Investigation of Alternative Work Zone Merging Sign Configurations

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This study investigated the effect of an alternative merge sign configuration within a freeway work zone. In this alternative configuration, the graphical lane closed sign from the MUTCD was compared with a MERGE/arrow sign on one side and a RIGHT LANE CLOSED sign on the other side. The study measured driver behavior characteristics including speeds and open lane occupancies. The measurements were taken at two identical work zones on I-70 in Missouri, one with the new test sign and the other with the standard MUTCD sign. 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. 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. Thus, the test sign proved to be a good alternative to the MUTCD sign. The analysis of speed characteristics did not reveal substantial differences between the two sign configurations. The 85th percentile speeds with the MUTCD sign were 1 mph and 2 mph lower than the test sign at the merge sign and taper locations, respectively.

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List of Abbreviations

Manual on Uniform Traffic Control Devices (MUTCD)
Mid-America Transportation Center (MATC)
Missouri Department of Transportation (MoDOT)
Temporary Traffic Control (TTC)
Vehicles per Hour (VPH)

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Disclaimer

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Abstract

This study investigated the effect of an alternative merge sign configuration in a freeway work zone. In this alternative configuration, the graphical lane closed sign from the MUTCD was compared with a MERGE/arrow sign on one side and a RIGHT LANE CLOSED sign on the other side. The study measured driver behavior characteristics including speeds and open lane occupancies. The measurements were taken at two identical work zones on I-70 in Missouri, one with the new test sign and the other with the standard MUTCD sign. 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. Thus, the test sign proved to be a good alternative to the MUTCD sign. The analysis of speed characteristics did not reveal substantial differences between the two sign configurations. The 85th percentile speeds with the MUTCD sign were 1 mph and 2 mph lower than the test sign at the merge sign and taper locations, respectively.

Executive Summary

The Manual on Traffic Control Devices (MUTCD) provides guidance on how temporary traffic control (TTC) plans are to be implemented at both short-term and long-term work zones. The TTC plans include information regarding work zone signage and sign locations. Research has shown that the advance warning area immediately before the taper exhibits the highest crash rates in the entire work zone; therefore, effective signage that encourages safer driving behavior in this area is desirable. The Missouri Department of Transportation (MoDOT) sought to investigate the performance of a new TTC plan with slightly different signage than the standard MUTCD. In this new TTC plan, the graphical lane closed sign is replaced with a MERGE/arrow sign on the closed-lane side and a RIGHT LANE CLOSED sign on the other side. In order to test the new TTC plan, a MUTCD request for experimentation was submitted by MoDOT and approved by FHWA in early 2013. This report presents the results of an analysis conducted to evaluate the effect of the test sign on traffic behavior. The goal of this research project was to compare the safety performance of the test sign with that of the MUTCD sign.

Field studies were conducted at a short-term work zone involving a left lane closure on a two-lane segment of westbound I-70 near Boonville, MO. The work activity involved the patching of the bridge deck over the Lamine River. The work zone scenario was repeated at the same location at approximately the same time of day on two different days. The weather was sunny and clear both days. Video monitoring was used at merging locations, and radar guns were used to collect vehicle speeds. The field data were analyzed, and the following measures of effectiveness were extracted:

Open lane occupancy, defined as the proportion of total traffic in the open lane at a given location, was computed at locations upstream and downstream of the merge sign. The location of

merge was recorded if it occurred within any of the three camera views. Lane occupancy differences were tested using a standard Z statistical test. Vehicle speeds were recorded at two locations—at the merge sign 1,000 ft upstream from the taper and 400 ft upstream from the taper; speed statistics such as mean speed, standard deviation, and 85th percentile speed were compared statistically across the two different merge sign configurations. The standard t-test was used to compare means, and the F-test was used to compare variances. The magnitude of the difference in the mean speeds between the MUTCD sign and the test sign was tested using effect size test; 85th percentile speeds were also collected and statistically tested to determine whether vehicles were compliant with speed limits.

The open lane occupancy values for the two signs at five different locations are reported in figure A.1. The five locations were: 1) 400 ft upstream of the merge sign, 2) at the merge sign, 3) 600 ft downstream of the merge sign, 4) at the start of the work zone taper, and 5) at the end of the work zone taper.

