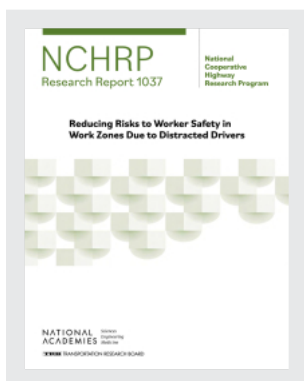


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Reducing Risks to Worker Safety in Work Zones Due to Distracted Drivers (2023)

DETAILS

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Evaluation of the Countermeasures

Methodology

The evaluation of each countermeasure used a simple comparison of distracted driving behaviors with and without each treatment deployed. The measure of effectiveness was driver visual attention (i.e., where drivers were looking immediately after they passed the countermeasure). Drivers who were looking directly forward at the roadway ahead (and not talking on their phones) were considered to have “undistracted” visual attention. When drivers were looking in the rear-view mirror, out the side window, at passenger(s), at a cellular phone, or down into the cab of the vehicle, their visual attention was considered “distracted.” While drivers’ cognitive distraction per se could not be measured within the scope and budget of this project, any drivers that were holding their cellular phone near their face (in a talking position) were included with the cellular phone distracted drivers. This type of distraction is likely underrepresented in the data because the use of Bluetooth-connected devices could not be discerned. In addition, if the data collectors could not discern driver attention from passing vehicles, these drivers were not included in the data.

Temporary Portable Rumble Strips

The Alabama Department of Transportation (ALDOT) had interest in assisting with the TPRS evaluation. While ALDOT maintenance crews do not widely use TPRSs, ALDOT Special Project Detail 2002-A shows how TPRSs can be used in the advance warning area, as shown in Figure 13.

During the week of February 28, 2022, data were collected in four different flagging operations along State Route 22 (a rural two-lane road) with and without the TPRSs deployed. ALDOT was performing tree-trimming work, so the flaggers and work vehicles moved around between the sets of advance warning signs located at each end of the work zone. No channelizing devices were used. Figure 14 shows how the advance warning area was modified when the TPRSs were removed, while Figure 15 shows images from one work zone with and without the TPRSs.

At each site, a team of two researchers simultaneously recorded distracted driving data near the “Road Work Ahead” sign (the “upstream” location) and immediately after the rumble strips, or TPRS position (the “downstream” location). Table 2 summarizes the observations.

The researchers first looked at the data collected at the upstream location of each TPRS site. Table 3 summarizes these data.

Two-proportion Z-tests were used for the analysis of the distracted drivers. The purpose of this analysis was to determine if there were any statistically significant differences in driver distraction rates at the upstream location (after drivers entered the work zone but before their

