MIDWEST SMART WORK ZONE DEPLOYMENT INITIATIVE

MwSWZDI

FHWA POOLED FUND STUDY

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D-25 Speed Advisory System	

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Supplemental Notes

Abstract

D-25 Speed Advisory System Evaluation

Geza Pesti

INTRODUCTION

A primary safety concern associated with work zones on rural interstate highways is the increased crash potential when congestion occurs on the approach to a work zone. Depending on the traffic volume and capacity of the work zone, the queue of slow-moving or stopped vehicles caused by the congestion may extend rapidly upstream creating a high speed differential between the end of the queue and approaching traffic. The unexpectedly sudden encounter with congestion often makes it very difficult for some drivers to safely reduce their speeds and avoid colliding with other vehicles as they approach the end of the queue.

The D-25 Speed Advisory Sign System from MPH Industries was one of the available technologies to address this problem. It uses a series of speed monitoring trailers in an innovative way. Although speed monitoring displays have been evaluated on numerous occasions (*1*,*2*,*3*), the present application has not been studied in detail. The system detects the presence of slow moving or stopped traffic on the approach to the work zone and provides warning to drivers via speed messages displayed on trailer-mounted variable message signs. The speed messages advise approaching motorists of the traffic speed ahead. A message board with the permanent message SPEED OF TRAFFIC AHEAD is mounted above the speed display. Another board with the message USE EXTREME CAUTION WHEN FLASHING is mounted below the speed display. When the measured speed falls below a specified threshold, two orange beacons mounted on both sides of the speed display begin flashing.

D-25 Speed Advisory Sign System was studied as part of the Midwest States Smart Work Zone Deployment Initiative, a pooled-fund study sponsored by Iowa, Kansas, Missouri, Nebraska, and the Federal Highway Administration. The objective of the study was to evaluate the effectiveness of the D-25 Speed Advisory System in reducing traffic speeds and speed differentials upstream of traffic slowdowns.

SYSTEM DESCRIPTION

The speed advisory sign system shown in Figure 1 included three identical speed trailers. Each trailer was equipped with: (1) an LED display with 25-inch speed digits, (2) a radar unit measuring the speed of downstream traffic, (3) two flashing strobes to warn drivers of downstream problems, (4) SPEED OF TRAFFIC AHEAD sign mounted over the speed display, and (5) USE EXTREME CAUTION WHEN FLASHING sign mounted beneath the speed display. The 25-inch LED display could be read from a distance up to 1500 feet away. The display height over 8 feet ensured that the trailer could be seen over other vehicles. The onboard directional radar was always pointed downstream to measure the speed of downstream traffic. The radar ignored wrong-direction targets, and was capable of measuring vehicle speeds within an accuracy of +/- 1mph. It was able to look past closest vehicle and monitor traffic ½ mile away from trailer.

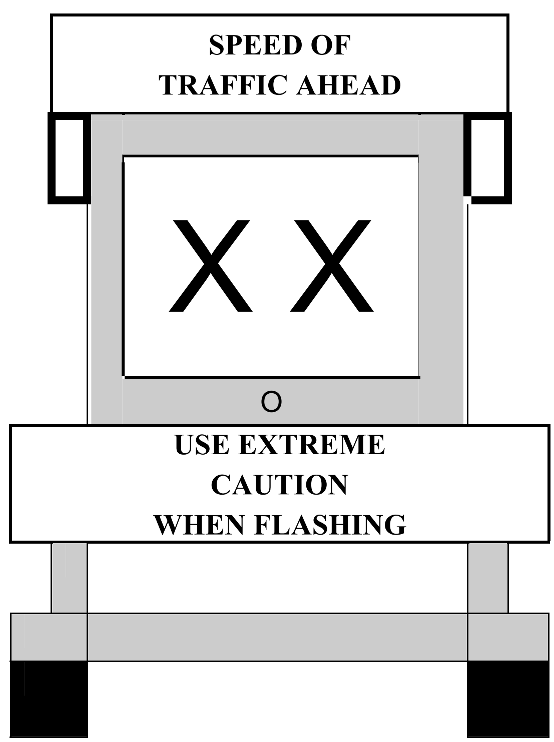

FIGURE 1 D-25 Speed Advisory Sign System

The system operated according to the following logic:

- Downstream speed monitored
- When downstream speed differential between the fastest and slowest vehicle < 15 mph
  - Strobe lights flash
  - Downstream speed displayed
- When downstream speed differential between the fastest and slowest vehicle > 15 mph
  - Strobe lights off
  - The slowest downstream speed of the strongest signal for every 1.75 seconds (ie the 7 readings measured every 0.25 seconds) or work zone speed limit displayed, whichever is lower

The data log stored vehicle speeds in every quarter of the second. However, the speed display on the trailer showed the average of 7 readings every 1.75 seconds. The 1.75 second interval was selected to avoid frequent changing of the speed display, and to provide sufficient time for the motorists, traveling at speeds between 40–75 mph, to observe and comprehend the speed messages.

