Automated Speed Photo Enforcement Effects on Speeds in Work Zones

Rahim F. Benekohal, Madhav V. Chitturi, Ali Hajbabaie, Ming-Heng Wang, and Juan C. Medina

Automated speed enforcement in construction zones has the potential to increase compliance with the speed limit and improve safety. The effectiveness of speed photo enforcement (SPE) (by radar) in reducing speeds and increasing speed limit compliance in work zones was evaluated for the first time in the United States, at Illinois work zones. Details are presented on SPE implementation and its effectiveness at the point it was stationed and at a downstream location in a work zone. Speed data were collected at the location of SPE and at a location 1.5 mi downstream in the work zone to determine the point and spatial effects of SPE. Speeds were measured for free-flowing and platooned cars and heavy vehicles in shoulder and median lanes. Results showed that SPE is effective in reducing the average speed and increasing compliance with work zone speed limit. The SPE reduced speed in the median lane more than in the shoulder lane, as expected. In addition, the speed of free-flowing vehicles was reduced more than for platooned vehicles. The reduction of the mean speed varied from 3.2 to 7.3 mph. The percentage of vehicles exceeding the speed limit near SPE was reduced from about 40% to 8% for free-flowing cars and from 17% to 4% for free-flowing heavy vehicles. Near the SPE van, none of the cars exceeded the speed limit by more than 10 mph, and none of the heavy vehicles exceeded it by more than 5 mph. The data also showed a mixed spatial effect for SPE. At the downstream location, the speed reduction for cars was not significant, while it varied from 0.9 to 2.5 mph for heavy vehicles.

Excessive speeding can increase work zone crash frequency and severity. Also, speed differential between the vehicles may be a contributing factor to crashes (*1–4*). Increasing the speed limit compliance can decrease the speed variance and improve work zone safety. In 2003, work zone fatalities in Illinois reached a peak of 46. In 2004, Illinois enacted the Automated Traffic Control Systems in Highway Construction or Maintenance Zones Act, authorizing the use of speed photo enforcement (SPE) in construction zones. This was the first time a state department of transportation in the United States was authorized to implement SPE in highway work zones. The objective of the SPE program in work zones is to improve the speed limit compliance and improve work zone safety.

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Transportation Research Record: Journal of the Transportation Research Board, No. 2055, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 11–20.
DOI: 10.3141/2055-02

This paper discusses the details of the how SPE was implemented in Illinois work zones, how it works, and its effectiveness in reducing the speeds and improving the speed limit compliance. Field data collected from a work zone in southern Illinois are used to quantify the effects.

LITERATURE REVIEW

Automated speed enforcement had not been implemented in work zones on highways in the United States before. To the best of the authors' knowledge, neither have there been studies in other countries. This section briefly describes some studies on automated speed enforcement.

Goldenbeld and Van Schagen studied the effects of speed enforcement with mobile radar on speeds and accidents on rural roads in the Dutch province of Friesland (*5*). The evaluation covered a 5-year period of enforcement. Their studies showed a significant reduction in mean speed and percentage exceeding the posted speed limit. They estimated a 21% decrease in the number of injury accidents and number of serious casualties.

Chen et al. evaluated the influence of the photo radar program on speeds of vehicles and collisions at the location of the photo radars and also at interleaving locations (*6*). They found that using photo radar reduced average speed and standard deviation of speed by 2.8 km/h and 0.5 km/h, respectively in their monitoring area(s). In addition, they observed a 14% ± 11% reduction in expected collisions at photo radar locations and a 16% ± 7% reduction along the study area.

Bloch studied the speed reduction effects of Photo-radar and speed display board on three streets in Riverside, California (*7*). The results showed that both devices significantly reduced vehicles speeds by 7 to 8 km/h, and they reduced the number of vehicles exceeding the speed limit by 16%. The study showed that only speed display board had carryover effects. He found out that the enforced display sign had a substantial short-term carryover effect while the unenforced display board had a longer-term carryover effect.

Oei studied the previous studies in Europe, Australia, and North America on speed enforcement, its effects on traffic safety, and potential halo effects of the treatments (*8*). He found a significant speed reduction at the enforcement location. However, evidence of the safety effect was not reliable. In addition, for the halo effect, further research was needed.

Rogerson et al. evaluated the effects of speed cameras on the incidence of automobile crashes in Melbourne (*9*). Their methodology did not include any speed measurements. They compared the number of crashes on days when the presence of the speed camera was assumed with the number of crashes on days when the speed camera was assumed to be absent. They found a statistically significant reduction in casualty crashes within 1 km of the site of the speed camera, because of a posted warning against traffic infringement. This paradox was confined to times of the week when alcohol consumption was highest. They defined the hours of low alcohol consumption as Monday to Thursday 6 a.m. to 6 p.m., Friday 6 a.m. to 4 p.m., Saturday 8 a.m. to 2 p.m., and Sunday 10 a.m. to 4 p.m. The hours defined as times of high consumption of alcohol were those not included among the times enumerated above. They observed the effect of the warning against bad driving for up to 2 weeks in the vicinity of the speed camera site. Newstead et al. continued this research and found that the speed cameras did not have a significant effect on automobile crashes in Victorian rural towns within 1 km of a camera site (*10*). But when they studied crashes within a 15-km radius of the camera site on Victorian rural highways, they observed a statistically significant reduction.

SPE PROGRAM IMPLEMENTATION IN ILLINOIS

In 2003, fatalities in work zones in Illinois increased to 46 (including 5 workers), from 31 in 2002 and 36 in 2001. Toughened work zone fines were introduced, and Illinois passed the Automated Traffic Control Systems in Highway Construction or Maintenance Zones Act. The Act authorized the use of cameras by the state police to enforce speed limits in construction zones. Currently, the Act requires that construction workers are present when SPE is used. The Act allows SPE to be used in daytime or nighttime and whether or not the workers are behind temporary concrete barriers. The law also requires that special signs (such as the one shown in Figure 1*a*) be posted to inform motorists of SPE in the work zones. Deployment of SPE vans started in summer 2006.

