Case Study of an Alternative Merging Sign Design for Temporary Traffic Control in Work Zones

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ABSTRACT

Signage plays an important role in work zones to provide guidance to drivers under changed conditions. This study investigated the safety effect of an alternative merge sign configuration in a freeway work zone. In this alternative configuration, the graphical-only lane closed sign from the Manual on Uniform Traffic Control Devices (MUTCD) was compared against a MERGE/arrow sign on one side and a RIGHT LANE CLOSED sign on the other side. Although the graphical-only MUTCD signage for work zones has been in use for several years, it is not known if the signage recommended by the MUTCD offers the highest safety for all jurisdictions. The study measured driver behavior characteristics including speeds and open lane occupancies. The measurements were taken at a work zone on Interstate 70 in Missouri. The study found that the open lane occupancy upstream of the merge sign was higher for the test sign in comparison to the MUTCD sign. The occupancy values at different distances between the merge sign and the taper were similar for both signs. The test sign had 11% more traffic in the open lane upstream of the merge sign. In terms of safety, it is desirable for vehicles to occupy the open lane as far upstream from the taper as possible to avoid conflicts due to the lane drop. The analysis of speed characteristics did not reveal substantial differences between the two sign configurations. The 85th percentile speeds with the MUTCD sign were only 1 mph and 2 mph lower than the test sign at the merge sign and taper locations, respectively. In considering all the aforementioned performance measures, the alternative sign configuration was not superior, but performed equal to the MUTCD sign configuration.

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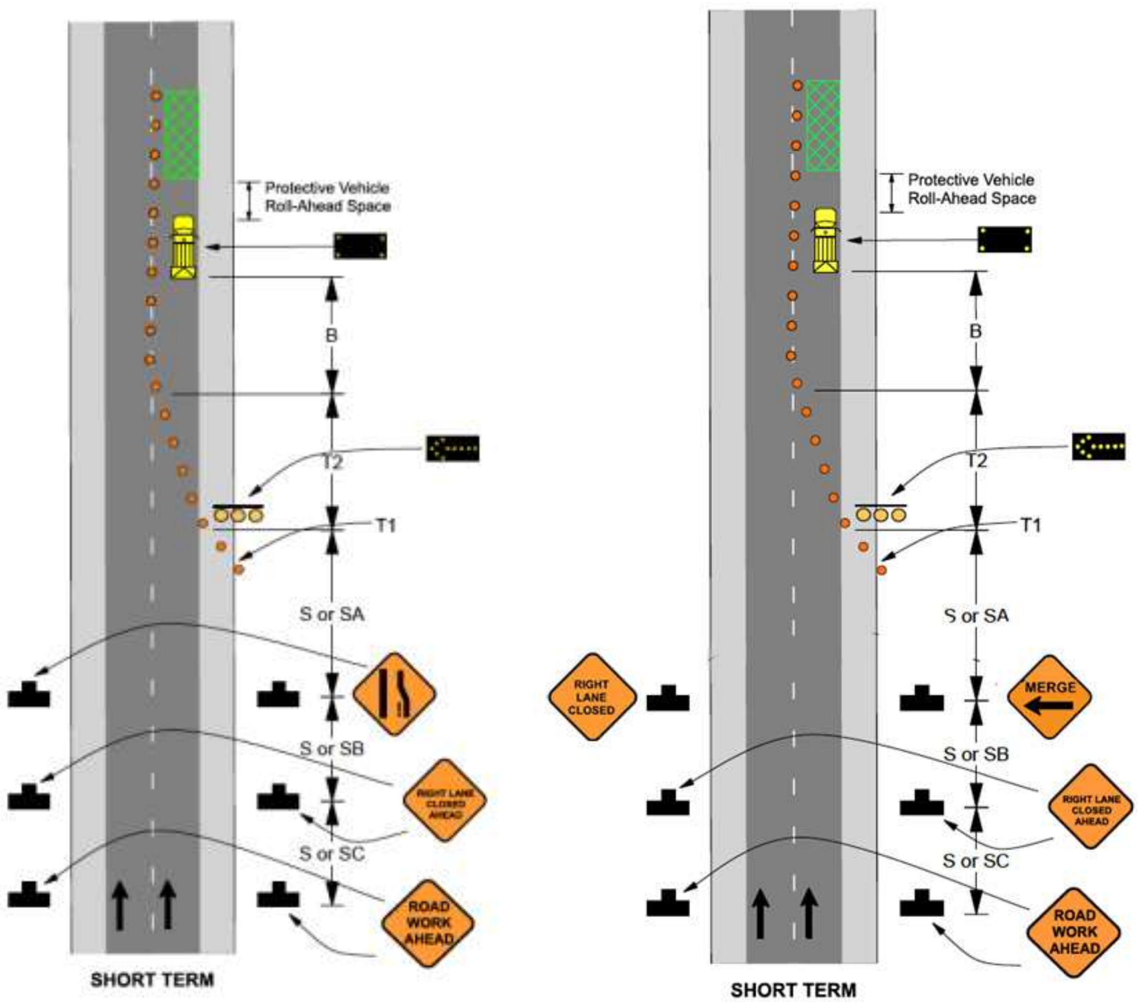
INTRODUCTION

Roadway construction and maintenance activities often involve lane closures that require vehicles to merge from closed lanes. A temporary traffic control (TTC) plan consisting of directions on the type of signage and their locations in a work zone is used to warn and guide drivers through a work zone. The Manual on Uniform Traffic Control Devices (MUTCD) (FHWA 2009) provides guidance on TTC plans for both short-term and long-term work zones. The MUTCD TTC plan used by the Missouri Department of Transportation (MoDOT) for a freeway work zone is shown in Figure 1(a).

