A Guide of Effective Countermeasures for Low Volume Road Fatalities in the Southeast USA

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Abstract

The largest proportion of fatal crashes in the Southeast USA occur on low-volume roads (LVRs) and many state transportation agencies are implementing countermeasures to reduce these fatality rates. A research effort was undertaken to summarize factors contributing to LVR crashes, identify countermeasures implemented in the Southeast to address them, and determine countermeasure effectiveness. Even though the synthesis only addressed practices used by the 12 Southeast Transportation Consortium (STC) member states, its findings are applicable to all states, since they were based on review of national practices. The research utilized a literature review and web-based survey to develop its findings. Countermeasures were evaluated based on a literature review including examination of manuals and handbooks developed for selecting appropriate treatments, and a survey of state transportation agencies of the STC. The most prominent and effective countermeasures used by a majority of responding agencies include pavement markings (e.g., adding new markings, repainting faded markings, and improving the retro-reflectivity of existing markings), pavement surface treatments (e.g., edge line and centerline rumble strips and high friction surface treatments), widening shoulders and installing horizontal warning signs are regarded as the most effective countermeasures. A stand-alone manual was developed that provides summary sheets for treatments that hold the most promise describing the countermeasure, commenting on their effectiveness, providing installation costs, and identifying crash types they could mitigate.

Keywords: low volume roads; highway safety; countermeasures.

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1. Introduction

Almost 75 percent of the more than four million miles of public roads in the United States are rural roads [1]. A large portion of US roadway system is made up of low-volume roads (LVRs) which carry an annual average daily traffic (AADT) volume of fewer than 2,000 vehicles per day (vpd) [1]. These roads account for approximately 20 percent of the rural National Highway System and over 50 percent of the Federal-Aid System [1]. Despite these roads carrying low-traffic volumes, historical crash data indicate their crash rates are higher than other highways, accounting for half of all fatalities [1]. Typically, LVRs are classified as local roads, and most are located in rural areas. In 2019, the fatality rate on rural roads was 1.66 fatalities per 100 million vehicles miles of travel (MVMT); conversely, for all roads the fatality rate was 1.11 fatalities per 100 MVMT [1]. Zegeer et al. [2] estimated a crash rate of 3.5 per MVMT on LVRs (which they defined as roads with ≤ 2,000 AADT) and a crash rate of 2.4 per MVMT on all high-volume roads.

In 2019, most of the Southeastern Transportation Consortium's (STC's) member states experienced higher fatality rates than the rest of the nation. For example, 732 fatality crashes occurred in Kentucky; 503 took place on rural roads (approximately 69 percent) and in Mississippi, 70 percent of its 643 fatal crashes occurred on rural roads [1]. The lack of traffic data for local roads limits the ability to prioritize safety interventions for LVRs due to the difficulty of estimating exposure. If one considers the percentage of the population that lives in rural areas for the STC states, these fatality rates may point to an even larger problem as they reveal that the percentage of rural highways is disproportionately large compared to rural populations.

To address these safety concerns, a synthesis was undertaken to address these issues aiming to summarize factors which contribute to LVR crashes, identify countermeasures that have been implemented to address LVR safety in the Southeast; and determine how effectively countermeasures address LVR safety.

2. Literature Review

Researchers have sought to determine what features of LVRs contribute to their high crash rates. Roadside features, cross-sectional elements, and geometric design elements significantly influence road safety. With respect to roadside features, culverts, bridges, driveways, trees, ditches, slopes, utility poles, and public broadcast service routing stations can all pose a threat to drivers [3]. Cross-sectional elements that impact road safety include lane width, shoulder type and width, and pavement edge drop off. Hossain [4] argued the higher risk levels and crash rates associated with LVRs may be a product of their substandard geometry. Lane width plays an important role as well. Gross and Jovanis [5] concluded that lane widths between 10 to 11.5 ft. and greater than 13 ft. were less safe than other lane widths (i.e., 12 ft.) for rural two-lane roads including low-volume roads. However, not all agreed that narrow lane widths are the main cause or that increasing lane and shoulder width would address all issues [6, 7]. Some of these factors could be also related to the driver's age. Stamatiadis et al. [8] noted that roads with an AADT less than 2,000 vpd posed a more pronounced risk to younger and middle-aged drivers.

