Final Report

FHWA/IN/JTRP-2006/18

EVALUATION OF WILDLIFE REFLECTORS IN REDUCING VEHICLE-DEER COLLISIONS ON INDIANA INTERSTATE 80/90

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Joint Transportation Research Program
Project Number: C-36-59BBB
File Number: 8-5-54
SPR-2449

Prepared in Cooperation with the
Indiana Department of Transportation and the
U. S. Department of Transportation
Federal Highway Administration

Purdue University
West Lafayette, IN 47907
July 2006

INDOT Research

TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

TRB Subject Code: 51 Transportation Safety *July 2006*
Publication No.FHWA/IN/JTRP-2006/18, SPR-2449 *Final Report*

Evaluation of Wildlife Reflectors in Reducing Vehicle-Deer Collisions on Indiana Interstate 80/90

Introduction

The Indiana Department of Transportation (INDOT) Operations Division is committed to reducing vehicle-deer collision incidents on the Indiana Interstate 80/90. Very few of the studies to reduce vehicle-deer collisions incorporated any sound statistical design. Some states (California, Colorado, Maine, Washington State, and Wyoming) have found that the use of wildlife reflectors did not reduce vehicle-deer collisions. However, some other states (Iowa, Minnesota, Oregon, and Wisconsin) and British Columbia-Canada found that the use of wildlife reflectors did reduce vehicle-deer collisions. INDOT is interested in cost-effective use of the Strieter-Lite Reflectors to reduce vehicle-deer collision incidents on the Interstate 80/90.

Findings

The following conclusions and recommendations were made on the basis of this study:

1. The effects of the reflector color, reflector spacing, median with or without reflectors, single or double reflectors and their interactions are not statistically significant.

2. The effects of the previous year data, 1998, number of deer-kills, are not statistically significant.

3. When comparing all combined reflector sites with all combined control sites, the Poisson Regression Analyses indicate that the difference between the Poisson Mean (μ) of the all reflectors sections and all the control sections is statistically significant. The use of reflectors provides an expected reduction in deer-vehicle collisions of 19% with 95% confidence limits of 5% to 30%. Maximum reduction is associated with 100 ft spacing regardless of the reflector color, median with or without reflectors, single or double reflectors.

Implementation

The cost-effectiveness of the reduction in deer vehicle collisions due to the use of reflectors will be behind any decision to use reflectors to reduce vehicle-deer collisions.

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TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/IN/JTRP-2006/18		

4. Title and Subtitle	5. Report Date
Evaluation of Wildlife Reflectors in Reducing Vehicle Deer Collisions on Indiana Interstate 80/90	July 2006
	6. Performing Organization Code
7. Author(s)	**8. Performing Organization Report No.**
Sedat Gulen, George McCabe, Ira Rosenthal, Samuel Wolfe, Virgil Anderson	FHWA/IN/JTRP-2006/18
9. Performing Organization Name and Address	**10. Work Unit No.**
Joint Transportation Research Program 1284 Civil Engineering Building Purdue University West Lafayette, IN 47907-1284	
	11. Contract or Grant No. SPR-2449
12. Sponsoring Agency Name and Address	**13. Type of Report and Period Covered**
Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, IN 46204	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the Indiana Department of Transportation and Federal Highway Administration.

16. Abstract

The Indiana Department of Transportation is committed to reducing vehicle-deer collision incidents on the Indiana Interstate I-80/90 as well as on the other roads. Very few of the studies to reduce vehicle-deer collisions incorporated any sound and complete statistical design. Some states (California, Colorado, Maine, Ontario-Canada, Washington State and Wyoming) have found that the use of wildlife reflectors did not reduce vehicle-deer collisions. However, some other states (British Columbia-Canada, Iowa, Minnesota, Oregon, Washington State and Wisconsin) found that the use of wildlife reflectors did reduce vehicle-deer collisions.

The main objective of this experimental study is to evaluate the effectiveness of the Reflectors in reducing vehicle-deer collisions. The experimental design uses one-mile long road sections for each combination of reflector colors (red and blue/green), reflector spacing (30 m and 45 m), reflector design (single and dual reflectors), and median (one with and one without reflectors). In this design there are sixteen treatment combinations. A complete set of treatment combinations is called a replicate and the design had two replicates. Two one-mile control sections were placed at each end of each replicate. Data for the peak months of April, May, October and November was used in the data analyses.

Poisson Regression models were used to analyze the data. No statistically significant differences among reflectors combinations or between reflectors and controls were found.

When comparing all combined reflector sites with all combined control sites, the Poisson Regression Analyses indicate that the difference between the Poisson Mean (μ) of the all reflectors sections and all the control sections is statistically significant. The use of reflectors provides an expected reduction in deer-vehicle collisions of 19% with 95% confidence limits of 5% to 30%. Maximum reduction is associated with 100 ft spacing regardless of the reflector color, median with or without reflectors, single or double reflectors.

The cost effectiveness of this reduction will be behind any decision to use reflectors to reduce vehicle-deer collisions.

17. Key Words	18. Distribution Statement
Reflectors, wildlife, and deer-vehicle collisions	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	45	

Form DOT F 1700.7 (8-69)

ACKNOWLEDGMENTS

This report was prepared by Sedat Gulen, George McCabe, Samuel E. Wolfe and Ira Rosenthal, for the Indiana Department of Transportation, Toll Road Division. The authors wish to thank Bob of Tollroad who maintained the reflectors, Larry Bateman, David Hinshaw and Samy Noureldin for their time and inputs.

I. Introduction:

The Indiana Department of Transportation Operation Division is committed to reducing vehicle-deer collision incidents on the Indiana Interstate I-80/90. Very few of the studies to reduce vehicle-deer collisions incorporated any sound statistical design. Some states[(1)] (California, Colorado, Maine, Ontario-Canada, Washington State and Wyoming) have found that the use of wildlife reflectors did not reduce vehicle-deer collisions. However, some other states[(2)] (British Columbia-Canada, Iowa, Minnesota, Oregon, Washington State and Wisconsin) found that the use of wildlife reflectors did reduce vehicle-deer collisions. INDOT is interested in cost-effective use of the Strieter-Lite Reflectors to reduce vehicle-deer collision incidents on the Interstate I-80/90.

II. Objective:

The main objective of this study is to evaluate the Strieter-Lite Reflectors to reduce the vehicle-deer collisions on the Indiana Interstate I-80/90.