The signage used in the advance warning area of a work zone provides critical information to drivers such as which lane is closed, when to merge, reduced speed limits, and other information. These types of information are critical to the overall safety of the work zone. One study, by Srinivasan et al. (2008) in Florida showed that approximately 34% of all work zone crashes occurred in the advance warning area of a work zone. In another study, Ishak et al. (2012) found that the advance warning area exhibited the highest crash rates in an entire work zone. Thus, effective signage that provides appropriate guidance in the advance warning area of a work zone is critical for traffic safety. A review of the existing literature did not reveal any studies investigating the effectiveness of different static merge signs in work zones. Studies of alternative signage for non-work zone conditions are also limited. A study conducted by Feldblum (2005) for the Connecticut DOT researched a new static merge sign at lane drops immediately downstream of a signalized intersection. The sign differed from the standard MUTCD graphical lane drop sign (see Figure 1(a)) in that it required alternating merges from both lanes. A rating system was developed based on visual inspection of the speed changes of merging vehicles. A vehicle received a higher rating if it experienced a lower speed change during merging. The study found that the alternating merge sign received a better overall rating from survey respondents than did the MUTCD sign.

Although the MUTCD TTC signage for work zones has been in use for several years, it is not known if the signage recommended by the MUTCD offers the highest safety for all jurisdictions. Investigating the safety performance of alternative signage in work zones and comparing it with the performance of the MUTCD signage is of value to both transportation agencies and drivers. In this study, one alternative merging sign configuration was investigated and its performance compared with the performance of the standard MUTCD signage. Section 6F.24 of the MUTCD recommends using W4-2 sign before the taper to advise approaching drivers of the lane reduction. In the alternative configuration, the MUTCD graphical lane closed sign shown in Figure 1 (a) is replaced with a MERGE/arrow sign on the closed-lane side and a RIGHT LANE CLOSED sign on the other side, as shown in Figure 1(b). In Figure 1, SA, SB, SC, T1, T2, and B refer to distances between signs or taper lengths, and are computed based on the road type, offset, and posted speed. In order to test the new signage in the field, a MUTCD request for experimentation was submitted by MoDOT and approved by FHWA in early 2013.

To accomplish the study objective of comparing the performance of the MUTCD and the test signage, field studies were conducted at a work zone site on Interstate 70 (I-70) in Missouri. Video monitoring was used to observe vehicle merge locations, and radar guns were used to collect vehicle speeds. The field data was analyzed, and several measures of effectiveness were extracted. These measures included the distribution of traffic in the open and closed lanes at various distances from the taper; 85th percentile speeds; mean speeds; and speed variance. It is not atypical in work zone research to test new signage, and other novel traffic control concepts at a limited number of sites. For example, Beacher et al (2005) field-tested the late merge traffic control strategy at one site in Virginia, Heaslip et al (2010) evaluated the effectiveness of portable rumble strips to improve truck safety on a closed course in Kansas, and Sun et al. (2011) tested portable rumble strips at one work zone location in Missouri.



(a) Missouri MUTCD-based **(b) Test merge sign**

FIGURE 1 Temporary traffic control plan for stationary lane closure on divided highway.

This paper first explains the field studies conducted to compare the effectiveness of the new merge sign ('test' sign) and the MUTCD sign. It then presents the methodology used to analyze the field data, followed by the results of various measures of effectiveness. Conclusions are then drawn based on the study findings.

FIELD STUDIES

Site Description

A short-term work zone involving a left lane closure on a two-lane segment of westbound I-70 near Boonville, MO was tested in this study. The work activity involved patching the bridge deck over the Lamine River. The work zone and temporary traffic control plan was set in place at 9:00 am and removed at 3:00 pm. The two data collection periods occurred at the same location and at approximately the same time of day on different days. Data collection occurred between 11:30 am and 2:00 pm. Weather conditions were sunny and clear on both days. In accordance with the TTC plan, merge signs were placed 1,000 feet upstream of the taper. The new static text merge sign, (hereafter referred to as the "test sign"), was tested on April 22nd, 2013, Monday; the MUTCD graphical sign was tested on April 25th, 2013, Thursday.

Figure 2 shows the configuration of the data collection setup. One radar gun was placed at the merge sign, and another radar gun was placed near the taper in order to capture longitudinal speed changes for individual vehicles. Three cameras covered the entire study area, as shown in Figure 2.