The self-contained SPE van as shown in Figure 1*b* was provided by a private vendor (ACS State and Local Solutions). The principle behind SPE is that radars monitor the speeds of the vehicles approaching the SPE van. As shown in Figure 1*b*, the SPE van is equipped with two radars: down-the-road radar and across-the-road radar. The speed obtained using down-the-road radar is displayed on the light-emitting diode display on top of the SPE van. This gives one last chance for speeding drivers to reduce their speeds and comply with the speed limit. The range of down-the-road radar is similar to that of typical radar used in work zones (about ¼ to ½ mi). Across-the-road radar measures the speeds of vehicles when they are about 150 ft upstream of the van. Across-the-road radar operates at a specified angle to the path of vehicles and accounts for the angle effect. Operation of the SPE van is shown in Figure 1*c*. If the speed of the vehicle (as measured by across-the-road radar) is greater than a specified value, the radar activates the two onboard cameras to take pictures of the vehicle. The camera at the rear of the van (Figure 2*a*) captures the face of the driver; and the front camera (Figure 2*b*) captures the rear license plate of the violating vehicle. It also shows the date and time of the violation. The vans are staffed by Illinois State Police officers trained to use the SPE vans. An officer at the deployment station (Figure 2*c*) can see the speeding vehicle on the computer monitor; a sound audible only to the officer also alerts him or her about the speeding vehicle. The SPE van can be operated at night and is equipped with two 140 W bulbs at the rear (Figure 2*d*) to act as a flash unit and provide light to take a clear picture of the car and the driver. The light at the front of the vehicle provides enough light to identify the license plate of the vehicle. The officer can activate

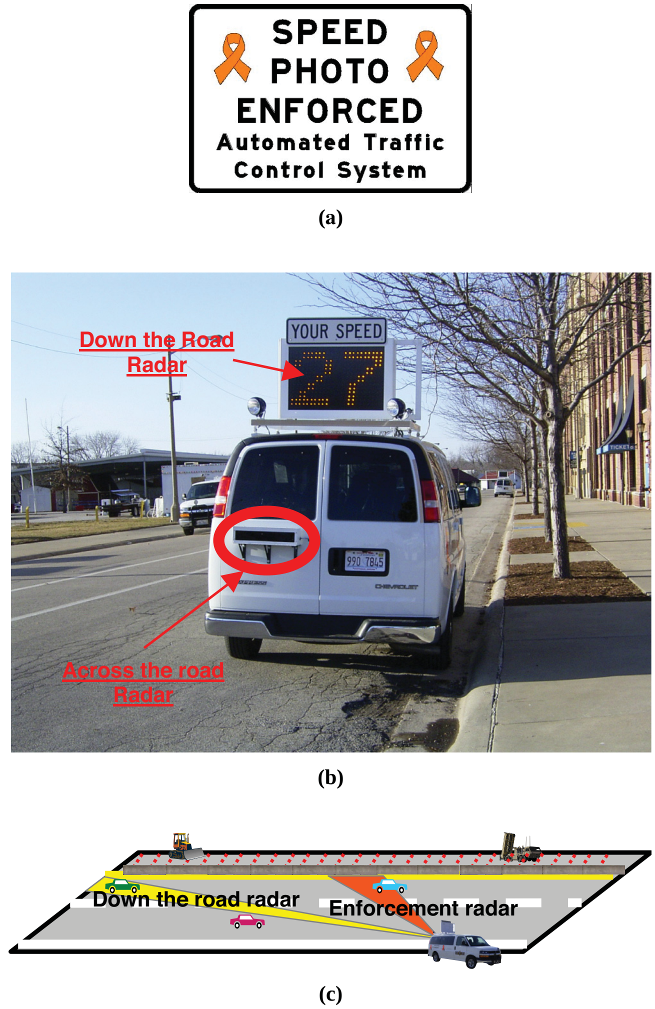
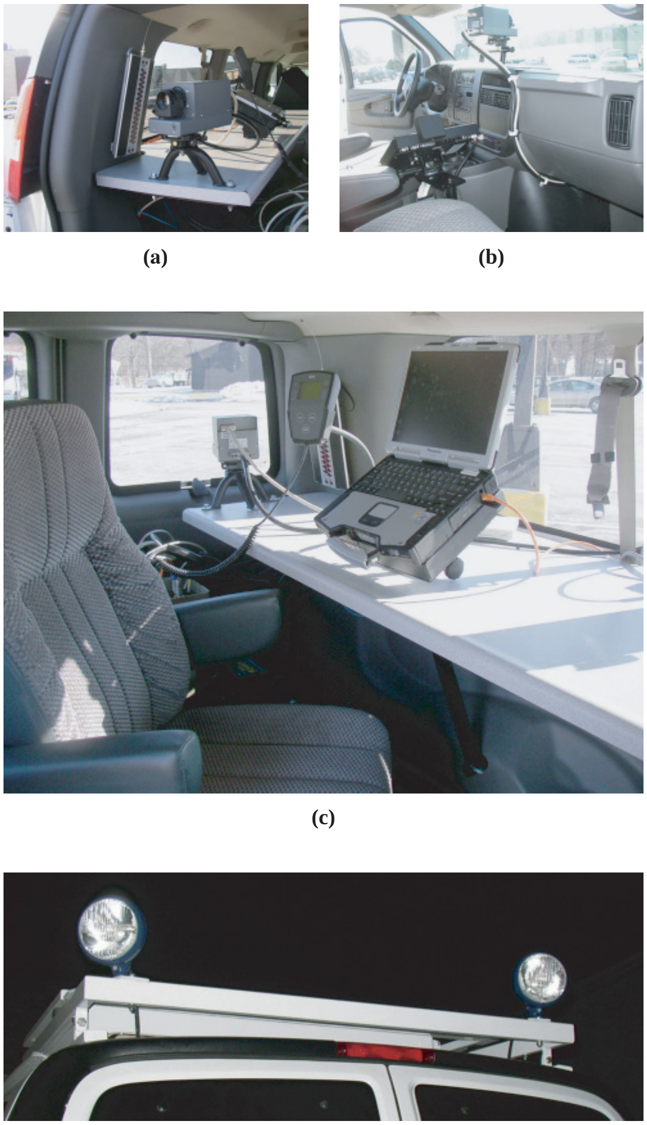


FIGURE 1 SPE signs, vehicle, and operation: (*a*) special signs to be posted in work zones when SPE is deployed, (*b*) photo enforcement vehicle, and (*c*) operation of photo enforcement.

a warning system (if installed) to warn the workers in the work area of an arriving speeding vehicle.