III. Experimental Design:

The experimental design[(3)] of this research study in detail is as follows:

(a) ***Reflector colors, fixed, two levels***

1. Red
2. Blue/Green

(b) ***Reflector Spacing, fixed, two levels***

1. 30 m (~100 feet)
2. 45 m (~150 feet)

(c) ***Reflector Design, fixed, two levels***

1. Single Reflector
2. Dual Reflector

(d) ***Median, fixed, two levels***

1. Median with reflector
2. Median without reflector

(e) ***Replicates, random, two levels***

The above design yields eight treatment combinations for each color, T1 to T8, Table 1. The whole experiment is called as a replicate that consists of sixteen treatment combinations, eight combinations for each color. This replicate was repeated two times. The replicates were randomly assigned to geographically homogenous portion of the Interstate and *four-mile* long spacing was maintained in between.

(f) ***Control Sections, fixed, three levels***

1. Two miles long, before the first replicate
2. Four miles long, between the two replicates
3. Two miles long, after the second replicate.

Monthly data (number of deer-vehicle collisions) have been obtained at each mile including the three control sections since March 1999.

IV. Site Selection and Reflector Installation

Test sites for two replicates were selected randomly with four miles of control sections between the two replicates. The control area between replicates has no reflectors. Reflectors were installed uniformly with respect to the design of experiment.

Treatment combinations were randomized for each replicate. The starting color of the reflector was also randomized. The final layout of the experiment is shown in Tables 2 and 3. The length of each treatment and control section is one mile. Placements of the reflectors for different conditions are shown in Figures 1-4. All the reflectors were installed in accordance with the manufacturer's suggestions. Typical single and double reflector is seen in Figure 5. Installation of all reflectors was completed by February 1999.

V. Data Collection:

The daily number of deer-vehicle collision data collection was started in March 1999 and continued to the end of 2005. The reflectors have been examined, cleaned, repaired or replaced when necessary. The uniformity of the reflectors was very important for the statistical analyses, for this reason, they were maintained during this experimental study.

VI. **Data Analysis**:

Five years of deer-vehicle incidents per mile have been collected prior to the placement of the wild life reflectors and 1998 data was selected to be used as a covariate in the statistical analyses.

The new collected and past data indicated that the most deer-vehicle incidents occur during the months of April, May, October and November, (Figure 6). The following are possible reasons:

1. In the first "smaller peak" (April-May) accidents are higher because of fawning. The increased nutritional requirements of raising young cause females to move and feed more often. In addition, the landscape begins to change with the "green-up" of vegetation and subsequent introduction of higher quality food.

2. In the "larger peak" (October-November) several things are occurring:

    a. Males and females are both undergoing behavioral changes induced by the rut (breeding season). The animals are not only more active, but also more brazen and careless.

    b. The landscape is changing drastically. Crops are harvested and understory growth dies off as leaves fall. This reduces cover and food availability for deer necessitating greater travel.

    c. Hunting season, particularly the end of archery and the firearms season (mid November) sees several hundred thousand hunters take to the field, which causes extensive movement of animals.

For the above stated reasons data from the peak months, i.e. April, May, October and November, were analyzed.

Poisson regression models were found to be suitable for the analysis since the values of the dependent variable, the number of deer-kills, are non-negative integers.

Poisson Regression Model

The Poisson regression model gets its name from the assumption that the dependent variable has a Poisson distribution, defined as follows. Let **y** be a variable that can only have non-negative integer values. We assume that the probability that **y** is equal to some number **r** is given by

$$\Pr(y = r) = \frac{\mu^r e^{-\mu}}{r!} \qquad \mathbf{r} = 0, 1, 2\ldots \qquad (1)$$

where μ is the expected value (mean) of **y** and **r! = r(r-1)(r-2)…(1).** Although **y** can only take on integer value, μ can be any positive number.

As μ gets larger, the Poisson distribution can be approximated by a normal distribution. For the Poisson distribution the mean and the variance are equal.

$$\textbf{Expected value of y = E (y) = variance (y) = } \mu \qquad (2)$$

For a Poisson regression model, the parameter μ depends on the explanatory variables. First, we write μ_i with a subscript **i** to allow parameter to vary across conditions (i=1, 2... n). The standard model expresses μ as a loglinear function of the explanatory **(x)** variables:

$$\log \mu_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_p x_{ip} \qquad (3)$$

This relationship will make μ greater than zero for any values of the **x's or β's**. We choose the maximum likelihood method to estimate the parameters of the model, the **β's**. This is easily accomplished using the SAS(6) Statistical Software with "PROC GENMOD" version 8.0.

When using the Poisson regression modeling, one should be aware of "overdispersion". When count variables often have a variance greater than the mean, this is called ***overdispersion.*** Overdispersion can occur when there are explanatory variables that are omitted from the model, (Overdispersion can lead to underestimates of the standard errors and overestimates of chi-square statistics.

What can be done about overdispersion? One can use the Pearson chi-square or the deviance chi-square correction in the model. These two methods are very close, however, the theory of quasi-likelihood estimation suggest the use of the Pearson chi-square (McCullagh and Nelder 1989)[4].

The adjustment for overdispersion discussed above is a huge improvement over conventional Poisson regression but it may not be ideal. The coefficients are still inefficient, meaning that they have more sampling variability than necessary. Efficient estimates are produced by an alternative model called negative binomial regression.

The negative binomial model is a generalized of the Poisson model. We modify equation (3) by adding a disturbance term, which accounts for the overdispersion:

$$\log \mu_I = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_p x_{ip} + \sigma\varepsilon_i \qquad (4)$$

We assume that the dependent variable $\mathbf{y_i}$ has a Poisson distribution with expected value μ_i, ***conditional on*** ε_i. Finally, we assume that expected (ε_i) has a standard gamma distribution (Agresti 1990, page 74)[5]. Then, it follows that the unconditional distribution of $\mathbf{y_i}$ is negative binomial distribution. The negative binomial regression model may be efficiently estimated by maximum likelihood. This is also easily accomplished using the SAS Statistical Software with "PROC GENMOD" version 8.0.

The Poisson regression model with the Pearson chi-square and the negative binomial regression were used for the analysis of our data.

