Effect of Radar Transmissions on Traffic Operations at Highway Work Zones

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A series of field studies was conducted at highway work zones where low-output radar transmissions were emitted (by motion detection devices) without the presence of visible law enforcement. Data were collected on vehicle speeds upstream and within the work zones, on speed changes made by vehicles as they approached the work zones, and on vehicle conflicts occurring in the 1,500-ft approach to the work zones. The results indicated that radar signals had only a small effect on average speeds within the work zone and on the change in speeds by motorists as they approached the work zone. However, the radar signals did appear to have a slightly greater effect on vehicles approaching the work zone at speeds greater than 65 mph and on trucks. Such results appear plausible, given the likelihood of greater radar detector use among these types of driver. The vehicle conflict study performed on the approach to the work zones found that severe braking-vehicle conflicts may increase in the presence of radar signals. There was an indication that increases in vehicle conflicts at a given work zone may depend on the amount that the average speed in the work zone (without radar) exceeds the posted work zone speed limit.

Despite impressive improvements in work zone traffic control procedures during the past two decades, work zone safety continues to be a topic of major concern to highway agencies. One of the difficult issues that has not yet been fully resolved is that of speed control within work zones. Although it is generally recommended that work zones be designed so as not to require drivers to reduce their speeds, the unusual and dynamic characteristics of work zones sometimes necessitate slower travel. When the need for reduced speeds is readily perceived by drivers, it is believed that most make appropriate adjustments so as to maintain safe and reasonable travel (*1*). However, if the need for slower speeds is not readily apparent, drivers cannot be expected to reduce their speeds without some active form of speed control.

Research throughout the decade has focused on various techniques available to highway agencies for controlling speeds in work zones (*2–7*). Of those tested, law enforcement has consistently proven to be one of the most effective work zone speed control methods available. Reductions in average speeds of up to 13 mph have been found in some instances (*2*). This result is not surprising; other research has found enforcement to be effective in reducing speeds in special situations such as school zones as well as on normal highway sections (*8*).

Unfortunately, law enforcement in most jurisdictions is a costly speed control method. Perhaps more important, enforcement resources are limited and must be distributed among a number of activities (in addition to traffic control) to preserve public safety. As a result, highway agencies continue to search for methods of work zone speed control that are less costly and easier to implement than law enforcement.

Recently, attention has turned to the possible use of radar transmissions to reduce speeds. Past research indicates that radar has an additional speed-reducing effect when used in conjunction with law enforcement (*8*). More recently, a limited amount of research has been performed evaluating the effect of radar *without* visible enforcement present (*9,10*). These studies, conducted on sections of highway other than work zones, suggest that average speeds can be reduced slightly when radar signals are emitted. These studies also found radar to affect high-speed vehicles more significantly.

Radar transmissions have the potential for reducing speeds at work zones as well. Furthermore, they may also serve as an attention-getting device, increasing the awareness of drivers as they approach the work zone. However, the overall effect that radar signals have on safety at work zones must first be determined. Radar, unlike other forms of work zone speed control (including visible enforcement), does not present a speed-reducing stimulus to each driver approaching a work zone. Rather, only those vehicles using a radar detector will receive any type of signal. Conflicts may develop between vehicles with detectors (that may decelerate suddenly when a radar signal is received) and vehicles without detectors. This study was conducted to evaluate these and other possible effects of radar transmissions at work zones.

STUDY DESCRIPTION

Objectives

The objectives of this study were twofold:

1. Determine the effect of radar signals (without the presence of visible law enforcement) on vehicle speeds approaching and passing through work zones without visible enforcement present.
2. Determine what effects radar signals may have on vehicle maneuvers and interactions between vehicles as they approach the work zone.

These objectives were accomplished through field studies at a total of eight work zone locations in Texas.

