Low-Cost Countermeasures for Ameliorating Run-Off-the-Road Crashes

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This project sought to determine the effectiveness of various low-cost countermeasures for reducing the number of fixed object and overturning crashes. A survey was conducted of the 50 state highway and transportation departments. Responses to the questionnaire show that all states are using chevron markers, and a majority are using delineators and standard warning signs. Respondents thought that these devices were most effective for reducing run-off-the-road crashes, although little documentation was supplied to support this contention. Most states have established procedures for selecting the most hazardous run-off-the-road sites, but few have formal guidelines for selecting the specific countermeasures for use at these sites. A critical analysis is needed to determine the actual effectiveness of several commonly used low-cost countermeasures.

The problems of run-off-the-road (fixed-object and overturning) crashes in Georgia and New Mexico have been examined in previous research (1-3). One of the principal findings of these studies has been that these crash sites exhibit adverse geometric conditions to a much greater extent than does the roadway system in general. Techniques for improving the roadway alignment and creating a safe roadside are well established, but they are expensive. Consequently, their application on a broad scale exceeds the financial constraints of operating agencies.

Substantial cutbacks in the budgets of highway agencies have accentuated the need to identify low-cost countermeasures for ameliorating run-off-the-road crashes. Numerous techniques short of roadway reconstruction and roadside improvement have been suggested for reducing the frequency of these crashes; however, there is little documentation to show that they have been evaluated to determine their effectiveness. This paper examines the use and apparent effectiveness of low-cost countermeasures through a questionnaire survey of state highway and transportation departments and reviews the responses in light of the current technical literature.

SURVEY OF STATE HIGHWAY AGENCIES

In the spring 1982 a survey was conducted of all state highway agencies to determine their experience with various low-cost run-off-the-road countermeasures. The purpose of the survey was to identify which devices were in common use and to assemble research results on their effectiveness. Supplementary information was collected on techniques for identifying hazardous locations and countermeasure selection and the use of surrogate measures. The survey questionnaire is shown in Figure 1. The questionnaires were distributed on a geographic basis by researchers from the Georgia Institute of Technology and the University of New Mexico.

Replies were received from traffic, safety, and design engineers in 38 of the 50 states contacted. The engineers were in agreement on several issues, but the respondents also showed considerable disparity in their approaches to run-off-the-road crash problems.

Countermeasures Used by State Agencies (Question 1)

Question 1 sought to determine which of the low-cost countermeasures had been used by the agencies at new sites within the past 5 years to ameliorate fixed-object or rollover crashes. The question was specific; however, positive responses from some states may indicate that the devices were used as part of a continuing program of upgrading traffic-control devices. The question did not differentiate between states that had extensive experience with a particular device versus those states where a device had been used infrequently. More than half the respondents indicated that they used (a) chevron markers, (b) delineators, (c) standard warning signs and markings, (d) warning signs with flashing beacons, (e) rumble strips, and (f) reflectorized pavement markers on center lines.

The responses to this question are summarized in Table 1. The chevrons are used universally, although they have only been an official traffic control device for a relatively few years. Raised reflectorized markings were also used commonly, more often on center lines than on edge lines. Several techniques, such as reflectorized paint on fixed objects, are used infrequently.

Evaluation of Low-Cost Countermeasures (Question 2)

Slightly more than half of the respondents (20) indicated that their agency had evaluated one or more of the countermeasures. The agencies appear to view their principal task as operations rather than research, which may account for the relatively low extent of evaluation. However, a number of states had participated in multistate evaluations (4) of selected countermeasures.

The principal impetus for undertaking the evaluations appears to be the requirements embodied in federal highway safety legislation. Many of the evaluations make use of the traditional before-and-after approach--a recognized high hazard location is improved and the respective accident experiences are compared. The statistical weaknesses of this technique, which fails to account for relevant factors such as regression to the mean, have been documented (5), although most of the operating agencies are apparently unaware of these deficiencies.

