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EVALUATION OF THE BENEFITS OF REFLECTORIZED SIGN POSTS TO DRIVERS

TRAFİK İŞARETİ DİREKLERİNDE KULLANILAN REFLEKTİF MALZEMELERİN SÜRÜCÜLER İÇİN FAYDALARININ İNCELENMESİ

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Abstract

In United States Federal Highway Administration (FHWA) provides departments of transportation (DOTs) the option of using retroreflective material on sign posts when the DOTs determine that there is a need to draw attention to the sign, especially at night. The State of Ohio Department of Transportation (ODOT) required all Stop, Yield, Do Not Enter, and Wrong Way sign posts to be reflectorized with RED reflective sheeting material and all Chevron, Stop Ahead, and One/Two Large Directional Arrow sign posts to be reflectorized with YELLOW (sign background color) reflective sheeting material as part of ODOT Comprehensive Highway Safety Plan and FHWA' recommendations.

In this study, a photometric analysis and a human factors analysis were conducted to estimate the benefits of reflectorized sign posts to driver visual perception, driver guidance and driver comprehension. The study showed that the reflectorized sign posts improve detection, recognition, and comprehension of traffic signs for drivers, especially in nighttime driving conditions.

Keywords: Traffic sign, Reflectivity, Human factors, Photometric analysis.

Özet

Amerika Birleşik Devletleri Federal Karayolları İdaresi, trafik işaretlerinin özellikle gece görülebilirliğini artırmak ve dikkat çekmek için trafik işareti direklerinde reflektif malzemelerin kullanılabilceğini belirtmektedir. Bu öneri doğrultusunda Ohio Eyaleti Ulaştırma Bölümü karayolları güvenliğini artırmak için tüm Dur, Yol Ver, Girilmez ve Yanlış Yön trafik işareti direklerinin kırmızı reflektif malzeme ile kaplanmasına ve tüm ok işaretli yön levhalarının gövdelerinin ise sarı reflektif malzeme ile kaplanmasına karar vermiştir.

Bu çalışmada, trafik işareti direklerinde kullanılan reflektif malzemelerin fotometrik analizi ve insan faktörleri analizi yapılmıştır. Bu analizler sonucunda trafik işareti direklerinde reflektif malzeme kullanımının sürücülerin trafik işaretlerini algılamasına, tanımasına ve anlamasına olan faydaları incelenmiştir. Çalışma sonucunda reflektörlü işaret direkleri, özellikle gece sürüş koşullarında, sürücülerin trafik işaretlerini algılamasına, tanımasına ve anlamasına faydasının olduğu görülmüştür.

Anahtar kelimeler: Trafik işaretleri, Reflektivite, İnsan faktörleri, Fotometrik analiz.

1 Introduction

In United States Federal Highway Administration provides Departments Of Transportation (DOTs) the option of using retroreflective material on sign posts when the DOTs determine that there is a need to draw attention to the sign, especially at night. Ohio Department of Transportation (ODOT) required all Stop, Yield, Do Not Enter sign posts to be reflectorized with RED reflective sheeting material and all Chevron, Stop Ahead, and One/Two Large Directional Arrow sign posts to be reflectorized with YELLOW (sign background color) reflective sheeting material as a part of ODOT Comprehensive Highway Safety Plan [1]. The pictures given below in Figure 1 show the installed sign post reflectors in Athens County, OH. The pictures were taken on US 56 and US 50.

It appears that this program, representing a part of ODOT's Comprehensive Highway Safety Plan for 2006, was implemented without the benefits of any prior research or existing positive practice results. One would expect a reduction in intersection crashes controlled by Stop/Yield signs with reflectorized sign posts, wrong way driving crashes on 4-lane divided highways, and run off the road crashes in curves where chevron and large arrow signs with reflectorized sign posts are used.

Figure 1: YIELD, STOP AHEAD, and STOP Signs with Sign Post Reflectors.

2 Methods

In this study the potential benefits of reflectorized sign posts for drivers were investigated from a visibility point of view, a photometric analysis point of view, a perception point of view, a driver's comprehension point of view, and a human factors point of view.

2.1 Literature Review

The reflectorized sign posts contribute to driver guidance at intersections and curves and driver comprehension on wrong way driving at night. No published studies were found in the literature specifically related to reflectorized sign posts, user acceptance of reflectorized sign posts, photometric analysis of reflectorized sign posts, and human factors analysis of reflectorized sign posts.