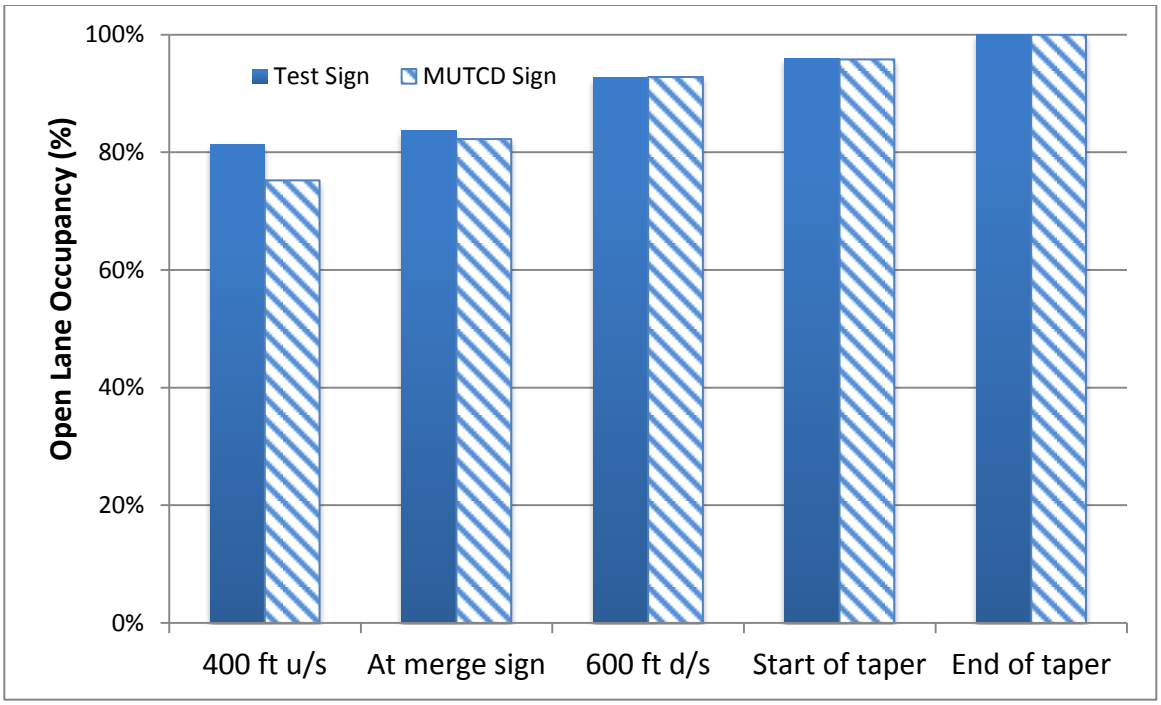

Figure A.1 Open lane occupancies

The 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. The test sign encouraged up to 11% more traffic to be 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 of the taper as possible to avoid the likelihood of severe crashes in the work area. Thus, the test sign proved to be a good alternative to the MUTCD sign.

Further occupancy analysis based on vehicle type revealed that passenger cars stayed in the closed lane longer, or closer to the taper, than trucks. This result was not unexpected, given that most commercial truck trips are work-related and drivers are therefore more likely to adopt safer driving practices. The merging behavior of truck drivers did not vary significantly with the type of merge sign deployed in the work zone. This result was partly due to the fact that more

than 90% of truck traffic switched to the open lane upstream of the merge sign, both for the test sign and the MUTCD sign. Finally, the analysis of speed characteristics did not reveal substantial differences between the two sign configurations. The 85th percentile speed at the merge sign location was 71 mph with the MUTCD sign and 72 mph with the test sign, both only slightly above the posted speed limit of 70 mph. These differences in 85th percentile speeds were statistically significant.

Chapter 1 Introduction

Roadway construction and maintenance activities often involve lane closures that require vehicles to merge from closed lanes. The Manual on Traffic Control Devices (MUTCD) provides guidance on temporary traffic control (TTC) plans for both short-term and long-term work zones. The TTC plans include information regarding work zone signage and sign locations. The MUTCD TTC plan used by the Missouri Department of Transportation (MoDOT) is shown in figure 1.1. MoDOT is interested in evaluating the performance of a new TTC plan with slightly different signage than the MUTCD plan. In this new TTC plan, the graphical lane closed sign 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 1.2. In order to test the new TTC plan, a MUTCD request for experimentation was submitted by MoDOT and approved by FHWA in early 2013.

In a recent study, Ishak et. al (2012) found that the advance warning area just before the taper exhibited the highest crash rates in an entire work zone. Thus, effective signage that encourages safer driving behavior in this area is desirable. 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 fig. 1.1) in that it required alternating merging 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.

The goal of this research project was to compare the safety performance of the new static merge sign configuration with the MUTCD merge sign at a work zone. Field studies were conducted at a work zone site on I-70 in Missouri. Video monitoring was used at 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.

This report discusses the different tasks undertaken to accomplish the research goal. Chapter 2 explains the field studies conducted to compare the effectiveness of the new merge sign and the MUTCD sign. Chapter 3 presents the methodology used to analyze the field data, and Chapter 4 presents the results of various measures of effectiveness. Conclusions are drawn based on the study findings, and are presented in Chapter 5.

