Comparison of Automated Speed Enforcement and Police Presence on Speeding in Work Zones

Ali Hajbabaie
Graduate Research Assistant, Department of Civil and Environmental Engineering
3150, Newmark Civil Engineering Laboratory
University of Illinois at Urbana-Champaign, Urbana, IL 61801 USA
Phone: (217)-333-8988, Fax: (217)-333-1924
ahajbab2@uiuc.edu

Rahim (Ray) F. Benekohal
Professor, Department of Civil and Environmental Engineering
1213, Newmark Civil Engineering Laboratory
University of Illinois at Urbana-Champaign, Urbana, IL 61801 USA
Phone: (217)-244-6288, Fax: (217)-333-1924
rbenekoh@uiuc.edu

Madhav Chitturi
Postdoctoral Research Associate, Department of Civil and Environmental Engineering,
University of Wisconsin-Madison, Wisconsin, USA,
Phone: (608)-265-8583
mchitturi@wisc.edu

Ming-Heng Wang
Graduate Research Assistant, Department of Civil and Environmental Engineering, UIUC
mwang4@uiuc.edu

Juan C. Medina
Graduate Research Assistant, Department of Civil and Environmental Engineering, UIUC
jcmedina@uiuc.edu

Word Count: 4928 for words
Number of Figures and Tables: 6

Submitted for Presentation/publication at the 88th TRB Annual Meeting in 2009

November 15, 2008

ABSTRACT

This paper compares the effects of four speed management techniques on speed and speeding on interstate highway work zones. The techniques are speed feedback trailer, police car, the speed feedback trailer plus police car, and automated speed photo-radar enforcement (SPE). The effects on mean speed and degree of speeding were studied. The results showed that in both moderately and extensively speeding sites all law enforcement treatments (including variations of police presence and SPE) significantly reduced the mean speeds and degree of speeding. In the moderately speeding site, the Trailer+Police treatment reduced the mean speeds more than the other treatments. It reduced the mean speed of free flowing cars in the median lane by 8.4 down to 48.6 mph, while the other law enforcement treatments reduced it by 6.1 – 6.4 mph. In the extensively speeding work zone, the Trailer+Police and the SPE treatments reduced the mean speeds similarly and more than the Police car alone. They reduced the mean speeds in the median lane by 7.8 mph down to 55.9 mph. In the moderately speeding site, Trailer + Police was more effective than the other treatments in reducing speeding. However, in the extensively - speeding site, all the law enforcement methods were similarly effective in reducing the speeding; yet 11% to 16% free flowing cars were speeding in median lane by more than 5 mph.

INTRODUCTION

In 2006, there were 42,642 traffic fatalities in the U.S. (1), and speeding was a contributing factor in 31% of them. In total 13,543 people lost their lives in speeding related crashes (2). The National Highway Traffic Safety Administration estimates that the economic cost of speeding-related crashes is $40.4 billion annually (2). In addition, the number of fatalities within the work zones in the U.S. increased from less than 800 in 1995 to more than 1050 in 2005 (NHTSA, FARS, 2005). The large number of crashes and fatalities due to speeding, and especially speeding in work zones, calls for practical and reliable techniques to reduce the speed of speeding vehicles in the work zones.

In work zones, traffic law enforcement by police officers is not feasible at all locations and in all times. It requires identifying a violator, pulling him/her over, checking the driving record of the violator, and issuing a citation. Although this one-on-one (one police officer working on one violator) approach works properly when police are present, its scope is limited due to the extensive manpower requirements, potential risks for the police officers working under live traffic conditions, and roadway/shoulder width constrains to park the vehicles. On the other hand, the SPE can overcome these limitations and has potential to offer a more powerful tool for traffic law enforcement. Recognizing this potential, in 2004, Illinois enacted the Automated Traffic Control Systems in Highway Construction or Maintenance Zones Act. This act authorized the use of the SPE van in the work zones.

The effects of the SPE on mean speed and degree of speeding are compared to two conditions without police presence (Base and speed display Trailer) and two conditions with some variations of police presence (Police without Lights on which is called Police, and Trailer + Police without Lights on which is called Trailer + Police). Data from two work zones one with moderate level of speeding and one with extensive level of speeding are used and the effects of different treatments were studied. This paper is organized in five sections: Literature review, Study objectives, methodology for data analysis, data collection/reduction, and findings are presented.

