Assessment of Channelizing Device Effectiveness on High Speed/High Volume Roadways

SWZDI
Smart Work Zone Deployment Initiative

Final Report
July 2007

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16. Abstract

Part 6 of the Manual on Uniform Traffic Control Devices (MUTCD) describes several types of channelizing devices that can be used to warn road users and guide them through work zones; these devices include cones, tubular markers, vertical panels, drums, barricades, and temporary raised islands. On higher speed/volume roadways, drums and/or vertical panels have been popular choices in many states, due to their formidable appearance and the enhanced visibility they provide when compared to standard cones. However, due to their larger size, drums also require more effort and storage space to transport, deploy and retrieve. Recent editions of the MUTCD have introduced new devices for channelizing; specifically of interest for this study is a taller (>36 inches) but thinner cone. While this new device does not offer a comparable target value to that of drums, the new devices are significantly larger than standard cones and they offer improved stability as well. In addition, these devices are more easily deployed and stored than drums and they cost less. Further, for applications previously using both drums and tall cones, the use of tall cones only provides the ability for delivery and setup by a single vehicle.

An investigation of the effectiveness of the new channelizing devices provides a reference for states to use in selecting appropriate traffic control for high speed, high volume applications, especially for short term or limited duration exposures. This study includes a synthesis of common practices by state DOTs, as well as daytime and nighttime field observations of driver reactions using video detection equipment. The results of this study are promising for the day and night performance of the new tall cones, comparing favorably to the performance of drums when used for channelizing in tapers. The evaluation showed no statistical difference in merge distance and location, shy distance, or operating speed in either daytime or nighttime conditions. The study should provide a valuable resource for state DOTs to utilize in selecting the most effective channelizing device for use on high speed/high volume roadways where timely merging by drivers is critical to safety and mobility.

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ASSESSMENT OF CHANNELIZING DEVICE EFFECTIVENESS ON HIGH SPEED/HIGH VOLUME ROADWAYS

Final Report
July 2007

Principal Investigator
Reginald Souleyrette
Professor, Department of Civil, Construction, and Environmental Engineering
Iowa State University

Co-Principal Investigators
Thomas McDonald
Safety Circuit Rider, Center for Transportation Research and Education
Iowa State University

Dennis Kroeger
Transportation Research Specialist, Center for Transportation Research and Education
Iowa State University

Authors
Reginald Souleyrette, Thomas McDonald, and Dennis Kroeger

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A report from
Center for Transportation Research and Education
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-8103
Fax: 515-294-0467
www.ctre.iastate.edu

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INTRODUCTION

The primary function of temporary traffic control (TTC) is to provide for the reasonably safe and efficient movement of vehicles through and around work zones, while protecting workers and equipment. A concurrent objective of TTC is the efficient construction and maintenance of the highway. Major requirements and guidance for the establishment and maintenance of TTC for work zones are contained in the Manual on Uniform Traffic Control Devices (MUTCD), and are supplemented by agency policies and specifications.

Part 6 of the MUTCD, Temporary Traffic Control, describes several types of channelizing devices to warn road users and guide them through work zones; these devices include cones, tubular markers, vertical panels, drums, barricades, and temporary raised islands. On higher speed and higher volume roadways, drums and/or vertical panels have been popular choices in many states due to their formidable appearance and the enhanced visibility they provide compared to standard cones. However, due to their larger size, these devices also require more effort and storage space to transport, deploy, and retrieve.

The 2003 edition of the MUTCD introduced additional options for channelizing devices, including a taller cone—greater than 36 in. in height. Descriptions of these devices in different states might include “grabber cones,” “42 in. channelizers,” “tall cones,” etc. While this new device does not offer a comparable target value to that of drums, the new devices are significantly taller than standard cones and they offer improved stability as well. In addition, these devices are more easily deployed and stored than drums. Figure 1 illustrates the various types of channelizing devices used.

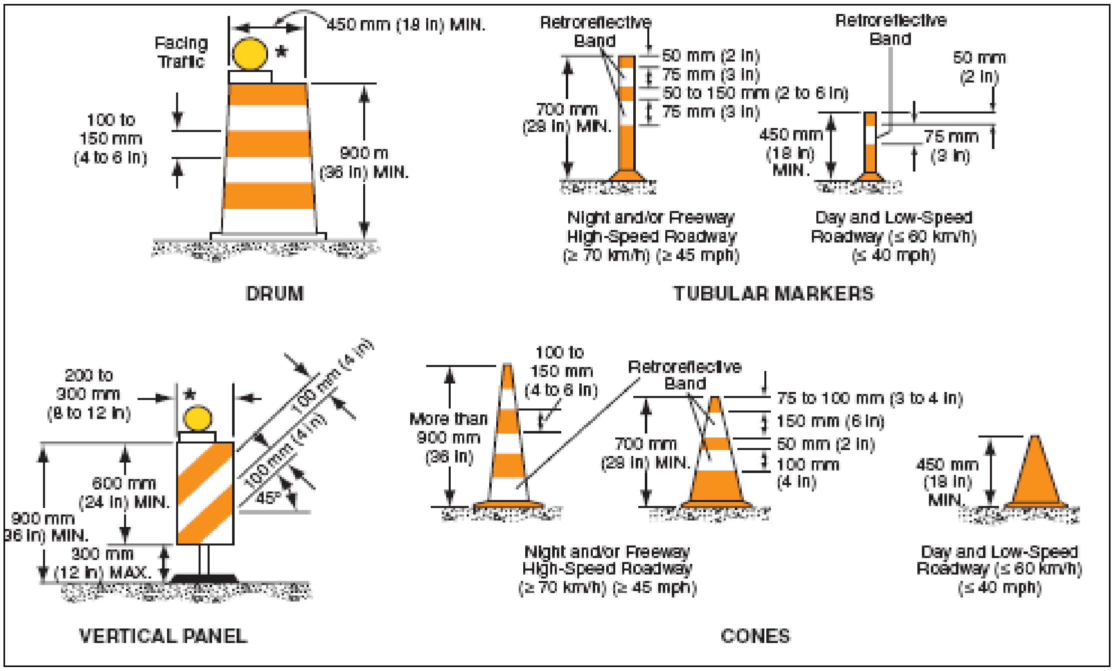


Figure 1. Various types of channelizing devices used

Another new device, introduced in the millennium edition of the MUTCD, was the direction indicator barricade, which provided positive guidance for drivers with an arrow sign (see Figure 2).

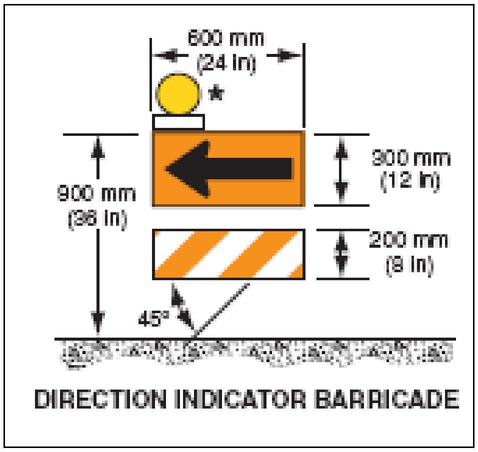


Figure 2. Direction indicator barricade

A critical point for traffic in a TTC zone for a lane closure is the transition area, where a shift in travel path or merge with an adjacent lane is required. Typical TTC for a transition area is a taper, which is outlined with channelizing devices, as described above. Since many work zone crashes occur in or around transition areas, transportation agencies are interested in providing the highest quality guidance for drivers in these locations.

In addition to the guidance in Part 6 of the MUTCD described previously, some states have taken advantage of Section 1A.10 of the MUTCD for an opportunity to experiment with design modifications of channelizing devices to enhance driver attention and compliance with work zone TTC. Some examples of taper experiments used in Pennsylvania are shown in Figures 3 and 4. Figure 3 shows alternative green and yellow panels, instead of the standard orange panels. Another alternative configuration is shown in Figure 4, using green and white striped drums at the exit taper.

Figure 3. Alternate-colored vertical panels at entrance taper (PennDOT)

Figure 4. Alternate-colored drums at exit taper (PennDOT)

A review of common state DOT practices in selected states for lane closures on multi-lane roadways finds close adherence to MUTCD guidance, with some variance between states in signing and in types of channelizing devices permitted, especially in tapers.

With many choices available for traffic guidance, transportation agencies could benefit from an effectiveness evaluation of various channelizing devices to aid in selecting the most beneficial and efficient devices, especially for short term stationary use on higher volume/high speed roadway applications.

This study was composed of several tasks, including the following:

- The establishment of an advisory team
- A review of relevant literature
- A synthesis of practice survey of selected midwestern state DOTs in the use of channelizing devices
- A comparison of effectiveness of several devices under field conditions
- An analysis of results
- The preparation of a final report

ADVISORY TEAM

The advisory team for the evaluation consisted of experienced staff from the Iowa DOT's Offices of Construction, Maintenance, and Traffic and Safety, as well as field maintenance staff. In addition, representatives from the Federal Highway Administration and contractor representatives were consulted. The advisory team members are listed below.

- Mr. Mark Bortle, Iowa Department of Transportation
- Mr. Dan Sprengler, Iowa Department of Transportation
- Mr. Will Zitterich, Iowa Department of Transportation
- Mr. Robert Younie, Iowa Department of Transportation
- Mr. Michael Krohn, Iowa Department of Transportation
- Mr. Terry Zimmerman, Iowa Department of Transportation
- Mr. Jerry Roche, Federal Highway Administration

LITERATURE REVIEW

No studies could be found that have been conducted on the effectiveness of the channelizing devices that were used in this experiment. A brief discussion of potentially-related studies is provided here.

A study conducted by the University of Wisconsin examined safety in reconstruction and maintenance work zones (*1*). The study examined various speed management techniques through work zones. The study concentrated on speeding as one of the major contributors of work zone crashes. Speeding reduces the driver’s ability to safely control, guide, and navigate a vehicle, which increases the possibility of crash occurrence. Many speed control technologies and traffic management strategies are currently being used throughout the country. To decrease the occurrence of potential speeding-related crashes, the Wisconsin Department of Transportation (WisDOT) is seeking effective methods of controlling speed at Wisconsin work zones to improve safety and mobility. To better understand how speed management strategies and technologies impact work zone speed profiles, there is a need to evaluate the effectiveness of these strategies in reducing speeds, reducing the number of speeders, and improving speed uniformity.

The two primary objectives for the Wisconsin study were as follows:

1. Record and compare the speed characteristics with and without speed management strategies at work zones.
2. Measure the effectiveness of speed management strategies at work zones.

Strategies including dynamic speed display boards, dynamic late merge systems, and various enforcement methods were evaluated in three Wisconsin long-term highway work zones located on Interstate highway I-94 and state highways STH 29 and STH 164. The three work zones were located in the northwest, central and southeast of Wisconsin, representing a typical geographic sample of Wisconsin drivers. Compared with previous research, the study provided more insight into the long-term impact of some speed control strategies and the effectiveness of combining various approaches. The results showed a promising outcome from using these speed management strategies.

A study conducted by the University of Kansas investigated whether observers attended more closely to moving work zone signs if those signs were surrounded by a fluorescent yellow-green (FYG) border. The logic of this signage change is that there is insufficient color contrast between the warning signs and the vehicles on which they are mounted. Two laboratory studies were conducted using very sensitive and robust techniques to measure the attention to signs with and without the FYG border. In each study, a different method for assessing observers’ attention was used. In the first study, a perceptual change detection method was used, in which observers were required to detect a change to an object in a traffic scene. Changing the sign to include a FYG border did cause observers to notice the sign more rapidly. However, while the eyes picked up on the changes to the sign, the observers did not spend more time looking at the sign. In other words, people saw a change in the sign but didn't necessarily read the sign. In the second study, eye-tracking data was collected for a set of observers. An increase in fixation time on an object indicates more attention is being paid to that object. In this study, there was again no difference between the two sign types. The researchers concluded that the addition of a FYG border did not increase driver attention to vehicle-mounted warning signs (*2*).

In an earlier study of a similar subject, Kamyab and Storm examined the effect of the FYG background on lane-changing behavior in Iowa. Undoubtedly, the FYG background creates a clear contrast between the orange sign and an orange Iowa DOT truck that follows a moving work area. This study examined the impact of the sign's improved visibility on encouraging drivers to make an early merge to the open lane prior to a lane closure.

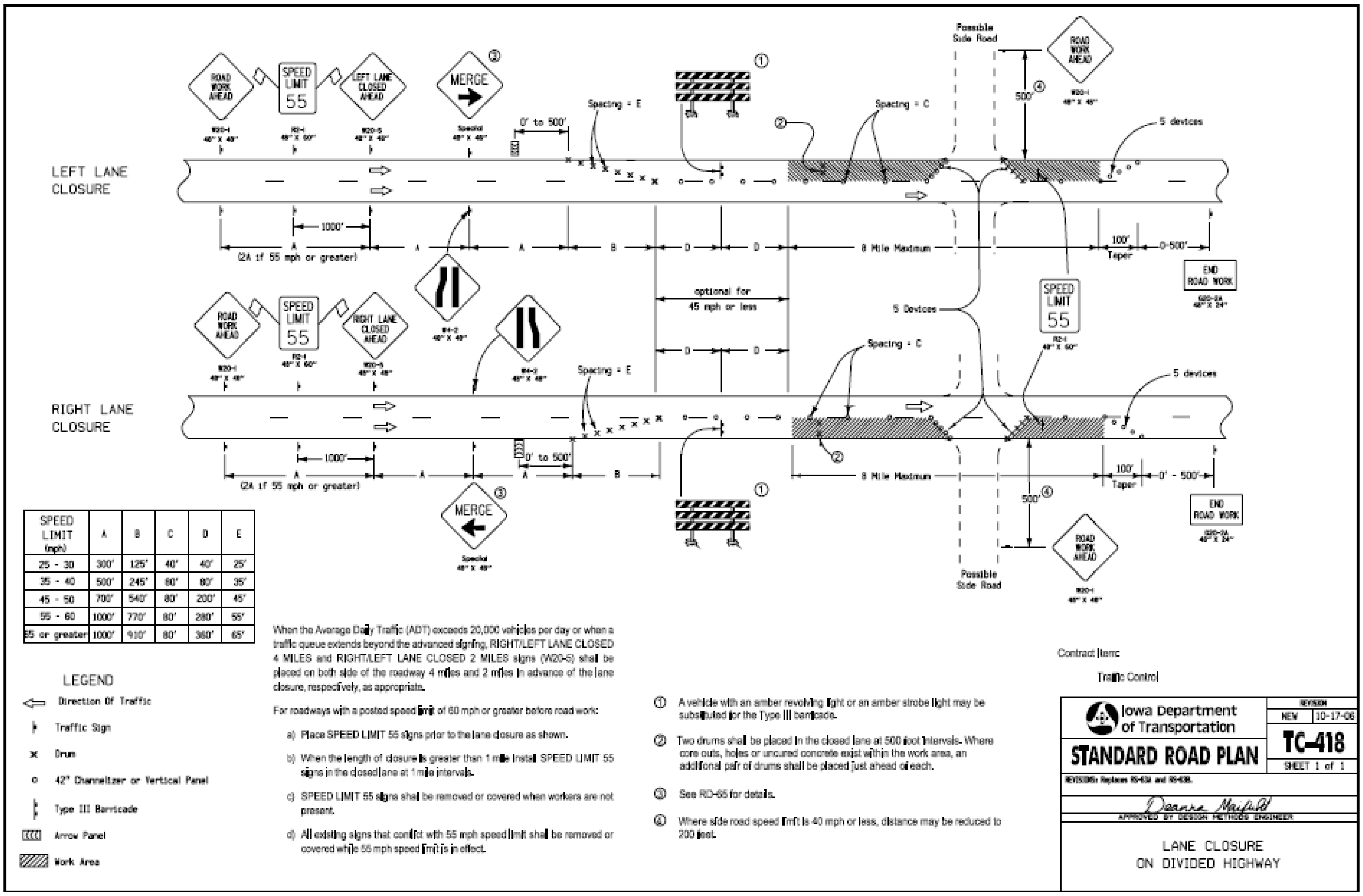
Kamyab and Storm's analysis of data indicated that overall right-lane traffic volumes, recorded during the seven days of data collection after the background placement, were 2% lower than the traffic observed in the "after" condition. The study concluded that the difference between the right-lane traffic observed in the "before" and "after" conditions was indeed statistically significant, at the 95% confidence level. The resulting right-lane traffic counts are representative of lane distribution changes within 100 feet upstream of the truck. Kamyab and Storm suggested that, if further research is conducted, it would be beneficial to collect data at locations where most approaching vehicles move to the open lane—for example, at a distance 500 ft. from the truck. However, using the data collection trailer or individuals to count traffic at a different location may influence drivers' lane-changing behavior.

