Evaluation of Speed Management Strategies: A Before and After Study

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Abstract

In recent years there has been a considerable amount of interest on the part of road authorities and their residents in stopping the progressive erosion of residential quality of life caused by street traffic. High traffic volumes and speeds, especially on local streets, potentially impact residents in terms of safety, noise, and pollution. Road authorities have expressed interest in implementation of speed management strategies (as a means of decreasing the cars' dominance) that are relatively low-cost in nature and easily implemented in the short-term periods (within 1-5 years). Speed management strategies aim at reducing the frequency of vehicle with speed too fast for the prevailing conditions and increase compliance with the posted speed limit. These speed management strategies encompass a wide range of measures that include enforcement, education, and engineering. It is critically important for road authorities to understand the effectiveness of these measures on operating speed of vehicles. This paper involves evaluation of three speed management engineering measures: (1) installation of the speed limit signs, (2) peripheral traverse bars, and (3) gateways where speed limit zones and land-use change. An observational before and after study with comparison group is used to evaluate the effects of these measures on speed. The data used for this study were collected from Trafalgar Road in the Regional Municipality of Halton, Ontario where these speed management measures were implemented. The results of the before and after study suggested that implementation of the speed management strategies resulted in the reduction of the average operating speeds, in the range of 4 to 8 percent; however these results were not statistically significant at a 95% confidence interval. The results of this study will assist road authorities in the decision making process for potential implementation of these measure in their jurisdiction for speed management purposes.

1 Introduction

Over the past five decades, society and individuals have benefited greatly from rapidly improving road systems. During the same period, the motor vehicle industry manufactured and sold motorised vehicles which were increasingly able to travel at higher speeds. On one hand, high speed travel can lead to greater mobility and shorter journey times. On the other hand, higher vehicle speeds have adverse effects, particularly in terms of collisions and environmental impacts (e.g. noise and exhaust emissions).

While speeding can be considered a national problem, it is clear that effective solutions must be applied locally [1]. Many jurisdictions and municipalities in Canada, U.S., and other countries have implemented various speed management strategies to reduce the speeding-related collisions, fatalities, and injuries. These speed management strategies involve a balanced effort in defining the relationship between speeding and safety, applying road design and engineering measures to obtain desired speeds, and manned or automated enforcement.

In recent years, many roadway authorities in Canada have expressed interest in implementation of speed management strategies that are relatively low-cost in nature and easily implemented in the short-term periods (within 1-5 years). Numerous studies have been published which evaluate the effects of different speed management strategies [2, 3]. However, such studies are by no means straightforward and the extent to which the study methodologies have addressed potential analysis problem must be borne when considering their findings. This papers aims to evaluate the three selected speed management engineering strategies for short-term implementations. These speed management engineering strategies are: (1) installation of the speed limit signs, (2) peripheral traverse bars, and (3) gateways where speed limit zones and land-use change. In this study, an observational before and after study with comparison group was used to evaluate the effects of above noted treatments on the average operating speed (85th percentile speeds) as well as traffic volume.

The organization of this paper is as follows: Section 2 provides the proposed methodology to evaluate the effect of speed management strategies on average operating speed and traffic volume. Section 3 describes the study area, the speed management treatments, and the data collection periods. Section 4 summarizes the results of the before and after analysis with comparison sites. Section 5 concludes the paper with an overall summary and some closing remarks.

2 Methodology

2.1 Conceptual Overview

To evaluate the effect of a treatment that has been implemented, an estimate of a measure of effectiveness (MOE) in the ‘after’ period should be compared with a prediction of the MOE in the same period if the treatment was not to be implemented. In this study, the MOEs are the average operating speed and traffic volume.

The proposed methodology is based on observational before and after study with comparison group, which involves the use of treatment sites and a comparison group of roadways that are similar in traits and characteristics to treatment sites. The expectation is that the change in speed and volume of the comparison group corridors from the ‘before’ to the ‘after’ period would be representative of the change in the same parameters occurring on the study corridor if the improvements were not applied. The basic assumptions for this method are: (a) with the exception of the speed management treatments, the overall factors that affected speed and traffic volume have changed in the same way from before the implementation to after for both the treatment and the comparison groups and (b) the changes in the various factors influence the speed and traffic volume of the treatment and the comparison groups in the same manner [4, 5].

2.2 Statistical Analysis

The approach used for this study follows methodology that was originally formulated and validated by Hauer (1997) [4]. In the following, the statistical analysis methodology for a before-and-after study with comparison group is explained in terms of both the observed speed data and their expected values. Table 1 summarizes the notations used to refer to the observed speed (or volume) data in the before and after periods at the treatment and comparison sites.

Table 1: Speed/Volume Notations

Period	Treatment Sites		Comparison Sites	
	Mean	Variance	Mean	Variance
Before	k	$var(k)$	μ	$var(\mu)$
After	λ	$var(\lambda)$	υ	$var(\upsilon)$

According to the notation in Table 1, the expected average speed in the after period for the treatment sites without improvement, π, can be predicted as the observed average speed in the before period for the treatment group, k, by the ratio of the observed speed values after the improvements to the observed speed values at the comparison sites, r_c, as follows:

$$\pi = k \times r_c \tag{1}$$

$$r_c = \frac{\left(\upsilon / \mu\right)}{\left(1 + \left(\mathrm{var}(\mu) / \mu^2\right)\right)} \tag{2}$$

Where:

υ = Observed average operating speed for comparison group in after period;

μ = Observed average operating speed for comparison group in before period;

k = Observed average operating speed for treatment group in before period; and

λ = Observed average operating speed for treatment group in after period.