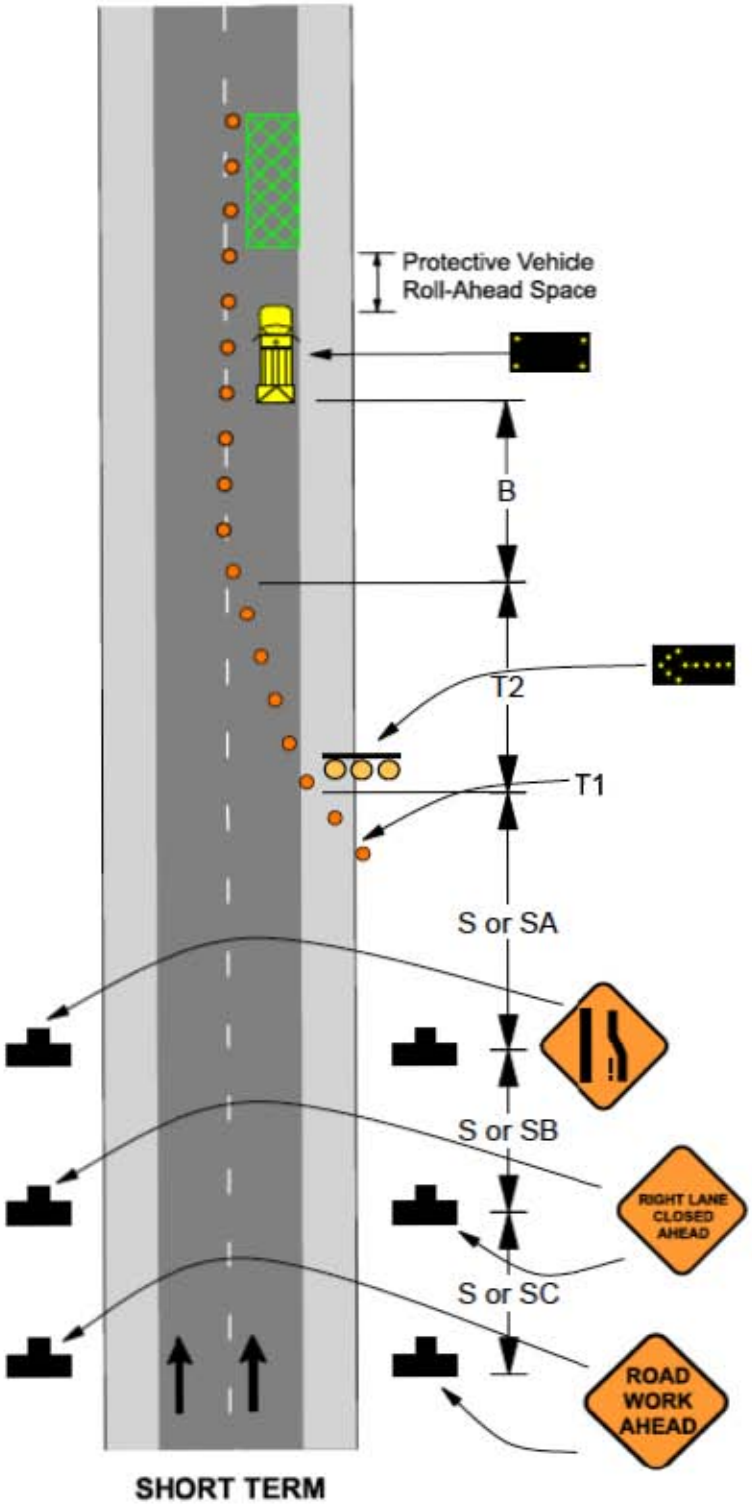

Figure 1.1 Missouri MUTCD-based temporary traffic control plan for a stationary lane closure on a divided highway

