TECH**BRIEF**

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Safety Evaluation of STOP AHEAD Pavement Markings

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This document is a technical summary of the Federal Highway Administration report, *Safety Evaluation of STOP AHEAD Pavement Markings.*

Objective

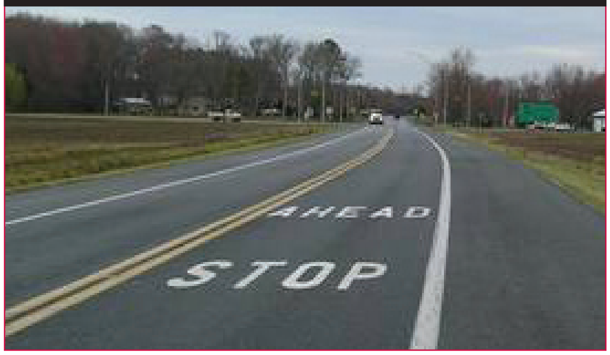
The Federal Highway Administration (FHWA) organized 26 States to participate in the FHWA Low-Cost Safety Improvements Pooled Fund Study as part of its strategic highway safety plan support effort. The purpose of the study is to evaluate the safety effectiveness of several low-cost safety improvement strategies through scientifically rigorous crash-based studies. One of the strategies evaluated for this study was STOP AHEAD pavement markings. STOP AHEAD pavement markings are intended to reduce the frequency of crashes related to lack of driver awareness of stop control at unsignalized intersections. The safety effectiveness of this strategy had not previously been thoroughly documented; therefore, this study attempts to provide an evaluation of STOP AHEAD pavement markings through scientifically rigorous procedures.

Introduction

Intersections account for a small portion of the total highway system, yet in 2005, approximately 2.5 million intersection-related crashes occurred. This number represents 41 percent of all reported crashes. In addition, 8,655 fatal crashes (22 percent of the total 39,189 fatal crashes) occurred at or within an intersection environment in 2005.[1]

Driver compliance with intersection traffic control is vital to intersection safety. Many unsignalized intersections may be unexpected or may not be visible to approaching drivers. Therefore, enhancing the visibility and conspicuity of unsignalized intersections has the potential to reduce the number of crashes associated with drivers' lack of awareness of such intersections. Providing pavement markings with supplementary messages (such as STOP AHEAD) can help alert drivers on the stop-controlled approach to the presence of an intersection. An example of a STOP AHEAD pavement marking is shown in figure 1.

Figure 1. Example of a Rural STOP AHEAD Installation.



A literature review did not uncover any studies related to the safety or operational effectiveness of STOP AHEAD pavement markings. Several studies have investigated STOP AHEAD signs, but these studies focused on operational effectiveness. One study investigated STOP AHEAD signs as a means of warning drivers of an upcoming, unexpected, and partially concealed stop-controlled intersection during daytime and nighttime driving conditions.[2] The study concluded that STOP AHEAD signs do not provide adequate visual stimulus; STOP AHEAD pavement markings may provide better visual stimulus to the driver due to the size and placement of the message. It is clear that a thorough investigation is needed to evaluate the safety effectiveness of STOP AHEAD pavement markings for different configurations of unsignalized intersections.

Methodology

Two States, Arkansas and Maryland, installed STOP AHEAD pavement markings at spot locations. Two counties in Minnesota implemented this pavement marking strategy as a blanketed effort (i.e., they were installed at all two-way stop-controlled intersections within the jurisdiction). Data were obtained from 8 sites in Arkansas, 9 sites in Maryland, and 158 sites in Minnesota. Data collected included the location and date of installation as well as the relevant geometric, traffic, and crash data. The analysis included a total of 1,669 intersection-years of data (69 intersection-years from Arkansas, 59 intersection-years from Maryland, and 1,541 intersection-years from Minnesota).

Empirical Bayes (EB) methods were incorporated in a before-after analysis to determine the safety effectiveness of STOP AHEAD pavement markings. The EB methodology for observational before-after studies[3] was used for the evaluation.

