Development of Crash Reduction Factors for Overhead Flashing Beacons at Rural Intersections In North Carolina

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ABSTRACT

The purpose of this project is to develop crash reduction factors for overhead flashing beacons at rural two-way stop sign controlled intersections in North Carolina. Overhead flashing beacons are a common countermeasure used in North Carolina to help alleviate crash problems at intersections where drivers have difficulty recognizing the stop control condition. The goal of this analysis is to develop crash reduction factors that reflect North Carolina conditions and decision-making.

A total of 34 treatment sites were chosen for analysis in this project. Each of the treatment sites was a rural, four-leg intersection with no turn lanes and two-way stop control. Each of the treatment sites had at least three years of after period crash data available.

Several different methodologies were used to calculate the crash reduction factors. The biggest threats to the validity of the analysis that must be accounted for at the 34 treatment sites in this study were regression to the mean and the increase in traffic volumes. Regression to the mean is a significant threat because each of the treatment sites was chosen for treatment because of its crash history. The increase in traffic volumes was also a concern because of the long duration of before and after periods at each of the sites.

Empirical Bayes before and after techniques were utilized to overcome the regression to the mean threat. One hundred and seventy reference sites were chosen and the method of sample moments was carried out to calculate the necessary parameters. A linear assumption was used to account for the increase in traffic flow. On the average, all categories of crashes studied decreased in the after period.

INTRODUCTION

The purpose of this project was to develop crash reduction factors for overhead flashing beacons at rural two-way stop sign controlled intersections in North Carolina. Overhead flashing beacons are a common countermeasure used in North Carolina to help alleviate crash problems at intersections where drivers have difficulty recognizing the stop control condition.

LITERATURE REVIEW

There are relatively few studies that have been completed regarding the use of overhead flashing beacons. Cribbins and Walton (*1*) conducted a study looking at the installation of overhead flashing beacons on rural North Carolina roadways in 1970. One year of before and after crash data at eleven four-leg intersections was considered. The main focus was placed on comparing before and after estimated property damage only (EPDO) crash rates. The study found that on average, the installation of a flashing beacon at four-leg intersections reduced the EPDO rate. A naïve before and after look at the total crash data shows a reduction in total crashes of 18%.

The Kentucky Transportation Center produced a study in 1996 entitled *Development of Accident Reduction Factors (2)*. This document recommends a reduction factor of 30% for total crashes be used for flashing beacons at intersections. This recommendation is based on a survey of 18 states that used crash reduction factors for intersection flashers and available research publications on this topic.

The previous studies that have been completed regarding overhead flashing beacons are fairly old and were conducted using older methodologies. The purpose of this project is to evaluate the effects of overhead flashing beacons using current methodologies on North Carolina specific data.

METHODOLOGY

Treatment Sites

Treatment sites were picked from Spot Safety projects developed and funded within the North Carolina Department of Transportation (NCDOT). Spot Safety projects are relatively low cost projects that are aimed at treating locations with defined safety problems. All efforts were made to obtain as homogeneous a sample as possible. The criteria for selecting treatment sites are listed below:

- Rural location
- Intersection of two, two-lane roads
- No turn lanes
- Two-way stop sign control
- At least three years of 'after' crash data available

Each treatment site was field inspected to ensure these criteria were met. Figure 1 shows what a typical treatment site might look like. Table 1 shows location and crash information for each of the 34 treatment sites chosen.