There is no literature found on the crash reduction potential of reflectorized sign posts; however, the literature shows that larger target size results in improved detection. The crash reduction potential of similar reflectorization measures is given. The improved detection of the signs should result in improved sign comprehension, which in turn will lead to fewer accidents during daytime and nighttime. The crash reduction effect of reflectorized sign posts is expected to be very small for daytime and slightly larger than daytime but still very small for nighttime. The crash reduction effect of reflective sign posts expected to be slightly larger for nighttime because of the increased visual signal at night. Stronger luminance values are expected at sign posts because of the headlamp beam pattern.

Relevant studies addressing certain aspects regarding the benefits of reflectorized sign posts for drivers are investigated and given as a part of this study.

Zwahlen and Schnell, [2]-[3] evaluated the new crossbuck designs with additional reflective sheeting on sign posts in Ohio. The researchers found that the use of reflective sheeting on sign posts reduced the number of crashes observed at the test sites by 22.3% and resulted in higher compliance with the signs. The higher conspicuity and warning power caused by the use of reflective sign sheeting on crossbuck sign posts may have caused the improvements.

The reflective sheeting materials are added to the Stop Sign, Stop Ahead Sign, Yield Sign, Chevron Sign, One Large Arrow Sign, Wrong Way Sign, and Do Not Enter Sign. The aim of reflectorization of these sign posts is to increase their contribution to driver guidance and comprehension. The additional reflective area would benefit drivers especially at stop controlled intersections, at curves, and at wrong way driving. The addition of the reflective sign sheeting on chevron sign posts may benefit curve delineation and provide guidance for drivers through curves by providing visual cues especially for nighttime driving conditions [4]-[5].

Zwahlen et al., [6] evaluated the reflective performance of flexible post delineators as a function of height, reflector dimensions, photometric performance, lateral offset, and spacing using a computer model. The researchers performed a small scale field evaluation of retroreflective patches by expert panel. The results revealed that the use of 45.72x2.54 cm retroreflective vertical strip patch design used on flexible post delineators performed better than the 15.24x7.62 cm and 30.48x3.81 cm patch designs. It provided excellent shape cue, guidance cue, and distance estimation cue to the drivers. In another study [7] the effects of the target aspect ratio on human threshold contrast was investigated. The researchers found that small target aspect ratios (shorter dimension to longer dimension) should be used to maximize rectangular target visibility. Reflective material application on traffic sign posts are rectangular targets with small target aspect ratios therefore similar potential benefits are expected from their use and they would provide higher visibility.

Stalder and Lauer, [8] investigated the effects of the amount and distribution of reflectorized materials on the level of visibility of railroad boxcars. They have found that the reflective materials increase the speed and perception of changing distances between vehicles. In another study [9] different methods to place reflective materials on boxcars were investigated. The researchers found that the mass application of reflective material was better than the distributed application of the material. Based on the results of these two studies from the literature it can be suggested that the reflective sign posts will provide better perception of traffic signs, and especially increase speed and accuracy of perception of curves at night. Reflectorized sign posts can be regarded as mass application of reflective materials and expected to provide better guidance.

2.2 Photometric Analysis

Target Visibility Predictor (TARVIP) software developed by the Operator Performance Laboratory of the University of Iowa [10] is used in the photometric analysis of the reflectorized sign posts. TARVIP is a deterministic model for nighttime reflective object visibility evaluation. The deterministic model is based on the dynamics of light, retroreflection, and atmospheric conditions under nighttime driving conditions. The inverse square law (brightness of a source is inversely proportional to the square of its distance) is adapted for TARVIP calculations. Road geometry, sign data, driver data, vehicle data, headlamp data are the inputs of TARVIP software.

Input menu of TARVIP features a set of graphical user interface windows to define a scenario. The first input item is the road option in TARVIP. Straight road geometry is selected for all scenarios in the photometric analysis. The straight road is defined as two lane rural roadway. The vehicle is assigned on the right lane (outer lane) of the road. The lane widths are assigned as 3.66 m and the vehicle is centered to the right lane. The road analysis for each scenario is performed for 25 m segments up to 300 m from the target. The road configuration used in TARVIP is given in Figure 2. The grade of the road segment is assumed to be zero.

The sign information is entered in the next step of the program. The dimensions of the signs are measured in the field on US 56 and US 50. Sign dimension information from ODOT Sign Design Manual [1] is also used. The sheeting materials for all signs are ASTM Type III (3M High Intensity) sheeting material. Another input variable in TARVIP is the headlamp and vehicle input. The vehicle dimensions and driver dimensions are adapted from a study by Zwahlen and Schnell, [11]. Average passenger car dimensions and three different driver dimensions are used in the scenarios. The driver dimensions are adapted from 1988 US Army Personnel Data. The data used are 5th percentile female (small female), 95th percentile male (large male), and 50th percentile adults (average human) in order to represent different driver types. In addition to the geometric inputs of the TARVIP, different headlamp data is entered to the program to estimate the effects. Various types of headlamps are available in TARVIP for analysis. In this study three different headlamps are evaluated.

