TECHBRIEF

Safety Evaluation of Cable Median Barriers in Combination with Rumble Strips on the Inside Shoulder of Divided Roads

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This document is a technical summary of the Federal Highway Administration (FHWA) report *Safety Evaluation of Cable Median Barriers in Combination with Rumble Strips on the Inside Shoulder of Divided Roads* (FHWA-HRT-17-070).

Objective

FHWA established the Development of Crash Modification Factors (DCMF) program in 2012 to address highway safety research needs for evaluating new and innovative safety strategies (improvements) by developing reliable quantitative estimates of their effectiveness in reducing crashes. The ultimate goal of the DCMF program is to save lives by identifying new safety strategies that effectively reduce crashes and promote those strategies for nationwide implementation by providing measures of their safety effectiveness and benefit-to-cost (B/C) ratios through research. State transportation departments and other transportation agencies need to have objective measures for safety effectiveness and B/C ratios before investing in broad applications of new strategies for safety improvements. Forty State transportation departments provided technical feedback on safety improvements to the DCMF program and implemented new safety improvements to facilitate evaluations. These States are members of the Evaluation of Low-Cost Safety Improvements Pooled Fund Study, which functions under

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the DCMF program. This study evaluated the application of cable median barriers in combination with rumble strips on the inside shoulder of divided roads. This strategy was intended to reduce the frequency of crashes by reducing the frequency and severity of cross-median crashes. Many studies have explored the safety effectiveness of cable median barrier or shoulder rumble strips; however, no study has conducted a rigorous evaluation of the effectiveness of the two strategies in combination. This study sought to fill this knowledge gap.

Introduction

Roadway or lane departure is an emphasis area in every State's strategic highway safety plan. One of the most severe and high-profile types of roadway departure crashes is cross-median crashes on divided roads. Proven, cost-effective strategies to reduce the frequency and severity of these crashes are necessary to address this problem. Many agencies have installed widespread shoulder rumble strips to reduce the frequency of run-off-road crashes and rigid or cable median barriers to prevent errant vehicles from crossing over the median into oncoming traffic.

States cite many reasons why cable barriers are becoming more favorable, including the following:

- Cable barriers contain vehicles in the median instead of redirecting them back into traffic.
- Typical installation and maintenance costs are lower than rigid barriers, although they may require more frequent maintenance and can sustain damage from snow plows.
- Snow can move through cable barriers more easily, preventing accumulation.
- Cable barriers are environmentally non-intrusive and more aesthetically pleasing.

There are also concerns about cable barriers being susceptible to penetration and hits by heavier vehicles. In addition, several studies indicate an increase in total crash frequency after installation of cable median barriers.

A literature review focused on the safety effects of cable median barriers, shoulder rumble strips, and cable median barriers alongside shoulder rumble strips. Studies have shown cable median barriers to reduce cross-median fatalities crashes by 92 percent, head-on fatal crashes by 93 percent, and multiple vehicle opposite direction crashes by 94 percent. However, studies also show them generally increasing run-off-road-left, single-vehicle, fixed-object, rear-end, and total crashes.[(1–3)] Studies have also widely shown that shoulder rumble strips reduce total, injury, single-vehicle run-off-road, and fixed-object crashes. Torbic et al. found an 11-percent reduction in single-vehicle run-off-road crashes and a 16-percent reduction in single-vehicle run-off-road crashes resulting in fatalities or injuries.[(4)] Monsere et al. examined the combined effects of cable median barriers and shoulder rumble strips using a simple before-after study. The researchers found a 100-percent reduction (i.e. from 3 to 0) in cross-median fatal and serious injury crashes across three-year before and after periods. The researchers compared this to an increase in overall barrier hits from 7 to 60 during the same timeframe; however, maintenance logs did not specify which barrier (i.e. on the left or right side of the road) was hit.[5]

Methodology

This study examined the safety impacts of cable median barriers with inside shoulder rumble strips in Illinois, Kentucky, and Missouri on cross-median crash frequency. This study also evaluated the effects on total crashes and all fatal and injury crashes. Data collection and sample size limitations prevented separate evaluations of median-related, run-off-road-left, and winter-related crashes.

The treatment itself is not exactly the same in the three States used in this evaluation. In Illinois and Kentucky, the introduction of cable median barriers came many years after the introduction of rumble strips on inside shoulders. The before condition for these two States included shoulder rumble strips. Conversely, Missouri installed cable median barriers and inside shoulder rumble strips around the same time. This study combined and evaluated Illinois and Kentucky separately from Missouri. Across all three States, the study used a total of 455 mi of treatment sites and more than 700 mi of reference sites in the evaluation.