FIGURE 1 Typical Treatment Site

TABLE 1 Treatment Site Crash Data

Site	County	Location Description	Before Period							After Period						
			Years	Begin	End	ADT	Total Crashes	Injury Crashes	Frontal Impact Crashes	Years	Begin	End	ADT	Total Crashes	Injury Crashes	Frontal Impact Crashes
1	Wake	SR 1010 (Ten Ten) at SR 2727 (Crowder / Sauls)	4.3	9/1/1995	12/31/1999	13,000	20	9	15	4.3	4/1/2000	7/31/2004	14,000	21	9	16
2	Vance	SR 1519 (Vicksboro) at SR 1533 (Carey Chapel / Rock Mill)	3.8	11/1/1996	7/31/2000	6,400	25	16	16	3.8	11/1/2000	7/31/2004	9,300	11	6	3
3	Johnston	NC 96 at SR 1934 (Old Beulah)	5.6	4/1/1993	10/31/1998	3,600	37	26	36	5.6	2/1/1999	8/31/2004	4,700	32	22	30
4	Johnston	NC 96 at SR 1178 (Keene)	5.5	6/1/1993	11/30/1998	2,500	9	6	9	5.5	3/1/1999	8/31/2004	2,900	6	3	6
5	Johnston	NC 210 at SR 1330	4.5	6/1/1995	11/30/1999	6,300	7	7	6	4.5	3/1/2000	8/31/2004	6,500	7	4	7
6	Yadkin	US 601 at SR 1002 (Lone Hickory) / SR 1733 (Old Stage)	7.0	7/1/1990	6/30/1997	7,200	16	8	8	7.0	10/1/1997	9/30/2004	7,600	10	6	5
7	Cabarrus	SR 1006 (Mt. Pleasant) at SR 2408 (Gold Hill)	4.6	4/1/1995	10/31/1999	3,800	7	3	6	4.6	2/1/2000	8/31/2004	6,100	2	2	2
8	Cabarrus	NC 200 at SR 1006 (Mt. Pleasant)	3.9	8/1/1996	6/30/2000	4,100	6	5	6	3.9	10/1/2000	8/31/2004	4,700	5	2	4
9	Harnett	SR 1703 (Red Hill Church) at SR 1725 (Ashe)	6.2	3/1/1992	4/30/1998	5,100	29	16	23	6.2	8/1/1998	9/30/2004	6,100	24	11	23
10	Hoke	SR 1202 (Fulford-McMillan) at SR 1203 (Turnpike)	4.4	9/1/1995	1/31/2000	2,100	6	6	6	4.4	5/1/2000	9/30/2004	1,800	1	0	1
11	Rowan	SR 1944 (Ridge) at SR 2048 (Woodleaf)	6.9	9/1/1990	7/31/1997	6,700	26	19	22	6.9	11/1/1997	9/30/2004	9,100	22	14	20
12	Polk	NC 9 at SR 1159	4.8	11/1/1994	7/31/1999	3,200	6	4	5	4.8	11/1/1999	7/31/2004	3,600	7	3	2
13	Warren	US 158 at SR 1305 (Warren Plains)	4.4	6/1/1995	10/31/1999	4,100	10	7	9	4.4	3/1/2000	7/31/2004	5,500	15	6	13
14	Granville	US 15 at SR 1103 (Gate 2) / SR 1728 (Cash)	4.3	2/1/1995	5/31/1999	7,400	23	14	20	4.3	11/1/1999	2/28/2004	10,100	27	15	23
15	Greene	US 13 at SR 1210	7.0	2/1/1990	1/31/1997	4,500	9	3	6	7.0	6/1/1997	5/31/2004	4,900	16	8	11
16	Nash	NC 97 at SR 1001 (Strickland Crossing)	4.5	3/1/1995	8/31/1999	4,200	19	9	12	4.5	2/1/2000	7/31/2004	4,800	16	12	14
17	Nash	SR 1001 at SR 1717 (Taylor's Crossroads)	4.5	3/1/1995	8/31/1999	3,600	10	6	10	4.5	2/1/2000	7/31/2004	4,200	10	7	8
18	Wayne	SR 1534 (Big Daddy) at SR 1543 (Lancaster)	6.2	12/1/1991	1/31/1998	3,400	13	8	13	6.2	6/1/1998	7/31/2004	3,900	7	5	7
19	Surry	NC 268 at SR 1003 (Siloam)	3.0	6/1/1998	5/31/2001	5,400	11	5	10	3.0	9/1/2001	8/31/2004	5,600	6	3	5
20	Alleghany	US 221 at NC 113	7.2	1/1/1990	2/28/1997	860	9	8	9	7.2	6/1/1997	7/31/2004	1,100	7	6	5
21	Union	US 601 at SR 1004 / SR 1612 (Lawyers)	6.5	4/1/1991	9/30/1997	6,200	13	10	10	6.5	2/1/1998	7/31/2004	9,700	12	6	9
22	Cumberland	SR 1006 (Clinton) at SR 1835 (Rockhill)	6.4	6/1/1991	10/31/1997	5,200	29	17	24	6.4	3/1/1998	7/31/2004	6,700	32	18	30
23	Harnett	NC 55 at SR 1532 (Oak Grove Church / Langdon)	5.9	6/1/1992	4/30/1998	6,600	15	12	14	5.9	9/1/1998	7/31/2004	7,700	9	3	7
24	Alamance	NC 49 at SR 1157 (Whites Kennel) / SR 2317 (Monroe Holt)	5.8	9/1/1992	6/30/1998	7,900	18	7	13	5.8	10/1/1998	7/31/2004	8,700	15	8	9
25	Rowan	SR 1002 (Old Concord) at SR 1221 (Old Beatty)	7.6	1/1/1990	7/31/1997	5,000	27	21	24	7.6	11/1/1997	5/31/2005	9,300	37	21	35
26	Johnston	NC 210 at SR 1309 (Old Fairground Church)	6.3	12/1/1990	2/28/1997	4,300	21	11	17	6.3	7/1/1997	9/30/2003	6,500	30	14	20
27	Wayne	NC 111 at SR 1754 (Zion Church)	6.3	9/1/1990	11/30/1996	2,800	8	2	7	6.3	5/1/1997	7/31/2003	3,800	9	7	6
28	Johnston	NC 231 at NC 222 / SR 2105 (Buck)	6.4	7/1/1990	11/30/1996	1,800	8	6	8	6.4	4/1/1997	8/31/2003	2,600	14	8	12
29	Wayne	NC 55 at SR 1948 (Camp Jubilee)	5.8	4/1/1992	12/31/1997	3,400	28	14	20	5.8	4/1/1998	12/31/2003	4,700	26	19	22
30	Wayne	NC 111 (Patetown) at SR 1571 (Tommy's)	3.5	5/1/1994	10/31/1997	7,480	23	13	17	3.5	3/1/1998	8/31/2001	8,830	17	12	13
31	Johnston	US 301 at SR 2141 (Bizzell Grove Ch) / Oak Grove Inn	6.0	12/1/1991	11/30/1997	4,000	23	12	15	6.0	5/1/1998	4/30/2004	5,800	7	5	4
32	Rutherford	NC 226 at SR 1733 (Jonestown) / SR 1006 (Bostic Sunshine)	5.0	11/1/1992	10/31/1997	3,100	8	5	7	5.0	4/1/1998	3/31/2003	2,900	6	5	5
33	Orange	SR 1716 (Murphy Sch) at SR 1713 (Mt Herman Ch) / SR 1841 (Cornwallis)	6.7	3/1/1992	10/31/1998	1,550	6	3	6	6.7	2/1/1999	9/30/2005	2,800	7	4	7
34	Union	SR 1154 / SR 2139 (Griffith) at SR 2146 (Plyer Mill)	4.3	11/1/1996	2/28/2001	3,600	9	5	9	4.3	6/1/2001	9/30/2005	4,500	9	3	8