A number of states indicated that they had conducted evaluations of specific improvement types but had not prepared written documentation of the procedures or results. Other agencies would benefit if such documentation were available.

Effective Existing Low-Cost Countermeasures (Question 3)

In the absence of extensive evaluations of most forms of remedial action, the engineer must rely on professional judgment to determine which improvements are most effective. This judgment is conditioned by education, experience, and familiarity with certain sources of technical information. This question sought to determine which countermeasures were thought to be most effective.

Although 20 different types of low-cost countermeasures were listed by the respondents, the most commonly cited improvements were chevron markers, delineators, and warning signs. Consensus on the effectiveness of other treatments was less common.

Table 2 summarizes the responses. Several countermeasures listed in this table, including guardrail, slope flattening, and skid treatment, may be effective although they are not necessarily low-cost improvements.

Promising or Unproven Countermeasures (Question 4)

We anticipated that some states had experimented with unique countermeasures that were not identified in question 1. This question sought professional input in order to identify promising techniques that might be effective in reducing the number or severity of run-off-the-road crashes. In response to this question, 12 states identified 21 promising countermeasures that might warrant further study. Reflectorized pavement markings on edge lines, rumble strips, and section contouring-slope flattening were each listed by two states, each of the 18 remaining countermeasures was identified by only one state. Several of the suggestions, which are given in Table 3, may deserve some additional attention; others appear to be improperly classified as unproven.

Use of Formal Guidelines for Selecting Sites for Improvement (Question 5)

Techniques used by highway agencies to identify hazardous locations vary among the states. One survey

Figure 1. Questionnaire sent to state highway agencies.

LOW-COST COUNTERMEASURES FOR RUN-OFF-THE-ROAD CRASHES

The University of New Mexico, in cooperation with the Georgia Institute of Technology, is conducting a nationwide study to identify and evaluate promising low-cost countermeasures for reducing the number and/or severity of roadside crashes. Your assistance in responding to this questionnaire would be sincerely appreciated.

1. Please indicate which of the following countermeasures were installed at new sites by your agency during the past five years for the purpose of decreasing the number or severity of fixed-object and rollover crashes. A "new site" is a location where the countermeasure had not previously been used.

Countermeasure	Installed at New Sites	
Standard warning signs	Yes ☐	No ☐
Standard pavement markings	Yes ☐	No ☐
Non-standard warning signs	Yes ☐	No ☐
Non-standard pavement markings	Yes ☐	No ☐
Reflectorized pavement markers on centerlines	Yes ☐	No ☐
Reflectorized pavement markers on edge lines	Yes ☐	No ☐
Reflectorized paint on trees, poles, etc.	Yes ☐	No ☐
Delineators	Yes ☐	No ☐
Chevron markers	Yes ☐	No ☐
Rumble strips	Yes ☐	No ☐
Warning signs with flashing beacons	Yes ☐	No ☐
Warning signs with traffic actuated flashing beacon	Yes ☐	No ☐
Traffic actuated warning signs	Yes ☐	No ☐
Other (please specify)	Yes ☐	No ☐

2. Please identify low-cost roadside crash countermeasures (from Question No. 1 or others) for which evaluation studies were conducted by your agency during the past five years. If a written report on the study is available, please enclose a copy and bill us for the cost.

Countermeasures Evaluated	Written Report Available	
______	Yes ☐	No ☐
______	Yes ☐	No ☐
______	Yes ☐	No ☐
______	Yes ☐	No ☐

3. Of all the existing low-cost countermeasures for reducing losses from fixed-object and rollover crashes, please list the three you consider to be the most effective.

First choice ______
Second choice ______
Third choice ______

4. Please list in order of preference any promising or unproven countermeasure (i.e., not yet in general use) which you think are likely to be effective in reducing the number or severity of fixed-object or rollover crashes.

First choice ______
Second choice ______
Third choice ______

5. Does your agency have formal guidelines for selecting sites for improvement? (If written guidelines are available, please enclose a copy.)

