Midwest Smart Work Zone Deployment Initiative: Kansas' Results

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During 1999, the Departments of Transportation from the states of Kansas, Nebraska, Iowa, and Missouri conducted a pooled-fund study of innovative devices designed to improve the safety and efficiency with which highway maintenance is conducted. In the state of Kansas, a total of nine devices were evaluated, including lighted raised pavement markers, CB-radio warning systems, and radar-triggered speed displays, among others. This paper gives an overview of the devices evaluated and summarizes the results of each of the evaluations. All of the products showed potential for improving work zone safety and operations. Some of the products require further development before they can be recommended for widespread deployment. The four products which seemed to show the most promise were orange removable rumble strips; the Vertical SafetyCade—designed to replace the reflectorized drum—a radar-triggered speed display, and an experimental configuration of Lightguard lighted raised pavement markers used to delineate a crossover in an interstate work zone. Speeds, lane distributions, and lane positions were used when appropriate to evaluate the effectiveness of each of the devices. In all cases, pneumatic hoses were used to collect the data. In most cases, one to two days of data were collected before and after device installation (or activation). Key words: work zone, maintenance, traffic control, speed.

INTRODUCTION

The State of Kansas ranks fourth in the country in public road mileage behind California, Texas, and Illinois (*1*). Of the more than 214,000 km (133,000 miles) of public roads in the state, the Kansas Department of Transportation (KDOT) is responsible for maintaining 15,450 km (9,600 miles) (*2*). With that in mind, it should be no surprise that work zone safety is one of KDOT's highest priorities. During 1999, KDOT joined with the DOTs from Nebraska, Iowa, and Missouri to evaluate innovative devices aimed at improving work zone safety. In Kansas, nine evaluations were conducted. For all evaluations, the devices were provided by the vendor at no cost to KDOT, and in exchange, KDOT funded the evaluation of the devices and the imminent publication of the results. The devices evaluated are shown in Table 1. The remainder of this paper contains a discussion of the data collection techniques used, followed by brief descriptions of the devices evaluated and a summary of the results from each evaluation.

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TABLE 1 Products Evaluated and Their Respective Manufacturers

Product	Manufacturer
SafetyCade Barricade	WLI Industries 1-800-323-2462 www.wli-industries.com
Traffic Graphics Software	Professional Traffic Graphics 1-877-827-3279 www.traffic-graphics.com
Removable Orange Rumble Strips	Advance Traffic Markings 1-252-536-2574 www.trafficmarking.com
Safety Warning System	MPH Industries, Inc. 1-800-835-0690 www.mphindustries.com
Light guard RPMs	Lightguard Systems, Inc. 1-707-542-4547 www.crosswalks.com
Wizard CB Alert System	Highway Technology/Trafcon Industries, Inc. 1-717-691-8007
Interplex Solar Powered RPMs	Interplex Solar, Inc. 1-203-466-6103
Radar Drones	Speed Measurement Laboratories 1-800-617-4929 www.speedlabs.com
Speed Display	Speed Measurement Laboratories 1-800-617-4929 www.speedlabs.com

DATA COLLECTION

Three basic types of data were collected as appropriate for each application: vehicle speeds, vehicle lane positions, and lane distributions. When lane distributions were relevant, data were collected at points 152 m, 304 m, and 457 m (500 ft, 1000 ft, and 1,500 ft, respectively) upstream of the lane taper. Data were analyzed separately for passenger cars and trucks, as well as for daylight and nighttime conditions. Data collection periods were limited to one or two days before and after device installation, except for the radar drones and the speed display, for which a week of data was collected before and after deployment. All data collection was performed using pneumatic hoses. In order to remove the effects of platooning, only records with an associated headway of 5 seconds or more were considered, based on the Highway Capacity Manual's recommendations for estimating percent time delay (*3*).

FIGURE 1 Vertical SafetyCade test site

VERTICAL SAFETYCADE

The original SafetyCade Type II barricade was developed through the SHRP Program. The benefits of the SafetyCade over conventional barricades include better visibility, more positive guidance, greater portability, and improved recoverability. The product evaluated was a version of the SafetyCade, called the Vertical SafetyCade, designed to replace the standard reflectorized drum. Approximately half the width of the original version, this version is particularly applicable to sites where limited real estate is available. The benefits of this product over drums are similar to the benefits afforded by its predecessor. The collapsible frame allows the barricade to simply fold flat when hit by a passing vehicle. To restore the device, the main panel need only be brought upright, automatically locking in place. The model tested contained a single panel sign with a black-on-orange chevron. The chevron is intended to provide more positive guidance than reflectorized drums.

The SafetyCades were evaluated at the entrance to an interstate work zone, as shown in Figure 1. There were no statistically significant changes in either speeds or lane distributions, indicating that the Vertical SafetyCades were no less visible than drums. Observations of the test site by KDOT personnel before and after the deployment of the SafetyCades suggested that the positive guidance provided by the chevron panel was superior to the guidance provided by drums.