20 Reducing Risks to Worker Safety in Work Zones Due to Distracted Drivers

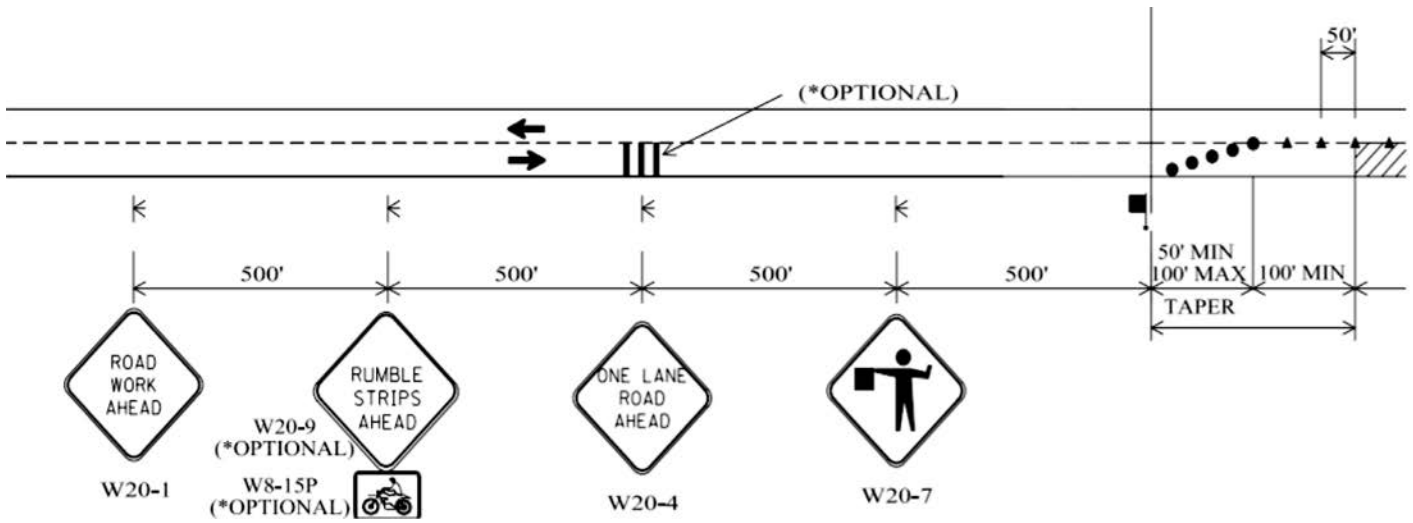


Figure 13. ALDOT Special Project Detail 2022-A (ALDOT 2018).

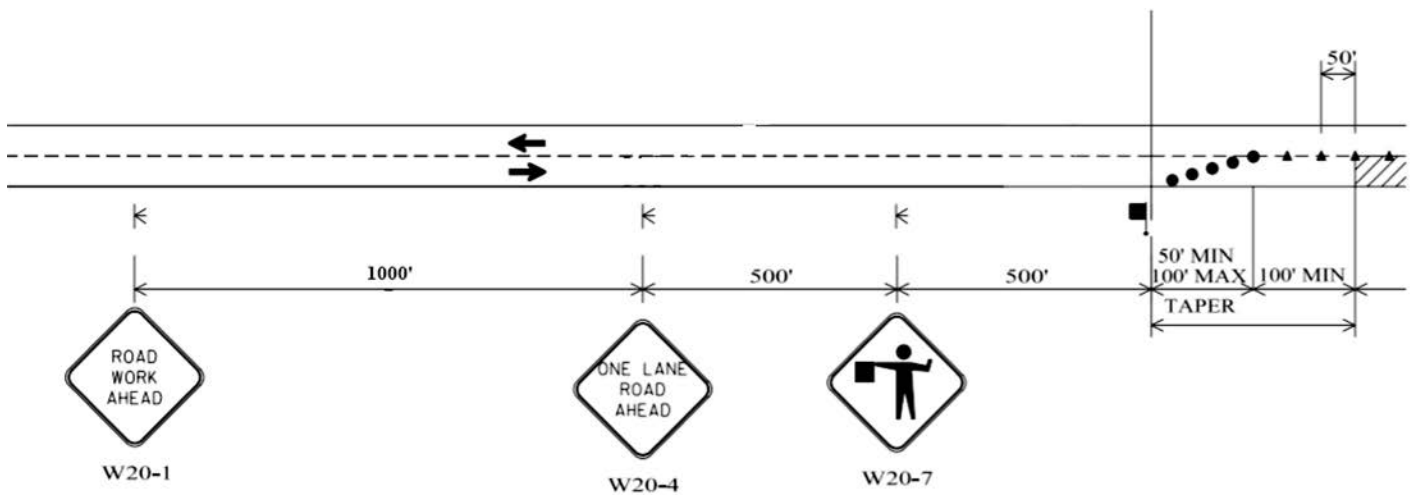


Figure 14. Modified advance warning area with TPRSs removed (ALDOT 2018, modified).



Figure 15. Site 1 with and without TPRSs.

Table 2. Data collection summary for the TPRS sites.