☐ Yes -- What are these guidelines based on (e.g., prior crash history, ADT, road geometry, etc.)? ______

☐ No ______

6. Does your agency have formal guidelines for selecting countermeasures at sites chosen for improvements? (If written guidelines are available, please enclose a copy.)

☐ Yes -- What are these guidelines based on (e.g., ADT, road design, costs, etc.)? ______

☐ No ______

7. There are numerous measures (i.e., surrogates) other than reductions in crashes that have been used to evaluate off-road fixed-object and rollover crash countermeasures (e.g., speed reduction, lane placement, compliance with the maximum speed limit). Please list up to three such measures you consider most satisfactory.

First choice ______
Second choice ______
Third choice ______

8. Person completing this questionnaire:

Name ______ Phone (___) ______

Address ______

9. Would you like to receive a copy of the survey results? Yes ☐ No ☐

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Please return the completed form to J. W. Hall, Bureau of Engineering Research, University of New Mexico, Albuquerque, New Mexico 87131.

Thank you for your cooperation.

Table 1. Run-off-the-road countermeasures installed by states at new sites during past five years.

	Installed	
Countermeasure	Number	Percent
Chevron marker	38	100
Delineator	35	92
Standard warning sign	34	89
Warning sign with flashing beacon	30	79
Standard pavement marking	28	74
Rumble strip	23	61
Reflectorized pavement marking on center line	21	55
Reflectorized pavement marking on edge line	15	39
Nonstandard warning sign	10	26
Other	9	24
Reflectorized paint on trees or poles	8	21
Warning sign with actuated flashing beacon	7	18
Traffic-actuated warning sign	5	13
Nonstandard pavement marking	3	8

Note: For survey purposes, a new site was a location where the countermeasure had not been used previously.

Table 2. Respondents' judgment of most effective low-cost countermeasures.

Countermeasure	Number	Percent
Chevron marker	26	68
Delineator	19	50
Warning sign	16	42
Standard pavement marking	9	24
Standard warning sign with beacon	6	16
Guardrail	6	16
Removal of fixed object	5	13
Rumble strip	4	11
Raised pavement marker	3	8
Shoulder or edge line striping	3	8
Delineators on trees or poles	3	8
Make object breakaway	3	8
Slope flattening	2	5
Reflectorized center line	1	3
Safe curve speed sign	1	3
Narrow bridge marking	1	3
Crash cushion	1	3
Traffic-actuated warning sign	1	3
Standard delineation	1	3
Skid treatment	1	3

(6) found that all states employ some criteria for identifying hazardous locations. Although the principal factor was generally the number of accidents, accident rates, accident severity, and economic loss were also used. Frequently different criteria were applied on different road systems.

Question 5 sought information on the more specific issue of how states select sites for improvements to reduce the number or severity of run-off-the-road crashes. Of the 38 respondents, 79 percent indicated that they had formal guidelines for site selection; the remainder apparently relied on the more general criteria used for selecting among all types of hazardous locations. Among states that had formal guidelines, the most commonly used factors were crash history and traffic volume. A few states included measures of roadway geometry in their site-selection process. Few states were able to comply with the request to provide a copy of their guidelines. Specific responses are summarized in Table 4.

The formality of the site-selection process appears to be limited by the completeness, accuracy, and compatibility of traffic record systems. States that reported better record systems appear to have more elaborate site-selection procedures.

Table 3. Promising or unproven countermeasures recommended by state transportation agencies.