Safety performance functions (SPFs) were calibrated separately for each State for use in the EB methodology. Generalized linear modeling was used to estimate the model coefficients using the software package STATA®,[4] assuming a negative binomial error distribution which is consistent with the state of research in developing these models.

SPFs were estimated for the following crash classifications:

- Total (all severities and crash types combined).
- Injury (all crash types combined).
- Right-angle (all severities combined).
- Rear-end (all severities combined).

The full report includes a detailed explanation of the methodology, including a description of how the estimate of percent reduction is calculated.

Results

Two sets of results were calculated. One set contains aggregate results for Arkansas and Maryland combined, as well as for each State individually. The other set is based on a disaggregate analysis that attempts to discern factors that may be most favorable to installing STOP AHEAD pavement markings. The aggregate analysis provides evidence for the general effectiveness of the strategy while the disaggregate analysis provides insight on the situations where the strategy may be most effective or most favorable (e.g., number of approaches, type of stop control, etc.). The Minnesota results are not combined with the other two States because crash rates at the STOP AHEAD sites are relatively low in that State and the installations were blanketed.

Aggregate Analysis

The aggregate results, shown in table 1, indicate a statistically significant reduction in total crashes in both Arkansas and Maryland, and overall for the two States combined. For both right-angle and rear-end crashes, the only significant change for the two primary States was in Arkansas, for which the decreases in crashes were statistically significant at the 95-percent confidence level for both crash types. For injury crashes, the crash reduction for the two States combined is statistically significant at the 90-percent confidence level. The results from Minnesota were not included in the combined model but support the conclusion from the evaluation of the other two States' implementations that this strategy is effective for reducing crashes. Please note the large standard errors in the Minnesota results.

Disaggregate Analysis

A disaggregate analysis of the Maryland and Arkansas sites was completed to determine if safety effects are more or less pronounced for specific conditions. Table 2 presents the results of the disaggregate analysis. The results of the disaggregate analysis are based on injury crashes and all crashes combined.

A disaggregate analysis could not be completed for area type (i.e., urban versus rural) because there were only two sites located in urban areas out of the 17 total sites. Thus, the results apply in general to rural sites, although the analysis was based on all 17 sites. The results are as follows:

- Installations at three-legged intersections are more effective than at four-legged intersections for injury and total crashes. For total crashes, the reductions for both three- and four-legged intersections are highly significant as is the difference in effects.

Table 1. Aggregate Analysis Results.

Jurisdiction by Crash Type	Sites	EB estimate of crashes expected in after period without strategy	Crash count observed in after period	Percent Reduction (S.E.)
Combined—Right-Angle (AR and MD)	17	48.7	51	-3.6% (18.1)
Combined—Rear-End (AR and MD)	17	29	21	29.0% (18.0)
Combined—Injury (AR and MD)	17	81	64	21.6% (12.0)
Combined—Total (AR and MD)	17	166.1	115	**31.1% (8.0)**
Arkansas—Right-Angle	8	22.1	13	**42.1% (17.5)**
Arkansas—Rear-End	8	10	1	**90.3% (9.5)**
Arkansas—Injury	8	25.9	18	31.7% (18.1)
Arkansas—Total	8	47.7	23	**52.3% (10.8)**
Maryland—Right-Angle	9	26.6	38	-39.0% (31.1)
Maryland—Rear-End	9	19	20	-1.6% (28.7)
Maryland—Injury	9	55.1	46	17.6% (15.4)
Maryland—Total	9	118.3	92	**22.9% (10.5)**
Minnesota—Right-Angle	158	6	2	**66.9% (23.4)**
Minnesota—Rear-End	158	3.1	1	**67.9% (32.1)**
Minnesota—Injury	158	11.2	2	**82.2% (12.6)**
Minnesota—Total	158	18.2	12	34.1% (19.3)

NOTE: Negative sign indicates an increase in crashes. Bold denotes statistically significant results at the 95% confidence level.