Site No.	Direction	Location Description	Posted Speed Limit (mph)	Number of Minutes of Data
1	Eastbound	West of County Road 100	55	251
2	Westbound	West of State Highway 49	45	250
3	Eastbound	East of County Road 17	55	264
4	Westbound	East of Georgia State Line	55	256

interaction with the TPRS). The hypothesis (H_0) was that the distracted driving percentages were the same at a 95 percent confidence interval ($\alpha = 0.05$). First, the pooled sample proportion (\hat{p}) for each site was calculated using the following formula for which x_1 = number of distracted drivers with treatment deployed, x_2 = number of distracted drivers without treatment deployed, n_1 = total number of drivers observed with treatment deployed, and n_2 = total number of drivers observed without treatment deployed:

$$\hat{p} = (x_1 + x_2) / (n_1 + n_2)$$

For site 1, $x_1 = 15$, $x_2 = 25$, $n_1 = 90$, $n_2 = 128$ and $\hat{p} = 0.183$ or 18.3 percent.

Next, the Z-test statistic (z) for each site was calculated by using the following formula:

$$z = (\hat{p}_1 - \hat{p}_2) / \sqrt{\hat{p} * (1 - \hat{p}) * \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}$$

For site 1, $\hat{p}_1 = x_1/n_1 = 15/90$ and $\hat{p}_2 = x_2/n_2 = 25/128$. Thus, $z = 0.5380$.

Then the Z-test statistic was converted to a p-value using a normal distribution probability function. The p-value can then be compared to $\alpha = 0.05$. If the p-value is greater than 0.05, then we fail to reject the hypothesis and the upstream percentages are the same (i.e., there is no statistically significant difference). Table 4 provides the results of this analysis and demonstrates that no differences in the distraction rates were found in the upstream data.

The researchers then looked at the data collected at the downstream location of each site with and without the TPRSs deployed. The total number of drivers observed does not exactly match the upstream data in Table 3 because:

- Vehicles may have entered or exited the advance warning area of the work zone between the upstream and downstream locations.

Table 3. Summary of TPRS data collected at upstream locations.

Site No.	TPRSs Deployed Downstream	Total No. of Drivers Observed	Number and Percentage of Distracted Drivers
1	Yes	90	15 (17%)
	No	128	25 (20%)
2	Yes	134	15 (11%)
	No	113	15 (13%)
3	Yes	84	14 (17%)
	No	110	18 (18%)
4	Yes	101	21 (21%)
	No	98	22 (22%)

Table 4. Results of TPRS statistical analysis of distracted drivers at upstream locations.

Site No.	Pooled Sample Proportion, \hat{p}	Z-test statistic, z	p-value	Statistically Significant Difference
1	18.3%	0.5380	0.5906	No
2	12.1%	0.4986	0.6180	No
3	17.2%	0.1763	0.8601	No
4	21.6%	0.2839	0.7765	No

- Some vehicles may have been missed at either location due to coordinated start and stop times for data collection.
- Driver attention may not have been discernable by one or both data collectors.

The researchers also noted whether the work operation (i.e., flagger, work vehicles, or queue traffic at the flagger station) was visible from the downstream position. Table 5 summarizes downstream location data.

The researchers calculated the percent change in distraction rates for each site with and without the TPRSs deployed (Table 6).

Considering the sample sizes of the data used to calculate each percentage, which ranged from 84 to 141 observations, an error in researcher categorization of distraction by as few as one or two drivers could have an impact on the change in percentage (Δp). Thus, the small increases of 1 percent in Table 6 are essentially negligible.

At site 1, the changes in percentages were insignificant. Both the upstream and downstream locations were in areas of similar roadside development, and the work operation was not visible from the downstream location during either data collection period. Table 7 shows a breakdown of the distracted driving behaviors observed at site 1. Differences in driver attention with and without the TPRSs present were not apparent at this site.