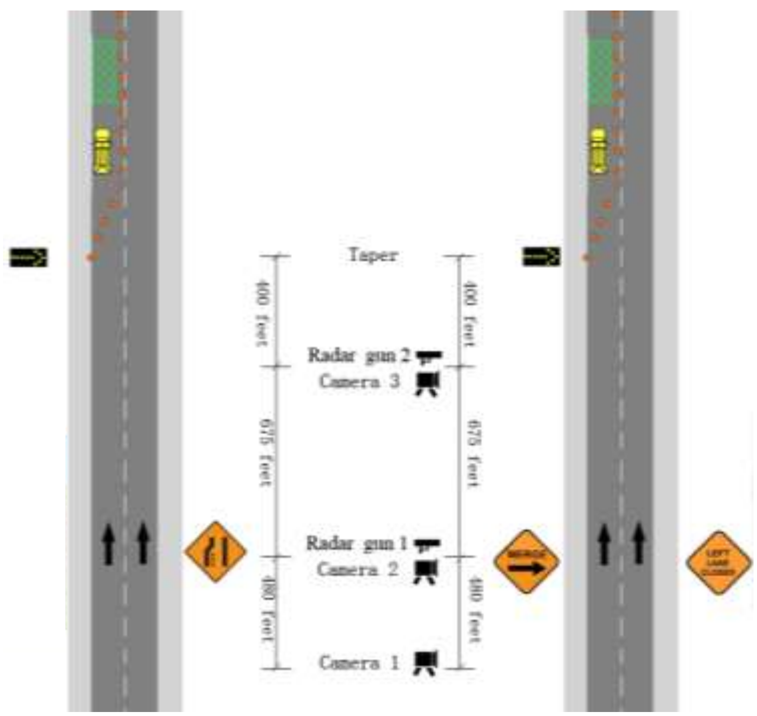


FIGURE 2 Data collection setup for MUTCD (left) and Test sign.

Camera 1 was located 480 feet upstream of the merge sign, and was raised 20 feet above the ground. This camera captured merge location data to determine where vehicles merged into the open lane. A radar gun and Camera 2 recording the speeds captured by the radar was placed at the merge sign location. The radar gun was positioned so that it would begin recording vehicles from both lanes near the merge sign. The camera coverage was also used to obtain merge location data for locations up to approximately 600 feet downstream of the merge sign. A radar gun capturing speeds at the beginning of the taper was deployed, along with Camera 3 to record its display. This camera coverage was used to obtain merge location data 400 feet upstream from the taper. All three cameras were shooting in the direction towards the taper.

Camera clocks were synchronized so that individual vehicle maneuvers could be monitored through the three cameras.

METHODOLOGY

Open Lane Occupancy

Open lane occupancy, defined as the proportion of total traffic in the open lane on a road segment, was computed at segments upstream and downstream of the merge sign. The location of a vehicle merge was recorded if it occurred within any of the three camera views described in the previous section. Every vehicle was tracked individually through the area between Camera 1 and the end of the taper, and the area was divided into six zones or segments for analysis. Figure 3 shows the six zones that were created. Whenever a vehicle merged from the left lane to the right lane, the zone in which the merging maneuver occurred was recorded.

Five delineators were used to identify the six zones in the camera coverage. Delineators were placed at 200 foot intervals for a distance of 400 feet upstream and 600 feet downstream from the merge sign. As shown in Figure 3, Zone 1 was between the two delineators farthest from the merge sign, and Zone 2 was between the delineator just upstream and the merge sign. Zone 3 was the area between the merge sign and the third delineator. Zone 4 covered the distance between the third and fifth delineators, 400 feet upstream of camera 3. Zone 5 included the distance between the fifth delineator and the beginning of the taper. Zone 6 covered the area beyond Zone 5 to the end of the taper. Lane occupancy differences were tested statistically using a standard z test because the differences were normally distributed (Milton and Arnold 2007).

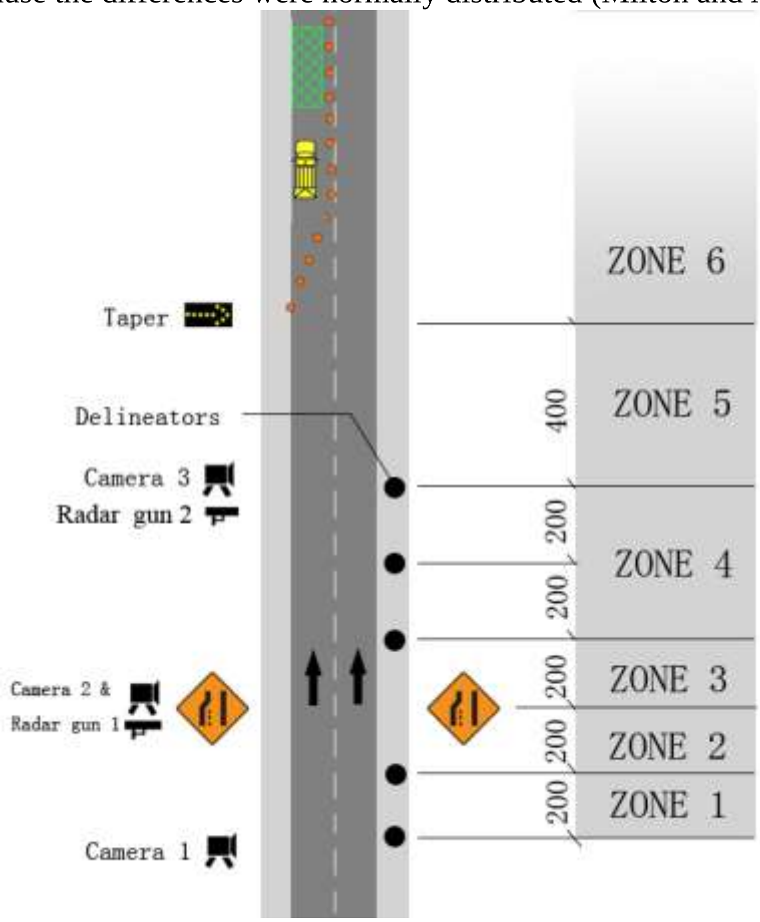


FIGURE 3 Lane occupancy analysis zones.