STUDY SITE

The Speed Advisory System was evaluated at a work zone on I-80 near Lincoln, Nebraska. The study site is shown in Figure 2. The average daily traffic volume on the four-lane section of I-80 was approximately 40,000 vehicles per day with 21 percent trucks. The normal speed limit on I-80 was 75 mph, and the speed limit in the work zone was 55 mph. The evaluation was conducted on the eastbound approach to the work zone. The work zone was for an interstate bridge reconstruction project, which involved the closing of the right lane, reducing the two eastbound lanes of I-80 to one lane. The traffic control plan on the approach is shown in Figure 3. It included the following sequence of signs on each side of the roadway:

1. ROAD WORK 2 MILES sign;
2. FINES FOR SPEEDING DOUBLED IN WORK ZONES sign about 9,500 feet before the merging taper;
3. RIGHT LANE CLOSED 1 MILE sign;
4. RIGHT LANE CLOSED ½ MILE sign;
5. REDUCED SPEED AHEAD sign about 1,500 feet before the merging taper;

6. Symbolic “lane reduction on the left” transition sign about 1,000 feet before the merging taper; and
7. SPEED LIMIT 55 sign with FINES DOUBLE sign plate about 500 feet before the merging taper

The speed advisory system included three speed trailers deployed on the right shoulder of I-80 in advance on the work zone lane reduction.

