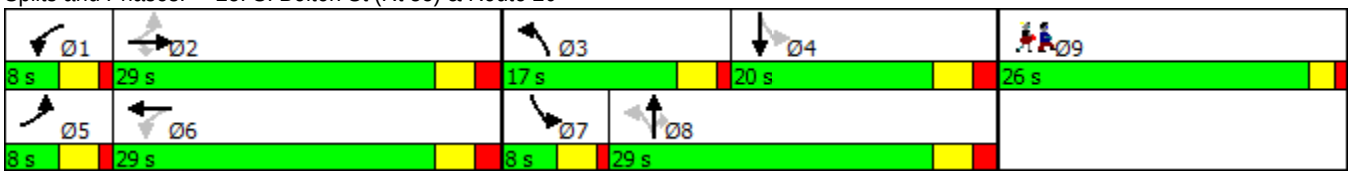
Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 78.5	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.93	
Intersection Signal Delay: 35.1	Intersection LOS: D
Intersection Capacity Utilization 76.1%	ICU Level of Service D
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	26.0
Total Lost Time (s)	
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

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

Splits and Phases: 25: S. Bolton St (Rt 85) & Route 20



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NEL	NET	NER	SWL	SWT	SWR
Lane Configurations												
Traffic Volume (vph)	111	98	9	79	178	36	8	460	92	6	312	125
Future Volume (vph)	111	98	9	79	178	36	8	460	92	6	312	125
Satd. Flow (prot)	1728	1790	0	1728	1763	0	1728	1765	0	0	1799	1531
Flt Permitted	0.540			0.676			0.435				0.987	
Satd. Flow (perm)	973	1790	0	1219	1763	0	791	1765	0	0	1777	1489
Satd. Flow (RTOR)		5			10			14				134
Confl. Peds. (#/hr)	6		4	4		6			5	5		6
Confl. Bikes (#/hr)												
Peak Hour Factor	0.92	0.92	0.92	0.94	0.94	0.94	0.91	0.91	0.91	0.85	0.85	0.85
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	130	126	0	91	246	0	9	655	0	0	404	159
Turn Type	Perm	NA		Perm	NA		Perm	NA		Perm	NA	Perm
Protected Phases		4			8			2			6	
Permitted Phases	4			8			2			6		6
Total Split (s)	23.0	23.0		23.0	23.0		42.0	42.0		42.0	42.0	42.0
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0			5.0	5.0
Act Effct Green (s)	18.1	18.1		18.1	18.1		28.2	28.2			28.2	28.2
Actuated g/C Ratio	0.30	0.30		0.30	0.30		0.47	0.47			0.47	0.47
v/c Ratio	0.45	0.23		0.25	0.46		0.02	0.79			0.49	0.21
Control Delay	29.1	21.6		23.6	24.1		11.9	23.4			15.0	4.5
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0			0.0	0.0
Total Delay	29.1	21.6		23.6	24.1		11.9	23.4			15.0	4.5
LOS	C	C		C	C		B	C			B	A
Approach Delay		25.4			24.0			23.3			12.0	
Approach LOS		C			C			C			B	
Queue Length 50th (ft)	34	30		22	62		1	155			80	4
Queue Length 95th (ft)	#151	112		91	#213		12	#550			240	40
Internal Link Dist (ft)		297			75			453			794	
Turn Bay Length (ft)	150											100
Base Capacity (vph)	309	572		387	567		516	1158			1161	1019
Starvation Cap Reductn	0	0		0	0		0	0			0	0
Spillback Cap Reductn	0	0		0	0		0	0			0	0
Storage Cap Reductn	0	0		0	0		0	0			0	0
Reduced v/c Ratio	0.42	0.22		0.24	0.43		0.02	0.57			0.35	0.16

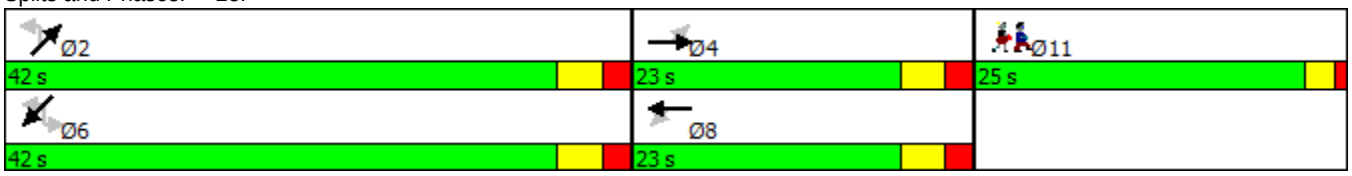
Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 60.2	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.79	
Intersection Signal Delay: 20.2	Intersection LOS: C
Intersection Capacity Utilization 66.4%	ICU Level of Service C
Analysis Period (min) 15	

Lane Group	Ø11
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
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	11
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
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

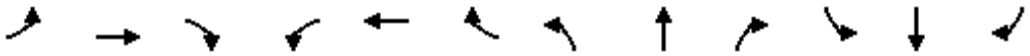
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 23:



Intersection Capacity Analysis
Route 20 at Lincoln Street, Marlborough

11/7/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	10	359	14	408	330	322	15	77	475	211	51	5
Future Volume (vph)	10	359	14	408	330	322	15	77	475	211	51	5
Satd. Flow (prot)	0	3431	0	1711	1667	0	0	1786	1531	0	1744	0
Flt Permitted		0.926		0.950				0.925			0.697	
Satd. Flow (perm)	0	3180	0	1711	1667	0	0	1666	1531	0	1264	0
Satd. Flow (RTOR)		4			88				83		1	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.95	0.95	0.95	0.91	0.91	0.91	0.88	0.88	0.88	0.82	0.82	0.82
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	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	435	0	484	774	0	0	113	583	0	352	0
Turn Type	Perm	NA		Prot	NA		Perm	NA	pm+ov	Perm	NA	
Protected Phases		2		1	6			4	1		8	
Permitted Phases	2						4		4	8		
Total Split (s)	25.0	25.0		35.0	60.0		35.0	35.0	35.0	35.0	35.0	
Total Lost Time (s)		5.0		5.0	5.0			5.0	5.0		5.0	
Act Effct Green (s)		15.7		27.0	47.9			26.7	58.8		26.7	
Actuated g/C Ratio		0.19		0.32	0.56			0.31	0.69		0.31	
v/c Ratio		0.73		0.89	0.79			0.22	0.54		0.88	
Control Delay		41.4		49.2	20.3			24.3	7.7		54.4	
Queue Delay		0.0		0.0	0.0			0.0	0.0		0.0	
Total Delay		41.4		49.2	20.3			24.3	7.7		54.4	
LOS		D		D	C			C	A		D	
Approach Delay		41.4			31.4			10.4			54.4	
Approach LOS		D			C			B			D	
Queue Length 50th (ft)		125		261	296			47	110		188	
Queue Length 95th (ft)		177		#463	465			90	199		#309	
Internal Link Dist (ft)		289			228			617			398	
Turn Bay Length (ft)									150			
Base Capacity (vph)		773		621	1140			605	1152		459	
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		0.56		0.78	0.68			0.19	0.51		0.77	

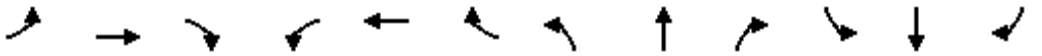
Intersection Summary			
Cycle Length: 95			
Actuated Cycle Length: 84.8			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.89			
Intersection Signal Delay: 30.6		Intersection LOS: C	
Intersection Capacity Utilization 86.6%		ICU Level of Service E	
Analysis Period (min) 15			

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

Splits and Phases: 21:

