Chapter 8 – Statistical Analysis of Roundabout and Comparable Intersections – Analysis I

Using standard statistical techniques *(15, 16)*, the output data from the SIDRA model was analyzed to determine how the operation of the roundabout (CG) compared to that of the two comparable two-way STOP controlled intersections (DW and JP). Twenty-two data points (hourly traffic counts) were available for each location. SIDRA provided data for each of six measures of effectiveness (MOEs). The statistical analysis of each MOE is presented individually in the following sections of the report.

SIDRA output for all sixty-six hourly traffic counts were evaluated using SAS. The statistical tests were performed using the Statistical Analysis Software (SAS) version 6.12 on the Kansas State University Unix operating system.

Two base assumptions exist for the use of most statistical tests: normality and equal variances. These two data assumptions were tested prior to determining what specific statistical test to use to evaluate the intersection operation as it related to the MOEs. The statistical process is summarized in Table 17.

The first test of normality was an evaluation of the relationship between the interquartile range and the standard deviation. The interquartile range is the difference between the 25th and 75th percentile values and was obtained from the SAS computer output. Similarly, the standard deviation for each data set was obtained from the SAS output. A normal distribution was indicated if the ratio of these two values was near 1.3. For the purposes of this study, this normality indicator was satisfied if the IQR/S value was within +/- 50% of the desired 1.3 value.

The Shapiro-Wilk test was also used for evaluating normality. This test is sensitive to small samples. To lessen the possibility of a false rejection, a small alpha value of 0.01 was chosen.

The determination of normality was based on the results of both tests. While in most cases, the results were similar (either showing normal or not normal); there was a range in the individual test results. Therefore, the normal determination was a judgement decision based on the two test results. Normality is identified as test ‘I’ in the MOE statistical tables.

The second area to be examined was that of equal variances. Equal variances between the three data sets were tested using the Levene’s test. This test is sensitive to normality assumptions; therefore, the null hypothesis was rejected only if the test p-value was less than 0.01 (α value). The equal variance test is identified as ‘II’ in the statistical summary tables.

One of three different statistical paths were chosen based on the results of the normality and equal variance tests (see tests III.A, IIIB and IIIC in Table 17).

If the data was found to be normally distributed with equal variances, the equality of the means was tested using the analysis of variance (ANOVA), F-test. An alpha value of 0.05 was used for this test. If the analysis of variance test resulted in a failure to reject the null hypothesis, then the statistical process stopped. Failure to reject the null hypothesis meant that the three means could be considered statistically equal. If the analysis of variance test resulted in a null hypothesis rejection, then the means were considered to be unequal. The next question was what intersection means were different. This was tested using Tukey’s and Duncan’s multiple comparison tests. This testing procedure is identified as ‘III.A.’ in the summary table and in the statistical tables for each MOE.

Table 17 - Statistical Test Summary Overview

Test:	**Comment:**
I. Normality	
- IQR/S ≈ 1.3	Interquartile divided by standard deviation
- Shapiro-Wilk P-value	H_o: 'have a normal distribution', $\alpha = 0.01$
II. Equal Variances	
Levene's test	H_o: $\sigma^2_{CG} = \sigma^2_{DW} = \sigma^2_{JP}$, $\alpha = 0.01$
III.A. Normal w/ Equal Variances	
Analysis of Variance F-test	H_o: $\mu_{CG} = \mu_{DW} = \mu_{JP}$, $\alpha = 0.05$
- Fail to reject – means considered equal, analysis stops	
- Reject – perform multiple comparisons	
Tukey's and Duncan tests	
III.B. Normal w/ Unequal Variances	
Welch's test	H_o: $\mu_{CG} = \mu_{DW} = \mu_{JP}$, $\alpha = 0.05$
- Fail to reject – means considered equal, analysis stops	
- Reject – perform multiple comparisons	
Fisher Least Significant Difference test	
III.C. Not normal	
Kruskal-Wallis test	H_o: 'Population distributions are the same', $\alpha = 0.05$
- Fail to reject – distributions considered equal, analysis stops	
- Reject – Observe data plots to determine rank order	

If the data was found to be normally distributed, but did not have equal variances, the equality of means was tested using Welch's test. An alpha value of 0.05 was used for this test. If the test returned a failure to reject the null hypothesis, the means could be considered equal and the statistical process stopped. If however, the test returned a rejection of the null hypothesis, the Fisher Least Significant Difference test was used to determine which means were statistically different. The normal with unequal variance tests are shown as 'III.B' in the summary statistical tables.

Finally, a non-parametric test was used if the data was found to be not normally distributed. The Kruskal-Wallis test was used to test whether the data populations were the same. An alpha value of 0.05 was used for this test. If this test returned a failure to reject the null hypothesis, then the statistical analysis stopped as the three populations could be considered statistically the same. If the null hypothesis was rejected, the populations could be considered statistically different. The specific differences in intersections MOE values were determined through observation of the data plots. The non-parametric test is identified as 'III.C.' in the statistical tables.

The next section of the report provides the results of the statistical analysis on the input and SIDRA traffic counts. This is followed by the results of the statistical analysis for each of the six measures of effectiveness. This chapter is concluded with a section that outlines the results of the MOE statistics for the evaluation of the roundabout and the two comparable intersections.

Plots are shown with lines between the data points for readability purposes only. No conclusions should be made that the lines indicate a statistical distribution. Note that the rankings used in the statistical tables are based on results of the statistical tests used and are provided to assist the understanding of the results for the reader.

Section 8.1 – Statistical Analysis of SIDRA Hourly Traffic Values (I)

SIDRA uses the peak traffic in an hour to evaluate the traffic conditions at an intersection. This traffic volume is calculated by dividing the actual hour volume by the peak hour factor.

The SIDRA hourly volumes were tested to see if they came from the same population using the null hypothesis shown in equation 6.2. The statistical testing went through the three statistical steps outlined previously. The results of that process are shown in Table 18.

Table 18 - Statistical Test Summary of SIDRA Traffic Volumes (I)

Test:	**Intersection:**		
I. Normality	**CG**	**DW**	**JP**
- IQR/S ≈ 1.3	1.4	1.8	1.4
- Shapiro-Wilk P-value	0.30	0.004	0.51
Normal?	Yes	No	Yes
II. Equal Variances			
Levene's test	$P = 0.0001 < \alpha = 0.01$ Reject		
III.C. Not normal			
Kruskal-Wallis test	$P = 0.435 > \alpha = 0.05$ Fail to reject		

The SIDRA traffic counts at two of the intersections were found to be normally distributed. The SIDRA counts at the DW intersection were borderline in one of the normality tests used and not normal in the other two. The three data sets were found to have unequal variances. Therefore, the null hypothesis was tested using the statistical non-parametric test, Kruskal-Wallis. This test produced a p-value that failed to reject the null hypothesis. Therefore, the three sets of SIDRA traffic counts can be considered to be statistically similar to one another. This conclusion allows the statistical evaluation of the SIDRA output.

