

Appendix E
Signal Warrant Analysis

Signal Warrant Analysis – Spring St/Hayden Ave/Patriot Way

Based on weekday traffic count data obtained in February 2009 described in section 2 of the Traffic Impact Report prepared for the Lexington Technology Park project, an analysis was conducted to ascertain if installation of a full signal is warranted at the Spring Street/Hayden Avenue/Patriot parkway intersection under existing, 2014 No Build and 2014 Build conditions. Automatic traffic recorders (ATRs) were used to collect data on two week days in February 2009 at four locations adjacent to the intersection – On Spring street south of Hayden Avenue, On Hayden Avenue just east of Spring Street, On spring Street just north of Hayden Avenue and on Patriot way just west of Spring Street. Average weekday hourly volume distribution was calculated based on this data. The average 24-hour data was used to calculate the highest eight-hour, four-hour and peak hour volumes under existing conditions. The volume calculation spreadsheets are attached.

For future No Build and Build conditions, morning and afternoon peak hour traffic volumes were calculated as described in section 3 of the report. These peak hour volumes were distributed across a 24-hour period based on the filed collected ATR data. These traffic volumes were reviewed to determine which, if any, of the traffic volume warrants contained in the Manual on Uniform Traffic Control Devices (MUTCD 2003) are met. Summarized below are our findings.

Warrant 1-Eight-Hour Vehicular Volume

Warrant 1 – Minimum Vehicular Volume (Condition A)

Criteria

The need for a traffic control signal shall be considered if an engineering study finds the vehicles per hour given in both of the 100 percent columns in Table 1 exist for each of any eight hours of an average day. In applying the condition the major street and minor street volumes shall be for the same eight hour periods. On the minor street, the higher volume shall not be required to be on the same approach during each of the eight hours. The volume criteria that must be met are highlighted in Table 1. We assumed 2 lanes on both the major street (Spring street) and minor street (Patriot way/Hayden Way).

Table 1 Minimum Vehicular Volumes for Warrant 1 (Condition A)

Number of Lanes for Moving Traffic on Each Approach		Vehicles Per Hour on Major Street (Total of both Approaches)			Vehicle Per Hour on Higher Volume Minor Street Approach (One Direction Only)		
<u>Major Street</u>	<u>Minor Street</u>	<u>100%¹</u>	<u>80%²</u>	<u>70%³</u>	<u>100%¹</u>	<u>80%²</u>	<u>70%³</u>
1	1	500	400	350	150	120	105
2 ≥	1	600	480	420	150	120	105
2 ≥	2 ≥	600	480	420	200	160	140
1	2 ≥	500	400	350	200	160	140

¹ Basic minimum hourly volumes

² Used for combination of Conditions A and B after adequate trial of other remedial measures

³ May be used when major street speed exceeds 70 km/h (40 mph) or in an isolated community with a population of less than 10,000.

Analysis Results

Table 2 provides the analysis of Warrant 1, Condition A for the study intersection. As noted in Table 2, the minimum vehicular volume threshold is not met in three and one of the eight hours under existing and No-Build conditions respectively. The criteria are met for all eight hours under Build conditions. The warrant requires that the volume threshold be met for eight hours. Consequently, the requirements for Warrant 1, Condition A are not met under existing and No-Build conditions and are met under Build conditions.

Table 2 Minimum Vehicular Volumes (Condition A)

Hour	2009 Existing			2014 No Build			2014 Build		
	Major	Minor	Criteria Satisfied	Major	Minor	Criteria Satisfied	Major	Minor	Criteria Satisfied
7:00 AM	989	271	YES	1587	247	YES	1736	332	YES
8:00 PM	1234	412	YES	1985	375	YES	2180	505	YES
9:00 PM	620	255	YES	1002	232	YES	1110	313	YES
2:00 PM	406	227	NO	588	749	NO	616	1099	YES
3:00 PM	663	222	YES	968	458	YES	1015	672	YES
4:00 PM	698	166	NO	1026	646	YES	1076	948	YES
5:00 PM	809	214	YES	1179	641	YES	1236	941	YES
6:00 PM	568	136	NO	829	286	YES	870	420	YES

NOTE: Volumes in **Bold** meet minimum vehicular requirements for that approach. To satisfy the warrant criteria, the volume threshold must be met for the Major and Minor streets.