Another factor that could lead to different results from those obtained by Kamyab and Storm is having a real lane closure. Due to the difficulties in developing an experimental design to collect traffic data in advance of an actual moving work zone, data for Kamyab and Storm's study were collected at an "imaginary" work zone. In a more realistic setup, where drivers actually face a real lane closure, a lower right-lane traffic volume is expected to be observed in the "after" condition.

Furthermore, Kamyab and Storm conducted a survey at a downstream rest area during the "after" condition which indicated that more than 50% of drivers identified the enhanced orange sign as a device seen on the back of the Iowa DOT truck before reaching the work zone (*3*).

COMMON PRACTICES OF STATES

To assess current practices for temporary traffic control when a single lane is closed on a four-lane divided roadway, several state departments of transportation were asked to provide typical applications. Information was furnished by Missouri, Kansas, Nebraska, Pennsylvania, and Iowa. The following illustrated layout (Figure 5) is used by the Iowa DOT and similar schemes are employed by the other surveyed states as well, all modeled after Typical Application TA-33 in the Manual on Uniform Traffic Control Devices.



SPEED LIMIT (mph)	A	B	C	D	E
25 - 30	300'	125'	40'	40'	25'
35 - 40	500'	245'	80'	80'	35'
45 - 50	700'	540'	80'	200'	45'
55 - 60	1000'	770'	80'	280'	55'
65 or greater	1000'	910'	80'	360'	65'

When the Average Daily Traffic (ADT) exceeds 20,000 vehicles per day or when a traffic queue extends beyond the advanced signing, RIGHT/LEFT LANE CLOSED 4 MILES and RIGHT/LEFT LANE CLOSED 2 MILES signs (W20-5) shall be placed on both side of the roadway 4 miles and 2 miles in advance of the lane closure, respectively, as appropriate.

For roadways with a posted speed limit of 60 mph or greater before road work:

a) Place SPEED LIMIT 55 signs prior to the lane closure as shown.

b) When the length of closure is greater than 1 mile install SPEED LIMIT 55 signs in the closed lane at 1 mile intervals.

c) SPEED LIMIT 55 signs shall be removed or covered when workers are not present.

d) All existing signs that conflict with 55 mph speed limit shall be removed or covered while 55 mph speed limit is in effect.

① A vehicle with an amber revolving light or an amber strobe light may be substituted for the Type III barricade.

② Two drums shall be placed in the closed lane at 500 foot intervals. Where core outs, holes or uncured concrete exist within the work area, an additional pair of drums shall be placed just ahead of each.

③ See RD-65 for details.

④ Where side road speed limit is 40 mph or less, distance may be reduced to 200 feet.

Figure 5. Work zone layout used with a right lane closure

The main point of difference in temporary traffic control among the contacted states for this situation concerns the selection of channelizing device type for use in the taper and lane delineation. As can be seen above, Iowa specifies the use of drums in the taper and 42 in. channelizers (tall cones) for lane delineation. Other states are somewhat less prescriptive. For example, Kansas uses tall conical delineators for channelizing devices. Missouri also selects 42 in. channelizers as the device of choice, but may allow contractors to use other devices such as drums, vertical panels, cones, or direction indicator barricades in certain situations. Nebraska uses drums for high speed roadways. In Pennsylvania, contractors are allowed to use a wide array of channelizing devices for both tapers and lane delineation. Spacing of devices is similar to guidance in the MUTCD—approximately equal to the roadway speed limit for tapers and twice the speed limit for lane delineation. Standard road plans used by these states are included in Appendix A.

STUDY DESIGN

Data Collection

Data were collected on US Highway 30 near Ames, Iowa on October 30, 31, November 1, and 2, 2006, using Autoscope video cameras. The cameras were erected on the Y Avenue Bridge on the county line between Boone and Story counties, overlooking US 30, as shown in Figure 6. Data were collected during the afternoon and evening hours on these days, from 3:00 PM to 8:30 PM.

Figure 6. Map of location of AutoScope trailer

The location of the AutoScope video equipment is indicated by the rectangle. This location was used because the cameras could be positioned away from traffic but still be able to focus on the traffic movements through the work zone. Also, we were able to establish a work zone away from the urban area, while still generating the traffic volume needed to complete the study.

Weather Conditions

The weather conditions during the data collection periods were typical for the early fall season in that it was dry and windy at that time. During the data collection periods, visibility was clear and unlimited. There were no weather conditions to hinder the data collection. The first two data collection periods, however, were marked by windy conditions, with gusts up to 35 mph. Table 1 shows the summary weather conditions during the data collection phase of the study.

Table 1. Summary of weather conditions during data collection period*

Date	Time	Air temp	Dew point	Rel hum	Wind speed	Gusts	Dir	Visibility	Condition
10/30/2006	15:12	71	41	34%	14 mph	18 mph	SW	10 miles	windy
10/30/2006	17:00	51	32		22 mph	35 mph	WNW	10 miles	windy
10/30/2006	19:00	41	32		21 mph	35 mph	WNW	10 miles	windy
10/31/2006	15:00	39	15	38%	10 mph	18 mph	NW	10 miles	clear
10/31/2006	16:00	38	14	41%	12 mph	18 mph	W	10 miles	clear
10/31/2006	17:00	35	14	44%	12 mph	20 mph	NW	9 miles	clear
10/31/2006	18:00	32	17	54%	5 mph	none	WNW	10 miles	clear
10/31/2006	19:00	32	17	69%	6 mph	none	WNW	9 miles	clear
10/31/2006	20:00	30	15	78%	7 mph	none	WNW	8 miles	clear
11/1/2006	15:00	41	10	68%	21 mph	none	W	10 miles	clear
11/1/2006	16:00	39	10	78%	20 mph	none	WNW	10 miles	clear
11/1/2006	17:00	37	12	81%	15 mph	none	W	10 miles	clear
11/1/2006	18:00	33	14	81%	12 mph	21 mph	WNW	10 miles	clear
11/1/2006	19:00	30	14	77%	7 mph	none	WNW	9 miles	clear
11/1/2006	20:00	28	15	66%	5 mph	none	WSW	8 miles	clear
11/2/2006	15:00	35	14	69%	13 mph	none	W	10 miles	clear
11/2/2006	16:00	33	12	78%	9 mph	none	NW	10 miles	clear
11/2/2006	17:00	32	14	47%	14 mph	none	WNW	10 miles	clear
11/2/2006	18:00	32	14	60%	calm	none		4miles	clear
11/2/2006	19:00	30	12	74%	3 mph	none	WSW	8 miles	clear
11/2/2006	20:00	28	14	74%	3 mph	none	W	8 miles	clear

*Source: NWS daily summary for Boone Municipal Airport

Channelizing Devices

The study examined the differences in merge behavior using different channelizing devices during the four days of data collection. The following figures show the channelizing devices used in this study. It should be noted that evaluation involved the use of various devices and spacing in the taper only. Lane delineation was accomplished with 42 in. channelizers set at 80 ft. spacing for all layouts evaluated.

Figure 7 illustrates the standard drum-like channelizers that are generally used in work zone areas to provide longitudinal channelization within the activity area if their larger size and additional retro-reflective area are deemed appropriate. Drum-like channelizers are not generally used in areas with limited lateral clearance. When specified, quantities may be calculated and shown in the project plans.

Figure 7. Drum-like channelizer

Figure 8 illustrates the 42 in. channelizers, sometimes referred to as “grabber cones”. These channelizing devices are used in work zones and can be used in ramp areas, intersections and areas with limited lateral clearances. These types of channelizers may be used in daytime or nighttime operations in many states. When specified, quantities may be calculated and shown in the project plans.

Figure 8. 42 in. channelizer

Figure 9 illustrates the direction indicator barricades (DIB) that can be used instead of other channelizers in merging tapers, as DIBs provide direction and have a larger visual target area for motorists. DIBs, however, are not recommended for shifting tapers. When specified, quantities may be calculated and shown in the project plans.

Figure 9. Direction indicator barricade

Previously, Figure 5 showed the work zone configuration used in the study. This is a standard temporary traffic control used by Iowa DOT for a lane closure on a multi-lane highway. This pattern was used with each of the channelizing devices on consecutive days. On the first day of data collection, the drum-like channelizer was used. The drums were set up in a 910 ft. long taper at 60 ft. spacing to close the right lane and shift traffic to the left lane. On the second and third days of data collection, the 42 in. channelizers were erected in the same area to simulate a work zone. On the second day, 42 in. channelizers were placed at 60 ft. apart. On the third day, the 42 in. channelizers were spaced at 40 ft. On the fourth day of data collection, a single DIB was placed at the top of the taper along with the 42 in. channelizers spaced at 60 ft. Weather and traffic conditions, however, were such that the DIB blew over several times during the data collection period; thus, its effectiveness was not fully measured.

The following three figures show different work zone configurations using different channelizing devices. Figure 10 shows the base line work zone configuration, with the standard drums set at 60 ft. intervals. Figure 11 shows the 42 in. channelizers set at 60 ft. intervals. Figure 12 shows the 42 in. channelizers, or “grabber cones,” set at 40 ft. intervals.

Figure 10. Drums at 60 ft.

Figure 11. 42 in. channelizers at 60 ft.

Figure 12. 42 in. channelizers at 40 ft.

US 30 traffic flow characteristics were collected during four days from October 30 to November 2, 2006 from the Y Avenue overpass over US 30 near Ames, Iowa. The data were collected with the AutoScope wide-area video detection system, which consists of a control unit, image sensors (or video cameras), and supervisor computer/software. For this research, two video cameras were mounted on a trailer and directly connected to the AutoScope control unit. Figure 13 shows the AutoScope trailer, cameras, and control unit. Traffic flow images were recorded with the cameras in the field and then stored on videotape using the electronic equipment contained in the enclosed trailer (see Figure 14).

Figure 13. AutoScope video traffic detection system

Figure 14. Video detection equipment

The AutoScope recorded the traffic flow onto videotape. The videotape was then post-processed to count the data. Because night vision capabilities are limited, the AutoScope was used primarily to record traffic flow and behavior. The data from pneumatic tubes were used for traffic speed and volume determination.

Several types of data were collected during the four days, including traffic performance, weather conditions that might affect driver visibility, and traffic flow characteristics (e.g., volume and speed). These data were collected with mobile video data collection equipment (i.e., the AutoScope), along with the pneumatic road tubes. All of the data collected were copied to DVD for ease of analysis. Overall, more than 24 hours of data were collected during the four days.

Data Reduction

A large amount of data post-processing was conducted following data collection. The video images taken each day were copied and stored to DVD for added resolution and ease of analysis. The DVD images were then projected onto a large screen so that the images were more easily seen. The traffic was observed and analyzed from this point. Figure 15 shows an image as copied to DVD.

Figure 15. Video copied to DVD, projected on large screen

Previously, large lines were painted on the shoulder of the highway in 100 ft. intervals, for a total of 1,000 ft., to be used as baseline. (The lines were large enough so that they could be seen by the AutoScope camera located on the bridge). In the laboratory, an area plot was established and graphed on the screen. The video was projected onto the screen and vehicles were observed and timed traveling by each line in the plotted area. Vehicle speed was then calculated. Speed and distance calculations were then converted to dimensions that could be projected onto the screen. Following each set of calculations, a master template was made for each day and treatment condition. Using the template and projecting the video images onto the screen, vehicles were tracked and observed as they merged. The merge distance for each vehicle was estimated by calculating the time that the vehicle passed a measured point in each video frame. The calibration for this formula is shown in Figure 16.

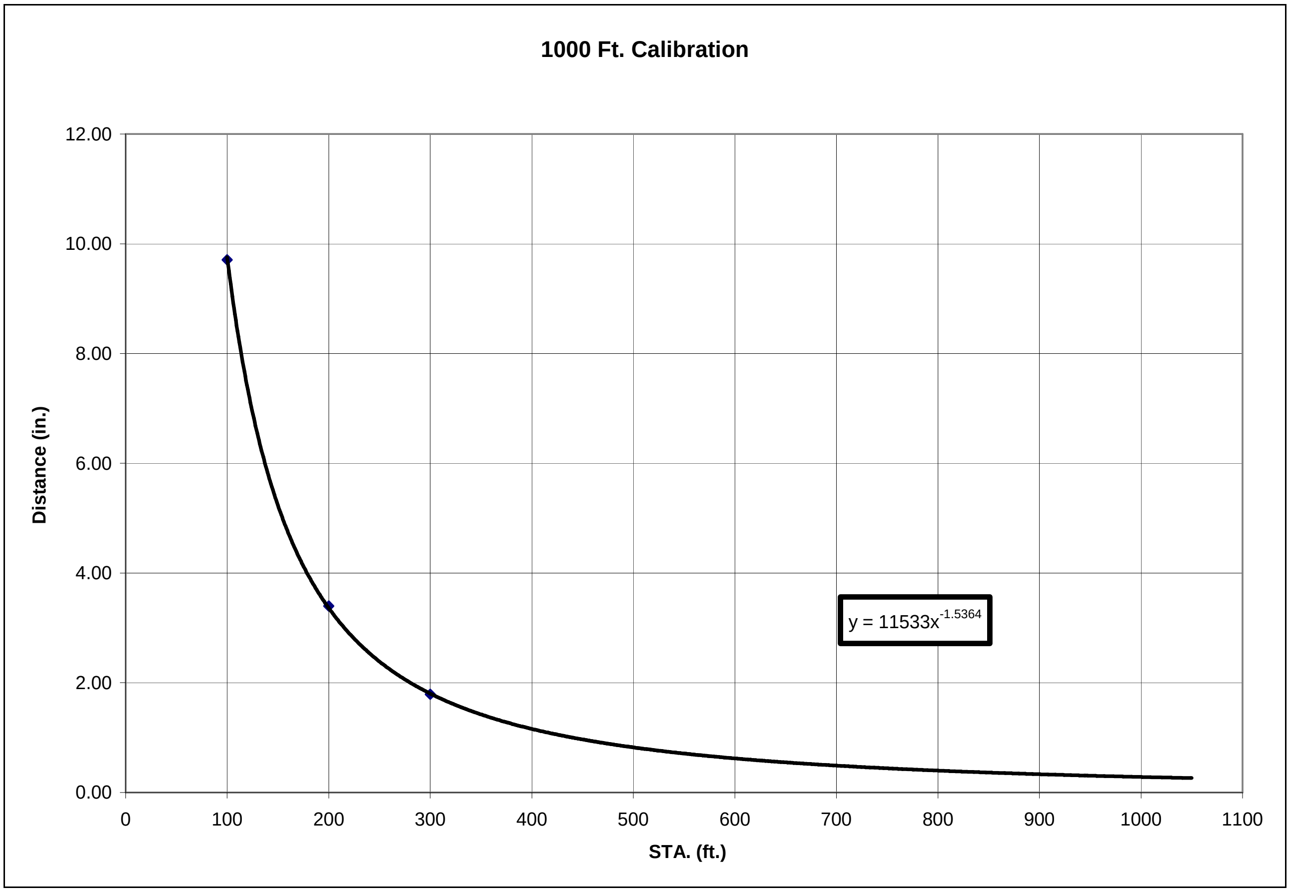


Figure 16. 1,000 ft. calibration for measuring merge distances

Table 2 describes the merging data collected from the video observations. Traffic movements through the work zone were observed and the vehicles were counted and measured as the drivers began to change lanes and merge to the left lane. The number in the “average begin merge” column is the location where drivers began the merging movement—defined as when the left side of a vehicle meets the center “skip” line. The “average end merge” column is the location where the merge movement was deemed to be completed, defined as when the right side of a vehicle meets the center “skip” line. Average length of merge is presented in the last column. The vehicle merge points were only measured within 3,000 ft. from the top of the taper. (Some vehicles did merge earlier than 3,000 ft., but the distances beyond 3,000 ft. could not be accurately measured with the AutoScope equipment.) The data are divided into day and night categories to determine the extent to which daylight influences merging behavior.