Speed-Based Measures

Vehicle speeds were recorded at two locations: at the merge sign, 1,000 feet upstream from the taper, and 400 feet upstream from the taper. Speed statistics such as mean speed, standard deviation, and 85th percentile speed were compared statistically between the two different merge sign configurations. The standard t-test was used for comparing means, and the F-test was used to compare variances. The magnitude of the difference in mean speeds between the MUTCD sign and the test sign was tested using an effect size test (Coe 2002). The effect size test thus complements the t-test. The 85th percentile speed was also calculated to determine whether vehicles were compliant with speed limits. The 85th percentile speeds across different merge sign configurations were statistically compared using a percentile test described in Hou et al. (2012). Speed differential between the merge sign and the beginning of the taper were calculated for each vehicle. A standard t-test was used to test the statistical difference of the speed differentials.

Description of Statistical Tests

The various statistical tests used in this study are briefly described below. The two sample t-test is commonly used for testing the statistical difference in the means of two data sets. Thus, the t-test can be used to identify differences in the means that are due to randomness. Assuming the two data sets are independent and are from a normal distribution, the t-test for unequal variance is presented as:

$$\text{Degrees of freedom: } \nu = \frac{\left(\frac{s_y^2}{n_y}+\frac{s_x^2}{n_x}\right)^2}{\frac{\left(\frac{s_y^2}{n_y}\right)^2}{n_y-1}+\frac{\left(\frac{s_x^2}{n_x}\right)^2}{n_x-1}}$$

$$\text{The test statistic is: } t = \frac{\bar{y}-\bar{x}}{\sqrt{\frac{s_y^2}{n_y}+\frac{s_x^2}{n_x}}}$$

Reject the null hypothesis if $|t| > t_{\nu,\alpha/2}$ or p-value < $\alpha/2$

where,

n is the sample size for the two data sets, x and y α is the user-selected significance level;

$\bar{y}$ *and* $\bar{x}$ are sample means $\bar{y} = \frac{\sum_{i=1}^{n_y} y_i}{n_y}$, $\bar{x} = \frac{\sum_{i=1}^{n_x} x_i}{n_x}$;

s_y^2 *and* s_x^2 are sample variances $s_y^2 = \frac{1}{n_y-1}\sum_{i=1}^{n_y}(y_i-\bar{y})^2$;

$t_{\nu,\alpha/2}$ is the upper critical point of a t distribution.

Similar to a t-test, the F-test is used to test the statistical significance of the difference in variance between two data sets. A large deviation of F from the value of 1.0 signifies that the difference in variance is significant and not due to randomness.

$$\text{The test statistic is: } F = \frac{s_y^2}{s_x^2}$$

The null hypothesis is rejected (i.e., there is a statistically significant difference in variances) if $F > f_{(n_y-1,n_x-1,\frac{\alpha}{2})}$ or $F < f_{(n_y-1,n_x-1,1-\frac{\alpha}{2})}$ where $f_{(n_y-1,n_x-1,\frac{\alpha}{2})}$ is the upper $\alpha/2$ critical point of an F-distribution with $n_y - 1$ and $n_x - 1$ degrees of freedom.

where, α is the user-selected significance level.

The effect size and 85th percentile tests are not as commonly used in transportation as the t-test and F-test. Cohen's d (Cohen 1988) is a standardized difference in means, which can be used as an effect size statistic. It helps analyze the magnitude of the difference on a standardized scale.

$$effect\ size = \frac{\bar{x}-\bar{y}}{s}$$

where,

$\bar{y}$ *and* $\bar{x}$ are sample means $\bar{y} = \frac{\sum_{i=1}^{n_y} y_i}{n_y}$, $\bar{x} = \frac{\sum_{i=1}^{n_x} x_i}{n_x}$

$s = \sqrt{\frac{(n_y-1)s_y^2+(n_x-1)s_x^2}{(n_y-1)+(n_x-1)}}$ is pooled sample standard deviation

The 85th percentile test was presented in Hou et al. (*10*) to test the statistical significance of 85th percentiles between two datasets. The 85th percentile test is analogous to the t-test for means.

The test statistic is:

$$\frac{X_{([n0.85]+1)}-Y_{([n0.85]+1)}}{1.530\sqrt{\frac{s_y^2}{n_y}+\frac{s_x^2}{n_x}}}$$

where,

$X_{([n0.85]+1)}$ and $Y_{([n0.85]+1)}$ are the 85th sample percentiles of two independent random samples;

s_y^2 *and* s_x^2 are sample variances $s_y^2 = \frac{1}{n_y-1}\sum_{i=1}^{n_y}(y_i-\bar{y})^2$;

n_y and n_x are sample sizes.