Study Approach

Prototype radar transmitters, constructed in a previous study of radar transmissions by the Texas Transportation Institute

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(9), were used during this study. These transmitters consisted of a microwave transmitter and battery installed in a small (2- by 4- by 8-in.) box. In the field, the unit was mounted to a sign, barrel, or railing at the beginning of the work zone. The unit was turned on and off by means of a small switch located on the top of the box. The transmitter itself was a standard motion detector that, when operating, emitted a traffic radar signal approximately 1,500 to 2,000 ft upstream, depending on geometric and environmental conditions.

A radar on–radar off analysis was used at each study site. Data were collected for a 30- to 45-min period without transmitting the radar signal. The transmitter was then turned on, and data were collected for another 30 to 45 min. This cycle was repeated throughout the day. The use of multiple time periods helped negate any effects differences in traffic volumes over the day at a given site may have had on speeds. Data collected while the transmitter was turned on were then compared with data collected with the radar off to determine what effect the presence of a radar signal had on traffic.

Study Site Section

Vehicle speeds in work zones are affected by a multitude of factors. These factors include the typical geometric, traffic, and environmental elements that affect speeds on normal roadway sections (8), as well as the unique and dynamic features of the work zone itself (11). The effectiveness of speed control methods may be influenced by these and other factors as well. Principal factors considered in the study design and site selection included the following:

1. Roadway type (Interstate or multilane highway);
2. Traffic volumes (low, moderate, high);
3. Work zone lane closure present (yes, no); and
4. Work zone speed limit (none, 10 mph below normal, more than 10 mph below normal).

The studies were limited to Interstate or multilane highways to ensure that a suitable vehicle sample size was obtained. Also, radar detector use would be highest on these types of roadway. Because the response to a radar signal at a location would be directly related to the percentage of vehicles with radar detectors, focusing the study on these types of roadways provided an indication of the maximum effects to be expected from radar. Testing over a range of traffic volumes was desired to see if undesirable vehicle conflicts increased at higher volume levels because of the radar signals. It was desirable to examine the influence of work lane closures on the effectiveness of radar transmitters. A lane closure reduces the capacity of the roadway dramatically, whereas a work zone without a lane closure may have little or no effect on capacity. Finally, because the premise of a radar signal is the simulation of the presence of enforcement, the effect of radar is expected to depend on the normal and work zone speed limits posted and whether actual speeds are dramatically higher than the posted limit.

Unfortunately, it was not possible to evaluate the radar transmitter at enough sites to fill a complete factorial design. Likewise, the limited number and location of potential study sites precluded the use of an incomplete factorial design. Therefore, sites were selected and categorized according to the factors given earlier, and the data collection effort was designed to maximize the statistical strength of an individual evaluation.

Table 1 presents a summary of the characteristics of the study sites. Sites 1 and 2, located on a section of four-lane

TABLE 1 SUMMARY OF STUDY SITE CHARACTERISTICS

Site	Road Type	No. of Lanes	Normal Speed Limit, mph	Average Operating Speed, mph	1987 ADT	Approx. vphpl Observed	Type of Work Zone	Work Zone Speed Limit, mph
1	Suburban Divided Highway	2	55	58.5	14,300	200	Detour with Lane Closure	40 (R)
2	Rural Divided Highway	2	55	60.3	12,600	200	Detour with Lane Closure	40 (R)
3	Suburban Interstate	2	55	61.3	22,000	300	Temporary Lane Closure	none posted
4	Suburban Interstate	2	55	59.3	22,000	250	Temporary Lane Closure	none posted
5	Suburban Interstate	2	65	59.2	51,000	650	Work Adjacent to Roadway	55 (R)
6	Suburban Interstate	2	65	57.3	67,000	800	Work Adjacent to Roadway	55 (R)
7	Suburban Interstate	3	55	53.9	163,000	1400	Work Adjacent to Roadway	none posted
8	Suburban Interstate	3	55	56.2	163,000	1250	Work Adjacent to Roadway	none posted

