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Final Report

WORK ZONE SPEED CONTROL

William (Skip) Outcalt

January 2009

COLORADO DEPARTMENT OF TRANSPORTATION
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16. Abstract
Traffic in the lanes next to work zones presents a continuous hazard to workers. By reducing the speed of the traffic through the work zone, the hazard can be mitigated somewhat. Accurate data on the effectiveness of the simultaneous use of radar detection devices and law enforcement support in work zones would be valuable information for equipment purchasing and budgeting purposes. A literature search found 17 studies relating to work zone speed control and investigating the use of variable message signs (VMS), presence of law enforcement, and various signing methods. However, none provided current documentation of the effectiveness of the use of a VMS in conjunction with the presence of a law enforcement officer who was ticketing violators.

The study found that the most dependable method of ensuring compliance with posted work zone speed limits is through the presence of law enforcement in the work zone, citing speeders.

Implementation:
This research provides CDOT with methods for effective management traffic speed in the vicinity of work zones. It will result in more reliable control of traffic speeds near work zones, improving safety for both the workers and the traveling public. Safety and Traffic engineers and Maintenance planners can use it to plan effective traffic control in work areas.

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EXECUTIVE SUMMARY

Traffic in the lanes next to work zones presents a continuous hazard to workers. By reducing the speed of the traffic through the work zone, the hazard can be mitigated somewhat. Accurate data on the effectiveness of the simultaneous use of radar detection devices and law enforcement support in work zones would be valuable information for equipment purchasing and budgeting purposes. A literature search found 17 studies relating to work zone speed control and investigating the use of variable message signs (VMS), presence of law enforcement, and various signing methods. However, none provided current documentation of the effectiveness of the use of a VMS in conjunction with the presence of a law enforcement officer who was ticketing violators.

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This research provides CDOT with methods for effective management traffic speed in the vicinity of work zones. It will result in more reliable control of traffic speeds near work zones, improving safety for both the workers and the traveling public. Safety and Traffic engineers and Maintenance planners can use it to plan effective traffic control in work areas.

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BACKGROUND

Every year crashes in and near highway work zones (WZ) cause property damage, injuries, and deaths, not only of workers, but also of drivers passing through the WZs. An article on the National Institute of Occupational Safety and Health (NIOSH) website, dated February of 2008, discusses WZ fatalities in 23 states from 1984 through 2007. Out of the 86 WZ fatalities, 23 (27%) were caused by non-construction traffic either entering the WZ or striking a worker outside the WZ – traffic control flaggers or workers crossing traffic going to and from the WZ, for example. (1)

For several reasons the speed of traffic adjacent to a WZ is of great concern. The faster a vehicle is traveling, the less time the driver has to react, and the less time workers have to get out of the way if the vehicle's driver looses control. A faster moving vehicle is also more likely to penetrate a barrier and to penetrate farther, threatening more workers.

Experience has shown that the use of signs to reduce the speed of traffic through WZs has varying degrees of effectiveness. It can depend on the normal posted speed limit and on the geometry and sight distance of the highway. The effectiveness of speed reduction signs sometimes varies considerably for no apparent reason other than the geographic location of the WZ; drivers in some locations seem always to be in a hurry. Speed reduction signs posted for long WZs that have no evidence of any activity are not only ineffective, they can make drivers skeptical of the validity of signs posted at other WZs.

The Colorado DOT wanted to know how effective various WZ speed limit control scenarios would be on Colorado highways. Other agencies have tried things like the use of RADAR variable message signs (RVMS) and having law enforcement officers at different locations through a WZ. A Transportation Research Information Services (TRIS) search found several reports investigating methods for reducing the speed of traffic through highway WZs. Many of them found that the greatest reduction in speeding came when some form of law enforcement was present in the WZ. The condensed results of the TRIS search are in **Appendix C**.

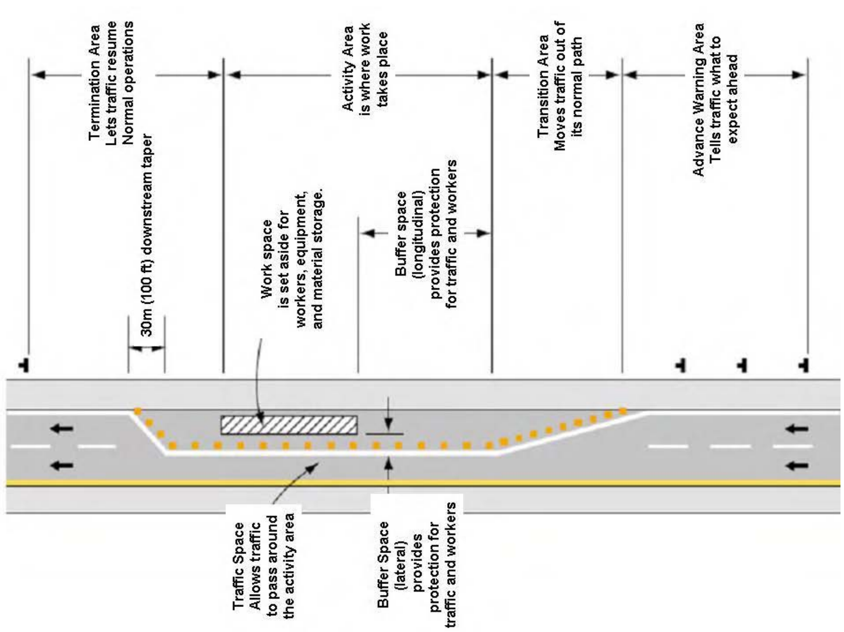

Figure 1. Component Parts of a temporary traffic control zone - MUTCD.

CDOT wanted to see to what degree those findings applied to Colorado highways so Maintenance Section 3 set up a WZ in western Colorado on I-70 near Gypsum. The site was chosen so nothing would influence the speed of traffic other than the posted WZ speed limit signs. It was on a divided four-lane highway with good sight distance both in the WZ and upstream where the warning signs began. The normal posted speed limit at the site was 75 mph.

The speed limit through the WZ was reduced from 75 mph using standard sign and cone placement as described in the 2003 MUTCD (Manual of Uniform Traffic Control Devices) section 6c.04. See **Figure 1.** above.

Thirteen different speed control scenarios were designed to evaluate various methods of slowing traffic through the WZ. For each of the first six scenarios the WZ speed limit was reduced to 55 mph. The basic MUTCD WZ signs were maintained but with varying additions consisting of various combinations of RVMS and the presence of law enforcement vehicles and officers at different locations in the WZ. The remaining seven scenarios used no law enforcement or RVMS. Changes in the WZ signs were made to establish speed limits of 70, 65, 60, 55, 50, and 45 mph.

For safety reasons a "dummy" WZ with no one actually working was used for the study. Maintenance and Research personnel felt that the changing nature of the traffic control might have unforeseen effects on the behavior of the traffic passing through the WZ. Also, people working in the zone would have no way to know which of the various planned control restrictions had been set. Although no work was being done, work trucks were parked in the WZ to give the appearance of activity. The WZ closed the right hand (#2) lane, eastbound. Standard 36 inch, orange, reflectorized traffic cones were used to delineate the closure.

DATA COLLECTION

To measure the speed of traffic through the WZ, a video camera was set up as unobtrusively as possible in the median, which was about 80 feet wide at this location. The use of video tape,