Identifying high-risk road segments and implementing cost-effective safety treatments on LVRs is an enormous challenge for STAs. Researchers have proposed countermeasures to bolster LVR safety. These include widening shoulders and lanes, adding centerline and/or edge line rumble strips, widening centerline and edge line markings, installing additional horizontal alignment signage, remedying shoulder, and side slope deficiencies, relocating objects situated near roads, correcting geometric deficiencies, and installing more visible pavement markings and signage [9,10, 11, 12].

3. Survey Results

A survey to transportation agencies in the STC was administered to solicit information on approaches and countermeasures used to improve LVR safety. The survey sought to recognize the most frequently used approaches and estimate their effectiveness. The findings from the survey, combined with the literature review findings were used to develop a list of countermeasures STAs can use to improve LVR safety.

A 75 percent response rate was achieved (i.e., nine of 12 STC member states) that was considered a representative sample of STC agencies. To alleviate subjectivity of the responses for ranking countermeasures, a verbal description of scores was provided associating the potential scores with expected attributes that defined the scale in a consistent manner for all respondents.

3.1 Countermeasures used and Effectiveness Scores

Respondents were provided with a list of potential countermeasures clustered in seven groups of potential improvements. These groups include: 1. Clear zone improvements, 2. Geometry improvements, 3. Pavement surface treatments, 4. Pavement markings, 5. Sign improvements, 6. Signal improvements, and 7. Other countermeasures. They were asked to rate the countermeasures on a scale from 1 (very effective) to 6 (not effective at all) and these scores were then aggregated to rank the countermeasures and determine their relative importance. These rankings allowed for identifying those countermeasures most frequently employed in the STC and their effectiveness. The highest ranked countermeasures were then used to prepare summary sheets for those treatments. To qualify for development of a summary sheet, treatments had to be used by at least five state agencies and garner a rating 3.0 or less. It should be noted that the scores were calculated based on the number of respondents who evaluated and not on the number of states that indicated that they have used them before. It should be noted that there was no weighing of the responses among the participants. Table 1 presents the highest ranking of the countermeasures considered.

Table 1. Countermeasure attributes summary

Countermeasure	Score/Participants
Add edge line rumble strips	1.14/7
Add high-friction pavement surface	1.29/8
Add pavement markings	1.38/8
Add centerline rumble strips	1.43/7
Install horizontal alignment signs	2.00/9
Widen shoulders	2.11/6
Add pavement markers	2.29/5
Remove/shield fixed objects	2.44/6
Increase clear zone	2.44/5
Re-align roadway segments	2.50/5
Add left-turn lane	2.75/6
Install advanced intersection warning signs	2.77/8
Install retro-reflective strips on signposts	3.00/7

4. Countermeasure Manual

The countermeasures noted in Table 1 were considered in developing summary sheets for use by the agencies. Table 2 presents them ranked by anticipated cost along with other pertinent information. The summary sheets developed describe the treatment, identify its effectiveness, present the crash types addressed by its use, provide a CMF estimate based on the FHWA CMF Clearinghouse [13], and present a generic cost estimate. In addition to the countermeasures identified with low scores and high usage, the addition of left-turn lane at intersections, addition of pavement markers, and installation of rumble strips at intersection or curve approaches were also included in the summaries because of their potential for safety gains and they had a reasonable number of states using them. Moreover, the installation of rumble strips is considered an effective and innovative countermeasure.