The variance of π can be calculated as follow:

$$VAR\{\pi\} = \pi^2 \times \left(\frac{\mathrm{var}(k)}{k^2} + \frac{\mathrm{var}(\mu)}{\mu^2} + \frac{\mathrm{var}(\upsilon)}{\upsilon^2}\right) \tag{3}$$

The effect of treatment can be evaluated by comparing λ and π using the "index of effectiveness":

$$\theta = \frac{\left(\lambda / \pi\right)}{\left(1 + \left(VAR\{\pi\} / \pi^2\right)\right)} \tag{4}$$

The standard deviation for θ is calculated as follow:

$$\sigma\{\theta\} = \theta \times \left(\frac{\text{var}(\lambda)}{\lambda^2} + \frac{VAR\{\pi\}}{\pi^2} \right)^{0.5} \Big/ \left(1 + \frac{VAR\{\pi\}}{\pi^2} \right) \quad (5)$$

When θ < 1, the treatment is effective; when θ > 1, the treatment is not effective. Percent change in the expected measure can be calculated as follow:

$$R = 100 \times (1 - \theta) \quad (6)$$

Finally, in order to determine whether the change in safety is statistically different between the before and after period, a Student's two-tailed T-test was conducted. In this case, the null hypothesis is that there is no difference in the average operating speed or traffic volume in the after period with the predicted average operating speed or traffic volume in the same period if the treatment had not been implemented. This is represented mathematically as follows:

H_o: $\lambda = \pi$ (7)

H_1: $\lambda \neq \pi$ (8)

The *t* statistic can be calculated and compared to the Student's *t* table value with (*n*-2) degree of freedom where *n* is number of observations in the treatment group. If the calculated value of *t* exceeds that for the 5% level (*t*=0.05), the null hypothesis is rejected. In other words, it can be concluded that the change in operating speed or traffic volume is statistically different between the before and after periods with a confidence level of 95%. Otherwise, if the calculated *t* statistic is smaller than the table value at the 5% level (*t*=0.05), there is no statistical change in operating speed or traffic volume.

3 Case Study

The data used for this study were collected from Trafalgar Road in the Regional Municipality of Halton, Ontario. The speed management strategies were implemented from Steeles Avenue (Regional Road 8) to Highway 7, in the Town of Halton Hills (Figure 1). The speed management strategies (treatments) at Trafalgar Road were a combination of the following treatments:

- Speed limit changes,
- Oversized speed limit signs,
- Traverse rumble strips,
- Peripheral bars,
- Speed display boards, and
- Gateways (in speed transition zones and/or approaching intersections/built-up areas).

As described, a before and after study with comparison group method was used for analysis of data in this study. Both treatment and comparison data collection location sites were chosen to be representative of streets that may be impacted by a change in traffic speeds and volumes as a result of the of the implemented speed management strategies. For the purpose of this study, Bronte Road (Highway 25) and 9th Line were selected as the comparison site corridors. These comparison sites were selected because of their similar landscape along with low density residential homes and their proximity to the

treatment site. Each of the data collection locations provide the motorist with access to both Highway 7 and Steeles Avenue. The locations of traffic data collection are depicted in Figure 2.