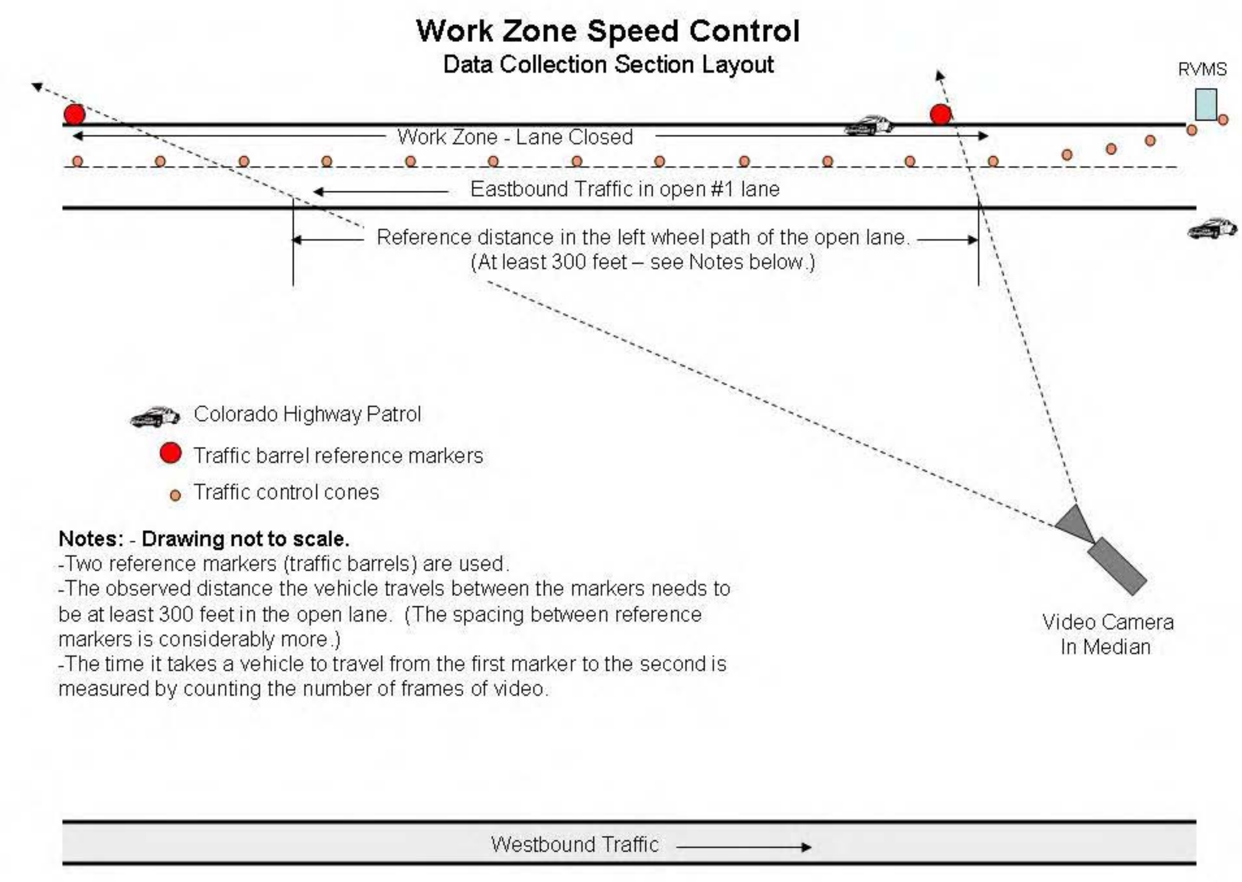

Figure 2. Video reference section layout.

rather than radar or laser speed guns, served two purposes: 1. Drivers with radar detectors were not alerted to slow down because they sensed RADAR, giving unreliable data. 2. The video tape would be available for review at any time to answer any questions about the data.

Calculations, using the camera's 30-frames-per-second frame rate, showed that accurate speed measurements required recording traffic for about 300 feet. To establish a reference area, two large traffic barrels that could be seen easily on the video tape were positioned on the outside edge of the right shoulder as shown in **Figure 2.** Their position was estimated so a vehicle would travel at least 300 feet after the point where it passed between the first barrel and the camera to the point where it passed between the second barrel and the camera. Marks were made in the left wheel path of the open lane along the sight line from the camera to each of the reference barrels. Finally, the distance between the marks was measured to establish the reference distance (which turned out to be 393 feet) to be used to calculate vehicle speed through the WZ.

Research personnel spent two days at the site collecting video tape of the traffic as it passed through the WZ. One hour of tape was recorded for each of the 13 speed control scenarios described below using a Sony camera. The Sony "Hi 8" video camera recorded at the rate of 30 frames per second and time-stamped each frame with the hour, minute, second and a frame number from 1 to 30. By counting the video frames between the time when a vehicle passed in front of the first barrel and the time when it passed in front of the second, vehicle speed was calculated.

For all of the 13 scenarios the traffic control signs consisted of the normal set of signs a driver would encounter at the beginning of a WZ. Their size, number, color, spacing and order were all according to the MUTCD recommended interstate setup. The intention was to have no unusual signs that might affect the drivers' actions in the WZ.

On the first day six hour-long scenarios were videotaped. For the first five hours, the speed limit was posted at 55 mph and the signs were not changed – the various additions described below were made.

- Hour one – the lane closure was coned off with a standard MUTCD lane closure with a posted speed limit of 55 mph using signs and an arrow board at the beginning of the cones.
- Hour two – added an RVMS that remained blank unless the approaching vehicle was going faster than 55 mph. If the vehicle was traveling more than 55 mph, the sign displayed the message "YOUR SPEED IS XX MPH."
- Hour three – the RVMS was removed, and a Colorado Highway Patrol (CHP) car was added on the right shoulder in the transition area (see **Figure 1**.) with its overhead lights on and a trooper in the car. The trooper was not operating a RADAR gun.
- Hour four – added a second CHP car and trooper parked in the median opposite the beginning of the transition area (see **Figure 1**.). Both troopers remained inside their cars and neither had RADAR operating.
- Hour five – moved both CHP cars to the right shoulder inside the cones near the beginning of the buffer space (see **Figure 1**.). The cars had their overhead lights on and the troopers were outside the cars operating a RADAR gun, stopping speeders, and writing tickets. Several drivers were ticketed during the hour.
- Hour six –both CHP cars were removed. The lane closure was unchanged. In the signs before the WZ, the speed limit was changed from 55 mph to 70 mph. This scenario was intended to serve as a data check to see if traffic resumed the higher speed when the signs were changed.

On the second day seven hours of video tape were recorded with only the normal MUTCD signs to restrict traffic speed. There was no law enforcement, RADAR, or RVMS. For the first hour, the speed limit through the WZ was set to 70 mph and the traffic videotaped. Then for one hour each, by changing the speed limit signs, the WZ speed limit was further reduced to 65 mph, to 60 mph, to 55 mph, to 50 mph, to 45 mph, and finally raised back to 65 mph. Extra sets of signs were added for the 50 mph and 45 mph scenarios to avoid a sudden 25 - 30 mph drop in the speed limit. The camera and reference point locations were the same as those used the previous day.

ANALYSIS

A special tape player was used to analyze the 13 hours of video tape. It had the capability of stopping the tape and advancing or rewinding one frame at a time to enable the operator to establish precisely when a vehicle entered and left the reference section. It also showed the time and frame stamp the camera put on each frame. During the tape analysis, the operator recorded the time and frame number when the front of a vehicle first blocked the view of the first reference barrel and the time and frame number when it first blocked the second barrel. From the number of frames that a vehicle took to travel 393 feet from the first reference point to the second, the vehicle speed was calculated. (At 55 mph a vehicle traveled slightly less than 2.7 feet per frame.)

For the purposes of this study, a vehicle's speed was considered valid only if it was not affected by any outside influence. When two vehicles, traveling closely one behind another, entered the

Figure 3. The white car is not counted.

Figure 4. The white car to the left cleared the reference area before the pickup entered. The pickup is counted.

reference section, the speed of the second was assumed to influenced by the one in front so only the front vehicle was counted. A vehicle was counted only if it was more than the length of the reference distance behind other traffic. In other words, a vehicle was counted only if the reference area was empty as it passed the first reference point. In **Figure 3** the white sedan will enter the reference zone before the pickup leaves it; it is assumed for data analysis purposes that the speed of the white sedan is being limited by the gray pickup it is following. The pickup is counted, the sedan is not. In **Figure 4** the white vehicle leaving the picture to the far left cleared the ending reference point before the pickup truck got to the beginning reference point, so the pickup counted.

To convert the video tapes to speed data, the analyst entered the time stamp and frame numbers into Excel spreadsheets which recorded the information and performed calculations to evaluate the data statistically. A small part of the data from the spreadsheet for the arrow board scenario can be seen in **Table 1**. Information in the yellow cells was entered by the analyst; the numbers in the Frame # columns and last three columns on the right were calculated by the spreadsheet from data in the yellow cells on the same row.

Table 1. Data analysis spreadsheet.

		Upstream Reference Point					Downstream Reference Point						SPEED	
#	Veh. Descript	Hr	Min	Sec	Frame	Frame #	Hr	Min	Sec	Frame	Frame #	Delta Frames	Feet/ Frame	MPH
1	SEMI		1	4	21	1941		1	9	20	2090	149	2.637	**54**
2	SEDAN		1	16	16	2296		1	22	17	2477	181	2.171	**44**
3	PU		1	38	17	2957		1	45	1	3151	194	2.025	**41**
4	SUVTRL		1	51	20	3350		1	57	21	3531	181	2.171	**44**

- The first column is a numerical count of the vehicles that entered an empty reference section. Vehicles following too closely are not listed in this count. Thus, vehicle #2, a sedan, may have been the fifth vehicle to enter the section if there were four vehicles in a tight group following the #1 vehicle; the semi.
- **Vehicle description** – is a brief identifier to facilitate locating a particular vehicle on the tape for any reason.
- **Upstream Reference Point: Hour, Minute, Second**, and **Frame** – are the time-stamp information recorded on the frame as the vehicle passed the first reference point.
- **Frame #** – is the absolute frame number on the tape calculated from the upstream hour, minute, second, and frame columns.
- **Downstream Reference Point: Hour, Minute, Second**, and **Frame** – are the time-stamp information recorded on the frame as the vehicle passed the second reference point.
- **Frame #** – is the absolute frame number on the tape calculated from the downstream hour, minute, second, and frame columns.
- **Delta Frames** – is the number of frames it took the vehicle to travel between the references.
- **Speed, (ft/frame)** – is the distance, in feet, the vehicle traveled in each frame, calculated from the Delta Frames column and the measured reference distance (spreadsheet cell J2).
- **Speed MPH** – is the vehicle's speed calculated from the delta frames and ft/frames columns. Frame counts accurate to within 1.5 frames for the transition of the test area yield speeds accurate to ± 1 mph at 75 mph – 3.9 frames at 45 mph.