A proportion is a count of a certain category divided by the entire sample size, such as truck percentages, lane occupancies, etc. When the sample size is large, the test statistic is distributed close to the standard normal distribution:

Pooled proportion of two samples: $\hat{p} = \frac{n_1\hat{p}_1+n_2\hat{p}_2}{n_1+n_2}$

Reject null hypothesis $p_1 = p_2$ if $\left|\frac{\hat{p}_1-\hat{p}_2-0}{\sqrt{\hat{p}(1-\hat{p})(\frac{1}{n_1}+\frac{1}{n_2})}}\right| > z_{\alpha/2}$

where,

$\hat{p}_1$ *and* $\hat{p}_2$ are the sample proportions. e.g. $Truck\% = \frac{truck\ counts}{Total\ vehicle\ counts}$;

n_1 and n_2 are sample sizes;

$z_{\alpha/2}$ is the upper critical point of a standard normal distribution;

α is the user-selected significance level.

RESULTS

Merge Location Analysis

Over 2000 vehicles were individually tracked for the two configurations, and their traffic characteristics are shown in Table 1. The traffic flow conditions on both data collection days were similar, at 652 vph and 694 vph. The relatively low flows imply that the performance measures were not dominated by traffic interactions and reflect driver reactions to the merge signage. Both the total number of vehicles and the percentage of trucks were slightly higher on the second day with the MUTCD configuration than on the first day with the test sign configuration. In order to assess the effect of different truck percentages, passenger vehicles and trucks were also analyzed separately. In this study, trucks were defined as all vehicles other than motorcycles, buses, and passenger cars with one- or two-axle trailers, including light pickups and minivans. Thus, trucks included single unit trucks and semi- and full tractor-trailers as classified by FHWA (TXDOT 2001).

TABLE 1 Traffic Volume and Composition for Sign Setups

	Test Sign	MUTCD Sign
Total Number of Vehicles	978	1041
Flow (vph)	652	694
Number of Passenger Cars	707	666
Number of Trucks	271	375
Truck percentage	27.7%	36.0%

The low traffic volumes at the work zone site did not pose any operational issues in terms of delays or queuing. Thus, the merging locations of vehicles did not have any significant effect on operational performance. In terms of safety during uncongested flow, it is desirable to have vehicles occupy the open lane as far upstream of the taper as possible to avoid merging conflicts near the taper. The cumulative open lane occupancies of seven different zones are shown in Table 2. At the start of Zone 1, the test sign saw 81% occupancy in the open lane, compared to 75% occupancy for the MUTCD sign. This 6% increase in open lane occupancy is desirable in terms of safety, because it means fewer vehicles will have to merge from the closed lane. The open lane occupancy for the test sign continued to be higher than that of the MUTCD sign until the merge sign location. Past the merge sign, however, the cumulative open lane occupancies for both sign configurations were equal.

TABLE 2 Cumulative Open Lane Occupancy at Different Locations (All Vehicles)

Location	Distance from Merge Sign	Test Sign	MUTCD Sign	Difference	p-value
Start of Zone 1	400 ft upstream	81%	75%	6%	0.0004
End of Zone 1	200 ft upstream	82%	77%	5%	0.0022
End of Zone 2	At the merge sign	84%	82%	1%	0.1999
End of Zone 3	200 ft downstream	87%	87%	0%	0.4739
End of Zone 4	600 ft downstream	93%	93%	0%	0.4809
End of Zone 5	1000 ft downstream (Start of taper)	96%	96%	0%	0.4389
End of Zone 6	End of taper	100%	100%		

This trend is also evident in Figure 4, which shows the open lane occupancies at five locations. The five locations included: 1) 400 feet upstream of the merge sign, 2) at the merge sign, 3) 600 feet downstream of the merge sign, 4) at the start of the work zone taper, and 5) at the end of the work zone taper.