At site 2, roadside development was similar at both the upstream and downstream locations, and the work operation was not visible from the downstream location during either data collection period. While collecting data without the TPRSs present, the researchers noted that many of the distracted drivers appeared to be glancing at a recreational facility situated near the downstream location. This behavior was not as prevalent when the TPRSs were deployed. After ALDOT removed the work zone at the end of the workday, the researchers stayed behind to gather additional data without the work zone present. Even with a very small amount of data,

Table 5. Summary of TPRS data collected at downstream locations.

Site No.	TPRSs Deployed	Total No. of Drivers Observed	Number and Percentage of Distracted Drivers	Work Operation Visible
1	Yes	103	18 (18%)	No
	No	125	26 (21%)	No
2	Yes	136	16 (12%)	No
	No	130	34 (26%)	No
3	Yes	85	9 (11%)	Yes
	No	102	25 (25%)	No
4	Yes	107	17 (16%)	No
	No	96	22 (23%)	No

Table 6. Comparison of upstream and downstream distracted driving at TPRS sites.

Site No.	TPRSs Deployed	Upstream Percentage, p_1	Downstream Percentage, p_2	Change in Percentage, Δp
1	Yes	17%	18%	+1%
	No	20%	21%	+1%
2	Yes	11%	12%	+1%
	No	13%	26%	+13%
3	Yes	17%	11%	-6%
	No	18%	25%	+7%
4	Yes	21%	16%	-5%
	No	22%	23%	+1%

Table 7. Site 1 downstream distracted driving behavior details.

Work Zone Present	TPRSs Deployed	Number and Percentage of Distracted Drivers					Totals
		Looking Down	Looking Out Side Window	Looking in Mirror	Looking at Passenger	Using Cellular Phone ¹	
Yes	Yes	4 (22%)	5 (27%)	1 (6%)	1 (6%)	7 (39%)	18 (100%)
Yes	No	8 (31%)	8 (31%)	2 (8%)	1 (4%)	7 (27%)	26 (100%)

¹ Includes those looking at or talking on a cellular phone.

the researchers noted that glances at the recreational facility accounted for half of the distracted behaviors with no work zone present. Thus, the TPRSs may have had an impact on the distraction by the recreational facility at this site. Table 8 shows the breakdown of distracted behaviors at the downstream location at site 2.

At site 3, the downstream location was near the crest of a vertical curve. The site was also at the end of a long (approximately 2-mile) section with limited sight distance due to horizontal and vertical roadway curvature. As drivers came over the hill, they entered a long, straight section of roadway where they could see a significant distance ahead. During the data collection period with the TPRSs deployed, the flagger, work vehicles, and any queued traffic at the flagger station were located near the downstream location and could easily be seen by approaching drivers. During the data collection period without the TPRSs deployed, the work operation was not visible from the downstream location. This likely impacted the distracted driving behaviors recorded at the downstream location of site 3. Table 9 shows the breakdown of distracted behaviors at the downstream location at site 3.

At site 4, drivers approaching the work zone were just crossing the Georgia state line into Alabama. For several miles upstream of the work zone, there was no commercial or retail

Table 8. Site 2 downstream distracted driving behavior details.

Work Zone Present	TPRSs Deployed	Number and Percentage of Distracted Drivers					Totals
		Looking Down	Looking Out Side Window	Looking in Mirror	Looking at Passenger	Using Cellular Phone ¹	
Yes	Yes	3 (19%)	6 (38%)	0 (0%)	1 (6%)	6 (38%)	16 (100%)
Yes	No	8 (24%)	17 (50%)	1 (3%)	2 (6%)	6 (18%)	34 (100%)
No	N/A	1 (14%)	4 (50%)	0 (0%)	1 (13%)	2 (25%)	8 (100%)

¹ Includes those looking at or talking on a cellular phone.

Table 9. Site 3 downstream distracted driving behavior details.