The headlamp patterns from [12] are evaluated. Schoettle et al. had analyzed the headlamp patterns of 20 best selling passenger cars in 2000. They had identified the25th, 50th, and 75th percentile US low beam headlamps patterns, which are used in TARVIP.

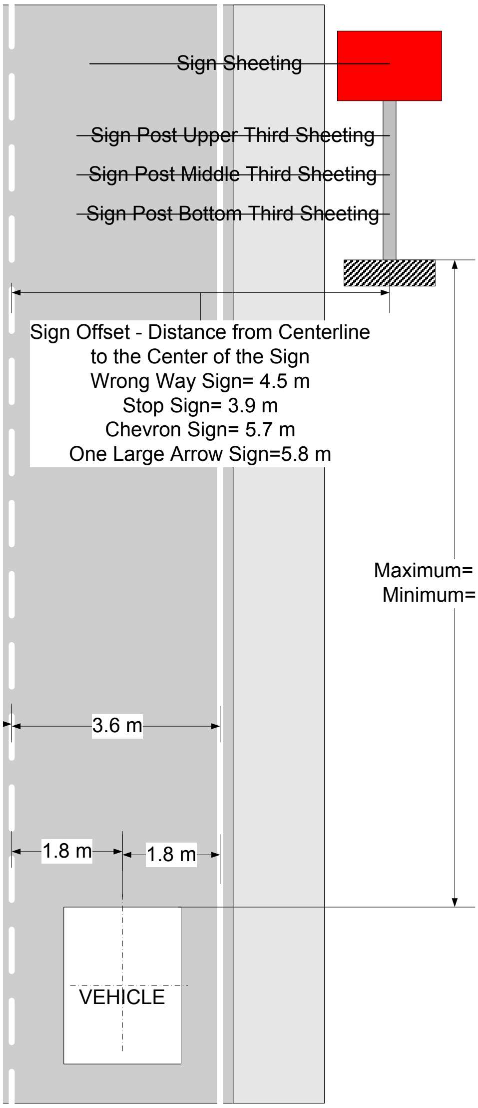

Figure 2: Straight Road Configuration for all Signs on the Right for TARVIP (not to scale).

The scenarios are run for each sign and the signs are analyzed separately for the sign sheeting material and the sign post sheeting material. The sign sheeting material is analyzed with respect to the legend sheeting material and background sheeting material. It is assumed that the materials are condensed at the center of the sign for analysis. The sign post sheeting material for each sign is analyzed in three sections. The sign is divided in three portions vertically and each of them analyzed separately.

TARVIP can generate target angles and photometry measurements. The observed luminance values are generated. The observed luminance values for driver side headlamp, passenger side headlamp, and total luminance are generated and compared for sign sheeting and sign post sheeting. Total of 252 scenarios (3 driver types X 3 headlamp types X 7 road/sign configuration X 4 target points for each sign) are run using TARVIP. The results of the scenarios for 50th percentile adult population and 50th percentile headlamp configuration with respect to sign/road configurations are given in this study. The total observed luminance values for the stop sign on the right side of a straight road is given in Figure 3.

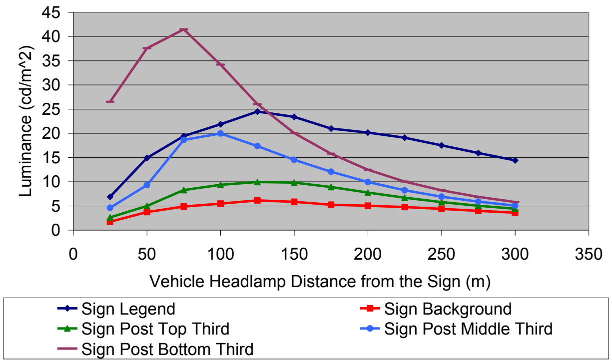

Figure 3: Total Observed Luminance for 50th Percentile Adult Population and 50th Percentile Headlamp Configuration for Stop Sign on the Right Side of the Straight Road.

Overall the photometric analysis of reflective sign posts with TARVIP showed that the sheeting material on sign posts provide higher luminance than the sign itself. The total reflective area of traffic signs increases with the additional sheeting on the sign posts. In Table 1, the increases in the reflective area of the signs are given in percentages. It can be concluded that the new application of reflectorized sign posts would be beneficial to drivers and it will provide higher levels of luminance to the drivers caused by the increased reflective area.