The evaluation made use of the empirical Bayes (EB) methodology for observational before-after studies.[6] This methodology is considered rigorous in that it accounts for regression-to-the-mean using a reference group of similar, but untreated, sites.

In the process, the use of safety performance functions (SPFs) addresses the following:

- Overcoming the difficulties of using crash rates in normalizing for volume differences between the before and after periods.
- Accounting for time trends.
- Reducing the level of uncertainty in the estimates of safety effect.
- Properly accounting for differences in crash experience and reporting practice in amalgamating data and results from diverse jurisdictions.
- Providing a foundation for developing guidelines for estimating the likely safety consequences of a contemplated strategy.

The project team estimated the SPFs used in the EB methodology through generalized linear modeling assuming a negative binomial error distribution, which is consistent with the state of research in developing these models. In specifying a negative binomial error structure, the project team estimated an overdispersion parameter based on segment length from the model and the data. For a given dataset, smaller values of this parameter indicate relatively better models.

When the data did not specify cross-median crash type, the project team used proxy crash types. In the Illinois and Kentucky analysis, the project team used head-on crashes plus opposite-direction-sideswipe crashes. The Missouri analysis used the cross-median crash indicator plus head-on crashes.

The full report includes a detailed explanation of the methodology and the development of SPFs, including a description of how the estimate of safety effects for target crashes were calculated.

Results

This brief presents the research results in two parts. The first part contains aggregate results. The second part is based on a disaggregate analysis that sought to identify the optimal conditions for installation of the treatment.

Aggregate Analysis

Table 1 and table 2 show the aggregate results for Illinois and Kentucky combined and Missouri, respectively. Both tables represent urban and rural sites together. For all crash types, the tables provide the estimates of expected crashes in the after period without treatment, the observed crashes in the after period, the estimated crash modification factor (CMF), and the standard error of the CMF. Fatal and injury crashes were defined as KAB or KABC.[1]

The results indicate statistically significant crash reductions at the 95-percent confidence level for all crash types analyzed in all States. The crash type with the smallest CMF, which marks the greatest reduction in crashes, is the cross-median CMF. This is consistent in Illinois and Kentucky combined and in Missouri. The evaluation yielded an estimated CMF of 1.267 for total crashes in Illinois and Kentucky and 1.247 in Missouri.

Table 1. CMFs from urban and rural sites in Illinois and Kentucky combined.

Crash Type	EB Estimate of Crashes Predicted in the After Period Without Strategy	Count of Crashes Observed in the After Period	CMF	Standard Error
Total	3,319.37	4,208	1.267*	0.026
Injury and fatal (KABC)	1,064.22	811	0.762*	0.033
Injury and fatal (KAB)	746.43	584	0.782*	0.039
Cross-median	59.63	31	0.518*	0.097

*Indicates CMF estimates that are statistically significant at the 95-percent confidence level.

[1] The KABCO scale is used to represent injury severity in crash reporting (K is fatal injury, A is incapacitating injury, B is non-incapacitating injury, C is possible injury, and O is property damage only).

Table 2. CMFs from urban and rural sites in Missouri.

Crash Type	EB Estimate of Crashes Predicted in the After Period Without Strategy	Count of Crashes Observed in the After Period	CMF	Standard Error
Total	1,781.03	2,221	1.247*	0.034
Injury and fatal (KABC)	589.10	439	0.745*	0.040
Injury and fatal (KAB)	170.96	134	0.783*	0.073
Cross-median indicator	24.35	1	0.041*	0.041
Cross-median indicator + head-on	41.92	5	0.119*	0.053

* Indicates CMF estimates that are statistically significant at the 95-percent confidence level.

Disaggregate Analysis

The disaggregate analysis examined the before-period EB predicted crash frequency, median width, speed limit, and annual average daily traffic to identify the conditions under which the treatment was most effective. The project team did not identify any patterns, which was possibly because of the limited sample of cross-median crashes.

Economic Analysis

Because cable median barriers resulted in an increase in total crashes and a reduction in injury and fatal crashes, implying an increase in property-damage-only (PDO) crashes, it was necessary to estimate the change in PDO crashes to determine accurate results. The project team calculated PDO crashes by subtracting KABC crashes from total crashes for the EB predicted crashes in the after period and the actual crashes in the after period.