Intersection Capacity Analysis
Route 20 @ Curtis Avenue/Post Road Plaza, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	198	858	57	46	890	74	53	63	80	92	35	192
Future Volume (vph)	198	858	57	46	890	74	53	63	80	92	35	192
Satd. Flow (prot)	1728	3424	0	1728	3455	1546	0	1696	0	1625	1673	1546
Flt Permitted	0.950			0.950				0.987		0.950	0.978	
Satd. Flow (perm)	1728	3424	0	1728	3455	1546	0	1696	0	1625	1673	1546
Satd. Flow (RTOR)		9				89		31				221
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.90	0.90	0.90	0.85	0.85	0.85	0.94	0.94	0.94
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	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 (%)										32%		
Lane Group Flow (vph)	220	1018	0	55	1068	89	0	249	0	72	74	221
Turn Type	Prot	NA		Prot	NA	pm+ov	Split	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4	8	8		4	4	
Permitted Phases						6						4
Total Split (s)	19.0	43.0		11.0	35.0	21.0	15.0	15.0		21.0	21.0	21.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	13.6	41.4		6.7	30.0	44.6		16.9		9.6	9.6	9.6
Actuated g/C Ratio	0.15	0.46		0.07	0.33	0.50		0.19		0.11	0.11	0.11
v/c Ratio	0.85	0.64		0.43	0.93	0.11		0.73		0.42	0.42	0.61
Control Delay	66.1	21.8		37.8	31.8	0.3		46.3		43.5	43.2	12.7
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	66.1	21.8		37.8	31.8	0.3		46.3		43.5	43.2	12.7
LOS	E	C		D	C	A		D		D	D	B
Approach Delay		29.7			29.8			46.3			24.9	
Approach LOS		C			C			D			C	
Queue Length 50th (ft)	122	255		24	95	0		116		42	43	0
Queue Length 95th (ft)	#242	313		m46	#412	m1		#277		78	80	60
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	268	1600		129	1151	914		343		288	297	456
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.82	0.64		0.43	0.93	0.10		0.73		0.25	0.25	0.48

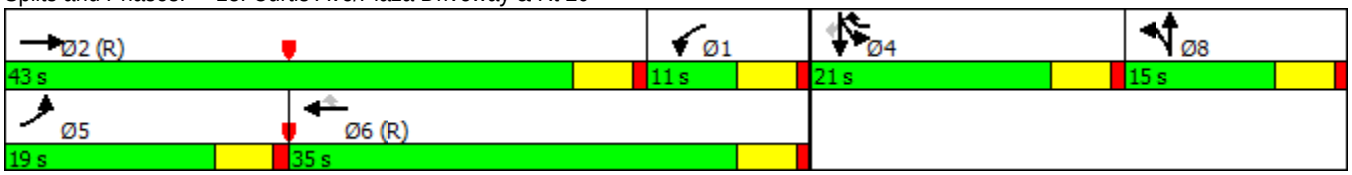
Intersection Summary		
Cycle Length: 90		
Actuated Cycle Length: 90		
Offset: 0 (0%), Referenced to phase 2:EBT and 6:WBT, Start of Green, Master Intersection		
Control Type: Actuated-Coordinated		
Maximum v/c Ratio: 0.93		
Intersection Signal Delay: 30.5	Intersection LOS: C	
Intersection Capacity Utilization 69.6%	ICU Level of Service C	

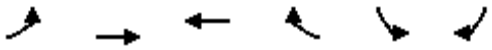
Analysis Period (min) 15

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

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

Splits and Phases: 18: Curtis Ave/Plaza Driveway & Rt 20





Lane Group	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Traffic Volume (vph)	277	742	809	285	217	157
Future Volume (vph)	277	742	809	285	217	157
Satd. Flow (prot)	1728	3455	3455	1546	1711	1531
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1728	3455	3455	1546	1711	1531
Satd. Flow (RTOR)				291		31
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.96	0.96	0.93	0.93	0.94	0.94
Growth Factor	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	312	835	939	331	249	180
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov
Protected Phases	5	2	6		7	5
Permitted Phases				6		7
Total Split (s)	28.0	65.0	37.0	37.0	25.0	28.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0
Act Effct Green (s)	20.0	62.9	37.9	37.9	17.1	42.1
Actuated g/C Ratio	0.22	0.70	0.42	0.42	0.19	0.47
v/c Ratio	0.81	0.35	0.65	0.40	0.77	0.25
Control Delay	44.4	2.2	16.3	4.2	50.2	11.4
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	44.4	2.2	16.3	4.2	50.2	11.4
LOS	D	A	B	A	D	B
Approach Delay		13.7	13.2		33.9	
Approach LOS		B	B		C	
Queue Length 50th (ft)	178	23	237	74	133	45
Queue Length 95th (ft)	m#264	37	126	19	212	78
Internal Link Dist (ft)		263	291		481	
Turn Bay Length (ft)	300			150		100
Base Capacity (vph)	441	2415	1454	819	380	719
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	0.71	0.35	0.65	0.40	0.66	0.25

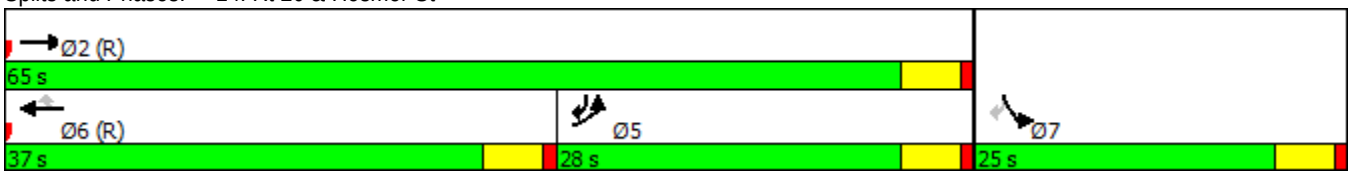
Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 84 (93%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.81	
Intersection Signal Delay: 16.5	Intersection LOS: B
Intersection Capacity Utilization 66.2%	ICU Level of Service C

Analysis Period (min) 15

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

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

Splits and Phases: 14: Rt 20 & Hosmer St



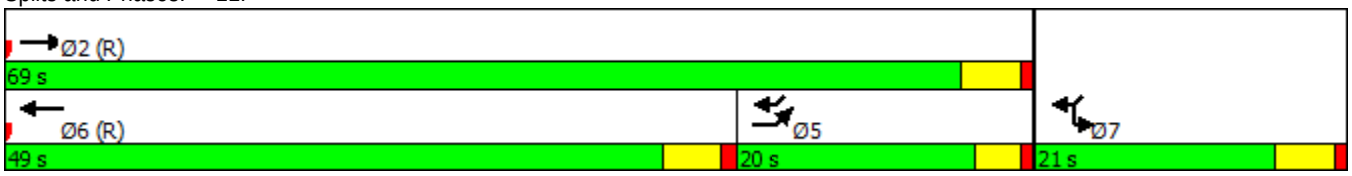
Lane Group	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (vph)	145	772	999	43	38	114
Future Volume (vph)	145	772	999	43	38	114
Satd. Flow (prot)	1728	2007	3518	0	1770	1689
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1728	2007	3518	0	1770	1689
Satd. Flow (RTOR)			7			48
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.98	0.98	0.95	0.95	0.81	0.81
Growth Factor	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	2%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	160	851	1185	0	51	152
Turn Type	Prot	NA	NA		Prot	pt+ov
Protected Phases	5	2	6		7	7 5
Permitted Phases						
Total Split (s)	20.0	69.0	49.0		21.0	
Total Lost Time (s)	4.0	5.0	5.0		5.0	
Act Effct Green (s)	13.0	70.8	53.8		9.2	26.2
Actuated g/C Ratio	0.14	0.79	0.60		0.10	0.29
v/c Ratio	0.65	0.54	0.56		0.28	0.29
Control Delay	38.1	4.8	13.4		39.7	16.4
Queue Delay	0.0	0.1	0.0		0.0	0.0
Total Delay	38.1	4.9	13.4		39.7	16.4
LOS	D	A	B		D	B
Approach Delay		10.2	13.4		22.3	
Approach LOS		B	B		C	
Queue Length 50th (ft)	68	132	191		28	45
Queue Length 95th (ft)	m132	39	333		51	67
Internal Link Dist (ft)		53	224		402	
Turn Bay Length (ft)						50
Base Capacity (vph)	307	1578	2107		314	621
Starvation Cap Reductn	0	100	0		0	0
Spillback Cap Reductn	0	0	0		0	0
Storage Cap Reductn	0	0	0		0	0
Reduced v/c Ratio	0.52	0.58	0.56		0.16	0.24