TPRSs Deployed	Number and Percentage of Distracted Drivers					Totals
	Looking Down	Looking Out Side Window	Looking in Mirror	Looking at Passenger	Using Cellular Phone ¹	
Yes	4 (44%)	2 (22%)	0 (0%)	1 (11%)	2 (22%)	9 (100%)
No	9 (36%)	12 (48%)	0 (0%)	2 (8%)	2 (8%)	25 (100%)

¹ Includes those looking at or talking on a cellular phone.

roadside development, the clear zone of the roadway was rather narrow, as Figure 16 shows. As drivers passed the rumble strips, they encountered a wider view and a busy convenience store, as Figure 17 shows. The work operation was not visible during either data collection period.

As with site 2, the researchers noticed that many drivers were distracted by the convenience store when the TPRSs were not present. Thus, a small amount of data was collected after ALDOT removed the work zone at the end of the workday. Table 10 shows the breakdown of distracted behaviors at the downstream location at site 4. It does appear that the TPRSs had an impact on the distraction by the convenience store located at this site.

Overall, the results show that TPRSs likely did reduce the visual distractions at two of the sites (i.e., the recreational facility at site 2 and the convenience store at site 4), but not at the other two sites. In addition, potential site-specific reasons for the lack of an effect of those sites have been presented.



Figure 16. Roadside development upstream of the work zone at site 4.



Figure 17. Roadside development near the downstream location at the site 4 work zone.

Table 10. Site 4 downstream distracted driving behavior details.

Work Zone Present	TPRSs Deployed	Number and Percentage of Distracted Drivers					Totals
		Looking Down	Looking Out Side Window	Looking in Mirror	Looking at Passenger	Using Cellular Phone ¹	
Yes	Yes	6 (35%)	6 (35%)	1 (6%)	0 (0%)	4 (24%)	17 (100%)
Yes	No	0 (24%)	20 (91%)	0 (0%)	0 (0%)	2 (9%)	22 (100%)
No	N/A	0 (14%)	5 (71%)	0 (0%)	0 (0%)	2 (29%)	7 (100%)

¹ Includes those looking at or talking on a cellular phone.

“Watch for Workers When Flashing” Warning Sign

The research team explored options for deploying a “Watch for Workers When Flashing” warning sign that included flashing lights indicating that the message was in effect. During past research efforts, the research team found that LED-style lights, which are very directional, may have reduced attention-getting capability when mounted on temporary portable sign stands such as those used with flexible roll-up signs, particularly in windy conditions (Theiss et al. 2022). Thus, for this research effort, the researchers pursued identification of rigid sign stands that are portable and already incorporate flashing lights, such as the sign shown in Figure 1. Researchers worked with a traffic control vendor to modify the sign, replacing the “Trucks Entering Roadway” warning sign with a “Watch for Workers” warning sign. The work truck detection system was disabled to allow the flashing lights to remain on continuously while researchers collected driver observation data.

During the week of March 14, 2022, data were collected in four different work zones located in the TxDOT Fort Worth District. All the work zones consisted of lane closures on multi-lane, divided highways, which used the TxDOT standard Traffic Control Plan (TCP) shown in Figure 18.

Distracted driving data were recorded with and without the “Watch for Workers When Flashing” sign deployed. Figure 19 shows how the advance warning area was modified when the sign was deployed. Figure 20 shows images from one work zone with and without the sign.

At each site, a team of two researchers simultaneously recorded distracted driving data near the “Road Work Ahead” sign (the upstream location) and immediately after the “Watch for Workers When Flashing” sign (the downstream location). Table 11 summarizes the observations.

At site 8, the researchers captured driver distraction data with the “Watch for Workers When Flashing” sign deployed. After the sign was removed, traffic congestion developed, and no data were collected without the sign deployed. Thus, site 8 data could not be used in the analysis. Table 12 summarizes the data collected at the upstream location of each of the remaining sites.

The two-proportion Z-tests were again used for the analysis of the distracted drivers at the upstream location for this treatment. Table 13 shows the results of this analysis, which demonstrates that no differences in the distraction rates were found in the upstream data.