The mean and standard deviation for the three sets of SIDRA traffic counts are shown in Table 19.

Table 19 - Summary Statistics of SIDRA Traffic Volumes (I)

	Intersection:		
Summary Statistics:	**CG**	**DW**	**JP**
Mean (μ)	394	463	407
Standard Deviation (σ)	67.8	138.0	95.6

Section 8.2 – Statistical Analysis of SIDRA Output for Roundabout and Comparable Intersections (I)

The results of the statistical evaluation for each individual MOE are provided in the following sections.

Section 8.2.1 – Statistical Analysis of 95 Percentile Queue (I)

The 95 percentile queue as described previously represents the bounds of the queue at the intersection. The 95 percentile queue values are shown with regard to the amount of entering traffic in Table 20 and Figure 15.

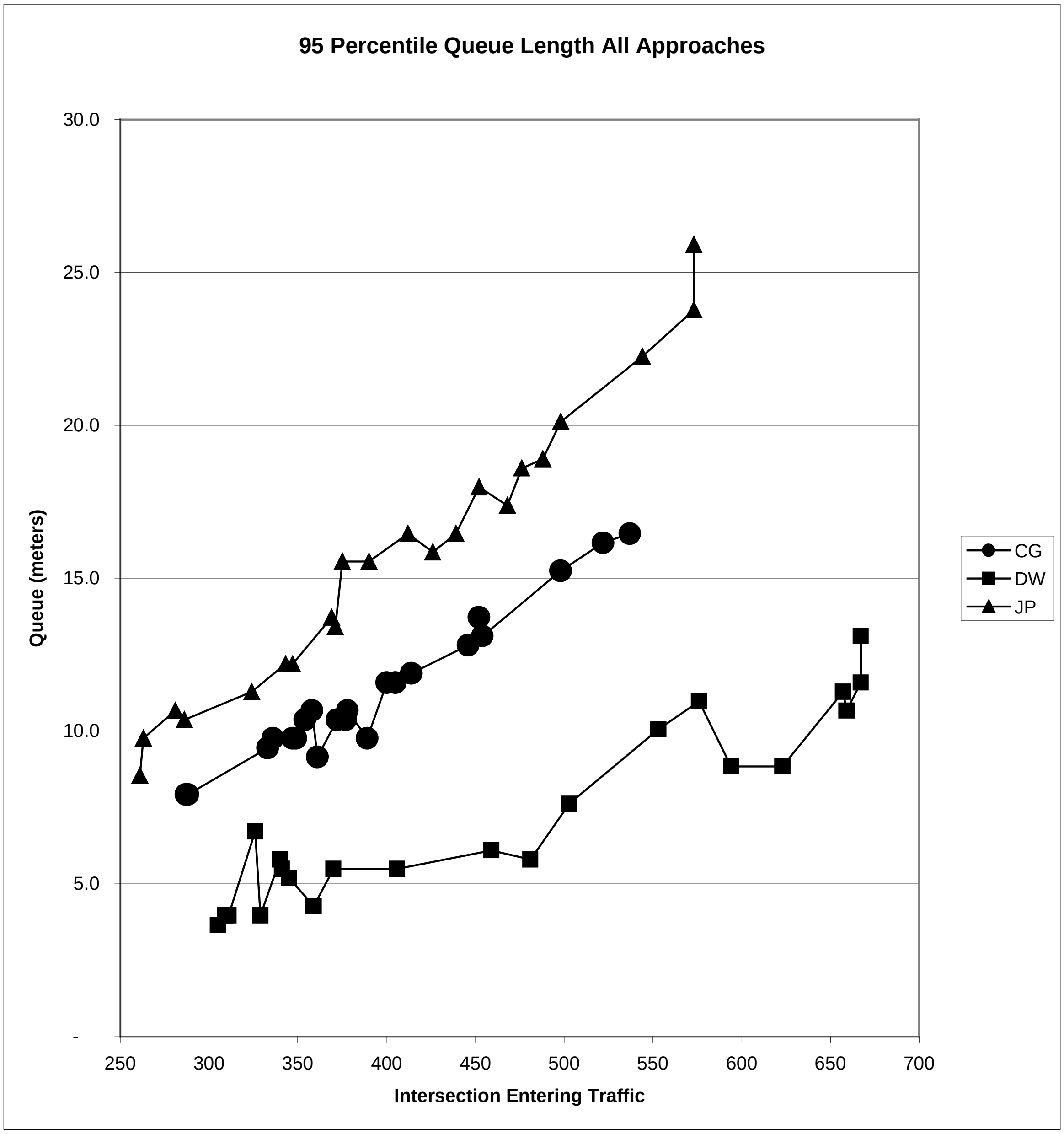
These values were tested statistically to determine if the three intersections (and two intersection control types) resulted in different values of 95 percentile queue (see Table 21).

The 95 percentile queue values were found to be normally distributed with equal variances. Therefore, the analysis of variance test was performed. This test rejected the null hypothesis of equal means. Tukey's and Duncan's multiple comparisons both concluded that all three means could be considered to be statistically different from one another. The mean and standard deviation values for the three intersections are shown in Table 22.

Therefore, for the MOE of 95 percentile queue, there appears to be no benefit or detriment to an intersection being controlled by either a two-way STOP or a roundabout at these traffic levels.

Table 20 - 95 Percentile Queue Values (I)

Candlewood Drive/ Gary Ave			**Dickens Ave/ Wreath Ave**			**Juliette Ave/ Pierre St**		
Traffic Volume	Queue (m)	(ft)	Traffic Volume	Queue (m)	(ft)	Traffic Volume	Queue (m)	(ft)
287	7.9	26	305	3.7	12	261	8.5	28
288	7.9	26	309	4.0	13	263	9.8	32
333	9.4	31	311	4.0	13	281	10.7	35
336	9.8	32	326	6.7	22	286	10.4	34
347	9.8	32	329	4.0	13	324	11.3	37
349	9.8	32	340	5.8	19	343	12.2	40
354	10.4	34	341	5.5	18	347	12.2	40
358	10.7	35	345	5.2	17	369	13.7	45
361	9.1	30	359	4.3	14	371	13.4	44
372	10.4	34	370	5.5	18	375	15.5	51
377	10.4	34	406	5.5	18	390	15.5	51
378	10.7	35	459	6.1	20	412	16.5	54
389	9.8	32	481	5.8	19	426	15.8	52
400	11.6	38	503	7.6	25	439	16.5	54
405	11.6	38	553	10.1	33	452	18.0	59
414	11.9	39	576	11.0	36	468	17.4	57
446	12.8	42	594	8.8	29	476	18.6	61
452	13.7	45	623	8.8	29	488	18.9	62
454	13.1	43	657	11.3	37	498	20.1	66
498	15.2	50	659	10.7	35	544	22.3	73
522	16.2	53	667	11.6	38	573	23.8	78
537	16.5	54	667	13.1	43	573	25.9	85