Main Experiment:

This experiment is called completely ***randomized***[(3)]. The main purpose of the analysis is to assess the effects of the main effects, replicate, rate, month, color, reflector type, and reflector spacing, median and all the two-way interactions of color, reflector type, reflector spacing and median. Then the following model was used:

$$
\begin{aligned}
\log(\mu_i) = \beta_0 + \beta_1\,\text{REP}(1) &+ \beta_2\,\text{MONTH}(4) + \beta_3\,\text{MONTH}(5) + \beta_4\,\text{MONTH}(10) + \\
&\beta_5\,\text{MONTH}(11) + \beta_6\,\text{MONTH}(16) + \ldots\ldots\ldots\ldots \\
&\theta_1\,\text{COLOR}(1) + \theta_2\,\text{SPACE}(1) + \theta_3\,\text{REF}(1) + \theta_4\,\text{MEDIAN}(1) + \\
&\theta_5\,\text{COLOR}(1)*\text{SPACE}(1) + \theta_6\,\text{COLOR}(1)*\text{REF}(1) + \\
&\theta_7\,\text{COLOR}(1)*\text{MEDIAN}(1) + \theta_8\,\text{SPACE}(1)*\text{REF}(1) + \\
&\theta_9\,\text{SPACE}(1)*\text{MEDIAN}(1) + \theta_{10}\,\text{REF}(1)*\text{MEDIAN}(1) + \gamma X_i \qquad (5)
\end{aligned}
$$

Where:

μ_i = E(y), the mean of the i-th observation

REP (1) = effect of the replicate = (1 if replicate=1, 0 otherwise)

MONTH (4) = effect of the month = (1 if month=4, 0 otherwise)

MONTH (5) = effect of the month = (1 if month=5, 0 otherwise)

MONTH (10) = effect of the month = (1 if month=10, 0 otherwise)

MONTH (11) = effect of the month = (1 if month=11, 0 otherwise)

MONTH (16) = effect of the month = (1 if month=16, 0 otherwise) (April in 2000)

MONTH (17) = effect of the month = (1 if month=17, 0 otherwise) (May in 2000)

……..

……..   .

COLOR (1) = effect of the color = (1 if color is red, 0 otherwise)

SPACE (1) = effect of the reflector spacing = (1 if spacing is 30m, 0 otherwise)

REF (1) = effect of the reflector type = (1 if reflector is single, 0 otherwise)

MEDIAN (1) = effect of the median = (1 if median is without reflector, 0 otherwise)

X_i = the covariate, the number of vehicle-deer collisions occurred in 1998.

COLOR (1)*SPACE (1) = interaction of the Color with Space.

COLOR (1)*REF (1) = interaction of the color with reflector type.

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REF (1)*MEDIAN (1) = interaction of the reflector type with median.

The corresponding indicator variables were generated for all the terms in equation (6) except the covariate X. This is accomplished by the SAS software by including the explanatory variables in a CLASS statement. The Poisson and negative binomial regressions models were used for the analysis. Results are listed in Tables 5 and 6.

Both methods indicated that the effects of the following terms are not statistically significant:

1. The effect of the covariate, X, the numbers of deer-kills in 1998, p-value=0.23 for Poisson and p-value=0.23 from negative binomial.
2. The effect of the replicate, p-value=0.49 and 0.49 from Poisson and Negative-Binomial.
3. The effects of color, spacing, reflector and median
4. The two-way interactions of the color, spacing, reflector and median

The only term, which is statistically significant, is the months as expected.

Comparisons of treatments with controls:

These comparisons were made in the following two ways:

A. Individual comparisons of the treatments:

Each of the sixteen reflector treatments was individually compared with each of the controls. The treatments are shown as TRT in Table 3. The reflector treatments are numbered from 1 to 16 in each replicate and the controls are numbered from 17 to 20. The following model was used:

$$\log(\mu_i) = \beta_0 + \beta_1 \text{ REP }(1) + \beta_2 \text{ MONTH }(4) + \beta_3 \text{ MONTH }(5) + \beta_4 \text{ MONTH }(10) + \beta_5 \text{ MONTH }(11) + \beta_6 \text{ MONTH }(16) + \ldots\ldots\ldots\ldots$$

$$\phi_1 \text{ TRT}(1)+ \phi_2 \text{ TRT}(2)+ \phi_3 \text{ TRT}(3)+ \phi_4 \text{ TRT}(4)+ \phi_5 \text{ TRT}(5)+$$
$$\phi_6 \text{ TRT}(6)+ \phi_7 \text{ TRT}(7)+ \phi_8 \text{ TRT}(8)+ \phi_9 \text{ TRT}(9)+ \phi_{10} \text{ TRT}(10)+\phi_{11} \text{ TRT}(11)+$$
$$\phi_{12} \text{ TRT}(12)+ \phi_{13} \text{ TRT}(13)+ \phi_{14} \text{ TRT}(14)+ \phi_{15} \text{ TRT}(15)+$$
$$\phi_{16} \text{ TRT}(16)+ \phi_{17} \text{ TRT}(17)+ \phi_{18} \text{ TRT}(18)+ \phi_{19} \text{ TRT}(19)+ \phi_{20} \text{ TRT}(20)$$
$$\gamma X_i \ \ldots\ldots\ldots \qquad (6)$$

where:

TRT (1) = effect of the treatment = (1 if TRT=1, 0 otherwise)

TRT (2) = effect of the treatment = (1 if TRT=2, 0 otherwise)

TRT (3) = effect of the treatment = (1 if TRT=3, 0 otherwise)

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TRT (19) = effect of the treatment = (1 if TRT=19, 0 otherwise)

The other terms are defined before.

The Poisson Regression analysis using the model, equation (6) showed that the following terms are not statistically significant (Table 7):

1. The covariate, X, p-value=0.12
2. TRT, p-value=0.59
3. REP, p-value=0.63

The only significant term is month as found before. The p-value of 0.59 for the TRT, indicates that differences among the 20 treatments (16 with reflectors and four controls) are not statistically significant.

Even though the treatments (TRT) failed to be statistically significant, comparisons of the controls (trt=17, 18, 19 and 20) with the other treatments (trt=1, 2… 16) were checked. These comparisons also failed to attain statistically significance (Table 8). The p-values are greater than 0.10.

For Example:

a) The p-value for the difference between the TRT=4 and TRT=20 (one of the four controls) is 0.1009, Table 8.
b) The p-value for the difference between the TRT=15 and TRT=19 (one of the four controls) is 0.9656, Table 8.

B. Comparisons of all reflector treatments to the controls:

There are four controls, designated as trt=17, 18, 19 and 20 in two replicates (rep). They are named as group 17, 18, 19 and 20.

The 16 reflector treatments are included in group 1.

The following Poisson Regression Model (7) was used to analyze the data.

$$\begin{aligned}\text{Log}(\mu_i) = {} & \beta_0 + \beta_1 \text{ REP }(1) + \beta_2 \text{ MONTH }(4) + \beta_3 \text{ MONTH }(5) + \\ & \beta_4 \text{ MONTH }(10) + \beta_5 \text{ MONTH }(11) + \beta_6 \text{ MONTH }(16) + \ldots\ldots\ldots \\ & \phi_1 \text{ GROUP }(1) + \phi_2 \text{ GROUP }(17) + \phi_3 \text{ GROUP }(18) + \\ & \phi_4 \text{ GROUP }(19) + \phi_5 \text{ GROUP }(20) \\ & + \gamma X_i \qquad \ldots\ldots\ldots(7)\end{aligned}$$

The results, as tabulated in Table 9, show that the following variables are not statistically significant:

1) REP, p-value=0.62
2) Covariate, X, p-value=0.11
3) GROUP, p-value=0.06

The explanatory variable, month was found statistically significant as expected.