(R) = regulatory speed limits   vphpl = vehicles per hour per lane   mph = miles per hour   ADT = average daily traffic divided highway with low traffic volumes, involved in long-term work zone lane closure (using barrels) and detour onto adjacent frontage roads. A reduced work zone speed limit of 40 mph was posted at these sites. Sites 3 and 4 were located on a section of a suburban four-lane Interstate with moderate traffic volumes. The work zones at these sites involved the temporary closing of one traffic lane (using cones); however, no work zone speed limits reduced below the normal 55-mph speed limit were posted. Sites 5 through 8 were work zones also located on suburban sections of four- and six-lane Interstate highways. No long- or short-term lane closures were present at these sites, however. In addition, Sites 5 and 6 were posted with a speed limit of 55 mph, reduced from the normal 65-mph limit. The speed limits of 55 mph at Sites 7 and 8 were not reduced in the study section.

Data Collection and Reduction

Vehicle Speeds and Speed Changes

Researchers collected two types of data during the studies. Figure 1 shows the basic data collection layout at each study site. Vehicle speeds, measured by traffic radar detuned so as to be undetectable by radar detectors, were collected at three stations upstream and within the work zone. The first station, situated approximately 3,000 ft upstream of the work zone and determined to be beyond the influence of the work zone or the radar signal, was used as a control. The second station was located about 750 to 1,250 ft upstream of the beginning of the work zone. The radar transmitter, always installed at the beginning of the work zone, had a range of approximately 1,500 ft. Therefore, speeds measured at Station 2 represented conditions immediately after those vehicles with radar detectors were first able to receive a signal. Because the quality and capabilities of radar detectors vary from model to model, some variation in the exact location individual drivers first received the signal was likely. The third station was positioned within the work zone immediately beyond the radar transmitter location.

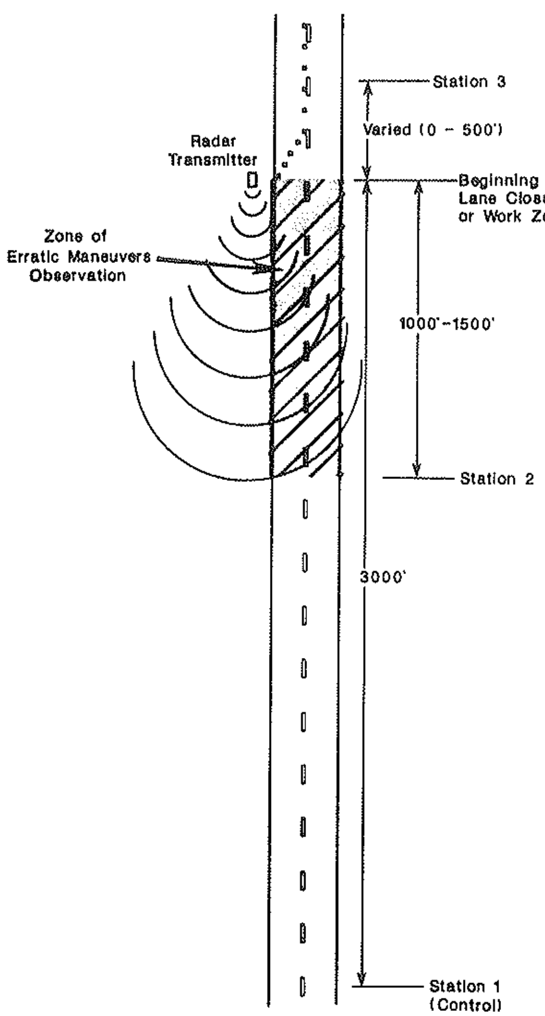

FIGURE 1 Layout of data collection plan.

At each station, data collection personnel recorded the speed of vehicles along with a description of the vehicle on a cassette recorder. This procedure allowed vehicles to be tracked through the study section so that changes in speed from Station 1 to Stations 2 and 3 could be examined. This approach provided a strong statistical design for evaluation.

Over 20,000 speed observations were collected at the eight study sites. Consolidated over all sites, approximately 60 percent of the vehicles recorded at Station 1 were tracked to Station 2, and 49 percent of vehicles at Station 1 were tracked to Station 3. On a site-by-site basis, these percentages were much greater for Sites 1 through 4, where traffic volumes were lower.