Finding Crash Data

A Crash analysis was performed at each location utilizing the Traffic Engineering Accident Analysis (TEAAS) software developed by NCDOT's Traffic Engineering Branch. The software accesses the North Carolina Traffic Records Database which contains all reported crashes in the State since 1990. The time periods for each location varied depending on when the flasher was installed and, in some cases, when other countermeasures at the treatment sites were installed. At several locations the flashers were replaced with fully actuated traffic signals. The crash analyses were terminated before any other known countermeasures were implemented. Table 1 provides a listing of before and after crash data at each site.

Naïve Before and After Analysis

The basic premise behind the naïve before and after analysis is that nothing changed from the before period to the after period except for the treatment, and that any changes can be attributed to the treatment. Hauer (*3*) lists five groups of factors that make the naïve assumption questionable. Each group of factors is listed below along with comments regarding its applicability to this study:

- Traffic, weather, road user behavior, vehicle fleet, and many other factors change autonomously over time. Therefore, the change in safety from 'before' and 'after' surely reflects the effect of change in all the factors, in addition to whatever is due to the treatment.

  Comments: Several of these factors have certainly changed from the 'before' to 'after' periods at these treatment sites. Traffic volumes, in fact, have changed significantly at most of the sites. The naïve before and after analysis does not take this into account.

- Besides the treatment of interest, various other treatments, programs and treatments may have been implemented at various times during the 'before' or 'after' periods.