The term Group was not statistically significant, p-value=0.06 and this again indicates that the differences among controls and reflectors are not evident in these data.

In addition, the differences between groups were also obtained and it shows that the only significant difference is between GROUP (1) that includes all reflectors and the GROUP (20) that includes the two control sections designated as trt=20.

C. Comparisons of all reflectors treatments with all controls

The reflectors treatments, trt=1, 2, 3 ….16 in two replicates are designated as COM 1 while all the controls, trt=17, 18, 19 and 20 were designated as COM 2. In other words, COM 1 includes all the reflectors treatments when COM 2 includes all the controls.

The following Poisson Regression Model (8) was used to analyze the data.

$$\log(\mu_i) = \beta_0 + \beta_1 \text{ REP } (1) + \beta_2 \text{ MONTH } (4) + \beta_3 \text{ MONTH } (5) + \beta_4 \text{ MONTH } (10) + \beta_5 \text{ MONTH } (11) + \beta_6 \text{ MONTH } (16) + \ldots\ldots\ldots \phi_1 \text{ COM} + \gamma X_i \quad \ldots\ldots\ldots\ldots\ldots (8)$$

The results of Poisson model tabulated in Table 10 indicate that the difference between the Poisson Mean (μ) of the all reflectors and all the control is statistically significant, p-value=0.01. This may be due to the control section 20 (trt=20) which is two miles away from each replicate of reflectors on the right side.

Table 11 shows the estimate and the 95 percent confidence interval COM 1. The estimate is -0.20 and the confidence interval is

(-0.36 to -.05)

These values can be translated to expected reductions in vehicle-deer collisions due to reflectors: 1- e-0.36 = 0.30, 1- e-0.05 =0.05 and 1-e0.20 =0.19. The expected reduction is 19% with 95% confidence limits of 5% to 30%.

VII. CONCLUSIONS

The following conclusions were based on the experimental research study:

1. The effects of the reflector color, reflector spacing, median with or without reflectors, single or double reflectors and their interactions are not statistically significant.

2. The effects of the previous year data, 1998, number of deer-kills, are not statistically significant

3. When comparing all combined reflector sites with all combined control sites, the Poisson Regression Analyses indicate that the difference between the Poisson Mean (μ) of the all reflectors sections and all the control sections is statistically significant. The use of reflectors provides an expected reduction in deer-vehicle collisions of 19% with 95% confidence limits of 5% to 30%. Maximum reduction is associated with 100 ft spacing regardless of the reflector color, median with or without reflectors, single or double reflectors.

4. Cost effectiveness of the reduction described above will be behind any decision to use reflectors to reduce vehicle-deer collisions.

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Table 1.

Design of Experiment
For each reflector color

SPACING OF REFLECTORS							
30 m (100 feet)				**45 m (150 feet)**			
SHOULDER REFLECTOR DESIGN				**SHOULDER REFLECTOR DESIGN**			
SINGLE REFLECTOR		***DUAL REFLECTOR***		***SINGLE REFLECTOR***		***DUAL REFLECTOR***	
MEDIAN		**MEDIAN**		**MEDIAN**		**MEDIAN**	
WITH REFLECTOR	***WITHOUT REFLECTOR***	***WITH REFLECTOR***	***WITHOUT REFLECTOR***	***WITH REFLECTOR***	***WITHOUT REFLECTOR***	***WITH REFLECTOR***	***WITHOUT REFLECTOR***
T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**

T1, T2…T8 are the treatment combinations.

Table 2.
The final layout of the Experiment

Control Sections												**Replicate 1**								**Control Sections**			
4	3	2	1	**T5**		**T8**		**T3**		**T1**		**T7**		**T2**		**T6**		**T4**		1	2	3	4
Mile Posts					**T7**		**T3**		**T1**		**T6**		**T4**		**T8**		**T2**		**T5**	Mile Posts			
82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	105	106

							Replicate 2									**Control Sections**			
T3		**T7**		**T5**		**T1**		**T4**		**T6**		**T8**		**T2**		1	2	3	4
	T8		**T1**		**T3**		**T6**		**T2**		**T7**		**T4**		**T5**	Mile Posts			
107	**108**	**109**	**110**	**111**	**112**	**113**	**114**	**115**	**116**	**117**	**118**	**119**	**120**	**121**	**122**	**123**	**124**	**125**	**126**

Note: T1, T2, T8 are the treatments in red colors while T1, T2, … T8 are the treatment combinations in Blue/Green colors.

Table 3. Treatments versus Controls

CONTROLS			REPLICATE=1			CONTROLS					REPLICATE=2				CONTROLS		
TRT	17	18	1 2 3 4 ….16			19	20		17	18	1 2 3 ……16				19	20	TRT
Miles Post	84	85	86	……………	101	102	103	104	105	106	107	………………..	121	122	123	124	Mile Posts

Table 4. Treatment Combinations

SPACE	COLOR (S1) RED	BLUE/GREEN
30 m	*trt1 trt2 trt3 trt4* ***S=1***	*trt9 trt10 trt11 trt12* ***S=3***
45 m	*trt5 trt6 trt7 trt8* ***S=2***	*Trt13 trt14 trt15 trt16* ***S=4***

REFLECTOR	COLOR (S2) RED	BLUE/GREEN
SINGLE	*trt1 trt2 trt5 trt6* ***S=1***	*trt9 trt10 trt13 trt14* ***S=3***
DOUBLE	*Trt3 trt4 trt7 trt8* ***S=2***	*Trt11 trt12 trt15 trt16* ***S=4***

MEDIAN	COLOR (S3) RED	BLUE/GREEN
WITH REFLECTOR	*Trt2 trt4 trt6 trt8* ***S=1***	*Trt10 trt12 trt14 trt16* ***S=3***
WITHOUT REFLECTOR	*Trt1 trt3 trt5 trt7* ***S=2***	*Trt9 trt11 trt13 trt15* ***S=4***

REFLECTOR	SPACE (S4) 30 m	45 m
SINGLE	*trt1 trt2 trt9 trt10* ***S=1***	*Trt5 trt6 trt13 trt14* ***S=3***
DOUBLE	*Trt3 trt4 trt11 trt12* ***S=2***	*Trt7 trt8 trt15 trt16* ***S=4***

MEDIAN	SPACE (S5) 30 m	45 m
WITH REFLECTOR	*Trt2 trt4 trt10 trt12* ***S=1***	*Trt6 trt8 trt14 trt16* ***S=3***
WITHOUT REFLECTOR	*Trt1 trt3 trt9 trt11* ***S=2***	*Trt5 trt7 trt13 trt15* ***S=4***

MEDIAN	REFLECTOR (S6) SINGLE	DOUBLE
WITH REFLECTOR	*Trt2 trt6 trt10 trt14* ***S=1***	*Trt4 trt8 trt12 trt16* ***S=3***
WITHOUT REFLECTOR	*Trt1 trt5 trt9 trt13* ***S=2***	*Trt3 trt7 trt11 trt15* ***S=4***

CONTROLS
TRT17 TRT18 TRT19 TRT20   S=5

Where for example; TRT11= TRT NUMBER 11 etc. as explained in Table 3.