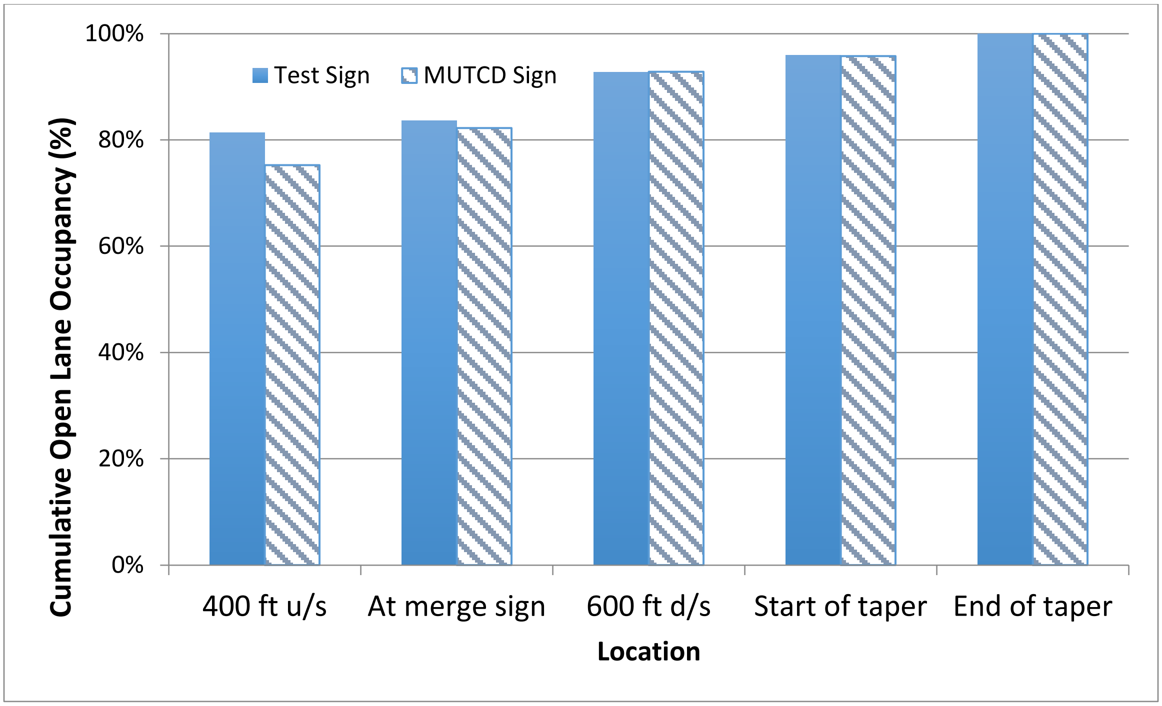


FIGURE 4 Open lane occupancies (all vehicles).

The results displayed in Figure 4 and Table 2 represent all vehicles observed during the data collection period. The vehicle population was separated into passenger cars and trucks to investigate any differences in merging behavior across the two vehicle types. The effects of each sign setup on passenger cars are shown in Table 3 and Figure 5. The open lane occupancies at all locations until the beginning of the taper were higher for the test sign than for the MUTCD sign. The highest occupancy differences, of 11% and 10%, were observed at the two upstream locations.

TABLE 3 Cumulative Open Lane Occupancy at Different Locations (Passenger Cars)

Location	Distance from Merge Sign	Test Sign	MUTCD Sign	Difference	p-value
Start of Zone 1	400 ft upstream	77%	66%	11%*	0.0000
End of Zone 1	200 ft upstream	78%	68%	10%*	0.0000
End of Zone 2	At the merge sign	80%	76%	4%*	0.0391
End of Zone 3	200 ft downstream	84%	82%	2%	0.1257
End of Zone 4	600 ft downstream	92%	90%	2%	0.1172
End of Zone 5	1000 ft downstream (Start of taper)	95%	94%	1%	0.1347
End of Zone 6	End of taper	100%	100%		

* statistically significant at 95% confidence level

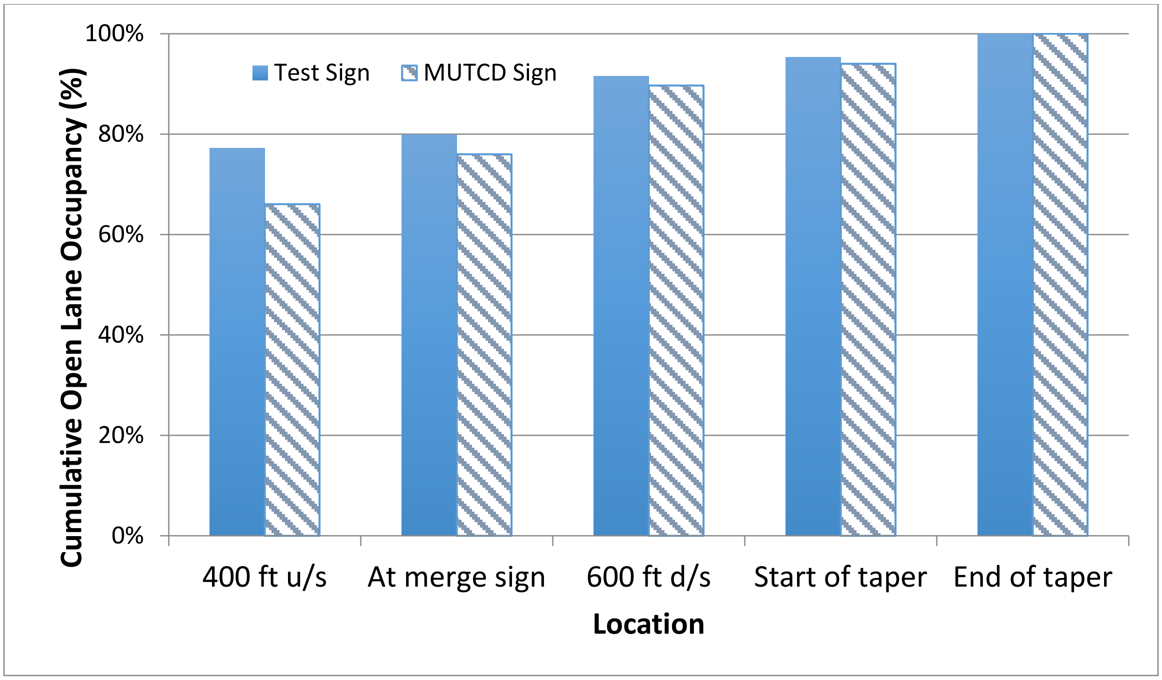


FIGURE 5 Open lane occupancies (passenger cars).