Table 2. Average merge distance by device (ft.)

Overall	Avg. begin merge	Avg. end merge	Avg. length merge
Drums—day	2,376	2,107	269
Drums—night	2,214	1,904	310
42 in. cones, 60 ft. —day	2,389	2,108	280
42 in. cones, 60 ft.—night	2,293	1,882	411
42 in. cones, 40 ft. —day	2,403	2,121	281
42 in. cones 40 ft. —night	2,327	1,929	398
42 in. cones + DIB—day	2,281	2,035	246
42 in. cones + DIB—night	2,284	1,954	330

Average merge distance can be expressed graphically as well, as shown in Figure 17.

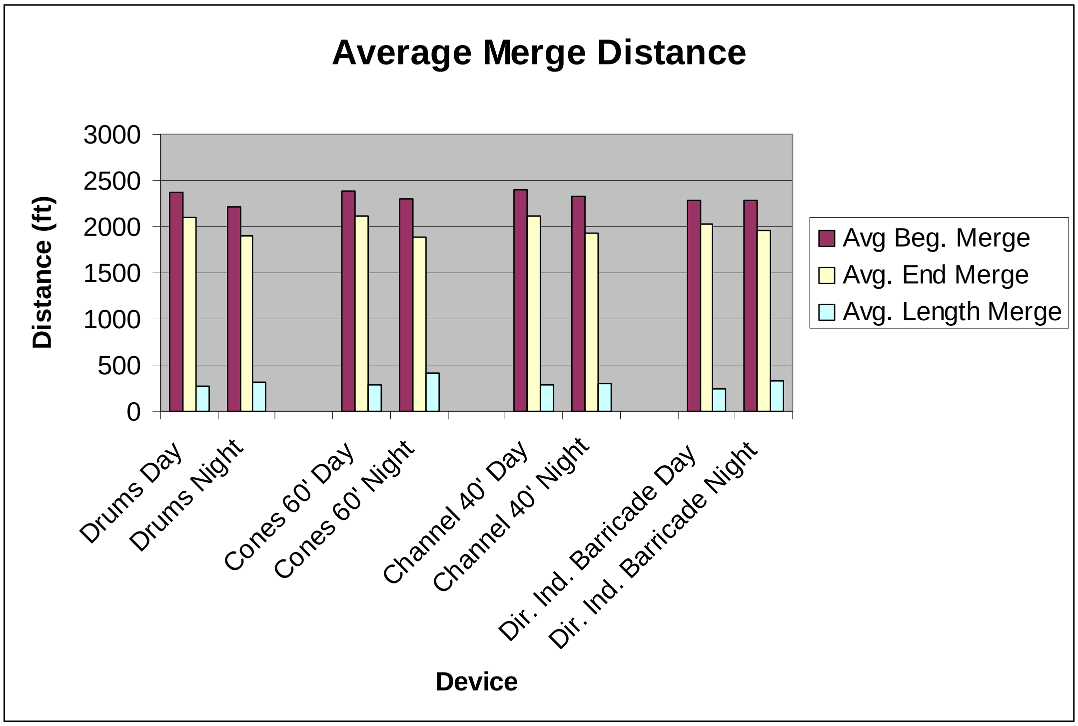


Figure 17. Average merge distance by device

Late merge activity was also estimated. Later merges were determined to be those vehicles that began their movements within 1,900 ft. of the top of the taper, or approximately 900 ft. from the beginning of the taper. Table 3 shows the averages of these late merges. It is important to note that the average length of merge was not significantly different between those who began their merge “early” and those who merged “late.”

The merge points are estimated distances from the top of the work zone taper. Thus, when conventional drums are used during the day, the average beginning merge point for the observed traffic is 1,529 ft. from the top of the taper. The average ending merge point is 1,265 ft. from the top of the taper. The average length of merge in this scenario is therefore 264 ft. As the work zone was set up in the vicinity of a crest vertical curve, only those vehicles merging after the channelizing devices came into view (within 1,900 ft. of the top of the taper) are presented in the data in Table 3. A t-test was run to compare the mean merge distances between drums and 42 in. cones at the same spacing (60 ft.). The test showed that, for night time conditions, differences were not significant. During the day, drivers actually merged earlier for the tall cones than for the drums.

Table 3. Average late merge distance by device (ft.)

Overall	Number of observed merges	Avg. begin merge	Avg. end merge	Avg. length of merge
Drums—day	38	1529	1265	264
Drums—night	36	1628	1367	261
42 in. cones, 60 ft.—day	26	1673	1404	269
42 in. cones, 60 ft. —night	15	1613	1231	382
42 in. cones, 40 ft. —day	42	1610	1314	295
42 in. cones, 40 ft. —night	53	1457	1128	328
42 in. cones, 60 ft. + DIB—day	39	1528	1351	177
42 in. cones, 60 ft. + DIB—night	25	1492	1280	212

Shy Distance

Shy distance is defined as the distance a vehicle is laterally displaced from the channelizing device at a designated point. Shy distance, in this instance, was estimated at the top of the taper by examining the videotape at reduced speed and calculating the distance from the designated spot, from zero to 12 ft. (12 ft. representing an entire traffic lane). Shy distances were estimated for each treatment. An examination of the data shows little significant difference between each device. Most of the shy distances were between 6 ft. to 8 ft. from the center line at the top of the taper. Distances did increase at night, however. The analysis indicates that during nighttime hours, the 42 in. channelizers at 40 ft. intervals nearly replicated the merging behavior observed with the standard drums. Shy distance for the 60 ft. intervals was lower. The treatment using the combination of 42 in. channelizers and direction indicator barricade also shows an increase in shy distances.

Table 4 illustrates the traffic behavior of the shy distances by device, separated by daytime hours and nighttime hours, with the estimated average shy distance recorded. The table is based on 100 observations made for each condition. A similar process to measuring merge distances was used. The distances were calculated estimates using the video observations of vehicle behavior through the work zone. A master template was placed on the video screen. The images were projected onto the screen, and the vehicles and distances were recorded as their images passed through the plotted area.

Table 4. Shy distances by type of channelizing device

Drums 60 ft. east day								
Distance (ft.)	12	10	8	6	4	2	Center line	Average
Number	0	7	24	37	20	12	0	5.88 ft.
Drums 60 ft. east night								
Distance (ft.)	12	10	8	6	4	2	Center line	Average
Number	0	1	23	53	21	12	0	6.00 ft.
Channelizers 60 ft. east day								
Distance (ft.)	12	10	8	6	4	2	Center line	Average
Number	0	1	21	36	34	6	0	5.42 ft.
Channelizers 60 ft. east night								
Distance (ft.)	12	10	8	6	4	2	Center line	Average
Number	0	1	13	33	42	11	0	5.04 ft.
Channelizers 40 ft. east day								
Distance (ft.)	12	10	8	6	4	2	Center line	Average
Number	0	5	32	33	24	6	0	6.12 ft.
Channelizers 40 ft. east night								
Distance (ft.)	12	10	8	6	4	2	Center line	Average
Number	0	3	9	51	34	3	0	5.50 ft.
Channelizers 60 ft. w/ DIB east day								
Distance (ft.)	12	10	8	6	4	2	Center line	Average
Number	0	6	31	35	22	5	1	6.16 ft.
Channelizers 60 ft. w/ DIB east night								
Distance (ft.)	12	10	8	6	4	2	Center line	Average
Number	1	17	42	34	6	1	0	7.40 ft.

Figures 17 and 18 illustrate the shy distances of the vehicles as they passed by the channelizing devices during daytime and nighttime hours. Figure 17 shows shy distances during daylight. Figure 18 shows shy distances as measured at night. The graphs show the number of cars by the distance they moved away from the center line near the top of taper. For example, when the drums were set up at 60 ft. during the day (at the peak), approximately 37 cars moved 6 ft. away from the center line.

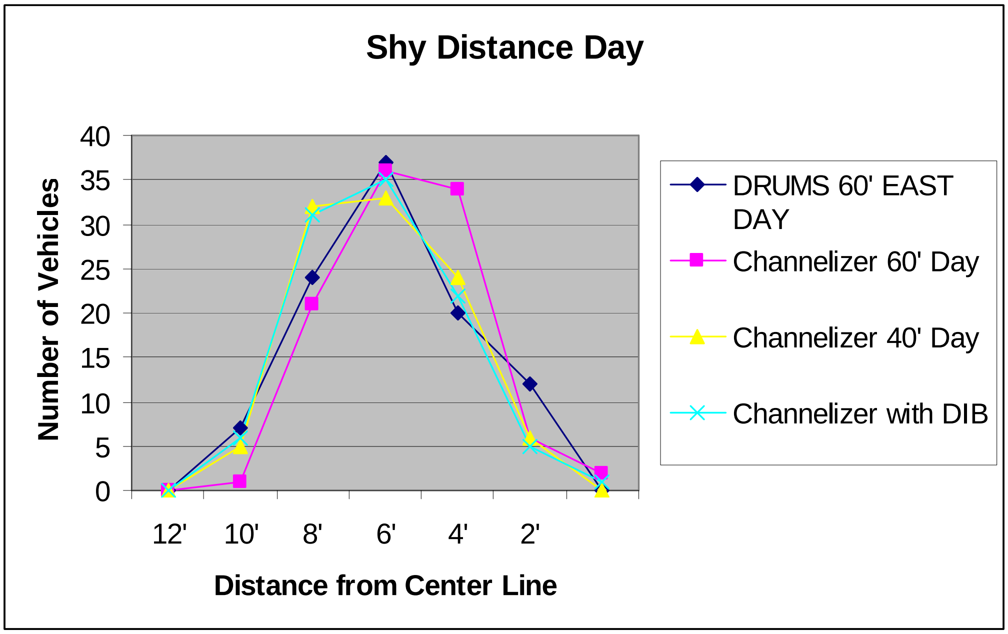


Figure 17. Shy distance by device by day

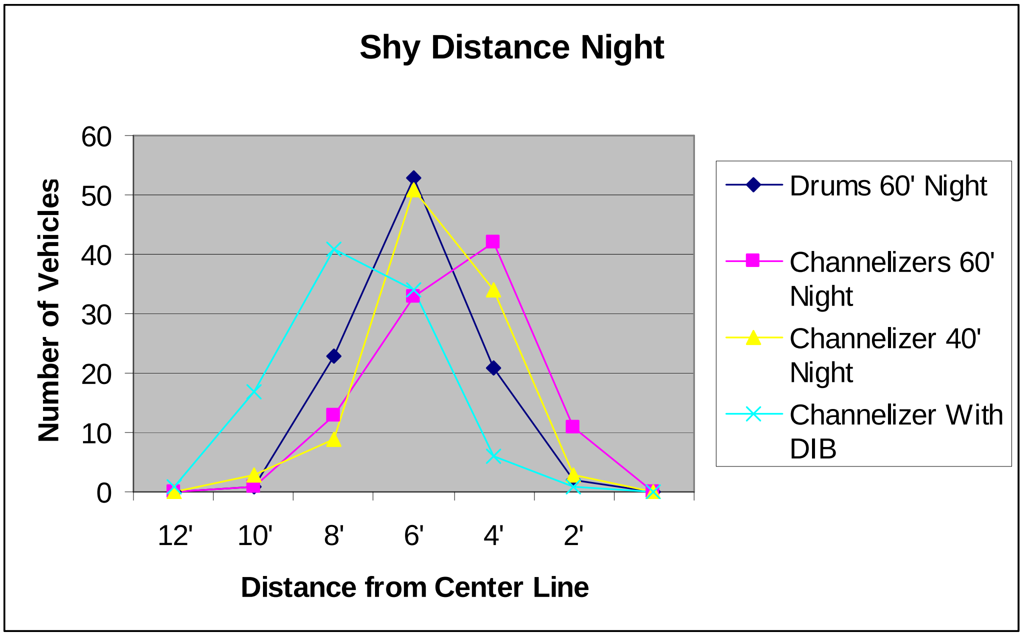


Figure 18. Shy distance by device by night

Speed Data

Speed was also analyzed for each channelization setup. Three sets of pneumatic road tube counters were placed on US 30 at various locations to gather traffic data. The posted speed limit for this section of US 30 is 65 mph. For this study, one set of tube counters was placed upstream, approximately one mile ahead of the work zone at mile marker 142.71. The second set was placed just under the Y Avenue Bridge, approximately 1,000 ft. from the beginning of the taper. The third set was placed approximately 1/4 mile from the end of the work zone at mile marker 144.10. The speed data show a general decrease in traffic speed through the work zone area. Figure 19 shows the approximate placement of the pneumatic road tubes on US 30 for this study. The tubes provided valuable speed and traffic data for the duration of the study.

Figure 19. Placement of pneumatic road tubes

The speed data for the study have been summarized in the following three tables. Table 5 shows data from the first counter at mile marker 142.71. Table 6 illustrates data from the counter placed under the Y Avenue Bridge. Table 7 shows data from the counter placed at mile marker 144.10, just beyond the work zone. These tables separate the data into two sections. The first section of each table is of normal traffic, with no work zone in place. The second section illustrates data with the work zone treatment installed. The data show that there is a decrease in speed as traffic travels through the work zone. More detailed data are included in Appendix B.

Table 5 provides the summary data from the first tube counter placed at mile marker 142.71 upstream of the work zone. The posted speed limit on this section of US 30 is 65 mph. This table is divided into two sections, one for initial traffic flow and one “treatment” period of the study, when the work zone was in effect. For all vehicles, the average speed was 68.7 mph during the entire four days of data collection, with 79% of traffic traveling over the posted limit. During the treatment period, when the work zone was set up, the average speed for all vehicles at this point was 68.7 mph, with 79% of traffic traveling over the posted speed limit.