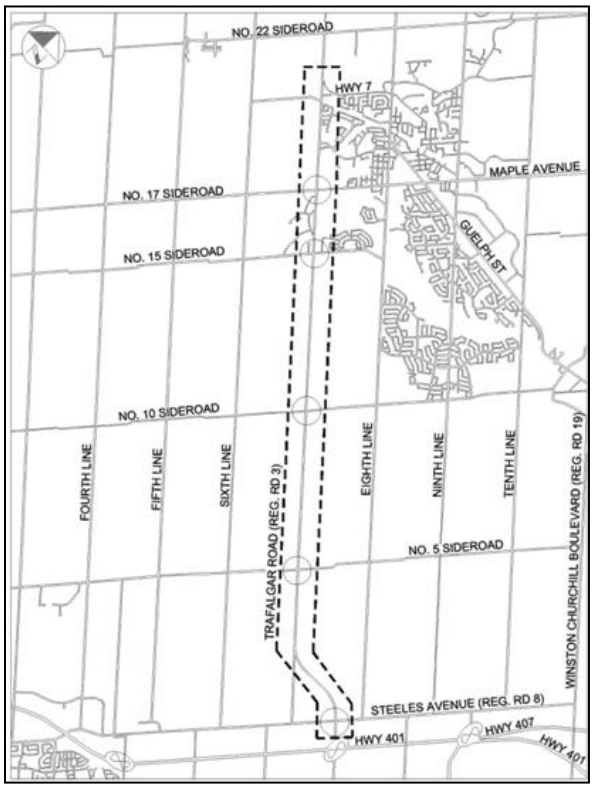


Figure 1: Trafalgar Road Study Area

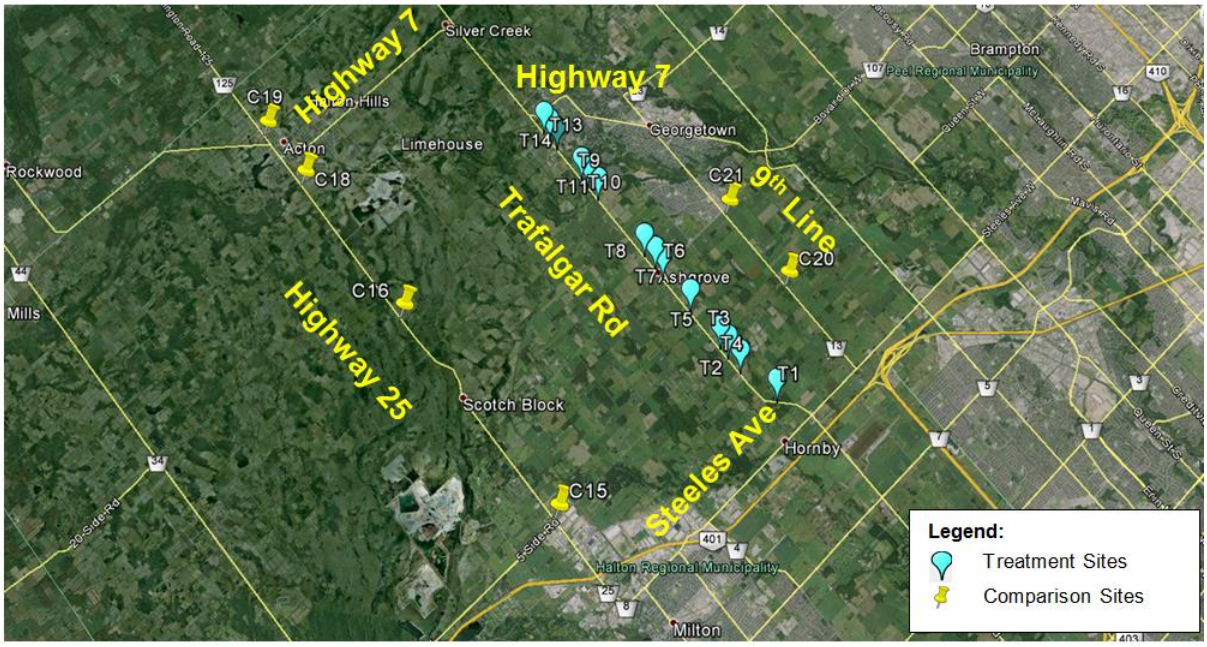


Figure 2: Data Collection Locations

The data collection was completed using Nu-Metrics traffic counters placed at the twenty selected locations “pinned” in Figure 2. Fourteen of the data collection locations were on Trafalgar Road, which received the speed management treatments, with the other six data collection locations along the comparison corridors.

The data collection lasted 24 consecutive hours and 7 days (including a weekend) at each location simultaneously and includes such characteristics as speed, vehicle classification, and headway. The data was recorded in 15 minute intervals.

The before data was collected from 12:00 am November 22nd, 2011 until 12:00 am November 29th, 2011. The data collection represented the weekday and weekend traffic patterns, separately. After the implementation of the speed management treatments, the data was collected from 12:00 am September 17th, 2013 and concluding at 12:00 am September 24th, 2013.

4 Analysis

The main objective of this study was to evaluate the effect of speed management treatments on vehicle speed and traffic volume. Based on the implemented treatments along the Trafalgar Road, three different treatment groups were identified for evaluate the effect of the treatments on the traffic speed and volume. These treatment groups are listed in Table 2.

The average operating speed (average 85th percentile speed) and traffic volume were used as measures for accomplishing this task. The data was divided into a 24 hour total, AM Peak period and PM Peak period. Based on the daily traffic patterns, the peak periods were identified for each treatment/comparison site during the before and after treatment periods.

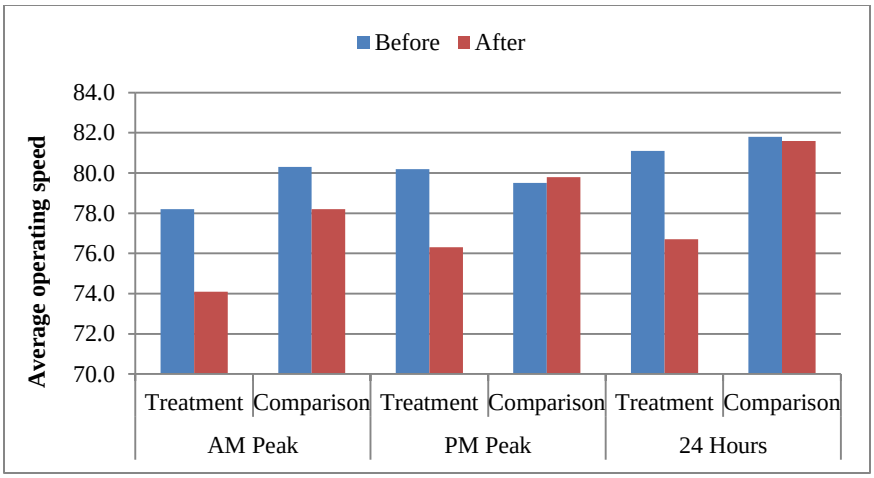
4.1 Speed Analysis

Figure 3 to Figure 5 show the average operating speed (average 85th percentile speed) for treatment and comparison sites for each period for speed sign, peripheral traverse bars, and gateways respectively. The results are shown for weekdays and weekends separately. The 85th percentile is the speed at which or below 85% of the vehicles are travelling [6]. The 85th percentile speed is representative of overall traffic behaviour on a road and is the value most commonly used in assessment of traffic data. For this reason, among others, the 85th percentile speed data was captured and analyzed as part of this study.

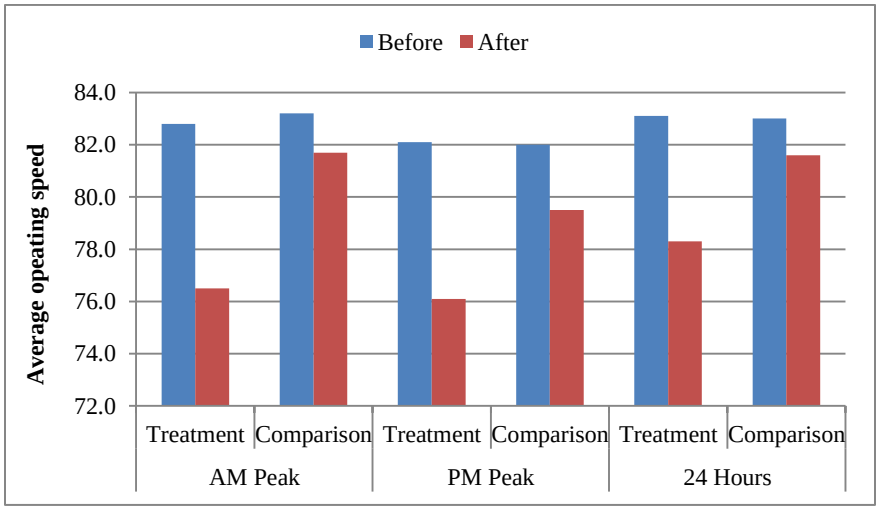
In order to conduct the before and after study, the operating speeds (85th percentile speed) were calculated for each site. Then the average of the operating speeds for treatment and comparison sites were calculated. Table 3 to Table 5 present the results of the before and after analysis, separated for each treatment groups.