  Comments: Local enforcement programs, speed limit changes, and sign replacements or upgrades are possible changes that have occurred at some of the sites. The investigator is not aware of any of these types of changes occurring, but because of the difficulty in tracking these changes, they can not be ruled out.

- The count of Property Damage Only accidents is affected by the cost of repairs which change gradually over time. Occasionally the accident count changes suddenly because of adjustments to the reportability limit.

  Comments: The minimum property damage threshold for a reportable crash in North Carolina was raised from $500 to $1000 on January 1, 1996. For this particular study, all reported crashes were used. An analysis of this issue on a statewide basis *concludes reported crashes did not experience a significant change around the period where the reportable threshold was raised (4).*

- The probability of accidents being reported may be changing with time.

  Comments: There is no knowledge that this has occurred at any large-scale level in North Carolina during the study period.

- The entities may have been chosen for treatment because they had unusually many or few accidents in the past. If so, because the past accident history is 'unusual' one can hardly hope that the 'unusual' is a good basis for predicting what would be expected in the future had the treatment not been applied.

  Comments: This is definitely a concern when applying naïve before and after methodologies in a study such as this. All the treatment sites were selected because of a pattern of correctable crashes. The treatment sites were not selected at random.

As noted above, there are several concerns with the use of a naïve before and after analysis. The results of the naïve before and after analysis are shown in Table 2 below for completeness and for use as a building block for subsequent analysis. Conventional Hauer (*3*) symbology and methodology was used.

TABLE 2 Parameter Estimates for Naïve Before and After Analysis

Total Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	482	$\sigma\{\lambda\}$	22
π	534	$\sigma\{\pi\}$	23
θ	0.90	$\sigma\{\theta\}$	0.06
Injury Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	277	$\sigma\{\lambda\}$	17
π	323	$\sigma\{\pi\}$	18
θ	0.85	$\sigma\{\theta\}$	0.07
Severe Injury Crashes			
λ	21	$\sigma\{\lambda\}$	5
π	60	$\sigma\{\pi\}$	8
θ	0.34	$\sigma\{\theta\}$	0.09
Frontal Impact Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	392	$\sigma\{\lambda\}$	20
π	438	$\sigma\{\pi\}$	21
θ	0.89	$\sigma\{\theta\}$	0.06
"Ran Stop Sign" Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	52	$\sigma\{\lambda\}$	7
π	103	$\sigma\{\pi\}$	10
θ	0.50	$\sigma\{\theta\}$	0.08

Where:

λ = Actual number of after period crashes
π = Predicted number of after period crashes
θ = Ratio of what safety was with the treatment to what it would have been without the treatment (Index of effectiveness)

The results of the naïve before and after analysis yield a 10% (+/- 6%) reduction in total crashes, a 15% (+/- 7%) reduction in injury crashes, a 66% (+/- 9%) reduction in severe injury crashes, an 11% (+/- 6%) reduction in frontal impact crashes, and a 50% (+/- 8%) reduction in "ran stop sign" crashes.

The value after the "+/-" notation indicates the standard deviation of the estimated crash reduction value. This is the conventional reporting format as used in the Hauer (3) book.

It should be noted that a "ran stop sign" crash is defined as a crash in which the investigating officer noted the vehicle did not stop at the stop sign or it could be reasonably inferred that the vehicle did not stop at the stop sign. This was determined through a manual review of each crash report. If there was question as to whether the vehicle ran the stop sign or not, the speeds at impact were reviewed. If the vehicle on the stop approach had an impact speed of greater than 20 mph at the time of the collision, the crash was considered a "ran stop sign" crash.

Severe injury crashes are defined as those crashes having a severity of Fatal or A Injury. A crash is rated by the most severe injury involved in the incident. If a crash had eight people involved and seven people sustained C type injuries and one person sustained type A injuries, the crash is recorded as an A Injury crash. In North Carolina, a Fatal Injury is defined as an injury that results in death within 12 months after the crash occurred. An A Injury is defined as an injury that is obviously serious enough to prevent the injured person from performing his or her normal activities for at least one day beyond the day of the crash. Massive loss of blood, broken bone, and unconsciousness of more than momentary duration are examples.