LITERATURE REVIEW

Benekohal et al. (3) studied the effects of the SPE on the speeds in the work zone over time and they observed that the SPE significantly reduced the speed of free flowing and in-platoon vehicles during the whole time period that it was present in the work zone. Goldenbeld, C. and I. Van Schagen (4) studied the effects of speed enforcement with mobile radar on speeds and accidents on rural roads for a 5-year period of enforcement. Their studies showed a significant reduction in mean speed and percentage exceeding the posted speed limit. Chen et al. (5) evaluated the influence of the photo radar program on speeds of vehicles at the location of the photo radars. They found out that using photo radar reduced average speed and speed standard deviation by 2.8 km/h and 0.5 km/h, respectively. Bloch (6) studied the speed reduction effects of photo-radar and speed display board on three streets in Riverside, California. The results showed that both devices significantly reduced vehicles speeds by 7 to 8 km/h, and reduced the number of vehicles exceeding the speed limit by 16%. Rogersson et al. (7) evaluated the effects of speed cameras on casualty crash frequency in Melbourne. They found a statistically significant reduction in casualty crashes within 1 km of speed camera site. Newstead et al. (8) continued Rogersson's research and found out that the speed cameras did not have a significant effect on casualty crashes on Victorian rural town within 1 km of a camera site. However, when they studied casualty crash within a 15 km radius of the speed camera site in Victorian rural highways they observed a statistically significant reduction.

Kentucky Transportation Center (9) conducted a study and evaluated the effects of typical signs, double fine sign only, double fine sign with police, and double fine sign with radar box and police. They found out that the highest mean speed reductions occurred when the police were present at the work zone. Zech et al. (10) evaluated the effectiveness of rumble stripes, and police presence in the work zone in combination with rumble stripes. They found out that the presence of the police resulted in more speed reduction (3 to 6 mph) compared to rumble stripes. The Minnesota DOT (11) assessed the effectiveness of police presence in work zone. They observed 8-9 mph reduction in the 85^{th} percentile speeds. Benekohal et al. (12) studied the effects of a circulating marked police car in work zone. They found out that while the police car was present in the work zone the mean speed of cars and trucks were reduced by 4 and 5 mph, respectively. In addition, they observed 14% and 32% reduction in the percentage of cars and trucks exceeding the speed limit, respectively. Brewer et al. (13) conducted a study to evaluate the effectiveness of speed display trailer, changeable message sign with radar, and orange-border speed limit signs on improving the speed limit compliance in the work zone. They observed a considerable potential for reducing the speed when showing the speed of drivers to them. They found out that in the lack of active speed enforcement drivers traveled as fast as they like.

The study of literature showed that automated speed enforcement and traditional law enforcement have significantly reduced the mean speed and percent exceeding the speed limit in the locations they have been implemented. However, no study was found that has compared the effects of automated speed enforcement and variations of police presence on the mean speed and speeding in the work zones. Thus, in this research the effects of the SPE and traditional law enforcement methods on speeds of vehicles in work zones are evaluated and compared.

OBJECTIVES

The main objective of this research is to evaluate the effects of four different speed reduction techniques on speed and degree of speeding in work zones with moderate and extensive speeding problems, and compare their effects to each other. The speed reduction techniques used in this research are:

1. Speed Photo-radar Enforcement (SPE)
2. Speed Display Trailer (Trailer)
3. Police car with lights off (Police)
4. Speed Trailer plus Police car with lights off (Trailer + Police)

Detailed descriptions of each of the speed reduction techniques are available in Benekohal et al. (14).

METHODOLOGY

The review of the literature showed that most of the researchers have used the average speed and percent exceeding the speed limit to study the effects of a speed reduction technique on speed. As a result, we decided to use the same indicators however, instead of the percent exceeding the speed limit we used the degree of speeding that covers the percent exceeding the speed limit and three more levels of speeding

The mean speed for different treatments and the Base condition were determined and compared to each other using Least Significant Difference (LSD) test. This test shows if two or more treatments have significantly different mean speeds at an assumed confidence level (90% used in this research). If the mean speed of a treatment is significantly less than the mean speed of the Base condition, it is concluded that the treatment has significantly reduced the mean speed compared to the Base condition. The same conclusion could be made for any two treatments. However, if the test shows that the mean speed of a treatment is not significantly different from the mean speed of the Base condition, it is concluded that the treatment did not have any significant speed reduction compared to the Base case.

In addition to assessing the effects on mean speeds, the effects of treatments on the degree of speeding are studied at four levels. The first level corresponds to the percent of drivers complying with the speed limit. The proportion of drivers that exceeded the speed limit by up to 5 mph is called the second level of speeding. The third level corresponds to speeding by more than 5 and up to 10 mph. Finally the fourth level shows the proportion of drivers that exceeded the speed limit by more than 10 mph. These intervals are not overlapping.

Effects of each treatment at a location near the treatment (point effects) are studied using the two indicators introduced above.

The mean speed of free flowing vehicles in each treatment was compared to the mean speed of the general traffic stream using t-test. In both Datasets, the mean speed of free flowing vehicles (for all treatments) was significantly higher than the mean speed of the general traffic stream at 90% confidence level. Similarly, for most of the cases, the mean speeds of cars were significantly higher than the mean speed of trucks; and finally, the mean speeds of vehicles traveling on the shoulder lane were significantly lower than the mean speeds of vehicles traveling on the median lane for most of the cases. These three observations led us to conduct the

analyses in the following way: the free flowing vehicles were separated from the general traffic stream (sampled vehicles). For each of them the analysis was done separately on shoulder lane and median lane with respect to the vehicle type. The results are presented after data collection and reduction section.