Countermeasure	State
Reflectorized pavement markings on edge line	La., Ga.
Rumble strips	La., Ill.
Section contouring and slope flattening	Fla., N.C.
Breakaway utility poles	Calif.
Safer design of mailboxes	Calif.
Flexible delineator posts	Calif.
Guardrail with white reflective epoxy coating	Del.
Powder-coated reflectorized guardrail	Ga.
Tree removal within 30 ft of pavement	Ga.
Sloped end sections on drainage pipes	Ga.
Improved delineation and superelevation	Ga.
Wider shoulders	Ga.
Warning signs with flashing beacons	La.
Utility pole delineation	Md.
California-type warning signs	Md.
Clear Roadside Recovery Area	Minn.
Traffic-actuated warning signs	Miss.
Chevron markers	Mont.
Shoulder-mounted concrete rail	Mont.
Waterwall attenuator	Mich.
Shoulder clearing	N.C.

Use of Formal Guidelines for Countermeasure Selection (Question 6)

Once the guidelines identified from the responses to Question 5 have been applied and sites that warrant correction have been identified, a highway agency is confronted with the problem of choosing the appropriate countermeasure for each site. On a cost basis options range from relatively inexpensive signing to costly roadway alignment. In the presence of reliable data on the effectiveness of candidate countermeasures, the techniques of engineering economy could be used to determine the most suitable improvement; however, responses to question 2 indicated that few of the low-cost countermeasures have been evaluated for effectiveness. Several summary reports (6) provide information on medium- to high-cost improvements, but their reliability has been questioned.

Therefore, only 24 percent of the respondents indicate that they have formal guidelines for countermeasure selection. In addition to economic considerations, the responses indicate that engineering judgment plays a prominent role in countermeasure selection. Replies to this question, which are given in Table 5, suggest that states are less likely to have formal guidelines for improving run-off-the-road crash sites than for improving generally hazardous locations.

Use of Surrogate Measures of Effectiveness (Question 7)

Because run-off-the-road crashes are comparatively rare events, states may not want to await their occurrence to identify hazardous locations or to evaluate improvements. Several studies have examined other measures (e.g., speed variance) in an attempt to identify the relation between these surrogates and actual experience with crashes. Although problems with surrogates have been noted (5), a number have been suggested for use as measures of effectiveness (7).

Question 7 sought to determine which surrogates were most suitable for the evaluation of run-off-the-road countermeasures. The most frequently listed surrogate was speed reduction (12 states), followed by compliance with the speed limit, and reduction in public complaints and driver interviews. The responses indicated that the states have a moderate level of confidence in the use of surrogates, but, consistent with their infrequent post-implementation of remedial action, the states had little experience in the use of these measures at run-off-the-road crash sites. Table 6 lists the responses to this question.

EFFECTIVENESS OF COUNTERMEASURES

The questionnaire survey has provided a reasonably comprehensive picture of what actions the states are taking to reduce run-off-the-road crashes. As given in Table 1, the most commonly used forms of remedial action are those that support the principles of positive guidance by providing the driver with information on the desired travel path and speed. The appeal of these actions may be intuitive. The survey provided limited information about their proven effectiveness.

Chevron Alignment Signs

All states report use of chevron alignment signs to reduce the frequency of run-off-the-road crashes; however, relatively little research has been devoted to the evaluation of chevron alignment signs. Limited research tends to support engineering judgment that these devices may be effective in alerting drivers to the presence and sharpness of an upcoming curve. The West Virginia Department of Highways (8) placed chevron alignment signs at 62 locations where identified run-off-the-road accident problems exist. A preliminary before-and-after evaluation at 28 sites found a 49 percent reduction in the rate of nighttime run-off-the-road crashes. The Montana Department of Highways (9) installed chevrons at 5 hazardous locations along curved sections of high-

Table 4. Formal guidelines for site selection.