Crash Type	Intersection Type	Sites	EB estimate of crashes expected in the after period without strategy	Count of crashes observed in the after period	Estimate of percent reduction (S.E.)
Injury Crashes	Three-legged	5	19.3	9	**54.7% (16.4)**
	Four-legged	12	61.7	55	11.9% (15.0)
	AWSC	7	34.0	20	**42.3% (14.9)**
	OWSC/TWSC	10	47.0	44	7.7% (17.5)
Total Crashes	Three-legged	5	37.0	15	**60.1% (11.2)**
	Four-legged	12	129.1	100	**23.0% (9.9)**
	AWSC	7	71.7	32	**55.9% (9.1)**
	OWSC/TWSC	10	94.4	83	12.8% (12.2)

Table 2. Disaggregate Analysis Results.

NOTE: Bold denotes statistically significant results at the 95% confidence level.

- There appears to be a difference between sites with all-way stop-control (AWSC) and those with one-way stop-control (OWSC) or two-way stop-control (TWSC). One-way stop-control corresponds to three-legged intersections where the stop-control is installed only on the minor approach. The results indicate that there is a reduction in total and injury crashes at both types of locations; however, the reductions are highly significant and relatively larger at AWSC intersections.
- There is a significant reduction in crashes for lower values of annual average daily traffic (AADT). The magnitude of the reduction appears to decrease and becomes insignificant as AADT values increase; however, these indications are too weak to support a definitive conclusion on the impact of AADT.

Further investigation was undertaken to ensure that the effects were not due to biases in the analysis.

There are advantages and disadvantages to applying the results from the disaggregate analysis. The disaggregate analysis can shed light on specific conditions where strategies may be most effective; however, disaggregate analyses are, by nature, based on smaller sample sizes than aggregate analyses. Smaller samples lead to larger confidence intervals and less precise results. In the case of the STOP AHEAD analysis, the aggregate analysis provides support for the use of this strategy (i.e., STOP AHEAD pavement markings are associated with a general reduction in crashes). The disaggregate analysis indicates specific conditions that should be given priority due to the relative effectiveness of this strategy (three-legged and AWSC locations).

Economic Analysis

An economic analysis was completed to evaluate the economic feasibility of STOP AHEAD pavement markings. An estimate of the life cycle costs of the strategy was first developed and expressed as an annual cost. The crash benefits required to offset these costs were then estimated using the most recent FHWA unit crash cost data for unsignalized intersections.

Installation and maintenance cost data provided by the two States suggests a conservatively high annual cost of $78 per approach for latex material and $366 per approach for thermoplastic material installations. This requires a $156 and $732 annual savings in crash costs per latex and thermoplastic installation, respectively, to achieve a 2:1 benefit-cost ratio. The results indicate significant reductions in total crashes, and the remainder of the economic analysis is based on total crashes; therefore, an undefined crash was used to reflect the cost of total crashes.

The most recent FHWA mean comprehensive costs per undefined crash for unsignalized intersections is $55,060, based on 2001 dollar values.[5] Comprehensive crash costs represent the present value, computed at a discount rate, of all costs over the victim's expected life span that result from a crash. The major categories of costs used in the calculation of comprehensive crash costs include medical-related costs, emergency services, property damage, lost productivity, and monetized quality-adjusted life years.[5]

The necessary savings to achieve a 2:1 benefit-cost ratio would require a reduction in total crashes of 0.006 crashes per intersection-year for the latex application, assuming TWSC with installations on two approaches. The corresponding number for the thermoplastic application is 0.027 crashes per intersection-year, assuming a TWSC installation. The necessary reductions per intersection-year would, however, change for an AWSC intersection. The necessary savings would require a reduction of 0.011 total crashes per intersection-year for the latex application while thermoplastic installations would require a reduction of 0.053 crashes per intersection-year. Based on the aggregate and disaggregate results, the necessary reductions are easily achievable; however, the benefits will be less pronounced for intersections with relatively low crash rates. While there is a realized benefit after installing STOP AHEAD pavement markings, a reduction of 0.05 crashes per intersection-year is not possible to achieve a 2:1 benefit-cost ratio for thermoplastic installations at AWSC locations.