The open lane occupancies for trucks are shown in Table 4 and Figure 6. The occupancies at all locations were higher than those observed for passenger cars for both sign setups. A few likely reasons are offered for the observed safer merging behavior of trucks as compared to passenger cars. Typically, most commercial trucks trips are work-related, and drivers are thus more likely to adopt safer driving practices, such as compliance with the speed limit and early merging. Although sight distance was not a problem at the study site, the higher line of sight for truck drivers in comparison to passenger car drivers helps truck drivers to detect signage sooner, thus encouraging earlier merges. Trucks also tend to remain in the right lane except when passing. Due to the work-related nature of truck trips, drivers also receive traveler information through additional means such as radio communications and third-party navigation sources that may lead to early merging. The differences in occupancies across the two signs were not as discernable for trucks as they were for passenger cars. Upstream of the merge sign, the performance of the test sign was slightly better than or the same as the MUTCD sign. This trend reversed downstream of the merge sign, where the performance of the MUTCD sign was slightly better than or the same as that of the test sign.

TABLE 4 Cumulative Open Lane Occupancy at Different Locations (Trucks)

Location	Distance from Merge Sign	Test Sign	MUTCD Sign	Difference	p-value
Start of Zone 1	400 ft upstream	92%	91%	1%	0.3600
End of Zone 1	200 ft upstream	92%	92%	0%	0.4535
End of Zone 2	At the merge sign	93%	93%	0%	0.4951
End of Zone 3	200 ft downstream	95%	96%	-1%	0.1888
End of Zone 4	600 ft downstream	96%	98%	-2%*	0.0270
End of Zone 5	1000 ft downstream (Start of taper)	97%	99%	-2%	0.0708
End of Zone 6	End of taper	100%	100%		

*- statistically significant at 95% confidence level

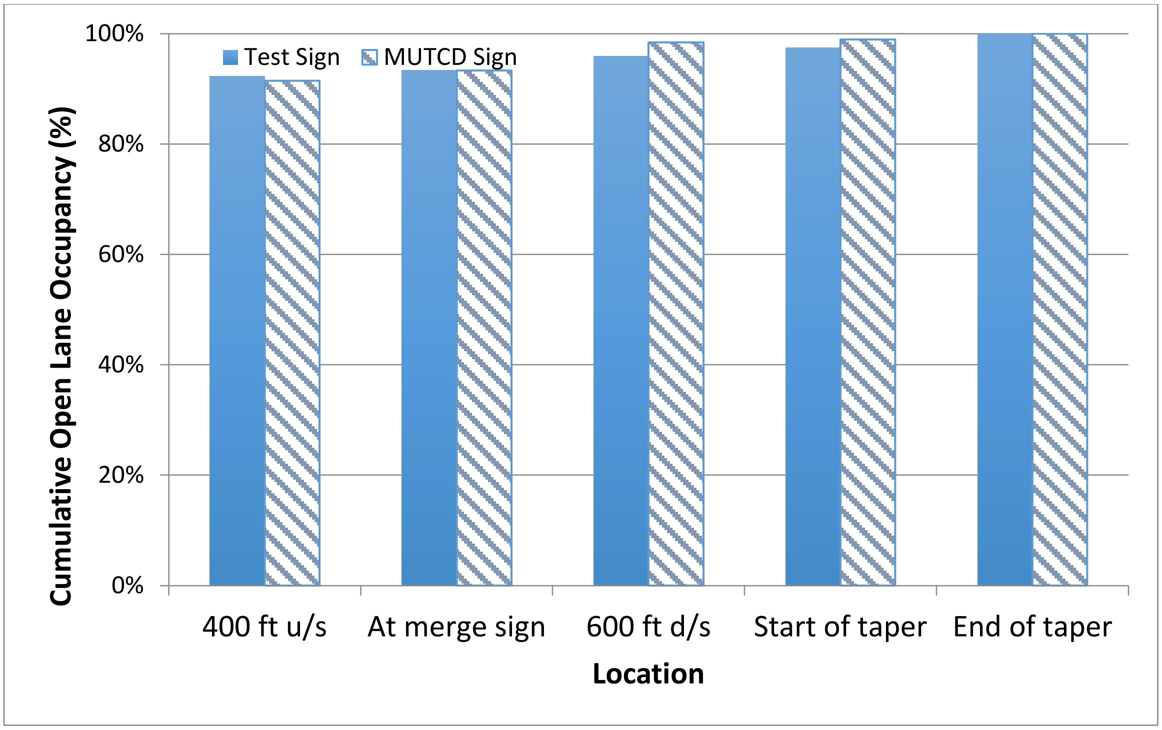


FIGURE 6 Open lane occupancies (trucks).