Warrant 1 – Interruption of Continuous Traffic (Condition B)

Criteria

The need for a traffic control signal shall be considered if an engineering study finds the vehicles per hour given in both of the 100 percent columns in Table 3 exist for each of any eight hours of an average day. In applying the condition the major street and minor street volumes shall be for the same eight hours. On the minor street, the higher volume shall not be required to be on the same approach during each of the eight hours. The volume criteria that must be met are highlighted in Table 3. The same assumptions as Condition A were used.

Table 3 Interruption of Continuous Traffic (Condition B)

Number of Lanes for Moving Traffic on Each Approach		Vehicles Per Hour on Major Street (Total of both Approaches)			Vehicle Per Hour on Higher Volume Minor Street Approach (One Direction Only)		
Major Street	Minor Street	100% ¹	80% ²	70% ³	100% ¹	80% ²	70% ³
1	1	750	600	525	75	60	53
2 ≥	1	900	720	630	75	60	53
2 ≥	2 ≥	900	720	630	100	80	70
1	2 ≥	750	600	525	100	80	70

1 Basic minimum hourly volumes

2 Used for combination of Conditions A and B after adequate trial of other remedial measures

3 May be used when major street speed exceeds 70 km/h (40 mph) or in an isolated community with a population of less than 10,000.

Analysis Results

Table 4 provides the analysis of Warrant 1, Condition B for the study intersection. As noted in Table 4, the minimum vehicular volume threshold is not met during six of the eight hours under existing conditions. The criteria are not met for two of the eight hours under both No-Build and Build conditions. The warrant requires that the volume threshold be met for all eight hours. Consequently, the requirements for Warrant 1, Condition B are not met under existing, No-Build and Build conditions.

Table 4 Minimum Vehicular Volumes (Condition B)

Hour	2009 Existing			2014 No Build			2014 Build		
	Major	Minor	Criteria Satisfied	Major	Minor	Criteria Satisfied	Major	Minor	Criteria Satisfied
7:00 AM	989	271	YES	1587	247	YES	1736	332	YES
8:00 PM	1234	412	YES	1985	375	YES	2180	505	YES
9:00 PM	620	255	NO	1002	232	YES	1110	313	YES
2:00 PM	406	227	NO	588	749	NO	616	1099	NO
3:00 PM	663	222	NO	968	458	YES	1015	672	YES
4:00 PM	698	166	NO	1026	646	YES	1076	948	YES
5:00 PM	809	214	NO	1179	641	YES	1236	941	YES
6:00 PM	568	136	NO	829	286	NO	870	420	NO

NOTE: Volumes in **Bold** meet minimum vehicular requirements for that approach. To satisfy the warrant criteria, the volume threshold must be met for the Major and Minor streets.

Warrant 2 – Four Hour Vehicular Volume

Criteria

The need for a traffic control signal shall be considered if an engineering study finds that, for each of four hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher volume minor street approach all fall above the applicable curve. On the minor street, the higher volume shall not be required to be on the same approach during each of these four hours.