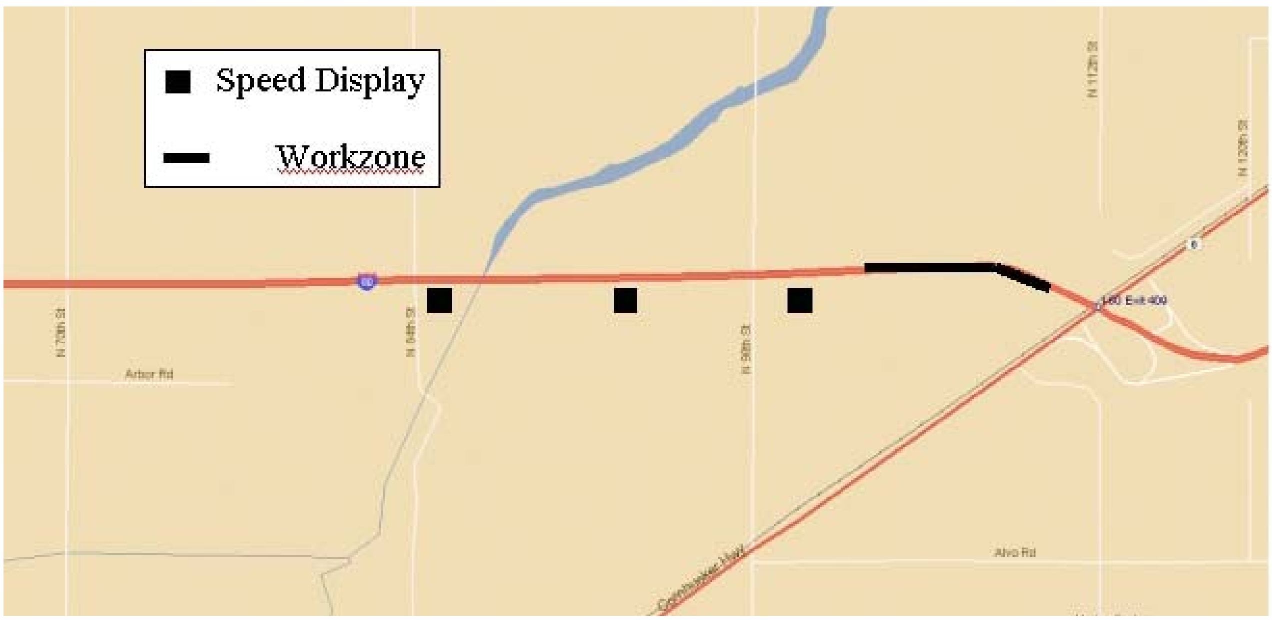

FIGURE 2 Study site

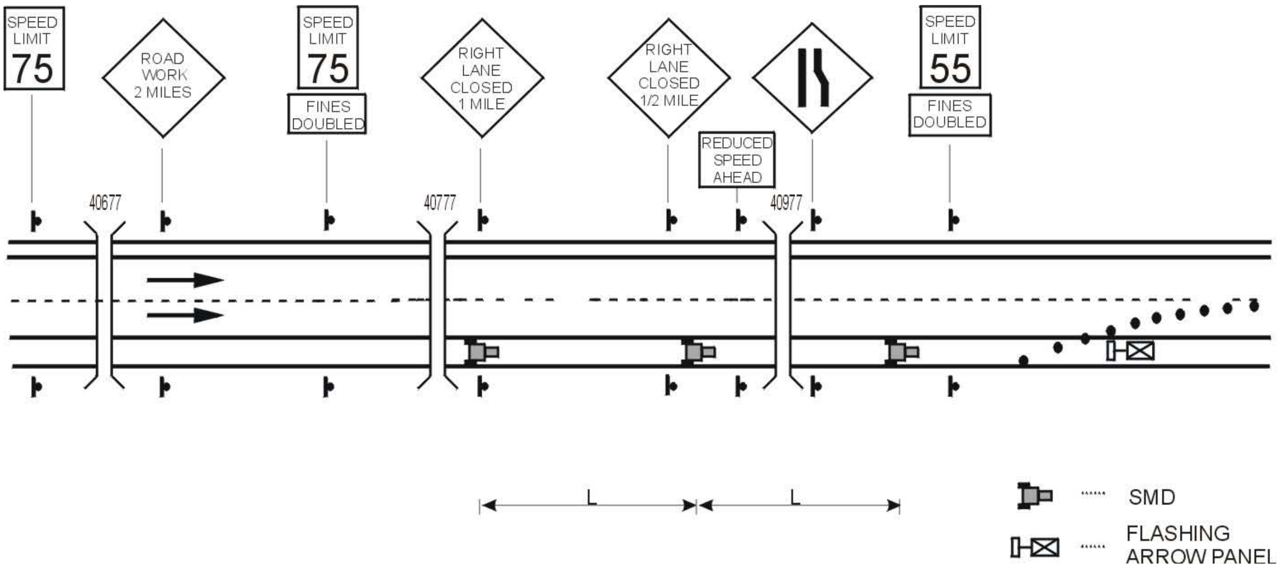

FIGURE 3 Traffic control plan in advance of work zone

DATA COLLECTION

The D-25 speed advisory system was evaluated based on traffic speeds measured before deployment, and during operation of the speed advisory system. The three speed trailers were deployed at ¼ mile, and therefore the zone affected by the speed messages was approximately ½ mile.

Before studies were conducted for at least 2 days before deployment and for another 2 days during the operation of the D-25 speed trailers for all deployment scenarios. Whenever it was possible, data collection before deployment and during system operation took place on the same days of the week, during approximately the same time period of the day, and under similar traffic and weather conditions (i.e., comparable traffic volumes, dry weather and pavement). Volume data and vehicle braking activity were also recorded during the time period of speed data collection.

Two types of speed data were collected to assess the effectiveness of the D-25 speed advisory system: speeds measured by laser guns, and speeds measured by the radar unit of the D-25 speed trailers.

To determine the change in driver deceleration behavior in response to the speed advisory messages, vehicle speed profiles were determined by tracking individual vehicles and measuring their speeds in three points as they approached the end of queues. Since the system was intended to mitigate the speed of vehicles approaching slow moving or stopped vehicle queues, speed data were collected only during those time periods when queues began forming. Speeds were measured approximately 500 ft upstream, at near, and 500 ft downstream of the speed displays. The speed measurement locations are indicated in Figure 4. The speed data were collected with ProLaser III Lidar units, which are capable of measuring the speed of vehicles with an accuracy of ±1.6 km/h (±1 mph). Three of these units were used by three survey crews. Throughout the study, the same observers collected speed data at each location. To minimize the cosine-error of the speed measurements, they positioned themselves as close to the side of the roadway as possible while making every effort to remain inconspicuous. The angle between the line of traffic and the laser beam was less than 3 degrees resulting in a negligible cosine-error of less than 0.16 km/h (0.1 mph) at each measurement location. Speeds were measured from vantage points behind the vehicles.