Table 5
Using Poisson Regression Model

Model Information

Data Set	WORK.NEW
Distribution	Poisson
Link Function	Log
Dependent Variable	y
Observations Used	896

Class Level Information

Class	Levels	Values
month	28	5 6 10 11 17 18 22 23 29 30 34 35 41 42 46 47 53 54 58 59 65 66 70 71 77 78 82 83
rep	2	1 2
color	2	1 2
space	2	1 2
ref	2	1 2
median	2	1 2
Rate	4	1 2 4 5

The GENMOD Procedure

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	856	1008.8559	1.1786
Scaled Deviance	856	908.7274	1.0616
Pearson Chi-Square	856	950.3187	1.1102
Scaled Pearson X2	856	856.0000	1.0000
Log Likelihood		-744.8256	

Algorithm converged.

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
rep	1	856	0.47	0.4928	0.47	0.4926
x	1	856	1.42	0.2333	1.42	0.2330
month	27	856	3.28	<.0001	88.61	<.0001
color	1	856	0.20	0.6517	0.20	0.6516
space	1	856	3.69	0.0549	3.69	0.0546
ref	1	856	0.01	0.9160	0.01	0.9160
median	1	856	0.61	0.4369	0.61	0.4367
color*space	1	856	0.60	0.4394	0.60	0.4391
color*ref	1	856	0.75	0.3882	0.75	0.3880
color*median	1	856	0.48	0.4900	0.48	0.4898
space*ref	1	856	0.10	0.7556	0.10	0.7555
space*median	1	856	1.24	0.2657	1.24	0.2654
ref*median	1	856	0.13	0.7144	0.13	0.7143

NOTE: The scale parameter was estimated by the square root of Pearson's Chi-Square/DOF in order to eliminate if there is overdispersion.

Table 6

Negative Binomial Distribution
Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	171	175.6565	1.0272
Scaled Deviance	171	175.6565	1.0272
Pearson Chi-Square	171	195.7538	1.1448
Scaled Pearson X2	171	195.7538	1.1448
Log Likelihood		-156.4281	

Algorithm converged.

Model Information

Data Set	WORK.NEW
Distribution	Poisson
Link Function	Log
Dependent Variable	y
Observations Used	896

Class Level Information

Class	Levels	Values
month	28	5 6 10 11 17 18 22 23 29 30 34 35 41 42 46 47 53 54 58 59 65 66 70 71 77 78 82 83
rep	2	1 2
color	2	1 2
space	2	1 2
ref	2	1 2
median	2	1 2
Rate	4	1 2 4 5

The GENMOD Procedure

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	856	1008.8559	1.1786
Scaled Deviance	856	908.7274	1.0616
Pearson Chi-Square	856	950.3187	1.1102
Scaled Pearson X2	856	856.0000	1.0000
Log Likelihood		-744.8256	

Algorithm converged.

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
rep	1	856	0.47	0.4928	0.47	0.4926
x	1	856	1.42	0.2333	1.42	0.2330
month	27	856	3.28	<.0001	88.61	<.0001

color	1	856	0.20	0.6517	0.20	0.6516
space	1	856	3.69	0.0549	3.69	0.0546
ref	1	856	0.01	0.9160	0.01	0.9160
median	1	856	0.61	0.4369	0.61	0.4367
color*space	1	856	0.60	0.4394	0.60	0.4391
color*ref	1	856	0.75	0.3882	0.75	0.3880
color*median	1	856	0.48	0.4900	0.48	0.4898
space*ref	1	856	0.10	0.7556	0.10	0.7555
space*median	1	856	1.24	0.2657	1.24	0.2654
ref*median	1	856	0.13	0.7144	0.13	0.7143

Table 7. The difference between control and treatment

Model Information

Data Set	WORK.TTR
Distribution	Poisson
Link Function	Log
Dependent Variable	y
Observations Used	1120

Class Level Information

Class	Levels	Values
trt	20	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
month	28	5 6 10 11 17 18 22 23 29 30 34 35 41 42 46 47 53 54 58 59 65 66 70 71 77 78 82 83
Rate	4	1 2 4 5
rep	2	1 2

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
rep	1	1071	0.23	0.6295	0.23	0.6294
x	1	1071	2.43	0.1194	2.43	0.1191
month	27	1071	3.70	<.0001	99.84	<.0001
trt	19	1071	0.90	0.5847	17.08	0.5847

Table 8. Differences of Least Squares Means for Treatments

Effect	trt	_trt	Standard Estimate	Chi- Error	DF	Square	Pr > ChiSq
trt	1	17	-0.1199	0.6630	1	0.03	0.8565
trt	1	18	-0.4523	0.5935	1	0.58	0.4460
trt	1	19	0.4310	0.7732	1	0.31	0.5772
trt	1	20	-0.5645	0.6211	1	0.83	0.3634
trt	2	17	-0.2483	0.6214	1	0.16	0.6894
trt	2	18	-0.5808	0.6440	1	0.81	0.3672
trt	2	19	0.3026	0.7655	1	0.16	0.6926
trt	2	20	-0.6929	0.5682	1	1.49	0.2226
trt	3	17	-0.1203	0.6635	1	0.03	0.8562
trt	3	18	-0.4527	0.5936	1	0.58	0.4457
trt	3	19	0.4306	0.7738	1	0.31	0.5779
trt	3	20	-0.5649	0.6223	1	0.82	0.3640
trt	4	17	-0.6375	0.7012	1	0.83	0.3632
trt	4	18	-0.9700	0.6869	1	1.99	0.1579
trt	4	19	-0.0866	0.8054	1	0.01	0.9143
trt	4	20	-1.0821	0.6597	1	2.69	0.1009
trt	5	17	0.1996	0.5521	1	0.13	0.7178
trt	5	18	-0.1329	0.5747	1	0.05	0.8172
trt	5	19	0.7505	0.7133	1	1.11	0.2927
trt	5	20	-0.2450	0.5004	1	0.24	0.6244
trt	6	17	-0.6393	0.7022	1	0.83	0.3626
trt	6	18	-0.9717	0.6870	1	2.00	0.1572
trt	6	19	-0.0884	0.8074	1	0.01	0.9128
trt	6	20	-1.0839	0.6637	1	2.67	0.1024
trt	7	17	-0.4065	0.6472	1	0.39	0.5299
trt	7	18	-0.7389	0.6667	1	1.23	0.2677
trt	7	19	0.1444	0.7892	1	0.03	0.8548
trt	7	20	-0.8511	0.6036	1	1.99	0.1585
trt	8	17	-0.2485	0.6211	1	0.16	0.6891
trt	8	18	-0.5809	0.6438	1	0.81	0.3669
trt	8	19	0.3024	0.7655	1	0.16	0.6928
trt	8	20	-0.6931	0.5682	1	1.49	0.2225
trt	9	17	-0.4562	0.7250	1	0.40	0.5292
trt	9	18	-0.7886	0.6620	1	1.42	0.2336
trt	9	19	0.0947	0.8268	1	0.01	0.9088
trt	9	20	-0.9008	0.6866	1	1.72	0.1895
trt	10	17	-0.3033	0.6385	1	0.23	0.6348
trt	10	18	-0.6357	0.6215	1	1.05	0.3064
trt	10	19	0.2476	0.7530	1	0.11	0.7423
trt	10	20	-0.7479	0.5968	1	1.57	0.2101
trt	11	17	-0.4576	0.6663	1	0.47	0.4922
trt	11	18	-0.7901	0.6499	1	1.48	0.2241
trt	11	19	0.0933	0.7768	1	0.01	0.9044
trt	11	20	-0.9022	0.6267	1	2.07	0.1500