Table 2: Treatment Groups

Group Number	Treatment	Treatment Site No.	Direction of the Travel for the Implemented Treatment
1	Speed Signs (both regular and oversized speed limit signs)	1	Northbound and Southbound
		2	Northbound and Southbound
		5	Southbound
		7	Southbound
		8	Southbound
		9	Northbound
		10	Northbound and Southbound
		11	Northbound and Southbound
		12	Northbound and Southbound
		13	Northbound and Southbound
		14	Northbound and Southbound
2	Peripheral traverse bars	9	Northbound
		10	Northbound and Southbound
		11	Northbound and Southbound
		12	Northbound
		13	Southbound
3	Gateways	8	Southbound
		9	Northbound
		13	Southbound
		14	Northbound

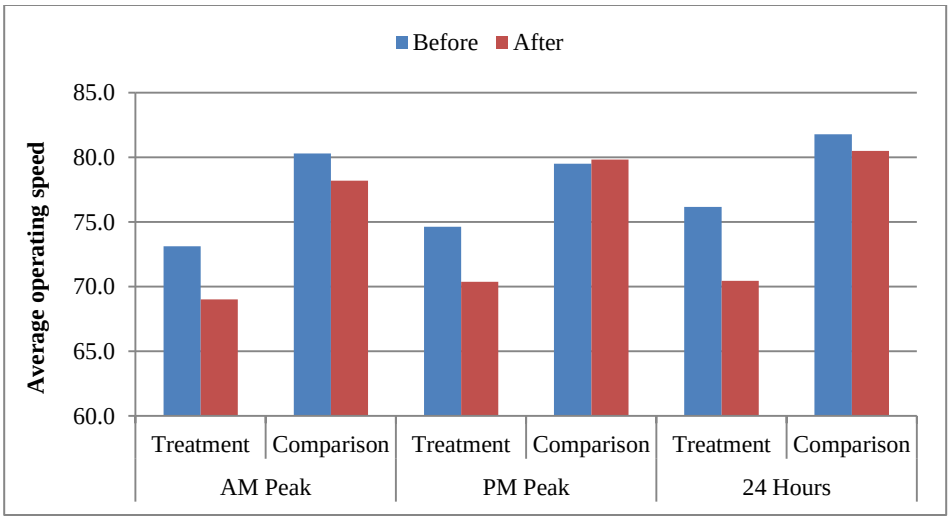


a) Weekday

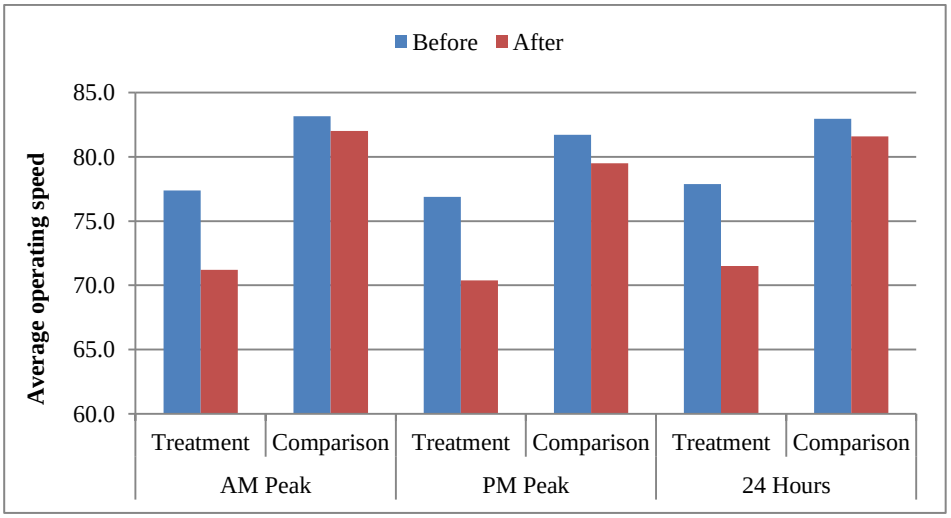


b) Weekend

Figure 3: Average Operating Speed for Treatment and Comparison Sites (Group 1: Speed Signs)