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 69 (77%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.65	
Intersection Signal Delay: 12.8	Intersection LOS: B
Intersection Capacity Utilization 57.2%	ICU Level of Service B

Analysis Period (min) 15

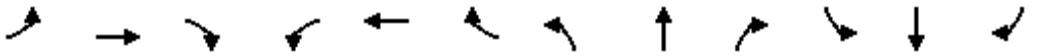
m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 11:



Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	45	499	106	380	901	44	124	59	259	56	79	51
Future Volume (vph)	45	499	106	380	901	44	124	59	259	56	79	51
Satd. Flow (prot)	1770	3539	1583	1787	3549	0	1787	1881	1599	0	1844	1599
Flt Permitted	0.950			0.950			0.950				0.980	
Satd. Flow (perm)	1770	3539	1583	1787	3549	0	1787	1881	1599	0	1844	1599
Satd. Flow (RTOR)			182		5							182
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.96	0.96	0.96	0.96	0.96	0.96	0.90	0.90	0.90	0.95	0.95	0.95
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	51	561	119	428	1064	0	149	71	311	0	154	58
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	15.0	28.0	28.0	35.0	48.0		16.0	16.0	35.0	16.0	16.0	16.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	8.0	19.4	19.4	28.7	42.8		11.2	11.2	44.2		11.2	11.2
Actuated g/C Ratio	0.08	0.20	0.20	0.30	0.45		0.12	0.12	0.47		0.12	0.12
v/c Ratio	0.34	0.77	0.25	0.79	0.66		0.71	0.32	0.42		0.71	0.17
Control Delay	51.2	45.0	2.3	44.2	25.1		62.4	47.2	19.1		61.8	1.0
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	51.2	45.0	2.3	44.2	25.1		62.4	47.2	19.1		61.8	1.0
LOS	D	D	A	D	C		E	D	B		E	A
Approach Delay		38.4			30.6			35.0			45.1	
Approach LOS		D			C			C			D	
Queue Length 50th (ft)	28	161	0	219	243		85	38	107		88	0
Queue Length 95th (ft)	80	#303	8	#531	481		#244	102	172		#249	0
Internal Link Dist (ft)		387			937			205			111	
Turn Bay Length (ft)	200		200	300			75		150			
Base Capacity (vph)	190	873	527	575	1641		210	222	776		217	349
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	0.27	0.64	0.23	0.74	0.65		0.71	0.32	0.40		0.71	0.17

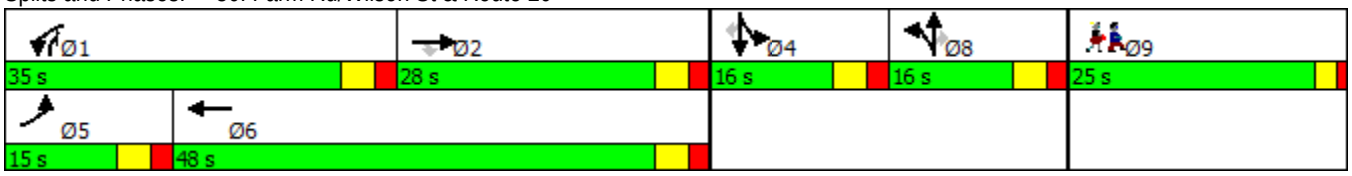
Intersection Summary	
Cycle Length: 120	
Actuated Cycle Length: 94.9	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.79	
Intersection Signal Delay: 34.4	Intersection LOS: C
Intersection Capacity Utilization 64.6%	ICU Level of Service C
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
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

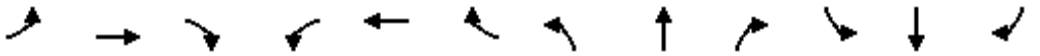
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicentzo Boulevard/Pomphrey Drive, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Future Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Satd. Flow (prot)	1728	3365	0	1711	3411	0	3173	1513	0	1636	1593	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1728	3365	0	1711	3411	0	3173	1513	0	1636	1593	0
Satd. Flow (RTOR)		23			2			29			9	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.94	0.94	0.94	0.70	0.70	0.70
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	3%	3%	3%	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)	35	871	0	68	1226	0	253	36	0	20	18	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	11.0	46.0		15.0	50.0		16.0	16.0		11.0	11.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	7.0	30.3		9.0	35.7		11.6	11.6		7.0	7.0	
Actuated g/C Ratio	0.10	0.41		0.12	0.49		0.16	0.16		0.10	0.10	
v/c Ratio	0.21	0.62		0.32	0.74		0.50	0.14		0.13	0.11	
Control Delay	46.1	21.6		43.3	22.0		39.5	20.6		46.0	34.2	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	46.1	21.6		43.3	22.0		39.5	20.6		46.0	34.2	
LOS	D	C		D	C		D	C		D	C	
Approach Delay		22.6			23.2			37.1			40.4	
Approach LOS		C			C			D			D	
Queue Length 50th (ft)	17	165		32	258		61	3		9	4	
Queue Length 95th (ft)	59	353		97	#588		#164	37		32	23	
Internal Link Dist (ft)		507			1696			203			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	164	2168		271	2337		554	288		156	159	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.21	0.40		0.25	0.52		0.46	0.13		0.13	0.11	

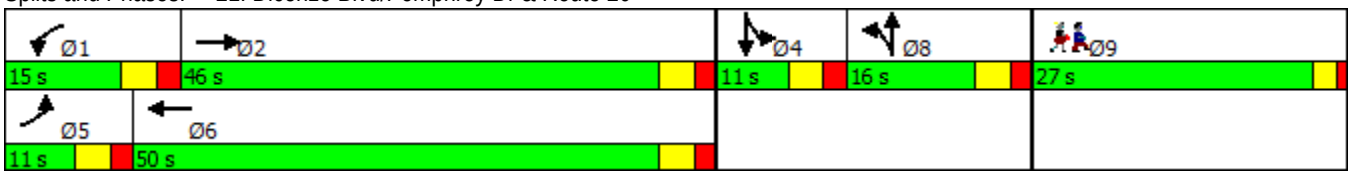
Intersection Summary			
Cycle Length: 115			
Actuated Cycle Length: 73.1			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.74			
Intersection Signal Delay: 24.8		Intersection LOS: C	
Intersection Capacity Utilization 64.3%		ICU Level of Service C	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
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

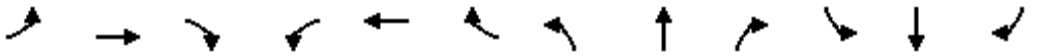
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