Vehicle Conflicts

The second type of data collected at each site was vehicle conflicts occurring within the 1,000- to 1,500-ft approach to the work zone. Traffic volumes were collected simultaneously to develop vehicle conflict rates for comparison purposes. Conflicts occurred in isolation (e.g., a single vehicle braking severely) and also because of vehicle interactions (e.g., vehicles behind a hard-braking vehicle were forced to swerve out of the lane or to also brake severely), and an attempt was made by the observer at each site to document the type of conflicts that occurred. However, the frequency of conflicts was not sufficient to maintain this distinction during analysis. Therefore, vehicle conflicts were categorized into four main types: (a) severe braking, identified by a dramatic nosedive or skidding by the vehicle; (b) abrupt last-second lane-changing; (c) accelerating into the work zone at high speeds to get around one or more vehicles before the lane closure or to exit at a downstream ramp; and (d) other vehicle conflicts (stopping on road, running off the road, etc.).

RESULTS

Effect of Radar on Vehicle Speeds

Table 2 presents a comparison of the average and standard deviation of speeds measured in the work zone (at Station 3) with and without a radar signal transmitted. In general, the effect of radar was fairly consistent, albeit slight. Average

TABLE 2 EFFECT OF RADAR ON SPEED CHARACTERISTICS WITHIN THE WORK ZONE

Site	Average Speed, Mph			Standard Deviation, Mph		
	Radar Off	Radar On	Diff.	Radar Off	Radar On	Diff.
1	[186] 46.3	[203] 45.7	-0.6	6.04	6.91	+0.87
2	[395] 54.7	[543] 53.1	-1.6*	6.56	6.55	-0.01
3	[339] 54.5	[484] 53.7	-0.8*	5.49	5.50	+0.01
4	[295] 56.8	[356] 56.5	-0.3	5.08	5.33	+0.25
5	[726] 55.4	[514] 54.9	-0.5	4.50	5.22	+0.72*
6	[483] 54.1	[493] 53.9	-0.2	4.69	4.49	-0.20
7	[723] 52.7	[409] 52.7	0.0	5.70	5.89	+0.19
8	[184] 53.1	[194] 52.8	-0.3	5.26	4.85	-0.41

Statistically significant (0.05 level of significance)

Numbers in brackets [ ] are the sample size at each site

speeds were slightly lower (0.2 to 1.6 mph) at seven of the eight sites when the radar was transmitting, but the change in average speed was statistically significant at only two sites. Statistical significance was measured by a t-test of the comparison of means (12). Because of the large sample sizes available at each site, however, this test approximated a standard z-test comparison of sample means with known variances.

Meanwhile, the standard deviation of speeds increased slightly at seven sites, although only one of these changes was found to be statistically significant. The changes are reported as differences between the radar off and radar on conditions (to illustrate the absolute magnitude of the changes observed). However, an f-test of the ratio of the variance estimates was used to detect statistical significance. This statistic was compared with a critical f-value with 0.05 level of significance and number of degrees of freedom equal to sample size with radar on and sample size with radar off.

Table 3 presents a comparison of how motorists adjusted their speeds between data collection Stations 1 (control) and 3 (within the work zone) for vehicles that could be tracked through the study site. Such a paired comparison increases the statistical strength of the analysis, providing stronger evidence about the actual effect of the transmitter on vehicle speeds. These changes in speeds between stations were averaged for the radar off and radar on conditions and compared using a paired t-test (12). These data indicate that the effect of radar was somewhat greater than that suggested in Table 2. The average change in speed between the stations was negative, indicating that speeds decreased as vehicles approached the work zone (as would be expected). The difference in the average speed changes, representing the effect of radar, indicated that an additional 0.2- to 4.5-mph reduction occurred when the radar was transmitting. On the basis of this analysis, the difference in speed changes was statistically significant at four of the eight sites.