The officer in the van can issue a citation for a speeding vehicle if the officer decides it is a clear case of excessive speeding. Currently, the violation is tied to the driver of the vehicle. From the license plate of the speeding vehicle, the vehicle's owner is identified. The picture of the speeding driver is compared with the picture of the owner, in the driver's license database. Currently, if the picture of the driver at the time of the violation matches the picture of the registered owner of the vehicle, the ticket is approved by the police. A sample citation is shown in Figure 3. The vendor processes the approved citation and mails it to the registered owner of the vehicle within 14 days. Local stakeholders are proposing legislative changes so that citations can be issued even when the registered owner is not the speeding driver. Currently, rental companies are sent affidavits of nonliability, and they are required to respond within 30 days.

In regard to SPE, the regular speeding fines in work zones apply. For the first violation, the ticket is for $375 ($125 goes to pay off-duty state troopers to provide additional enforcement in work zones). For the second violation, the fine is $1,000 ($250 for trooper hire-back) and a 90-day suspension of the license. Court appearance is mandatory for each violation. The vans are being provided under a contract



(a) (b) (c) (d)

FIGURE 2 Inside and outside SPE van: (*a*) rear camera, (*b*) front camera, (*c*) deployment station, and (*d*) flash unit at rear of van.

by the vendor at a cost of $2,950 per month per van (including the van, equipment, maintenance, upgrades, and training) plus a processing fee of $15 per ticket.

EVALUATION OF SPE IN WORK ZONES

The objectives of this study are to evaluate the point and spatial effectiveness of the SPE van in reducing speeding in the work zone. In the following sections, the data collection, data reduction, and analyses are presented.

Data Collection

The SPE was deployed in an add-a-lane construction zone on Interstate 64 in St. Clair County, Illinois, in July 2006. The speed limit inside the work zone was 55 mph for cars and trucks. Data were collected at this site for the following scenarios: base data, in which no speed enforcement was present; and an SPE van deployed in the work zone.

The SPE van could have a spatial effect. In other words, it may reduce speeds of vehicles not just in the immediate vicinity of the van but also at a downstream location from the van. To quantify the spatial effect of SPE van, data were collected at another location about 1.5 mi downstream of the treatment location, referred to as downstream location in this paper.

The data had to be collected without interfering with the work zone traffic flow. Also, the data collection devices needed the capability to collect information on individual vehicles. This information is crucial, as will be explained later, for the data analyses. Therefore, video cameras were used for collecting the data at the two locations. The treatment location and the downstream location were on eastbound direction of Interstate 64 and located 1.5 mi apart. At both locations, two lanes were open for traffic. The work activity area was separated from the travel lanes through the use of concrete barriers. Video cameras were used to capture the vehicles as they passed the two markers that the research team placed near the shoulder. These two markers were about 500 ft downstream of the treatment location, thereby giving the drivers ample space to react to the treatment before their speeds were measured. A schematic diagram of the data collection is shown in Figure 4. General information about the work zone layout (number of lanes open, location of closed lanes, speed limit, weather conditions, position of ramps, etc.) was also recorded.

Data Reduction

The videotapes were time stamped with frame numbers to provide the capability to read times to the accuracy of a frame (or $1/30$ s). Data were collected for every free-flowing vehicle that traveled through the work zone. A free-flowing vehicle was one that was not constrained by the vehicles ahead of it at the data collection point. A vehicle was considered free flowing when its headway was greater than 4 s. In addition, data were collected on systematically sampled vehicles (every fifth vehicle across both lanes) to represent the traffic that traveled through the work zone. These are called sampled vehicles. The sampled vehicles include some free-flowing vehicles, but the majority of them come from in-platoon vehicles. The average of the sampled vehicle speeds represents the average speed of the traffic stream. The average speed of free-flowing vehicles represents the speed for those that could travel faster if drivers wanted to.

For every identified vehicle, the following data were collected:

1. Vehicle type, classified into two categories in this research:
   – Passenger cars, minivans, pickup trucks, and sport utility vehicles and
   – Single-unit trucks, semitrailers, and combination trucks.
2. Travel lane—median lane or shoulder lane;
3. Free-flowing or fifth vehicle, classified into three categories:
   – F: Free-flowing vehicle,
   – TF: Fifth and free-flowing vehicle, and
   – T: Fifth and not free-flowing vehicle.
4. Times at which the vehicle passed the two markers.

The times at which vehicles crossed the markers are used to determine speeds of the vehicles. It should be noted that the results

ILLINOIS STATE POLICE
Sangamon County

Notice of Infraction

Mail Date: 06/10/05

REGISTERED OWNER INFORMATION

S013883011

Diane [redacted]
500 [redacted] Suite 100
Springfield, IL 62703[redacted]

Your vehicle was photographed violating Section 11-605.1 of the Illinois Vehicle Code on the date and time listed below. Under Illinois State law, the vehicle operator is liable for the violation recorded using an automated traffic enforcement system. The penalties for and consequences of a traffic violation recorded by an automated traffic control system are the same as for any similar violations of the Illinois Vehicle Code. The basis for the citation is the photographic images recorded by the automated traffic control system.