Each scenario was put in a separate spreadsheet, then, in addition to the recorded data and speed calculations listed above, Excel was used to generate "Rank and percentile" statistical calculations for the data. In the spreadsheets this information is recorded in four columns to the right of the entered data; however, there is no connection between the rank percentile information and the data that appears on the same row in the spreadsheet. **Table 2**, below, shows an example of the Rank and Percentile columns in a spreadsheet. In the Rank and Percentile columns information about the vehicles is listed from the fastest vehicle to the slowest. The information in the columns is as follows:

- o **Vehicle** – is the numerical count of the vehicle from the first data column of **Table 1** – the top line in **Table 2** was the fastest vehicle on this particular spreadsheet. It was the 90th vehicle observed for this scenario.
- o **MPH** – is the speed of the vehicle – the fastest vehicle in the table was 65 mph.

- **Rank** – is the ranking of the vehicle by speed. The fastest vehicle ranks 1. Vehicles 2 and 3 were traveling 61 mph; they both get ranked 2. The next vehicle down the list was doing 60 mph. It is 4th in the table so all vehicles going 60 mph are ranked 4.
- **Percent** – is the percentile ranking of the vehicle based on its speed: 100% means this is the fastest vehicle; 98.7% (ranking 2) means these vehicles are traveling as fast as or faster than 98.7% of the vehicles observed for this scenario.

Table 2. Rank and percentile statistics.

Vehicle #	MPH	Speed Rank	Faster than Percent
90	65	1	100.00%
53	61	2	98.70%
89	61	2	98.70%
113	60	4	96.90%

Table 3 shows the results of the statistical analysis of the video tape for the first day of testing – the six scenarios at 55 mph. A complete list of statistical analysis results for all 13 scenarios is in **Appendix B.**

Table 3. Statistical analysis for scenarios 1-6.

	MUTCD Signs + Arrow Bd	+RADAR VMS	CHP Car with OH Lights on	2 CHP Cars with no lights	2 CHP Cars writing Tickets	Speed limit 70 mph
WZ Speed limit posted	55	55	55	55	55	70
85th percentile speed	56	57	56	55	54	69
Mean (mph)	49.96	50.93	49.98	49.12	47.21	61.49
Range (mph)	29	30	26	43	27	37
Minimum (mph)	36	38	37	24	32	43
Maximum (mph)	65	68	63	67	59	80
Count (vehicles)	163	155	131	148	164	220
> 5 mph over	1.8%	3.2%	1.5%	1.4%	0%	0.9%

From a traffic control viewpoint, the fact that the 85th percentile speeds for all of the speed control scenarios were within 2 mph of the 55 mph posted speed through the WZ could be interpreted to mean all of the scenarios were successful. As **Table 3** shows, very few vehicles were traveling more than 5 mph over the posted speed limit.

During the fifth scenario, with two CHP troopers writing tickets immediately upstream of the reference section, there were no speeders more than 5 mph over 55, even though this scenario had the second highest vehicle count. It must be assumed, since the troopers wrote several tickets, that they stopped every vehicle going more than 5 mph over the speed limit. Since the speeders were stopped just before they entered the videotaping section of the WZ and were accelerating to highway speeds as they passed through the taping section, it is possible that they accounted for some of the slower speeds recorded. However, there was no way to determine which vehicles on the video tapes were the ones that had been stopped by the troopers.

To compare the results of using a RVMS or law enforcement to the results achieved with only standard sign setups, a second day of taping was done at the same site. Everything about the WZ lane closure was the same as the first day except there were no law enforcement officers and no RVMS board was used. The closure was set up in the same location and the same reference points were used. Traffic was recorded for an hour at each of seven speeds: 70 mph, 65 mph, 60 mph, 55 mph 50 mph, 45, mph, and 65 mph. The statistical breakdown of that data is in **Table 4**, below.

Table 4. Statistical analysis for scenarios 7-13.

	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12	Scenario 13
WZ Speed limit posted	70	65	65	60	55	50	45
Count (vehicles)	178	156	173	193	180	168	116
Mean (mph)	62.02	58.72	59.25	56.09	53.11	51.67	48.22
85th percentile speed (mph)	70	67	67	64	60	58	55
Maximum (mph)	79	80	72	79	73	69	73
Minimum (mph)	43	37	27	42	38	33	28
Range (max-min)	36	43	45	37	35	36	45
> 5 mph over	1.1%	3.8%	1.7%	5.7%	8.3%	19.6%	30.2%

Table 4 shows the data from the vehicles observed on the second day. These six scenarios involved six posted speed limits. Not surprisingly, lower percentages of vehicles were speeding on the first day when the RADAR VMS and law enforcement were present. This is consistent with results obtained by other studies.

The percentages that were exceeding the posted limit by more than 5 mph are listed in the bottom row. It is generally assumed that law enforcement officers ignore speeders until they exceed the speed limit by more than 5 mph. The “> 5 mph over” row shows the percentages of vehicles whose speeds would most probably be influenced by the presence of law enforcement.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Maintenance personnel throughout the state expressed the opinion that, "The greater the speed limit reduction is through the WZ, the more likely drivers are to exceed the speed limit in the WZ." That observation is supported by the data in **Table 4.** On the second day, with no law enforcement present, the percentage of speeders increased as the speed limit was lowered until, at 45 mph, nearly one in three drivers was exceeding the posted limit.

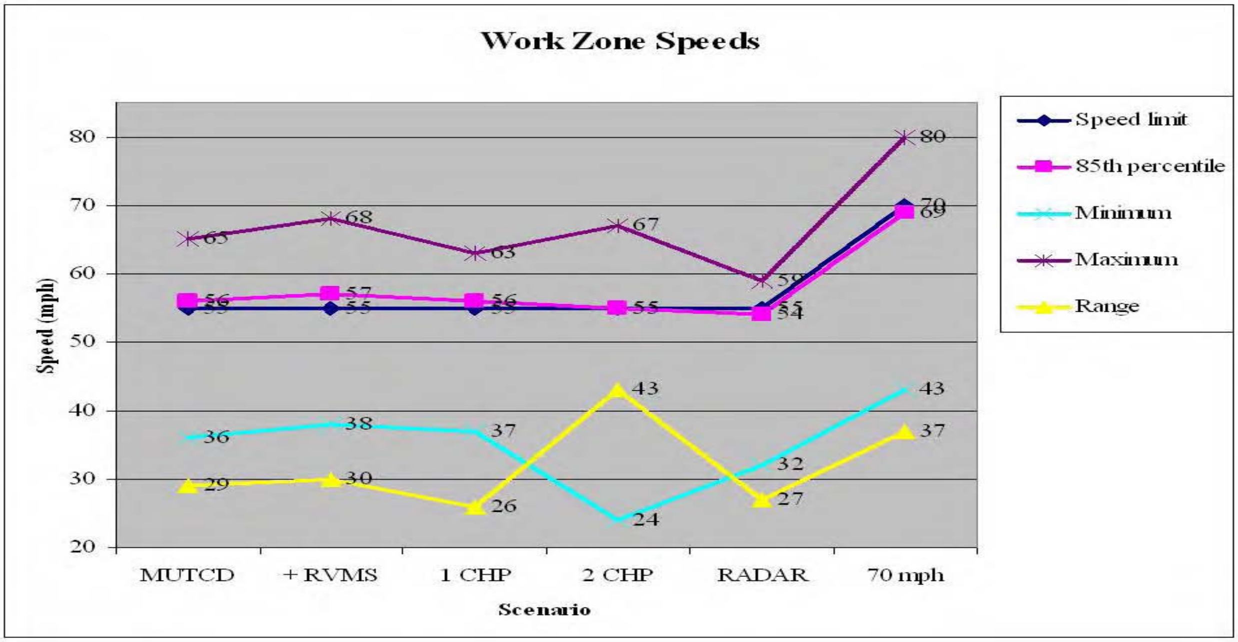

Figure 5. WZ Speeds with various additions to the sign setup.