Table 5. Aggregate speed data: 1st counter MM 142.71

	Eastbound—no treatment		
65 mph posted	**All vehicles**	**Passenger cars**	**Trucks**
Average speed	68.7	69	67
85th % speed	74	74	72
Standard deviation	5.08	5.07	4.81
Minimum	24	31	24
Maximum	99	99	82
% >limit	79	80.6	69.2
% >5 over limit	43.3	46	26.4
% >10 over limit	9.7	10.7	3.8
% >15 over limit	1.8	2.1	0.3
% >20 over limit	0.3	0.4	0.0
	Eastbound—3:00–8:30 PM treatment		
65 mph posted	**All vehicles**	**Passenger cars**	**Trucks**
Average speed	68.7	68.9	67.1
85th% speed	74	74	72
Standard deviation	4.74	4.68	4.8
Minimum	26	26	26
Maximum	96	96	81
% >limit	79.1	80.6	68.4
% >5 over limit	42.8	44.6	29.9
% >10 over limit	8.7	9.4	3.3
% >15 over limit	1.5	1.7	0.1
% >20 over limit	0.4	0.4	0.0

Table 6 shows the data collected from the under the Y Avenue Bridge just prior to the work zone area, approximately 1,000 ft. from the beginning of the taper. The non-treatment period shows a slight increase in speed from the first counter—an average 69.4 mph for all vehicles, with 82.2% traveling over the posted speed limit. The treatment periods show an average speed of 67.3 mph, with 68.2% of traffic traveling over the posted speed limit.

Table 6. Aggregate speed data: 2nd counter under bridge

Eastbound—no treatment			
65 mph posted	**All vehicles**	**Passenger cars**	**Trucks**
Average speed	69.4	69.7	67.8
85th % speed	75	75	73
Standard deviation	5.2	5.22	4.74
Minimum	23	23	25
Maximum	80	103	94
% >limit	82.2	83.7	73.9
% >5 over limit	50.6	53.6	33.9
% >10 over limit	13.3	14.5	6.4
% >15 over limit	2.5	2.9	0.69
% >20 over limit	0.6	0.7	0.1
Eastbound—3:00–8:30 PM treatment			
65 mph posted	**All vehicles**	**Passenger cars**	**Trucks**
Average speed	67.3	67.6	65.4
85th % speed	73	73	71
Standard deviation	5.27	5.22	5.27
Minimum	25	37	25
Maximum	95	95	81
% >limit	68.2	70.1	54.6
% >5 over limit	34.4	36.5	19.7
% >10 over limit	6.1	6.7	1.7
% >15 over limit	1.1	1.2	0.3
% >20 over limit	0.2	0.2	0.0

Table 7 provides the speed data downstream from the work zone area. The data show an average speed of 69.2 mph with 81.1% of the traffic traveling over the posted speed limit under normal traffic conditions. During the treatment periods, however, the data show an average speed of 61.7 mph, with only 32.2% of the traffic traveling over the posted limit. These data indicate that traffic was slowing down within the work zone area, especially commercial traffic, even without a reduced regulatory speed limit in place.

Table 7. Aggregate speed data: 3rd counter MM 144.10

Eastbound—no treatment			
65 mph posted	**All vehicles**	**Passenger cars**	**Trucks**
Average speed	69.2	69.5	67.8
85th % speed	74	75	73
Standard deviation	5.19	5.22	4.79
Minimum	14	14	28
Maximum	100	100	99
% >limit	81.1	75.8	73
% >5 over limit	48.2	50.6	33.8
% >10 over limit	12.5	13.6	6.2
% >15 over limit	2.5	2.9	0.9
% >20 over limit	0.5	0	0.1
Eastbound—3:00–8:30 PM treatment (1 lane)			
65 mph posted	**All vehicles**	**Passenger cars**	**Trucks**
Avg. speed	61.7	61.9	60.4
85th % speed	69	69	67
Standard deviation	6.92	6.99	6.21
Minimum	26	26	36
Maximum	85	85	76
% >limit	32.2	33.4	22.7
% >5 over limit	11.8	12.7	5
% >10 over limit	1.4	1.6	0.1
% >15 over limit	0.1	0.2	0
% >20 over limit	0	0	0

Table 8 illustrates the average speed of traffic for each day and night during the "treatment" periods. In general, although a reduced speed was not posted, the data show a decrease in traffic speed through the work area.

Table 8. Average speed of vehicles for each treatment

Passenger cars			
Treatment	**Upstream**	**Under bridge**	**In work zone**
Drums at 60 ft.—day	69.8	68.1	62.2
Drums at 60 ft.—night	68.7	67.4	59.7
Cones at 60ft.—day	69.2	67.8	62.6
Cones at 60 ft.—night	68.2	67.0	59.3
Cones at 40 ft.—day	69.6	68.3	63.6
Cones at 40 ft.—night	68.2	66.5	59.6
Cones at 60 ft.w/ DIB—day	68.9	67.7	62.9
Cones at 60 ft. w/ DIB—night	68.0	66.4	59.8
Trucks			
Treatment	**Upstream**	**Under bridge**	**In work zone**
Drums at 60 ft.—day	67.2	65.2	60.5
Drums at 60 ft.—night	66.8	65.1	57.2
Cones at 60ft.—day	66.9	65.7	61.3
Cones at 60 ft.—night	66.8	64.9	57.3
Cones at 40 ft.—day	67.9	66.7	62.3
Cones at 40 ft.—night	67.5	64.8	59.0
Cones at 60 ft.w/ DIB—day	67.2	64.8	61.2
Cones at 60 ft. w/ DIB—night	65.7	64.7	56.9

STUDY LIMITATIONS

This research regarding the effectiveness of channelizing devices has several limitations. First, the study relied on data gathered in an area where the road geometry was not ideal. This was due to the desire for an overhead observation point that would not influence traffic behavior on a facility that was sufficiently busy, but not too busy (e.g., Interstate). The only such point within reasonable distance from the research facility was the chosen point on US 30. The test work zone was placed just past a crest vertical curve, so the channelizing devices were not immediately visible to motorists until passing the crest of the curve. Second, the brightness of light generated from the arrow panel placed ahead of the work zone was very evident at night and may have influenced the merging behavior of motorists. Third, in compliance with standard operating procedure of the maintenance crew, warning lights were operating on the maintenance truck that was placed in the work zone. We simply do not know if these lights influenced merging behavior, or if there is another factor affecting late merge movements. The design of future evaluation and research studies for channelizing device effectiveness should take these limitations into consideration. In other words, it may be difficult to generalize the findings from individual merging activity because of the variations in intensity, duration, standardization, content, and format of the work zone type and road geometry.

CONCLUSIONS

In the conduct of this research study, data were gathered in several different ways. A literature review was conducted to identify similar studies or relevant references, inquiries were made of selected state departments of transportation for common practices, advice and guidance were sought from a group of expert professionals, and data were gathered from an analysis of several temporary traffic control options for taper channelization under field conditions. From a synthesis of this information, the following conclusions can be drawn:

- Selected state DOTs follow the MUTCD Part 6 recommendations closely for TTC for lane closures on multi-lane roadways.
- States vary somewhat in requirements for type of channelizing devices used in these lane closures.
- Some additional guidance for states in selection of channelizing devices would be beneficial.
- Little variation in traffic performance, day or night, was observed, regardless of channelizing device used or spacing of the devices.
- The direction indicator barricade (DIB) could not be fully analyzed due to the device being displaced at times and the fact that only one device was available for evaluation. More research is needed to verify the potential benefits of this device.
- Taller cones (36–42 inches) seem to perform similarly to drums in traffic guidance and should require less effort in deployment and retrieval than drums, as well as requiring less storage space.
- Road users, especially commercial vehicle operators, reduced speeds significantly when passing through the work area, even without a posted reduced speed limit.
- Most drivers seem to merge into the proper lane well in advance of the taper, regardless of channelizing device used, indicating the probable positive impact of the arrow panel.

RECOMMENDATIONS

Based on the data gathered and analyzed as part of this study, the following recommendations are offered:

- Direction indicator barricades may offer promise for more definitive guidance for drivers, but these devices must be properly stabilized to prevent dislocation by rapidly moving commercial traffic and weather conditions.
- Maintenance crews may want to experiment with this device in tapers for short term/short duration operations to better assess the potential effectiveness of the taper.
- Agencies may consider substitution of tall cones for drums in channelizing traffic in tapers and for lane delineation. Experimentation with reduced spacing might be considered to enhance visibility, especially in tapers for night use.

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1. Chen, Yali, Xiao Qin, and David Noyce. “Evaluation of Speed Management Strategies in Highway Workzones.” Proceedings of the 2006 Mid-Continent Transportation Research Forum. Madison, Wisconsin.

2. Atchley, Paul, and Jeff Dressel. “The Effect of Fluorescent Yellow-Green Background for Vehicle Mounted Work Zone Signs on Attention and Eye Movements. Smart Work Zone Deployment Initiative, University of Kansas, 2006.

3. Kamyab, Ali, and Brandon Storm. “Fluorescent Yellow-Green Background for Vehicle Mounted Work Zone Signs.” Center for Transportation Research and Education, Iowa State University, 2001.

APPENDIX A. STATE DOT STANDARDS AND GUIDELINES

Kansas

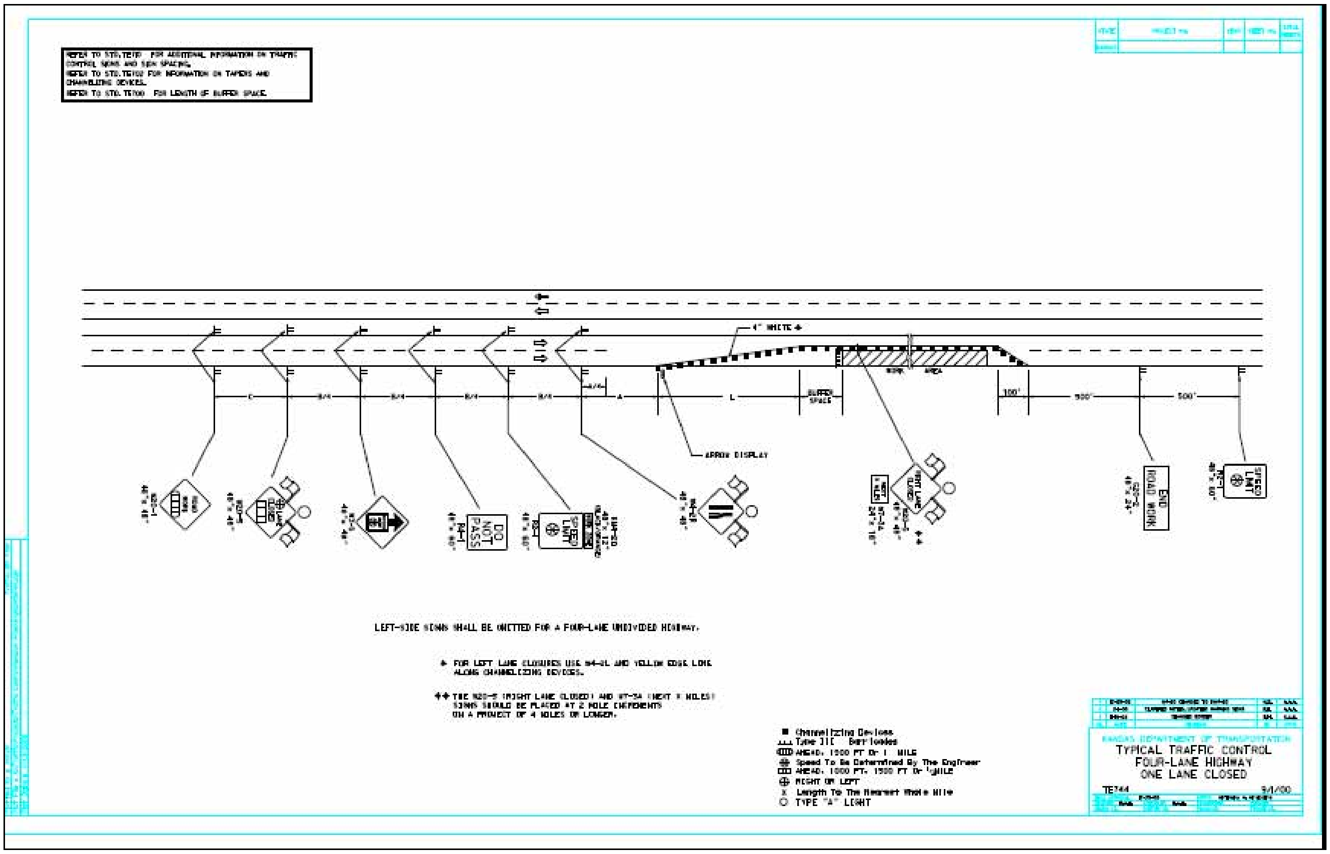
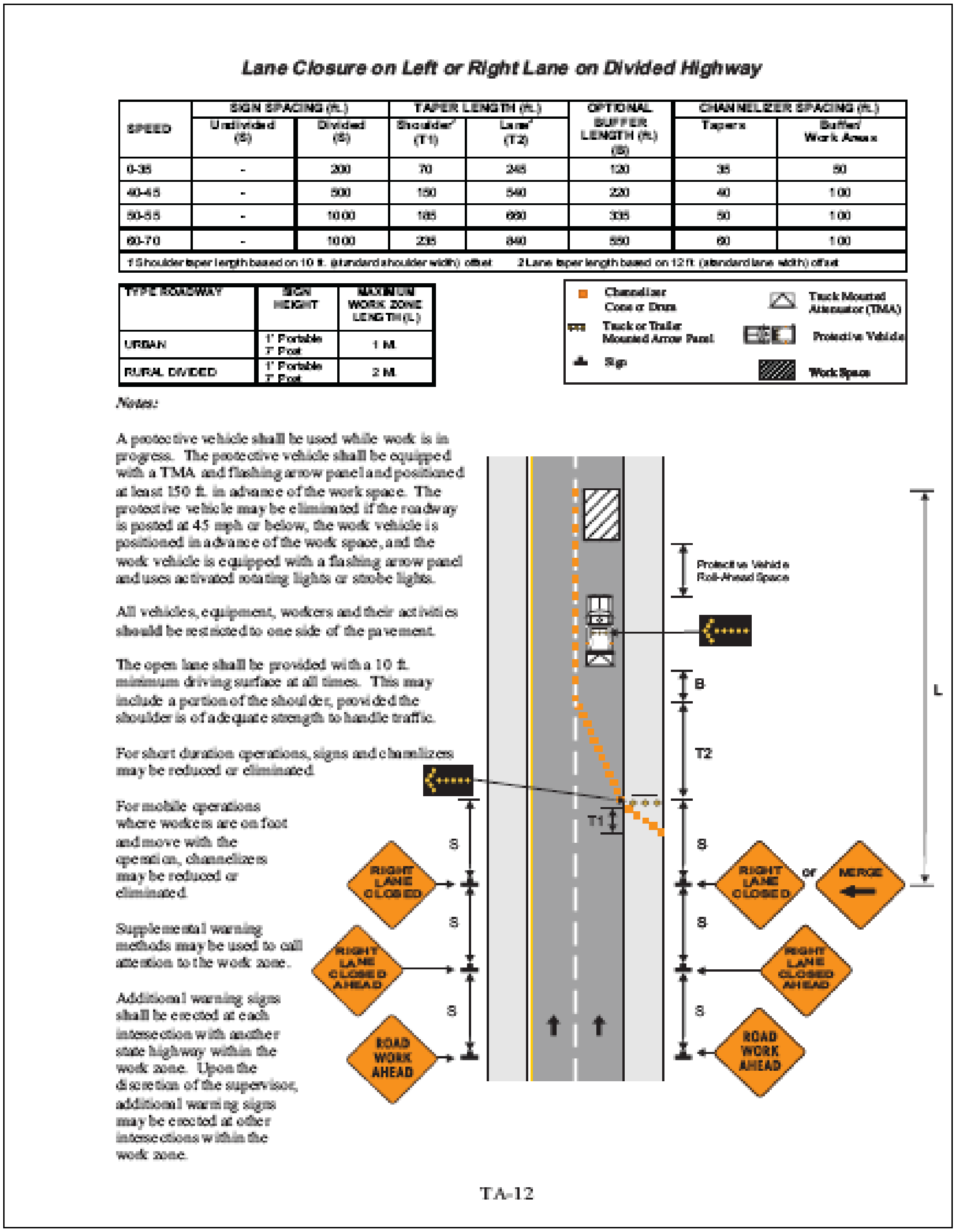


Figure A.1. Standard TE744: Typical Traffic Control 4-Lane Highway One Lane Closed

Conical delineators (Trim line tall cones) used as channelizing devices.