trt	12	17	-0.0478	0.5991	1	0.01	0.9363
trt	12	18	-0.3803	0.5836	1	0.42	0.5147
trt	12	19	0.5031	0.7169	1	0.49	0.4829
trt	12	20	-0.4924	0.5463	1	0.81	0.3673
trt	13	17	-0.0959	0.6827	1	0.02	0.8882
trt	13	18	-0.4284	0.6706	1	0.41	0.5229
trt	13	19	0.4550	0.5963	1	0.58	0.4455
trt	13	20	-0.5405	0.6326	1	0.73	0.3928

Table 8. (Continued). Difference between control and treatments

Differences of Least Squares Means

Effect	trt	_trt	Estimate	Standard Error	DF	Chi-Square	Pr > ChiSq
trt	14	17	-0.4546	0.6644	1	0.47	0.4938
trt	14	18	-0.7871	0.6497	1	1.47	0.2257
trt	14	19	0.0963	0.7732	1	0.02	0.9009
trt	14	20	-0.8992	0.6195	1	2.11	0.1467
trt	15	17	-0.5862	0.6853	1	0.73	0.3923
trt	15	18	-0.9186	0.7050	1	1.70	0.1926
trt	15	19	-0.0353	0.8190	1	0.00	0.9656
trt	15	20	-1.0308	0.6399	1	2.60	0.1072
trt	16	17	-0.4535	0.6651	1	0.46	0.4954
trt	16	18	-0.7859	0.6511	1	1.46	0.2274
trt	16	19	0.0974	0.7730	1	0.02	0.8997
trt	16	20	-0.8981	0.6182	1	2.11	0.1463

Table 9
Reflectors Treatments versus Controls

The GENMOD Procedure

Model Information

Data Set	WORK.NEW
Distribution	Poisson
Link Function	Log
Dependent Variable	y
Observations Used	1120

Class Level Information

Class	Levels	Values
rep	2	1 2
Group	5	1 17 18 19 20
trt	20	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
month	28	5 6 10 11 17 18 22 23 29 30 34 35 41 42 46 47 53 54 58 59 65 66 70 71 77 78 82 83
Rate	4	1 2 4 5

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	1086	1293.3039	1.1909
Scaled Deviance	1086	1145.0980	1.0544
Pearson Chi-Square	1086	1226.5570	1.1294
Scaled Pearson X2	1086	1086.0000	1.0000
Log Likelihood		-924.1429	

Algorithm converged.

The GENMOD Procedure

LR Statistics For Type 3 Analysis

Source	Num DF	Den DF	F Value	Pr > F	Chi-Square	Pr > ChiSq
rep	1	1086	0.24	0.6233	0.24	0.6232
x	1	1086	2.62	0.1056	2.62	0.1053
month	27	1086	3.74	<.0001	101.00	<.0001
Group	4	1086	2.23	0.0636	8.93	0.0629

Differences of Least Squares Means

Effect	Group	_Group	Estimate	Standard Error	DF	Chi-Square	Pr > ChiSq
Group	1	17	-0.2121	0.1455	1	2.12	0.1450
Group	1	18	-0.1273	0.1510	1	0.71	0.3992
Group	1	19	-0.0707	0.1560	1	0.21	0.6504
Group	1	20	-0.3775	0.1362	1	7.69	0.0056

Group	17	18	0.0848	0.2021	1	0.18	0.6748
Group	17	19	0.1414	0.2064	1	0.47	0.4933
Group	17	20	-0.1654	0.1913	1	0.75	0.3874
Group	18	19	0.0566	0.2103	1	0.07	0.7878
Group	18	20	-0.2502	0.1955	1	1.64	0.2007
Group	19	20	-0.3068	0.1999	1	2.36	0.1248

Table 10.
Comparisons of all reflector treatments to all controls

The GENMOD Procedure

Model Information

Data Set	WORK.NEW
Distribution	Poisson
Link Function	Log
Dependent Variable	y
Observations Used	1120

Class Level Information

Class	Levels	Values
rep	2	1 2
Group	5	1 17 18 19 20
trt	20	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
month	28	5 6 10 11 17 18 22 23 29 30 34 35 41 42 46 47 53 54 58 59 65 66 70 71 77 78 82 83
Rate	4	1 2 4 5
COM	2	1 2

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	1089	1219.8156	1.1201
Scaled Deviance	1089	1219.8156	1.1201
Pearson Chi-Square	1089	1151.5025	1.0574
Scaled Pearson X2	1089	1151.5025	1.0574
Log Likelihood		-1043.9348	

Algorithm converged.