Figure 5, above, graphically compares the six scenarios on the first day of observation - the WZ posted speeds (55 mph in all but #7), the 85th percentile speed, the maximum and minimum speeds, and the range between the maximum and minimum speeds measured for each scenario. The average vehicle speed for all six of the first-day scenarios was near the posted speed, but the difference between the highest and lowest speeds measured for each one was at least 26 mph and as much as 45 mph.

Normal CDOT practice limits a WZ speed reduction to 20 mph below the posted normal speed for a given section of highway. This can be changed in extreme cases, but the dangers caused by the wider disparity in the speeds of the vehicles may offset any benefits to having slower traffic in the WZ.

The purpose of this study was to compare the effectiveness of various methods used to slow traffic traveling through WZs to improve safety for both workers and drivers. With speed reductions from the highway normal 75 mph down to 65 mph, 85 percent of drivers comply with the lower limit (within 2 mph). This can be considered a successful speed limit that drivers respect – fewer than about 1 in 25 exceed the limit by more than 5 mph. When the reduction is 15 mph or more, however, the number of drivers who exceed the posted limit increases sharply from slightly less than 1 in 17 at a 15 mph reduction to nearly 1 in 3 at a 30 mph reduction.

Based on the data used here, for a speed reduction of 10 mph or less the use of signs can be expected to slow about 85 percent of traffic to the WZ posted speed. For situations requiring speed reductions of 15 mph or more the use of additional signs in the form of RADAR variable message signs and the addition of law enforcement vehicles and officers may be justified.

Speed reductions of more than 20 mph will probably require the presence of law enforcement and may necessitate the use of pilot vehicles to force traffic to slow to the posted speed. Speed reductions of more than 20 mph are very seldom used by CDOT. However, when this great a reduction is called for, compliance will almost certainly be critical to the safety of the workers in the WZ and to the safety of the drivers using the highway, so extreme measures may be the best alternative to complete closure of the lanes.

Recommendations

The presence of law enforcement at work zone locations is recommended. This is especially true for work zones requiring more than a 10 mph reduction in traffic speed. As the reduction below the normal speed limit increases, the presence of law enforcement becomes more important.

If a long work zone is necessary, more than one officer and patrol car may be needed to ensure compliance throughout the work zone.

Speed reductions of more than 20 mph should be used only in extreme cases. The speed limit through the work zone should be raised to the highest safe speed as soon as practical.

Speed reductions should be established for the shortest distance that is practical to protect workers and drivers.

If possible, speed reduction signs for work zones should be removed when no activity is on-going in the work zone.

Long work zones with no activity or large speed reductions in work zones where workers and equipment are far away from through traffic tend to make drivers doubt the validity of the reduced speed limit. When these things happen often, drivers may loose respect for the posted speed limit in other work zones. Speed reductions should be carefully evaluated and reduced work zone speed limits not set lower than necessary or for longer distances than necessary for the safety of the workers and drivers.

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APPENDIX A – STUDY PROPOSAL

CDOT RESEARCH PROBLEM STATEMENT

1. **Problem title:** Work Zone Speed Control

2. **Subject area**: Safety

3. **RIC Sponsor:** Gabriela Vidal, Safety and Traffic

4. **Description of Problem:** Traffic in the lanes next to work zones presents a continuous hazard to workers. By reducing the speed of the traffic through the work zone, the hazard can be mitigated somewhat.

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6. **Background:** Accurate data on the effectiveness of the simultaneous use of radar detection devices and law enforcement support in work zones would be valuable information for equipment purchasing and budgeting purposes. A literature search found 17 studies dated between 1987 and 2003, relating to work zone speed control and investigating the use of VMS's, presence of law enforcement or various signing methods. However none provide current documentation the effectiveness of the use of a VMS in conjunction with the presence of a law enforcement officer who was ticketing violators.

7. **Product of Research:** The research would provide CDOT with the most effective method for managing traffic speed in the vicinity of work zones.

8. **Benefits of Research:** The research will result in more reliable control of traffic speeds near work zones, improving safety for both the workers and the traveling public. Periodic checks of compliance with speed limits at various sites can be used to verify the results.

9. **Implementation Plan:**

   A. Category of Implementation Product: Maintenance Practice Change

   B. Further Description of Implementation Product: The results of the research will help Maintenance workers and Safety and Traffic engineers to plan traffic control in work areas, and help in budgeting for the expenses involved.

C. Implementation Steps and Person/Organization Responsible:

10. **Champion:** Wayne Lupton, Maintenance

11. **Leverage:** NA

12. **Cost for Research:** $10,000

13. **Cost for Implementation:** none

14. **Time to complete research:** One year

APPENDIX B – SCENARIO STATISTICS

	MUTCD Signs + Arrow Bd (1)	RADAR VMS (2)	HP Car with OH Lights on (3)	2 HP Cars with no lights (4)	2 HP Cars Troopers writing Tickets (5)	Speed limit 70 mph (6)	Speed limit 70 mph (7)	Speed limit 65 mph (8)	Speed limit 65 mph (9)	Speed limit 60 mph (10)	Speed limit 55 mph (11)	Speed limit 50 mph (12)	Speed limit 45 mph (13)
Speed limit	55	55	55	55	55	70	70	65	65	60	55	50	45
85th percentile	56	57	56	55	54	69	70	67	67	64	60	58	55
Mean	49.96	50.93	49.98	49.12	47.21	61.49	62.02	58.72	59.25	56.09	53.11	51.67	48.22
Standard Error	0.41	0.40	0.43	0.48	0.45	0.46	0.51	0.59	0.54	0.48	0.47	0.48	0.63
Median	50	51	50	49	48	62	62	60	60	56	54	52	47
Mode	52	52	53	48	46	62	66	60	60	55	56	52	44
Standard Deviation	5.26	5.03	4.92	5.78	5.77	6.86	6.81	7.42	7.14	6.67	6.36	6.19	6.76
Sample Variance	27.64	25.27	24.23	33.45	33.29	47.02	46.35	55.00	50.96	44.48	40.47	38.37	45.74
Kurtosis	-0.06	0.72	0.00	2.36	-0.31	0.02	0.31	-0.07	2.11	0.58	0.32	0.60	1.87
Skewness	-0.11	0.17	-0.20	-0.69	-0.20	-0.34	-0.45	-0.23	-1.02	0.42	-0.35	0.16	0.73
Range	29	30	26	43	27	37	36	43	45	37	35	36	45
Minimum	36	38	37	24	32	43	43	37	27	42	38	33	28
Maximum	65	68	63	67	59	80	79	80	72	79	73	69	73
Sum	8144	7894	6548	7270	7743	13528	11040	9160	10250	10826	9559	8681	5593
Count (vehicles)	163	155	131	148	164	220	178	156	173	193	180	168	116
95% Confidence Level	0.81	0.80	0.85	0.94	0.89	0.91	1.01	1.17	1.07	0.95	0.94	0.94	1.24
Vehicles speeding	23	26	13	13	14	17	19	27	33	42	73	104	73
Speeding (%)	14.1%	16.8%	9.9%	8.8%	8.5%	7.7%	10.7%	17.3%	19.1%	21.8%	40.6%	61.9%	62.9%
> 5 mph over	1.8%	3.2%	1.5%	1.4%	7.9%	0.9%	1.1%	3.8%	1.7%	5.7%	8.3%	19.6%	30.2%
> 10 mph over	-	0.6%	-	0.7%	-	-	-	0.6%	-	3.1%	1.7%	10.7%	11.2%
> 15 mph over	-	-	-	-	-	-	-	-	-	1.0%	0.6%	2.4%	6.0%
> 20 mph over	-	-	-	-	-	-	-	-	-	-	-	-	2.6%
> normal posted speed	-	-	-	-	-	0.9%	1.1%	0.6%	-	1.0%	-	-	-

APPENDIX C - TRIS SEARCH RESULTS

TRIS SEARCH – WZ SPEED CONTROL 9/2/2005

1 Efficacy Of Speed Monitoring Displays In Increasing Speed Limit Compliance In Highway WZs

Author(s): Saito, M; Bowie, J
Publication Date: 07/00/2003

Pagination: 174p

Period Covered: 0206-0307

Report No: UT-03.12,; Final Report
Features: FIGS: 25 Fig. TABS: 13 Tab. PHOT: REFS: 36 Ref. APPS: 4 App.