State	Formal Guidelines	Response
Ark.	No	Accident history
Ariz.	Yes	Computer-selected sites based on annual average daily traffic (AADT) and accidents
Calif.	Yes	Safety index (existing-expected accidents)
Colo.	Yes	Hazard index using accident history, severity, average daily traffic (ADT), and average rate for similar highways
Conn.	Yes	Crash history
Del.	Yes	Severity index, crash history, and site review
Fla.	Yes	Accident records, grouped single-vehicle roadside obstacle accidents by milepost and section
Ga.	Yes	ADT, geometry, accident history, funds, and benefit/cost ratio
Hawaii	No	
Iowa	Yes	Accident rates
Idaho	Yes	Prior crash history, ADT, and road geometry
Ill.	No	
Ind.	No	Based on investigation of site due to complaint from public, local agency, or internally
Kans.	No	
Ky.	No	
La.	Yes	Abnormal accident listings
Mass.	Yes	Crash histories, ADT, and hazard cost index
Md.	Yes	High accident sections of roadway based on accident rates
Maine	No	
Mich.	Yes	Identify control sections that have highest crash rates
Minn.	Yes	Crash history and geometry
Mo.	Yes	Accident history of location being considered for improvement
Miss.	Yes	Engineering study of ADT, road geometry, and crash history
Mont.	Yes	Prior crash history and road geometry
N.C.	Yes	
N. Dak.	Yes	Crash history, traffic exposure, roadway geometrics, improvement costs, and user complaints
N. Mex.	Yes	Accident history
Nev.	Yes	
N.Y.	Yes	Accident surveillance, crash rates, and geometrics
Okla.	Yes	Accidents
Oreg.	Yes	Index based on crash history, severity, and ADT
S.C.	No	
Tenn.	Yes	Critical accident rate method together with economic loss to develop priority and on-site studies
Tex.	Yes	Existing and expected accident frequency and severity (cost), ADT, and project cost
Va.	Yes	ADT, road geometry, crash history, and cost
Vt.	Yes	ADT and crash history
Wash.	Yes	Crash history
W.Va.	Yes	Federal Highway Program Manual 8.2.3. procedures

Table 5. Formal guidelines for countermeasure selection.

State	Formal Guidelines	Response
Ark.	No	
Ariz.	No	
Calif.	No	Engineering judgment
Colo.	No	Each identified location is studied as a unique problem
Conn.	No	Benefit/cost analysis using published data
Del.	Yes	Manual on Uniform Traffic Control Devices (MUTCD)
Fla.	No	Warrants for crash attenuators are being developed
Ga.	Yes	Benefit/cost ratio, right-of-way available, actual cost, ADT, reasonable alternative, road design
Hawaii	No	Countermeasure selected based on apparent need; e.g., raised pavement marker rumble strip to alert sleepy drivers before sharp curve
Iowa	No	
Idaho	Yes	Engineering judgment based on proved countermeasures
Ill.	No	
Ind.	No	Based on site investigation and engineering judgment
Kans.	No	
Ky.	No	
La.	No	Engineering study made by district traffic engineer
Mass.	No	
Md.	No	
Maine	No	
Mich.	Yes	Type C guardrail installed when ADT exceeds 30,000
Minn.	No	
Mo.	Yes	Guidelines based on benefit/cost ratio for each proposed countermeasure considered for implementation
Miss.	No	
Mont.	No	
N.C.	No	
N.Dak.	No	Engineering studies of sites usually determine specific improvements to be made on case-by-case method
N.Mex.	No	
Nev.	Yes	
N.Y.	No	
Okla.	No	
Oreg.	Yes	Pattern of accident experience and benefit/cost analysis based on collision diagrams
S.C.	No	
Tenn.	No	Technical guidelines from research reports and MUTCD
Tex.	Yes	Based on accident information and field visits
Va.	Yes	ADT, road design, costs, and accident data
Vt.	No	
Wash.	No	
W.Va.	No	

Table 6. Surrogate measures of effectiveness recommended by state transportation agencies.