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 15 – 95 Percentile Queue Values (I)

Table 21 - Statistical Test Summary of 95 Percentile Queue (I)

Test:	**Intersection:**		
I. Normality	**CG**	**DW**	**JP**
- IQR/S ≈ 1.3	1.3	1.7	1.4
- Shapiro-Wilk P-value	0.079	0.030	0.670
Normal?	Yes	Yes	Yes
II. Equal Variances			
Levene's test	P = 0.0127 < α = 0.01 Fail to reject		
III.A. Normal w/ Equal Variances			
ANOVA test	P = 0.0001 < α = 0.05 Reject		
Tukey's groupings	CG ≠ DW ≠ JP		
Duncan's groupings	CG ≠ DW ≠ JP		

Table 22 - 95 Percentile Mean and Standard Deviation (I)

Intersection:	**Mean(μ):**	**Ranking*:**	**Standard Deviation(σ):**
CG	11 m (37 ft)	B	2.42 m (7.86 ft)
DW	7 m (24 ft)	A	2.97 m (9.65 ft)
JP	16 m (52 ft)	C	4.69 m (15.24 ft)

*Means with the same letters are not statistically significantly different.

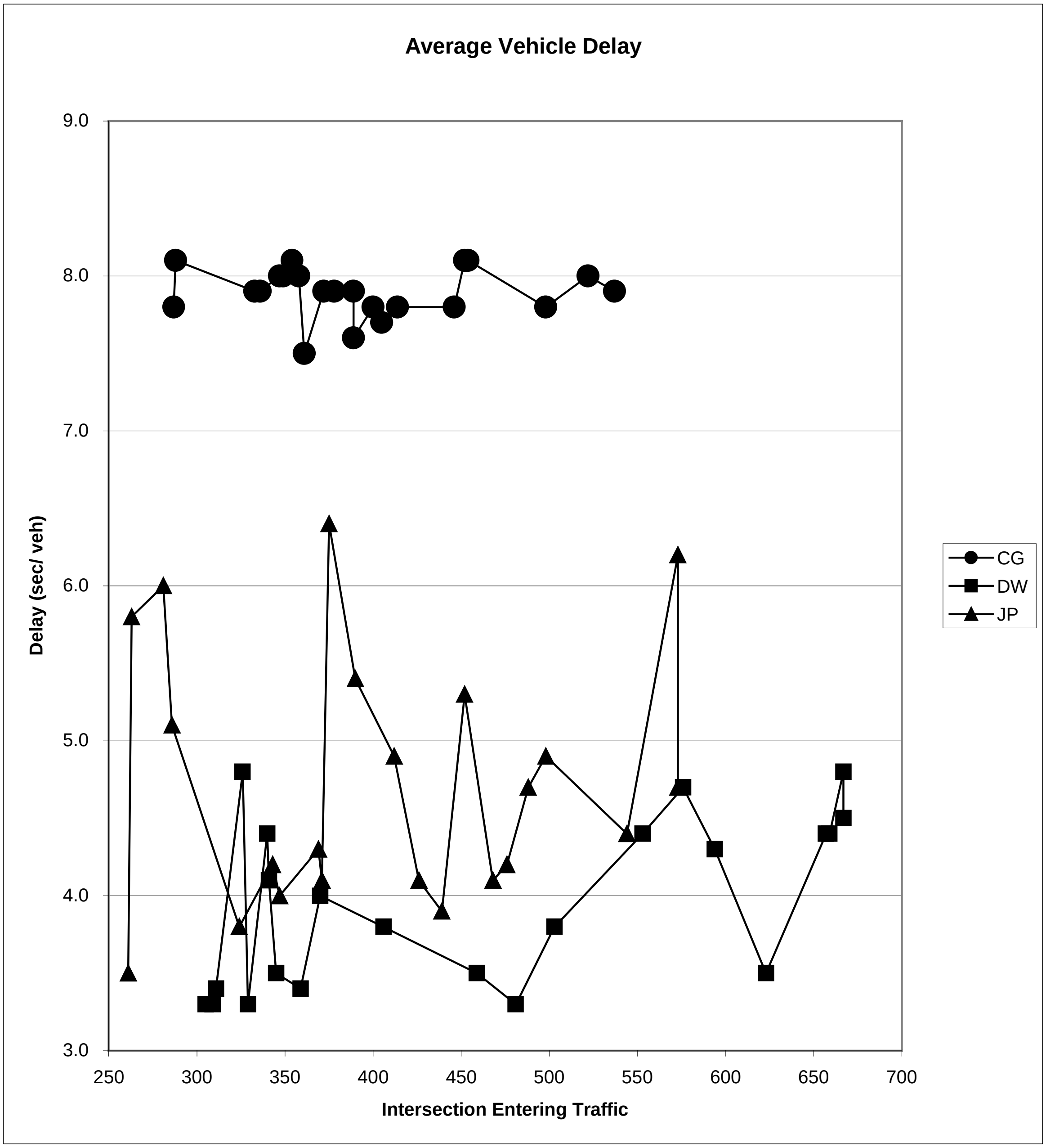
Section 8.2.2 – Statistical Analysis of Average Delay (I)

The average intersection delay as described previously represents the total vehicle delay for the hour divided by the number of entering vehicles. The SIDRA output values for the average vehicle delay are shown in Table 23 and Figure 16. The values were tested statistically to determine if the three intersections (and two intersection control types) resulted in different values of average delay.

Table 23 - Average Vehicle Delay (I)

Candlewood Dr/ Gary Ave		**Dickens Ave/ Wreath Ave**		**Juliette Ave/ Pierre St**	
Traffic Volume	Delay (sec/veh)	Traffic Volume	Delay (sec/veh)	Traffic Volume	Delay (sec/veh)
287	7.8	305	3.3	261	3.5
288	8.1	309	3.3	263	5.8
333	7.9	311	3.4	281	6.0
336	7.9	326	4.8	286	5.1
347	8.0	329	3.3	324	3.8
349	8.0	340	4.4	343	4.2
354	8.1	341	4.1	347	4.0
358	8.0	345	3.5	369	4.3
361	7.5	359	3.4	371	4.1
372	7.9	370	4.0	375	6.4
378	7.9	406	3.8	390	5.4
389	7.9	459	3.5	412	4.9
389	7.6	481	3.3	426	4.1
400	7.8	503	3.8	439	3.9
405	7.7	553	4.4	452	5.3
414	7.8	576	4.7	468	4.1
446	7.8	594	4.3	476	4.2
452	8.1	623	3.5	488	4.7
454	8.1	657	4.4	498	4.9
498	7.8	659	4.4	544	4.4
522	8.0	667	4.8	573	6.2
537	7.9	667	4.5	573	4.7

The average delay values were found to be normally distributed with unequal variances (see Table 24). Therefore, the means were evaluated using the Welch's test. This test rejected the null hypothesis of equal means. Fisher's multiple comparison concluded that all three means could be considered to be statistically different from one another. The mean and standard deviation values for the three intersections are shown in Table 25.