The radar units of the D-25 speed trailers were also used to measure speeds. These speeds together with volume data were used to check if there were any significant changes in traffic conditions between the “before” and “during” periods of the study period. Speeds were measured by the D-25 trailers’ radar units in every quarter of a second, and the data were stored in a system log. The speed measurement zones for the trailers’ radar units are indicated in Figure 4. The speed trailers were deployed for the entire study period (even during the “before” studies) in order to use their radar unit for speed data collection. For the “before” studies, the speed display unit of the trailers were folded down, as shown in Figure 5. Only the radar units were used during this period. During system operation the speed displays were folded up and activated; they informed approaching motorists about the traffic speed ahead. Speed data were downloaded from the speed trailers’ system logs every 3 days or whenever there was a change in the setup. Approximately 165 hours of speed data were collected.

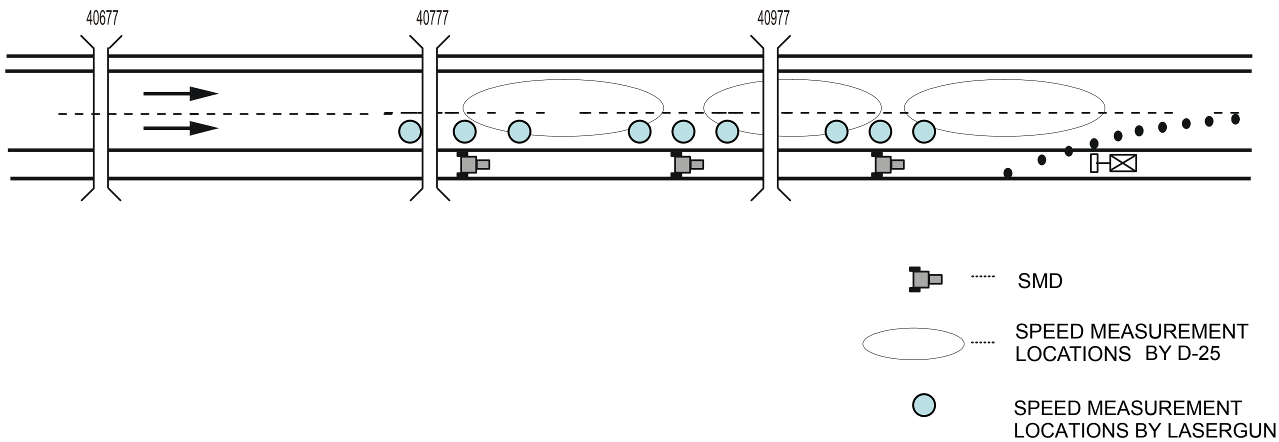

FIGURE 4 Speed Measurement Locations

FIGURE 5 Speed Data Collection by Speed Trailers' Radar Unit during "Before" Study

FIGURE 6 D-25 Speed Trailer in Operation close to the Work Zone

DATA ANALYSIS

From the speed data, collected every quarter of the second by the radar units of the speed trailers, 1-minute average speeds were determined for all trailer locations. From the time-series of these average speeds the time periods, when congestion began developing, were identified.

The speed data plotted in Figure 7 indicate several traffic slow-downs with or without queue formation. Since the system was intended to mitigate the speed of vehicles approaching slow moving or stopped vehicle queues, only the time periods when queues were likely to form were considered. Then these time periods were matched with the times when vehicle speed profiles were determined from laser gun speed measurements. From the 165 hours of data, approximately 25 hours corresponded to congestions, and only slightly more than 3 hours of data corresponded to periods when both queues were forming and vehicle speed profiles were measured by laser guns. The time of queue formations in the vicinity of the speed trailers took from 1 minute to almost half an hours. The half-hour period captured a series of events when congestion began to develop but no long queues were formed. Because of the near capacity flow conditions, queues were periodically building up and then dissipating.