Surrogate Measure of Effectiveness	No. of States
Speed reduction	12
Speed limit compliance	4
Reduction in public complaints and driver interviews	4
Fewer skid marks	3
Lane placement and shoulder encroachment	3
Severity	2
Brake applications	2
Pace narrowing	1
Site examination	1
Erratic maneuvers	1
Traffic conflicts	1
Roadway realignment	1
Improved skid resistance	1
Advisory speed compliance	1
Amount of maintenance costs incurred	1
Before and after studies at point areas	1
Enforcement of 55-mph speed limit	1
Enforcement and education regarding drunk drivers	1

way, each about 1-mile long, and recorded a 32 percent reduction in the nighttime run-off-the-road accident rate. These results appear promising; however, both studies had comparatively small sample sizes, and, because of the high accident experience in the before periods, regression to the mean has a significant effect on the results.

Post Delineators

More than 90 percent of the states reported the use of post delineators to reduce the frequency of run-off-the-road crashes. In comparison with chevrons, the delineators are a much older type of traffic control device; therefore, more research has been conducted on their effectiveness. A 1966 study (10) found that the use of post-mounted delineators can be an effective means of reducing crashes at sites where roadway curvature exceeds 5 degrees. Delineation was effective for curves between 5 and 10 degrees that have a central angle between 20 and 40 degrees. Based on this research, the central angle may be the better indicator of the need for delineation.

Another study (11) attempted to evaluate nine delineation configurations by using post-mounted delineators and other devices along one horizontal curve test section. The treatments were evaluated with surrogate measures. The researchers recommended that amber delineators be used for right-turning curves (on the left side of the roadway) and that crystal delineators be used for left-turning curves (on the right side). Post-mounted delineators were also recommended for two-lane rural roads, pavement width transitions, and all curves that have curvature greater than 5 degrees and have a central angle in excess of 20 degrees.

Standard Signs

Most of the states indicated that they used curve warning and advisory speed signs, although less than half thought that such signs were among the most effective countermeasures. Evaluations of the effects of standard signs on driver behavior have produced mixed results. Bezkorovainy (12) studied the influence of advisory speed limits at horizontal curves on spot speeds at 12 locations. He sought to determine the effects of a standard curve sign used with a standard advisory speed plate and with an experimental advisory speed plate that contained the words SLOW TO followed by the numerical value. The results implied that advisory speed signs are generally ineffective in changing the speed of drivers at the center of the curve. A special study indicated, however, that a 30-mph advisory produced a greater rate of deceleration along the approach to the curve than did a 50-mph advisory sign.

Lyles (13) evaluated five sign treatments for controlling driver speeds in the vicinity of hazardous horizontal curves on rural two-lane highways. The treatment included standard curve warning signs, advisory speed signs, and speed limit signs. Lyles reported that neither a single sign nor a group of signs was consistently more effective in decreasing the potential hazard at the curves. His work suggests that, when a hazardous curve exists, advisory speed plates and regulatory signs will be ineffective.

An FHWA study (14) of speed control signs concluded that passive signs were generally ineffective in slowing traffic as it passed through a small rural town. On the other hand, a before-and-after study of advisory speed limit signing in combination with curve warning signs appeared to reduce single-vehicle crashes significantly (15). On the basis of these conflicting results, a firm conclusion cannot be reached on the effects of these devices.

Pavement Markings

The standard pavement markings applicable to run-off-the-road crashes include painted center lines and edge lines. Three-quarters of the states reported the use of standard markings as a countermeasure, but only 24 percent think that standard markings are among the most effective forms of remedial action. Most of the studies of the effectiveness of pavement markings have been conducted on a limited scale. In one of the larger studies Taylor (11) reported an improvement in driver behavior, as measured by reduced variance of lateral placement, when a roadway that had a freshly painted center line was compared with the base condition of a weathered center line and no delineators. The addition of edge lines at horizontal curves (on roads where they do not exist on tangents) was found to improve lateral placement characteristics and possibly reduce accident experience. Paint, however, was judged inferior to raised pavement markings in most applications.