Table 1: Comparison of Traffic Sign Reflective Area of the Sign and the Sign Post.

Sign Type	Sign Area (Legend and Background) (cm^2)	Sign Post Area (cm^2)	Increase in Reflective Area
Wrong Way Sign	5575	1665	29.86%
Stop Sign	4787	1161	24.26%
Chevron Sign	1839	1200	65.26%
One Large Arrow Sign*	5284	2439	46.15%

*One Large Arrow Sign has 2 reflective sign posts.

The increase in the luminance values by increased area is calculated using TARVIP luminance output. The sign areas are converted into square meters and then multiplied by the luminance values. The luminance values for sign area and sign post area are compared. Table 2 shows the percent increase in the luminous intensity observed on the signs with the addition of reflective sign posts.

The photometric analysis of reflective sign posts with TARVIP shows that the sheeting material on sign posts provide higher luminance than the sign itself. The sheeting material on the sign post can get more illumination from the headlamp since it is closer to the headlamp axis. The total reflective area of traffic signs increases with the additional sheeting on the sign posts. The analysis shows that the increase in the sign reflective area is 30% for Wrong Way Sign, 24% for Stop Sign, 65% for Chevron Sign, and 46% for One Large Arrow Sign. The luminous intensity is also increased with the additional reflective area by 23% for Wrong Way Sign, 26% for Stop sign, 286% for Chevron Sign, and 84% for One Large Arrow Sign at 225 m distance.

Table 2: Comparison of the Luminous Intensity of the Signs and the Sign Posts.

Sign Type		Luminous Intensity (cd)		
Wrong Way Sign		75 m	150 m	225 m
	Sign	2.19	2.74	2.26
	Sign Post	0.66	0.72	0.51
	Increase in Luminous Intensity*	30%	26%	23%
Stop Sign				
	Sign	3.81	4.58	3.74
	Sign Post	2.64	1.71	0.96
	Increase in Luminous Intensity*	69%	37%	26%
Chevron Sign				
	Sign	0.96	1.24	1.10
	Sign Post	8.45	6.02	3.11
	Increase in Luminous Intensity*	875%	486%	286%
One Large Arrow Sign				
	Sign	6.46	8.18	6.90
	Sign Post	12.28	10.41	5.75
	Increase in Luminous Intensity*	190%	127%	84%

*Increase in luminous intensity=sign post/sign

2.3 Human Factors Analysis

The driving task primarily depends on information gathered through visual stimuli. Therefore the human limitations are mainly of a visual nature. The visual limitations increase with age especially at night. The detection capabilities of a target like a sign decreases by age [13]. For night driving the luminance is one of the most important factors that affects visual detection. The performance of the human eye is greatly reduced at low illumination levels and also the contrast sensitivity and color discrimination of the eye are lower at low illumination levels [14]. Human vision declines by age (the amount of light needed by drivers doubles every 13 years after age 20), [15].

Based on the examination of the human limitations and the physical characteristics, the reflectorized sign posts should result in increase in the detection and recognition of signs slightly, decrease in reaction time slightly to initiate correct action, increase in recognition and comprehension of signs slightly, and ultimately should decrease crashes slightly.

For curve delineation, reflectorized chevron sign posts also create a perceptual fence effect that helps in the correct perception of the curve radius and selection of the curve speed. The fence effect provides improved curve delineation, which improves a driver's ability to estimate the radius of the curve.

For all signs the reflectorized sign posts also create a "perceptual grounding effect" which anchors signs more effectively in to the environment and improves distance estimation from driver to sign. The grounding effect anchors the sign more effectively into the driving environment and improves a driver's distance estimation capability.

3 Conclusions

A number of positive qualitative benefits of reflectorized sign posts to the drivers have been identified, especially for nighttime driving. Increased size, area, and visual signal, more reflective area, more luminance and luminous intensity, more color, perceptual fence effect, perceptual grounding effect and decreased reaction times due to increased visual signal and increased luminous intensity are the major benefits provided to drivers by the application of reflective sheeting material on traffic sign posts. However none of these benefits are of a reliable quantitative nature, which would allow a reliable cost/benefit analysis. Detailed analysis of relevant crash data at intersections, curves, and highways has to be analyzed for run-off-the-road crashes, failure to yield crashes, and wrong way driving crashes. The crash rates for previous three years before the implementation of reflective sign posts and crash rates for three years after the implementation of reflective sign posts may provide more reliable data on the cost/benefit analysis of reflectorized sign posts.

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