Publisher/Corporate Author(s):

Brigham Young University
Department of Civil and Environmental Engineering
Provo, UT 84602-4081

Utah Department of Transportation
4501 South 2700 West
Salt Lake City, UT 84119

Abstract:

Safety in highway WZs has become a concern at the Utah Department of Transportation (UDOT) as the highway network has begun to age and more maintenance and construction work has been necessary. Researchers are looking at several mechanisms for improving safety in highway WZs. This study focuses on the goal of reducing speed in WZs. First, research on methods of speed reduction used by state DOTs throughout the country is identified and summarized. Next, the methodology and results of a field study that tests the efficacy of the Speed Monitoring Display (SMD) are described in detail, Finally, the results of a survey that was conducted to ascertain drivers' opinions of the SMD are presented. For the field study, three main conditions were analyzed: a no-treatment case, with the Manual on Uniform Traffic Control Devices (MUTCD) signs and barriers; a treatment case using the SMD; and a treatment case using a police vehicle. In the no-treatment case, average vehicle speed was reduced about 3 mph as vehicles entered the work area of the WZ. With the SMD, average vehicle speed was reduced 7 mph. With the police vehicle, average vehicle speed was reduced about 9 mph. (These conclusions are valid at a 95% confidence level.) The results of the study suggest that the SMD is a promising option for state DOTs.

Read Document Online: http://www.udot.utah.gov/download.php/tid=296/Report%20UT-03.12.pdf

2 Use Of Police In WZs On Highways In Virginia

Author(s): Arnold, ED, Jr
Publication Date: 12/00/2003

Pagination: 53p

Report No: FHWA/VTRC 04-R9,; Final Report
Publisher/Corporate Author(s):

Virginia Transportation Research Council
530 Edgemont Road
Charlottesville, VA 22903
Virginia Department of Transportation
1401 East Broad Street
Richmond, VA 23219
Abstract:

It is generally accepted that one of the most effective ways of controlling speed in a WZ is to have a staffed police car positioned at the beginning of the WZ with its lights flashing and radar on. Drivers detect the presence of police either visually or via radar detectors and reduce their speed to comply with the posted WZ speed limit. The reduced speeds and reduced variation in speeds result in fewer accidents and minimize dangerous interactions between vehicles and WZ workers and equipment. A number of studies support these observations. The use of police enforcement in WZs is a common practice among state departments of transportation, and the Virginia Department of Transportation (VDOT) is no exception. VDOT has an agreement with the Virginia State Police (VSP) for paying for and implementing the strategy in VDOT WZs and a mutually developed set of guidelines for using police enforcement. The purpose of the research was to document the current practices regarding the use of police in WZs in Virginia and to determine if any enhancements could be made. The research effort consisted of literature reviews to establish the background for police enforcement in WZs, discussion with and input from VDOT and VSP personnel, and the administration of a questionnaire survey. A questionnaire survey was sent to personnel in VDOT, VSP, and VMS, Inc., asking the respondent's opinion about the effectiveness of using police in WZs and a number of questions about the WZ enforcement practices being used. The use of police in WZs was almost unanimously felt to be effective in reducing speeds and improving safety in WZs, and few adverse effects were noted. Recommendations were made regarding the development and implementation of training in basic WZ operations, the development of a standard agreement for possible use with local police agencies, the use of more than one police officer, the promotion of the maximum $500 fine for speeding in WZs, the requirement that police officers wear safety vests when outside their vehicle in a WZ, and the development of a standard pay practice for cancellations.

Read Document Online: http://www.virginiadot.org/vtrc/main/online_reports/pdf/04-r9.pdf

3 Development Of Speed Reduction Strategies For Highway WZs

Author(s): Dixon, K; Wang, C
Publication Date: 07/00/2002

Pagination: 115p

Period Covered: 9810-0205

Report No: FHWA-GA-02-9810,; Final Report
Publisher/Corporate Author(s):

Georgia Institute of Technology
School of Civil Engineering

Atlanta, GA 30332
Georgia Department of Transportation
15 Kennedy Drive
Forest Park, GA 30050
Federal Highway Administration
400 7th Street, SW
Washington, DC 20590

Abstract:

This study was conducted to identify the potential of fluorescent orange sheeting, an innovative message sign, and a changeable message sign with radar (CMR) for reducing speeds in highway WZs. It investigates the effect of each strategy right after implementation as well as several weeks after implementation. In addition to the overall effect of each strategy on all vehicles, the study includes the effect on specific vehicle types during varying lighting conditions. The researchers collected traffic data before, immediately after, and 2-3 weeks after implementation of each strategy (three consecutive weeks for the CMR). They collected data upstream of the WZ, in the advance warning area, and adjacent to the active work area. They used various statistical tests to evaluate the significance of speed changes from phase to phase and adjusted vehicle speeds with the upstream speed changes over time. Results indicate that fluorescent orange sheeting and the innovative message sign do help reduce speeds at highway WZs. There is, however, a novelty effect, and speeds tend to return to normal after a certain period of time. Moreover, both strategies influence reduced vehicle speeds more during the day than at night. Passenger vehicles tend to decrease their speeds more than trucks. CMR radar significantly reduces vehicle speeds in the immediate vicinity of the sign and are not sensitive to a novelty effect.

Read Document Online

4 Evaluation Of Radar Activated Changeable Message Signs For WZ Speed Control

Language: English

Publication Date: 01/00/2002

Pagination: 6p

Report No: Technical Report 01-16

Publisher/Corporate Author(s):

Maine Department of Transportation
16 Statehouse Station
Augusta, ME 04333-

Abstract:

The Maine Department of Transportation (MDOT) recently tested new equipment designed to help reduce the incidence of speeding in construction WZs. The project utilized a radar-activated, trailer mounted, changeable message sign (CMS). MDOT, like other state transportation agencies, relies on portable CMS trailers to warn drivers of roadway and traffic conditions on construction maintenance projects. The unit tested in this experimental project

utilizes a radar unit to detect vehicle speeds. If the unit detects a speeding vehicle a selected sequence of warning messages is displayed. The unit is solar powered backup and is programmed and operated using a hand-held controller. Optionally, a lap-top computer can also be used. Several states have used similar radar activated signs. Recent research conducted in Texas, Virginia, Nebraska, and Montana has shown that speed trailers are effective in reducing average speeds. Radar speed trailers have also been used effectively by municipal police in many states.

5 Feasibility Of Real-Time Remote Speed Enforcement For WZs

Author(s): Fontaine, MD; Schrock, SD; Ullman, G

Journal Title: Transportation Research Record

Issue: 1818

Publication Date: 00/00/2002

Pagination: pp 25-31

Features: FIGS: 1 Fig. TABS: 3 Tab. PHOT: 1 Phot. REFS: 13 Ref.

Publisher/Corporate Author(s):

<u>Transportation Research Board</u>
500 Fifth Street, NW
Washington, DC 20001-

Abstract:

Studies have shown that a large percentage of vehicles involved in WZ crashes are traveling at excessive speeds. Although traditional speed enforcement has been shown to reduce speeds through the work area, enforcement under these conditions can be dangerous to both the motoring public and enforcement officers. The WZ layout often limits the locations at which an officer can set up to enforce the speed limit and the locations at which violators can be stopped. Automated speed enforcement technology could help eliminate the need to stop violators in a WZ, but it is not currently a popular concept in the United States because of concerns about motorist privacy. Researchers hypothesized that this technology could be useful for WZ enforcement if adapted to a more real-time operation. The initial testing of the concept of remote speed enforcement is summarized. An automated speed enforcement system (consisting of digital video and lidar technology) was meshed with a wireless communications system. The unit determined when vehicles exceeded a certain speed threshold. If a vehicle was detected as exceeding the threshold, a digital photograph was taken of the violator. This photograph was then transmitted to an observer stationed downstream of the site. The technical feasibility of the system was assessed through field tests. Focus groups of law enforcement personnel were used to determine potential

6 Long-Term Effectiveness Of Speed Monitoring Displays In WZs On Rural Interstate Highways

Author(s): Pesti, G; McCoy, PT

Journal Title: Transportation Research Record

Issue: 1754

Publication Date: 00/00/2001

Pagination: pp 21-30

Features: FIGS: 6 Fig. TABS: 5 Tab. PHOT: 1 Phot. REFS: 13 Ref.