Summary

The results of the aggregate analysis indicate a statistically significant reduction in total crashes for Arkansas, Maryland, and overall for the two States combined. For both right-angle and rear-end crashes, the only significant change for the two States is in Arkansas, for which there is a statistically significant reduction in both crash types at the 95-percent confidence level. The aggregate analysis in Arkansas and Maryland indicates that STOP AHEAD pavement markings may significantly reduce total crashes at unsignalized intersections. The results for Minnesota support the conclusion from the evaluation of the other two States' implementations that this strategy is effective for reducing crashes.

The disaggregate analysis provided further insight into the circumstances where crash reductions were identified. Installations at three-legged intersections were found to be more effective than at four-legged intersections. The analysis also indicates a highly significant reduction in injury and total crashes for AWSC intersections. The effectiveness of STOP AHEAD pavement markings also appeared to vary by AADT, but these indications are based on too small of a sample size to support a definitive conclusion on the impact of AADT.

Conclusion

A reduction in crashes can be expected with the installation of STOP AHEAD pavement markings. The results are consistent between Arkansas and Maryland, which are combined in the main analysis. Minnesota was not included in the main analysis because of the relatively low crash rates at the STOP AHEAD sites; however, the results support those from Arkansas and Maryland.

The aggregate analysis supports the conclusion that a total crash reduction of at least 15 percent can be expected with the installation of STOP AHEAD pavement markings as presented in table 3. It is likely that STOP AHEAD pavement markings will be most effective at locations with a high frequency of target collisions (i.e., right-

Table 3. Expected Crash Reductions for Installations of STOP AHEAD Pavement Markings.

Crash Type	Point Estimate	Standard Error	Conservative Estimate[1]
Total Crashes	31.1%	8.0	**15.4%**

[1] The conservative estimates are based on the lower 95% confidence interval and are calculated as the point estimate minus 1.96 times the standard error.
Note: Bold numbers indicate statistically significant results at the 95% confidence level.

angle and rear-end), particularly where driver awareness may be an issue. The disaggregate analysis supports that the reduction may not be consistent across intersection types and provides evidence for those locations where this strategy may be most effective. Given the low-cost of this strategy, even with conservative assumptions, a modest reduction in crashes is needed to justify their use. Based on the evidence provided by the estimated safety effectiveness of STOP AHEAD pavement markings, the necessary reduction to obtain a 2:1 benefit-cost ratio is easily achieved. Therefore, this strategy has the potential to reduce crashes cost-effectively, particularly at three-legged and AWSC intersections with a high-crash frequency.

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Safety Evaluation of Increasing Retroreflectivity of STOP Signs

FHWA Publication No.: FHWA-HRT-08-047

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This document is a technical summary of the Federal Highway Administration report, *Safety Evaluation of Increasing Retroreflectivity of STOP Signs.*

Objective

The Federal Highway Administration (FHWA) organized 26 States to participate in the FHWA Low-Cost Safety Improvements Pooled Fund Study to evaluate low-cost safety strategies as part of its strategic highway safety plan support effort. The purpose of the study is to evaluate the safety effectiveness of several low-cost safety improvement strategies through scientifically rigorous crash-based studies. STOP signs with higher retroreflectivity strategy was one of the strategies evaluated for this study. This strategy is intended to reduce the frequency of crashes related to driver unawareness of stop control at unsignalized intersections. The safety effectiveness of this strategy had not been thoroughly documented previously; therefore, this study is an attempt to provide an evaluation through scientifically rigorous procedures.