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 16 - Average Vehicle Delay (I)

Table 24 - Statistical Test summary for Average Vehilcle Delay (I)

Test:	**Intersection:**		
I. Normality	**CG**	**DW**	**JP**
- IQR/S ≈ 1.3	1.3	1.8	1.5
- Shapiro-Wilk P-value	0.084	0.013	0.130
Normal?	Yes	Yes	Yes
II. Equal Variances			
Levene's test	P = 0.0001 < α = 0.01 Reject		
III.B. Normal w/ Unequal Variances			
Welch's test	P = 0.0001 < α = 0.05 Reject		
Fishers LSD groupings	CG ≠ DW ≠ JP		

Table 25 - Average Vehicle Delay Mean and Standard Deviation (I)

Intersection:	**Mean(μ):**	**Ranking:**	**Standard Deviation(σ):**
CG	7.9 sec	C	0.160 sec
DW	4.0 sec	A	0.544 sec
JP	4.7 sec	B	0.826 sec

Therefore, for the MOE of average delay, the two-way STOP controlled intersections appear to operate better than the roundabout controlled intersection.

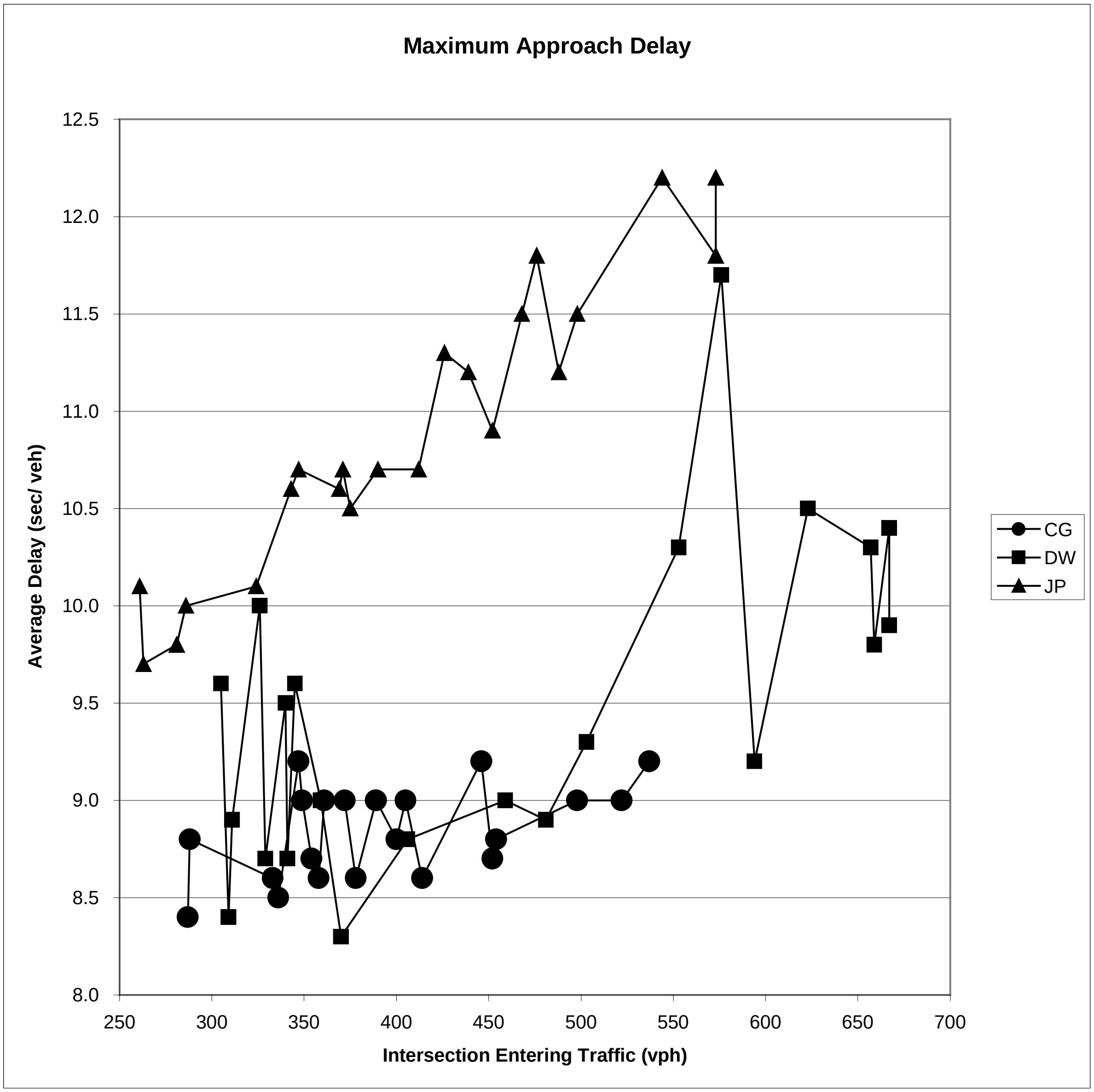
This apparent advantage to the two-way STOP controlled intersections is due to the inherent priority given to the "main street" traffic at a two-way STOP controlled intersection. In some cases, this priority to the "main street" occurs at the cost of efficiency to the side street. Therefore, there may be great disparities between the overall intersection average delay value and the approach which experiences the worst delay. A roundabout evenly distributes intersection delays to all approaches not giving priority treatment to any one street or approach.

Section 8.2.3 – Statistical Analysis of Maximum Approach Delay (I)

The maximum approach delay was described previously. SIDRA provides delay for the entire intersection (average delay) and then apportions this value to the intersection approaches based on amount of entering traffic (see Table 26 and
Figure 17). The approach that experienced the highest average delay was evaluated.

