TECH**BRIEF**

Safety Evaluation of Profiled Thermoplastic Pavement Markings

FHWA Publication No.: FHWA-HRT-17-076

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This document is a technical summary of the Federal Highway Administration report *Safety Evaluation of Profiled Thermoplastic Pavement Markings* (FHWA-HRT-17-076).

Objective

The Federal Highway Administration (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 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 provide technical feedback on safety improvements to the DCMF program and implement new safety improvements to facilitate evaluations. These States are members of the Evaluation of Low-Cost Safety Improvements Pooled Fund Study, which functions under the DCMF program. This study evaluated the application of profiled thermoplastic pavement markings. This strategy involves upgrading existing markings from flat-line thermoplastic or other standard markings to the profiled product. These markings are designed to provide an improved level of vision to drivers, particularly during wet-road surface conditions. The profiled nature also provides a rumble effect for

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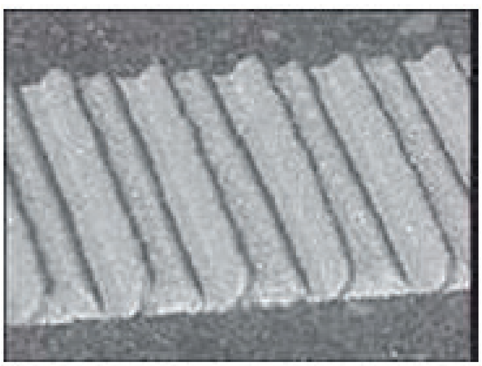
errant vehicles. There are two types of profiled markings—raised and inverted profile patterns—as shown in figure 1 and figure 2.

Figure 1. Photo. Raised profiled thermoplastic marking.[1]

Figure 2. Photo. Inverted profiled thermoplastic marking.[1]



Introduction

This research examined the safety impacts of profiled thermoplastic pavement markings in Florida and South Carolina. The States applied the markings only on edge lines and mostly on rural, two-lane undivided roads, with some use on rural, multilane divided roadways.

A literature review found no published research evaluating the effect of profiled thermoplastic pavement markings on crashes after the application. According to FHWA, several agencies have used the treatment with good results, but none have conducted a safety effectiveness evaluation.[1]

Methodology

The objective of this study was to estimate the safety effectiveness of this strategy as measured by crash frequency. This study excluded intersection-related, snow/slush/ice, and animal crashes. The study considered the following target crash types:

- Total crashes (all types and severities combined).
- Fatal and injury crashes (K, A, B, and C injuries on the KABCO scale) (K is fatal injury, A is incapacitating injury, B is non-incapacitating injury, C is possible injury, and O is property damage only).
- Run-off-road crashes (all severities combined).
- Head-on crashes (all severities combined).
- Sideswipe-opposite-direction crashes (all severities combined).
- Sideswipe-same-direction crashes (all severities combined).
- Wet-road crashes (all types and severities combined).
- Nighttime crashes (all types and severities combined).
- Nighttime wet-road crashes (all types and severities combined).

A further objective was to conduct a disaggregate analysis to investigate whether the safety effects vary by factors such as the level of traffic volume, the frequency of crashes before treatment, roadway type, posted speed limit, lane width, and shoulder width.

The evaluation of overall effectiveness included the consideration of the installation costs and crash savings in terms of the B/C ratio.

The project team used the empirical Bayesian (EB) methodology for observational before–after studies for this evaluation.[2] 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 project team applied safety performance functions (SPFs). SPFs are equations that serve to estimate the expected crash frequency of a site based on characteristics that influence crashes (e.g., traffic volumes). The use of SPFs in the EB methodology was found to have the following advantages:

- Overcomes the difficulties of using crash rates in normalizing for volume differences between the before and after periods.
- Accounts for time trends.
- Reduces the level of uncertainty in the estimates of safety effect.
- Properly accounts for differences in crash experience and reporting practice in amalgamating data and results from diverse jurisdictions.