Intersection Capacity Analysis
Route 20 at Raytheon Driveway, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	545	3	1	925	15	240	0	141	12	0	41
Future Volume (vph)	29	545	3	1	925	15	240	0	141	12	0	41
Satd. Flow (prot)	1711	1801	1583	1728	1877	0	0	1787	1599	0	1651	0
Flt Permitted	0.082			0.266				0.950			0.989	
Satd. Flow (perm)	148	1801	1583	484	1877	0	0	1787	1599	0	1651	0
Satd. Flow (RTOR)			119		1				167		129	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.93	0.93	0.93	0.97	0.97	0.97	0.91	0.91	0.91	0.66	0.66	0.66
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	2%	2%	2%	1%	1%	1%	1%	1%	1%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Parking (#/hr)												
Mid-Block Traffic (%)		0%			0%			0%			0%	
Shared Lane Traffic (%)												
Lane Group Flow (vph)	34	633	3	1	1047	0	0	285	167	0	87	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		Split	NA	pm+ov	Split	NA	
Protected Phases	5	2		1	6		3	3	1	4	4	
Permitted Phases	2		2	6					3			
Total Split (s)	8.0	52.0	52.0	8.0	52.0		20.0	20.0	8.0	9.0	9.0	
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0			4.0	4.0		4.0	
Act Effct Green (s)	52.1	47.1	47.1	53.8	50.4			16.0	20.9		5.0	
Actuated g/C Ratio	0.60	0.54	0.54	0.62	0.58			0.18	0.24		0.06	
v/c Ratio	0.21	0.65	0.00	0.00	0.96			0.87	0.33		0.40	
Control Delay	9.5	18.8	0.0	6.0	41.6			62.4	5.2		8.7	
Queue Delay	0.0	0.0	0.0	0.0	0.0			0.0	0.0		0.0	
Total Delay	9.5	18.8	0.0	6.0	41.6			62.4	5.2		8.7	
LOS	A	B	A	A	D			E	A		A	
Approach Delay		18.2			41.6			41.3			8.7	
Approach LOS		B			D			D			A	
Queue Length 50th (ft)	7	244	0	0	~652			158	0		0	
Queue Length 95th (ft)	17	365	0	2	#894			#302	39		0	
Internal Link Dist (ft)		655			458			102			237	
Turn Bay Length (ft)	100		300	150								
Base Capacity (vph)	160	972	909	355	1085			328	510		216	
Starvation Cap Reductn	0	0	0	0	0			0	0		0	
Spillback Cap Reductn	0	0	0	0	0			0	0		0	
Storage Cap Reductn	0	0	0	0	0			0	0		0	
Reduced v/c Ratio	0.21	0.65	0.00	0.00	0.96			0.87	0.33		0.40	

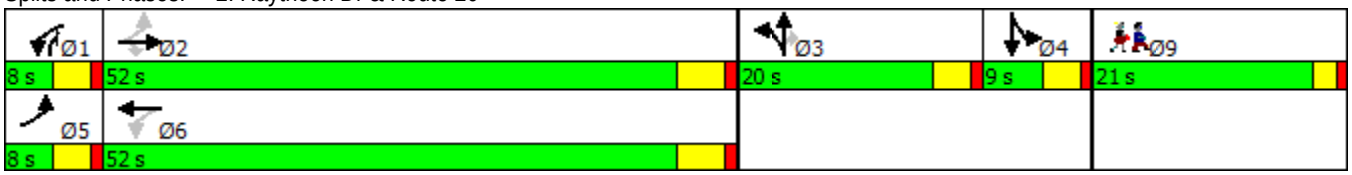
Intersection Summary	
Cycle Length: 110	
Actuated Cycle Length: 87.2	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.96	
Intersection Signal Delay: 33.3	Intersection LOS: C
Intersection Capacity Utilization 82.1%	ICU Level of Service E
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	21.0
Total Lost Time (s)	
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

~ 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: 2: Raytheon Dr & Route 20



Intersection Capacity Analysis
Route 20 at Wayside Inn Road/Hager Street, Marlborough

11/9/2016

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	SBL2	SBL	SBR	NWL	NWR	NWR2
Lane Configurations												
Traffic Volume (vph)	106	520	83	4	702	5	5	23	79	118	61	3
Future Volume (vph)	106	520	83	4	702	5	5	23	79	118	61	3
Satd. Flow (prot)	1787	1881	1599	1787	1879	0	0	1770	1583	1787	1599	0
Flt Permitted	0.950			0.950				0.950		0.950		
Satd. Flow (perm)	1787	1881	1599	1787	1879	0	0	1770	1583	1787	1599	0
Satd. Flow (RTOR)			145						182		182	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.97	0.97	0.97	0.91	0.91	0.91	0.86	0.86	0.86	0.94	0.94	0.94
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	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)	118	579	92	5	839	0	0	35	99	136	73	0
Turn Type	Prot	NA	Perm	Prot	NA		Prot	Prot	Perm	Prot	Prot	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases			2						8			
Total Split (s)	14.0	66.0	66.0	8.0	60.0		10.0	10.0	10.0	15.0	15.0	
Total Lost Time (s)	4.0	5.0	5.0	4.0	5.0			5.0	5.0	5.0	5.0	
Act Effct Green (s)	9.8	63.0	63.0	4.1	50.5			5.1	5.1	10.1	10.1	
Actuated g/C Ratio	0.10	0.64	0.64	0.04	0.51			0.05	0.05	0.10	0.10	
v/c Ratio	0.66	0.48	0.09	0.07	0.87			0.38	0.39	0.74	0.22	
Control Delay	64.1	12.7	0.6	53.4	33.2			62.2	4.5	69.8	1.6	
Queue Delay	0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	
Total Delay	64.1	12.7	0.6	53.4	33.2			62.2	4.5	69.8	1.6	
LOS	E	B	A	D	C			E	A	E	A	
Approach Delay		19.0			33.4			19.5		46.0		
Approach LOS		B			C			B		D		
Queue Length 50th (ft)	71	139	0	3	400			21	0	83	0	
Queue Length 95th (ft)	#193	426	6	18	#902			#63	0	#230	0	
Internal Link Dist (ft)		1291			594			327		483		
Turn Bay Length (ft)	150		100	50					50		100	
Base Capacity (vph)	184	1246	1108	73	1067			91	254	184	328	
Starvation Cap Reductn	0	0	0	0	0			0	0	0	0	
Spillback Cap Reductn	0	0	0	0	0			0	0	0	0	
Storage Cap Reductn	0	0	0	0	0			0	0	0	0	
Reduced v/c Ratio	0.64	0.46	0.08	0.07	0.79			0.38	0.39	0.74	0.22	

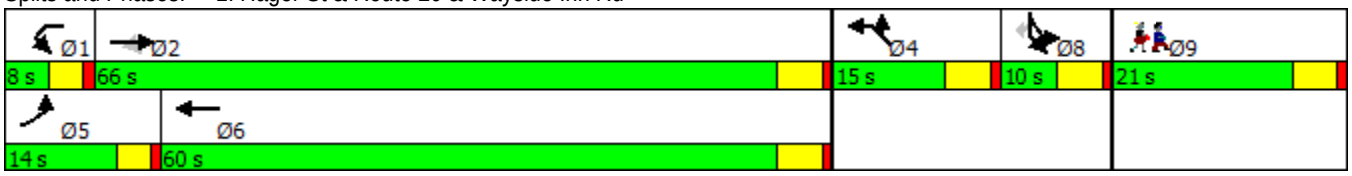
Intersection Summary			
Cycle Length: 120			
Actuated Cycle Length: 98.2			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.87			
Intersection Signal Delay: 28.0		Intersection LOS: C	
Intersection Capacity Utilization 73.6%		ICU Level of Service D	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	21.0
Total Lost Time (s)	
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

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

Splits and Phases: 1: Hager St & Route 20 & Wayside Inn Rd

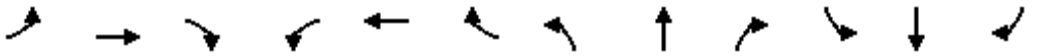


APPENDIX K

Intersection Capacity Analyses
Summer Saturday Midday Peak Hour
Projected 2040 Traffic Conditions with Proposed Improvements