Table 26 - Maximum Approach Avenage Vehicle Delay (I)

Candlewood Drive/ Gary Ave		**Dickens Ave/ Wreath Ave**		**Juliette Avenue/ Pierre Street**	
Traffic Volume	Delay (sec/veh)	Traffic Volume	Delay (sec/ veh)	Traffic Volume	Delay (sec/veh)
287	8.4	305	9.6	261	10.1
288	8.8	309	8.4	263	9.7
333	8.6	311	8.9	281	9.8
336	8.5	326	10.0	286	10.0
347	9.2	329	8.7	324	10.1
349	9.0	340	9.5	343	10.6
354	8.7	341	8.7	347	10.7
358	8.6	345	9.6	369	10.6
361	9.0	359	9.0	371	10.7
372	9.0	370	8.3	375	10.5
378	8.6	406	8.8	390	10.7
389	9.0	459	9.0	412	10.7
389	9.0	481	8.9	426	11.3
400	8.8	503	9.3	439	11.2
405	9.0	553	10.3	452	10.9
414	8.6	576	11.7	468	11.5
446	9.2	594	9.2	476	11.8
452	8.7	623	10.5	488	11.2
454	8.8	657	10.3	498	11.5
498	9.0	659	9.8	544	12.2
522	9.0	667	10.4	573	11.8
537	9.2	667	9.9	573	12.2



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 17 - Maximum Approach Average Vehicle Delay (I)

The maximum approach delay values were found to be normally distributed with unequal variances (see Table 27). Therefore, the means were evaluated using the Welch's test. This test rejected the null hypothesis of equal means. Fisher's multiple comparison concluded that all three means could be considered to be statistically different from one another. The mean and standard deviation values for the three intersections are shown in Table 28.

Table 27 - Statistical Test Summary for Maximum Approach Delay (I)

Test:	**Intersection:**		
I. Normality	**CG**	**DW**	**JP**
- IQR/S ≈ 1.3	1.7	1.3	1.4
- Shapiro-Wilk P-value	0.69	0.24	0.47
Normal?	Yes	Yes	Yes
II. Equal Variances			
Levene's test	$P = 0.0002 < \alpha = 0.01$ Reject		
III.B. Normal w/ Unequal Variances			
Welch's test	$P = 0.0001 < \alpha = 0.05$ Reject		
Fishers LSD groupings	CG ≠ DW ≠ JP		

Therefore, for the MOE of maximum approach delay, the two-way STOP controlled intersections appear to operate worse than the roundabout controlled intersection. This is due to the inherent priority given to the "main street" traffic at a two-way STOP controlled intersection. This priority results in severe delays being experienced by the side street traffic.

Table 28 - Maximum Approach Delay Mean and Standard Deviation (I)

Intersection:	**Mean(μ):**	**Ranking:**	**Standard Deviation(σ):**
CG	8.9 sec	A	0.237 sec
DW	9.5 sec	B	0.823 sec
JP	10.9 sec	C	0.734 sec

A roundabout evenly distributes intersection affects to all approaches not giving priority treatment to any one street or approach. The results of the analysis of maximum approach and average delay show this. While the average delay for the entire intersection may be worse at a roundabout carrying traffic volumes examined here, the disparity between the approach delays results in the maximum approach delay being better at the roundabout.

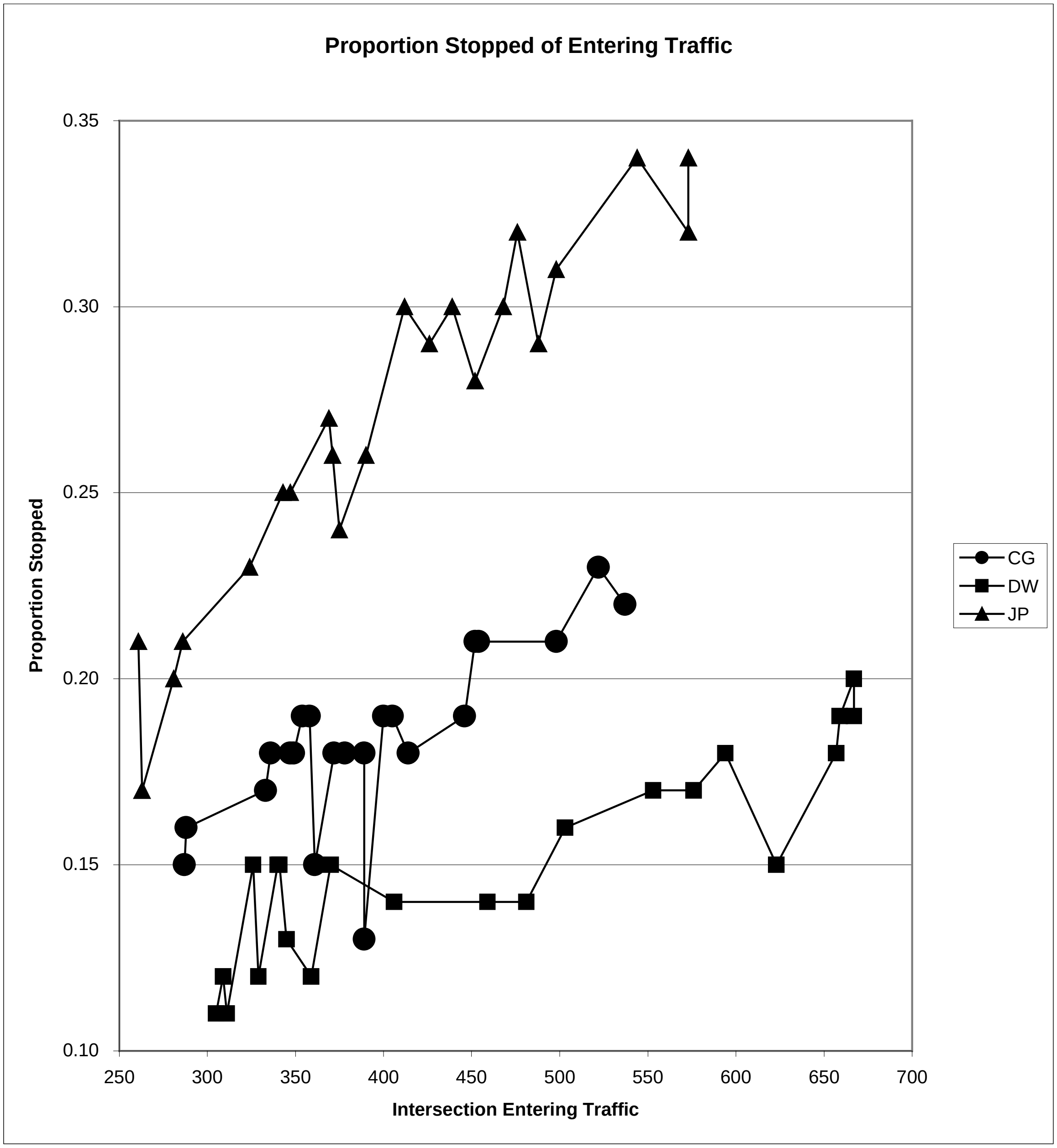
Section 8.2.4 – Statistical Analysis of Proportion Stopped (I)

The proportion stopped as described previously represents the proportion of entering vehicles stopped by the presence of a vehicle(s) already in the intersection. The values for proportion stopped can range from 0.0 to 1.0 (see Table 29 and Figure 18).