DATA COLLECTION/REDUCTION:

Two datasets were collected in two work zones on Interstate Highways. Dataset 1 contains the off-peak AM traffic data collected on I-64 in Illinois near St Louis. Dataset 3 was collected on I-55 near Joliet, a western suburb of Chicago, IL during off-peak hours in the afternoon. In both work zones, the posted speed limit was 55 mph and two lanes were open to traffic. The construction zones on I-64 and I-55 were for adding a third lane in the median. Concrete barriers separated the work area from the traveled lanes. In the I-55 construction zone, also bridge deck repair was taking place at the time of data collection. In both sites at the locations we collected data, there were two traveled lanes open, and a normal-width-right-hand-side shoulder was available.

In both work zones, data was collected at a location that was several hundred feet downstream of where the treatment was located. This distance provided additional room for the drivers to react to the treatments, and the treatments were visible before the drivers reached this point. Data was collected using a camcorder and two markers that were about 200 feet apart as shown in Figure 1. All data collection equipments were placed outside of the shoulder with no interference with the traffic stream. The camcorder was placed far from the traveled lane such that drivers could not see it easily in order to reduce any potential effect it may have on the speeds of vehicles.

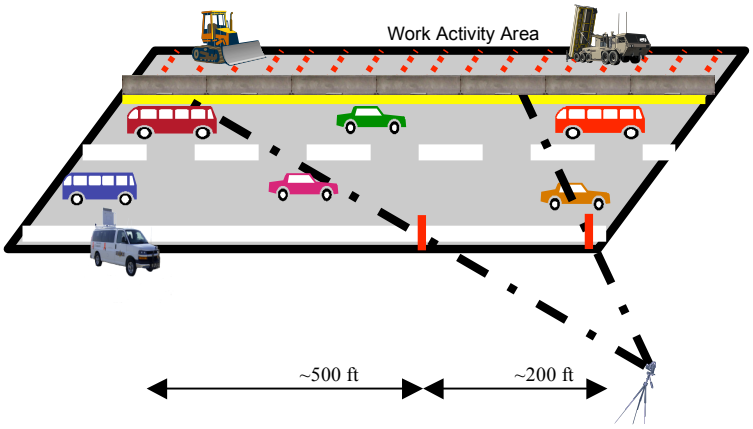

Figure 1: Schematic Diagram of the Data Collection Setup

For data reduction, the frame numbers of the image when a vehicle was passing a marker were read to obtain an accuracy of 0.033 second in time (one frame). This level of accuracy in reading travel time between two markers and the large enough sample size, resulted in speed measurement error that was less than 1 mph. Around an hour of the recorded videos were reduced for each treatment in both datasets. The following information was recorded for all free flowing vehicles and a systematic sample of the general traffic stream:

- Time at the first and second markers (time when the left edge of the front bumper reaches the marker)

- Vehicle type (passenger car or heavy vehicle), vehicle lane (shoulder lane or median lane), and whether the vehicle is free flowing or in-platoon

Knowing the distance vehicles traveled between the markers, time at each marker, travel lane, and vehicles type, speeds of vehicles were calculated

As mentioned, the information for all free flowing vehicles was recorded. Free flowing vehicles were those who had the freedom to travel at their desired speed in the work zones, and they were not closely following another vehicle. To distinguish free flowing vehicles from in-platoon vehicles a four-second headway criterion was used. This means that if the headway between a vehicle and the vehicle in front was four sec or more, the following vehicle was considered a free flowing vehicle. To obtain the information for the general traffic stream a systematic sampling approach was used. The information for all fifth vehicles in the traffic stream was recorded regardless of the lane the vehicle was traveling.

The work zone on I-64 Highway was around 7 miles long. The starting milepost was 9 and treatments were placed around milepost 14. The work zone on I-55 highway was also about 7 miles long. The starting milepost was 255, and treatments were placed around milepost 259. Table 1 presents the volume, percent heavy vehicle, and percent of vehicles in each lane for both datasets.

Table 1: Volume (both lanes) distributions for different treatments

Dataset		Treatments				
		Base	Trailer	Police w/o Lights on	Trailer + Police w/o Lights on	SPE Van
1	Volume (vph)	1510	1540	1300	1500	1510
	% Trucks	19%	17%	13%	17%	18%
	% in Shoulder	46%	86%	71%	53%	71%
3	Volume (vph)	2240	2274	2145	2405	2005
	% Trucks	28%	24%	21%	20%	22%
	% in Shoulder	53%	58%	59%	58%	58%

FINDINGS

In this section the effects of each treatment on speed and speeding at the location the treatment was implemented are discussed. Table 2 summarizes the findings of the speed of vehicles in both Datasets. As the table shows in all cases, the average speed in the I-55 work zone (Dataset 3) was higher than the average speed in the I-64 work zone (Dataset 1). This means that, speeding was more prevalent in I-55 work zone compared to I-64 work zone. As a result, sometimes I-64 work zone is called moderate-speeding site and I-55 work zone is called extensive-speeding site.