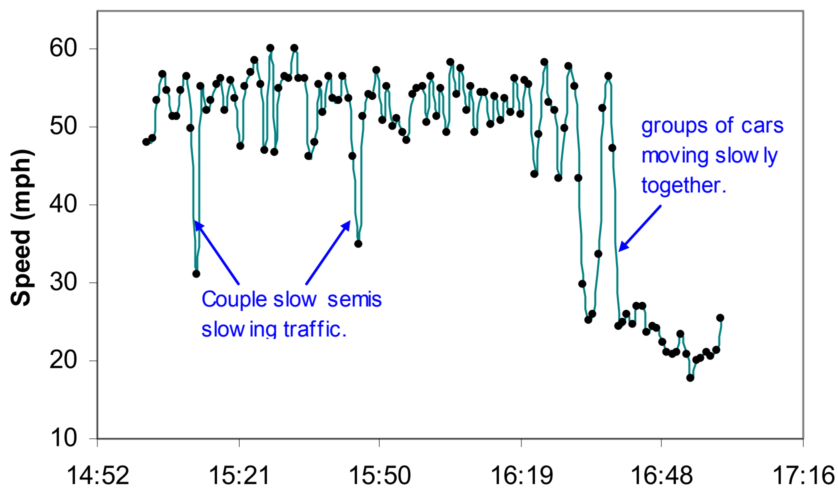

FIGURE 7 Speed Data Indicating Traffic Slow Downs with and without Queue Formations

The speeds of individual vehicles measured in three points - upstream, near, and downstream of the speed trailers - determined a series of speed profiles during periods of queue formations. The slopes of the speed profiles between the three speed data collection points characterized the drivers' deceleration behavior as they approached the end of the queues, and passed by the speed trailers. These slopes (decelerations) were used as measures of effectiveness in the evaluation of the speed advisory system. Before analyzing the speed profiles, significance tests were conducted to determine if there were statistically significant differences in the traffic conditions (i.e. speeds and volumes) before and during the operations of the speed advisory system. A series of t-tests conducted at the 5%-level of significance indicated that the traffic conditions (i.e., average speeds and volumes) did not significantly (α=0.05) change between the "before" and "during" periods. Therefore, it is expected that any changes in driver deceleration behavior occurred in response to the speed advisory messages only. Decelerations between the upstream measurement point and the trailer (a_{1-2}), and between the trailer and downstream measurement point (a_{2-3}) was calculated for each speed trailer location. Average decelerations (a_{1-3}) between the upstream and downstream speed measurement points were also determined. The significance of changes in a_1, a_2, and a between the "before" and "during" periods were evaluated using a simple t-test.

RESULTS

The average speed profiles determined for the 3 speed trailer locations are shown in Figure 8. The average decelerations between speed measurement points 1-2 (i.e., between upstream measurement point and trailer location), and 2-3 (i.e., between trailer location and downstream measurement point) are given in Table 1. The shaded cells in the table indicate statistically significant (α=0.05) differences between the decelerations observed before the system was deployed and the decelerations observed during the system was operated.

TABLE 1 Average Decelerations (Ft/Sec^2) before and during Speed Advisory System Operation

	Speed Trailer 1		Speed Trailer 2		Speed Trailer 3	
	Before	During	Before	During	Before	During
a_{1-2}	-2.6	-2.9	-1.0	-4.6	-2.1	-9.6
a_{2-3}	-8.9	-8.5	-11.5	-7.3	-11.4	-4.6
a_{1-3}	-5.8	-5.7	-6.2	-6.0	-6.7	-7.1

The speed profiles observed during the operation of the speed advisory system are generally smoother than those observed before system deployment. Before the trailers were deployed, vehicles began decelerating later but more intensively than after their deployment. Deceleration pattern at the trailer farthest from the lane closure taper (trailer 3) has completely changed when the speed trailer began displaying speed messages. Before system deployment most drivers hardly reduced their speed between the first two speed measurement points, and most of the speed reduction concentrated between the second and third measurement points. This behavior changed significantly in the opposite direction after the speed displays began operating. After deployment motorists at trailer 3 decelerated more in advance of the speed trailer than after they passed it. The speed profiles observed at the first trailer (i.e., the one closest to the lane closure) were very similar before and after deployment. The speed trailer did not significantly affect driver behavior at this location.