The use of retroreflective pavement markers has increased greatly in recent years. More than half of the states use them on center and edge lines. Although the markers are perceived favorably by the general public, comparatively few of the highway engineers thought that they were effective in reducing run-off-the-road crashes. Advantages claimed for markers over paint stripes include reduced maintenance and more positive all-weather, nighttime delineation. The markers have also been reported to be effective in delineating detours through construction zones (16).

Traffic performance studies have suggested that pavement markers are more effective than post-mounted delineators on isolated horizontal curves (17). Researchers (4) have reported that highway sections along tangents or along winding sites that have raised pavement markers along the center lines have lower accident rates than do those that have painted center lines. The results of the analyses were not as definitive for isolated horizontal curves.

The Florida Department of Transportation installed raised pavement markers along a 19-mile section of the main highway to Key West. The markers were placed along the center line (four abreast at 20-ft centers) and across the 4-ft-wide paved shoulders at a 45-degree angle. A before-and-after evaluation showed a 42 percent decrease in projected crashes and a 38.4 percent decrease in injury and fatal crashes. Fixed-object crashes decreased from 25 to 4 per year and run-into-water accidents decreased from 22.5 to 4 per year (18).

A study of the effectiveness of raised pavement markers along a rural horizontal curve in combination with painted edge lines (11) found that speeds of passenger vehicles were not affected by the markers. Vehicular placement variability, however, was reduced by the use of raised pavement markers. Of four configurations tested, raised pavement markers along the center line used with freshly painted edge lines produced less vehicular placement variability than did a painted center line, and drivers tended to adopt a more central position in their lane. In a related study, which may be inconclusive due to small sample sizes, a correlation was found between lateral placement variability and accident experience. Based on their conclusion that raised pavement markers show an advantage over a painted center line because markers cause drivers to move farther away from the center line and reduce variance in the travel path, the researchers recommended the use of these markers on hazardous horizontal curves.

Transverse Stripes and Rumble Bars

Although more than 60 percent of the states use rumble bars or strips to improve potential run-off-the-road sites, few consider them to be effective devices for this purpose. The technical literature suggests that they have an affect on driver behavior that may be time dependent. The Michigan Department of Highways (19) performed three experiments to evaluate the use of transverse pavement stripes and rumble bars. In all the tests the stripes and rumble bars were placed with variable spacing to give the illusion of acceleration to the driver traveling at a constant speed. The researchers report that the effect of yellow pavement striping was marginal. Before stripe installation the speed reduction through the highway construction area caused by normal sign obedience was slightly more than 4 mph. Immediately after striping the total speed reduction jumped to 8.3 mph. A month later, however, it dropped to 4.3 mph, which was close to the initial condition. Two kinds of rumble bars were tested, and both caused larger reductions in average speeds than did the colored stripes. However, the speed reduction obtained by these devices also diminished over time.

In a more recent experiment with these devices (20), the Transport and Road Research Laboratory found that their installation at the approaches to roundabouts on dual carriageways reduced speed-related accidents significantly. They were most effective in reducing fatal and serious injury accidents. They also had a greater effect during the daytime and on wet road surfaces.

An FHWA evaluation (14) of speed control for small rural towns showed that pavement markings and rumble strips were second (after traffic-actuated signs) in effectiveness at night as measured by the percentage of drivers who complied with the speed limit.

The Virginia Department of Highways and Transportation (21) reported that rumble strips installed along approaches to rural STOP intersections reduced the number of crashes. An analysis of nine rumble-strip locations showed an overall reduction of 37 percent in the total number of crashes.

Signs With Flashing Beacons and Traffic-Actuated Speed Violation Signs

Because of cost and power requirements, signs with flashing beacons and traffic-actuated speed violation signs may not be used as widely as some of the other treatments. Only seven states reported using them to alleviate run-off-the-road crashes, and only one state thought that they were highly effective. However, limited technical literature on these devices is moderately optimistic. Hanscom (22) reported speed reductions at critical curve locations in response to signing that employed flashing hazard beacons. In this study of signing to warn of wet weather skidding hazard he recommended that the beacons be activated at the onset of rainfall.

