Evaluation of Low-Cost Treatments on Rural Two-Lane Curves: On-Pavement Markings

tech transfer summary

The majority of lane departure crashes occur in rural areas, and mostly on two-lane roadways. A disproportionate number of these crashes occur on horizontal curves.

Background

A large number of rural crashes occur on curves. Some sources estimate the crash rate on curves to be three times the crash rate of tangent sections. Curve-related crashes involve a number of roadway and driver causative factors. Driver errors on horizontal curves are often due to inappropriate selection of speed and inability to maintain lane position.

Factors that contribute to excessive speed include driver inexperience, workload, sobriety, distraction, fatigue, sight distance, misperception of degree of roadway curvature, and situational complexity.

As agencies attempt to improve safety, they are often looking for low-cost measures that can be applied quickly and economically. The use of several low-cost treatments—such as post-mounted delineators, on-pavement curve warning signs, raised pavement markings, and wider edge lines—have been used to provide additional delineation on curves.

Supplementary on-pavement markings showing a curve arrow and a SLOW warning between two perpendicular bars were evaluated

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RESEARCH PROJECT TITLE
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The mission of the Center for Transportation Research and Education (CTRE) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, and reliability while improving the learning environment of students, faculty, and staff in transportation-related fields.

Problem Statement

Even though agencies have been applying a number of different low-cost treatments, the effectiveness of those treatments toward improving safety is not well understood or documented.

Project Objectives

The Center for Transportation Research and Education (CTRE) conducted a study to evaluate low-cost strategies to reduce speeds and crashes on curves. Use of on-pavement curve markings is one of several strategies evaluated and is the focus of this tech transfer summary.

Treatment Description

These markings show a curve warning in advance of the curve on the pavement. The treatment may also show the speed limit. Several other limited studies have evaluated different variations of on-pavement curve markings.

Chrysler and Schrock (2005) evaluated several different types of advance on-pavement curve markings. They found no speed changes with CURVE AHEAD, a 4 mph speed reduction with CURVE 55 MPH, and a speed reduction of 7 mph for the curve symbol plus 50 MPH markings.

Installation of supplementary on-pavement markings on DMC 99

Retting and Farmer (1998) evaluated use of SLOW and two white perpendicular white lines in advance of curves. They found a 1.1 to 3.4 mph decrease in mean speed depending on time of day. They also found a large reduction in drivers exceeding the advisory speed.

The treatments used for this study were a thermoplastic product that shows a curve arrow, SLOW, and two white bars perpendicular to the direction of travel.

Site Selection

The team compiled a list of high-crash horizontal curves (five or more crashes within five years) on rural two-lane paved roadways in Iowa. The researchers reviewed the sites using aerial imagery and site visits. The team selected the final sites using the following criteria:

- No major access points present within the curve (i.e., railroad, intersection)
- Posted speed limit on tangent section of 50 mph or higher
- Demonstrated speeding problem (determined during site visit and defined as a mean or 85th percentile speed that was 5 or more mph over the posted or advisory curve speed)
- No unusual features that would make certain types of treatment or speed data collection difficult
- No major maintenance or safety improvements over the three years prior to the study and no plans for major maintenance or safety improvements within the next three years

The team then selected two of the final sites for the installation of supplementary on-pavement curve markings. The markings were applied on DMC 99 and CR L20/Loess Hills Trail.

Test site details

Site	AADT (vpd)	Posted Speed Limit	Curve Advisory Speed
DMC 99	780	55	none
CR L20	1,880	55	35

AADT = average annual daily traffic
vpd = vehicles per day

Data Collection and Reduction

The researchers collected speed and volume data at each test location using the pneumatic road tubes. Data were collected about one month before the treatment installation (referred to as before data) and at one month after installation for both sites. Data were also available for 12 months after installation for the two sites, given the treatments were installed in 2010.

The researchers used the following speed metrics to determine the effectiveness of the treatments: change in mean and 85th percentile speeds and number of vehicles exceeding the advisory speed, if present, or the posted speed (if not present) by a set amount.

The researchers assessed changes in mean speed using a t-test, assuming unequal variances, and compared the percentage of vehicles exceeding the posted or advisory speed using a test of proportions.

The researchers compared change in the percentage of vehicles exceeding a certain speed threshold by subtracting the percentage of vehicles exceeding that threshold in the before period from the percentage exceeding that threshold in the after period.

For instance, if 45 percent of vehicles were exceeding the advisory speed in the before period and 20 percent of vehicles were exceeding that threshold in the after period, the change would be 25 percent.

The on-pavement signs were not expected to be more visible at night. As a result, data are presented for both daytime and nighttime together.

Findings

DMC 99 On-Pavement Curve Markings

The on-pavement curve advisory signs were placed at the site in July 2010. The treatment was installed at the north point of curvature (PC) for southbound (SB) vehicles and at the south PC for northbound (NB) vehicles.

Data are presented at the PC for vehicles traveling in the direction of the curve and at the center of the curve for both directions of travel, given all drivers within the curve would have encountered the pavement markings.