For the moderate-speeding site the reductions in the 15% and 85% speeds were not that much different however, in the extensive-speeding site, the reduction in the 85% speed was more than the reduction in the mean speed and this reduction was more than the reduction in 15% speed. This means that the treatments reduced the speed of fast moving vehicles more than the speed of slow moving vehicles.

Table 2: Brief Findings for Free Flowing Vehicles

Data sets	Lane	Veh. Type	Treatment	Free Flowing Vehicles								
				Min	15%	Reduction	Mean	Reduction	85%	Reduction	Max	Sample Size
1	Median	Cars	Base	43.9	52.9	0.0	57.0	0.0	61.3	0.0	70.3	119
			Trailer	48.2	52.1	0.8	55.9	1.1	60.2	1.1	71.3	136
			Poloce w/o Lights om	41.3	47.1	5.7	50.9	6.1	53.7	7.6	68.9	155
			Traile + Police w/o Lights on	40.4	45.1	7.8	48.6	8.4	52.1	9.2	65.9	113
			SPE Van	33.4	46.5	6.4	50.6	6.4	55.4	5.9	63.5	146
		Trucks	Base	45.1	50.2	0.0	53.7	0.0	56.9	0.0	60.7	40
			Trailer	46.9	49.4	0.8	52.0	1.7	55.0	1.9	57.5	43
			Poloce w/o Lights om	43.9	45.8	4.5	49.4	4.2	51.7	5.2	55.9	42
			Traile + Police w/o Lights on	39.8	44.1	6.1	48.0	5.7	51.7	5.2	56.6	39
			SPE Van	43.8	46.9	3.3	50.3	3.4	54.1	2.8	56.8	41
	Shoulder	Cars	Base	38.2	47.6	0.0	51.2	0.0	54.8	0.0	64.3	135
			Trailer	41.6	46.8	0.7	50.9	0.3	53.6	1.3	73.3	211
			Poloce w/o Lights om	35.1	42.8	4.8	46.7	4.5	50.0	4.8	54.8	186
			Traile + Police w/o Lights on	36.8	41.6	6.0	45.9	5.3	50.3	4.5	56.6	125
			SPE Van	33.9	42.8	4.8	47.0	4.2	50.8	4.0	62.6	191
		Trucks	Base	41.7	47.9	0.0	50.3	0.0	53.2	0.0	58.3	41
			Trailer	40.3	45.8	2.1	49.5	0.7	52.4	0.8	58.1	71
			Poloce w/o Lights om	39.1	42.5	5.4	46.3	3.9	49.6	3.5	51.3	56
			Traile + Police w/o Lights on	38.5	43.1	4.8	45.7	4.6	48.7	4.5	52.5	49
			SPE Van	36.6	42.0	5.9	46.1	4.1	49.7	3.5	54.1	54
3	Median	Cars	Base	50.7	57.7	0.0	63.7	0.0	69.8	0.0	80.7	106
			Trailer	49.2	56.5	1.2	61.7	2.0	66.9	2.8	77.1	103
			Poloce w/o Lights om	48.9	52.2	5.4	55.9	7.8	59.4	10.3	64.3	100
			Traile + Police w/o Lights on	47.6	53.0	4.7	56.4	7.2	60.5	9.3	68.5	81
			SPE Van	40.7	51.4	6.3	55.9	7.8	60.4	9.4	75.9	102
		Trucks	Base	40.9	52.7	0.0	56.2	0.0	59.9	0.0	65.8	119
			Trailer	48.6	54.3	-1.6	57.0	-0.8	59.4	0.4	64.6	91
			Poloce w/o Lights om	45.6	51.7	1.0	54.1	2.1	56.5	3.4	60.3	95
			Traile + Police w/o Lights on	42.2	50.2	2.5	52.9	3.3	55.6	4.3	63.7	98
			SPE Van	43.3	48.6	4.1	52.3	3.9	55.3	4.5	63.8	99
	Shoulder	Cars	Base	49.8	56.1	0.0	61.5	0.0	67.1	0.0	78.4	204
			Trailer	48.2	55.5	0.7	59.7	1.8	64.3	2.9	72.5	163
			Poloce w/o Lights om	45.5	51.1	5.0	54.7	6.8	58.1	9.0	68.1	208
			Traile + Police w/o Lights on	43.6	50.3	5.8	53.7	7.7	57.0	10.1	65.0	181
			SPE Van	38.5	49.4	6.7	53.6	7.8	58.0	9.2	67.1	219
		Trucks	Base	50.5	53.1	0.0	57.0	0.0	60.6	0.0	63.6	40
			Trailer	44.2	51.8	1.3	56.2	0.7	60.7	-0.2	65.1	38
			Poloce w/o Lights om	46.0	48.3	4.9	52.6	4.4	55.6	4.9	59.6	31
			Traile + Police w/o Lights on	44.1	48.0	5.1	51.8	5.2	56.0	4.6	58.8	30
			SPE Van	41.9	47.4	5.7	51.2	5.8	54.7	5.9	62.8	43

Since the free flowing cars had higher mean speeds than the sampled cars, free flowing trucks, and sampled trucks, we decided to present the effects of different treatments on free flowing cars in this section. Further information about other cases is available in (14).