TRAFFIC GRAPHICS SOFTWARE

This product was a departure from the rest of the products evaluated. Rather than a roadside device or pavement marking, the Traffic Graphics Software is a comprehensive set of images for use in CorelDRAW, including macros, which help produce professional diagrams easily and quickly. The package was evaluated by two different areas within the DOT—the Bureau of Traffic Engineering and Public Relations. Both areas found the software easy-to-use and capable of generating complex traffic control diagrams quickly and efficiently. The traffic engineering area felt that while the software is powerful and easy-to-use, it is not necessarily superior to the CAD based software currently used for this purpose. The public relations personnel felt that this software would represent an improvement over their current methods of generating traffic control diagrams. One key difference between the two responses may be that the public affairs personnel had previous experience with CorelDRAW, whereas the traffic engineering personnel did not. The public affairs personnel felt the software was a good investment and would recommend its purchase if the decision was theirs to make. They did comment that the learning curve could be reduced by more intuitive organization of the component files. Currently, images are organized by a terminology drawn from the Manual on Uniform Traffic Control Devices (MUTCD)—a resource familiar to traffic engineers, but not to public relations personnel.

REMOVABLE ORANGE RUMBLE STRIPS

Removable orange rumble strips were tested and evaluated on a rural two-lane highway, at the approach to a work zone in which a temporary signal was in use and KDOT's standard asphalt rumble strips were in place. The daytime data showed a statistically significant change in mean speeds and 85^{th} percentile speeds downstream of the removable rumble strips for both passenger cars and trucks (95% confidence level). Because of the low volumes at night, analysis of data collected at night did not yield usable results.

Perhaps the primary benefit of the removable rumble strips is that they are easily installed and removed. The test installation went smoothly, and based on the test experience, three workers familiar with the installation procedures could probably install a full complement of strips in 30 minutes or less. To test the capabilities of the adhesive, no preparatory work was done to the pavement before installing the strips. While the adhesive was insufficient under the test conditions, the use of a blower to clear the installation area of loose particles would likely yield a satisfactory seal between the strips and the pavement. After two weeks, the strips showed no noticeable wear.

The thickness of the strips, 3.175 mm (125 mil), seemed insufficient to create noticeable, audible, and tactile warning to the driver, especially in trucks. However, the reductions observed in both the mean and the 85^{th} percentile speeds indicate that the color of the strips alone is sufficient to have a positive effect.

FIGURE 2 Crossover delineated by Lightguard lighted RPMs

Additionally, drivers have been observed crossing the centerline to circumvent standard asphalt rumble strips. Rumble strips that are less dramatic in their effect might serve the purpose of alerting the inattentive driver, while providing less impetus for drivers to leave their lane in an unsafe avoidance maneuver.

The qualitative analysis of the strips' effectiveness from the driver's perspective suggested that changes in the configuration tested could significantly improve the effectiveness of the device. The advantage afforded by the visible warning provided by the orange color of the strips was considered to be very significant by the KDOT Bureau of Traffic Engineering. KDOT is interested in conducting a subsequent evaluation in which strips with a greater thickness will be used, possibly as much as 6.35 mm (250 mil).

SAFETY WARNING SYSTEM

The Safety Warning System (SWS) is designed to inform drivers of an upcoming work zone through a message encoded in a radar signal broadcast from a trailer mounted transmitter. The system consists of two components: a transmitter that broadcasts messages encoded in a radar signal and an in-vehicle receiver capable of interpreting the messages. Many recent models of radar detectors are SWS compatible, and SWS receivers are available that do not function as radar detectors, making them legal for commercial vehicle operators. The SWS was deployed at a lane taper followed by a crossover at the entrance to a rural interstate work zone.

Speeds and lane distributions were collected at points 152 m, 304 m, and 457 m (500 ft, 1000 ft, and 1,500 ft, respectively) upstream of the lane taper, and speeds were collected at approximately the midpoint of the initial curve of the crossover. Data collection difficulties rendered the speed data prior to the taper unusable. Lane distributions showed no change with the deployment of the SWS transmitter. However, speeds within the crossover did show a statistically significant decrease (95% confidence level).

LIGHTGUARD LIGHTED RAISED PAVEMENT MARKERS

The Lightguard lighted raised pavement markers (RPMs) were deployed in the crossover at the same work zone entrance where the SWS was evaluated. One day of data was collected before the SWS was switched on, and a second day of data was collected before the Lightguard RPMs were lit. As mentioned previously, mean speeds decreased with the deployment of the SWS. When the Lightguard system was turned on (the SWS remaining active), an additional decrease in mean and 85th percentile speeds occurred. The change was statistically significant at a 95% confidence level for both trucks and passenger cars during both daylight and darkness conditions, though the more dramatic change occurred at night. The percentage of passenger cars passing within 30 cm (1 ft) of the edgeline decreased from 8.9 to 5.2 percent with the deployment of the RPMs, indicating that drivers were keeping closer to the center with the RPMs active. Percent changes for passenger cars at other distances from the edge line and percent changes for trucks at all distances from the edge line were not statistically significant at a 95% confidence level. Figure 2 shows the crossover delineated by the Lightguard RPMs. For comparison, Figure 3 shows another crossover in the same work zone where no lit delineators were installed.