Speed Analysis

Table 5 displays the descriptive statistics pertaining to speeds for all vehicles and by vehicle type for passenger cars and trucks. The statistics include mean speed, standard deviation of speeds, and 85th percentile speeds at the merge sign and at the taper. Statistical significance, as indicated by p-values, is reported following the comparison of means using the t-test, and variances using the F-test. The speed differential between the two locations was also computed for each vehicle (i.e., the increase or decrease in speeds from merge sign to taper). The speed differentials for all vehicles were averaged and reported in the last column of Table 5. The positive sign of the mean speed differential indicated a decrease in speeds from the merge sign to the taper. The magnitude of the differences in mean speeds between the two sign setups was quantified using the Cohen's effect size measure (Cohen 1988). Effect size is a measure of the practical effect of the magnitude in the differences, and Cohen's measure is equivalent to the ratio of the difference over the standard deviation.

The speeds at the merge sign and at the taper were slightly lower for the MUTCD sign than for the test sign. The differences of 1.3 mph in mean speed and 1 mph in 85th percentile speed were statistically significant, but the difference of 0.01 in speed standard deviation and 0.23 mph in speed differential were not. The small values of the effect size measure (i.e., 0.238 and 0.324), as reported in Table 5, indicate that the differences in mean speeds between the MUTCD sign and the test sign was practically insignificant despite being statistically significant. Thus, the speed analysis did not demonstrate any substantial differences between the test sign and the MUTCD sign. In summary, the test sign could be considered a good alternative to the MUTCD sign given similar results from traffic speed measures.

TABLE 5 Descriptive Statistics of Speeds

	Location						
All vehicles	At merge sign			At taper			Mean Speed Differential (mph)
	Speed statistics (mph)			Speed statistics (mph)			
Sign Type	Mean	Standard deviation	85^{th} percentile	Mean	Standard deviation	85^{th} percentile	
Test sign	66.6	5.5	72.0	65.1	5.7	72.0	2.5
MUTCD sign	65.3	5.5	71.0	63.1	6.0	70.0	2.8
p-value	<0.001	0.465	0.004	0.00	0.069	<0.001	0.078
Cohen’s	0.238	-	-	0.324	-	-	-
Passenger Vehicles							
Test sign	68.1	5.3	73.0	66.2	5.8	73.0	2.8
MUTCD sign	66.8	5.6	73.0	64.4	6.4	71.0	3.2
p-value	<0.001	0.047	0.456	<0.001	0.001	<0.001	0.045
Cohen’s	0.233	-	-	0.316	-	-	-
Trucks							
Test sign	62.7	3.7	67.0	61.7	4.2	66.0	1.7
MUTCD sign	62.6	4.0	67.0	60.9	4.4	65.0	2.0
p-value	0.345	0.183	0.5	0.009	0.236	0.027	0.100
Cohen’s	0.030	-	-	0.190	-	-	-

CONCLUSIONS

This study investigated the effect of a new merge sign configuration for freeway work zones. One main difference between this new configuration and the MUCTD is the replacement of the graphical-only lane closed sign. This is one of the first studies evaluating an alternative static merging sign for work zones. The study measured driver behavior characteristics including speeds and open lane occupancies. Measurements were taken from the same work zone on different days using two configurations: one with the new test configuration and the other with the standard MUTCD configuration. Statistical tests were conducted to ensure that the comparisons between the experimental sign and the MUTCD sign were statistically valid. Based on an analysis of the measurements, the following conclusions were drawn:

1) Open lane occupancy was higher for the test sign in comparison to the MUTCD sign upstream of the merge sign. The occupancy values at different distances between the merge sign and the taper were similar for both the test and MUTCD signs, but the test sign encouraged up to 11% more cars to be in the open lane immediately upstream of the merge sign. In terms of safety, it is desirable for vehicles to occupy the open lane as far upstream of the taper as possible to avoid merging conflicts near the taper. Thus, the test sign proved to be a good alternative to the MUTCD sign.

2) Traffic monitoring results showed that passenger cars stayed in the closed lane longer, or closer to the taper, than did trucks. This was not unexpected given that commercial trucks typically operate in the right lane unless for passing, truck drivers have better sight distances to

spot signage earlier, and since commercial trips are work-related, drivers are more likely to adopt safer driving practices.

3) The merging behavior of truck drivers did not vary significantly with the type of merge sign deployed in the work zone. This is partly because more than 90% of truck traffic were already in the open lane upstream of the merge sign, both for the test sign and the MUTCD sign.

4) The analysis of speed characteristics did not reveal substantial differences between the two sign configurations. The mean speeds with the MUTCD configuration were 1.3 mph and 2 mph lower than the test configuration at the merge sign and taper locations, respectively. However, the effect size of 0.238 and 0.324 were very small, thus the speed results are not very useful despite being statistically significant.

There are several directions for future research. One is to survey motorists to obtain their perceptions towards the test sign configuration. Another is to evaluate the test sign configuration at additional work zone sites or using driving simulator experiments to further validate its performance. A third is to study the effect of sign performance as a function of the position of closed lane (right versus left lane). A fourth direction is to evaluate the test sign in a long-term construction work zone and to compare the performance with the short-term work zone evaluated in the current study. Due to habituation, driver reaction to signs and other temporary traffic control in long-term work zones could be different from that of short-term work zones. Finally, the performance of the test sign in nighttime work zones can be investigated.

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