For SB vehicles, mean speeds decreased slightly for both time periods at both the North PC and center of curve, while 85th percentile speeds increased by up to 2 mph.

The percentage of vehicles traveling 5 or more mph over the posted speed limit for the north PC (SB vehicles) increased by up to 10 percent. Results for 10, 15, and 20 mph over showed little change for either the 1 month or 12 month after period.

The percent of vehicles traveling 5 or more mph over the posted speed limit increased for SB vehicles at the center of the curve with little change for vehicles traveling 10, 15, and 20 or more mph over.

For NB vehicles, mean speeds decreased by 1.7 mph at the south PC, while 85th percentile speeds remained constant. Mean speeds for NB vehicles decreased by 1.8 and 1.5 mph for the 1 and 12 month after periods, respectively, while 85th percentile speeds decreased by 1 mph.

Significant decreases resulted in the percentage of vehicles traveling 5 or more mph over the posted speed for the south PC with decreases up to 14 percent. Moderate decreases resulted for 10 or more mph over (up to 5 percent) and little change resulted for vehicles traveling 15 or 20 mph over the posted speed.

Use of a blow torch to attach thermoplastic pavement markings on CR L20

At the center of the curve, NB vehicles showed a 2 and 5 percent decrease in vehicles traveling 5 or more mph over the posted speed limit with little change for the 10, 15, and 20 or more mph speed thresholds.

County Road L20/Loess Hills Trail On-Pavement Curve Markings

The on-pavement curve advisory signs were placed at the site in August 2010. The treatment was installed at the north point of curvature (PC) for southbound (SB) vehicles and at the south PC for northbound (NB) vehicles.

Data are presented at the PC for vehicles traveling in the direction of the curve and at the center of the curve for both directions of travel, given all drivers within the curve would have encountered the pavement markings.

At the north PC (SB vehicles), mean and 85th percentile speeds decreased by about 1 mph for both after periods. At the center of the curve, mean and 85th percentile speeds were unchanged for SB vehicles for the 1 month after period and both speed metrics decreased by around 2 mph for the 12 month after period.

The percentage of vehicles traveling 5 or 10 or more mph over the posted speed limit for the north PC remained relatively unchanged for both after periods, while the percentage of vehicles traveling 15 mph over decreased by 7 and 4 percent for the 1 and 12 month after periods, respectively. The percentage of vehicles traveling 20 or more mph over the advisory decreased by 5 to 6 percent.

At the center of the curve, the percentage of southbound vehicles traveling over the advisory speed did not have any significant changes for the 1 month after period. Decreases of 8, 16, 11, and 4 percent resulted for the 12 month after period for vehicles traveling 5, 10, 15, and 20 mph over, respectively.

Mean and 85th percentile speeds at the south PC (NB vehicles) decreased by around 1 mph for both after periods. At the center of the curve, mean and 85th percentile speeds also decreased by around 1 mph for northbound vehicles.

The percentage of vehicles traveling 5 or more mph over the advisory speed saw little change at the south PC (northbound vehicles), while about a 6 percent decrease occurred for the percentage of vehicles traveling 10 or 15 mph over for both after periods. A 2 to 4 percent decrease was noted for vehicles traveling 20 or more mph over.

Northbound vehicles at the center of the curve saw about a 6 percent decrease in vehicles traveling 5 or more mph over and a 10 to 12 percent decrease for vehicles traveling 10 or more mph over. A 5 to 6 percent decrease resulted for vehicles traveling 15 or more mph over the advisory speed and little change occurred for vehicles traveling 20 or more mph over.

Conclusions

Results for the on-pavement curve markings include the following:

- At the DMC 99 site, change in mean and 85th percentile speeds showed mixed results. The percentage of vehicles traveling 5 or 10 or more mph over the posted speed limit increased by up to 10 percent at the north PC but decreased significantly at the center of the curve and at the south PC. Little change was noted for any location for vehicles traveling 15 or 20 mph over the posted speed limit.
- At the CR L20 site, mean and 85th percentile speeds decreased by up to 2 mph. Moderate decreases in the percentage of vehicles exceeding the advisory speed by 5, 10, 15, or 20 or more mph resulted for the north and south PC (up to 7 percent), while significant decreases occurred at the center of the curve for all thresholds (up to 16 percent).

Overall, the treatment was moderately effective. The greatest impact was in reducing vehicles traveling over the posted or advisory speed by 5, 10, or 15 or more mph.

Implementation Readiness and Benefits

Given these treatments are relatively low cost, they show promise in reducing speeds on rural two-lane curves. While reducing speeds on curves is assumed to result in a reduction in crashes, the relationship is not known.

References

Chrysler, Susan T. and Steven D. Schrock. Field Evaluation and Driver Comprehension *Studies of Horizontal Signing*. FHWA/TX-05/0-4471-2. Texas Transportation Institute. February 2005.

Retting, Richard A. and Charles M. Farmer. "Use of Pavement Markings to Reduce Excessive Traffic Speeds on Hazardous Curves." *ITE Journal*. September 1998. pp. 30–36.