Analysis Results

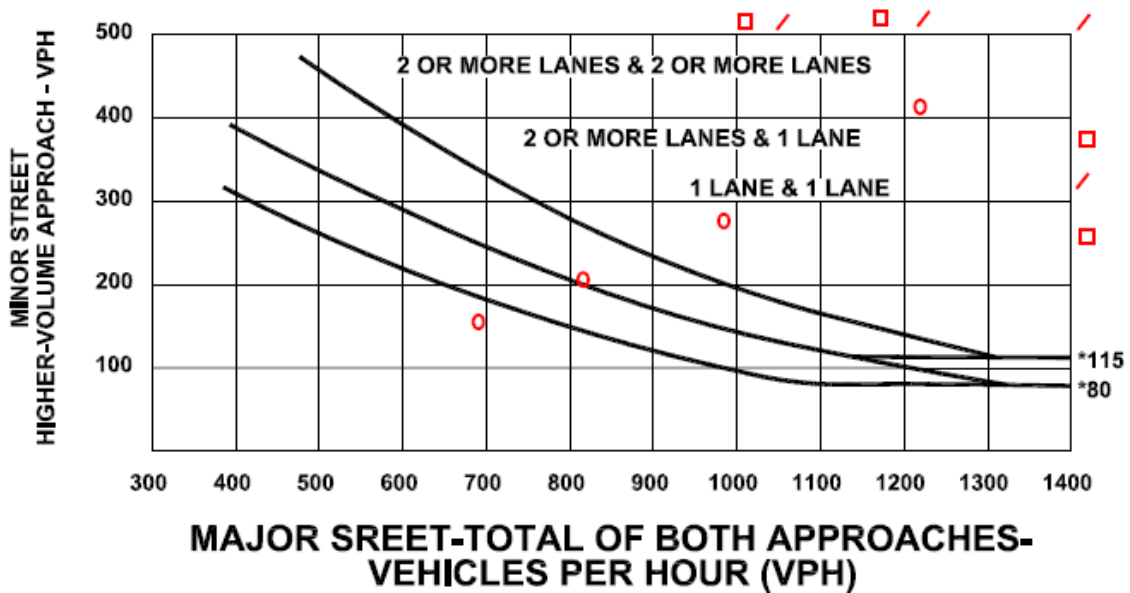
Table 5 presents the highest four-hour volumes for the study intersection. The four highest volume hours of the day were plotted on the graph contained in Figure 4C-1 of the MUTCD 2003, which is presented below. As can be seen, two of the four highest hours under existing conditions fall below the 2 or more lanes & 2 or more lanes line, which is appropriate for the study intersection. All of the four highest hour volumes under both No-Build and Build conditions fall above the 2 or more lanes + 2 or more lanes line. Therefore, the requirements for Warrant 2 are not met under existing conditions. However the warrants are met under future No-Build and Build conditions.

Table 5 Highest Four-Hour Volumes

Hour	2009 Existing			2014 No Build			2014 Build		
	Major	Minor	Criteria Satisfied	Major	Minor	Criteria Satisfied	Major	Minor	Criteria Satisfied
7:00 AM	989	271	YES	1587	247	YES	1736	332	YES
8:00 PM	1234	412	YES	1985	375	YES	2180	505	YES
4:00 PM	698	166	NO	1026	646	YES	1076	948	YES
5:00 PM	809	214	NO	1179	641	YES	1236	941	YES

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Figure 4C-1. Warrant 2, Four-Hour Vehicular Volume



*Note: 115 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 80 vph applies as the lower threshold volume for a minor-street approach with one lane.

LEGEND
 Existing - ○ No-Build - □ Build - /

Warrant 3 – Peak Hour Volume

Criteria

The need for a traffic control signal shall be considered if an engineering study finds that the criteria in either of the following two categories are met:

- 1) The plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher volume minor street approach (one direction only) for one hour of an average day falls above the applicable curve (figure 4C-3 of MUTCD 2003 is also shown below).