Table 29 - Proportion Stopped (I)

Candlewood Dr/ Gary Ave		**Dickens Ave/ Wreath Ave**		**Juliette Ave/ Pierre St**	
Traffic Volume	Stopped	Traffic Volume	Stopped	Traffic Volume	Stopped
287	0.15	305	0.11	261	0.21
288	0.16	309	0.12	263	0.17
333	0.17	311	0.11	281	0.20
336	0.18	326	0.15	286	0.21
347	0.18	329	0.12	324	0.23
349	0.18	340	0.15	343	0.25
354	0.19	341	0.15	347	0.25
358	0.19	345	0.13	369	0.27
361	0.15	359	0.12	371	0.26
372	0.18	370	0.15	375	0.24
378	0.18	406	0.14	390	0.26
389	0.18	459	0.14	412	0.30
389	0.13	481	0.14	426	0.29
400	0.19	503	0.16	439	0.30
405	0.19	553	0.17	452	0.28
414	0.18	576	0.17	468	0.30
446	0.19	594	0.18	476	0.32
452	0.21	623	0.15	488	0.29
454	0.21	657	0.18	498	0.31
498	0.21	659	0.19	544	0.34
522	0.23	667	0.20	573	0.32
537	0.22	667	0.19	573	0.34

The statistical testing performed here is for the proportion of vehicles from all approaches being stopped. As with previous MOEs the testing was done to determine if there were statistical differences in the amount of stopping experienced at the three intersections.



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 18 - Proportion Stopped (I)

The proportion stopped values were found to be normally distributed with unequal variances (see Table 30). Therefore, the means were evaluated using the Welch's test. This test rejected the null hypothesis of equal means. Fisher's multiple comparison concluded that all three means could be considered to be statistically different from one another. The mean and standard deviation values for the three intersections are shown in Table 31.

Table 30 - Statistical Test Summary for Proportin Stopped (I)

Test:	**Intersection:**		
I. Normality	**CG**	**DW**	**JP**
- IQR/S ≈ 1.3	1.0	1.5	1.3
- Shapiro-Wilk P-value	0.32	0.37	0.62
Normal?	Yes	Yes	Yes
II. Equal Variances			
Levene's test	P = 0.0015 < α = 0.01 Reject		
III.B. Normal w/ Unequal Variances			
Welch's test	P = 0.0001 < α = 0.05 Reject		
Fishers LSD groupings	CG ≠ DW ≠ JP		

Table 31 - Proportion Stopped Mean and Standard Deviation (I)

Intersection:	**Mean(μ):**	**Ranking:**	**Standard Deviation(σ):**
CG	0.18	B	0.0236
DW	0.15	A	0.0267
JP	0.27	C	0.0466

Based on the statistical testing and the results shown for the proportion stopped means for the three intersections are different. However, upon examination of the intersection means, there appears to be no advantage or disadvantage for the roundabout or two-way STOP intersection control.

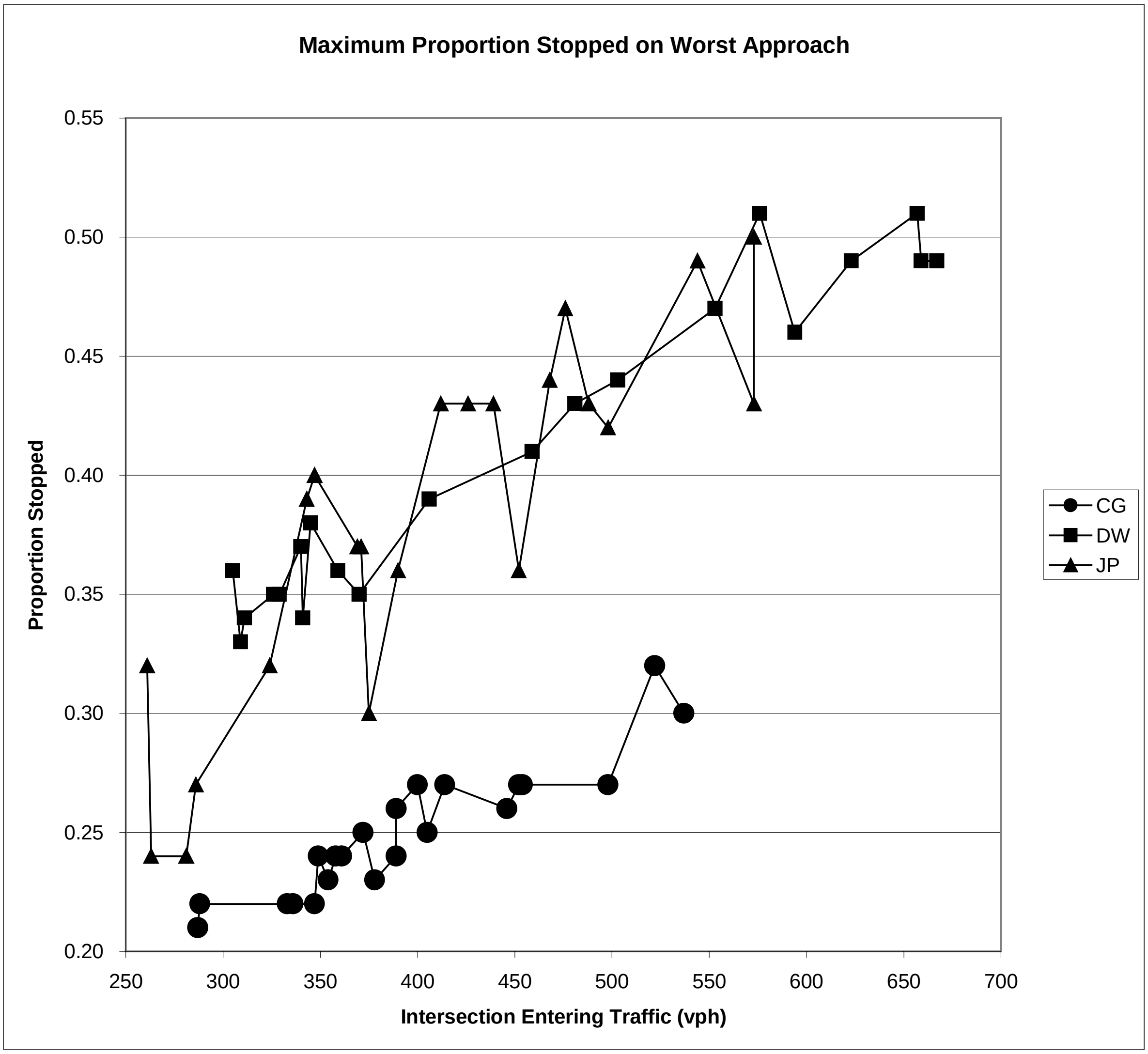
Section 8.2.5 – Statistical Analysis of Maximum Proportion Stopped (I)

The maximum proportion stopped as described previously represents the approach experiencing the highest level of vehicles being stopped by intersection traffic. These values can range from 0.0 to 1.0 (see Table 32 and Note: Lines between data points are used only to aid in the readability of the figure.