Free Flowing Cars

All law enforcement methods effectively reduced the speed of free flowing cars in both median and shoulder lanes for both moderate-speeding and extensive-speeding sites. Figure 2 presents

the cumulative speed distribution of the free flowing cars for different treatments in median and shoulder lane separately, for both dataset. It shows that the Trailer slightly shifted the cumulative speed distribution towards left and that corresponds to a small decrease in the speeds. This shift was more pronounced for the treatments that contained some law enforcement in the work zones. In both datasets, the shifts for all law enforcement methods were very similar; however, in Dataset 1 in the median lane the shift for the Trailer + Police case was larger than the other law enforcement methods. The cumulative speed distribution shows that the law enforcement methods reduced speed in all speed ranges. Two statistical tests, Chi Squared and Kolmogorov-Smirinov, were conducted to determine whether these distributions were significantly different. The results of these tests showed that in both datasets the cumulative speed distribution of all law enforcement methods were significantly different from that for the Base and Trailer cases (90% confidence level). These analyses showed that law enforcement treatments (police presence and the SPE) had effects on entire speeds of the free flowing cars. The effects of different treatments on the mean speeds are presented in the next section.

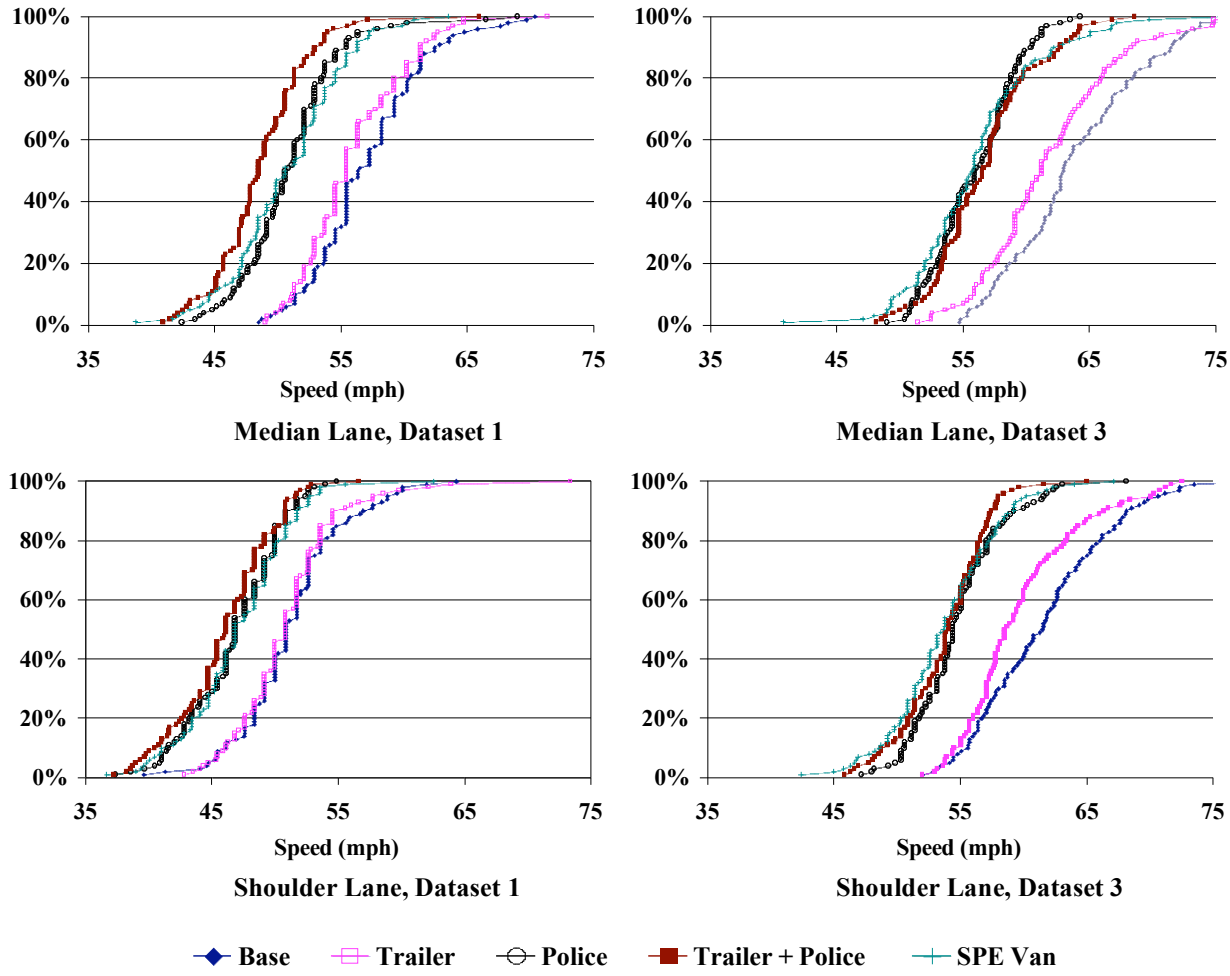

Figure 2: Cumulative Speed Distribution for the Free Flowing Cars

Mean Speeds and Speed Reductions

The Least Significant Difference (LSD) test was conducted to determine whether the mean speeds in different treatments were different. Table 3 shows the results of LSD test for free flowing cars for both datasets. In column one of the table, each treatment is marked with a letter. For the treatments marked with the same letter, mean speeds are not significantly different with 90% confidence level. If treatments are marked with different letters, the mean speeds are significantly different.