The speed changes made by drivers as they approached the work zone appeared to be slightly more variable when the radar was in operation. The standard deviation of the changes in speed between Stations 1 and 3 increased slightly at every site. This increased variability might have been caused by those drivers with radar detectors slowing their vehicles much more dramatically than drivers without detectors. Unfortunately, this hypothesis could not be proven in this study. An f-test of the estimates of sample variances was again used to test the statistical significance of the changes between the radar on and radar off conditions.

The analysis of speeds taken 1,000 to 1,500 ft from the work zone (Station 2) did not exhibit as consistent trends as were evident at Station 3. Apparently, motorists with radar detectors had just received the radar signal and had not yet adjusted

TABLE 3 EFFECT OF RADAR ON CHANGES IN SPEED BETWEEN STATIONS 1 AND 3

Site	Average Change in Speed Between Stations, Mph			Standard Deviation of Speed Changes Between Stations, Mph		
	Radar Off	Radar On	Diff.	Radar Off	Radar On	Diff.
1	[186] -12.1	[203] -12.5	-0.4	6.82	7.83	+1.01
2	[395] -3.9	[541] -5.4	-1.5*	6.03	6.64	+0.61
3	[279] -5.4	[424] -6.0	-0.6	6.00	6.50	+0.50
4	[294] -4.5	[355] -5.3	-0.8*	6.21	7.01	+0.80*
5	[461] -2.9	[160] -3.1	-0.2	4.72	4.80	+0.08
6	[341] -3.0	[351] -3.6	-0.6	4.72	4.88	+0.16
7	[162] -1.1	[79] -2.8	-1.7*	5.80	6.30	+0.50
8	[7] -0.4	[23] -4.9	-4.5*	2.37	4.39	+2.02

Statistically Significant (0.05 level of significance)

Numbers in brackets [ ] are the sample size at each site

their speeds. As a result, no clear trends were evident, and so data from that station are not presented here. This information can be found in the study documentation (*13*).

It is generally recognized that the primary use of radar detectors is to avoid ticketing by law enforcement for exceeding the posted speed limit (*9*). Therefore, radar detectors could be assumed to be in more prevalent use on vehicles traveling at higher speeds. Also, the effect of the transmitter on these high-speed vehicles would be expected to be more pronounced. Figure 2 shows a comparison of speed changes between Stations 1 and 3 that supports this hypothesis. The effect of radar on average speed changes between Stations 1 and 3 is shown for the entire speed sample taken at each site and for the portion of the sample that exceeded 65 mph at Station 1 (the control station). As the figure shows, radar generally had a larger speed-reducing effect on those vehicles that were initially exceeding 65 mph as compared to the sample as a whole. At Sites 1 through 4, the effect of radar was from 1 to 3 mph greater for the portion of traffic exceeding 65 mph than it was for the entire sample size overall.

The influence on high-speed vehicles is less pronounced at the other sites, although a small difference is still evident. Because of congestion and data collection problems, no vehicles at Site 8 were observed to have exceeded 65 mph at

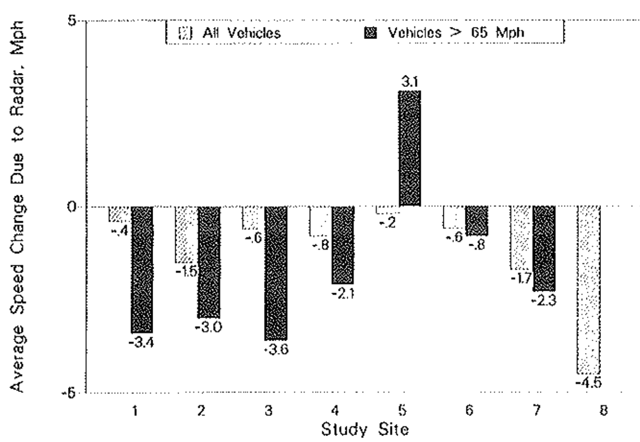

FIGURE 2 Comparison of radar effect on all vehicles and vehicles exceeding 65 mph.