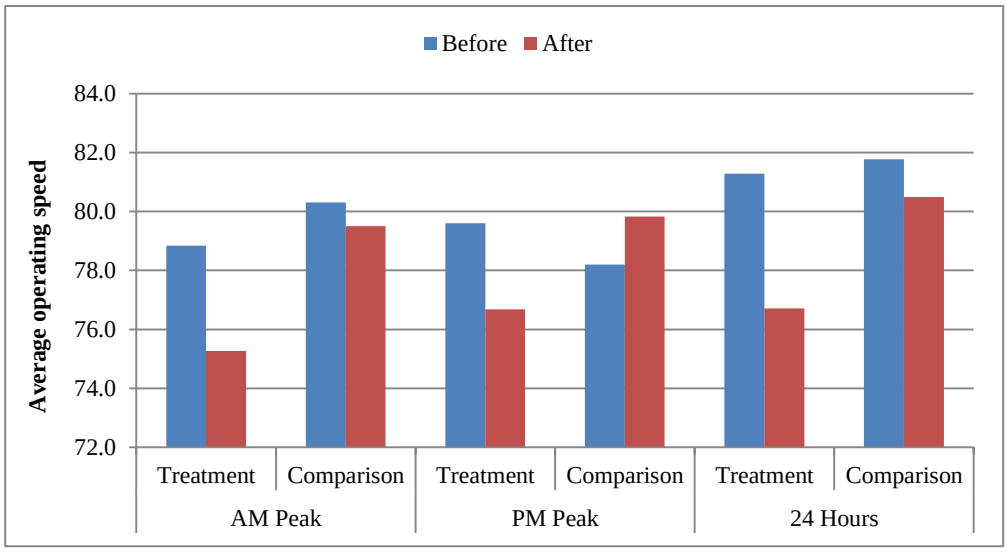


a) Weekday

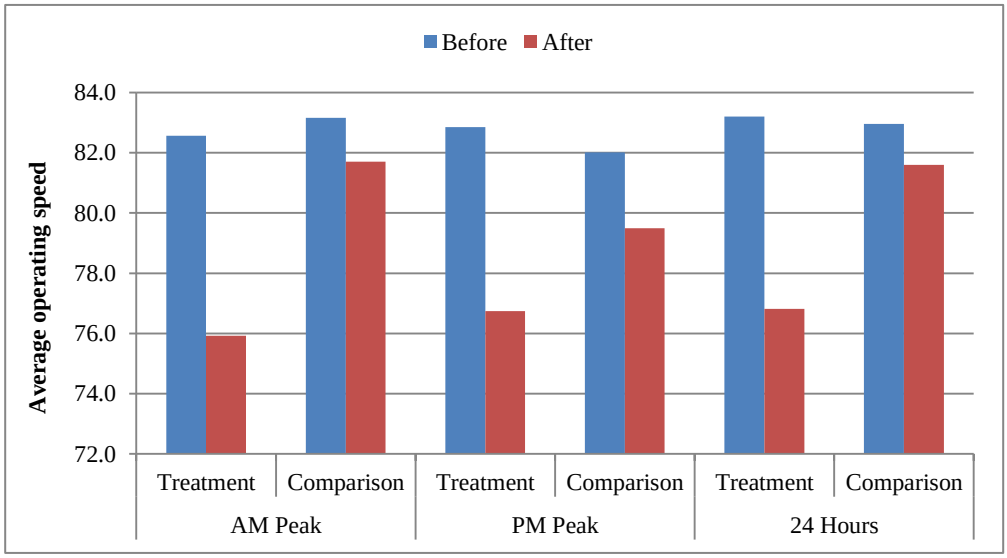


b) Weekend

Figure 4: Average Operating Speed for Treatment and Comparison Sites (Group 2: Peripheral Traverse Bars)



a) Weekday



b) Weekend

Figure 5: Average Operating Speed for Treatment and Comparison Sites (Group 3: Gateways)

Table 3: Results of the Before and After Study for Average Operating Speed (Group 1: Speed Signs)

Weekday vs. Weekend	Period	Index of effectiveness	Percent Change (R)	Treatment				Comparison				Significant?
				Average Operating Speed (km/h)		Standard Deviation of Speed (km/h)		Average Operating Speed (km/h)		Standard Deviation of Speed (km/h)		
				Before	After	Before	After	Before	After	Before	After	
Weekday	24-Hour	0.940	6.0% reduction	81.1	76.7	12.4	11.2	81.8	81.6	13.9	11.9	No
	AM	0.950	5.0% reduction	78.2	74.1	12.5	11.1	80.3	78.2	13.5	12.2	No
	PM	0.930	7.0% reduction	80.2	76.3	12.3	10.5	79.5	79.8	8.9	11.1	No
Weekend	24-Hour	0.939	6.1% reduction	83.1	78.3	12.0	10.3	83.0	81.6	14.0	11.7	No
	AM	0.924	7.6% reduction	82.8	76.5	11.9	10.4	83.2	81.7	13.1	11.3	No
	PM	0.939	6.1% reduction	82.1	76.1	11.5	9.6	82.0	79.5	14.3	11.1	No

Table 4: Results of the Before and After Study for Average Operating Speed (Group 2: Peripheral Traverse Bars)

Weekday vs. Weekend	Period	Index of effectiveness	Percent Change (R)	Treatment				Comparison				Significant?
				Average Operating Speed (km/h)		Standard Deviation of Speed (km/h)		Average Operating Speed (km/h)		Standard Deviation of Speed (km/h)		
				Before	After	Before	After	Before	After	Before	After	
Weekday	24-Hour	0.920	8.0% reduction	76.2	70.5	11.9	10.1	81.8	80.5	13.9	11.9	No
	AM	0.946	5.4% reduction	73.1	69.0	12.3	10.0	80.3	78.2	13.5	12.2	No
	PM	0.922	7.8% reduction	74.6	70.4	11.7	9.7	79.5	79.8	13.0	11.1	No
Weekend	24-Hour	0.915	8.5% reduction	77.9	71.5	11.6	9.3	83.0	81.6	14.0	11.7	No
	AM	0.92	8.0% reduction	77.4	71.2	11.1	9.6	83.2	82.0	13.1	11.3	No
	PM	0.927	7.3% reduction	76.9	70.4	11.3	8.7	81.7	79.5	14.3	11.1	No

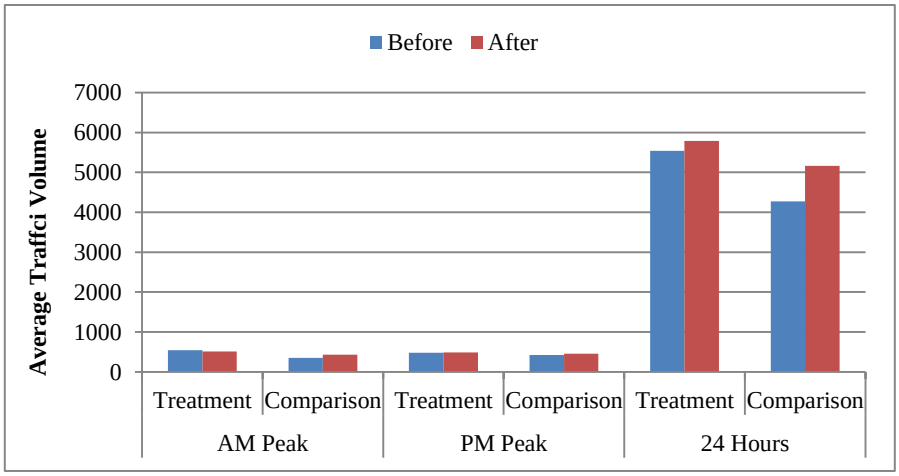
Table 5: Results of the Before and After Study for Average Operating Speed (Group 3: Gateways)