Table 3: LSD result for Free Flowing Cars

	Dataset	Grouping	Mean Speed	Reduction	Scenario
Free Flowing Cars in Median Lane	1	A	57.0	-	Base
		B	55.9	1.1	Trailer
		C	50.9	6.1	Police
		C	50.6	6.4	SPE Van
		D	48.6	8.4	Trailer + Police
	3	A	63.7	-	Base
		B	61.7	2	Trailer
		C	56.4	7.3	Trailer + Police
		C	55.9	7.8	Police
		C	55.9	7.8	SPE Van
Free Flowing Cars in Shoulder Lane	1	A	51.2	-	Base
		A	50.9	0.3	Trailer
		B	47.0	4.2	SPE Van
		B	47.0	4.2	Police
		C	45.9	5.3	Trailer + Police
	3	A	61.5	-	Base
		B	59.7	1.8	Trailer
		C	54.7	5.8	Police
		D	53.7	6.8	Trailer + Police
		D	53.6	6.9	SPE Van

In both work zone sites, all treatments significantly reduced the mean speed of free flowing vehicles except the Trailer for free flowing cars in shoulder lane. When the trailer reduced the mean speeds, it was only by 1.1 – 2.0 mph; that may not be considered practically significant. On the other hand, all speed reduction techniques that contained some kind of law enforcement reduced the mean speeds by 4.2 – 8.4 mph. The speed reductions were slightly higher in the extensive-speeding site except for the Trailer + Police treatment. The expected higher speed reductions in Dataset 3 were confirmed. This means that when drives travel faster, the law enforcement methods reduce the speeds more.

In the moderate-speeding site, Trailer + Police resulted in the highest speed reductions in both shoulder and median lanes (8.4 mph and 5.3 mph, respectively). It reduced the mean speed from 57.0 mph down to 48.6 mph in the median lane, and from 51.2 mph down to 45.9 mph in the shoulder lane. In this site, the SPE reduced the mean speed as much as the Police treatment did (6.1 - 6.4 mph in median lane and 4.2 mph in shoulder lane).

However, in the extensive-speeding site, the SPE reduced the mean speeds as much as the Trailer + Police. They reduced the speed similarly by 7.8 mph down to 55.9 mph in the median lane and by 6.8 – 6.9 mph in the shoulder lane bringing the mean speed down to 53.6 – 53.7 mph. In this site the speed reductions caused by these two treatments in the median lane was

similar to the reductions by the Police treatment but in the shoulder lane, the speed reductions were slightly higher than those by the Police case.

These observations indicate that in the work zone with moderate-speeding, using a speed Trailer plus a Police car resulted in the highest speed reductions for the free flowing cars, and the SPE and Police cases resulted in similar and slightly lower speed reductions. On the other hand, in an extensive-speeding site, the SPE and Trailer + Police treatments similarly reduced the mean speed of free flowing cars but Police treatments, resulted in slightly lower speed reductions.

Degree of Speeding

The degree of speeding for different treatments at four levels is shown in Figure 3. The figure shows that the speeding was higher in the Dataset 3 compared to Dataset 1. In both moderately and extensively speeding sites, the speed Trailer slightly reduced the speeding however, all law enforcement treatments reduced the speeding substantially.

In the moderate-speeding site, more than 68% of the free flowing cars in the median lane and only 15% of them in the shoulder lane exceeded the speed limit. Having the speed Trailer in the work zone did not reduced this percentage that much however, all law enforcement treatments almost eliminated speeding in the shoulder lane. But in the median lane, still some of the drivers exceeded the speed limit. The SPE decreased the percent exceeding the speed limit to 17%. The Police and Trailer + Police treatments reduced this percentage to 11% and 4%, respectively. This means that police presence was more successful in increasing the speed limit compliance for the free flowing cars in the median lane. When the police was present in the work zone, up to 3% of drivers exceeded the speed limit by more than 5 mph.