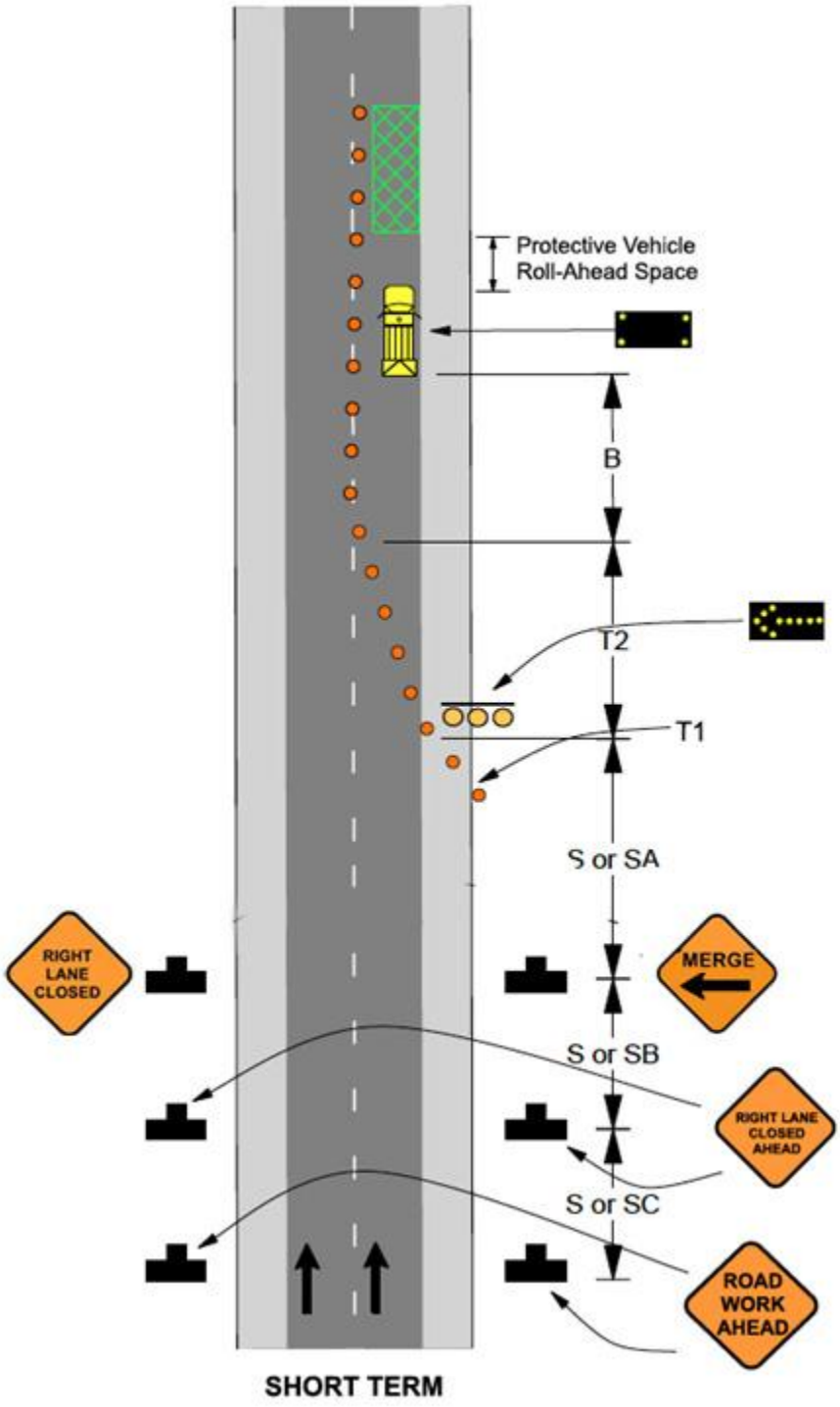

Figure 1.2 Test merge sign temporary traffic control plan for a stationary lane closure on a divided highway

Chapter 2 Experimental design and field studies

2.1 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 posted speed limit inside the work zone was 70 mph. 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, selected based upon peak hourly traffic volumes for the location. Weather conditions were sunny and clear on both days. In accordance with the TTC plan, merge signs were placed 1,000 ft upstream of the taper. The new static text merge sign, (hereafter referred to as the "test sign"), was tested on April 22nd, 2013; the MUTCD graphical sign was tested on April 25th, 2013.

Figure 2.1 shows the configuration of the data collection setup. One radar gun was placed at the merge sign, and another radar gun was placed at the taper in order to capture longitudinal speed changes for individual vehicles. Three cameras covered the entire study area, as shown in figure 2.1.