Publisher/Corporate Author(s):

Transportation Research Board
2101 Constitution Avenue, NW
Washington, DC 20418

Abstract:

The long-term effectiveness of speed monitoring displays (SMDs) was evaluated as part of the Midwest States Smart WZ Deployment Initiative, a pooled-fund study sponsored by Iowa, Kansas, Missouri, Nebraska, and the Federal Highway Administration. Three SMDs were deployed for a 5-week period along a 4.35-km (2.7-mi) section between two WZs on I-80 near Lincoln, Nebraska. The mean, 85th percentile, and standard deviation of vehicle speeds and the percentage of vehicles complying with the 89-km/h (55-mph) speed limit and the 97 and 105-km/h (60 and 65-mph) speed thresholds were used as measures of effectiveness (MOEs). The SMDs were found to be effective in lowering speeds, increasing the uniformity of speeds, and increasing speed-limit compliance over the 5-week period. Statistically significant improvements in speed parameters and speed-limit compliance were observed at the measurement points downstream of the first two SMDs. The improvement in standard deviation and some compliance percentages were not statistically significant at the third SMD. Greater speed reductions and compliance increases were observed for passenger cars than for other vehicles. The combined long-term effect of the three SMDs was also assessed using spatially aggregated MOEs. Statistically significant improvement was found in terms of both speed reduction and speed-limit compliance. One week after the removal of the SMDs, there were still statistically significant speed reductions and compliance increases, although they were less than during the deployment.

7 Evaluation Of WZ Speed Reduction Measures

Author(s): Maze, T; Kamyab, A; Schrock, S
Publication Date: 04/00/2000

Pagination: 141p

Report No: 99-44
Publisher/Corporate Author(s):

Center for Transportation Research and Education
Iowa State University, 2901 S Loop Drive, Suite 3100
Ames, IA 50010-8632

Abstract:

The Iowa Department of Transportation (DOT) has made improving WZ (WZ) safety a high priority. Managing vehicle speeds through WZs is perceived to be an important factor in achieving this goal. A number of speed reduction techniques are currently used by transportation

agencies throughout the country to control speeds and reduce speed variation at WZs. The purpose of this project is to study these and other applicable WZ speed reduction strategies. Furthermore, this research explores transportation agencies' policies regarding managing speeds in long-term, short-term, and moving WZs. This report consists of three chapters. The first chapter, a literature review, examines the current speed reduction practices at WZs and provides a review of the relevant literature. The speed control strategies reviewed in this chapter range from posting regulatory and advisory speed limit signs to using the latest radar technologies to reduce speeds at WZs. The second chapter includes a short write-up for each identified speed control technique. The write-up includes a description, the results of any field tests, the benefits and the costs of the technology or technique. To learn more about other state policies regarding WZ speed reduction and management, the Center for Transportation Research and Education conducted a survey. The survey consists of six multipart questions. The third chapter provides summaries of the response to each question.

Read Document Online: http://www.ctre.iastate.edu/reports/workzone.pdf

8 Evaluation Of Two Strategies For Improving Safety In Highway Work Zones Author: Meyer, E Corporate Source: Iowa State University, Ames, Center for Transportation Research and Education, 2901 S Loop, Ames, IA, 50010-8632, Pag: pp 62-66 Supplemental Notes: The proceedings can be located on-line at www.ctre.iastate.edu/. **Abstract**: During 1999, the Departments of Transportation from the states of Kansas, Nebraska, Iowa, and Missouri conducted a pooled-fund study of innovative devices designed to improve the safety and efficiency with which highway maintenance is conducted. In the state of Kansas, a total of nine devices were evaluated. This paper discusses the two devices that showed the greatest potential for improving the safety of highway WZs, a radar-triggered speed display and Lightguard lighted raised pavement markers (RPMs). The devices are described as they were evaluated, and the results are discussed with respect to the effectiveness of the devices relative to the current practice in Kansas. The speed display was also compared directly with active law enforcement at the same site. Speeds were used as a measure of effectiveness for both devices. Lane position was also used to evaluate the effectiveness of the Lightguard RPMs, which were used to delineate a crossover. In all cases, pneumatic hoses were used to collect the data. Data were collected for four days before and four days after the deployment of the speed display. Only one day of data was collected before and after activation of the RPMs. Both devices produced significant reductions in mean and 85th percentile speeds (statistically and practically significant). The RPMs resulted in a reduction in the percentage of passenger cars tracking within 30 cm (1 ft) of the edge line. The reduction was statistically significant at a 95% confidence level, though practical significance is difficult to assess in this case. Both devices were evaluated at rural interstate WZs. Further evaluation is needed to determine to what extent, if any, the effects of the devices decrease over time in a context with a high percentage of repeat traffic, such as an urban freeway. Conference Title: Mid-Continent Transportation Symposium 2000 Conference Location: Ames, Iowa Conference Begin Date: 20000515 Conference End Date: 20000516 Conference Sponsor: Iowa State University; Iowa Department of Transportation; Midwest Transportation Consortium; and Missouri Valley Section of the Institute of Transportation Engineers.

9 WZ Ahead: Reduce Speed

Author(s): Fors, C

Language: English

Journal Title: Roads and Bridges

Volume: 38 **Issue:** 1

Publication Date: 01/00/2000

Pagination: 3p

ISSN: 87509229

Features: PHOT: 3 Phot.

Publisher/Corporate Author(s):

Scranton Gillette Communications, Incorporated
380 E Northwest Highway
Des Plaines, IL 60016-2282
USA

Abstract:

In December 1999, specific laser analysis of vehicle speeds was conducted at four different WZs in four different states: Interstate 10 (I-10) outside of Deming, New Mexico; I-35 West north of Forth Worth, Texas; Nebraska Highway 2 (NE-2) near Lincoln, and US-81 north of Concordia, Kansas. The analysis, involving some 4,551 laser targeted vehicles, sought to measure vehicle speeds and help officials gain insight into how best to achieve reductions in vehicle speeds at WZs. The low work-zone speed limit of 45 mph (72 kph) in New Mexico had little or no effect in improving work-zone speed limit compliance percentages. The visibility of the lane closure did have an effect on lower New Mexico average speeds compared with Texas. Over-the-limit speeds were similar to Texas. The increased average speeds for both cars and trucks in Texas can be attributed to lack of visibility to the lane closure and not the actual speed limit. The lower average speeds for cars and trucks in New Mexico can be attributed to the visibility of the lane closure and not the 45-mph (72-kph) speed limit. Speed-limit compliance rates were high in Kansas on US 81. This sample included a higher percentage of local traffic compared with Nebraska. The work-zone lane closure was visible for almost 2 mi (3.2 km) compared with a much shorter distance in Nebraska because of hilly terrain. Lower average speeds for both cars and trucks along the lower over-the-limit figures for Kansas can be attributed to a longer visibility of the lane closure. It is concluded that next to having police officers in the WZ or radar speed trailers at the entry point, the best method of slowing work-zone traffic is visibility of the WZ.

10 Evaluation Of Traffic Control Devices For Rural High-Speed Maintenance WZs: Second Year Activities And Final Recommendations

Author(s): Fontaine, MD; Carlson, PJ; Hawkins, HG, Jr

Language: English

Publication Date: 10/00/2000

Pagination: 142p

Period Covered: 9909-0008

Report No: FHWA/TX-00/1879-2,; Research Report 1879-2

Features: FIGS: Figs. TABS: Tabs. PHOT: Phots. REFS: 34 Ref. APPS: 6 App.

Publisher/Corporate Author(s):

Texas Transportation Institute
Texas A&M University
College Station, TX 77843
Texas Department of Transportation
Office of Research and Technology Transfer, P.O. Box 5080
Austin, TX 78763-508

Abstract:

This report documents the second year of a two-year project to evaluate the effectiveness of innovative WZ traffic control devices. Researchers evaluated these devices at short-term rural WZs. During the second year of the project, seven devices were tested at eight WZs. The devices evaluated included portable rumble strips, portable variable message signs (VMS), radar drones, fluorescent yellow-green worker vests, retroreflective vehicle visibility improvements, fluorescent orange signs, and speed display trailers. A radar activated flagger paddle was evaluated, but on a more limited basis. The effectiveness of these devices was assessed based on the vehicle speeds in the WZ, the ease of installation and removal, the impact of the device on vehicle conflicts, and worker comments. Analysis of the data collected revealed that the speed display trailer had the largest impact on speeds. The VMS had a positive benefit in reducing conflicts. The fluorescent orange signs, vehicle visibility improvements, and yellow-green worker vests all acted to improve the conspicuity of the workers.

Read Document Online

11 Effectiveness Of Changeable Message Signs In Controlling Vehicle Speeds In WZs - Phase II

Author(s): Garber, NJ; Srinivasan, S

Language: English

Publication Date: 01/00/1998

Pagination: 104p

Report No: FHWA/VTRC 98-R10; Final Report

Features: FIGS: Figs. TABS: Tabs. PHOT: Phots. REFS: 16 Ref. APPS: 7 App.