In the extensive-speeding site, more than 97% of free flowing cars in the median lane and more than 91% of them in the shoulder lane exceeded the speed limit. The law enforcement methods extensively reduced speeding in the work zone. Having law enforced in the work zone reduced speeding to 55% - 58% in the median lane and in the shoulder lane reduced it to 40% - 44%. All the law enforcement treatments were similarly effective, but still 11% - 16% of drivers exceeded the speed limit by more than 5 mph in the median lane and 2% - 9% of them in the shoulder lane. In addition, in the SPE and Trailer + Police cases, still 7% and 4% of free flowing cars in the median lane exceeded the speed limit by more than 10 mph. The Police reduced this percentage to zero. In the shoulder lane, less than 1% of drivers exceeded the speed limit by more than 10 mph when the law was enforced.

These observations indicate that in both moderately and extensively speeding locations, all law enforcement techniques were effective in improving the speed limit compliance. The results of Dataset 3 in both lanes, and Dataset 1 in shoulder lane shows that all of the treatments were similarly effective however, the findings in Dataset 1 for the median lane showed that Trailer + Police treatment was more effective than the other treatments. However, in both datasets, still some of the drivers exceeded the speed limit by more than 5 or more than 10 mph. The percentage of these drivers in the moderate-speeding site was low but in the extensive-speeding site, this percentage was not negligible. This means that although the law enforcement methods increased the speed limit compliance, they could not entirely eliminate the extensive-speeding (more than 5 or 10 mph) in the work zone especially in Dataset 3. In terms of excessive speeding, all of the law enforcement methods had approximately similar results.