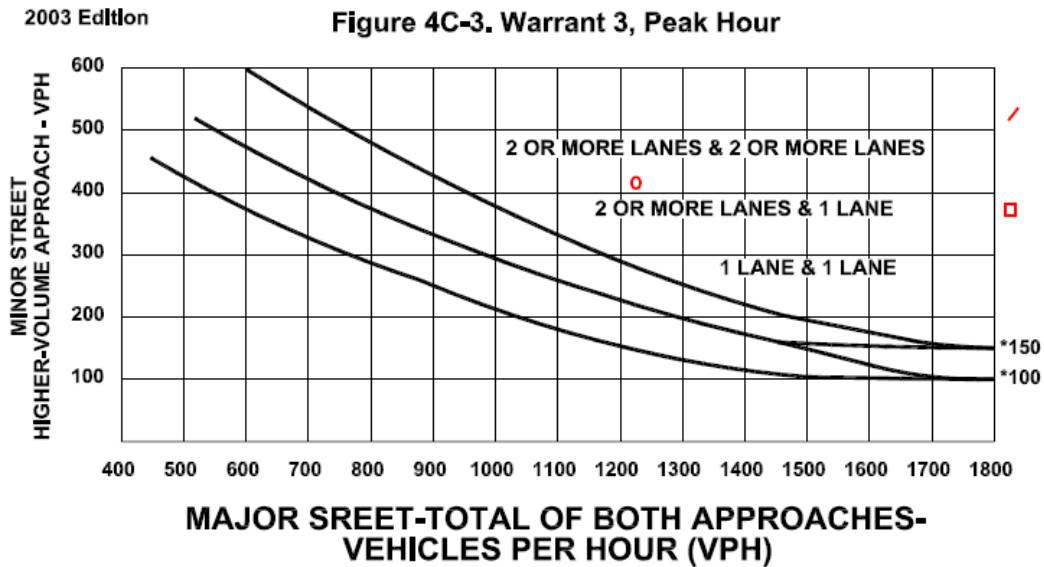
- 2) If all three of the following conditions exist for the same hour on a average day:
- a) The total stop delay experienced by the traffic on one minor street approach controlled by a STOP sign equals or exceeds four vehicle-hours of delay on a one lane approach or five vehicles hours of delay on a two lane approach
 - b) The volume on the same minor street approach equals or exceeds 100 vehicles per hour for one lane approach or 150 vehicles per hour for a two lane approach
 - c) The total entering volume serviced during the hour equals or exceeds 650 vehicles per hour for intersections with three approaches and 800 vehicles per hour for intersections with four or more approaches.

Analysis Results

Table 6 presents the highest peak-hour volumes for the study intersection. As shown on the Figure, plotted volumes for the peak hour of the day plot above the 2 or more lanes + 2 or more lanes line on the graph. Therefore, the requirements for Warrant 3 are met under all conditions.

Table 6 Highest Peak-Hour Volumes

Hour	2009 Existing			2014 No Build			2014 Build		
	Major	Minor	Criteria Satisfied	Major	Minor	Criteria Satisfied	Major	Minor	Criteria Satisfied
8:00 PM	1234	412	YES	1985	375	YES	2180	505	YES



*Note: 150 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 100 vph applies as the lower threshold volume for a minor-street approach with one lane.

LEGEND
 Existing - o No-Build - □ Build - /

Summary

Table 7 provides a summary of the above signal warrant analysis. As noted in Table 7, the study intersection would likely meet three of the nine signal warrants defined in the MUTCD 2003 only under future 2014 Build conditions.

Table 7 Signal Warrant Analysis Summary

Warrants	Warrant Criteria Satisfied		
	2009 Existing	2014 No-Build	2014 Build
Warrant 1 – Eight Hour Vehicular Volume			
Condition A	NO	NO	YES
Condition B	NO	NO	NO
Warrant 2 - Four Hour Vehicular Volume	NO	YES	YES
Warrant 3 - Peak Hour Vehicular Volume	YES	YES	YES
ALL THREE WARRANTS MET?	NO	NO	YES