Weekday vs. Weekend	Period	Index of effectiveness	Percent Change (R)	Treatment				Comparison				Significant?
				Average Operating Speed (km/h)		Standard Deviation of Speed (km/h)		Average Operating Speed (km/h)		Standard Deviation of Speed (km/h)		
				Before	After	Before	After	Before	After	Before	After	
Weekday	24-Hour	0.939	6.1% reduction	81.3	76.7	13.6	11.2	81.8	80.5	13.9	11.9	No
	AM	0.958	4.2% reduction	78.8	75.3	13.7	11.4	80.3	79.5	13.5	13.0	No
	PM	0.942	5.8% reduction	79.6	76.7	12.9	11.0	78.2	79.8	12.2	11.1	No
Weekend	24-Hour	0.92	8.0% reduction	83.2	76.8	12.3	10.5	83.0	81.6	14.0	11.7	No
	AM	0.919	8.1% reduction	82.6	75.9	12.0	11.8	83.2	81.7	13.1	11.3	No
	PM	0.938	6.2% reduction	82.8	76.7	12.4	9.4	82.0	79.5	14.3	11.1	No

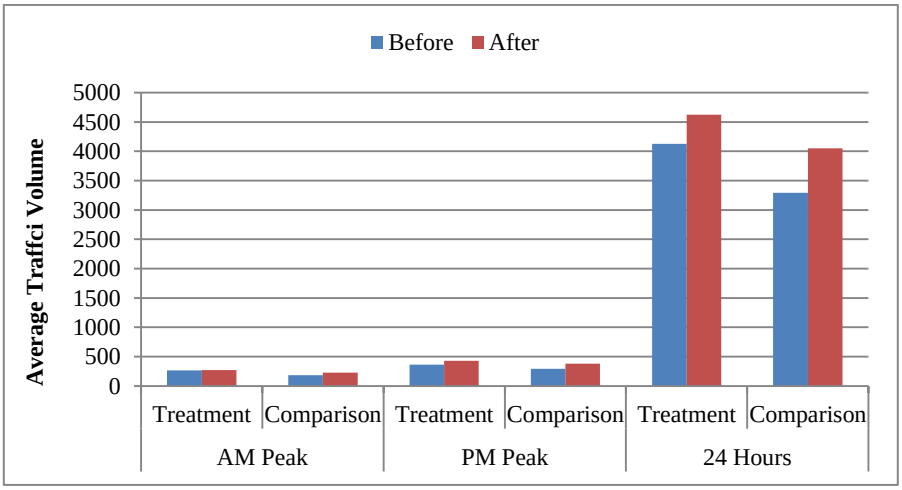
The results of before and after study in the above tables indicate that the implementation of the speed management strategies resulted in the reduction of the average operating speeds, in the range of 4 to 8 percent for each of the three time periods studied. However, the results of the t-test in these tables confirm that the changes in the average operating speeds were not statistically significant at the 95% confidence level.

4.2 Traffic Volume Analysis

Figure 6 to Figure 8 show the average traffic volume for treatment and comparison groups during the peak periods and 24-hours for the before and after treatment period. The results were separated for each treatment group and weekend/weekdays observations.