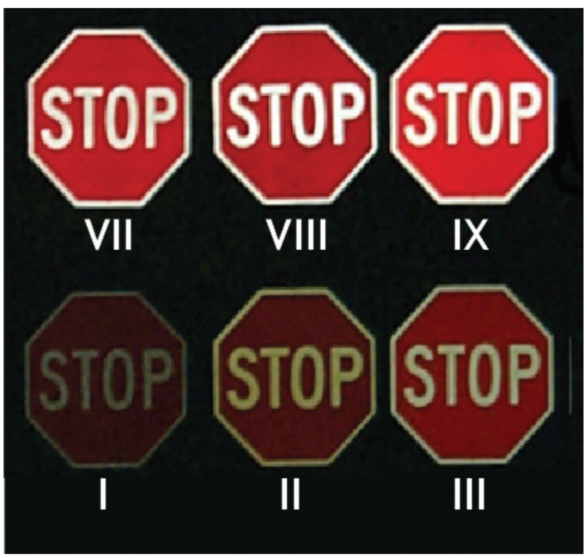
Introduction

Intersections account for a small portion of the total highway system, yet in 2005, approximately 2.5 million intersection-related crashes occurred. This represents 41 percent of all reported crashes. In addition, 8,655 fatal crashes (22 percent of the total 39,189 fatal crashes) occurred at or within an intersection environment in 2005.[1]

Driver compliance with intersection traffic control devices is vital to intersection safety. At stop-controlled intersections, drivers on the stop-controlled approach must identify and observe the STOP sign to be able to comply with the message. Therefore, the STOP sign must be visible and conspicuous. This is particularly important during nighttime or other reduced visibility conditions, such as rainy weather. One method to increase both the visibility and conspicuity of STOP signs is to use higher retroreflectivity sheeting.

Retroreflectivity is the property of a material that reflects a large portion of the light directly back to the source through a wide range of angles of incidence of illumination. When applied to a sign, retroreflective sheeting redirects light from the driver's headlights back toward the headlights, which are in close proximity to the driver's eyes. The amount of light from an object reaching the driver's eyes will have a great impact on the ability of the driver to see that object. Figure 1 provides a relative visual comparison of STOP signs with six grades of retroreflective sheeting.

Figure 1. Relative Visual Comparison of Sheeting Types.



The States of Connecticut and South Carolina have installed a large number of STOP signs with increased retroreflectivity as a proactive, systemwide effort (i.e., they were installed at all of the unsignalized intersections within the jurisdiction) to improve safety.

Methodology

Detailed data were collected for the intersections in South Carolina and Connecticut where the STOP signs were installed for the periods before and after the installation of STOP signs with higher retroreflectivity. In addition to the locations and dates of the STOP sign installations, geometric, traffic, and crash data were obtained at unsignalized intersections for 231 sites in Connecticut and 108 sites in South Carolina. The analysis included a total of 3,323.8 intersection-years of data (2,038.6 intersection-years from CT and 1,285.2 intersection-years from SC). Intersection-years are the number of intersections where the strategy was applied multiplied by the number of years the strategy was in place at each intersection. For example, if a strategy was applied at nine intersections and has been in place for 3 years at all nine intersections, this is 27 intersection-years.

It was not possible to identify those STOP signs that had poor retroreflectivity before the installation of the new signs. The exact condition of each of the signs, including the age or degree of deterioration of the signs, was unknown.

Empirical Bayes (EB) methods were incorporated in a before-after analysis to determine the safety effectiveness of increasing the sign retroreflectivity. The EB methodology for observational before-after studies[2] was used for the evaluation.

Safety performance functions (SPFs) were developed for use in the EB methodology. Generalized linear modeling was used to estimate model coefficients using the software package Statistical Analysis Software® (SAS®) and assuming a negative binomial error distribution which is consistent with the state of research in developing these models.

SPFs were estimated for the following crash classifications:

- Total (all severities and types combined).
- Injury (all crash types combined).
- Right-angle (all severities combined).

- Rear-end (all severities combined).
- Day (all severities and types combined).
- Night (all severities and types combined).

The full report includes a detailed explanation of the methodology, including a description of how the estimate of percent reduction is calculated.

Results

Based on the data, two sets of results were calculated and are presented in the following sections. One set contains aggregate results for each State and for the two combined; the other set is based on a disaggregate analysis that attempts to discern factors that that may be most favorable to increasing STOP sign retroreflectivity.

Aggregate Analysis

The aggregate results are shown in table 1. The results that are statistically significant at the 95-percent confidence level are shown in bold. Note that a negative sign indicates an increase in crashes. Only one statistically significant difference was found—rear-end crashes, both day and night combined, were reduced by 17.5 percent in South Carolina.