Before and After Analysis using a Safety Performance Function

Using the naïve before and after analysis as a building block, a safety performance function was used to predict the number of crashes at each site based on the traffic volumes. The safety performance function used in this analysis was taken from work by Vogt and Bared (5) on the development of crash models for two-lane rural roads. One product of their work was the development of crash models for four leg stop controlled intersections. These models are well respected and have been used in the Interactive Highway Safety Design Model (IHSDM). The model for predicting crashes at rural, four leg stop controlled intersections is:

$$N = C_i \, e^{(-9.34 + 0.60 \ln(ADT1) + 0.61 \ln(ADT2))}$$

Where:

ADT1 = Average Daily Volume on Major Road
ADT2 = Average Daily Volume on Minor Road
C_i = Calibration Factor Based on Local Crash Data

It should be noted that the model was developed with crash data from the State of Minnesota. The Minnesota study considered all crashes within 250 feet of an intersection on the major approach and 100 feet on the minor approach. The North Carolina crash data used in this study includes all crashes within 150 feet of any approach to the intersection. Obviously there are also significant differences between North Carolina and Minnesota in climate, driver population, and crash reporting practices. These differences were accounted for by calibrating the model with North Carolina crash data. The calibration procedure in the Vogt and Bared (5) document recommends at least 100 intersections be used to calibrate the model for a particular state. This study considered 170 four leg, stop controlled intersections (same locations as were used for reference sites in the Emperical Bayes method discussed later). The value of the calibration factor is 1.86 as calculated following the procedure in the Vogt and Bared (5) document.

The results of the before and after analysis using a calibrated safety performance function to adjust for changes in traffic volume are shown in Table 3 below. The safety performance function is only applicable to total crashes.

TABLE 3 Parameter Estimates for Before and After Analysis Using a Calibrated Safety Performance Functions

Total Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	482	$\sigma\{\lambda\}$	22
π	426	$\sigma\{\pi\}$	21
θ	1.13	$\sigma\{\theta\}$	0.07

The results using the safety performance function analysis method yield a 13% (+/- 7%) increase in total crashes.

Empirical Bayes Method

The Empirical Bayes before and after analysis is necessary for this project because of the threat of regression to the mean. Regression to the mean is the presumption that a site will return to its long-term mean crash frequency after an extraordinarily high or low period. This phenomenon is a significant threat to the treatment sites due to the fact that the sites were picked because of the crash history. It should be noted that the Empirical Bayes before and after analysis does not take into account the change in traffic volume that was experienced at the treatment sites.

The basic idea behind the Empirical Bayes approach is that two separate pieces of information are used to estimate the safety of a certain entity. The two pieces of information are the crash history of the entity in question and what is known about the safety of other entities with similar traits (*3*). This requires the use of reference sites. The criteria used for selecting reference sites were:

- Rural location
- Intersection of two two-lane roads
- No turn lanes
- Two-way stop sign control with no flashers

This is basically the same criteria that were used for selecting the treatment sites. One hundred and seventy reference sites were chosen from the same counties as the treatment sites. Five reference sites were chosen for each treatment site.

Crash data for the reference sites were compiled separately for each of the 34 treatment sites' unique 'before' period begin and end study dates. Table 4 shows the results of the Empirical Bayes analysis.

TABLE 4 Parameter Estimates for Before and After Analysis Using Empirical Bayes Methods

Total Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	482	$\sigma\{\lambda\}$	22
π	420	$\sigma\{\pi\}$	17
θ	1.14	$\sigma\{\theta\}$	0.07
Injury Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	277	$\sigma\{\lambda\}$	17
π	230	$\sigma\{\pi\}$	12
θ	1.20	$\sigma\{\theta\}$	0.09
Severe Injury Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	21	$\sigma\{\lambda\}$	5
π	26	$\sigma\{\pi\}$	3
θ	0.81	$\sigma\{\theta\}$	0.19
Frontal Impact Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	392	$\sigma\{\lambda\}$	20
π	329	$\sigma\{\pi\}$	15
θ	1.19	$\sigma\{\theta\}$	0.08
"Ran Stop Sign" Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	52	$\sigma\{\lambda\}$	7
π	52	$\sigma\{\pi\}$	4
θ	0.98	$\sigma\{\theta\}$	0.16

The results of the Empirical Bayes analysis method yield a 14% (+/- 7%) increase in total crashes, a 20% (+/- 9%) increase in injury crashes, a 19% (+/- 19%) decrease in severe injury crashes, a 19% (+/- 8%) increase in frontal impact crashes, and a 2% (+/- 16%) reduction in "ran stop sign" crashes.