On the back of this notice you will find detailed information and instructions regarding payment and ticket adjudication.

VIOLATION INFORMATION

Ticket Number:	S013883011
Issue Date:	12/14/04
Issue Time:	10:30 AM
Violation Code:	T119
Description:	Speed Photo Radar
Location:	Test Location
Vehicle Tag:	IL 0173
Vehicle Make:	4DR
Vehicle Speed:	63mph
Posted Speed:	35mph
First available court date:	January 20, 2005

Your answer to this notice of infraction must be received by the payment due date listed below.

Failure to pay the fine or otherwise answer in the manner and time required is an admission of liability. This will result in additional penalties and the loss of your right to a hearing. In addition, your home state may place a hold on the renewal of your vehicle registration.

Detach and return this portion with your payment in the envelope provided, or you may pay your ticket through the Internet at http://www.isp.state.il.us

Ticket Number: S013883011 **Vehicle Tag:** IL 0173 **Mail Date:** 06/10/05

Payment Due Date: 07/10/05
Initial Fine Amount Due: $375.00

You can view full color version of the image below at http://www.public.cite-web.com
Citation Number: 01388301 Pin Number: [redacted]65

Amount Paid: $

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FIGURE 3 Sample citation.

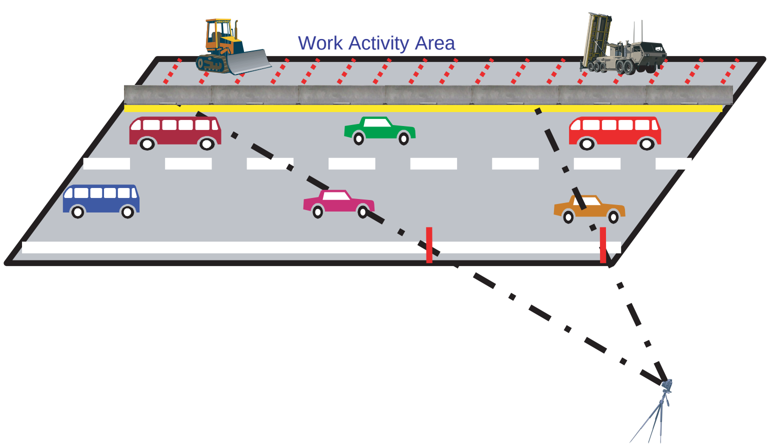

FIGURE 4 Schematic diagram of data collection setup.

presented are based on a minimum of 100 vehicles for each of the four categories:

- Median lane free-flowing vehicles,
- Median lane sampled vehicles,
- Shoulder lane free-flowing vehicles, and
- Shoulder lane sampled vehicles.

Data for the base and SPE conditions were collected during weekdays and at similar times of day to avoid the effect of volume variation. The data used for the analyses did not include peak traffic periods. In this paper, the SPE effects are compared with those of the base case (no treatment) data.

RESULTS

SPE Effects near the Van

Effects of SPE on Cars

Mean Speed and Speed Distribution Speeds of the vehicles under base and SPE conditions were determined by vehicle type (car or heavy vehicles), travel lane (median or shoulder), and traffic flow status (free-flowing or sampled). See Table 1. SPE reduced the average speeds of free-flowing passenger cars by 6.4 mph to 50.6 mph in the median lane and by 4.2 mph to 47.0 mph in the shoulder lane. Similarly, the average speeds of the sampled cars were reduced by 5.1 mph and 4.3 mph to 49.8 mph and 45.5 mph for the median and shoulder lanes, respectively. SPE reduced the average speeds significantly below the speed limit level (55 mph) on both the median and shoulder lanes. The effect of SPE on speed distributions is considered next.

Figure 5*a* to 5*d* show distributions of car speeds near the SPE van. Figure 5*a* and 5*b* show the distributions for free-flowing cars on the median and shoulder lanes, respectively. Similarly, Figure 5*c* and 5*d* show the speed distributions of sampled cars on the median and shoulder lanes, respectively. As Figure 5 clearly shows, there is a shift in the distribution of the speeds of cars to lower speeds when a SPE van was present. As expected, the shift is more pronounced on the median lane than on the shoulder lane because speeds on the median lane were greater to begin with. Similarly, the shift is more pronounced on the free-flowing cars than on sampled cars. Figure 5 also shows the significant decrease in the percentage of cars exceeding the speed limit. Specifically, note that nearly 15% of the sampled cars on the median lane and 40% on the shoulder lane reduced their speeds to below 45 mph in a 55 mph work zone.

Speeding Near the SPE van, the percentage of free-flowing cars exceeding the speed limit was reduced from 39.8% to 8.3%. A similar trend was observed for sampled cars: the percentage exceeding the speed limit was reduced from 27.7% to 6.3%. Drivers with excessive speeds are of more concern than those who exceed the speed limit by a few miles per hour. The degree of speeding is shown in Figure 6. Speeders are divided into three categories: 0 to 5 mph over the speed limit, 5 to 10 mph over the speed limit, and more than 10 mph over the speed limit. It should be noted that the numbers are for both the lanes together. Of the 8.3% speeding free-flowing cars (in SPE case), 6.5% exceeded the speed limit by less than 5 mph and the rest 1.8% exceeded the speed limit between 5 and 10 mph. No free-flowing cars traveled more than 10 mph over the speed limit. All the 6.3% speeding sampled cars were within 5 mph over the speed limit.