The researchers then looked at the data collected at the downstream location of each site with and without the “Watch for Workers When Flashing” warning sign deployed. The researchers also noted whether the work operation (i.e., workers, work activity, or work vehicles) was visible from the downstream position. Table 14 summarizes the downstream location data.

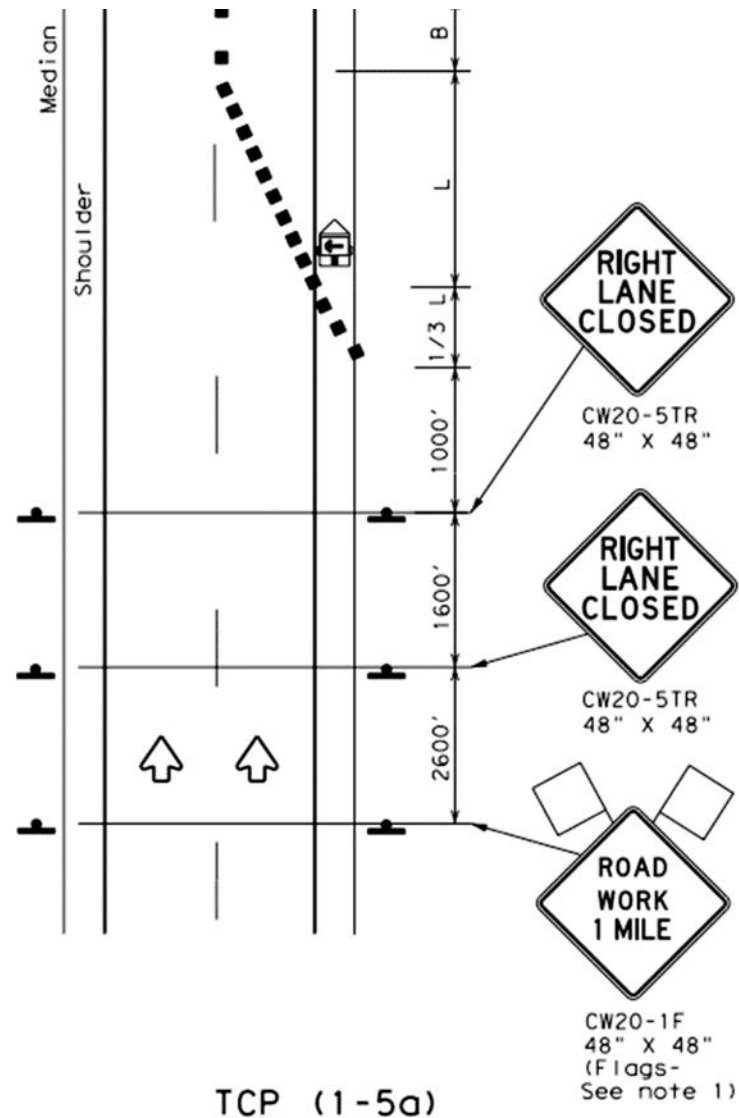


Figure 18. TxDOT TCP (1-5a) lane closure used at sites 6 and 7 (TxDOT 2018).

The researchers calculated the percent change in distraction rates for each site with and without the “Watch for Workers When Flashing” warning sign deployed (Table 15).

At site 5, the upstream location was near an entrance ramp on a freeway with three lanes in the direction of the single lane closure. Distracted driving data were recorded at the upstream location only for vehicles in the right lane (or third lane) since the “Watch for Workers When Flashing” warning sign was located on the right side of the road at the downstream location. When the “Watch for Workers When Flashing” warning sign was deployed, it was located between the first and second advance warning signs (see Figure 19). The work operation was not visible from the downstream location during either data collection period. The data in Table 15 appear to show slight increases in the percentage of distracted driving behaviors at the downstream location, although the increase was greater when the sign was not present. The researchers looked at the breakdown of distracted driving behaviors, which Table 16 shows. The distribution of the various behaviors appears to be very similar, regardless of the presence of the “Watch for Workers When Flashing” warning sign.