In a speed control study for small rural towns (14), traffic-actuated warning (speed violation) signs were the most effective system tested. They were found to reduce speed by 3 to 4 mph more than passive signs. Signs with flashing beacons were second in effectiveness during daylight, but they were found to reduce speeds by only 1 to 2 mph more than the passive signs. The researchers reported that the addition of flashing beacons to a sign produces a slight, but insignificant, increase in its effectiveness.

SUMMARY AND CONCLUSIONS

This study has attempted to determine the state of the art in using low-cost countermeasures to reduce the frequency and severity of fixed-object and overturning crashes. A questionnaire survey was distributed to state highway and transportation departments, and the responses were examined in light of the technical literature on this topic. Some limited conclusions can be reached based on this study.

Certain low-cost countermeasures appear to have a favorable impact on surrogate measures of effectiveness; however, separate studies of the same device have reached differing conclusions. Chevron signs have been used widely, and highway agencies consider chevrons the most effective low-cost devices for reducing run-off-the-road crashes. Although some limited studies suggest that these may be effective, the evidence is not conclusive. Delineation and standard warning signs are also used extensively, but there is less consensus on their effectiveness. Raised markers appear to be more effective than paint.

Most states have formal guidelines, typically based on crash history and average daily traffic, for identifying the most hazardous run-off-the-road sites. Despite evidence that roadway geometry is a principal contributor to these crashes, less than a quarter of the agencies consider this factor in site selection. Few states have formal guidelines for countermeasure selection.

Speed reduction is thought to be the best surrogate for evaluating the effectiveness of run-off-the-road improvements, although the literature suggests that lateral placement may be a better criterion. Actual postimplementation evaluation of these types of remedial action is comparatively rare. To assist the engineer in making the best use of limited funds, the need is critical for additional study of those countermeasures whose effectiveness has not been documented through comprehensive and statistically valid studies.

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Motorists' Reaction to Exclusive/Permissive Left-Turn Signal Phasing

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The findings of a study of motorists' perceptions of exclusive/permissive (E/P) signal phasing at 10 intersections in Virginia are presented. Traffic volumes and conflict rates were counted at each site and accident files were investigated. In addition, 1,252 residences and small businesses in the vicinity of the sites were sent questionnaires to determine motorists' opinions and perceptions of E/P phasing. A total of 460 completed questionnaires were received and analyzed. Roughly one-third of those queried were confused by the E/P signal the first time they encountered it, but the confusion dissipated over time. Advance publicity of an E/P signal modification or installation and an explanatory sign placed adjacent to the signal head will do much to reduce motorists' confusion. More than 70 percent of those surveyed were in favor of E/P signal phasing and 77 percent thought that it reduced intersection delay. On-site observations revealed that vehicular conflicts at E/P intersections are most frequent at locations that have high volumes of turning vehicles and various movements of traffic. The conflict rate could not be attributed to any one characteristic of an intersection, however. The same was true for the accident rate.

Several means can be used to accommodate left-turn movements at signalized intersections. One of these is the recently introduced exclusive/permissive (E/P) left-turn signal phase, which permits left turns during the display of both the green arrow and the green ball. During the green-arrow phase the motorist is unopposed in making a left turn; during the green-ball phase he or she must yield to opposing vehicular traffic. The left-turn arrow may either follow or precede the green ball.

Several studies have been conducted nationwide to determine the best method for signalizing left-turn movements and as many as two dozen signal indications are available for use. One recent study conducted in Kentucky determined that E/P left-turn phasing is efficient because it results in fewer delays than other types of left-turn phasing; however, it was found to lead to an increase in accidents compared with exclusive phasing. The number of these mostly minor accidents decreased as drivers became familiar with the intersection. More than 90 percent of the drivers queried in that study were in favor of this type of signal, but many indicated that they had not understood the signal the first time they encountered it. They indicated that more advance publicity on the E/P signal was necessary (1).

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