TABLE 1 Average Speeds near SPE Van and Downstream Location

			Shoulder Lane			Median Lane		
	Vehicle Type	Treatment	Reduction (mph)	Mean Speed (mph)	Sample Size	Reduction (mph)	Mean Speed (mph)	Sample Size
Treatment Location								
Free-flowing vehicles	PC	Base		51.2	135		57.0	119
		SPE	4.2	47.0	191	6.4	50.6	146
	HV	Base		50.3	41		53.5	40
		SPE	4.1	46.1	54	3.2	50.3	41
Sampled vehicles	PC	Base		49.8	81		54.9	85
		SPE	4.3	45.5	155	5.1	49.8	97
	HV	Base		52.6	44		53.3	36
		SPE	7.3	45.3	38	4.4	48.9	40
Downstream Location								
Free-flowing vehicles	PC	Base		58.6	188		61.8	98
		SPE	0.6[a]	57.9	209	0.2[a]	61.6	126
	HV	Base		57.3	57		59.4	43
		SPE	0.9[b]	56.4	73	2.5	56.8	52
Sampled vehicles	PC	Base		57.2	82		60.1	78
		SPE	0.1[a]	57.1	128	0.8[a]	59.3	94
	HV	Base		57.0	43		58.6	38
		SPE	1.7	55.3	42	1.9	56.7	43

Note: All other numbers are significant at 99% confidence level.
[a]Not significant at 85% confidence level.
[b]Significant at 90% confidence level.

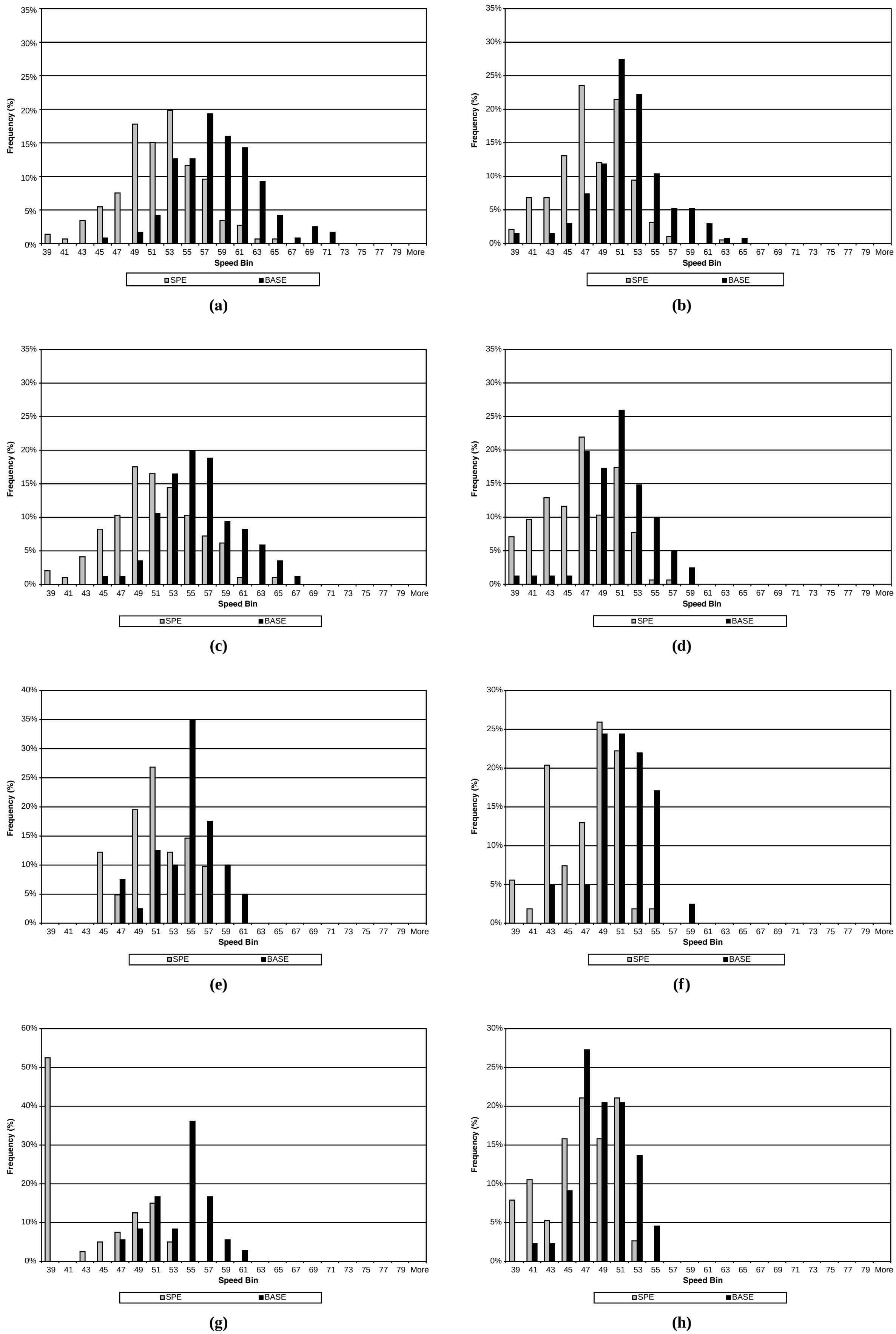

FIGURE 5 Speed distributions at treatment location: (*a*) median lane free-flowing cars, (*b*) shoulder lane free-flowing cars, (*c*) median lane sampled cars, (*d*) shoulder lane sampled cars, (*e*) median lane free-flowing trucks, (*f*) shoulder lane free-flowing trucks, (*g*) median lane sampled trucks, and (*h*) shoulder lane sampled trucks.