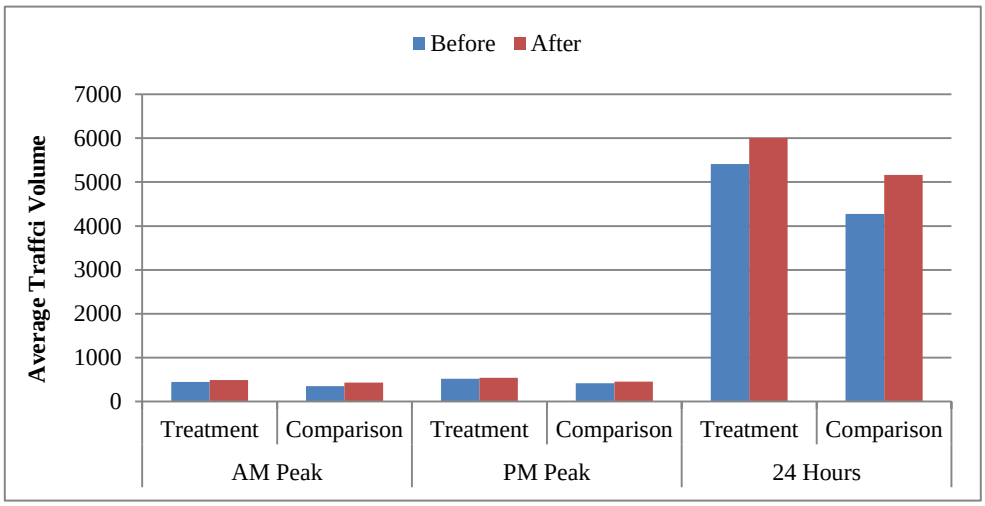


c) Weekday

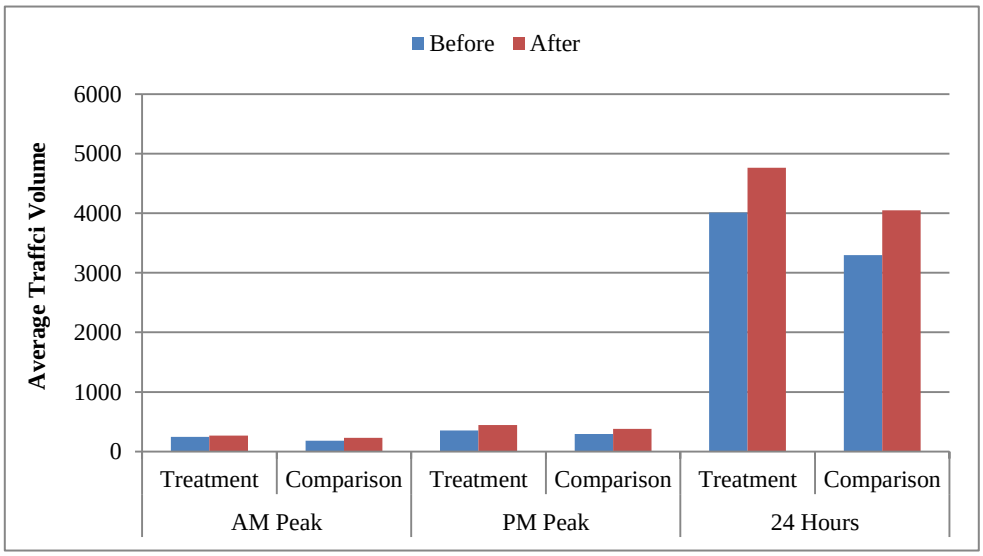


d) Weekend

Figure 6: Average Traffic Volume for Treatment and Comparison Sites (Group 1: Speed Signs)

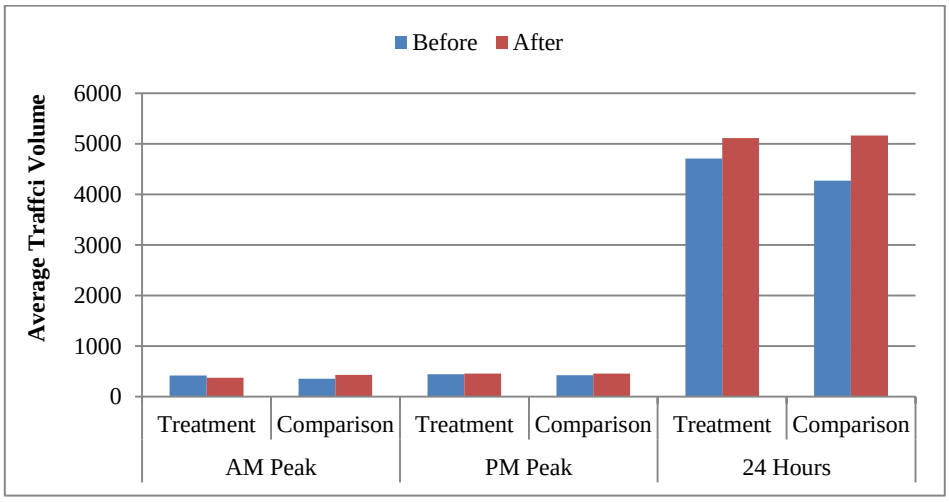


c) Weekday

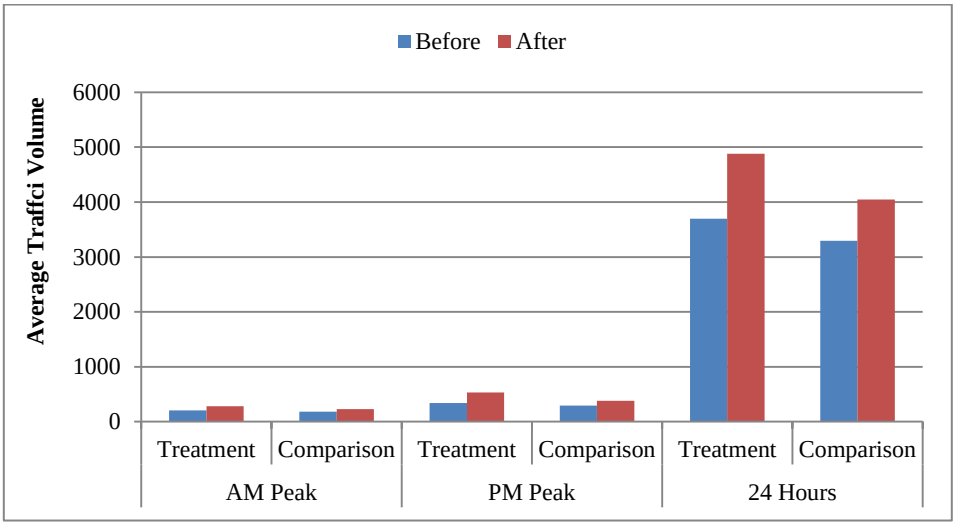


d) Weekend

Figure 7: Average Traffic Volume for Treatment and Comparison Sites (Group 2: Peripheral Traverse Bars)



c) Weekday



d) Weekend

Figure 8: Average Traffic Volume for Treatment and Comparison Sites (Group 3: Gateways)

The results of the above figures suggest that after the speed management treatments took place along Trafalgar Road, the 24 hour traffic volume increased marginally, while the traffic volume remained relatively unchanged during AM and PM peak periods. However, the results of the before and after study suggest that from 2011 to 2013, the traffic volume increased more for the alternative routes comparing to the Trafalgar Road. According to the results of the t-test and 95% confidence interval in Table 6 to Table 8, for most case, the increase of traffic volume for Trafalgar Road was from 10.7% to 26.2% less than the increase of traffic volume for alternative routes.