Publisher/Corporate Author(s):

Virginia Transportation Research Council
P.O. Box 3817, University Station
Charlottesville, VA 22903
USA

Virginia Department of Transportation
1401 East Broad Street
Richmond, VA 23219
Federal Highway Administration
400 7th Street, SW
Washington, DC 20590

Abstract:

Highway WZs have been plagued with increasing numbers of accidents in recent years. Drivers' lack of compliance with speed restrictions within WZs has been cited as one of the major contributing factors to this trend. The conventional practice for regulating WZ speeds has been static signing procedures (using regulatory or advisory speed signs). It has been found that drivers do not slow down in response to these static control measures. A Changeable Message Sign (CMS) equipped with a radar unit can be used to display specific warning messages to speeding drivers. This offers a more dynamic speed control environment and therefore may prove to be more effective in influencing drivers to reduce their speeds. This report is the second phase of a longitudinal research study. The first phase of the project, conducted by Garber and Patel, examined the short term effectiveness of CMSs in reducing vehicle speeds in WZs. That research established that the CMS (with the radar unit) is more effective in reducing speeds in WZs than the standard Manual on Uniform Traffic Control Devices (MUTCD) signs. This study, while attempting to replicate the results obtained in Phase I of the project, concentrated on evaluating the effect of duration of exposure of the CMS with radar on its effectiveness in reducing speeds and influencing speed profiles in WZs. The impact of length of the WZ and vehicle type on speed reductions was also studied. Speed and volume data for the population and for speeding drivers were collected through automatic traffic counters and video cameras respectively at three WZs. These data were collected at the beginning, middle and end of each WZ, to study the behavior of high speed drivers in particular and to compute their average speed reduction in response to the warning message. The results of the study indicate that the duration of exposure of the CMS does not have a significant impact

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12 Effects of Police Presence on Speed in a Highway WZ: Circulating Marked Police Car Experiment. Project report

Author(s): Benekohal, RF; Resende, PTV; Orloski, RL

Publication Date: 05/00/1992

Pagination: 41p

Period Covered: 89-92

Features: FIGS: 27 Fig. TABS: 8 Tab. REFS: 9 Ref. APPS: 1 App.

Publisher/Corporate Author(s):

Illinois University, Urbana-Champaign
Department of Civil Engineering
Urbana, IL 61801
Illinois Department of Transportation

Bureau of Materials & Physical Research, 126 East Ash
Springfield, IL 62706

Abstract:

This study evaluated the effects of police presence on the speed of vehicles in a WZ and determined the "halo" effects of police presence (lasting effects when police are gone) on vehicular speeds. A marked police car circulated in a 4-mile long interstate highway WZ and actively enforced the speed limit laws. Variables such as the average speed, speed distribution, percentage of fast-moving motorists, and net speed reductions for cars and trucks were used for evaluation. The results indicated that the average speeds of the cars and trucks were 4.3-4.4, and 4.3-5.0 mph, respectively, lower when police were patrolling the WZ compared to no-police patrol condition. The percentage of fast-moving cars and trucks before the work space decreased by 14% and 32%, respectively, when police were in the WZ. These speed reductions indicate that the police presence was effective in decreasing the speed of vehicles in the WZ. The police presence had halo effects on trucks but not on cars. Trucks traveled at reduced speed when police were present in the WZ and this trend of traveling at the reduced speed continued for a time period at least one hour after the police departed from the WZ. However, cars traveled 2.4-3.0 mph faster and the percentage of fast-moving cars in the WZ increased after the police left the area.

13 Speed Control Through WZs: Techniques Evaluation and Implementation Guidelines. Final Report

Author(s): Noel, EC; Dudek, CL; Pendleton, OJ; McGee, HW; Sabra, ZA

Publication Date: 02/00/1987

Pagination: 46p

Period Covered: 8509-8702

Report No: FHWA-IP-87-4

Publisher/Corporate Author(s):

Daniel Consultants, Incorporated
Columbia, MD N/A
Dudek and Associates
Bryan, TX N/A
Bellomo-McGee
410 Pine Street, SE
Vienna, VA 22180
Federal Highway Administration
Office of Implementation, 6300 Georgetown Pike
McLean, VA 22101

Abstract:

This report presents the implementation and evaluation of four techniques for improving the effectiveness of speed zoning in construction areas on multi-lane freeways. The techniques are (a) the flagging procedure of the "Manual on Uniform Traffic Control Devices" (MUTCD), (b) the use of the MUTCD flagging procedure as well as motioning motorists to slow and pointing at

a nearby speed limit sign with the free hand of the flagger, (c) a marked police car with cruiser lights and radar active, and (d) a uniformed police officer standing to control traffic. Each of the techniques were applied continuously on six-lane freeways for a period of 10-15 days. The results of the analysis indicate that all four techniques can derive significant reduction in traffic speed through highway construction zones. The flagging methods were effective in construction areas where one lane remained open to traffic. The law enforcement methods demonstrated a stronger speed reduction capability, particularly when the lane closures result in two or more lanes open. The construction projects used for the field data collection required speed reduction from the regulatory 55 mph to an advisory 45 mph. Although the law enforcement techniques were determined to be effective, their implementation requires a high degree of administrative coordination and cooperation involving police departments, highway officials and construction contractors. A User Guide on speed control in WZs is provided in Appendix D.

Read Document Online: http://www.fhwa.dot.gov/tfhrc/safety/pubs/87004/87004.pdf

14 Controlling Vehicle Speeds In Highway Construction Zones Author: Hall, J; Wrage, E Corporate Source: University of New Mexico, Albuquerque, Department of Civil Engineering, Albuquerque, NM, 87131-1351, New Mexico State Highway and Transportation Department, State Highway Department Building, P.O. Box 1149, Sante Fe, NM , 87504-1149, Report Number: NMSHTD-97-07,;CE-97 (01) Pag: 46p Publication Date: 19971200 Publication Year: 1997 availability: New Mexico State Highway and Transportation Department ; State Highway Department Building, P.O. Box 1149 ; Sante Fe ; NM ; 87504-1149 **Abstract:** The objective of this project was to evaluate the effectiveness of alternative treatments for controlling vehicle speeds in WZs. Field studies were conducted at three rural, high-speed locations, two urban freeway WZs, and five arterial locations. Three treatments were investigated in the project: a radar beam that would activate motorists' radar detectors, a special WZs speed limit sign with flashing beacons, and a speed trailer that monitors vehicle speeds and displays this information to the driver. Vehicle speeds were collected in WZs in a "before" period, with the normal traffic control plan in operation, and in a "during" period, with the supplemental treatment in place. The study found that the radar was ineffective in reducing vehicle speeds through construction zones, perhaps because those motorists with radar detectors could see that speed regulations weren't being enforced. The WZ speed limit sign with beacons was also ineffective. In applications on urban arterials, the speed trailer was effective in reducing speeds by 4 to 5 mph; use of this treatment on an urban freeway in conjunction with enforcement also resulted in improved speed compliance. The study recommends that WZ speed limits be set realistically, that the speed trailer be used more extensively, and that other, non-engineering solutions be explored.

15 A Study Of The Effectiveness Of Unmanned Radar As A Speed Control Technique In Freeway WZs Author: Turochy, RE; Sivanandan, R Corporate Source: Virginia Polytechnic Institute & State University, Center for Transportation Research, 1700 Kraft Drive, Suite 2000, Blacksburg , VA, 24061-0536, Mid-Atlantic Universities Transportation Center, Pennsylvania State University, Research Office Building, University Park, PA, 16802-, Report Number: MAUTC III-9703;Final Report Pag: 127p Supplemental Notes: This study was sponsored by a grant from the U.S. Department of Transportation, University Transportation Centers Program. Publication Date: 19970500 Publication Year: 1997 **Abstract:** In July of 1996, the Center for

Transportation Research at Virginia Tech initiated a study to determine the effectiveness of unmanned radar as a speed control technique in WZs on Interstate 81. The assistance of the Virginia Department of Transportation and the sponsorship of the Mid-Atlantic Universities Transportation Center were instrumental in this research effort. As a part of this effort, a review of literature on speed control techniques was undertaken, with particular attention focused on unmanned radar and police presence. In addition, data were collected in WZs on Interstate 81 under several combinations of WZ types and speed control conditions. Based on a statistical analysis of the data, conclusions and recommendations on the use of unmanned radar, as well as recommendations for further research, have been developed. The goal of this research effort has been to determine the effectiveness of unmanned radar and police presence as speed control techniques in freeway WZs in Virginia. The impacts of simulated and real police presence on traffic in WZs on Interstate 81 were assessed quantitatively using the following measures of effectiveness: change in mean speed of traffic; change in standard deviation of speed (speed variance); change in percent of traffic exceeding 65 mph; change in percent of traffic exceeding 55 mph; and change in eighty-fifth percentile speed.
Read Document Online: http://scholar.lib.vt.edu/theses/available/etd-94112239721111/