Empirical Bayesian With Consideration for Traffic Increase

As discussed in the earlier section, the Empirical Bayes analysis was used to account for regression to the mean at the treatment sites. The Empirical Bayes analysis did not account for the increase in volume. The analysis periods for the treatment sites were between 3 and 8 years. The length of the analysis periods also meant that there was a significant change in traffic volume between the before and after periods. The average change in volume at the treatment sites was approximately 27%. To account for the increase in traffic volumes, a linear assumption was made because there was no feasible way known to the authors to combine the use of the safety performance function described above with the Empirical Bayes method. The safety performance function is also limited because it is only applicable to total crashes. Table 5 shows the results from combining the Empirical Bayes analysis with the traffic volume adjustment factor.

TABLE 5 Parameter Estimates for Before and After Analysis Using Empirical Bayes Methods With Consideration for Traffic Increase

Total Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	482	$\sigma\{\lambda\}$	22
π	548	$\sigma\{\pi\}$	28
θ	0.88	$\sigma\{\theta\}$	0.06
Injury Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	277	$\sigma\{\lambda\}$	17
π	301	$\sigma\{\pi\}$	21
θ	0.91	$\sigma\{\theta\}$	0.08
Severe Injury Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	21	$\sigma\{\lambda\}$	5
π	33	$\sigma\{\pi\}$	7
θ	0.60	$\sigma\{\theta\}$	0.17
Frontal Impact Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	392	$\sigma\{\lambda\}$	20
π	430	$\sigma\{\pi\}$	25
θ	0.91	$\sigma\{\theta\}$	0.07
"Ran Stop Sign" Crashes			
Estimates of Parameters		Estimates of Standard Deviations	
λ	52	$\sigma\{\lambda\}$	7
π	69	$\sigma\{\pi\}$	10
θ	0.74	$\sigma\{\theta\}$	0.14

The results of the Empirical Bayes analysis method with consideration for traffic increase yielded a 12% (+/- 6%) decrease in total crashes, a 9% (+/- 8%) decrease in injury crashes, a 40% (+/- 17%) decrease in severe injury crashes, a 9% (+/- 7%) decrease in frontal impact crashes, and a 26% (+/- 14%) reduction in "ran stop sign" crashes.

FINAL COMMENTS

The recommended crash reduction factors for use with overhead flashing beacon installations at rural four-leg stop control intersections are the factors calculated by the Empirical Bayes method with consideration for traffic increase. This was the method that accounted for the most serious threats to the validity of the analysis in the best possible way. The recommended crash reduction factors are:

Total Crashes	-12%
Injury Crashes	-9%
Severe Injury Crashes	-40%
Frontal Impact Crashes	-9%
"Ran Stop Sign" Crashes	-26%

The overhead flashing beacon sites studied in this report did not perform as well as anticipated at their time of implementation. The severe injury and "ran stop sign" crash categories seemed to benefit the most from the flasher installation, as expected. Project documentation suggests that some flashing beacons were installed as a reaction to high profile, severe injury "ran stop sign" type crashes. Overhead flashing beacons address these types of crashes fairly well, but these crash types were generally not the predominant pattern of crashes at each site. It is logical that "ran stop sign" crashes would see a significant decrease due to the flasher, which provides increased warning to the driver that a stop condition exists. It is also logical that the severe injury crashes would see a decrease as drivers on the stop approach are made more aware of the stop condition and drivers on the mainline are alerted to the presence of an intersection by the flasher. This may indicate that drivers on the mainline approach used more caution and perhaps reduced their speed as they proceeded through the intersection. However, for a relatively expensive countermeasure (approximately $20,000 to install plus recurring operations and maintenance costs), the overall crash reduction is rather disappointing.

It should be noted that this project only considered rural, four-leg stop control intersections with no turn lanes in North Carolina. There is currently a pooled-fund study being coordinated by the Federal Highway Administration (FHWA) involving 26 states that will take a more comprehensive look at the crash effects of overhead flashing beacons at intersections.

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