WIZARD CB ALERT SYSTEM

The Wizard CB Alert System is a device intended to provide advance warning of work zone conditions to travelers via messages broadcast over CB channel 19. The device was deployed at a lane drop at the entrance to a typical interstate construction zone. Lane distributions showed no change with the deployment of the CB Wizard. Low traffic volumes and excellent visibility may have rendered this a poor site for evaluating the effectiveness of this device. KDOT is still interested in using this device in the future.

FIGURE 3 Crossover without lighted delineation

INTERPLEX SOLAR POWERED RAISED PAVEMENT MARKERS

The Interplex solar powered raised pavement markers were used to delineate a lane taper at an Interstate work zone entrance. The advantage of these RPMs is that they are easily installed (self-adhering) and require very little maintenance, being solar powered. However, the configuration evaluated was insufficient to impact driver behavior. No change occurred in lane distributions with the deployment of the RPMs. Compared to the Lightguard system, which requires a hard-wired power source, the Interplex RPMs were much less visible. Operating the RPMs in a flashing mode rather than steady burn might improve their effectiveness. Additionally, deploying more units with smaller spacings might provide better delineation. The ease of installation and low maintenance are noteworthy benefits, but a more effective configuration must be developed before these can be recommended for delineation of lane drops.

RADAR DRONES

Radar drones are intended to trigger radar detectors, causing those drivers to reduce their speed. Assuming that drivers using radar detectors tend to travel faster than the mean, this would reduce not only the mean speed but also the variation in speeds. Two radar drone units were deployed within a work zone approximately 1.6 km (1 mi) apart. Speeds were collected for four days prior to the deployment of the drones and for four days after deployment. Speeds were collected at a total of 10 points between the drones units. Some changes in the mean and 85th percentile speeds were observed, but no consistent pattern existed. One difficulty encountered was that the tractor batteries used to power the drones (one battery each) proved insufficient to maintain operation for the intended test period of one week. While the batteries were recharged during the week, it is suspected that the units were operational for only about half of the time during which the data was being collected. Consequently, no conclusions could be made regarding the effectiveness of the device from this evaluation.

SPEED DISPLAY

Following the radar drone evaluation, a radar-triggered speed display was deployed at the same site. The speed display evaluated comprised a back lit dynamic speed display, a standard speed limit sign posted above the display, and a strobe flash, all contained in a trailer mount. The strobe flash was set to activate when a vehicle's speed exceeded 64 mph. During the operation of the speed display, statistically significant reductions occurred in mean speeds for both passenger cars and trucks during daylight and nighttime conditions. Near the device, the mean speed of passenger cars was reduced from 100.3 kph (62.3 mph) to 95.8 kph (59.5 mph), and the percent of passenger cars exceeding the posted speed of 60 mph (about 97 kph) dropped from 67% before the deployment of the device to 36% afterwards. Approximately 0.8 km (½ mi) downstream from the device, the mean speed was reduced to 98.8 kph (61.4 mph), and the percent speeding was reduced to 60%. Compared to the effects on passenger cars, the effects on trucks were somewhat more pronounced at night and slightly less pronounced during the day. All reductions were statistically significant at a 95% confidence level.

CONCLUSIONS

All the devices evaluated showed potential for improving the safety and efficiency with which highway maintenance is performed, even though several caused no statistically significant change in the relevant quantitative evaluation parameters. The devices that were the most effective based on the quantitative data collected were the speed display and the Lightguard RPMs. Other devices whose effectiveness was not strongly reflected in the data, but which seemed to generate significant interest among KDOT traffic control personnel based on their own qualitative observations, were the SafetyCade Barricade and the orange removable rumble strips. All of these devices are commercially available, although the configuration used with the Lightguard RPMs was experimental.

The speed display is easily deployed, very mobile, and highly effective at reducing speeds. Speed reductions resulting from the deployment of the Speed Display were comparable to those occurring during active law enforcement.

The Lightguard RPMs resulted in substantial reductions in speeds and improvements in lane placement. Several enhancements might further improve the effectiveness of the RPMs, including a random flash mode for daytime operation and a sequenced flash (chasing) mode for nighttime operation.

The Vertical SafetyCade did not produce any significant changes in speeds or lane distributions. The chevron panel provides more positive guidance than standard reflectorized drums, which could result in reducing instances of vehicles encroaching on the work area.

The orange removable rumble rtrips did produce statistically significant reductions in speeds for both passenger cars and trucks, although the reductions were small. The potential for the strips to improve driver attention to the driving task while approaching the work zone is very promising. To maximize their effectiveness, the evaluated configuration should be altered and thicker strips should be developed or a double thickness used (i.e., one stripe on top of another).

REFERENCES

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