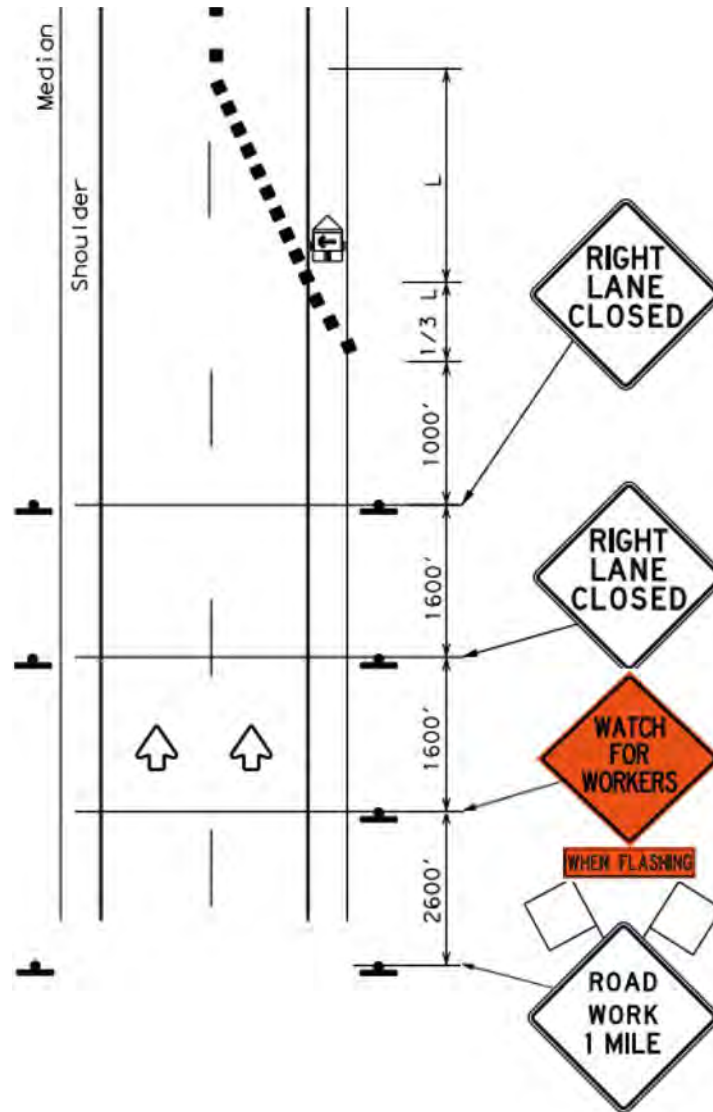


Figure 19. TxDOT TCP 1-5(a) lane closure on divided highways used at site 5 (TxDOT 2018, modified).



Figure 20. Site 6 with and without a "Watch for Workers When Flashing" sign.

Table 11. Data collection summary for the “Watch for Workers When Flashing” sign.

Site No.	Roadway	Direction	Location Description	Posted Speed Limit (mph)	Number of Minutes of Data
5	Interstate 30	Eastbound	East of Ridgmar Blvd.	65	60
6 ¹	State Highway 303	Westbound	West of State Highway 161	45	74
7 ¹	State Highway 303	Westbound	West of State Highway 161	45	65
8	Interstate 35	Northbound	South of US 67	70	47

¹ Site 6 was a double-right-lane closure, and site 7 was a double-left-lane closure at approximately the same location.

Table 12. Summary of “Watch for Workers When Flashing” warning sign data collected at upstream locations.

Site No.	WFWWF ¹ Warning Sign Deployed Downstream	Total No. of Drivers Observed	Number and Percentage of Distracted Drivers
5	Yes	441	84 (19%)
	No	426	84 (20%)
6	Yes	352	82 (23%)
	No	289	67 (23%)
7	Yes	266	42 (15%)
	No	204	41 (20%)

¹ WFWWF = “Watch for Workers When Flashing.”