Missouri



Lane Closure on Left or Right Lane on Divided Highway

SPEED	SIGN SPACING (ft.)		TAPER LENGTH (ft.)		OPTIONAL BUFFER LENGTH (ft.) (B)	CHANNELIZER SPACING (ft.)	
	Undivided (S)	Divided (S)	Shoulder¹ (T1)	Lane² (T2)		Tapers	Buffer/ Work Areas
0-35	-	200	70	245	120	35	50
40-45	-	500	150	540	220	40	100
50-55	-	1000	185	660	335	50	100
60-70	-	1000	235	840	550	60	100

1 Shoulder taper length based on 10 ft. (standard shoulder width) offset   2 Lane taper length based on 12 ft. (standard lane width) offset

TYPE ROADWAY	SIGN HEIGHT	MAXIMUM WORK ZONE LENGTH (L)
URBAN	1' Portable 7' Post	1 M.
RURAL DIVIDED	1' Portable 7' Post	2 M.

■	Channelizer Cone or Drum	△	Truck Mounted Attenuator (TMA)
▬	Truck or Trailer Mounted Arrow Panel	▭	Protective Vehicle
▲	Sign	▨	Work Space

Notes:

A protective vehicle shall be used while work is in progress. The protective vehicle shall be equipped with a TMA and flashing arrow panel and positioned at least 150 ft. in advance of the work space. The protective vehicle may be eliminated if the roadway is posted at 45 mph or below, the work vehicle is positioned in advance of the work space, and the work vehicle is equipped with a flashing arrow panel and uses activated rotating lights or strobe lights.

All vehicles, equipment, workers and their activities should be restricted to one side of the pavement.

The open lane shall be provided with a 10 ft. minimum driving surface at all times. This may include a portion of the shoulder, provided the shoulder is of adequate strength to handle traffic.

For short duration operations, signs and channelizers may be reduced or eliminated.

For mobile operations where workers are on foot and move with the operation, channelizers may be reduced or eliminated.

Supplemental warning methods may be used to call attention to the work zone.

Additional warning signs shall be erected at each intersection with another state highway within the work zone. Upon the discretion of the supervisor, additional warning signs may be erected at other intersections within the work zone.

TA-12

Figure A.2. Standard TA-12: Lane Closure on Left or Right Lane on Divided Highway

Trim-Line Channelizers are preferred as channelizing devices, but other devices (such as drums, vertical panels, cones, or direction indicator barricades) are allowed in the standard plan notes.

Nebraska

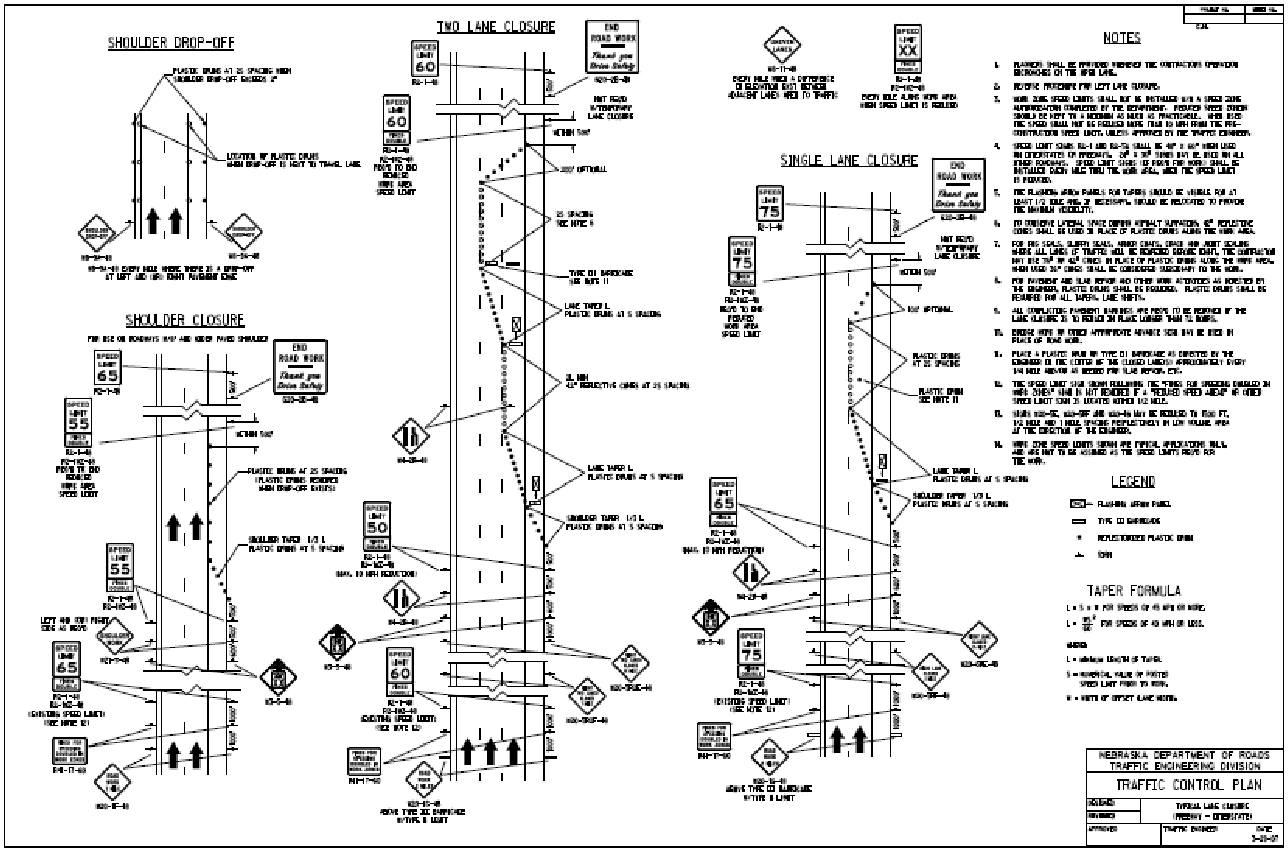
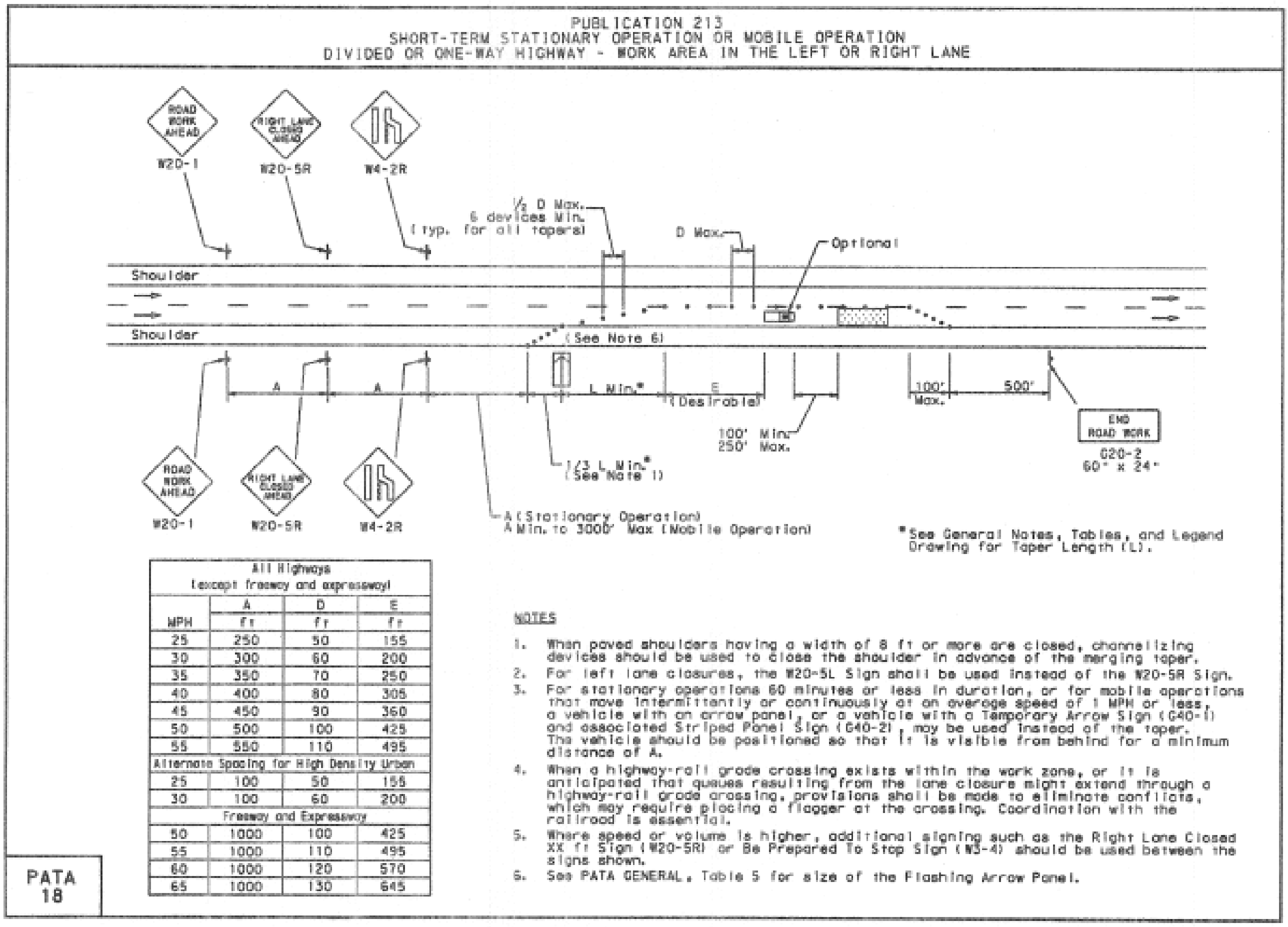


Figure A.3. Traffic Control Plan: Typical Lane Closure (Freeway - Interstate)

Plastic drums are used in the tapers; either 42 in. cones or drums can be used for lane delineation. Drums must be used if a drop-off behind them is greater than 2 in. Vertical panels are an acceptable substitute when the site conditions are not favorable for cones or drums.

Pennsylvania



PUBLICATION 213
SHORT-TERM STATIONARY OPERATION OR MOBILE OPERATION
DIVIDED OR ONE-WAY HIGHWAY - WORK AREA IN THE LEFT OR RIGHT LANE

*See General Notes, Tables, and Legend Drawing for Taper Length (L).

All Highways (except freeway and expressway)			
	A	D	E
MPH	ft	ft	ft
25	250	50	155
30	300	60	200
35	350	70	250
40	400	80	305
45	450	90	360
50	500	100	425
55	550	110	495
Alternate Spacing for High Density Urban			
25	100	50	155
30	100	60	200
Freeway and Expressway			
50	1000	100	425
55	1000	110	495
60	1000	120	570
65	1000	130	645

NOTES

1. When paved shoulders having a width of 8 ft or more are closed, channelizing devices should be used to close the shoulder in advance of the merging taper.
2. For left lane closures, the W20-5L Sign shall be used instead of the W20-5R Sign.
3. For stationary operations 60 minutes or less in duration, or for mobile operations that move intermittently or continuously at an average speed of 1 MPH or less, a vehicle with an arrow panel, or a vehicle with a Temporary Arrow Sign (G40-1) and associated Striped Panel Sign (G40-2), may be used instead of the taper. The vehicle should be positioned so that it is visible from behind for a minimum distance of A.
4. When a highway-rail grade crossing exists within the work zone, or it is anticipated that queues resulting from the lane closure might extend through a highway-rail grade crossing, provisions shall be made to eliminate conflicts, which may require placing a flagger at the crossing. Coordination with the railroad is essential.
5. Where speed or volume is higher, additional signing such as the Right Lane Closed XX ft Sign (W20-5R) or Be Prepared To Stop Sign (W3-4) should be used between the signs shown.
6. See PATA GENERAL, Table 5 for size of the Flashing Arrow Panel.

PATA
18

Figure A.4. Standard PATA 18: Short Term Stationary Operation or Mobile Operation, Divided or One-Way Highway—Work Area in the Left or Right Lane

Exact type of channelizing device (drum, vertical panel, etc.) is not specified.