Nighttime crashes were the primary target of this measure. There was a small reduction in nighttime crashes in Connecticut and a small increase in South Carolina. However, both of these results are statistically insignificant. There were very few nighttime crashes, making it difficult to identify a sufficient sample of sites that had crashes related to low retroreflectivity.

The results, which are inconclusive and based on nonselective implementations, emphasize the need for a disaggregate analysis to see if significant effects can be detected for specific conditions.

Disaggregate Analysis

Table 2 presents the disaggregate analysis results, which are based on all crashes combined. The results that are statistically significant at the 95-percent confidence level are shown in bold. Note that a negative sign indicates an increase in crashes.

Nighttime crashes were the primary targets of this measure and should be the basis for this analysis; however, there are too few of these crashes to facilitate a disaggregate analysis. The three factors that provided indications of an association with crash effects were environment (urban versus rural), number of approach

Table 1. Results of the Aggregate Analysis.

State and crash type	Sites	EB estimate of crashes expected in the after period without strategy	Count of crashes observed in the after period	Percent reduction (standard error)
CT—Rear End (both day and night)	231	663.6	729	-9.7 (5.7)
CT—Night	231	510.8	478	6.6 (5.5)
CT—Total	231	2,019.2	2025	-0.2 (3.1)
SC—Rear End (both day and night)	108	257.4	213	**17.5% (7.3)**
SC—Night	108	134.5	141	-4.4% (10.8)
SC—Total	108	692.9	656	5.4% (4.9)
Combined—Rear End	339	921.0	942	-2.2 (4.8)
Combined—Night	339	645.3	619	4.4 (6.0)
Combined—Total	339	2,712.1	2681	1.2 (2.7)

NOTE: Bold denotes statistically significant results at the 95% confidence level. Negative sign indicates an increase in crashes.

Table 2. Results of the Disaggregate Analysis.				
Intersection Type	**Sites**	**EB estimate of crashes expected in the after period without strategy**	**Count of crashes observed in the after period**	**Estimate of percent reduction (standard error)**
SC urban	47	333.9	288	**13.7% (6.7)**
SC rural	61	360.0	368	-2.0% (7.0)
SC three-legged	48	354.7	299	**15.9% (6.3)**
SC four-legged	60	338.2	357	-5.3% (7.4)
SC three-legged, urban	20	172.9	128	**26.3% (8.3)**
SC four-legged, urban	27	160.0	160	0.05% (10.6)
SC three-legged, rural	28	181.8	171	6.3% (9.4)
SC four-legged rural	33	178.2	197	-10.2 (10.2)
CT urban	190	1,789.5	1,830	-2.2% (3.3)
CT rural	41	229.7	195	15.4% (8.1)
CT three-legged	172	1,458.0	1,399	4.1% (3.5)
CT four-legged	59	559.2	625	-11.6% (6.3)
CT three-legged, rural	29	152.6	118	**23.1% (9.2)**
CT four-legged, rural	12	75.2	76	-0.2% (15.8)
SC < 1,200 minor AADT	42	219.0	165	**24.9% (7.2)**
SC > 1,200 minor AADT	66	473.9	491	-3.4% (6.3)
CT < 1,000 minor AADT	90	509.0	437	**14.3% (5.6)**
CT >1,000 minor AADT	141	1,510.7	1,588	-5.1% (3.7)

NOTE: Bold denotes results that are statistically significant at the 95% confidence level. The negative sign indicates an increase in crashes.

legs, and minor road entering average annual daily traffic (AADT). For each of these factors, the results are as follows:

- There are opposing indications from the two States for urban/rural, with the more favorable effects for rural installations in Connecticut and urban installations in South Carolina. Based on discussions with representatives from both States, there were no discernable explanations as to why this may be the case.
- For both States, installations at three-legged intersections are more effective than at four-legged intersections.
- For minor entering AADT, there is a consistent pattern with clear indications that this strategy is more effective at lower volumes.

Data were available for an analysis of other possible factors that might influence crash effects. However, no such effects could be ascertained. The other factors examined were sign size (762 mm (30 inches) versus 1,219 mm (48 inches)), presence of lighting (for Connecticut), presence of other measures such as STOP AHEAD signs, major road entering volume, and expected crash frequency prior to strategy.