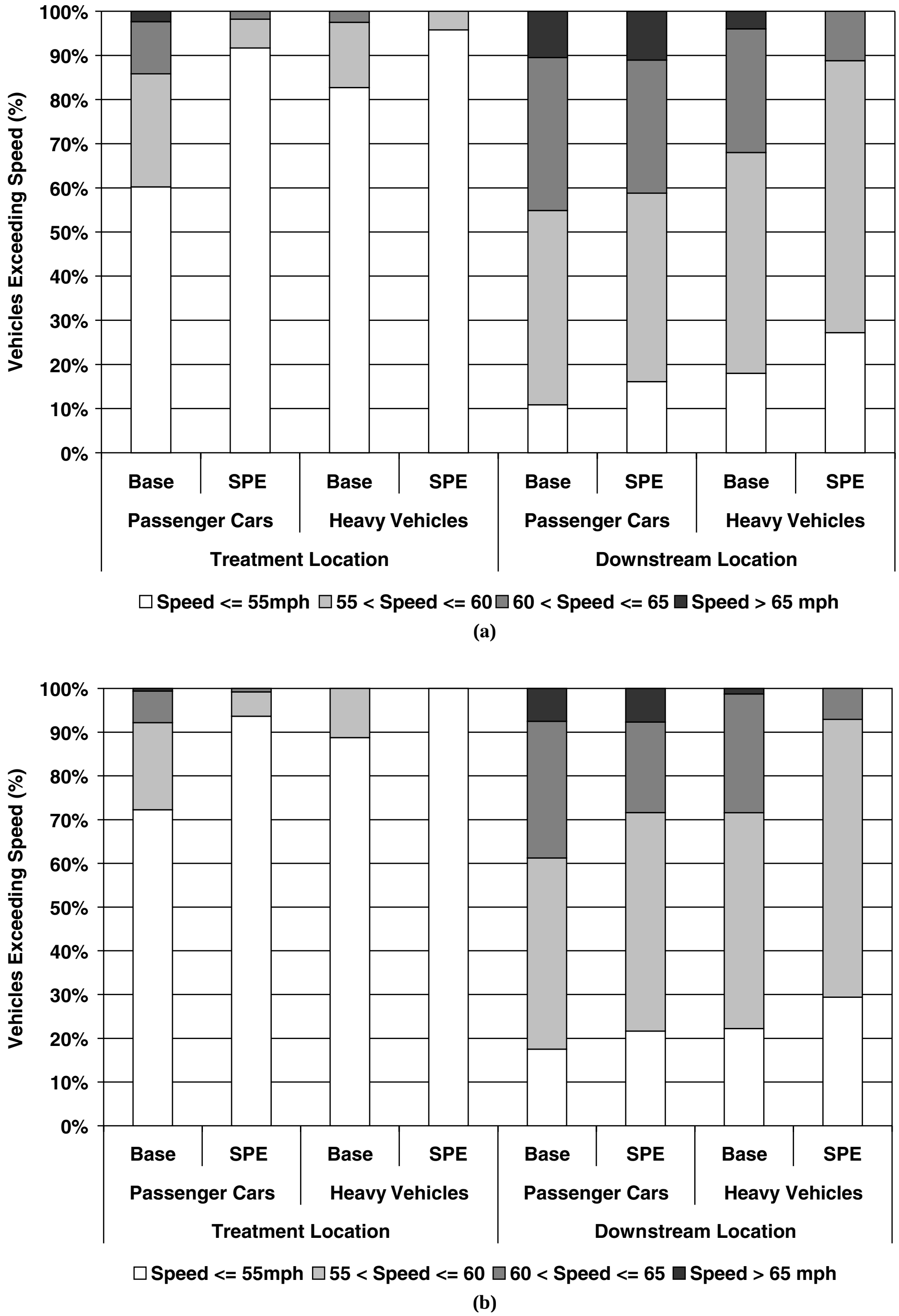

FIGURE 6 Degree of speeding: (*a*) free-flowing vehicles and (*b*) sampled vehicles.

If exceeding the speed limit by more than 10 mph is considered excessive speeding, then excessive speeding of cars near SPEs is completely eliminated.

Effects of SPE on Heavy Vehicles

Mean Speed and Speed Distribution The average speeds of free-flowing heavy vehicles were reduced by a significant 3.2 mph to 50.3 mph and 4.1 mph to 46.1 mph for median and shoulder lanes, respectively. Similarly, the average speeds of the sampled heavy vehicles were reduced by 4.4 mph to 48.9 mph and 7.3 mph to 45.3 mph for the median and shoulder lanes, respectively. As with cars, SPE reduced the average speeds significantly below the speed limit (55 mph) on both lanes and for free-flowing and sampled heavy vehicles. Generally, the heavy vehicles had slightly lower speeds than did cars near the SPE van. The effect of SPE on the speed distributions is presented next.

Figure 5*e* to 5*h* show the speed distributions for heavy vehicles near the SPE van. As with cars, a left shift in the speed distributions can be observed in all the four categories: median lane free-flowing, median lane sampled, shoulder lane free-flowing, and shoulder lane sampled heavy vehicles. The shift is more pronounced on the median lane than on the shoulder lane and on free-flow heavy vehicles than on sampled heavy vehicles. As in the case of cars, there is a significant decrease in the percentage of heavy vehicles exceeding the speed limit. About 60% of median lane and 39% of shoulder lane sampled heavy vehicles reduced their speeds to less than 45 mph.

Speeding Near the SPE van, the percentage of free-flowing heavy vehicles exceeding the speed limit was reduced to 4.2% from 17.3%. The percentage of sampled heavy vehicles exceeding the speed limit was reduced to zero from 11.3%. The degree of speeding is shown in Figure 6. All the speeding free-flowing heavy vehicles were within 5 mph over the speed limit. Although the average speeds of cars and heavy vehicles were only slightly different, the data indicate that SPE has more effect on heavy vehicles in regard to achieving higher compliance with the speed limit and lower degree of speeding by heavy vehicles than the effect on passenger cars.

SPE Effects at Downstream Location

Effects on Cars

Mean Speed and Speed Distribution Table 1 shows the mean speeds of the vehicles under base and SPE conditions classified by vehicle type (car or heavy vehicles), travel lane (median or shoulder), and traffic flow status (free-flowing or sampled). Also shown are the sample sizes. The average speeds on both lanes and of both free-flowing and sampled cars were greater than the speed limit (55 mph). When compared with the base case, the average speeds of passenger cars with SPE did not decrease significantly. Therefore, SPE had no effect on the average speeds of cars at the downstream location.