Using the number of mile-years in the after period, the project team determined the change in PDO crashes per mile-year and the change in KABC crashes per mile-year. KABC crashes decreased by 0.53/mi-year in Illinois and Kentucky and 0.18/mi-year in Missouri. PDO crashes increased 2.38/mi-year in Illinois and Kentucky and 0.72/mi-year in Missouri.

This study used comprehensive crash cost estimates for KABC and PDO crashes from the recent report by Persaud (updated from an earlier report by Council et al.) to estimate the annual economic benefits.[7,8] A KABC crash was assumed to cost $498,579, and the cost of a PDO crash was $18,877. Using these numbers, the safety benefit per mile-year was $217,725 in Illinois and Kentucky and $77,917 in Missouri.

Persaud refers to a June 2013 United States Department of Transportation (USDOT) memo that prescribes sensitivity analysis based on low and high values of crash costs.[7,9] Specifically, the USDOT memo suggests that sensitivity analysis should be done by estimating B/C ratios for 0.57 and 1.41 times the 2014 crash costs.[9]

The research team estimated the annualized cost of the treatment, as shown in figure 1.

Figure 1. Determining annual cost.

$$Annual\ Cost = \frac{C * R}{1-(1+R)^{-N}}$$

C = Treatment cost.

R = Discount rate (as a decimal) and assumed to be 0.07.

N = Expected service life (years).

The annualized treatment cost per mile is $26,286 in Illinois and Kentucky and $18,810 in Missouri.

The B/C ratio was calculated as the ratio of the annual crash savings to the annualized treatment cost. The resulting B/C ratio is 8.28 for Illinois and Kentucky and 4.14 for Missouri. A sensitivity analysis indicated the B/C ratio for Illinois and Kentucky could range from 4.72 to 11.68, and the B/C ratio for Missouri could range from 2.36 to 5.84.

Summary and Conclusions

The objective of this study was to undertake a rigorous before-after evaluation of the safety effectiveness of cable median barriers in combination with inside shoulder rumble strips along divided roads. The study used data from three States—Illinois, Kentucky, and Missouri—to examine the effects for specific crash types, including total, fatal and injury (KABC and KAB), and cross-median crashes. This study did not include crashes occurring at or related to an intersection and animal-related crashes.

In Illinois and Kentucky, inside shoulder rumble strips were present prior to the implementation of cable barriers. As a result, the evaluation in Illinois and Kentucky determined the safety effect of adding cable barriers on divided roads where inside shoulder rumble strips were already present. On the other hand, Missouri installed inside shoulder rumble strips and cable barriers around the same time (or within a few years of each other). The evaluation in Missouri determined the combined safety effect of cable barriers and inside shoulder rumble strips. Therefore, for the purpose of this evaluation, the treatment in Missouri is different from the treatment in Illinois and Kentucky. A disaggregate analysis of the results did not reveal any specific patterns, possibly because of the limited sample of cross-median crashes.

Table 3 provides the recommended CMFs when the before condition includes inside shoulder rumble strips. The average B/C ratio for this treatment is 8.28.

Table 4 provides the recommended CMFs when the before condition has neither inside shoulder rumble strips nor cable median barriers. The average B/C ratio for the combined treatment is 4.14.

Table 3. CMFs for combination of cable median barriers and rumble strips when before condition includes inside shoulder rumble strips.

Crash Type	CMF	Standard Error
Total	1.267	0.026
Injury and fatal (KABC)	0.762	0.033
Injury and fatal (KAB)	0.782	0.039
Head-on plus opposite-direction-sideswipe (proxy for cross-median crashes)	0.518	0.097

Table 4. CMFs for combination of cable median barriers and rumble strips when before condition has neither inside shoulder rumble strips nor cable median barrier.

Crash Type	CMF	Standard Error
Total	1.247	0.034
Injury and fatal (KABC)	0.745	0.040
Injury and fatal (KAB)	0.783	0.073
Cross-median (cross-median indicator plus head-on)	0.119	0.053

The results indicate an overall increase in crashes, with nearly 50-percent reduction in cross-median crashes where inside shoulder rumble strips were already present a nearly 90-percent reduction in cross-median crashes when a State installed cable median barrier and shoulder rumble strips together. This is generally consistent with prior research evaluating the installation of cable median barriers.

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