LR Statistics For Type 1 Analysis

Source	2*Log Likelihood	DF	Chi-Square	Pr > ChiSq
Intercept	-2205.3169			
rep	-2205.2755	1	0.04	0.8386
x	-2195.7091	1	9.57	0.0020
month	-2094.4008	27	101.31	<.0001
COM	-2087.8696	1	6.53	0.0106

LR Statistics For Type 3 Analysis

Source	DF	Chi-Square	Pr > ChiSq
rep	1	0.21	0.6503
x	1	2.77	0.0959

month	27	102.29	<.0001
COM	1	6.53	0.0106

Differences of Least Squares Means

Effect	COM	_COM	Estimate	Standard Error	DF	Chi-Square	Pr > ChiSq
COM	1	2	-0.2038	0.0784	1	6.75	0.0094

Table 11. 95% Confidence intervals of the variables

Criteria For Assessing Goodness Of Fit

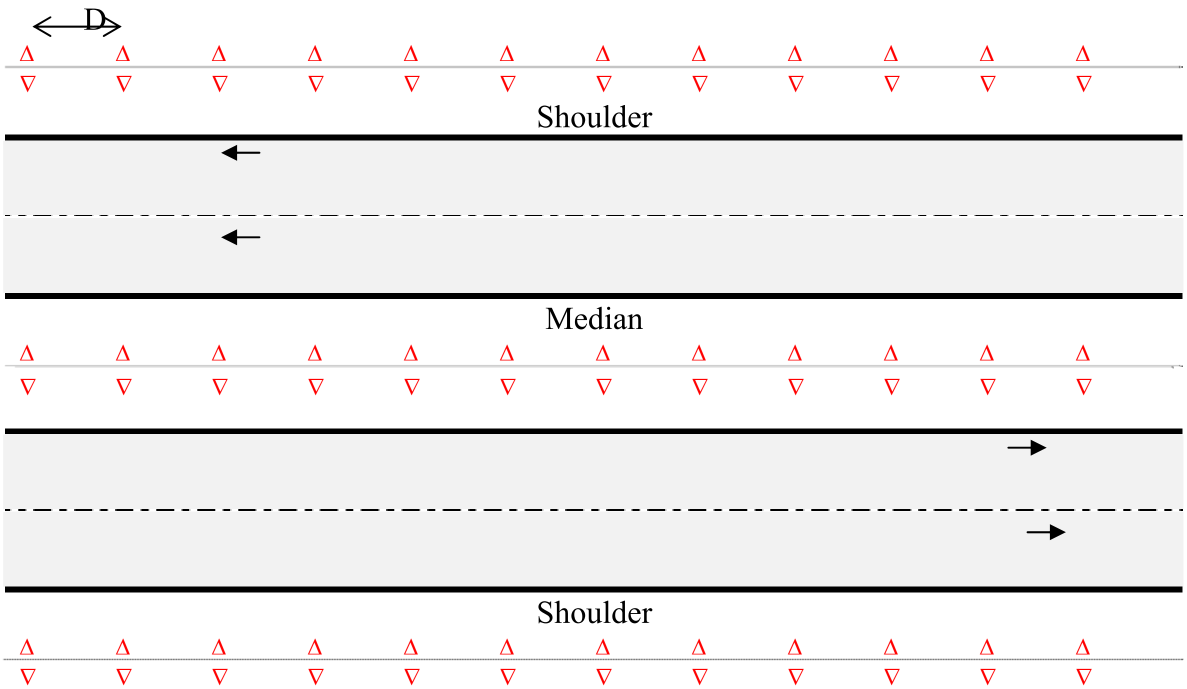
Criterion	DF	Value	Value/DF
Deviance	1089	1219.8156	1.1201
Scaled Deviance	1089	1219.8156	1.1201
Pearson Chi-Square	1089	1151.5025	1.0574
Scaled Pearson X2	1089	1151.5025	1.0574
Log Likelihood		-1043.9348	

Algorithm converged.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		1	-0.2013	0.2063	-0.6056	0.2031	0.95	0.3292
rep	1	1	-0.0305	0.0673	-0.1624	0.1014	0.21	0.6502
rep	2	0	0.0000	0.0000	0.0000	0.0000	.	.
x		1	0.0591	0.0350	-0.0096	0.1277	2.84	0.0918
month	5	1	-0.0780	0.2781	-0.6231	0.4670	0.08	0.7790
month	6	1	-0.9427	0.3600	-1.6483	-0.2371	6.86	0.0088
month	10	1	0.2083	0.2589	-0.2992	0.7157	0.65	0.4212
month	11	1	0.0645	0.2620	-0.4489	0.5780	0.06	0.8055
month	17	1	0.2726	0.2566	-0.2303	0.7756	1.13	0.2881
month	18	1	-0.4496	0.3070	-1.0513	0.1521	2.14	0.1431
month	22	1	0.1205	0.2640	-0.3971	0.6380	0.21	0.6482
month	23	1	0.2852	0.2498	-0.2043	0.7748	1.30	0.2535
month	29	1	0.2188	0.2597	-0.2902	0.7278	0.71	0.3995
month	30	1	-0.5068	0.3123	-1.1189	0.1053	2.63	0.1046
month	34	1	0.4817	0.2452	0.0010	0.9624	3.86	0.0495
month	35	1	0.6062	0.2357	0.1442	1.0682	6.61	0.0101
month	41	1	0.0986	0.2667	-0.4242	0.6214	0.14	0.7116
month	42	1	0.1265	0.2645	-0.3919	0.6449	0.23	0.6324
month	46	1	-0.7062	0.3315	-1.3559	-0.0566	4.54	0.0331
month	47	1	0.3812	0.2452	-0.0993	0.8618	2.42	0.1199
month	53	1	0.3538	0.2528	-0.1416	0.8493	1.96	0.1616
month	54	1	0.5510	0.2430	0.0747	1.0272	5.14	0.0234
month	58	1	0.5056	0.2444	0.0265	0.9847	4.28	0.0386
month	59	1	0.3829	0.2452	-0.0976	0.8634	2.44	0.1183
month	65	1	-0.1169	0.2808	-0.6673	0.4335	0.17	0.6772
month	66	1	-0.1206	0.2805	-0.6704	0.4293	0.18	0.6674
month	70	1	0.0541	0.2679	-0.4709	0.5792	0.04	0.8398
month	71	1	0.5297	0.2387	0.0618	0.9975	4.92	0.0265
month	77	1	0.3786	0.2515	-0.1144	0.8715	2.27	0.1323
month	78	1	0.2952	0.2549	-0.2045	0.7949	1.34	0.2469
month	82	1	0.7482	0.2348	0.2881	1.2084	10.16	0.0014
month	83	0	0.0000	0.0000	0.0000	0.0000	.	.
COM	1	1	-0.2038	0.0784	-0.3576	-0.0501	6.75	0.0094
COM	2	0	0.0000	0.0000	0.0000	0.0000	.	.
Dispersion		1	0.0799	0.0520	0.0223	0.2863		

Figure 1. Typical Reflector Installation
Dual shoulder and dual median reflectors (T3 or T7)



LEGEND:
……… Reflector Line
∆ Reflector
D = Distance between reflectors; 30 or 45 meters

Figure 2. Typical Reflector Installation
Dual shoulder and no median reflectors (T4 or T8)