Figure 7 shows the distributions of the speeds of cars and heavy vehicles at the downstream location. Figure 7*a* and 7*b* show the distribution for free-flowing cars on the median and shoulder lanes, respectively. Similarly, Figure 7*c* and 7*d* show the speed distributions of sampled cars on the median and shoulder lanes, respectively. Unlike at the treatment location, where a significant shift of the distribution to the left is visible, Figure 7 shows no such shift. However, it clearly shows that, generally, at the higher end of the speed spectrum, the SPE columns are shorter than for the base case, and at the lower end of the spectrum, the SPE columns are taller. This trend is consistent for all the four categories of cars: median lane free-flowing, shoulder lane free-flowing, median lane sampled, and shoulder lane sampled. Unlike at the treatment location, the effect is more pronounced on the shoulder lane than on the median lane and also more pronounced on sampled cars than on free-flowing cars. This situation could exist perhaps because cautious drivers are usually in the shoulder lane and less likely to be free flowing, and there seems to be some spatial effect of SPE on such drivers. Figure 7 also shows that there is some decrease in the percentage of cars exceeding the speed limit at the downstream location. The actual decrease in the percentage of vehicles exceeding the speed limit and by how much are presented in the next section.

Speeding At the downstream location (both lanes together), the percentage of free-flowing cars exceeding the speed limit was slightly reduced from 89.2% to 83.9%. The degree of speeding is shown in Figure 6. The percentages of speeders in different categories also changed only modestly. However, it should be noted that the percentage of cars exceeding the speed limit by more than 10 mph remained the same or increased modestly. A similar trend is also shown by sampled cars: the percentage exceeding the speed limit reduced slightly from 82.5% to 78.4%. The percentage of drivers exceeding the speed limit by more than 10 mph remained the same. Therefore, it seems that the speeds of aggressive car drivers (speeding over 10 mph) at the downstream location are not affected by the presence of SPE upstream.

Effects on Heavy Vehicles

Mean Speed and Speed Distribution The average speeds of free-flowing heavy vehicles were reduced by a significant 2.5 mph to 56.8 mph and 0.9 mph (at 90% confidence level) to 56.4 mph for median and shoulder lanes, respectively. The average speeds of the sampled heavy vehicles were reduced by 1.9 mph and 1.7 mph for the median and shoulder lanes to 56.7 and 55.3 mph, respectively. As opposed to cars, the speed reductions for heavy vehicles are significant.

Figure 7*e* to 7*h* show the speed distributions for heavy vehicles at the downstream location. As with cars, the consistent trend is that there are fewer heavy vehicles traveling at the higher speeds than in the base and more heavy vehicles traveling at the lower speeds than in the base. In addition, some shift in the speed distribution and reduction in percentage of vehicles exceeding the speed limit can also be observed.

Speeding For the free-flowing heavy vehicles (both lanes together), the percentage of exceeding the speed limit was reduced to 72.8% from 82%. The percentage of sampled heavy vehicles exceeding the speed limit was reduced to 70.7% from 77.8%. As shown in Figure 6, none of the heavy vehicles exceeded the speed limit by more than 10 mph. About 10% of the heavy vehicles (both sampled and free-flowing) exceeded the speed limit by 5 to 10 mph. SPE seems to have a more pronounced effect on the degree of speeding of heavy vehicles than on cars at the downstream location also.

Spatial Effects of SPE

Speed Reductions

Table 1 compares the speed reduction effects of SPE near the van and 1.5 mi downstream from the van. Speed reductions near the SPE van (treatment location) on cars varied from 4.2 mph to 6.4 mph depending on the lane and whether the cars were free-flowing or sampled. For heavy vehicles, the speed reductions near the SPE van ranged from 3.2 to 7.3 mph. All the speed reductions near SPE were statistically significant. The spatial effect of SPE in regard to speed reductions were not significant for cars, while they were significant (90% or more confidence level) for heavy vehicles. The heavy vehicle speed reduction ranged from 0.9 mph to 2.5 mph at the downstream location.

Speeding

The percentage of cars and heavy vehicles exceeding the speed limit near the SPE van was reduced to less than 10% and 5%, respectively. Near the SPE, none of the cars exceeded the speed limit by

