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16. Abstract

This report provides information on year 2 activities for TxDOT Project 0-4048 including: characteristics of animal crashes and potential treatments; additional insight into characteristics of crashes on low-volume, rural two-lane highways using information provided by officers in their crash narratives; a methodology for conducting before-and-after studies; and findings for before-and-after evaluations performed at four sites. Approximately 3800 animal crashes occurred on Texas on-system, rural highways in 1999. Animal crashes are most likely to occur at night; are more common during October, November, and December; and usually involve deer or cows. A study in four selected Texas counties revealed driver inattention was a factor in 25 percent of all crashes. Other predominant factors were failure to control speed, failure to yield right-of-way, unsafe speeding, and faulty evasive action. The before-and-after methodology used in this project involves a 16-step process in which researchers gathered, reduced, and analyzed information on site characteristics, crash and volume history, and improvement details. The success of this process is dependent on a variety of individuals such as researchers, survey respondents, record keepers, and their respective staffs. Before-and-after evaluations performed at four sites with improvements produced mixed results on definitive measures of effectiveness. Some improvements appeared to be effective at reducing crashes, while others had too few crashes or too little traffic volume (or both) during the study period to make a conclusive determination.

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ADDITIONAL CHARACTERISTICS OF CRASHES ON RURAL TWO-LANE HIGHWAYS

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Kay Fitzpatrick, P.E. (TX-86762) and Marcus A. Brewer prepared the report. The engineer in charge of the project was Kay Fitzpatrick.

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As part of a project entitled "Low-Cost Design Safety Improvements for Rural Highways," the Texas Transportation Institute performed the research reported herein. The research was sponsored by the Texas Department of Transportation in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

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CHAPTER 1

INTRODUCTION

The majority of the highway system in Texas, as well as the United States, consists of two- and three-lane rural roads. A substantial mileage of these roads carries relatively low traffic volumes. These low-volume rural roadways generally have high speeds, and crashes can be severe due to the high speeds. Because of the low volume and relatively low crash frequency on these sections, it is often not cost-effective to perform high-cost treatments to reduce crashes. To address these concerns, the Texas Department of Transportation (TxDOT) sponsored Project 0-4048 with the following objectives:

- Identify common types of crashes on low-volume roadways (less than 2000 average daily traffic [ADT]).
- Identify potential low-cost safety improvements for low-volume rural Texas roadways.
- Investigate the effectiveness of selected low-cost safety improvements.

During the project, researchers developed the following documents to provide transportation practitioners with information on crash characteristics for rural roads in Texas:

- *Characteristics of and Potential Treatments for Crashes on Low-Volume, Rural Two-Lane Highways in Texas*, FHWA/TX-02/4048-1, Draft, October 2001 (*1*).
- *Treatments for Crashes on Rural Two-Lane Highways in Texas*, FHWA/TX-02/4048-2, Draft, April 2002 (*2*).

Report 4048-1 discussed information from the initial year of the project. It provided information on:

- types of crash treatments being used in Texas and in other states,
- characteristics of vehicle crashes on low-volume, rural two-lane highways,

- evaluation of the differences in crashes between counties in the eastern and western portions of the state, and
- findings from the literature review on the types and effectiveness of crash treatments.

In year 2 of the project, researchers developed Report 4048-2. It presented discussion on low-cost safety treatments used on highways and at intersections, along with their known effectiveness. The report also included experiences with selected treatments in Texas, including whether the treatment would be considered elsewhere. The document was developed to provide transportation practitioners with information on crash characteristics for rural roads in Texas. It will be produced in a three-ring binder to allow easy additions or changes as new or updated information is available on the effectiveness of crash treatments.

This report, Report 4048-3, provides information on other year 2 activities within the project including:

- characteristics of animal crashes and potential treatments,
- additional insight into characteristics of crashes on low-volume, rural two-lane highways using information provided by officers in their crash narratives,
- methodology for conducting before-and-after studies, and
- findings for before-and-after evaluations performed at four sites.

CHAPTER 2

ANIMAL CRASHES

CHARACTERISTICS OF ANIMAL CRASHES

Nationally, it has been estimated that over 1.5 million deer-vehicle crashes (DVC) occur annually (but that only about 50 percent of these are actually reported), and that the vehicle damage cost from those reported DVCs is over 1.1 billion dollars (*3*). Table 1 lists the number of deer-vehicle crashes reported in Wisconsin, Minnesota, Michigan, Illinois, and Iowa. These states are the founding members of the Deer-Vehicle Crash Information Clearinghouse. In the Upper Midwest, DVCs can represent a significant percentage of the total crashes reported. For example, in Wisconsin the total number of DVCs represented approximately 15 percent (or about one in every seven) of all the reported crashes that year (*4*).

Table 1. Upper Midwest Deer-Vehicle Crashes – Year 2000 (*4*).