The methodology also provides 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 iteratively estimated an overdispersion parameter, which is used in the EB calculations, from the model and the data. For a given dataset, smaller values of this parameter indicate relatively better models.

The full report contains a detailed explanation of the methodology, including a description of how the project team calculated the estimate of safety effects for target crashes.

Results

The results are presented in two parts. The first part contains aggregate results, and the second part discusses a disaggregate analysis that attempted to discern factors that may be most favorable to the installation of profiled thermoplastic pavement markings.

Aggregate Analysis

Table 1 and table 2 detail the results for each State. This includes the estimates of predicted crashes in the after period without treatment, the observed crashes in the after period, and the estimated crash modification factor (CMF) and its standard error for all crash types considered.

The results were consistent between the two States in that no CMF results were statistically significantly different from 1.0. Results for both States also indicated a modest reduction in total crashes and a reduction in nighttime wet-road crashes of approximately 10 percent, although these were not statistically significant at the 95-percent confidence level.

Table 3 provides the results for the combined South Carolina and Florida data for the crash types analyzed in both States. Even with the combined data, none of the estimated CMFs were statistically significant at the 95-percent confidence level.

Table 1. Results for South Carolina.

Crash Type	EB Estimate of Crashes Predicted in After Period Without Strategy	Count of Crashes Observed in After Period	Estimate of CMF	Standard Error of Estimate of CMF
Total	789.81	779	0.986	0.041
Fatal and injury	312.59	281	0.898	0.060
Run-off-road	254.45	292	1.146	0.078
Head-on and sideswipe-opposite-direction	49.09	44	0.894	0.143
Sideswipe-same-direction	35.57	36	1.009	0.177
Wet-road	152.73	157	1.027	0.089
Nighttime	281.57	261	0.926	0.064
Nighttime wet-road	60.76	55	0.903	0.131

Table 2. Results for Florida.

Crash Type	EB Estimate of Crashes Predicted in After Period Without Strategy	Count of Crashes Observed in After Period	Estimate of CMF	Standard Error of Estimate of CMF
Total	1,136.28	1,085	0.954	0.035
Fatal and injury	582.48	590	1.012	0.049
Run-off-road	182.59	172	0.941	0.080
Head-on	19.47	24	1.229	0.259
Wet-road	204.13	201	0.983	0.078
Nighttime	348.31	352	1.010	0.062
Nighttime wet-road	63.52	58	0.910	0.129

lines as measured by crash frequency. The study used data from two-lane and multilane roads in two States—Florida and South Carolina—to examine the effects for specific crash types, including total, fatal and injury, run-off-road, head-on, sideswipe-opposite-direction, sideswipe-same-direction, wet-road, nighttime, and nighttime wet-road crashes. Only nighttime wet-road crashes, the principal target crash type, experienced a material change in yielding a CMF of 0.908, which was not unexpected, because this was the primary target crash type. Although the project team based the estimated CMF on a small sample of crashes and it was not statistically significant at the 95-percent confidence level, it was consistent between the two States, which suggests its use may be justifiable.

Based on the consistent reduction in nighttime wet-road crashes, and estimated with conservative cost and service life assumptions, the B/C ratio relative to flat-line thermoplastic markings was 3.65:1. Applying the sensitivity analysis recommended by the USDOT, this value could range from 2.01:1 to 5.04:1. These results suggest that the treatment—even with conservative assumptions on cost, service life, and the value of a statistical life—can be applied cost effectively despite the relatively low crash effects.

With additional data, future research may provide statistically significant results for those crash types for which a CMF could not be recommended or was statistically insignificant and provide more informative analyses to develop disaggregate CMFs that reflect different application circumstances.

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Key Words—Profiled thermoplastic pavement markings, low-cost, safety improvements, safety evaluations, empirical Bayesian.

DECEMBER 2017

FHWA HRT 17 076
HRDS-20/12-17(200)E