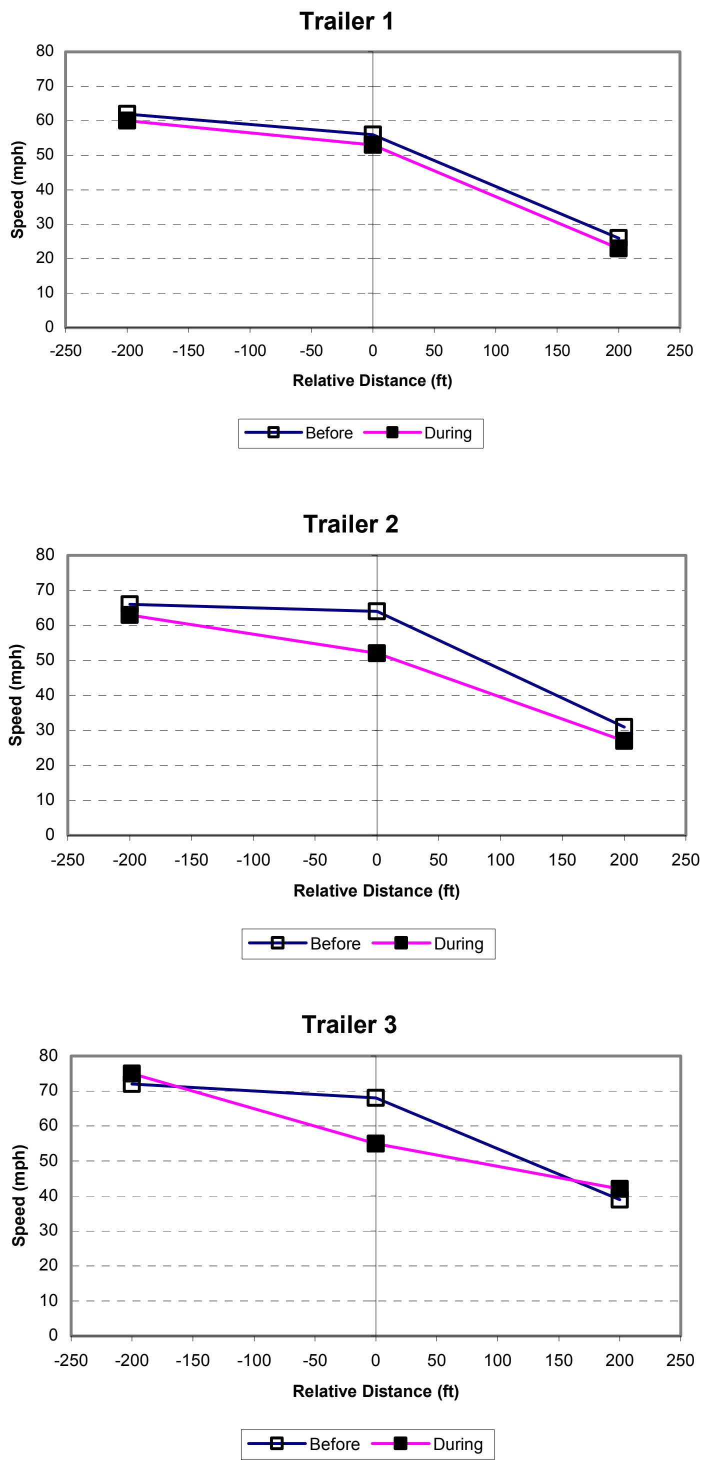

FIGURE 8 Speed Profiles Observed at the three Speed Trailers

CONCLUSION

The D-25 Speed Advisory Sign System was intended to warn drivers of stopped or slow-moving traffic ahead and thereby enable them to reduce their speeds and avoid rear-end crashes with these vehicles. The three speed trailers were operated independently, and the speed displays showed the speed of the downstream traffic. When a traffic slowdown was detected, the strobe lights began flashing. When there was no slowdown, the strobe lights were off, and either the speed of traffic downstream or the work zone speed limit was displayed, which ever was lower. The system deployed for the purpose of the field evaluation consisted of three speed trailers placed at approximately ¼-mile interval in advance of a work zone on Interstate 80 near Lincoln, Nebraska. The results of the analysis indicated that the speed messages were effective in reducing the speed of vehicles approaching queued traffic during time periods when congestion was building. The speed profiles observed during the operation of the speed advisory system were generally smoother than those observed before system deployment. Before the trailers were deployed, vehicles began decelerating later but more intensively than after their deployment. Deceleration pattern at the trailer farthest from the lane closure taper (trailer 3) has completely changed when the speed trailer began displaying speed messages. Before system deployment most drivers only slightly reduced their speed between the first two speed measurement points, and they mostly reduced their speed between the second and third measurement points. After system deployment, motorists at trailer 3 decelerated more before they reached the speed trailer than after they passed it. Due to the limited time available for the field studies the long-term effectiveness of the speed advisory system could not be determined.

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