Intersection Capacity Analysis
Route 20 at Lincoln Street, Marlborough

11/9/2016

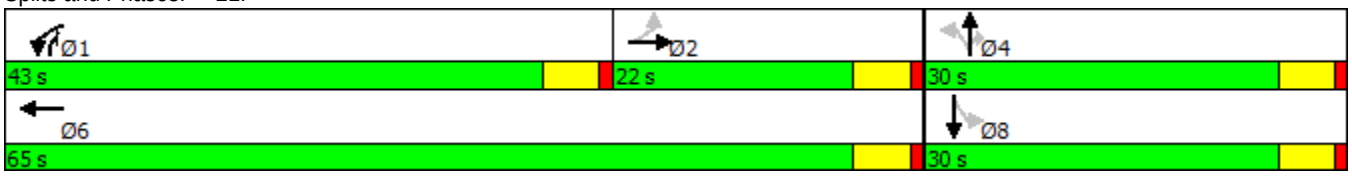


Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	6	376	16	463	410	234	14	49	517	173	28	3
Future Volume (vph)	6	376	16	463	410	234	14	49	517	173	28	3
Satd. Flow (prot)	0	3431	0	1728	1704	0	0	1781	1531	0	1740	0
Flt Permitted		0.938		0.950				0.917			0.707	
Satd. Flow (perm)	0	3221	0	1728	1704	0	0	1651	1506	0	1279	0
Satd. Flow (RTOR)		4			59				41		1	
Confl. Peds. (#/hr)	5					5			2	2		
Confl. Bikes (#/hr)												
Peak Hour Factor	0.93	0.93	0.93	0.86	0.86	0.86	0.91	0.91	0.91	0.86	0.86	0.86
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	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	463	0	581	809	0	0	75	614	0	256	0
Turn Type	Perm	NA		Prot	NA		Perm	NA	pm+ov	Perm	NA	
Protected Phases		2		1	6			4	1		8	
Permitted Phases	2						4		4	8		
Total Split (s)	22.0	22.0		43.0	65.0		30.0	30.0	43.0	30.0	30.0	
Total Lost Time (s)		5.0		5.0	5.0			5.0	5.0		5.0	
Act Effct Green (s)		15.1		31.6	52.0			20.2	51.8		20.2	
Actuated g/C Ratio		0.18		0.38	0.63			0.24	0.63		0.24	
v/c Ratio		0.78		0.88	0.74			0.19	0.63		0.82	
Control Delay		44.3		40.9	15.3			28.1	9.8		53.0	
Queue Delay		0.0		0.0	0.0			0.0	0.0		0.0	
Total Delay		44.3		40.9	15.3			28.1	9.8		53.0	
LOS		D		D	B			C	A		D	
Approach Delay		44.3			26.0			11.8			53.0	
Approach LOS		D			C			B			D	
Queue Length 50th (ft)		134		300	267			34	137		138	
Queue Length 95th (ft)		#214		#461	394			72	216		#241	
Internal Link Dist (ft)		289			228			617			398	
Turn Bay Length (ft)									150			
Base Capacity (vph)		695		830	1279			522	1114		405	
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		0.67		0.70	0.63			0.14	0.55		0.63	

Intersection Summary			
Cycle Length: 95			
Actuated Cycle Length: 82.6			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.88			
Intersection Signal Delay: 28.0		Intersection LOS: C	
Intersection Capacity Utilization 82.2%		ICU Level of Service E	
Analysis Period (min) 15			

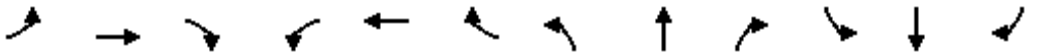
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 21:



Intersection Capacity Analysis
Route 20 at Curtis Avenue/Post Road Plaza, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	236	855	49	67	887	117	43	78	82	135	56	242
Future Volume (vph)	236	855	49	67	887	117	43	78	82	135	56	242
Satd. Flow (prot)	1728	3422	0	1728	3455	1546	0	1701	0	1658	1708	1561
Flt Permitted	0.950			0.950				0.897		0.950	0.979	
Satd. Flow (perm)	1725	3422	0	1724	3455	1506	0	1539	0	1658	1708	1530
Satd. Flow (RTOR)		8				137		31				294
Confl. Peds. (#/hr)	2		3	3		2	5					5
Confl. Bikes (#/hr)												
Peak Hour Factor	0.98	0.98	0.98	0.92	0.92	0.92	0.86	0.86	0.86	0.89	0.89	0.89
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%	0%	0%
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 (%)										30%		
Lane Group Flow (vph)	260	996	0	79	1041	137	0	255	0	115	117	294
Turn Type	Prot	NA		Prot	NA	pm+ov	Perm	NA		Split	NA	Perm
Protected Phases	5	2		1	6	4		8		4	4	
Permitted Phases						6	8					4
Total Split (s)	21.0	42.0		11.0	32.0	21.0	16.0	16.0		21.0	21.0	21.0
Total Lost Time (s)	5.0	5.0		5.0	5.0	5.0		5.0		5.0	5.0	5.0
Act Effct Green (s)	15.5	37.4		7.9	27.5	38.8		15.7		11.3	11.3	11.3
Actuated g/C Ratio	0.17	0.42		0.09	0.31	0.43		0.17		0.13	0.13	0.13
v/c Ratio	0.88	0.70		0.53	0.99	0.19		0.87		0.55	0.55	0.65
Control Delay	65.9	25.3		37.6	41.8	1.1		63.6		46.2	45.6	11.8
Queue Delay	0.0	0.0		0.0	0.0	0.0		0.0		0.0	0.0	0.0
Total Delay	65.9	25.3		37.6	41.8	1.1		63.6		46.2	45.6	11.8
LOS	E	C		D	D	A		E		D	D	B
Approach Delay		33.7			37.1			63.6			26.8	
Approach LOS		C			D			E			C	
Queue Length 50th (ft)	145	254		45	~323	3		126		65	66	0
Queue Length 95th (ft)	#277	312		m#67	#433	m0		#291		114	115	65
Internal Link Dist (ft)		686			186			446			263	
Turn Bay Length (ft)	360			175		175				75		125
Base Capacity (vph)	307	1494		150	1055	806		293		294	303	513
Starvation Cap Reductn	0	0		0	0	0		0		0	0	0
Spillback Cap Reductn	0	0		0	0	0		0		0	0	0
Storage Cap Reductn	0	0		0	0	0		0		0	0	0
Reduced v/c Ratio	0.85	0.67		0.53	0.99	0.17		0.87		0.39	0.39	0.57

Intersection Summary

Cycle Length: 90
Actuated Cycle Length: 90
Offset: 0 (0%), Referenced to phase 2:EBT and 6:WBT, Start of Green, Master Intersection
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.99
Intersection Signal Delay: 36.2 — Intersection LOS: D
Intersection Capacity Utilization 72.2% — ICU Level of Service C

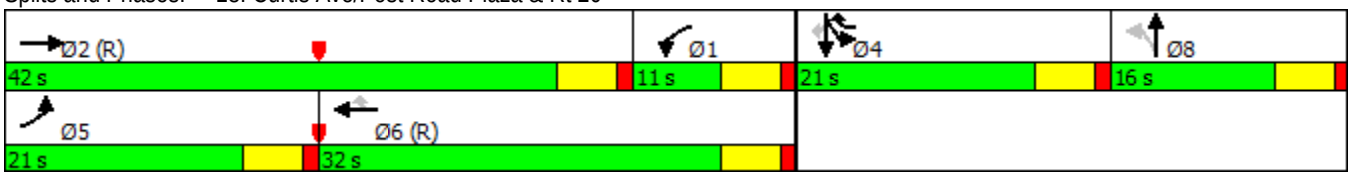
Analysis Period (min) 15

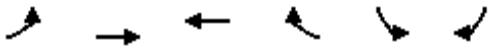
~ Volume exceeds capacity, queue is theoretically infinite.
Queue shown is maximum after two cycles.