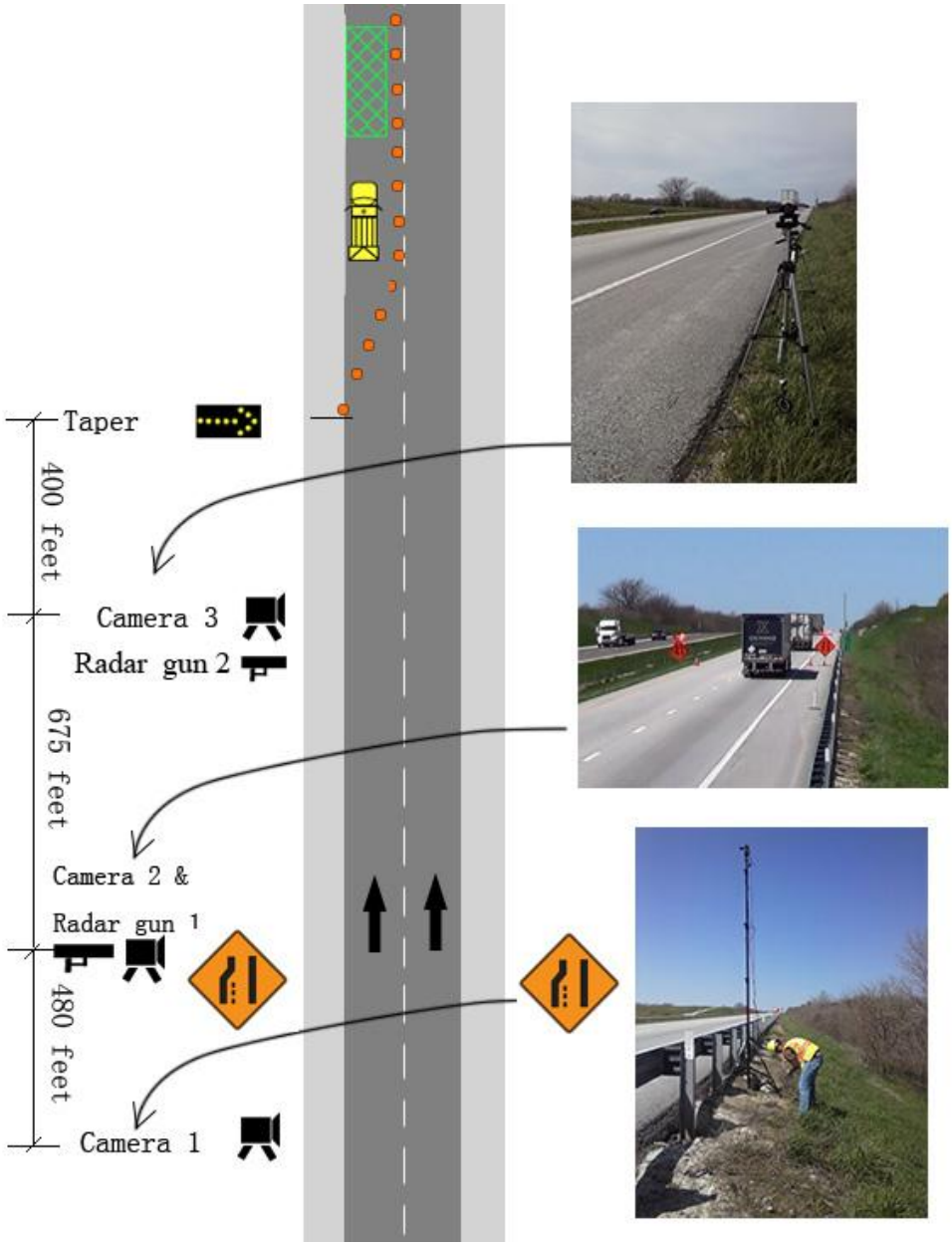

Figure 2.1 MUTCD plan for a stationary lane closure on a divided highway

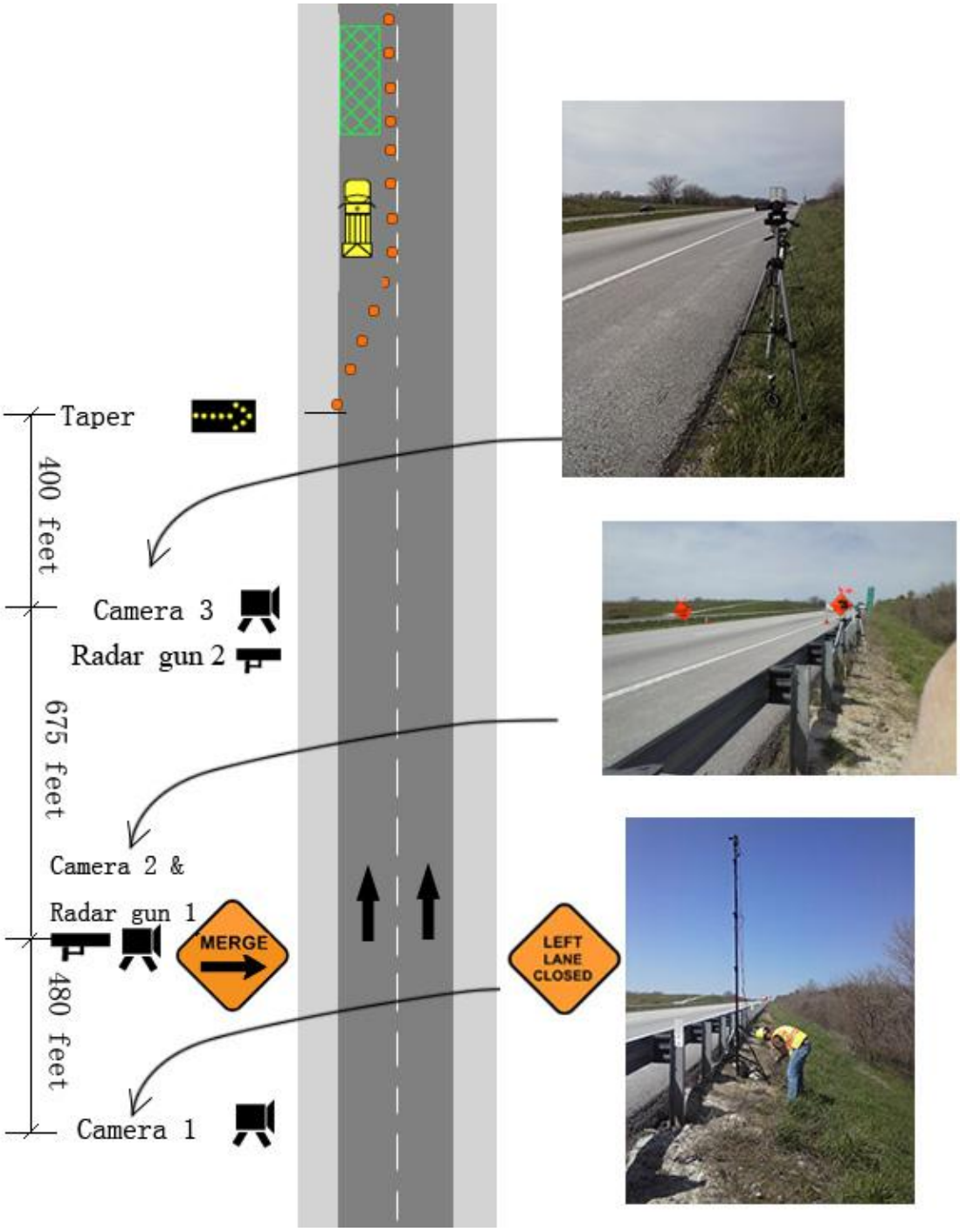

Figure 2.2 Test sign for a stationary lane closure on a divided highway

Camera 1 (upstream of the merge sign): The first camera was located 480 ft upstream of the merge sign, and was raised 20 ft above ground. This camera captured merge location data to determine where vehicles merged into the open lane.

Camera 2 (at the merge sign): A radar gun with a camera recording the speeds captured by the display 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 600 ft downstream of the merge sign.

Camera 3 (beginning of taper): A radar gun capturing speeds at the beginning of the taper was deployed, along with an accompanying camera to record the display. This camera coverage was used to obtain merge location data 400 ft upstream of the taper. All three cameras were shooting in the direction of the taper. Camera clocks were synchronized so that individual vehicle maneuvers could be monitored through the three cameras.

Chapter 3 Methodology

3.1 Open Lane Occupancy

Open lane occupancy, defined as the proportion of total traffic in the open lane at a given location, was computed at locations upstream and downstream of the merge sign. The location of merge was recorded if it occurred within any of the three camera views described in the previous chapter. 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 for analysis. Figure 3.1 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 ft intervals for a distance of 400 ft upstream and 600 ft downstream from the merge sign. As shown in figure 3.1, zone 1 was between the first two delineators upstream of the merge sign, and zone 2 was between the second delineator 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 ft 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 using a standard z test (Milton and Arnold 2007).