Table 6: Results of the Before and After Study for Traffic Volume (Group 1: Speed Signs)

Weekday vs. Weekend	Period	Index of effectiveness	Percent Change (R)	Treatment				Comparison				Significant?
				Average Traffic Volume		Standard Deviation		Average Traffic Volume		Standard Deviation		
				Before	After	Before	After	Before	After	Before	After	
Weekday	24-Hour	0.865	13.5% reduction	5541.1	5791.6	49.4	46.8	4273.5	5164.6	38.5	41.0	Yes
	AM	0.778	22.2% reduction	540.6	513.7	14.8	12.0	352.8	430.5	10.0	13.1	Yes
	PM	0.942	5.8% reduction	479.7	488.3	11.8	14.4	420.3	453.7	15.9	11.5	Yes
Weekend	24-Hour	0.912	8.8% reduction	4126.1	4623.3	31.1	35.2	3294.7	4048.5	26.8	33.0	Yes
	AM	0.82	18.0% reduction	262.8	268.7	10.1	8.6	182.4	226.5	7.8	14.0	Yes
	PM	0.912	8.8% reduction	362.0	430.8	9.2	10.5	292.9	382.0	10.9	10.0	Yes

Table 7: Results of the Before and After Study for Traffic Volume (Group 2: Peripheral Traverse Bars)

Weekday vs. Weekend	Period	Index of effectiveness	Percent Change (R)	Treatment				Comparison				Significant?
				Average Traffic Volume		Standard Deviation		Average Traffic Volume		Standard Deviation		
				Before	After	Before	After	Before	After	Before	After	
Weekday	24-Hour	0.918	8.2% reduction	5408.1	6002.2	44.4	47.1	4273.5	5164.6	38.5	41.0	Yes
	AM	0.893	10.7% reduction	450.7	491.9	14.4	12.7	352.8	430.5	10.0	13.1	Yes
	PM	0.962	3.8% reduction	520.1	540.6	11.5	17.3	420.3	453.7	15.9	11.5	No
Weekend	24-Hour	0.967	3.3% reduction	4009.3	4765.8	30.1	35.9	3294.7	4048.5	26.8	33.0	Yes
	AM	0.871	12.9% reduction	245.1	266.0	10.2	8.9	182.4	226.5	7.8	14.0	Yes
	PM	0.958	4.2% reduction	355.1	443.9	9.9	11.3	292.9	382.0	10.9	10.0	No

Table 8: Results of the Before and After Study for Traffic Volume (Group 3: Gateways)

Weekday vs. Weekend	Period	Index of effectiveness	Percent Change (R)	Treatment				Comparison				Significant?
				Average Traffic Volume		Standard Deviation		Average Traffic Volume		Standard Deviation		
				Before	After	Before	After	Before	After	Before	After	
Weekday	24-Hour	0.899	10.1% reduction	4706.7	5113.4	40.7	40.0	4273.5	5164.6	38.5	41.0	Yes
	AM	0.738	26.2% reduction	416.1	375.1	13.3	12.3	352.8	430.5	10.0	13.1	Yes
	PM	0.942	5.8% reduction	444.4	452.4	12.0	9.9	420.3	453.7	15.9	11.5	No
Weekend	24-Hour	1.074	7.4% increase	3698.0	4881.0	27.4	39.8	3294.7	4048.5	26.8	33.0	Yes
	AM	0.917	8.3% reduction	206.1	278.2	10.9	7.5	182.4	226.5	7.8	14.0	No
	PM	1.21	21.0% increase	338.3	534.2	7.5	13.6	292.9	382.0	10.9	10.0	Yes

5 Conclusions and Recommendations

The primary goal of this research was to evaluate the effect of the implementation of speed management treatments on vehicle speeds and traffic volumes along the corridor of Trafalgar Road between Steeles Avenue and Highway 7. The treatments were combined into three different groups:

1. Installation of speed signs (both regular and oversized speed limit signs),
2. Peripheral traverse bars, and
3. Gateways (in speed transition zones and/or approaching intersections/built-up areas).

A before-and-after study using comparison group method was conducted to accomplish this objective. Traffic volume and speed data were collected for the before and after implementation of the above treatments. Based on the results of the average operating speeds, the following conclusions can be made:

- Installation of the speed signs reduced the average operating speeds by 6.0% (during weekdays) and 6.1% (during weekends) for the 24 hour period. During the AM peak periods, the average operating speeds was reduced by 5.0% (during weekdays) and 7.6% (during weekends). As for the PM peak period, the reduction in average operating speeds was found to be 7.0% and 6.1%, for weekdays and weekends, respectively.
- The implementation of the peripheral traverse bars reduced the average operating speeds by 8.0% (during weekdays) and 8.5% (during weekends) for the 24 hour period. During the AM peak periods, the average operating speeds was reduced by 5.4% (during weekdays) and 8.0% (during weekends). As for the PM peak period, the reduction in average operating speeds was found to be 7.8% and 7.3%, for weekdays and weekends, respectively.
- The implementation of the gateways reduced the average operating speeds by 6.1% (during weekdays) and 8.0% (during weekends) for the 24 hour period. During the AM peak periods, the average operating speeds was reduced by 4.2% (during weekdays) and 8.1% (during weekends). As for the PM peak period, the reduction in average operating speeds was found to be 5.8% and 6.2%, for weekdays and weekends, respectively.

In summary, the results of analyzing the average operating speeds indicate a reduction in vehicle speeds from before to after periods of between 4.2 % and 8.5 %. However, the results were found not to be statistically significant at 95% confidence interval when comparing “before” and “after” operating speed data.

While the average operating speeds reduced from before to after periods, traffic volumes along the Trafalgar Road after the implementation of the treatments showed an increase. It is speculated that one possible reason for this increase might be relevant to the average traffic growth in the area. Another reason might be the novelty effect of the new traffic calming treatment measure, attracting drivers to Trafalgar Road to view the treatments. However, this increase of traffic volumes (from 2011 to 2013) on Trafalgar Road was smaller comparing to the increase of traffic volumes along the routes in the comparison group (i.e. Highway 25 and 9th Line), for all AM, PM, and 24 hour periods. For example, after the installation of the speed signs, the increase of traffic volume from 2011 to 2013 along Trafalgar Road was 13.5% less than the increase of traffic volume along alternative routes. One possible reason for this increase might be that some portions of the traffic volumes were diverted to alternative routes because of the speed management treatments.

Since the analysis was conducted immediately following the treatment period in 2013, it is recommended to conduct another before and after study in the near future to evaluate of the long-term effect of the treatments on the speed and traffic volumes along the Trafalgar Road.

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