Table 13. Results of “Watch for Workers When Flashing” warning sign statistical analysis of distracted drivers at upstream location.

Site No.	Pooled Sample Proportion, \hat{p}	Z-test statistic, z	p-value	Statistically Significant Difference
5	19.4%	0.2498	0.8028	No
6	23.2%	0.0334	0.9733	No
7	19.4%	0.3538	0.7235	No

Table 14. Summary of “Watch for Workers When Flashing” warning sign data collected at downstream locations.

Site No.	WFWWF ¹ Warning Sign Deployed	Total No. of Drivers Observed	Number and Percentage of Distracted Drivers	Work Operation Visible
5	Yes	449	103 (23%)	No
	No	447	115 (26%)	No
6	Yes	344	82 (23%)	No
	No	287	67 (23%)	No
7	Yes	274	42 (15%)	Yes
	No	217	49 (23%)	Yes

¹ WFWWF = “Watch for Workers When Flashing.”

Table 15. Comparison of upstream and downstream distracted driving at “Watch for Workers When Flashing” warning sign sites.

Site No.	WFWWF ¹ Warning Sign Deployed	Upstream Percentage, p_1	Downstream Percentage, p_2	Change in Percentage, Δp
5	Yes	19%	23%	+4%
	No	20%	26%	+6%
6	Yes	23%	23%	0%
	No	23%	23%	0%
7	Yes	15%	15%	0%
	No	20%	23%	+3%

¹ WFWWF = “Watch for Workers When Flashing.”

Table 16. Site 5 downstream distracted driving behavior details.

WFWWF ¹ Warning Sign Deployed	Number and Percentage of Distracted Drivers					Totals
	Looking Down	Looking Out Side Window	Looking in Mirror	Looking at Passenger	Using Cellular Phone ²	
Yes	26 (25%)	12 (12%)	8 (8%)	13 (13%)	44 (43%)	103 (100%)
No	24 (21%)	15 (13%)	7 (6%)	17 (15%)	52 (45%)	115 (100%)

¹ WFWWF = “Watch for Workers When Flashing.”

² Includes those looking at or talking on a cellular phone.

At site 6, the upstream location was near an intersection with a tollway frontage road. Distracted driving data were recorded at the upstream location only for all vehicles, regardless of which of the three lanes they were using. The work zone consisted of a double-right-lane closure for milling work, so all traffic was in a single (left) lane upon reaching the downstream location. The “Watch for Workers When Flashing” warning sign was deployed close to the work area. On this day, the work operation was not visible from the downstream data collection location during the data collection. Table 15 shows no differences in distracted driving behaviors with or without the “Watch for Workers When Flashing” warning sign deployed.

Site 7 data were collected at the same upstream and downstream locations as site 6 on the following day, except the contractor was using a double-left-lane closure to continue the milling and begin the overlay work. When the “Watch for Workers When Flashing” warning sign was deployed, the milling equipment was visible from the downstream data collection location. After the sign was removed, the researchers began to collect data without the warning sign deployed. Before that effort could be completed, the contractor began unloading equipment near the downstream location. This likely impacted the distracted driving behaviors recorded at the downstream location, as Table 17 shows.

Overall, then, the challenges experienced at the sites when attempting to evaluate this particular treatment limits what can be confidently concluded. The data from sites 5 and 7 suggest that the sign may have a small positive effect on distraction in some cases.

Table 17. Site 7 downstream distracted driving behavior details.

WFWWF ¹ Warning Sign Deployed	Number and Percentage of Distracted Drivers					Totals
	Looking Down	Looking Out Side Window	Looking in Mirror	Looking at Passenger	Using Cellular Phone ²	
Yes	14 (33%)	12 (29%)	0 (0%)	1 (3%)	15 (36%)	42 (100%)
No	7 (14%)	17 (35%)	0 (0%)	3 (6%)	22 (45%)	49 (100%)

¹ WFWWF = “Watch for Workers When Flashing.”

² Includes those looking at or talking on a cellular phone.