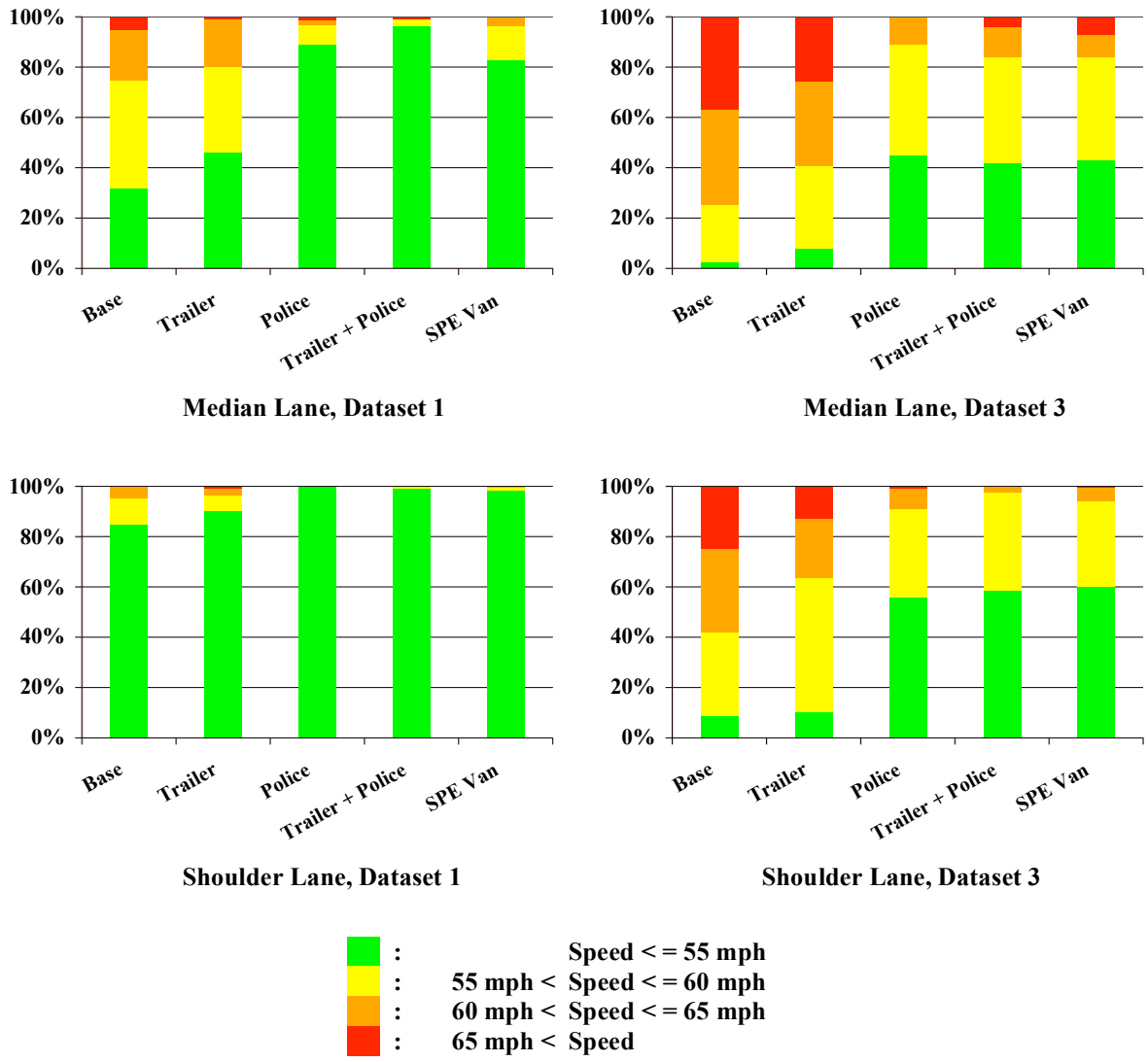

Figure 3: The Degree of Speeding for Free Flowing Cars

CONCLUSIONS

The findings of this research showed that all law enforcement methods, including SPE, were effective in reducing the mean speed and speeding to various degrees. In both datasets, all the law enforcement methods significantly reduced the mean speed of free flowing cars by 6.1 – 8.4 mph in the median lane and by 4.2 - 6.9 mph in the shoulder lane. This brought down the mean speeds in the median lane to 48.6 – 56.4 mph and in the shoulder lane to 45.9 – 54.7 mph. In the moderately speeding site, Police and the SPE reduced the mean speeds similarly in both lanes; however, Trailer + Police treatment resulted in even larger speed reduction. On the other hand, in the extensively speeding site, the SPE and Trailer + Police treatments resulted in similar

reductions in the mean speeds, and both were higher than the reductions due to the Police treatment.

In the moderately speeding site, Trailer + Police was more effective than the other treatments in reducing speeding, but in the extensively speeding site, all the law enforcement methods reduced the speeding similarly; yet 11% to 16% were still speeding by more than 5 mph in median lane.

The effects of the speed reduction techniques on individual vehicles would reveal how different drivers react to the different speed management techniques. A study to determine such effects is recommended. In addition, the effects of the SPE and other speed reduction techniques on the traffic flow characteristics in the work zone are not known. Conducting a research on the effects of low enforcement on traffic flow characteristics is recommended.

ACKNOWLEDGEMENTS

This study was sponsored by Illinois Department of Transportation (IDOT) through Illinois Center for Transportation (ICT). The authors appreciate the suggestions and feedback from the Technical Review Panel members. The content of this report represent the views of the authors and not of IDOT and the authors are responsible for its content.

REFERENCE

1. National Highway Traffic Safety Administration. Traffic Safety Facts, 2006 Data. Overview. NHTSA's National Center for Statistical Analysis, DOT HS 810 809, Washington D.C.

2. National Highway Traffic Safety Administration. Traffic Safety Facts, 2006 Data. Speeding. NHTSA's National Center for Statistical Analysis, DOT HS 810 814, Washington D.C.

3. Benekohal R. F., A. Hajbabaie, M. V. Chitturi, M. Wang, and J. C. Medina, *Automated Speed Enforcement: Effects on Speeding and Platooning in Work Zones.* Compendium of AATT conference, Athens, Greece, 2008.

4. Goldenbeld, C. and I. Van Schagen, *The effects of speed enforcement with mobile radar on speed and accidents: An evaluation study on rural roads in the Dutch province Friesland. Accident Analysis and Prevention*, v 37, n 6, November, 2005, p 1135-1144.

5. Chen, G., W. Meckle, and J. Wilson. *Speed and safety effect of photo radar enforcement on a highway corridor in British Columbia*. *Accident Analysis and Prevention*, v 34, n 2, March, 2002, p 129-138.

6. Bloch, S. A., *Comparative study of speed reduction effects of photo-radar and speed display boards, Transportation Research Record*, n 1640, Nov, 1998, p 27-36.

7. Rogerson, P., Newstead, S., Cameron, M.,. *Evaluation of the Speed Camera Program in Victoria 1990–1991, Phase 3*. Accident Research Centre, Monash University, 1994.

8. Newstead, S., Mullan, N., Cameron, M.,. *Evaluation of the Speed Camera Program in Victoria 1990–1993, Phase 5: Further Investigation Of Localised Effects On Casualty Crash Frequency*. Accident Research Centre, Monash University, 1995.

9. Evaluation of Work Zone Safety Operations and Issues. Research Report KTC-06-08/SPR287-05-1F, Kentucky Transportation Center, March 2006, 78p.

10. Zech, W. C., S. Mohan, and J. Dmochowski. *Evaluation of rumble strips and police presence as speed control measures in highway work zones. Practice Periodical on Structural Design and Construction*, v 10, n 4, November, 2005, p 267-275.

11. *Effectiveness of Law Enforcement in Reducing Vehicle Speeds in Work Zones.* Office of Construction, Construction Programs Section, Minnesota Department of Transportation, January 1999.

12. Benekohal, R.F., Resende, P.T.V., and R.L. Orloski. *Effects of Police Presence on Speed in a Highway Work Zone: Circulating Marked Police Car Experiment.* Report FHWA-IL/UI-240. University of Illinois, Urbana, IL, 1992

13. Brewer, M. A., G. Pesti, and W. Schneider IV. Improving Compliance with Work Zone Speed Limits: Effectiveness of Selected Devices. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1948,* TRB, National Research Council, Washington, D.C., 2006, pp67-76.

14. Benekohal R. F., A. Hajbabaie, J. C. Medina, M. Wang, and M. V. Chitturi. Speed Photo-Radar Enforcement Evaluation in Illinois Work Zones. Report to IDOT. University of Illinois, Urbana, IL, 2008