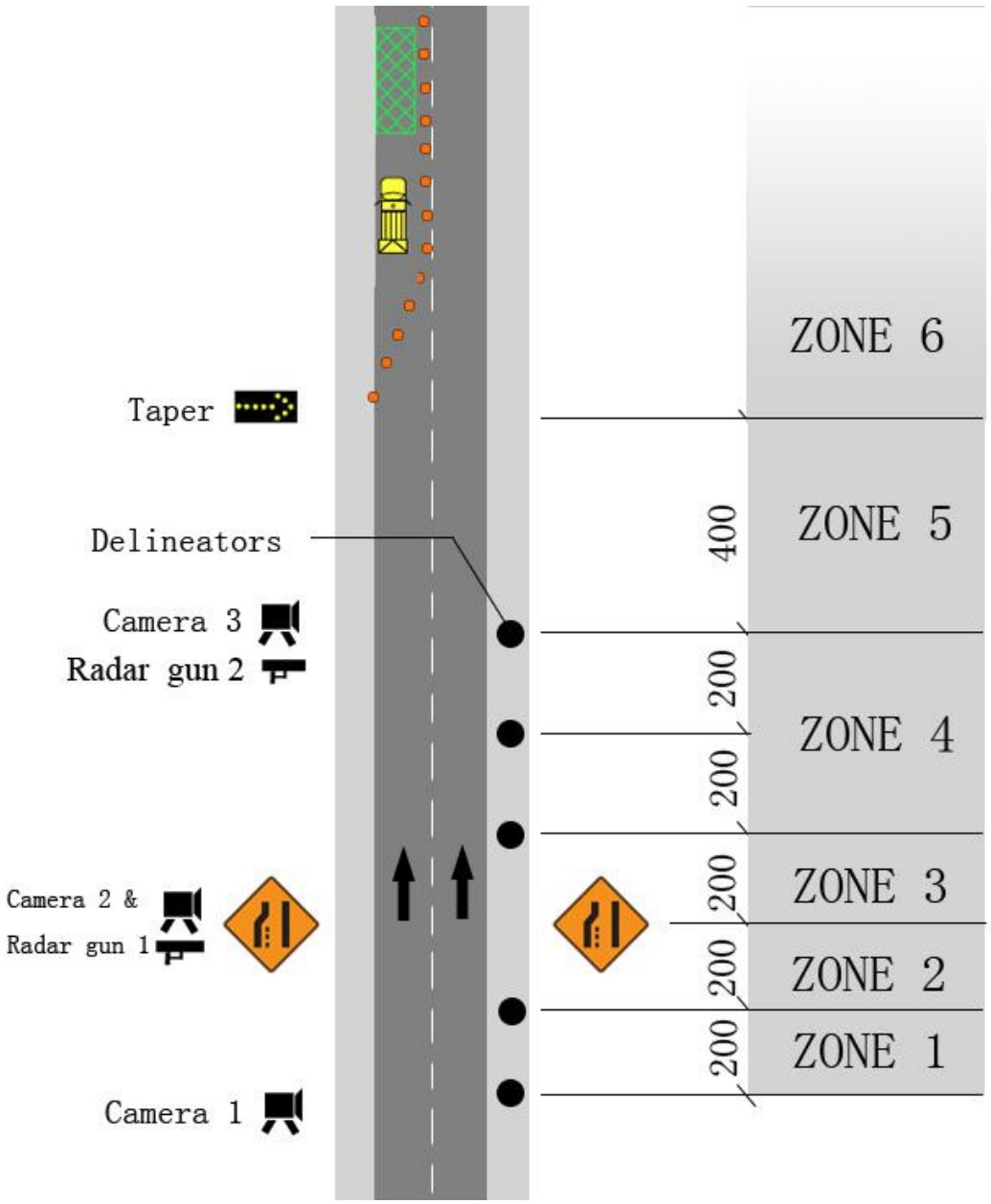

Figure 3.1 Analysis Zones

3.2 Speed-Based Measures

Vehicle speeds were recorded at two locations: first at the merge sign 1,000 ft upstream of the taper, and again 400 ft upstream of the taper. Speed statistics such as mean speed, standard deviation, and 85th percentile speed were compared statistically across 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 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 also statistically compared using a test described in Hou et al. (2012). Speed differences 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.

The various statistical tests used in this study are described below:

t-test: The two sample t-test is a common measure 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:

$$\text{Degree of freedom: } \nu = \frac{\left(\frac{s_y^2}{n_y}+\frac{s_x^2}{n_x}\right)^2}{\frac{\left(\frac{s_y^2}{n_y}\right)^2}{n_y-1}+\frac{\left(\frac{s_x^2}{n_x}\right)^2}{n_x-1}} \tag{3.1}$$

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

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.

F-test: 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.

$$\text{The test statistic is: } F = \frac{s_y^2}{s_x^2} \tag{3.2}$$

Reject null hypothesis (i.e., there is statistical 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 a $n_y - 1$ and $n_x - 1$ degrees of freedom.

where,

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

α is the user-selected significance level.

Cohen's effect size: Cohen's d 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.

$$effect\ size = \frac{\bar{x}-\bar{y}}{s} \tag{3.3}$$

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

Statistical test on 85th percentile: This test was presented in Hou et al. (2012) 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:

$$\frac{X_{([n0.85]+1)} - Y_{([n0.85]+1)}}{1.530\sqrt{\frac{s_y^2}{n_y} + \frac{s_x^2}{n_x}}} \tag{3.4}$$

where,

$X_{([n0.85]+1)}$ and $Y_{([n0.85]+1)}$ are the 85th sample quantiles 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.

Inference on proportions: Proportion is the 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: $\hat{p} = \frac{n_1\hat{p}_1 + n_2\hat{p}_2}{n_1 + n_2}$ (3.5)

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.