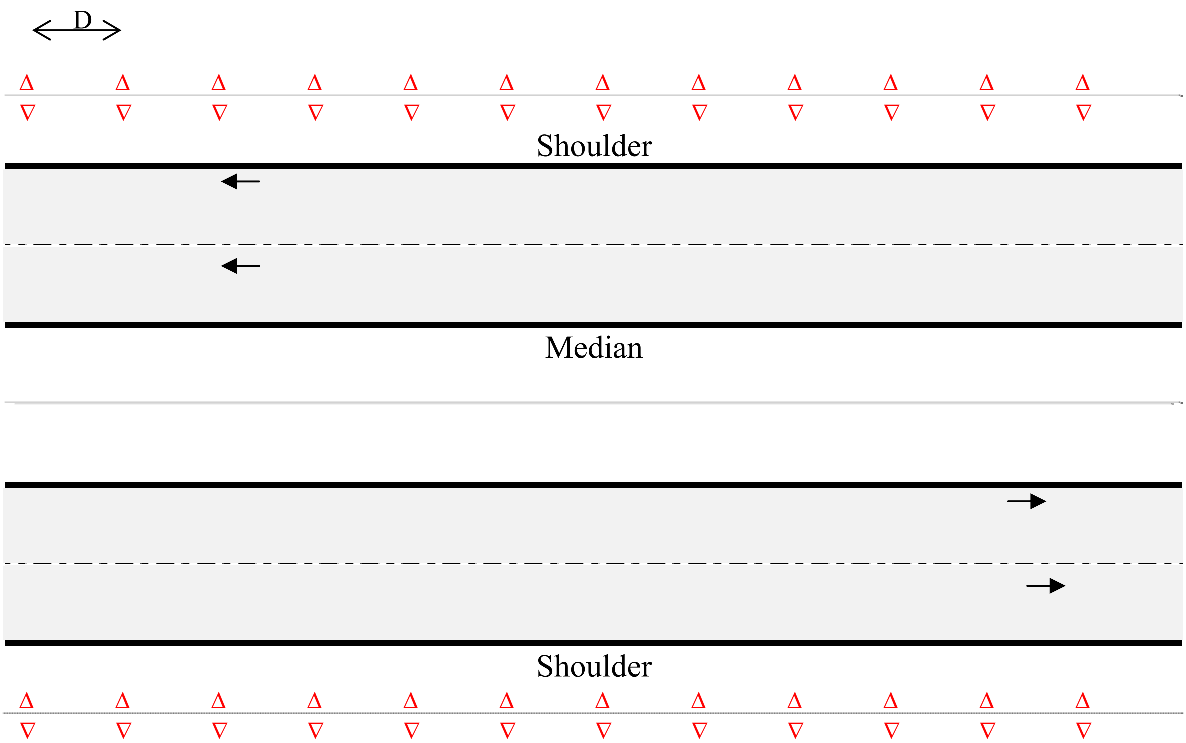


Figure 3. Typical Reflector Installation

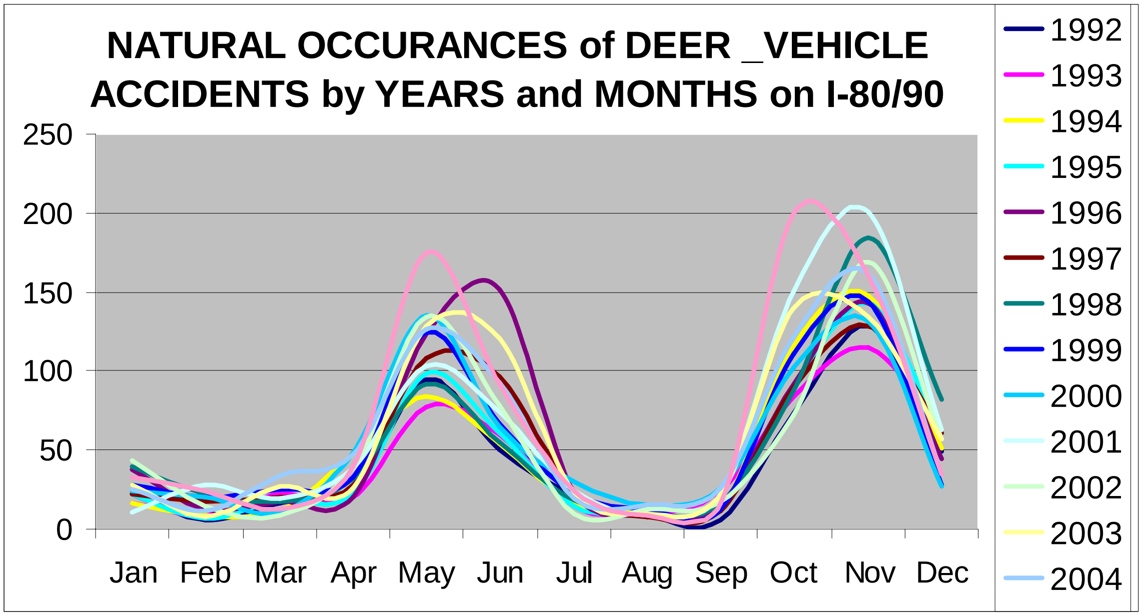
Single shoulder and dual median reflectors (T1 or T5)

Figure 4. Typical Reflector Installation

Single shoulder and no median reflectors (T2 or T6)

Figure 5. Single and Double Reflectors

Figure 6. The number of deer-kills along the test sections by months.



Accumulative Deer Kill Reports on Toll Road

Year	J	F	M	A	M	J	J	A	S	O	N	D	Total
1992	22	6	16	24	95	50	21	9	6	73	128	49	499
1993	16	9	22	20	77	60	14	10	24	84	115	62	513
1994	16	9	12	47	84	54	16	11	13	116	148	51	577
1995	22	7	18	22	98	61	14	10	14	89	143	61	559
1996	38	13	17	20	124	152	23	9	15	92	143	44	690
1997	22	17	20	28	108	97	23	8	12	90	128	61	614
1998	40	22	17	32	92	55	18	10	16	88	184	82	656
1999	28	20	25	33	125	67	22	13	13	111	144	28	629
2000	24	20	11	48	135	65	30	15	26	102	131	27	634
2001	11	28	19	39	103	74	24	9	22	151	201	63	744
2002	43	14	9	39	134	78	10	13	17	72	169	57	655
2003	28	8	27	26	128	121	23	10	21	140	134	57	723
2004	25	12	34	47	126	93	19	15	26	122	161	35	715
2005	33	24	13	40	175	92	24	9	16	200	160	35	821

Figure 7. The number of deer killed along the mile posts for the months April, May, October and November.