Table 2. Countermeasure attributes summary

Countermeasure	Affected Crashes	Cost	Maintenance		Effectiveness	
			Cost	Frequency	CMF	B/C
Install safety edge	Run-off-road Drop off	Low	-	20 years	0.85-0.92	40.9
Add centerline rumble strips	Run-off-road Head-on Sideswipe Adverse weather condition crashes	Low	-	10 years	0.75 to 0.85	26.1
Add edge line rumble strips	Run-off-road Adverse weather crashes	Low	-	10 years	0.78 to 0.90	71.8
Install advanced intersection warning signs	Right angle Rear end Head-on	Low	-	15 years	0.73; 0.425 (rear end)	-
Install horizontal alignment signs	Run-off-road	Low	$1,280	5 years	0.70	43.5
Install retro-reflective strips on sign posts	Run-off-road Right angle Rear end Head-on	Low	-	-	-	-
Install rumble strips for intersection/curve approaches	Run-off-road (for curves) Right angle Rear end Head-on	Low	-	-	0.76 to 0.91	-
Add pavement markers	Run-off-road wet or night conditions	Low-Medium	-	3 years	CMF ≤ 0.76	-
Add pavement markings	Run-off-road Head-on Sideswipe Night crashes	Medium	-	5 years	0.56 -062 (edge line); 0.67 (centerline)	20.2 (centerline and edge line)
Add high-friction pavement surface	Run-off-road wet conditions	High	-	10 years	0.25 to 0.60	4.1
Remove/shield fixed objects	Run-off-road fixed object	High	$7,000	5 years	CMF ≤ 0.71	4.6
Widen shoulders	Run-off-road Sideswipe Head-on	High-Very High	-	-	0.90 - 0.97	-
Add left-turn lane	Head-on Rear end	Very High	$20,000	10 years	-	6.0 (Four-leg); 3.7 (three-leg)
Increase clear zone	Run-off-road fixed object	Very High	-	-	0.78 (3.3 ft to 16.7 ft)	-
Re-align roadway segments	Head-on Sideswipe Rear end Run-off-road	Very High	-	-	Reduce crashes by 28 percent	-

The countermeasures identified here present a mix of low-cost countermeasures that are reasonably effective (CMFs ranging from 0.70 to 0.92) as well as medium-cost treatments (CMFs ranging from 0.56 to 0.76) and high-cost countermeasures (CMFs ranging from 0.25 to 0.71. Each type targets a different set of crashes, and its effectiveness is proportional to the investment. A set of very expensive countermeasures is also provided that would typically require major reconstruction or potentially acquiring additional right of way. Survey respondents tended to view them as less effective, but the expense for their implementation may not have allowed for fully understanding their effectiveness. It is therefore possible that these treatments may be more effective at reducing crash severity, although further research is needed.

5. Conclusions

This research aimed at developing a tool for transportation agencies to address the challenge of implementing cost-efficient safety treatments on LVRs to address high crash locations. Through a combination of literature review and agency survey, the research team identified promising countermeasures that could be used to address safety in LVRs. Most researchers and practitioners note the importance of understanding of the issues to be addressed, i.e., crash types and severity, before determining which countermeasure(s) is optimal. The research team developed summary sheets for each countermeasure that agencies in the Southeast currently in use to bolster LVR safety (Figure 1). As Table 2 indicates, most of the countermeasures are inexpensive and can be used as either a spot treatment or more systemically.

INSTALL SAFETY EDGE

DESCRIPTION

"A safety edge is a treatment intended to minimize drop-off-related crashes. With this treatment, the pavement edge is sloped at an angle (30-35 degrees) to make it easier for a driver to safely reenter the roadway after inadvertently driving onto the shoulder. This treatment is designed to be a standard policy for any overlay project." [1]

IMPLEMENTATION

This treatment frequently aims to allow for safe correction of vehicles that have left the traveled way and encounter a pavement-shoulder drop-off [1]. The safety edge is typically implemented on the entire length of a project where frequent edge drop-offs occur, particularly on rural roads with unpaved shoulders [1]. Iowa first used the safety edge in 2008 along a county road in Clinton County. In 2010, Iowa DOT adopted the safety edge as a Standard Practice for construction and rehabilitation projects [2].

CRASHES AFFECTED

Run-off-road and drop-off related crashes

EFFECTIVENESS

The benefit-cost ratio for installing a safety edge on a road with lower volume narrower conditions is 40.9 [1]. Safety edge treatments appear to have a small positive crash reduction effect with the best effectiveness measure for rural two-lane highways having a CRF of 5.7 [3].

COST

Low; Initial investment: $2,145 per mile; Cost of maintenance: N/A; Frequency of maintenance: 20 years

SOURCES

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Figure 1. Example of summary sheets

An issue meriting further investigation is the application of multiple countermeasures; an issue to be addressed in future revisions of the Highway Safety Manual. The influence of countermeasures on crash severity is another understudied topic of interest. Acquiring more data to look at these issues will help researchers make more accurate determinations of countermeasure effectiveness.

Even though this effort developed the summary sheets based on input from STC agencies, the manual can be used by other agencies throughout the USA and the world and provide them with a starting point to identify countermeasures to achieve their targeted safety outcomes. In addition, future research could focus on further evaluating the performance of countermeasures on LVRs in the Southeast, evaluating the performance of multiple countermeasures used in combination, and evaluating how the performance of countermeasures adopted systemically differs from spot applications.

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