16 Controlling Vehicle Speeds in WZs: Effectiveness of Changeable Message Signs with Radar Author: Fontaine, MD; Garber, NJ Corporate Source: Virginia University, Charlottesville, VA, 22903, Report Number: UVA/529242/CE96/102 Pag: 73p Supplemental Notes: Sponsored by the U.S. Department of Transportation and the Virginia Department of Transportation. Publication Date: 19960700 Publication Year: 1996 Bibliographic/Data Appendices: 5 App. Availability: Pennsylvania Transportation Institute ; Mid-Atlantic Universities Transportation Center, Region III; University Park ; PA ; 16802 **Abstract:** Studies have found that a major cause of WZ accidents is vehicles traveling at unsafe speeds. Traditionally, standard speed limit signs have been employed to regulate WZ speeds, but motorists tend to ignore these signs. In this study a radar unit was attached to a changeable message sign (CMS). If the radar detected a vehicle traveling above a preset speed threshold, the CMS displayed the message "YOU ARE SPEEDING SLOW DOWN". This study evaluated the effectiveness of the CMS with radar in reducing WZ speeds. Also, this project determined if there were significant differences between the average speeds of different vehicle types after they were exposed to the CMS with radar. The results of this project were also compared to the results of a similar study by Garber and Patel in order to learn if the two study sites produced consistent data. The CMS with radar was tested at two sites in southwestern Virginia and speed data was collected with automatic traffic counters. This speed data was analyzed using statistical methods to learn if the speed reductions were significant. T-tests revealed that speeders reduced their speeds by a significant amount from the beginning of the WZ to the middle and end of the WZ. Analysis of variance showed that no significant differences existed in the speed reductions between vehicle types. Analysis of variance also revealed that average speeds were reduced and fewer vehicles were speeding by any amount or by 5mph or more for all traffic in the middle of the WZ when CMS was in operation. CMS with radar appears to be an effective alternate form of speed control.

APPENDIX D - PROCEDURES AND GUIDES

COLORADO DEPARTMENT OF TRANSPORTATION
TRANSPORTATION SAFETY AND TRAFFIC ENGINEERING BRANCH
PROCEDURE FOR DETERMINING WORK ZONE SPEED LIMITS (1)

April 4, 1997

INTRODUCTION: As required by State law, CDOT provides traffic control devices (signs, signals and pavement markings) in accordance with the guidelines and standards set forth in the federal Manual on Uniform Traffic Control Devices (MUTCD). Although the MUTCD contains guidelines for establishing permanent speed limits it contains no uniform guidelines for determining specific, temporary work zone speed limits. The purpose of this document is to establish a philosophy and a uniform method of determining work zone speed limits in an effort to improve the credibility of such limits with the motoring public, enhance work zone safety, and help support speed limit enforcement activities.

Numerous scientific studies of and practical experience with both permanent and temporary work zone speed limits have repeatedly shown that motorists will not voluntarily comply with posted speed limits they deem to be unrealistic. It seems obvious that effective speed limits rely on voluntary compliance. Since the majority of drivers will select a speed that they believe to be suitable for the conditions that exist at any given place and time, and since the behavior of the majority should be considered legal, realistic speed limits must reflect real-world circumstances. What is clear is that artificially low speed limits do not affect the speed of most drivers to any significant degree.

Any procedure to establish realistic work zone speed limits must recognize the difference between such realistic limits and a desire to significantly affect the driving speeds of motorists; these are in fact separate issues. The procedure that follows is intended to be a guide for those charged with the establishment of realistic speed limits for both contract and maintenance work zones.

PROCEDURE: The following steps leading to the establishment of realistic work zone speed limits are listed in order of priority:

1. From the standpoint of overall safety and public mobility, speed limit reductions in work zones should be avoided whenever possible. To accomplish this goal, work zone designs that can safely allow traffic to operate at the permanently-posted speed limit should be considered whenever practical. In any case, the speed limit in effect at any given time must reflect the real world conditions that exist at that time. This may require that the speed limits be changed on a project or at a work site as the nature and location of the work changes.
2. No speed limit reduction is recommended when the distance to the work is over 10 feet from the edge of the traveled way QI when the work area is protected by concrete barrier and lane widths are not reduced.
3. Establish work zone speed limits in accordance with the recommendations contained in Table I (attached).
4. Work zone speed limits for those unique circumstances not described in 1. through 3. above shall be determined by the Region Traffic Engineer or Staff Traffic Engineer. In establishing such limits, consideration should be given to the intent and "philosophy" outlined in the Introduction to this document. Standard traffic engineering techniques shall be used to establish all work zone speed limits.

TABLE I
RECOMMENDED **MINIMUM** WORK ZONE SPEED LIMITS

POSTED SPEED LIMIT	MINIMUM WIDTH AVAILABLE TO TRAFFIC *	WORK DISTANCE FROM EDGE OF TRAVELED WAY **	NORMAL WORK ZONE SPEED LIMIT	THRU AREAS WHERE ACTIVE WORK IS UNDERWAY	APPROACHING A POTENTIAL STOP CONDITION
75 MPH	14 FT.	2-10 FT.	65 MPH	40-65 MPH	40 MPH
70 MPH.	14 FT	2-l0 FT.	60 MPH	40-60 MPH	40 MPH
65 MPH	14 FT.	2-10 FT.	55 MPH	40-55 MPH	40 MPH
60 MPH	14 FT.	2-10 FT.	50 MPH	40-50 MPH	40 MPH
55 MPH	14 FT.	2-10 FT.	45 MPH	40-45 MPH	40 MPH
50 MPH	12 FT.	2-10 FT.	40 MPH	40 MPH	40 MPH
45 MPH	12 FT.	2-l0 FT.	40 MPH	40 MPH	40 MPH

No Reduction Recommended in Posted Speed Limits of 40 MPH or Less

* Minimum width available to traffic shall include any combination of designated lane width and shoulder width available for traffic to use.
** No speed limit reduction recommended if more than 10 feet.

NOTES:
A. The speed limit on one side of a freeway/expressway operating as a two-lane, two-way roadway should be 65 MPH Q£ the normally posted speed limit for that freeway/expressway, whichever is lower.

B. On roadways having three or more lanes normally available for a given direction of travel, Table I should be used to determine the work zone speed limit if the minimum width in the traffic lane available to traffic directly adjacent to the work is 10 feet or more.

099.00 Work Zone Safety, Traffic Control

ALWAYS

Have supervisor/lead-worker verify that operators are capable and qualified on each type of equipment before allowing the equipment to be operated unsupervised.

Follow Part VI of the Manual on Uniform Traffic Control Devices (MUTCD) and the CDOT Work Zone Safety Hand Manual.

- Do before going to the work site:

a. Have a traffic control plan.

b. Load needed traffic-control devices; such devices shall be in good operating condition.

c. Make sure employees have needed personal protective equipment.

- Park in areas that:

a. Provide safe entrances and exits of the work area.

b. Do not create potential conflicts with other vehicles/equipment operating in the work area.

c. Provide maximum protection for workers getting in and out of vehicles.

Be alert to job site hazards and identify appropriate escape routes.

Inspect the work zone frequently to ensure devices are in-place and that traffic is flowing adequately. When inspecting, ask yourself, “What is the driver’s view?”

Remove the traffic control devices in a timely manner and in a manner that provides the workers the most protection.

Arrange for police support when necessary. (Example: Traffic Signal Technician servicing a traffic signal.)

Be alert to wide or oversized loads progressing through work zone.

NEVER

Flag without properly trained and equipped workers.

Leave signs out in work zone when workers are not present at work zones.

Leave equipment such as tripods unattended when positioned in or adjacent to the traveled way.

PERSONAL PROTECTIVE EQUIPMENT

CDOT issued orange vest and hard hat

Revised: 3/22/99

SAFE OPERATING GUIDE

POTENTIAL HAZARDS

Backing
Flying debris
Moving equipment
Moving traffic
Noise
Temperature extremes

RELATED SAFE OPERATING GUIDES

Arrow Board, Trailer/Truck

Equipment Mounting and Dismounting

Field Incident Response
Traffic Variable Message Sign, Permanent
– Maintenance & Repair

Truck Mounted Attenuator
Truck, 1-2 Ton, Other
Dump

Revised: 3/22/99

"Colorado Department of Transportation Workplace Safety Manual" Section 0099.00 – Work Zone Safety, Traffic Control, Colorado Department of Transportation, December 15, 2008.

http://www.dot.state.co.us/WorkplaceSafetyManual/WP%20Safety%20Manual%20Intranet/WP%20Safety%20Manual%20-%20PDF/Safe%20Operating%20Guides/SOG%20Completed/Activities/0099.00.pdf