Station 1. Also, the data from Site 5 suggest that radar had less effect on high-speed vehicles than on the entire vehicle population. Sporadic police presence was noted by the data collection personnel throughout the day at this site, which may explain these inconsistent findings. Also, the results at

Site 5 may have been caused by some other extraneous factor not accounted for in the analysis.

Pigman et al. (*10*) found that radar detector use is generally greater among trucks than among automobiles. Consequently, the effect of radar would also be expected to have a more pronounced effect on trucks than on automobiles. Figure 3 shows the difference between automobiles and trucks in terms of the effect of the transmitter on the changes in speed between Stations 1 and 3. Generally, the transmitter had a more pronounced effect on trucks than on automobiles, although this result was not the case at Sites 1 and 5. Again, site-specific factors unaccounted for in the analysis likely were the cause of the differing results at these locations.

Effect of Radar on Vehicle Conflicts

Vehicles conflicts were recorded manually at each site during each study. Traffic volumes were recorded simultaneously so that conflict rates could be computed for comparison purposes (with and without the transmitter in operation). As stated previously, vehicle conflicts were categorized into three main types:

1. Severe braking (evidenced by a dramatic nosedive by a vehicle or by vehicle skidding),
2. Last-second or abrupt lane-changing, and
3. Accelerations into work zone (to pass a vehicle before reaching the lane closure or exit ramp).

A final category was simply labeled "other" to include any other maneuvers considered by data collection personnel to have resulted in conflict.

Results of the conflict analysis are presented in Tables 4 and 5. The category of other was used so infrequently that it was not included in this analysis (only three maneuvers total from all eight sites). A Poisson analysis was used to determine if the changes observed were statistically significant (*14*). Analyses were performed for each type of conflict at each site, for all three types of conflicts combined at each site, and for each type of conflict for all sites combined.

Vehicle conflict rates varied significantly from site to site, presumably because of the differences in volumes, work zone activity and traffic control, roadway geometrics, etc. At seven of the eight sites, severe braking conflict rates were higher when the radar was transmitting. The increases were statistically significant at two sites. Although an attempt was made to determine whether these maneuvers occurred in isolation or because of another vehicle, the small sample sizes at some of the sites and extremely high volumes at the other sites made this impossible to accomplish.

Conversely, last-second lane changes and vehicle accelerations into the work zone did not appear to be significantly affected by the radar transmissions. None of these changes was found to be statistically significant on a site-by-site basis.

For summary purposes, Tables 4 and 5 also present vehicle conflict rates averaged over all sites. Severe braking maneuvers increased from 21.7 to 26.6 conflicts per 1,000 vehicles, a statistically significant increase of 22.6 percent. Overall, last-second lane changing and accelerations into the work zone decreased slightly when the radar was transmitting (4.6 and 5.3 percent, respectively), but neither change was statistically significant. Consolidating all types of vehicle conflicts observed at all sites, the conflict rate increased by 7.9 percent, increasing from 47.1 conflicts per 1,000 vehicles without radar to 50.8 conflicts per 1,000 vehicles with the radar transmitting. The increase in total conflicts was also not found to be statistically significant.

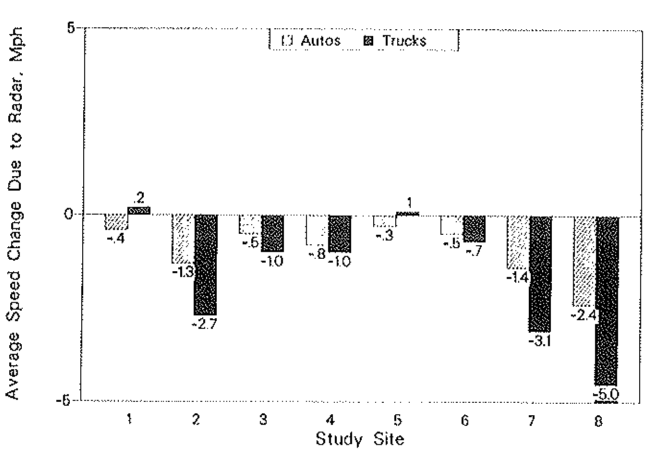

FIGURE 3 Comparison of radar effect on automobiles and trucks.