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

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

Splits and Phases: 18: Curtis Ave/Post Road Plaza & Rt 20





Lane Group	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Traffic Volume (vph)	224	842	890	236	279	217
Future Volume (vph)	224	842	890	236	279	217
Satd. Flow (prot)	1728	3455	3455	1546	1728	1546
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1727	3455	3455	1511	1728	1521
Satd. Flow (RTOR)				218		23
Confl. Peds. (#/hr)	1			1		3
Confl. Bikes (#/hr)						
Peak Hour Factor	0.95	0.95	0.95	0.95	0.95	0.95
Growth Factor	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	255	957	1012	268	317	247
Turn Type	Prot	NA	NA	Perm	Prot	pm+ov
Protected Phases	5	2	6		7	5
Permitted Phases				6		7
Total Split (s)	25.0	62.0	37.0	37.0	28.0	25.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0	5.0
Act Effct Green (s)	17.2	59.8	37.6	37.6	20.2	37.4
Actuated g/C Ratio	0.19	0.66	0.42	0.42	0.22	0.42
v/c Ratio	0.78	0.42	0.70	0.35	0.82	0.38
Control Delay	41.0	3.8	19.4	3.9	50.5	14.3
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	41.0	3.8	19.4	3.9	50.5	14.3
LOS	D	A	B	A	D	B
Approach Delay		11.6	16.1		34.7	
Approach LOS		B	B		C	
Queue Length 50th (ft)	159	53	265	19	168	71
Queue Length 95th (ft)	m233	m65	172	32	#268	113
Internal Link Dist (ft)		253	302		474	
Turn Bay Length (ft)	300			150		100
Base Capacity (vph)	384	2295	1444	758	441	687
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	0.66	0.42	0.70	0.35	0.72	0.36

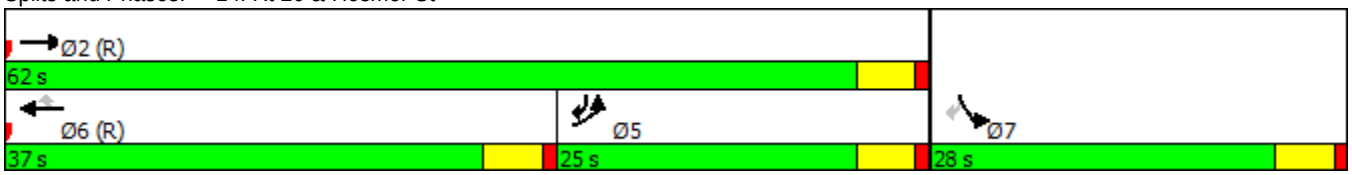
Intersection Summary			
Cycle Length: 90			
Actuated Cycle Length: 90			
Offset: 72 (80%), Referenced to phase 2:EBT and 6:WBT, Start of Green			
Control Type: Actuated-Coordinated			
Maximum v/c Ratio: 0.82			
Intersection Signal Delay: 17.8		Intersection LOS: B	
Intersection Capacity Utilization 69.2%		ICU Level of Service C	

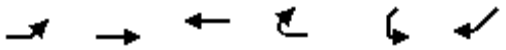
Analysis Period (min) 15

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

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

Splits and Phases: 14: Rt 20 & Hosmer St





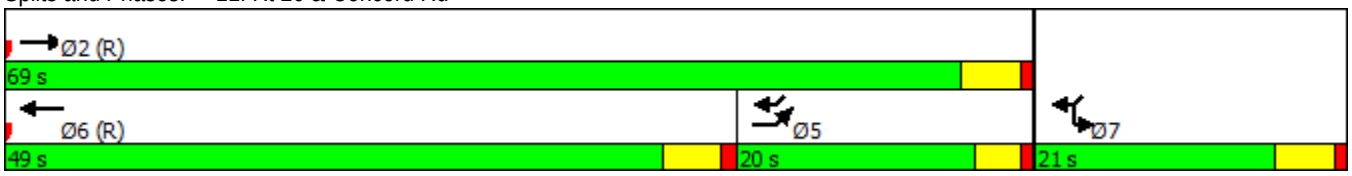
Lane Group	EBL	EBT	WBT	WBR	SWL	SWR
Lane Configurations						
Traffic Volume (vph)	136	951	987	48	47	138
Future Volume (vph)	136	951	987	48	47	138
Satd. Flow (prot)	1728	2007	3549	0	1787	1706
Flt Permitted	0.950				0.950	
Satd. Flow (perm)	1728	2007	3549	0	1787	1706
Satd. Flow (RTOR)			8			55
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.96	0.96	0.98	0.98	0.91	0.91
Growth Factor	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	1%	1%	1%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)		0%	0%		0%	
Shared Lane Traffic (%)						
Lane Group Flow (vph)	153	1070	1141	0	56	164
Turn Type	Prot	NA	NA		Prot	pt+ov
Protected Phases	5	2	6		7	7 5
Permitted Phases						
Total Split (s)	20.0	69.0	49.0		21.0	
Total Lost Time (s)	4.0	5.0	5.0		5.0	
Act Effct Green (s)	12.7	71.8	55.0		8.2	25.0
Actuated g/C Ratio	0.14	0.80	0.61		0.09	0.28
v/c Ratio	0.63	0.67	0.53		0.34	0.32
Control Delay	39.6	6.7	11.9		43.3	17.3
Queue Delay	0.0	0.0	0.0		0.0	0.0
Total Delay	39.6	6.7	11.9		43.3	17.3
LOS	D	A	B		D	B
Approach Delay		10.8	11.9		23.9	
Approach LOS		B	B		C	
Queue Length 50th (ft)	66	189	179		30	47
Queue Length 95th (ft)	m127	26	276		66	89
Internal Link Dist (ft)		44	217		349	
Turn Bay Length (ft)						75
Base Capacity (vph)	307	1600	2173		317	631
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	0.50	0.67	0.53		0.18	0.26

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 68 (76%), Referenced to phase 2:EBT and 6:WBT, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.67	
Intersection Signal Delay: 12.4	Intersection LOS: B
Intersection Capacity Utilization 66.6%	ICU Level of Service C

Analysis Period (min) 15

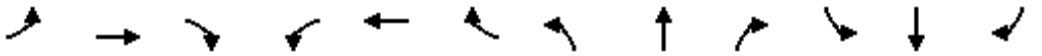
m Volume for 95th percentile queue is metered by upstream signal.

Splits and Phases: 11: Rt 20 & Concord Rd



Intersection Capacity Analysis
Route 20 at Farm Road, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	97	703	64	254	732	61	99	53	309	80	64	83
Future Volume (vph)	97	703	64	254	732	61	99	53	309	80	64	83
Satd. Flow (prot)	1787	3574	1599	1787	3525	0	1770	1863	1583	0	1830	1599
Flt Permitted	0.950			0.950			0.950				0.973	
Satd. Flow (perm)	1781	3574	1599	1787	3525	0	1764	1863	1562	0	1828	1575
Satd. Flow (RTOR)			190		8							190
Confl. Peds. (#/hr)	2					2	1		1	1		1
Confl. Bikes (#/hr)												
Peak Hour Factor	0.94	0.94	0.94	0.92	0.92	0.92	0.88	0.88	0.88	0.83	0.83	0.83
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	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)	111	808	74	298	931	0	122	65	379	0	187	108
Turn Type	Prot	NA	Perm	Prot	NA		Split	NA	pm+ov	Split	NA	Perm
Protected Phases	5	2		1	6		8	8	1	4	4	
Permitted Phases			2						8			4
Total Split (s)	14.0	35.0	35.0	25.0	46.0		13.0	13.0	25.0	17.0	17.0	17.0
Total Lost Time (s)	5.0	5.0	5.0	5.0	5.0		5.0	5.0	5.0		5.0	5.0
Act Effct Green (s)	9.0	25.2	25.2	20.1	36.3		8.2	8.2	28.2		12.2	12.2
Actuated g/C Ratio	0.10	0.28	0.28	0.22	0.40		0.09	0.09	0.31		0.14	0.14
v/c Ratio	0.62	0.81	0.13	0.75	0.65		0.76	0.38	0.77		0.75	0.29
Control Delay	58.5	38.3	0.4	48.0	25.1		72.6	49.9	38.9		59.9	1.9
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0
Total Delay	58.5	38.3	0.4	48.0	25.1		72.6	49.9	38.9		59.9	1.9
LOS	E	D	A	D	C		E	D	D		E	A
Approach Delay		37.7			30.7			47.4			38.7	
Approach LOS		D			C			D			D	
Queue Length 50th (ft)	58	206	0	148	197		65	34	161		98	0
Queue Length 95th (ft)	#181	#403	0	#394	389		#209	92	#363		#254	0
Internal Link Dist (ft)		394			534			205			111	
Turn Bay Length (ft)	350		50				75		150			
Base Capacity (vph)	182	1215	669	405	1642		160	169	500		248	378
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	0.61	0.67	0.11	0.74	0.57		0.76	0.38	0.76		0.75	0.29