Figure 19). Statistical testing was performed to determine which, if any, of the intersections could be considered to be experiencing a different value of this MOE (see Table 33).

Table 32 - Maximum Approach Proportion Stopped (I)

Candlewood Dr/ Gary Ave		**Dickens Ave/ Wreath Ave**		**Juliette Ave/ Pierre St**	
Traffic Volume	Proportion Stop	Traffic Volume	Proportion Stop	Traffic Volume	Proportion Stop
287	0.21	305	0.36	261	0.32
288	0.22	309	0.33	263	0.24
333	0.22	311	0.34	281	0.24
336	0.22	326	0.35	286	0.27
347	0.22	329	0.35	324	0.32
349	0.24	340	0.37	343	0.39
354	0.23	341	0.34	347	0.40
358	0.24	345	0.38	369	0.37
361	0.24	359	0.36	371	0.37
372	0.25	370	0.35	375	0.30
378	0.23	406	0.39	390	0.36
389	0.24	459	0.41	412	0.43
389	0.26	481	0.43	426	0.43
400	0.27	503	0.44	439	0.43
405	0.25	553	0.47	452	0.36
414	0.27	576	0.51	468	0.44
446	0.26	594	0.46	476	0.47
452	0.27	623	0.49	488	0.43
454	0.27	657	0.51	498	0.42
498	0.27	659	0.49	544	0.49
522	0.32	667	0.49	573	0.43
537	0.30	667	0.49	573	0.50



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 19 - Maximum Approach Proportion Stopped (I)

The proportion stopped values were found not to be normally distributed. Therefore, the distributions were evaluated using the Kruskal-Wallis test. This test rejected the null hypothesis of equal distributions. The mean and standard deviation values for the three intersections are shown in Table 34.

Table 33 - Statistical Test Summary for Maximum Approach Stopped (I)

Test:	**Intersection:**		
I. Normality	**CG**	**DW**	**JP**
- IQR/S ≈ 1.3	1.4	2.2	1.5
- Shapiro-Wilk P-value	0.12	0.01	0.24
Normal?	Yes	No	Yes
II. Equal Variances			
Levene's test	P = 0.0001 < α = 0.01 Reject		
III.C. Not Normal			
Kruskal-Wallis test	P = 0.0001 < α = 0.05 Reject		
Box plot observation	CG < JP < DW		

Table 34 - Maximum Proportion Stopped Mean and Standard Deviation (I)

Intersection:	**Mean(μ):**	**Standard Deviation(σ):**
CG	0.25	0.0276
DW	0.41	0.0646
JP	0.38	0.0751

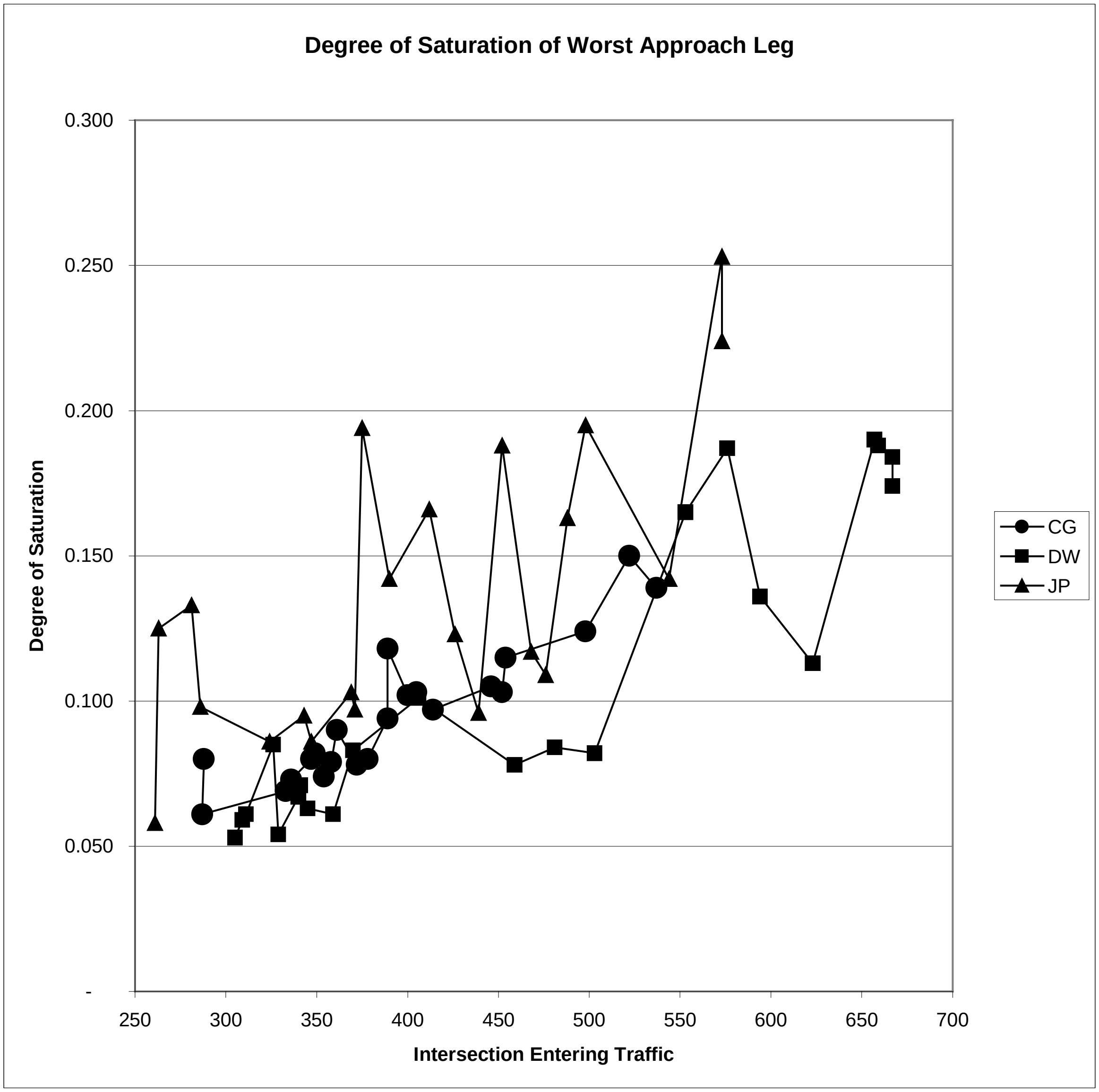
Therefore, for the MOE of maximum approach stopped, the two-way STOP controlled intersections both experienced higher maximum stop rates than the roundabout.