Discussion

The results just described indicate that a radar signal has some effect on speeds at work zones. However, these effects are small, generally less than 2 to 3 mph. Because of these small changes, there is no way of discerning, either statistically or through engineering judgment, how the site specific factors (traffic volume, work zone type, work zone speed limit) considered in this study influence the effectiveness of radar transmissions at work zones.

Overall, the small reductions in average speeds found in this study are consistent with those obtained in other studies of unmanned radar (at nonwork zone locations). In most situations, radar will not reduce overall speeds in a dramatic way. Radar does affect the behavior of drivers using radar detectors who are exceeding the posted speed limit by large amounts.

Interestingly, the results of this study are not consistent with those of other studies with respect to the effect of radar on speed variability. Although the past studies found speed variance lower when radar was transmitting, this study suggests that the variability of speeds at locations within the work zone may actually increase in some cases. The results of the comparison of speed changes between stations suggest that the variability of these speed changes increases when radar is present. Presumably, this increased variability is caused by drivers with detectors who decelerate dramatically on receiving a signal from their detector. Evidence collected during this study suggests that these drivers tend to be the high-speed motorists, and the transmitter appears to have a more pronounced speed-reducing effect on them.

The vehicle conflict data indicate that the presence of a radar signal increases the frequency of severe braking maneuvers. This increase is expected to be related to the work zone speed limit posted and the actual driving speeds at the

TABLE 4 VEHICLE CONFLICT DATA (RATE PER 1,000 veh)

Site	Severe Braking		Last-Second Lane-Changing		Accelerating into Work Zone		Total	
	Radar Off	Radar On	Radar Off	Radar On	Radar Off	Radar On	Radar Off	Radar On
1	[7] 11.9	[9] 18.3	[2] 3.4	[7] 14.2	[9] 15.3	[7] 14.3	[18] 30.6	[23] 46.8
2	[16] 27.8	[26] 47.8	[4] 6.9	[11] 20.2	[5] 8.7	[2] 3.7	[25] 43.4	[39] 71.7
3	[2] 2.5	[3] 4.9	[16] 20.3	[14] 22.9	[14] 17.8	[11] 14.9	[32] 40.6	[28] 42.7
4	[18] 29.9	[30] 40.6	[1] 1.6	[3] 4.1	[4] 6.6	[4] 5.4	[23] 38.1	[37] 50.1
5	[11] 4.6	[5] 2.7	[23] 9.5	[16] 8.5	[9] 3.7	[13] 6.9	[43] 17.8	[34] 18.1
6	[16] 8.5	[36] 12.1	[13] 6.9	[27] 9.1	[1] 0.5	[5] 1.7	[30] 15.9	[68] 22.9
7	[45] 15.5	[78] 18.7	[45] 15.5	[51] 12.2	[0] 0.0	[0] 0.0	[90] 31.0	[129] 30.9
8	[207] 40.2	[238] 51.6	[196] 48.1	[181] 49.3	[0] 0.0	[2] 0.4	[403] 88.3	[421] 101.3
Total	21.7	26.6	21.6	20.6	3.8	3.6	47.1	50.8

* Statistically significant (0.05 level of significance)

Numbers in brackets [ ] are the sample size at each site

work zone. Specifically, work zone sites at which drivers normally travel much faster than the posted work zone speed limit would be expected to have higher vehicle conflict rates in the presence of radar, as drivers with detectors try to slow down quickly to comply with the posted limit, and any vehicles following are forced to respond in a similar fashion.

To examine this hypothesis, the relationship between the percentage increase in total vehicle conflicts at each site was plotted against the difference in the average speed in the work zone (without radar) and the posted speed limit in the work zone. This relationship is shown in Figure 4. Clearly, a trend towards larger increases in conflicts exists at sites where average speeds are much higher than the speed limit posted in the work zone. Although the actual relationship between accidents and vehicle conflicts at work zones is not known, these data suggest a potential safety problem with the use of radar at sites where the posted speed limit is considerably lower than the normal speed of traffic.