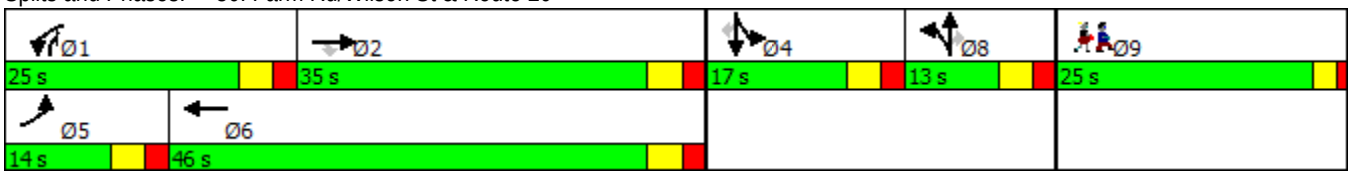
Intersection Summary	
Cycle Length: 115	
Actuated Cycle Length: 89.9	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.81	
Intersection Signal Delay: 36.8	Intersection LOS: D
Intersection Capacity Utilization 63.8%	ICU Level of Service B
Analysis Period (min) 15	

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	25.0
Total Lost Time (s)	
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

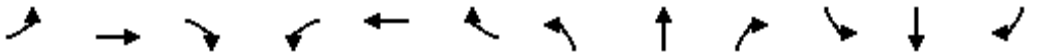
95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Splits and Phases: 30: Farm Rd/Wilson St & Route 20



Intersection Capacity Analysis
Route 20 at Dicenzo Boulevard/Pomphrey Drive, Marlborough

11/9/2016



Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Future Volume (vph)	29	595	123	62	1087	25	220	6	25	13	6	6
Satd. Flow (prot)	1728	3365	0	1711	3411	0	3173	1513	0	1636	1593	0
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1728	3365	0	1711	3411	0	3173	1513	0	1636	1593	0
Satd. Flow (RTOR)		23			2			29			9	
Confl. Peds. (#/hr)												
Confl. Bikes (#/hr)												
Peak Hour Factor	0.89	0.89	0.89	0.98	0.98	0.98	0.94	0.94	0.94	0.70	0.70	0.70
Growth Factor	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%	108%
Heavy Vehicles (%)	1%	1%	1%	2%	2%	2%	3%	3%	3%	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)	35	871	0	68	1226	0	253	36	0	20	18	0
Turn Type	Prot	NA		Prot	NA		Split	NA		Split	NA	
Protected Phases	5	2		1	6		8	8		4	4	
Permitted Phases												
Total Split (s)	11.0	46.0		15.0	50.0		16.0	16.0		11.0	11.0	
Total Lost Time (s)	5.0	5.0		5.0	5.0		5.0	5.0		5.0	5.0	
Act Effct Green (s)	7.0	30.3		9.0	35.7		11.6	11.6		7.0	7.0	
Actuated g/C Ratio	0.10	0.41		0.12	0.49		0.16	0.16		0.10	0.10	
v/c Ratio	0.21	0.62		0.32	0.74		0.50	0.14		0.13	0.11	
Control Delay	46.1	21.6		43.3	22.0		39.5	20.6		46.0	34.2	
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	46.1	21.6		43.3	22.0		39.5	20.6		46.0	34.2	
LOS	D	C		D	C		D	C		D	C	
Approach Delay		22.6			23.2			37.1			40.4	
Approach LOS		C			C			D			D	
Queue Length 50th (ft)	17	165		32	258		61	3		9	4	
Queue Length 95th (ft)	59	353		97	#588		#164	37		32	23	
Internal Link Dist (ft)		391			775			209			131	
Turn Bay Length (ft)	120			400								
Base Capacity (vph)	164	2168		271	2337		554	288		156	159	
Starvation Cap Reductn	0	0		0	0		0	0		0	0	
Spillback Cap Reductn	0	0		0	0		0	0		0	0	
Storage Cap Reductn	0	0		0	0		0	0		0	0	
Reduced v/c Ratio	0.21	0.40		0.25	0.52		0.46	0.13		0.13	0.11	

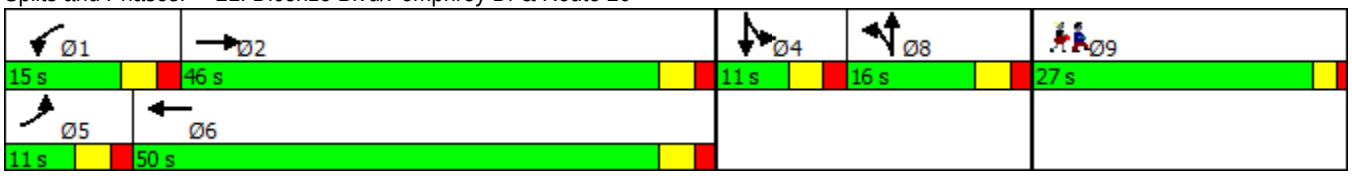
Intersection Summary			
Cycle Length: 115			
Actuated Cycle Length: 73.1			
Control Type: Actuated-Uncoordinated			
Maximum v/c Ratio: 0.74			
Intersection Signal Delay: 24.8		Intersection LOS: C	
Intersection Capacity Utilization 64.3%		ICU Level of Service C	
Analysis Period (min) 15			

Lane Group	Ø9
Lane Configurations	
Traffic Volume (vph)	
Future Volume (vph)	
Satd. Flow (prot)	
Flt Permitted	
Satd. Flow (perm)	
Satd. Flow (RTOR)	
Confl. Peds. (#/hr)	
Confl. Bikes (#/hr)	
Peak Hour Factor	
Growth Factor	
Heavy Vehicles (%)	
Bus Blockages (#/hr)	
Parking (#/hr)	
Mid-Block Traffic (%)	
Shared Lane Traffic (%)	
Lane Group Flow (vph)	
Turn Type	
Protected Phases	9
Permitted Phases	
Total Split (s)	27.0
Total Lost Time (s)	
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

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

Splits and Phases: 21: Dicenzo Blvd/Pomphrey Dr & Route 20



APPENDIX L

MassDOT Project Development Process

Overview of the Project Development Process

Transportation decision-making is complex and can be influenced by legislative mandates, environmental regulations, financial limitations, agency programmatic commitments, and partnering opportunities. Decision-makers and reviewing agencies, when consulted early and often throughout the project development process, can ensure that all participants understand the potential impact these factors can have on project implementation. Project development is the process that takes a transportation improvement from concept through construction.

The MassDOT Highway Division has developed a comprehensive project development process which is contained in Chapter 2 of the *MassDOT Highway Division's Project Development and Design Guide*. The eight-step process covers a range of activities extending from identification of a project need, through completion of a set of finished contract plans, to construction of the project. The sequence of decisions made through the project development process progressively narrows the project focus and, ultimately, leads to a project that addresses the identified needs. The descriptions provided below are focused on the process for a highway project, but the same basic process will need to be followed for non-highway projects as well.

1. Needs Identification

For each of the locations at which an improvement is to be implemented, MassDOT leads an effort to define the problem, establishes project goals and objectives, and defines the scope of the planning needed for implementation. To that end, it has to complete a Project Need Form (PNF), which states in general terms the deficiencies or needs related to the transportation facility or location. The PNF documents the problems and explains why corrective action is needed. For this study, the information defining the need for the project will be drawn primarily, perhaps exclusively, from the present report. Also, at this point in the process, MassDOT meets with potential participants, such as the Metropolitan Planning Organization (MPO) and community members, to allow for an informal review of the project.