Spring St/Patriot Way/Hayden Ave						Peak volumes (Highlighted) are from 2009 TIS report Figures 4 & 9													
Intersection Approach Volumes						Traffic volume distributions				2014 No Build Volumes					2014 Build Volumes				
Traffic Volumes from ATR Counts						NB	SB	EB Pat way	WB Hay Ave	NB	SB	EB Pat way	WB Hay Ave	TOTAL	NB	SB	EB Pat way	WB Hay Ave	TOTAL
Time	NB	SB	EB Pat way	WB Hay Ave	TOTAL														
12:00 AM	14	5	3	8	29														
01:00 AM	6	6	2	4	17														
02:00 AM	6	5	2	4	16														
03:00 AM	4	4	0	3	11														
04:00 AM	6	3	4	4	16														
05:00 AM	98	30	6	29	161														
06:00 AM	245	171	14	82	512														
07:00 AM	384	605	29	271	1288	71%	88%	145%	66%	632	956	155	247	1989	725	1011	265	332	2333
08:00 AM	544	690	20	412	1665	100%	100%	100%	100%	895	1090	107	375	2467	1027	1153	183	505	2868
09:00 AM	341	279	45	255	920	63%	40%	225%	62%	561	441	241	232	1475	644	467	412	313	1835
10:00 AM	203	150	43	140	536														
11:00 AM	220	139	70	140	568														
12:00 PM	265	158	59	157	638														
01:00 PM	212	168	49	148	576														
02:00 PM	240	167	164	227	796	46%	59%	117%	106%	364	223	749	324	1660	382	235	1099	364	2079
03:00 PM	440	224	100	222	985	84%	79%	71%	104%	668	300	458	316	1743	700	315	672	356	2043
04:00 PM	506	192	141	166	1004	96%	68%	101%	78%	770	257	646	236	1909	806	270	948	266	2290
05:00 PM	526	283	140	214	1162	100%	100%	100%	100%	800	379	641	305	2125	838	398	941	343	2520
06:00 PM	376	192	63	136	766	71%	68%	45%	63%	572	258	286	194	1309	599	270	420	218	1507
07:00 PM	151	107	30	66	353														
08:00 PM	75	54	6	37	171														
09:00 PM	78	50	12	31	171														
10:00 PM	106	29	4	51	189														
11:00 PM	26	14	5	14	58														

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Final Volumes to be used for Signal Warrant Analysis

Existing Conditions Analysis

Peak Hour Warrant		
Time	Major St	Minor St
08:00 AM	1234	412
Four Hour Warrant		
Time	Major St	Minor St
07:00 AM	989	271
08:00 AM	1234	412
04:00 PM	698	166
05:00 PM	809	214
Eight Hour Warrant		
Time	Major St	Minor St
07:00 AM	989	271
08:00 AM	1234	412
09:00 AM	620	255
02:00 PM	406	227
03:00 PM	663	222
04:00 PM	698	166
05:00 PM	809	214
06:00 PM	568	136

2014 No Build Conditions Analysis

Peak Hour Warrant		
Time	Major St	Minor St
08:00 AM	1985	375
Four Hour Warrant		
Time	Major St	Minor St
07:00 AM	1587	247
08:00 AM	1985	375
04:00 PM	1026	646
05:00 PM	1179	641
Eight Hour Warrant		
Time	Major St	Minor St
07:00 AM	1587	247
08:00 AM	1985	375
09:00 AM	1002	232
02:00 PM	588	749
03:00 PM	968	458
04:00 PM	1026	646
05:00 PM	1179	641
06:00 PM	829	286

2014 Build Conditions Analysis

Peak Hour Warrant		
Time	Major S	Minor St
08:00 AM	2180	505
Four Hour Warrant		
Time	Major S	Minor St
07:00 AM	1736	332
08:00 AM	2180	505
04:00 PM	1076	948
05:00 PM	1236	941
Eight Hour Warrant		
Time	Major S	Minor St
07:00 AM	1736	332
08:00 AM	2180	505
09:00 AM	1110	313
02:00 PM	616	1099
03:00 PM	1015	672
04:00 PM	1076	948
05:00 PM	1236	941
06:00 PM	870	420