Wisconsin

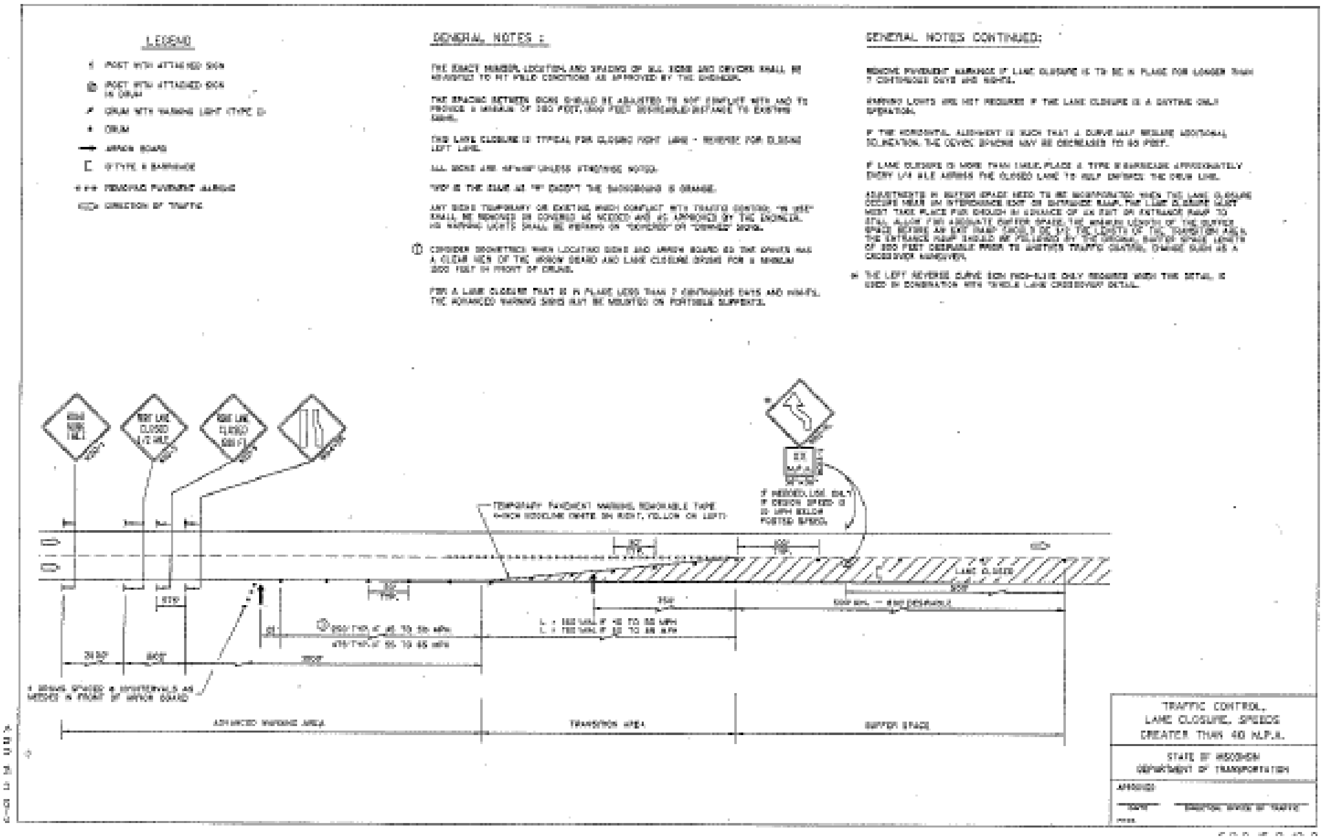
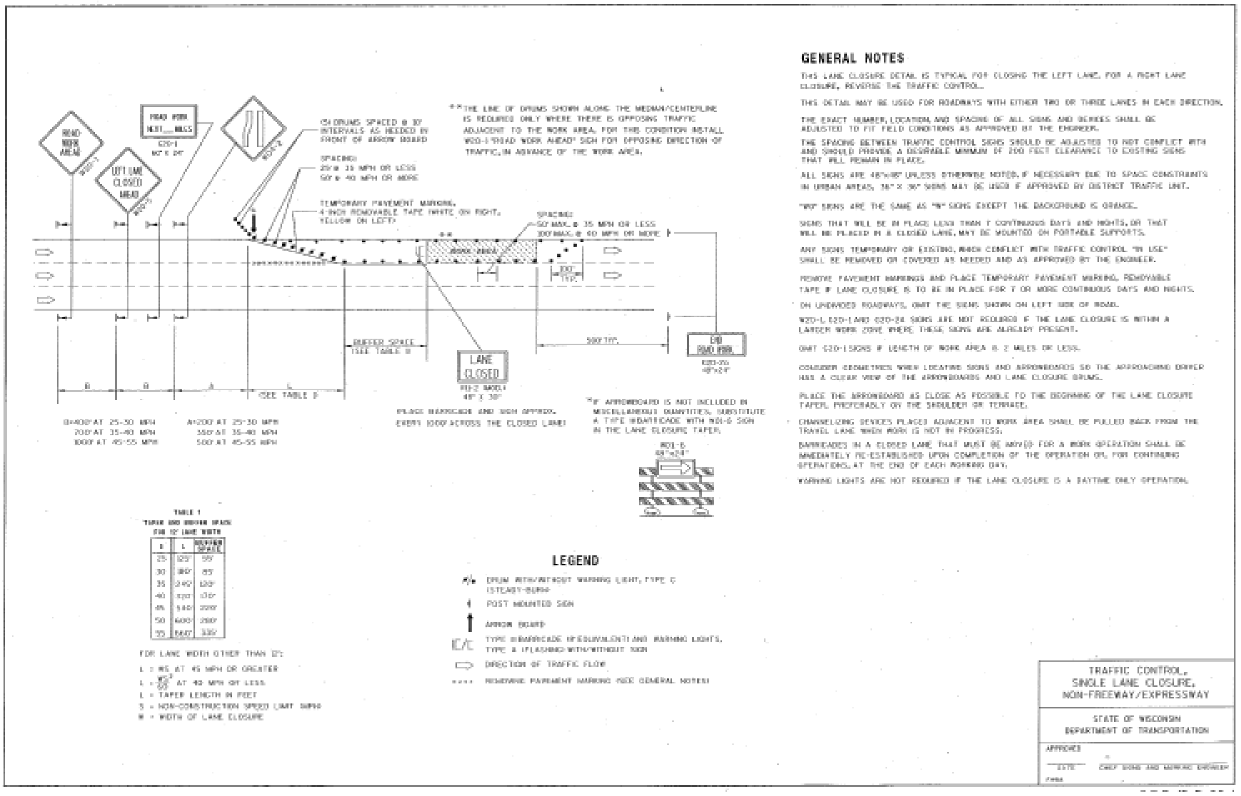


Figure A.5. Standard TTC: Lane Closure for Speeds Greater than 40 mph

Drums are preferred for channelizing devices, but vertical panels are allowed where 360-degree visibility of the devices is not needed (e.g., away from intersections and driveways). Also, tall cones are occasionally allowed for lane delineation (tangent sections) where space is inadequate for drums and work duration is short-term.

Wisconsin



** THE LINE OF DRUMS SHOWN ALONG THE MEDIAN/CENTERLINE IS REQUIRED ONLY WHERE THERE IS OPPOSING TRAFFIC ADJACENT TO THE WORK AREA. FOR THIS CONDITION INSTALL W20-1 "ROAD WORK AHEAD" SIGN FOR OPPOSING DIRECTION OF TRAFFIC, IN ADVANCE OF THE WORK AREA.

PLACE BARRICADE AND SIGN APPROX. EVERY 1000' ACROSS THE CLOSED LANE)

* IF ARROWBOARD IS NOT INCLUDED IN MISCELLANEOUS QUANTITIES, SUBSTITUTE A TYPE III BARRICADE WITH M01-6 SIGN IN THE LANE CLOSURE TAPER.

GENERAL NOTES

THIS LANE CLOSURE DETAIL IS TYPICAL FOR CLOSING THE LEFT LANE. FOR A RIGHT LANE CLOSURE, REVERSE THE TRAFFIC CONTROL.

THIS DETAIL MAY BE USED FOR ROADWAYS WITH EITHER TWO OR THREE LANES IN EACH DIRECTION.

THE EXACT NUMBER, LOCATION, AND SPACING OF ALL SIGNS AND DEVICES SHALL BE ADJUSTED TO FIT FIELD CONDITIONS AS APPROVED BY THE ENGINEER.

THE SPACING BETWEEN TRAFFIC CONTROL SIGNS SHOULD BE ADJUSTED TO NOT CONFLICT WITH AND SHOULD PROVIDE A DESIRABLE MINIMUM OF 200 FEET CLEARANCE TO EXISTING SIGNS THAT WILL REMAIN IN PLACE.

ALL SIGNS ARE 48"x48" UNLESS OTHERWISE NOTED. IF NECESSARY DUE TO SPACE CONSTRAINTS IN URBAN AREAS, 36" X 36" SIGNS MAY BE USED IF APPROVED BY DISTRICT TRAFFIC UNIT.

"WO" SIGNS ARE THE SAME AS "W" SIGNS EXCEPT THE BACKGROUND IS ORANGE.

SIGNS THAT WILL BE IN PLACE LESS THAN 7 CONTINUOUS DAYS AND NIGHTS, OR THAT WILL BE PLACED IN A CLOSED LANE, MAY BE MOUNTED ON PORTABLE SUPPORTS.

ANY SIGNS TEMPORARY OR EXISTING, WHICH CONFLICT WITH TRAFFIC CONTROL "IN USE" SHALL BE REMOVED OR COVERED AS NEEDED AND AS APPROVED BY THE ENGINEER.

REMOVE PAVEMENT MARKINGS AND PLACE TEMPORARY PAVEMENT MARKING, REMOVABLE TAPE IF LANE CLOSURE IS TO BE IN PLACE FOR 7 OR MORE CONTINUOUS DAYS AND NIGHTS.

ON UNDIVIDED ROADWAYS, OMIT THE SIGNS SHOWN ON LEFT SIDE OF ROAD.

W20-1, G20-1 AND G20-2A SIGNS ARE NOT REQUIRED IF THE LANE CLOSURE IS WITHIN A LARGER WORK ZONE WHERE THESE SIGNS ARE ALREADY PRESENT.

OMIT G20-1 SIGNS IF LENGTH OF WORK AREA IS 2 MILES OR LESS.

CONSIDER GEOMETRICS WHEN LOCATING SIGNS AND ARROWBOARDS SO THE APPROACHING DRIVER HAS A CLEAR VIEW OF THE ARROWBOARDS AND LANE CLOSURE DRUMS.

PLACE THE ARROWBOARD AS CLOSE AS POSSIBLE TO THE BEGINNING OF THE LANE CLOSURE TAPER, PREFERABLY ON THE SHOULDER OR TERRACE.

CHANNELIZING DEVICES PLACED ADJACENT TO WORK AREA SHALL BE PULLED BACK FROM THE TRAVEL LANE WHEN WORK IS NOT IN PROGRESS.

BARRICADES IN A CLOSED LANE THAT MUST BE MOVED FOR A WORK OPERATION SHALL BE IMMEDIATELY RE-ESTABLISHED UPON COMPLETION OF THE OPERATION OR, FOR CONTINUING OPERATIONS, AT THE END OF EACH WORKING DAY.

WARNING LIGHTS ARE NOT REQUIRED IF THE LANE CLOSURE IS A DAYTIME ONLY OPERATION.

TABLE 1
TAPER AND BUFFER SPACE FOR 12' LANE WIDTH

S	L	BUFFER SPACE
25	125'	55'
30	180'	85'
35	245'	120'
40	320'	170'
45	540'	220'
50	600'	280'
55	660'	335'

FOR LANE WIDTH OTHER THAN 12':

L = WS AT 45 MPH OR GREATER
L = $\frac{WS^2}{60}$ AT 40 MPH OR LESS
L = TAPER LENGTH IN FEET
S = NON-CONSTRUCTION SPEED LIMIT (MPH)
W = WIDTH OF LANE CLOSURE

LEGEND

●/●	DRUM WITH/WITHOUT WARNING LIGHT, TYPE C (STEADY-BURN)
♦	POST MOUNTED SIGN
↑	ARROW BOARD
⊏/⊏	TYPE III BARRICADE (OR EQUIVALENT) AND WARNING LIGHTS, TYPE A (FLASHING) WITH/WITHOUT SIGN
⇨	DIRECTION OF TRAFFIC FLOW
▪▪▪▪	REMOVABLE PAVEMENT MARKING (SEE GENERAL NOTES)

TRAFFIC CONTROL,
SINGLE LANE CLOSURE,
NON-FREEWAY/EXPRESSWAY

STATE OF WISCONSIN
DEPARTMENT OF TRANSPORTATION

APPROVED

DATE
CHIEF SIGNS AND MARKING ENGINEER

Figure A.6. Standard TTC: Single Lane Closure Non-Freeway/Expressway

Drums are used as channelizing devices.

APPENDIX B. DETAILED TRAFFIC COUNTER DATA

Table B.1 shows the speed data taken on day 1 of the data collection, when the standard drums were used in the work zone area. These data are from the three sets of road tubes. The first set was placed upstream from the work zone during the daytime data collection period. The second set was placed under the observation bridge and the third set was placed at the end of the work zone. The posted speed limit on this section of US 30 is 65 mph.

One item of note: the 85th percentile speed for passenger cars varied from 75 mph ustream, to 69 mph at the end of the work zone. The 85th percentile speed for trucks varied from 72 mph upstream to 67 mph at the end of the work zone. The mean truck speed is also in better compliance than passenger cars.

Table B.1. Day 1: Daytime data 3:00–6:00 PM

3:00–6:00 PM 1st counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	69.46608696	Mean	69.75858685	Mean	67.19083969
Standard error	0.140694851	Standard error	0.148781751	Standard error	0.377604792
Median	69	Median	70	Median	68
Mode	69	Mode	70	Mode	69
Standard deviation	4.771194517	Standard deviation	4.749378241	Standard deviation	4.321884389
Sample variance	22.76429712	Sample variance	22.55659368	Sample variance	18.67868467
Kurtosis	1.896886049	Kurtosis	1.794333247	Kurtosis	1.659941203
Skewness	0.287980733	Skewness	0.397290931	Skewness	0.911925815
Range	46	Range	44	Range	27
Minimum	50	Minimum	52	Minimum	50
Maximum	96	Maximum	96	Maximum	77
Sum	79886	Sum	71084	Sum	8802
Count	1150	Count	1019	Count	131
85th	74	85th	75	85th	72
>limit	82.2	>limit	84.2	>limit	67.1
>5limit	48.1	>5limit	49.1	>5limit	29.7
>10limit	12.5	>10limit	13.8	>10limit	1.5
>15limit	2.6	>15limit	2.9	>15limit	0
>20limit	0.6	>20limit	0.6	>20limit	0
3:00–6:00 PM 2nd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	67.75975039	Mean	68.09991158	Mean	65.21192053
Standard error	0.146611756	Standard error	0.152647504	Standard error	0.441211384
Median	68	Median	68	Median	66
Mode	68	Mode	68	Mode	70

Table B.1. (*continued*)

3:00–6:00 PM 2nd counter					
All vehicles overall		**All vehicles overall**		**All vehicles overall**	
Standard deviation	5.249437955	Standard deviation	5.13358799	Standard deviation	5.421696256
Sample Variance	27.55659884	Sample Variance	26.35372566	Sample Variance	29.39479029
Kurtosis	1.731252267	Kurtosis	1.778109097	Kurtosis	0.835537778
Skewness	0.016896983	Skewness	0.146336293	Skewness	0.569789062
Range	50	Range	46	Range	35
Minimum	45	Minimum	49	Minimum	45
Maximum	95	Maximum	95	Maximum	80
Sum	86868	Sum	77021	Sum	9847
Count	1282	Count	1131	Count	151
85th	73	85th	73	85th	70
>limit	69.5	>limit	71.6	>limit	54.3
>5limit	36.8	>5limit	38.9	>5limit	20.5
>10limit	7.2	>10limit	7.9	>10limit	1.9
>15limit	1.2	>15limit	1.3	>15limit	0.6
>20limit	0.3	>20limit	0.4	>20limit	0

3:00–6:00 PM 3rd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	62.02340094	Mean	62.2185022	Mean	60.5170068
Standard error	0.195780741	Standard error	0.208390254	Standard error	0.557758348
Median	63	Median	63	Median	62
Mode	64	Mode	63	Mode	64
Standard deviation	7.009934846	Standard deviation	7.020617876	Standard deviation	6.762460586
Sample variance	49.13918655	Sample variance	49.28907536	Sample variance	45.73087317
Kurtosis	0.907499715	Kurtosis	0.92628666	Kurtosis	0.809689909
Skewness	-0.60470813	Skewness	0.595073058	Skewness	0.793997896
Range	50	Range	50	Range	37
Minimum	32	Minimum	32	Minimum	36
Maximum	82	Maximum	82	Maximum	73
Sum	79514	Sum	70618	Sum	8896
Count	1282	Count	1135	Count	147
85th	69	85th	69	85th	67
>limit	33.3	>limit	34.8	>limit	22.4
>5limit	12.7	>5limit	13.8	>5limit	4.7
>10limit	1.7	>10limit	1.9	>10limit	0
>15limit	0.2	>15limit	0.2	>15limit	0

Table B.2 shows the speed data taken from day 1 with the drums, during the evening hours. These data are from the same set of pneumatic road tubes. During the night time hours the 85th percentile speed for passenger cars varied from 74 mph upstream, to 67 mph at the end of the work zone. The 85th percentile speed for trucks, during the night time hours, varied from 72 mph upstream to 62 mph at the end of the work zone. The mean truck speed is also in better compliance than passenger cars.