Chapter 4 Results

4.1 Merge Location Analysis

Data pertaining to traffic volumes and vehicle composition from each test setup were compiled for 1.5 hours, and are shown in table 4.1. The traffic flow conditions on both data collection days were similar, at 652 vph and 694 vph. The relatively lower 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 higher on the second day with the MUTCD configuration than on the first day with the test sign configuration. In this study, trucks were defined as all vehicles other than FHWA classes 1 and 2, which are motorcycles 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 (Pickett 2012).

Table 4.1 Traffic volume and composition for the two 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%

Open lane occupancy, defined as the proportion of total traffic in the open lane at a given location, was computed at locations upstream and downstream of the merge sign. 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, 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 open lane occupancies at seven different locations are shown in table 4.2. 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 open lane occupancies for both sign configurations were equal. This trend is also evident in figure 4.1, which shows the open lane occupancies at five locations. The five locations included: 1) 400 ft upstream of the merge sign, 2) at the merge sign, 3) 600 ft downstream of the merge sign, 4) at the start of the work zone taper, and 5) at the end of the work zone taper.

Table 4.2 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%		

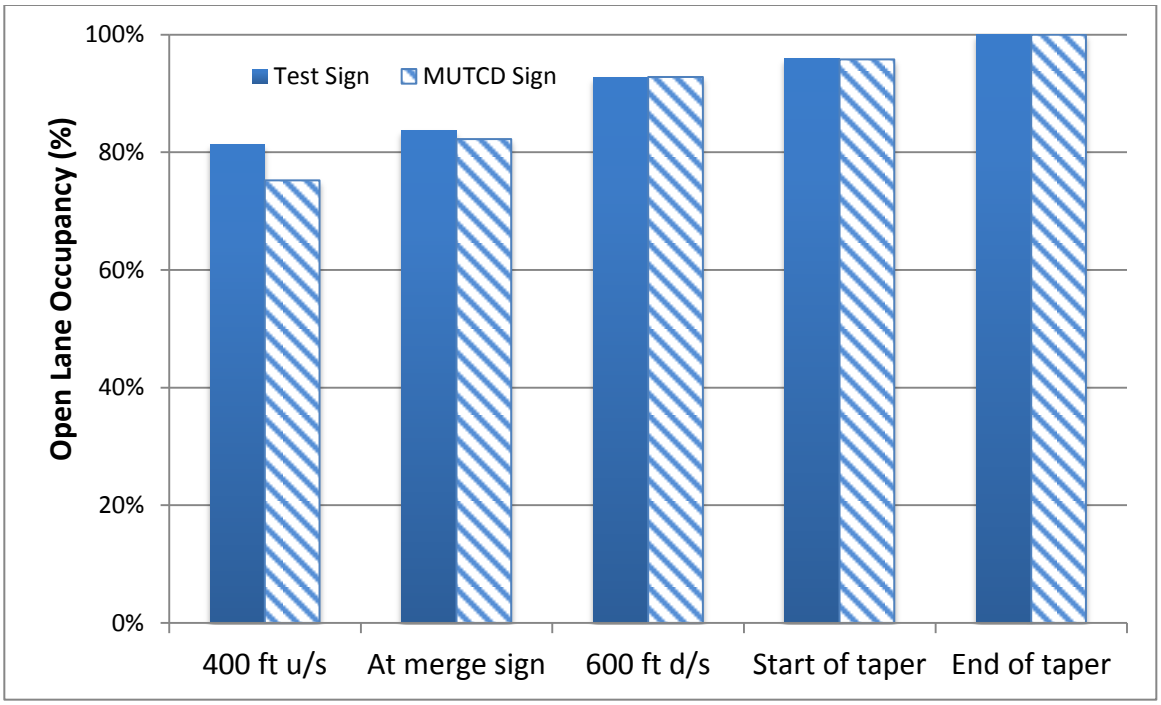

Figure 4.1 Open lane occupancies (all vehicles)

The results displayed in figure 4.1 and table 4.2 represent all vehicles observed during the data collection period. The vehicle population was separated into passenger cars and trucks to ascertain any differences in merging behavior across the two vehicle types. The effects of each sign setup on passenger cars are shown in figure 4.2 and table 4.3. 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 4.3 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%		