Section 8.2.6 – Statistical Analysis of Degree of Saturation (I)

The degree of saturation as described previously represents the amount of the intersection capacity that is being used by the stated traffic level. Degree of saturation is commonly referred to as the volume to capacity (v/c) ratio (see Table 35 and Figure 20). The degree of saturation values were tested to determine if any of the three intersections could be considered to operate at different level with regard to this MOE.

Table 35 - Degree of Saturation (I)

Candlewood Dr/ Gary Ave		**Dickens Ave/ Wreath Ave**		**Juliette Ave/ Pierre St**	
Traffic Volume	Saturation	Traffic Volume	Saturation	Traffic Volume	Saturation
288	0.080	305	0.053	261	0.058
287	0.061	309	0.059	263	0.125
333	0.069	311	0.061	281	0.133
336	0.073	326	0.085	286	0.098
347	0.080	329	0.054	324	0.086
349	0.082	340	0.067	343	0.095
354	0.074	341	0.071	347	0.086
358	0.079	345	0.063	369	0.103
361	0.090	359	0.061	371	0.097
372	0.078	370	0.083	375	0.194
378	0.080	406	0.101	390	0.142
389	0.094	459	0.078	412	0.166
389	0.118	481	0.084	426	0.123
400	0.102	503	0.082	439	0.096
405	0.103	553	0.165	452	0.188
414	0.097	576	0.187	468	0.117
446	0.105	594	0.136	476	0.109
452	0.103	623	0.113	488	0.163
454	0.115	657	0.190	498	0.195
498	0.124	659	0.188	544	0.142
522	0.150	667	0.184	573	0.253
537	0.139	667	0.174	573	0.224



Note: Lines between data points are used only to aid in the readability of the figure.

Figure 20 - Degree of Saturation (I)

The degree of saturation values were found not to be normally distributed (see Table 36). Therefore, the distributions were evaluated using the Kruskal-Wallis test. This test rejected the null hypothesis of equal distributions. Observing the box plots and mean values found the intersection ranking shown. The mean and standard deviation values for the three intersections are shown in Table 37.

Therefore, with regard to the degree of saturation, the roundabout operates better at the traffic levels analyzed than do two-way STOP controlled intersections.

Table 36 - Statistical Test Summary for Degree of Saturation (I)

Test:	**Intersection:**		
I. Normality	**CG**	**DW**	**JP**
- IQR/S ≈ 1.3	1.1	1.2	1.4
- Shapiro-Wilk P-value	0.17	0.0008	0.18
Normal?	Yes	No	Yes
II. Equal Variances			
Levene's test	P = 0.0007 < α = 0.01 Reject		
III.C. Not Normal			
Kruskal-Wallis test	P = 0.0068 < α = 0.05 Reject		
Box plot observation	CG < DW < JP		

Table 37 - Degree of Saturation Mean and Standard Deviation (I)

Intersection:	**Mean(μ):**	**Standard Deviation(σ):**
CG	0.095	0.0231
DW	0.106	0.0510
JP	0.136	0.0500

Section 8.2.7 – Summary of Statistical Analysis of SIDRA Output (I)

The purpose of analyzing the MOE data was to determine if and how the three intersections (two intersection control types) differed in operation at the present traffic levels. There were two two-way STOP controlled intersections in this study: Dickens Avenue/ Wreath Avenue (DW) and Juliette Avenue/ Pierre Street (JP). There was one roundabout under observation: Candlewood Drive/ Gary Avenue (CG). The evaluation of the three intersections was done through statistical testing of the data. The results of that testing are shown in Table 38.

Table 38 - Summary of MOE Statistical Results - Analysis I

Measure of Effectiveness:	**Statistical Result:**	**Operational Advantage:**
95 Percentile Queue	DW < CG < JP	None*
Average Delay	DW < JP < CG	two-way STOP provides less average delay
Maximum Approach Delay	CG < DW < JP	Roundabout provides lower maximum approach delay
Proportion Stopped	DW < CG < JP	None*
Maximum Approach Stopped	CG < JP < DW	Roundabout provides lower maximum approach stopped
Degree of Saturation	CG < DW < JP	Roundabout provides lower degree of saturation

Note that the 'None' response in the summary table does not indicate that there is not an advantage to one intersection control type over another; only that no statistical conclusion could be drawn.

All results shown in the table met the criteria to be considered statistically significant at the 95% confidence level.

Table 38 shows that there were two MOEs that produced no clear conclusion with regard to a preferred intersection control at the traffic level under study. These were the amount of 95% queue and proportion stopped.

Average delay was found to favor two-way STOP control at the traffic level under study. This result is different when the delays are examined on an approach by approach basis. A roundabout provides for the lowest maximum approach delay.

This apparent discrepancy in the delays at two-way STOPs and roundabouts becomes evident when examining the way in which right-of-way (ROW) is assigned. At two-way STOP intersections, there is preference given to traffic on the major street. The STOP controlled street is delayed by the stopping maneuver, even when no stop is needed to accommodate cross street traffic. If the STOP direction does not match the major traffic flow at the intersection, large delays may occur. Or, as happened at the JP intersection, if the major flow approaches to the intersection are perpendicular to one another, a two-way STOP control always penalizes one of these major approaches. This leads to large delays for the stopped major approach. As the direction of the STOP signs cannot adjust to traffic conditions, it is possible that over time, the major street or approaches do become stopped and the intersection operation degrades.

All approaches to a roundabout are YIELD controlled. Therefore, a roundabout allows equal access to the intersection from all approaches. While this resulted in higher overall delays at the intersection, delay equity was achieved. In other words, no approach received preferential treatment at the expense (high delay) of another.

At the traffic levels studies here, it becomes a choice of the intersection control designer whether to provide lower overall delay while penalizing one or more approaches with higher delays (i.e.: two-way STOP) or to minimize the worst approach delay through installation of a roundabout.

The maximum approach stopped is the least when a roundabout controls the intersection.

Degree of saturation is also the lowest under roundabout intersection traffic control. This MOE measures how much of the available intersection capacity is being used. Therefore, it can be concluded that at the traffic levels under study, a roundabout uses the available intersection capacity better than would two-way STOP control.

Overall, despite this roundabout operating at the low end of the scale for those in the United States with regard to traffic volume, it appeared to operate better than a comparable two-way STOP intersection.