CONCLUSIONS

This study examined the effect of radar transmissions (without visible enforcement) on vehicle speeds and vehicle conflicts at eight work zone locations on multilane roadways in Texas. The work zones varied with respect to the amount of traffic present, type of work zone (with or without a lane closure), and the reduction in normal speed limits through the work zone. Overall, the effect on speeds was small, as average speeds at the study sites were generally reduced by less than 2 mph. From the analysis of the changes in speeds between data collection stations as vehicles approach the work zone, there may be, in some cases, a greater effect of radar on trucks (in comparison with automobiles) and on high-speed vehicles (in comparison with the entire vehicle sample). Such results correlate well with expectations that radar detector use may be more prevalent among trucks and among high-speed vehicles.

TABLE 5 EFFECT OF RADAR ON VEHICLE CONFLICTS (RATE PER 1,000 veh)

Site	Change in Severe Braking Conflicts	Change in Last-Second Lane-Changing Conflicts	Change in Accelerating into Work Zone Conflicts	Change in Total Conflicts
1	+6.4 (+53.8%)	+10.8 (+317.7%)	-1.0 (-6.5%)	+16.2 (+52.9%)
2	+20.0* (+71.9%)	+13.3 (+192.8%)	-5.0 (-57.5%)	+28.3* (+65.2%)
3	+2.4 (+96.0%)	+2.6 (+12.8%)	-2.9 (-16.3%)	+2.1 (+5.2%)
4	+11.7 (+39.1%)	+2.5 (+156.3%)	-1.2 -(18.2%)	+12.0 +(31.5%)
5	-1.9 (-41.3%)	-1.0 (-10.5%)	+3.2 (+86.5%)	+0.3 (+1.7%)
6	+3.6 (+42.4%)	+2.2 (+31.9%)	+1.2 (+240.0%)	+7.0* (+44.0%)
7	+3.2 (+20.7%)	-3.3 (-21.3%)	0.0 (---)	-0.1 (-0.3%)
8	+11.4* (+28.4%)	+1.2 (+2.5%)	+0.4 (---)	+13.0 (+14.7%)
Total	+4.9* (+22.6%)	-1.0 (-4.6%)	-0.2 (-5.3%)	+3.7 (+7.9%)

* Statistically significant (0.05 level of significance)

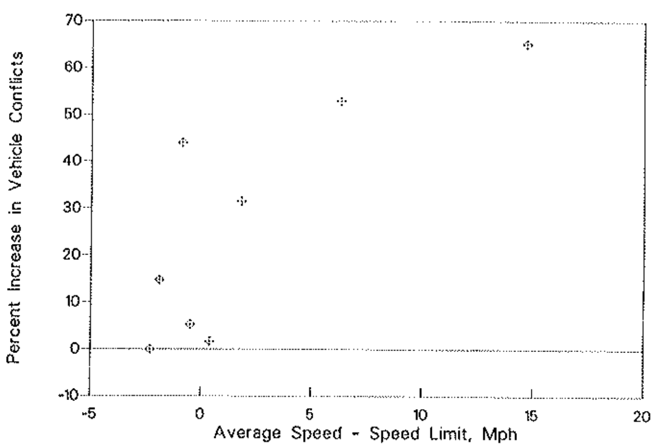

FIGURE 4 Change in vehicle conflicts versus difference in average speed and posted speed limit.

Severely braking vehicle conflicts increased significantly at two of the eight sites when radar was operating in comparison to when radar was not in operation. Increases (although not statistically significant) were also observed at the other six sites. The increases were larger for the four sites where lane closures were present and were the highest at the two sites where average speeds were normally much higher than the posted limit. Overall, it appears that the use of radar may result in additional conflicts on the approach to the work zones, particularly if the posted speed limit is considerably lower than that at which drivers wish to travel.

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