The mean speeds are slightly lower for the evening hours than during the daytime hours, and there was less traffic during these hours as well.

Table B.2. Day 1: Nighttime data 6:00–8:00 PM

6:00-8:00 PM 1st counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	68.59574468	Mean	68.80314961	Mean	66.71428571
Standard error	0.216330377	Standard error	0.222200566	Standard error	0.777354962
Median	69	Median	69	Median	67
Mode	70	Mode	70	Mode	68
Standard deviation	4.449259042	Standard deviation	4.337182029	Standard deviation	5.037835938
Sample variance	19.79590602	Sample variance	18.81114795	Sample variance	25.37979094
Kurtosis	1.107540503	Kurtosis	1.313058364	Kurtosis	0.181555648
Skewness	0.252974528	Skewness	0.342709131	Skewness	0.098325148
Range	34	Range	34	Range	21
Minimum	53	Minimum	53	Minimum	57
Maximum	87	Maximum	87	Maximum	78
Sum	29016	Sum	26214	Sum	2802
Count	423	Count	381	Count	42
85th	74	85th	74	85th	72
>limit	78	>limit	80	>limit	59.5
>5limit	42	>5limit	43.5	>5limit	28.5
>10limit	5.4	>10limit	7.6	>10limit	7.1
>15limit	1.1	>15limit	1.3	>15limit	0
>20limit	0.2	>20limit	0.2	>20limit	0
6:00-8:00 PM 2nd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	67.12975391	Mean	67.35572139	Mean	65.11111111
Standard error	0.247401746	Standard error	0.260201254	Standard error	0.740067034
Median	67	Median	67	Median	66
Mode	66	Mode	67	Mode	66
Standard deviation	5.230660359	Standard deviation	5.217018918	Standard deviation	4.964520586
Sample variance	27.35980779	Sample variance	27.21728639	Sample variance	24.64646465

Table B.2. (*continued*)

6:00-8:00 PM 2nd counter					
All vehicles overall		**All vehicles overall**		**All vehicles overall**	
Kurtosis	1.525799925	Kurtosis	1.818301226	Kurtosis	0.336211397
Skewness	-0.407087744	Skewness	-0.451290011	Skewness	0.148614598
Range	41	Range	41	Range	22
Minimum	43	Minimum	43	Minimum	55
Maximum	84	Maximum	84	Maximum	77
Sum	30007	Sum	27077	Sum	2930
Count	447	Count	402	Count	45
85th	72	85th	72	85th	70
>limit	66.4	>limit	67.9	>limit	53.3
>5limit	32.4	>5limit	33.5	>5limit	22.2
>10limit	6	>10limit	6.4	>10limit	2.2
>15limit	0.6	>15limit	0.7	>15limit	0
>20limit	0	>20limit	0	>20limit	0

6:00-8:00 PM 3rd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	59.3803132	Mean	59.66089109	Mean	56.74418605
Standard error	0.327856105	Standard error	0.351279351	Standard error	0.747156309
Median	60	Median	60	Median	56
Mode	60	Mode	60	Mode	58
Standard deviation	6.931656561	Standard deviation	7.060627574	Standard deviation	4.899431567
Sample variance	48.04786268	Sample variance	49.85246174	Sample variance	24.00442968
Kurtosis	0.478326058	Kurtosis	0.499070623	Kurtosis	0.311049334
Skewness	0.123820949	Skewness	0.183114939	Skewness	0.132183311
Range	39	Range	39	Range	19
Minimum	40	Minimum	40	Minimum	47
Maximum	79	Maximum	79	Maximum	66
Sum	26543	Sum	24103	Sum	2440
Count	447	Count	404	Count	43
85th	67	85th	67	85th	62
>limit	21.7	>limit	23.5	>limit	6.9
>5limit	7.1	>5limit	7.9	>5limit	0
>10limit	0.4	>10limit	0.4	>10limit	0
>15limit	0	>15limit	0	>15limit	0
>20limit	0	>20limit	0	>20limit	0

Table B.3 shows the daytime speed data taken on day 2 of the data collection, in which 42 in. channelizers at 60 ft. spacing were used in the work zone area. The 85th percentile speed for passenger cars varied from 74 mph upstream, to 69 mph at the end of the work zone. The 85th percentile speed for trucks varied from 72 mph upstream to 68 mph at the end of the work zone. The mean truck speed is also in better compliance than passenger cars.

Table B.3. Day 2: Daytime data 3:00–6:00 PM

3:00–6:00 PM 1st counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	68.85062612	Mean	69.15440415	Mean	66.93464052
Standard error	0.135805967	Standard error	0.145152925	Standard error	0.345827903
Median	69	Median	69	Median	67
Mode	69	Mode	69	Mode	65
Standard deviation	4.540877163	Standard deviation	4.50909567	Standard deviation	4.27765492
Sample variance	20.61956541	Sample variance	20.33194376	Sample variance	18.29833161
Kurtosis	2.71225761	Kurtosis	3.04590514	Kurtosis	1.161554536
Skewness	0.117129036	Skewness	0.098027159	Skewness	0.375451533
Range	47	Range	47	Range	28
Minimum	44	Minimum	44	Minimum	50
Maximum	91	Maximum	91	Maximum	78
Sum	76975	Sum	66734	Sum	10241
Count	1118	Count	965	Count	153
85th	74	85th	74	85th	72
>limit	80.2	>limit	83.1	>limit	61.4
>5limit	42.8	>5limit	45.3	>5limit	26.7
>10limit	9.3	>10limit	10.2	>10limit	0
>15limit	1.4	>15limit	1.6	>15limit	0
>20limit	0.2	>20limit	0.3	>20limit	0
3:00–6:00 PM 2nd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	67.53913738	Mean	67.81985294	Mean	65.67682927
Standard error	0.137892111	Standard error	0.147220363	Standard error	0.361524526
Median	68	Median	68	Median	66
Mode	66	Mode	69	Mode	65
Standard deviation	4.879120941	Standard deviation	4.85604084	Standard deviation	4.629772915
Sample variance	23.80582116	Sample variance	23.58113264	Sample variance	21.43479725
Kurtosis	1.362050438	Kurtosis	1.60307317	Kurtosis	0.692174853
Skewness	0.233809156	Skewness	0.288146786	Skewness	0.05318917
Range	40	Range	40	Range	31
Minimum	44	Minimum	44	Minimum	50

Table B.3. (*continued*)

3:00–6:00 PM 2nd counter					
All vehicles overall		**All vehicles overall**		**All vehicles overall**	
Maximum	84	Maximum	84	Maximum	81
Sum	84559	Sum	73788	Sum	10771
Count	1252	Count	1088	Count	164
85th	73	85th	73	85th	71
>limit	68.7	>limit	71.4	>limit	51.2
>5limit	33.4	>5limit	35.4	>5limit	20.1
>10limit	6	>10limit	6.6	>10limit	2.4
>15limit	1.1	>15limit	1.1	>15limit	0.6
>20limit	0	>20limit	0	>20limit	0
3:00–6:00 PM 3rd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	62.4054054	Mean	62.5629562	Mean	61.3395061
Standard error	0.17624902	Standard error	0.19109176	Standard error	0.44160268
Median	63	Median	63	Median	61
Mode	65	Mode	65	Mode	62
Standard deviation	6.25125242	Standard deviation	6.32626301	Standard deviation	5.62068449
Sample variance	39.0781569	Sample variance	40.0216036	Sample fariance	31.5920941
Kurtosis	0.44366667	Kurtosis	0.48814613	Kurtosis	0.18355359
Skewness	0.455546251	Skewness	0.489440786	Skewness	0.30011155
Range	41	Range	41	Range	30
Minimum	39	Minimum	39	Minimum	43
Maximum	80	Maximum	80	Maximum	73
Sum	78506	Sum	68569	Sum	9937
Count	1258	Count	1096	Count	162
85th	69	85th	70	85th	68
>limit	32.9	>limit	34	>limit	25.3
>5limit	11.6	>5limit	12.3	>5limit	7.4
>10limit	1.2	>10limit	1.4	>10limit	0
>15limit	0	>15limit	0	>15limit	0
>20limit	0	>20limit	0	>20limit	0

Table B.4 shows the nighttime speed data taken on day 2 of data collection, in which 42 in. channelizers at 60 ft. spacing were used in the work zone area. The 85th percentile speed for passenger cars varied from 73 mph upstream, to 67 mph at the end of the work zone. The 85th percentile speed for trucks varied from 72 mph upstream to 64 mph at the end of the work zone. The mean truck speed is also in better compliance than passenger cars.

Table B.4. Day 2: Nighttime data 6:00–8:00 PM

6:00–8:00 PM 1st counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	68.02261307	Mean	68.17183099	Mean	66.79069767
Standard error	0.240127215	Standard error	0.250065931	Standard error	0.80801504
Median	68	Median	69	Median	67
Mode	69	Mode	69	Mode	67
Standard deviation	4.790522887	Standard deviation	4.711603152	Standard deviation	5.298508953
Sample variance	22.94910953	Sample variance	22.19920427	Sample variance	28.07419712
Kurtosis	2.644146876	Kurtosis	2.824880588	Kurtosis	1.751489349
Skewness	-0.79852968	Skewness	0.774135074	Skewness	0.882365836
Range	37	Range	37	Range	28
Minimum	44	Minimum	44	Minimum	51
Maximum	81	Maximum	81	Maximum	79
Sum	27073	Sum	24201	Sum	2872
Count	398	Count	355	Count	43
85th	73	85th	73	85th	72
>limit	74.3	>limit	74.6	>limit	72
>5limit	37.6	>5limit	38.5	>5limit	30.2
>10limit	7	>10limit	7.6	>10limit	2.3
>15limit	0.5	>15limit	0.5	>15limit	0
>20limit	0	>20limit	0	>20limit	0
6:00–8:00 PM 2nd counter					
All vehicles overall		**All vehicles overall**		**All vehicles overall**	
Mean	66.77803738	Mean	67.00261097	Mean	64.86666667
Standard error	0.285743551	Standard error	0.305770839	Standard error	0.731402417
Median	67	Median	68	Median	66
Mode	66	Mode	66	Mode	67
Standard deviation	5.911508553	Standard deviation	5.984053283	Standard deviation	4.906396567
Sample variance	34.94593338	Sample variance	35.80889369	Sample variance	24.07272727
Kurtosis	0.961321992	Kurtosis	1.036564722	Kurtosis	0.593255398
Skewness	0.207064274	Skewness	0.225746121	Skewness	-0.52965663
Range	46	Range	46	Range	19
Minimum	48	Minimum	48	Minimum	54
Maximum	94	Maximum	94	Maximum	73
Sum	28581	Sum	25662	Sum	2919
Count	428	Count	383	Count	45
85th	73	85th	73	85th	70
>limit	64.4	>limit	65.7	>limit	48.8
>5limit	34.3	>5limit	36.5	>5limit	11.1

Table B.4. (*continued*)

6:00–8:00 PM 2nd counter					
All vehicles overall		**All vehicles overall**		**All vehicles overall**	
>10limit	6	>10limit	6.7	>10limit	0
>15limit	0.7	>15limit	0.7	>15limit	0
>20limit	0.2	>20limit	0.2	>20limit	0
6:00–8:00 PM 3rd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	59.11888112	Mean	59.31185567	Mean	57.29268293
Standard error	0.35911254	Standard error	0.381615401	Standard error	1.006226895
Median	60	Median	60	Median	57
Mode	61	Mode	62	Mode	64
Standard deviation	7.438052118	Standard deviation	7.516951638	Standard deviation	6.442995819
Sample variance	55.32461931	Sample variance	56.50456192	Sample variance	41.51219512
Kurtosis	0.274532827	Kurtosis	0.226269575	Kurtosis	-1.05192215
Skewness	0.162407274	Skewness	0.193380233	Skewness	0.016018774
Range	41	Range	41	Range	26
Minimum	38	Minimum	38	Minimum	45
Maximum	79	Maximum	79	Maximum	71
Sum	25362	Sum	23013	Sum	2349
Count	429	Count	388	Count	41
85th	67	85th	68	85th	64
>limit	20	>limit	21.6	>limit	4.8
>5limit	8.1	>5limit	8.7	>5limit	2.4
>10limit	0.9	>10limit	1	>10limit	0
>15limit	0	>15limit	0	>15limit	0
>20limit	0	>20limit	0	>20limit	0

Table B.5 reduces the speed data for day 3 during daytime hours, when 42 in. channelizers were placed at 40 ft. intervals. The mean vehicle speeds do decrease from the first tube counter to the third tube counter—from 68.85 mph to 62.40 mph. Truck mean speeds are even lower—from 66.93 mph to 61.34 mph. This shows a positive effect of the channelizers in that vehicle speeds decrease as they move through the work zone area.

Table B.5. Day 3: Daytime data 3:00–6:00 PM

3:00–6:00 PM 1st counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	69.35881842	Mean	69.61546287	Mean	67.85714286
Standard error	0.137965006	Standard error	0.147805922	Standard error	0.361310161
Median	69	Median	69	Median	68
Mode	69	Mode	69	Mode	69
Standard deviation	4.680654729	Standard deviation	4.634134066	Standard deviation	4.683114929
Sample variance	21.90852869	Sample variance	21.47519854	Sample variance	21.93156544
Kurtosis	3.916880611	Kurtosis	2.974495112	Kurtosis	7.959099096
Skewness	0.069712144	Skewness	0.365922738	Skewness	1.573386756
Range	52	Range	47	Range	41
Minimum	40	Minimum	45	Minimum	40
Maximum	92	Maximum	92	Maximum	81
Sum	79832	Sum	68432	Sum	11400
Count	1151	Count	983	Count	168
85th	74	85th	74	85th	72
>limit	83.4	>limit	84.5	>limit	77.9
>5limit	46.5	>5limit	48.6	>5limit	34.5
>10limit	10.5	>10limit	11.8	>10limit	2.9
>15limit	1.9	>15limit	2.1	>15limit	0.5
>20limit	0.9	>20limit	1.1	>20limit	0

3:00–6:00 PM 2nd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	68.08863636	Mean	68.32180851	Mean	66.71875
Standard error	0.14025712	Standard error	0.151759384	Standard error	0.352271228
Median	68	Median	68	Median	67
Mode	70	Mode	68	Mode	66
Standard deviation	5.095794215	Standard deviation	5.096946866	Standard deviation	4.881213318
Sample variance	25.96711868	Sample variance	25.97886736	Sample variance	23.82624346
Kurtosis	2.399565478	Kurtosis	2.261239588	Kurtosis	2.819505528
Skewness	0.117665155	Skewness	0.002668427	Skewness	1.010002885
Range	47	Range	47	Range	32
Minimum	45	Minimum	45	Minimum	48
Maximum	92	Maximum	92	Maximum	80
Sum	89877	Sum	77067	Sum	12810
Count	1320	Count	1128	Count	192
85th	73	85th	73	85th	71
>limit	74	>limit	75	>limit	68.7
>5limit	38.1	>5limit	39.8	>5limit	28.1

Table B.5. (*continued*)

3:00–6:00 PM 2nd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
>10limit	8.2	>10limit	9.3	>10limit	2
>15limit	1.7	>15limit	1.9	>15limit	0.5
>20limit	0.5	>20limit	0.6	>20limit	0
3:00–6:00 PM 3rd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	63.39772727	Mean	63.5647986	Mean	62.3258427
Standard error	0.177330511	Standard error	0.194359988	Standard error	0.409804192
Median	64	Median	64	Median	63
Mode	66	Mode	66	Mode	57
Standard deviation	6.442737399	Standard eeviation	6.568102408	Standard deviation	5.467469862
Sample variance	41.50886519	Sample variance	43.13996924	Sample variance	29.89322669
Kurtosis	0.554885401	Kurtosis	0.654055339	Kurtosis	0.684962167
Skewness	0.453929471	Skewness	0.501278807	Skewness	0.193692456
Range	44	Range	44	Range	27
Minimum	41	Minimum	41	Minimum	49
Maximum	85	Maximum	85	Maximum	76
Sum	83685	Sum	72591	Sum	11094
Count	1320	Count	1142	Count	178
85th	70	85th	71	85th	69
>limit	41.3	>limit	42.6	>limit	33.1
>5limit	15.8	>5limit	17	>5limit	7.8
>10limit	2.8	>10limit	3.1	>10limit	0.5
>15limit	0.5	>15limit	0.6	>15limit	0
>20limit	0	>20limit	0	>20limit	0

Table B.6 shows the speed data during the evening hours of day 3 where 42 in. channelizers were used at 40 ft. spacing. For all vehicles, the mean speeds were 68.02 mph at the first counter and 59.12 mph at the third counter, just after the work zone. The 85th percentile speed also decreased as traffic entered the work zone. The 85th percentile speed at the first counter was 73 mph and the 85th percentile speed at the third counter was 67 mph. It is important to note, however, that there were fewer vehicles during the evening hours than the daytime hours—1,118 vehicles measured during the day and 429 vehicles measured during the evening hours.