State	Pre-Hunt Number of Deer Herd	Deer-Vehicle Crashes*	Deaths	Injuries	Vehicle Damage**
Michigan	1,900,000	65,000	8	2000	$110 mil
Wisconsin	1,600,000	20,000	5	800	$34 mil
Minnesota	960,000	19,000	2	450	$32 mil
Illinois	800,000	19,700	5	800	$33 mil
Iowa	210,000	7800	3	600	$13 mil
Total	5,470,000	131,500	23	4650	$222 mil

*2000 Reported deer-vehicle crashes only.
** Damage estimate assumes $1,700 property damage per reported crash.

In Texas, about 3800 animal crashes occurred in 1999 on rural highways. Researchers classified a crash as an animal crash in the study if it had “animal” as the first harmful event or “swerved, animal” or “slowed, animal” coded as an “Other Factor” in the cause of the crash. Researchers used the population group variable to define rural. If the crash occurred in a town with less than 5000 population or was coded as “rural” within the population code, it was considered in this review.

Table 2 lists the number of crashes along with the crash rate, while Figure 1 shows the number of animal crashes per year. Note that in 1995 a change occurred in the crash-reporting procedures. On July 1, 1995, there was a change in the Texas crash-reporting threshold. On that date, the Department of Public Safety (DPS) began reporting only those crashes in which (a) one or more people involved in a crash were killed or injured and/or (b) one or more crash-involved vehicles had to be towed from the scene. Property Damage Only (PDO) collisions that do not result in a vehicle being towed from the scene are no longer reported by DPS. As a result, statewide traffic crashes in the second half of 1995 decreased by about 30 percent compared to the first half of the year. The result in this study is that it appears that there was a large decrease in animal crashes in 1995 when the decrease was a reflection of the reporting change. Therefore, any review that includes both pre-and post-1995 data must consider the change in reporting procedure.

Table 2. Animal Crashes on Texas On-System Rural Highways between 1990 and 1999.

Year	Total Animal Crashes Reported	PDO Crashes	Other than PDO Crashes	DVMT (million)	Total Animal Crashes/MVMT	Other Than PDO/MVMT
1990	3241	2322	919	127.44	0.070	0.020
1991	3218	2287	931	129.62	0.068	0.020
1992	3514	2523	991	132.91	0.072	0.020
1993	3670	2689	981	137.17	0.073	0.020
1994	3868	2764	1104	143.93	0.074	0.021
1995	3190	1986	1204	147.91	0.059	0.022
1996	3290	1793	1497	155.36	0.058	0.026
1997	3178	1729	1449	161.25	0.054	0.025
1998	3835	2136	1699	169.71	0.062	0.027
1999	3785	2140	1645	173.95	0.060	0.026

Note: 1 mi = 1.61 km.
DVMT = Daily vehicle miles traveled MVMT = Million vehicle miles traveled

Figure 1 shows the total number of animal crashes along with the number of PDO crashes and the number of other than PDO crashes (i.e., possible injury, non-incapacitating, incapacitating, and fatal). The effects of the change in reporting procedures is clearly shown in the PDO crashes line – a large decrease from 2764 PDO crashes in 1994 to only 1986 PDO crashes in 1995 to 1793 PDO crashes in 1996. The other than PDO crash plot shows a continual increase in the number of animal injury/potential injury crashes.