The PNF is reviewed by the MassDOT Highway Division district office whose jurisdiction includes the location of the proposed project. MassDOT also sends the PNF to the MPO, for informational purposes. The outcome of this step determines whether the project requires further planning, whether it is already well supported by prior planning studies, and, therefore, whether it is ready to move forward into the design phase, or whether it should be dismissed from further consideration.

2. Planning

This phase will likely not be required for the implementation of the improvements proposed in this planning study, as this planning report should constitute the outcome of this step. However, in general, the purpose of this implementation step is for the project proponent to identify issues, impacts, and approvals that may need to be obtained, so that the subsequent design and permitting processes are understood.

The level of planning needed will vary widely, based on the complexity of the project. Typical tasks include: define the existing context, confirm project need, establish goals and objectives, initiate public outreach, define the project, collect data, develop and analyze alternatives, make

recommendations, and provide documentation. Likely outcomes include consensus on the project definition to enable it to move forward into environmental documentation (if needed) and design, or a recommendation to delay the project or dismiss it from further consideration.

3. Project Initiation

At this point in the process, the proponent, MassDOT Highway Division, fills out a Project Initiation Form (PIF) for each improvement, which is reviewed by its Project Review Committee (PRC) and the MPO. The PRC is composed of the Chief Engineer, each District Highway Director, and representatives of the Project Management, Environmental, Planning, Right-of-Way, Traffic, and Bridge departments, and the MassDOT Federal Aid Program Office (FAPO). The PIF documents the project type and description, summarizes the project planning process, identifies likely funding and project management responsibility, and defines a plan for interagency and public participation. First the PRC reviews and evaluates the proposed project based on the MassDOT's statewide priorities and criteria. If the result is positive, MassDOT Highway Division moves the project forward to the design phase, and to programming review by the MPO. The PRC may provide a Project Management Plan to define roles and responsibilities for subsequent steps. The MPO review includes project evaluation based on the MPO's regional priorities and criteria. The MPO may assign project evaluation criteria score, a Transportation Improvement Program (TIP) year, a tentative project category, and a tentative funding category.

4. Environmental Permitting, Design, and Right-of-Way Process

This step has four distinct but closely integrated elements: public outreach, environmental documentation and permitting (if required), design, and right-of-way acquisition (if required). The outcome of this step is a fully designed and permitted project ready for construction. However, a project does not have to be fully designed in order for the MPO to program it in the TIP. The sections below provide more detailed information on the four elements of this step of the project development process.

Public Outreach

Continued public outreach in the design and environmental process is essential to maintain public support for the project and to seek meaningful input on the design elements. The public outreach is often in the form of required public hearings, but can also include less formal dialogues with those interested in and affected by a proposed project.

Environmental Documentation and Permitting

The project proponent, in coordination with the Environmental Services section of the MassDOT Highway Division, will be responsible for identifying and complying with all applicable federal, state, and local environmental laws and requirements. This includes determining the appropriate project category for both the Massachusetts Environmental Protection Act (MEPA) and the National Environmental Protection Act (NEPA). Environmental documentation and permitting is often completed in conjunction with the **Preliminary Design** phase described below.

Design
There are three major phases of design. The first is **Preliminary Design**, which is also referred to as the 25-percent submission. The major components of this phase include full survey of the project area, preparation of base plans, development of basic geometric layout, development of preliminary cost estimates, and submission of a functional design report. Preliminary Design, although not required to, is often completed in conjunction with the Environmental Documentation and Permitting. The next phase is **Final Design**, which is also referred to as the 75-percent and 100-percent submission. The major components of this phase include preparation of a subsurface exploratory plan (if required), coordination of utility relocations, development of traffic management plans through construction zones, development of final cost estimates, and refinement and finalization of the construction plans. Once Final Design is complete, a full set of **Plans, Specifications, and Estimates (PS&E)** is developed for the project.

Right-of-Way Acquisition
A separate set of Right-of-Way plans are required for any project that requires land acquisition or easements. The plans must identify the existing and proposed layout lines, easements, property lines, names of property owners, and the dimensions and areas of estimated takings and easements.

5. Programming (Identification of Funding)
Programming, which typically begins during the design phase, can actually occur at any time during the process, from planning to design. In this step, which is distinct from project initiation, the proponent requests that the MPO place the project in the region's Transportation Improvement Program (TIP). The proponent requesting the project's listing on the TIP can be the community or it can be one of the MPO member agencies (the Regional Planning Agency, MassDOT, and the Regional Transit Authority). The MPO then considers the project in terms of state and regional needs, evaluation criteria, and compliance with the regional Transportation Plan and decides whether to place it in the draft TIP for public review and then in the final TIP.

6. Procurement
Following project design and programming of a highway project, the MassDOT Highway Division publishes a request for proposals. It then reviews the bids and awards the contract to the qualified bidder with the lowest bid.

7. Construction
After a construction contract is awarded, MassDOT Highway Division and the contractor develop a public participation plan and a management plan for the construction process.

8. Project Assessment
The purpose of this step is to receive constituents' comments on the project development process and the project's design elements. MassDOT Highway Division can apply what is learned in this process to future projects.

Project Development Schematic Timetable

Description	Schedule Influence	Typical Duration
Step I: Problem/Need/Opportunity Identification The proponent completes a Project Need Form (PNF). This form is then reviewed by the MassDOT Highway District office which provides guidance to the proponent on the subsequent steps of the process.	The Project Need Form has been developed so that it can be prepared quickly by the proponent, including any supporting data that is readily available. The District office shall return comments to the proponent within one month of PNF submission.	1 to 3 months
Step II: Planning Project planning can range from agreement that the problem should be addressed through a clear solution to a detailed analysis of alternatives and their impacts.	For some projects, no planning beyond preparation of the Project Need Form is required. Some projects require a planning study centered on specific project issues associated with the proposed solution or a narrow family of alternatives. More complex projects will likely require a detailed alternatives analysis.	Project Planning Report: 3 to 24+ months
Step III: Project Initiation The proponent prepares and submits a Project Initiation Form (PIF) and a Transportation Evaluation Criteria (TEC) form in this step. The PIF and TEC are informally reviewed by the Metropolitan Planning Organization (MPO) and MassDOT Highway District office, and formally reviewed by the PRC.	The PIF includes refinement of the preliminary information contained in the PNF. Additional information summarizing the results of the planning process, such as the Project Planning Report, are included with the PIF and TEC. The schedule is determined by PRC staff review (dependent on project complexity) and meeting schedule.	1 to 4 months
Step IV: Design, Environmental, and Right of Way The proponent completes the project design. Concurrently, the proponent completes necessary environmental permitting analyses and files applications for permits. Any right of way needed for the project is identified and the acquisition process begins.	The schedule for this step is dependent upon the size of the project and the complexity of the design, permitting, and right-of-way issues. Design review by the MassDOT Highway district and appropriate sections is completed in this step.	3 to 48+ months
Step V: Programming The MPO considers the project in terms of its regional priorities and determines whether or not to include the project in the draft Regional Transportation Improvement Program (TIP) which is then made available for public comment. The TIP includes a project description and funding source.	The schedule for this step is subject to each MPO's programming cycle and meeting schedule. It is also possible that the MPO will not include a project in its Draft TIP based on its review and approval procedures.	3 to 12+ months
Step VI: Procurement The project is advertised for construction and a contract awarded.	Administration of competing projects can influence the advertising schedule.	1 to 12 months
Step VII: Construction The construction process is initiated including public notification and any anticipated public involvement. Construction continues to project completion.	The duration for this step is entirely dependent upon project complexity and phasing.	3 to 60+ months
Step VIII: Project Assessment The construction period is complete and project elements and processes are evaluated on a voluntary basis.	The duration for this step is dependent upon the proponent's approach to this step and any follow-up required.	1 month

Source: MassDOT Highway Division Project Development and Design Guide