Truck speeds decreased even further. The 85th percentile for trucks was 72 mph at the first counter and 64 mph at the third counter—a decrease of 8 mph.

Table B.6. Day 3: Nighttime data 6:00–8:00 PM

6:00–8:00 PM 1st counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	68.1097852	Mean	68.17772	Mean	67.5
Standard error	0.224114991	Standard error	0.238706	Standard error	0.638714228
Median	68	Median	68	Median	67.5
Mode	69	Mode	69	Mode	68
Standard deviation	4.587519443	Standard deviation	4.634828	Standard deviation	4.139341293
Sample variance	21.04533464	Sample variance	21.48163	Sample variance	17.13414634
Kurtosis	3.519746428	Kurtosis	3.761047	Kurtosis	0.129868436
Skewness	0.261085521	Skewness	0.255564	Skewness	0.223151705
Range	46	Range	46	Range	18
Minimum	49	Minimum	49	Minimum	60
Maximum	95	Maximum	95	Maximum	78
Sum	28538	Sum	25703	Sum	2835
Count	419	Count	377	Count	42
85th	73	85th	73	85th	73
>limit	75.1	>limit	75.5	>limit	71.4
>5limit	35	>5limit	35.5	>5limit	30.9
>10limit	5.7	>10limit	6.1	>10limit	2.3
>15limit	1.4	>15limit	1.5	>15limit	0
>20limit	0.2	>20limit	0.2	>20limit	0
6:00–8:00 PM 2nd counter					
All vehicles overall		**Passenger vehicles overall**		**Trucks overall**	
Mean	66.31759657	Mean	66.50361	Mean	64.80392157
Standard error	0.243774257	Standard error	0.259792	Standard error	0.671562187
Median	67	Median	67	Median	66
Mode	69	Mode	70	Mode	66
Standard deviation	5.262362957	Standard deviation	5.292357	Standard deviation	4.795913293
Sample variance	27.69246389	Sample variance	28.00904	Sample variance	23.00078431
Kurtosis	0.277881313	Kurtosis	0.364036	Kurtosis	-0.12478285
Skewness	0.422541882	Skewness	-0.46389	Skewness	-0.23647402
Range	35	Range	35	Range	21
Minimum	51	Minimum	51	Minimum	53
Maximum	86	Maximum	86	Maximum	74
Sum	30904	Sum	27599	Sum	3305
Count	466	Count	415	Count	51
85th	72	85th	72	85th	69
>limit	62.4	>limit	65.7	>limit	50.9
>5limit	29.1	>5limit	31	>5limit	13.7

Table B.6. (*continued*)

6:00–8:00 PM 2nd counter					
All vehicles overall		**All vehicles overall**		**All vehicles overall**	
>10limit	3	>10limit	3.3	>10limit	0
>15limit	0.4	>15limit	0.4	>15limit	0
>20limit	0.2	>20limit	0.2	>20limit	0

6:00–8:00 PM 3rd counter					
All vehicles overall		**All vehicles overall**		**All vehicles overall**	
Mean	59.49568966	Mean	59.55156	Mean	59
Standard error	0.309358447	Standard error	0.327968	Standard error	0.934486755
Median	60	Median	60	Median	59
Mode	60	Mode	60	Mode	53
Standard deviation	6.663784878	Standard deviation	6.697291	Standard deviation	6.40651842
Sample variance	44.4060289	Sample variance	44.85371	Sample variance	41.04347826
Kurtosis	0.134007349	Kurtosis	0.210387	Kurtosis	0.529686208
Skewness	0.416771494	Skewness	-0.44747	Skewness	0.131078978
Range	38	Range	38	Range	29
Minimum	36	Minimum	36	Minimum	44
Maximum	74	Maximum	74	Maximum	73
Sum	27606	Sum	24833	Sum	2773
Count	464	Count	417	Count	47
85th	67	85th	67	85th	66
>limit	20.9	>limit	21.1	>limit	19.1
>5limit	4.9	>5limit	5.2	>5limit	2.1
>10limit	0	>10limit	0	>10limit	0
>15limit	0	>15limit	0	>15limit	0
>20limit	0	>20limit	0	>20limit	0

The speed data for day 4 in Table B.7 shows similar results from the previous days. In the configuration set for day 4, the 42 in. channelizers were used again; however, the spacing of the devices was set at 60 ft. intervals and a single direction indicator barricade (DIB) was placed at the top of taper. The mean speed for all vehicles at the first counter was 68.72 mph and the mean speed for all vehicles at the third counter was measured at 62.73 mph, a decrease of 5.99 mph. The 85th percentile speed for all vehicles decreased from 74 mph to 70 mph from the first to third counters.

Truck speeds decreased even further. The 85th percentile for trucks was 72 mph at the first counter and 67 mph at the third counter—a decrease of 5 mph.

The purpose of this configuration was to determine the effectiveness of the direction indicator barricade. The data show a decrease in speeds; however, for part of the time during the data collection period, the DIB was blown over and not standing upright. It had to be re-set twice during the data collection period. The effectiveness analysis of this device is not conclusive, as it not known how long it was up or down.

Table B.7. Day 4: Daytime data 3:00–6:00 PM

3:00–6:00 PM 1st counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	68.72165821	Mean	68.92610365	Mean	67.2
Standard error	0.138282897	Standard error	0.146326012	Standard error	0.399151206
Median	69	Median	69	Median	68
Mode	69	Mode	69	Mode	68
Standard deviation	4.754197357	Standard deviation	4.723407282	Standard deviation	4.722820764
Sample variance	22.60239251	Sample variance	22.31057635	Sample variance	22.30503597
Kurtosis	6.761341295	Kurtosis	7.627551476	Kurtosis	1.798703424
Skewness	0.698153504	Skewness	0.692358866	Skewness	0.848678413
Range	61	Range	61	Range	28
Minimum	26	Minimum	26	Minimum	49
Maximum	87	Maximum	87	Maximum	77
Sum	81229	Sum	71821	Sum	9408
Count	1182	Count	1042	Count	140
85th	74	85th	74	85th	72
>limit	79.9	>limit	81.4	>limit	68.5
>5limit	42.7	>5limit	44.6	>5limit	28.5
>10limit	7.3	>10limit	7.6	>10limit	5
>15limit	1.2	>15limit	1.4	>15limit	0
>20limit	0.5	>20limit	0.5	>20limit	0

3:00–6:00 PM 2nd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	67.3138416	Mean	67.68877551	Mean	64.79428571
Standard error	0.143591205	Standard error	0.149360803	Standard error	0.425099014
Median	68	Median	68	Median	65
Mode	67	Mode	67	Mode	67
Standard deviation	5.277831426	Standard deviation	5.122008569	Standard deviation	5.623531372
Sample variance	27.85550456	Sample variance	26.23497178	Sample variance	31.62410509
Kurtosis	3.780127381	Kurtosis	1.09743136	Kurtosis	14.16601871
Skewness	0.633316071	Skewness	0.290560703	Skewness	2.290086701
Range	64	Range	39	Range	53
Minimum	25	Minimum	50	Minimum	25
Maximum	89	Maximum	89	Maximum	78
Sum	90941	Sum	79602	Sum	11339

Table B.7. (*continued*)

3:00–6:00 PM 2nd counter					
All vehicles overall		**All vehicles overall**		**All vehicles overall**	
Count	1351	Count	1176	Count	175
85th	73	85th	73	85th	70
>limit	68.3	>limit	71.5	>limit	46.8
>5limit	34.4	>5limit	37.5	>5limit	30.8
>10limit	5.9	>10limit	6.6	>10limit	1.7
>15limit	1.1	>15limit	1.3	>15limit	0
>20limit	0.2	>20limit	0.2	>20limit	0
3:00–6:00 PM 2nd counter					
All vehicles overall		**All vehicles overall**		**All vehicles overall**	
Mean	62.73071217	Mean	62.94745763	Mean	61.20833333
Standard Error	0.179004016	Standard Error	0.19470046	Standard Error	0.422058428
Median	63	Median	64	Median	62
Mode	66	Mode	65	Mode	66
Standard Deviation	6.572153835	Standard Deviation	6.68818045	Standard Deviation	5.470502464
Sample Variance	43.19320603	Sample Variance	44.73175774	Sample Variance	29.92639721
Kurtosis	0.960640976	Kurtosis	1.016959075	Kurtosis	0.434495181
Skewness	0.571359733	Skewness	0.613954405	Skewness	0.475525621
Range	57	Range	57	Range	30
Minimum	26	Minimum	26	Minimum	43
Maximum	83	Maximum	83	Maximum	73
Sum	84561	Sum	74278	Sum	10283
Count	1348	Count	1180	Count	168
85th	70	85th	70	85th	67
>limit	36.6	>limit	25.5	>limit	38.2
>5limit	14.7	>5limit	4.7	>5limit	16.1
>10limit	1.4	>10limit	0	>10limit	1.6
>15limit	0.2	>15limit	0	>15limit	0.3
>20limit	0	>20limit	0	>20limit	0

Table B.8 shows speed data for day 4 during the evening hours. To reiterate, this configuration set the channelizers at 60 ft. intervals with a single DIB placed at the top of the taper. The mean speed for all vehicles at the first counter was 68.11 mph, slightly less than during daytime. The mean speed for all vehicles at the third counter was measured at 59.49 mph, a decrease of 8.62 mph. The 85th percentile speed for all vehicles decreased from 73 mph to 67 mph from the first to third counters.

Truck speeds decreased even further. The 85th percentile for trucks was 73 mph at the first counter and 66 mph at the third counter—a decrease of 7 mph.

Table B.8. Day 4: Nighttime data 6:00–8:00 PM

6:00–8:00 PM 1st counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	67.72058824	Mean	67.97630332	Mean	65.72222222
Standard error	0.223001104	Standard error	0.21603602	Standard error	0.972873397
Median	68	Median	68	Median	67
Mode	69	Mode	69	Mode	71
Standard deviation	4.865309691	Standard deviation	4.437949879	Standard deviation	7.149130219
Sample variance	23.67123839	Sample variance	19.69539913	Sample variance	51.11006289
Kurtosis	10.96717739	Kurtosis	0.409569122	Kurtosis	17.51113589
Skewness	1.431037595	Skewness	0.133424223	Skewness	3.365756611
Range	55	Range	28	Range	51
Minimum	26	Minimum	53	Minimum	26
Maximum	81	Maximum	81	Maximum	77
Sum	32235	Sum	28686	Sum	3549
Count	476	Count	422	Count	54
85th	73	85th	73	85th	71
>limit	70	>limit	70.8	>limit	61.1
>5limit	35.8	>5limit	36.7	>5limit	27.7
>10limit	5.6	>10limit	6.1	>10limit	1.8
>15limit	0.6	>15limit	0.7	>15limit	0
>20limit	0	>20limit	0	>20limit	0

6:00–8:00 PM 2nd counter					
All vehicles overall		**Passenger cars overall**		**Trucks overall**	
Mean	66.21442125	Mean	66.40471092	Mean	64.73333333
Standard error	0.230303961	Standard error	0.244810017	Standard error	0.653485512
Median	67	Median	67	Median	65
Mode	68	Mode	68	Mode	64
Standard deviation	5.286968411	Standard deviation	5.29038922	Standard deviation	5.061877011
Sample variance	27.95203498	Sample variance	27.9882181	Sample variance	25.62259887
Kurtosis	2.024901316	Kurtosis	2.303227089	Kurtosis	0.609956889
Skewness	0.826982724	Skewness	0.885871225	Skewness	-0.50201541
Range	44	Range	44	Range	27
Minimum	37	Minimum	37	Minimum	49
Maximum	81	Maximum	81	Maximum	76
Sum	34895	Sum	31011	Sum	3884
Count	527	Count	467	Count	60
85th	72	85th	72	85th	70
>limit	59.5	>limit	61	>limit	16.5
>5limit	27.1	>5limit	28	>5limit	5.7

Table B.8. (*continued*)

6:00–8:00 PM 2nd counter					
All vehicles overall		**All vehicles overall**		**All vehicles overall**	
>10limit	2.4	>10limit	2.5	>10limit	0.5
>15limit	0.3	>15limit	0.4	>15limit	0
>20limit	0	>20limit	0	>20limit	0
6:00–8:00 PM 3rd counter					
All vehicles overall		**All vehicles overall**		**All vehicles overall**	
Mean	59.4952381	Mean	59.81623932	Mean	56.85964912
Standard error	0.324046784	Standard error	0.344393172	Standard error	0.888677947
Median	60	Median	60	Median	57
Mode	56	Mode	69	Mode	56
Standard deviation	7.424844576	Standard deviation	7.450363454	Standard deviation	6.709371368
Sample variance	55.12831698	Sample variance	55.50791559	Sample variance	45.01566416
Kurtosis	0.223815067	Kurtosis	0.155005239	Kurtosis	0.541507621
Skewness	-0.30761046	Skewness	0.350728524	Skewness	0.139853807
Range	42	Range	42	Range	30
Minimum	36	Minimum	36	Minimum	40
Maximum	78	Maximum	78	Maximum	70
Sum	31235	Sum	27994	Sum	3241
Count	525	Count	468	Count	57
85th	68	85th	69	85th	64
>limit	24.7	>limit	26.4	>limit	10.5
>5limit	6.8	>5limit	7.4	>5limit	1.7
>10limit	0.7	>10limit	0.8	>10limit	0
>15limit	0	>15limit	0	>15limit	0
>20limit	0	>20limit	0	>20limit	0