Economic Analysis

An economic analysis was completed to evaluate the economic feasibility of increasing the retroreflectivity of STOP signs. An estimate of the life-cycle costs of the strategy was developed and expressed as an annual cost. The crash benefits required to offset these costs were then estimated using the most recent FHWA unit crash cost data for unsignalized intersections.

Based on the Office of Management and Budget suggested discount rate of 7 percent and on the expected service life (8 years), the initial costs per intersection were converted to annual costs using the standard economics formula for a capital recovery factor. Cost data provided by the two States suggest a conservatively high initial cost of about $200 per intersection, considering the mix of three-legged and four-legged intersections and sign sizes. Costs would be even lower if the marginal costs of replacing the signs were used. As of 2007, the approximate costs of Type I sheeting is $0.75 per square foot, Type II sheeting is $1.25 per square foot, and Types VII, VIII, and IX is $3.50 per square foot. Using the more conservative $200 initial installation cost translates into an annual cost of around $33 over the 8-year cycle, requiring an annual crash saving of more than $66 per intersection to achieve a benefit cost ratio of at least 2:1.

The most recent FHWA mean comprehensive costs per crash for unsignalized intersections[3] are $13,238 for rear-end and $61,114 for right-angle crashes. Comprehensive crash costs represent the present value, computed at a discount rate, of all costs over the victim's expected life span that result from a crash. The major categories of costs used in the calculation of comprehensive crash costs include medical-related costs, emergency services, property damage, lost productivity, and monetized quality-adjusted life years.[3] By applying the more conservative figure of $13,238, a $66 saving would require a reduction of approximately 0.005 crashes per intersection per year. This is a reduction of approximately 0.5 percent for rural Connecticut intersections which have an annual crash frequency of 1.11 crashes per year, the lowest of the four State/environment groups.

Summary

The aggregate analysis indicates that higher retroreflective STOP signs may affect the likelihood of crashes at unsignalized intersections, but the effect is not detectable with the study design and available sample size. The exception is for rear-end crashes in South Carolina, where there was a significant reduction.

The disaggregate analysis provides further insight into the circumstances where crash reductions were identified. Installations at all three-legged intersections and three-legged urban intersections in South Carolina were found to have a statistically significant reduction in crashes. In Connecticut, a statistically significant reduction in crashes was found for three-legged rural intersections. The disaggregate analysis also shows that the strategy is more effective at lower volumes for motorists approaching the intersection along the minor road. At higher volume intersections, there are more visual cues for minor road motorists approaching a stop-controlled intersection.

For the urban versus rural factor, there are opposing indications from the two States, with the more favorable effects for rural installations in Connecticut and urban installations in South Carolina. There was no explanation available for these inconsistent results between the two States.

There are no detectable effects for nighttime crashes. As discussed previously, this might be because there are relatively few of these crashes at the study sites. It is also likely that this is because these are blanket installations, and the significant benefits at relatively few nighttime crash problem locations become diluted by the negligible effects at other locations.

It should be noted that the study results do not support the degradation of signs below any desired retroreflectivity requirements. The results of this study are based on a wide-scale installation with no knowledge of the previous sign conditions. Therefore, it is difficult to determine the safety effectiveness of more highly retroreflective sheeting on STOP signs for specific conditions; there was not a large enough sample size to detect any significant effects. The sample size required to detect a significant effect would be outside the scope of this project. As indicated in the FHWA Supplemental Notice of Proposed Amendments,[4] improving sign retroreflectivity will be a benefit to all drivers, including older ones. All drivers need legible signs in order to make important decisions at key locations, such as intersections and exit ramps on high speed facilities. This is particularly true for regulatory and warning signs, where noncompliance can have severe results.

Conclusion

A minimal reduction in crashes can be expected with the installation of higher retroreflective STOP signs. However, given the low cost of this strategy, even with conservative assumptions, only a very modest reduction in crashes is needed to justify its use. Therefore, this strategy has the potential to reduce crashes cost effectively, particularly at lower-volume intersections.

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