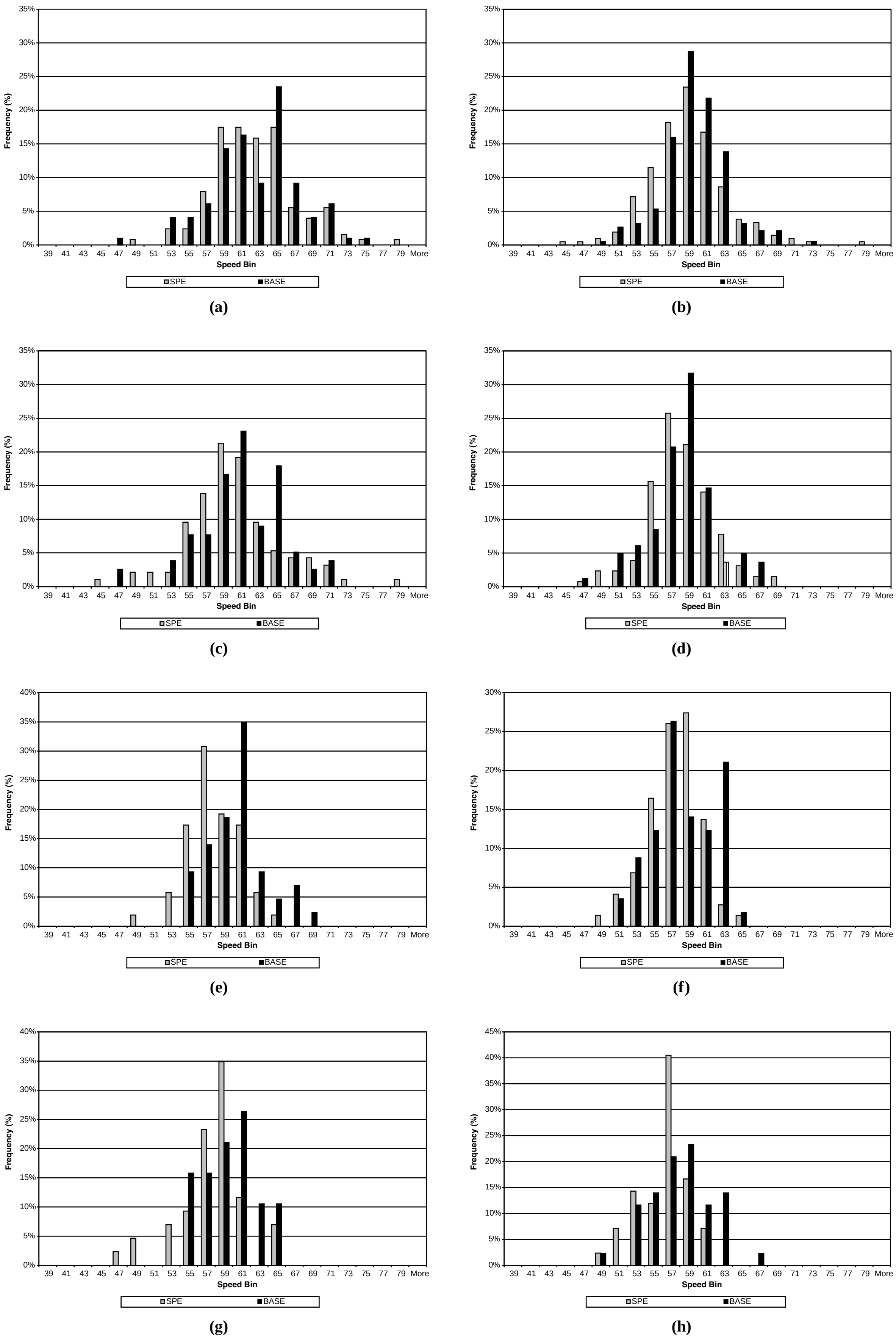

FIGURE 7 Speed distributions at downstream location: (*a*) median lane free-flowing cars, (*b*) shoulder lane free-flowing cars, (*c*) median lane sampled cars, (*d*) shoulder lane sampled cars, (*e*) median lane free-flowing trucks, (*f*) shoulder lane free-flowing trucks, (*g*) median lane sampled trucks, and (*h*) shoulder lane sampled trucks.

greater than 10 mph, while none of the heavy vehicles exceeded the speed limit by more than 5 mph. Therefore, SPE eliminated aggressive driving (speeding more than 10 mph). At the downstream location, the percentage exceeding the speed limit was reduced marginally by 4% to 5% for cars and 7% to 9% for heavy vehicles. The percentage of aggressive (speeding by more than 10 mph) car drivers at the downstream location remained the same as in the base case. However, there were no aggressive drivers of heavy vehicles at the downstream location. As with the speed reductions, it seems that SPE affects speeding behavior of heavy vehicles more than it does cars at the downstream location.

CONCLUSIONS AND RECOMMENDATIONS

Automated SPE via radar reduced mean speed and increased compliance with the speed limit in an Illinois work zone. Near the SPE van, the average speeds of free-flowing passenger cars were reduced by 6.4 mph to 50.6 mph. For the shoulder lane, the average speed of free-flowing vehicles was reduced by 4.2 mph to 47 mph. Similarly, the average speeds of sampled cars were reduced by 5.1 and 4.3 mph for the median and shoulder lanes to 49.8 and 45.5 mph, respectively. The average speeds of free-flowing heavy vehicles were reduced by 3.2 and 4.1 mph for the median and shoulder lanes to 50.3 and 46.1 mph, respectively. The average speeds of sampled heavy vehicles were reduced by 4.4 and 7.3 mph for the median and shoulder lanes to 48.9 and 45.3 mph, respectively. Therefore, near the SPE van, average speeds of cars and heavy vehicles (regardless of lane and whether free-flowing or platooning) were reduced to significantly below the speed limit of 55 mph.

Near SPE, the percentage exceeding the speed limit was reduced from 39.8% to 8.3% for free-flowing cars and from 27.7% to 6.3% for sampled cars. None of the cars exceeded the speed limit by more than 10 mph. Near SPE, the percentage of free-flowing heavy vehicles exceeding the speed limit was reduced from 17.3% to 4.2%; and the percentage of sampled heavy vehicles was reduced from 11.3% to zero. None of the heavy vehicles exceeded the speed limit by more than 5 mph at the SPE location. If exceeding the speed limit by greater than 10 mph is considered excessive speeding, then SPE eliminated excessive speeding.

The spatial effect of SPE (at a location 1.5 mi downstream) was mixed and marginal. Speed reductions on cars were not statistically significant, but speed reductions for heavy vehicles were statistically significant and ranged from 0.9 to 2.5 mph. SPE presence reduced speeding at the downstream location by 4% to 5% among cars and by 7% to 9% among heavy vehicles. None of the heavy vehicles exceeded the speed limit by more than 10 mph at the downstream location. However, the proportion of cars exceeding the speed limit by greater than 10 mph remained about the same. These data indicate some spatial effect on heavy vehicles but practically none on cars.

All the results presented in this paper are from one work zone. The study is ongoing, and more datasets would be added. Further research is recommended to determine the effect of SPE on the capacity and mobility aspects of work zone operation and also how it compares with other enforcement strategies such as police presence.

ACKNOWLEDGMENTS

This study was supported by the Illinois Department of Transportation (DOT). The authors also acknowledge the pictures used in this paper that were donated by Illinois DOT.

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The Work Zone Traffic Control Committee sponsored publication of this paper.