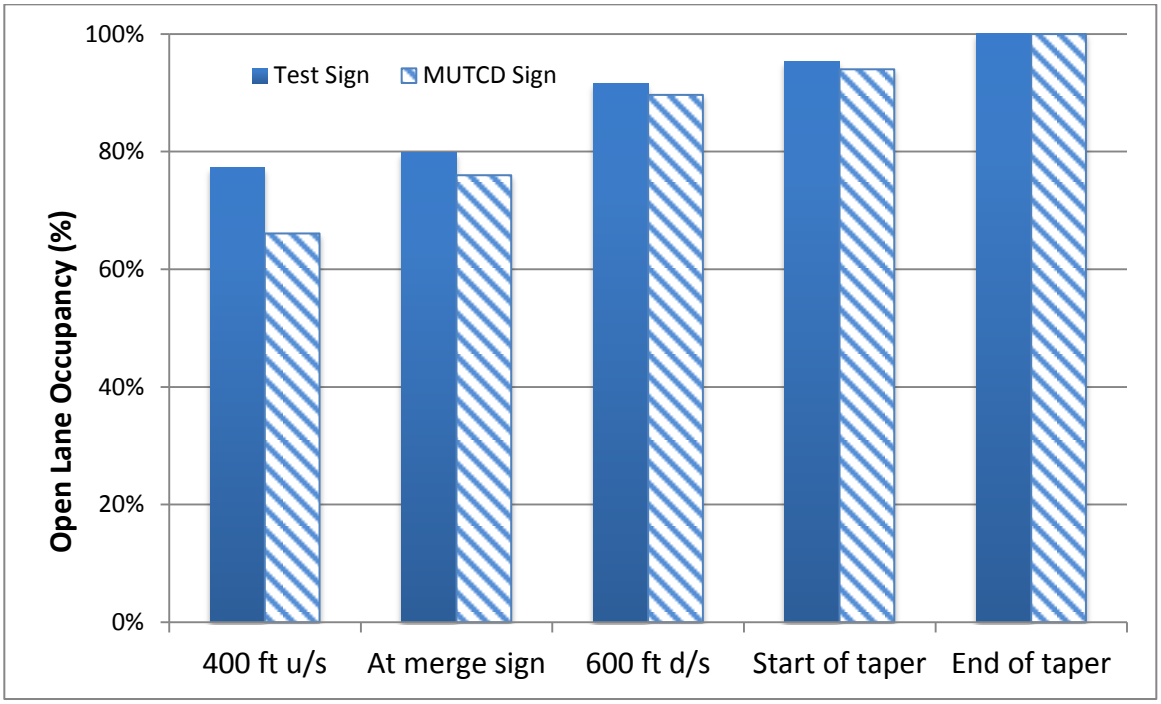

Figure 4.2 Open lane occupancies (passenger cars)

The open lane occupancies for trucks are shown in figure 4.3 and table 4.4. 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. 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 4.4 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%		

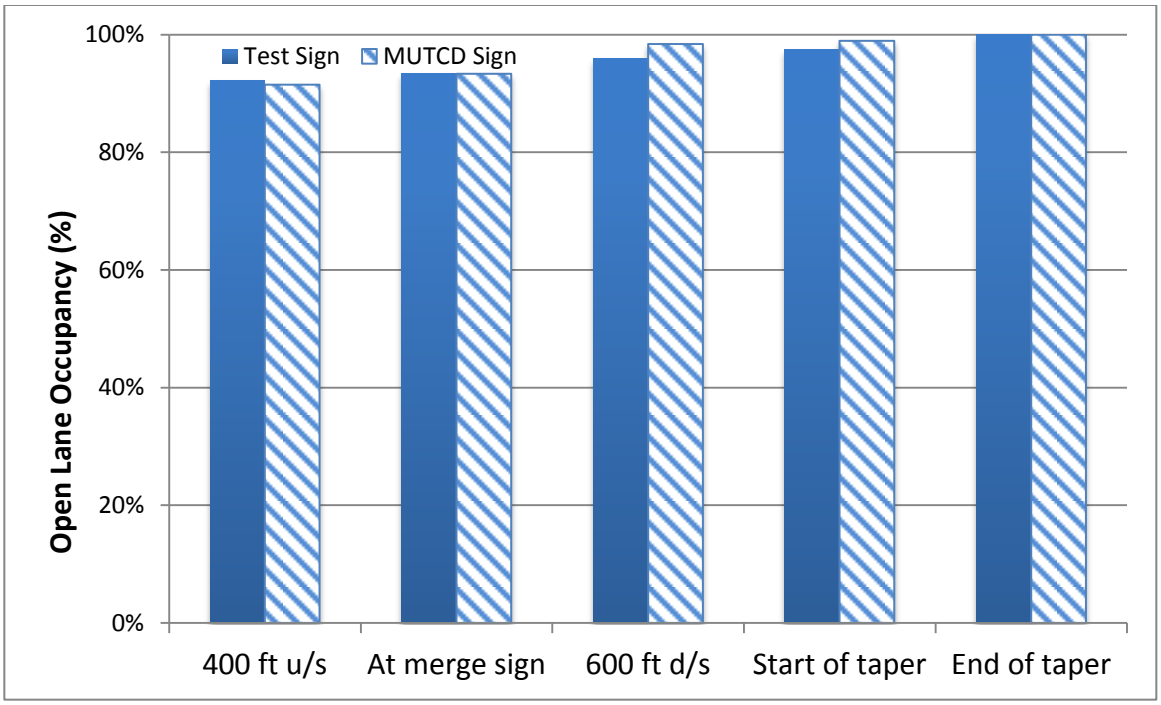

Figure 4.3 Open lane occupancies (trucks)

4.2 Speed Analysis

Table 4.4 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 absolute values of speed differentials for all vehicles were averaged and reported in the last column of table 4.4.

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 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 small values of this measure (i.e., 0.238 and 0.324), as reported in table 4.4, indicate that the magnitude of the differences in mean speeds was small. 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 4.4 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	85th percentile	Mean	Standard deviation	85th 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			

Chapter 5 Conclusions

This study investigated the effect of a new merging sign in a freeway work zone. The study measured driver behavior characteristics including speeds and open lane occupancies. Measurements were taken from the same work zone on different days, one with the new test sign and the other with the standard MUTCD sign. 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. The test sign encouraged up to 11% more traffic to be 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 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 most commercial truck trips are work-related, and the drivers thus 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 switched to 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 85th percentile speeds with the MUTCD sign were 1 mph and 2 mph lower than the test sign at the merge sign and taper locations, respectively.

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