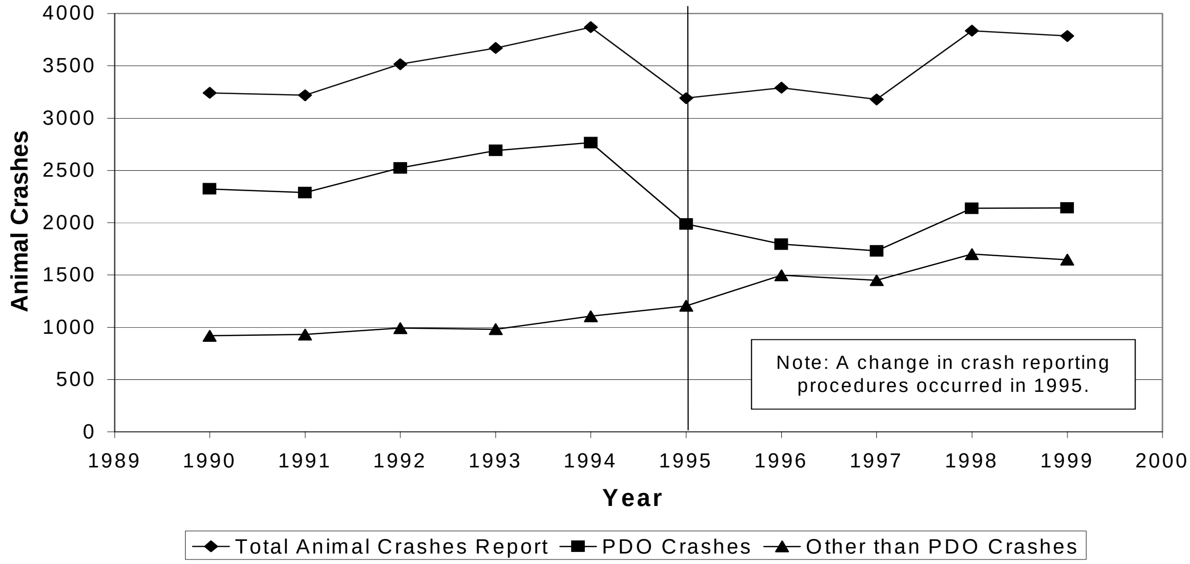
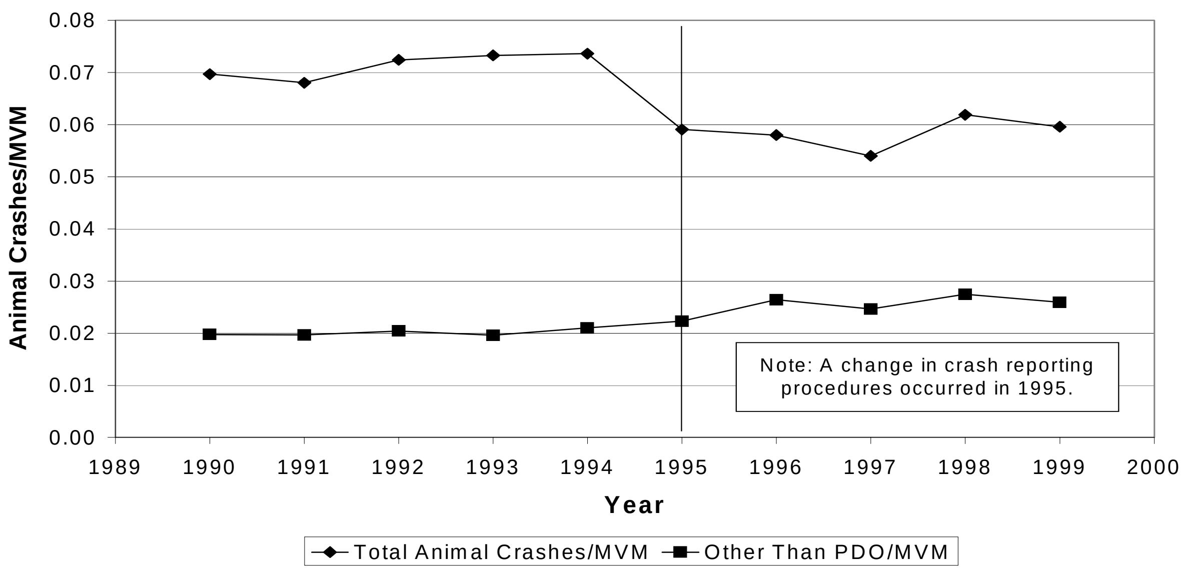


Figure 1. Animal Crashes on Texas On-System, Rural Highways.

Figure 2 shows the animal crash rate per million vehicle miles traveled by year. The vertical line at 1995 serves as a division between the two reporting practices. The total number of animal crashes was fairly constant between 1995 and 1997 and then jumped by about 650 crashes in 1998 (see Figure 1). Accompanying the increase in total number of crashes was an increase in the amount of miles being driven in the rural areas. Therefore, some of the increase in number of animal crashes can be explained by the increase in miles driven. An increase in the rate of animal crashes can be seen in Figure 2.



(1 mi = 1.6 km)

Figure 2. Animal Crash Rate.

The majority of the animal crashes are non-injury/property damage only crashes. Table 3 lists the number of animal crashes on rural highways between 1997 and 1999. Over half were PDO crashes (56 percent). Vehicle-animal crashes occur more frequently at night. Of the reported animal crashes in the state, 73 percent occurred at night. Researchers found the animal crash frequency to be about four times higher at night than during the day (6530 occurred in dark with no lights or street lights present, while only 1591 occurred during the day, and another 452 occurred in the dawn or dusk period).

Table 3. Animal Crashes on Rural, Two-Lane Highways Occurring in 1997 to 1999 by Severity.

Severity	Number of Crashes	Percent (%)
Non-Injury (Property Damage Only)	6005	56
Possible Injury	2257	21
Non-Incapacitating Injury	1942	18
Incapacitating Injury	531	5
Fatal	63	1
TOTAL	**10,798**	**100**

Between the years of 1997 and 1999 on rural two-lane highways, 10,798 animal crashes occurred. Most of these animal crashes occurred in the fall months of October, November, and December (see Table 4). The deer mating season, associated with greater movement among deer, occurs during the months of October to December.

Table 4. Animal Crashes on Rural, Two-Lane Highways Occurring in 1997 to 1999 by Month.

Month	Number of Crashes	Percent
January	742	7
February	651	6
March	720	7
April	775	7
May	809	7
June	699	6
July	771	7
August	802	7
September	928	9
October	1366	13
November	1452	13
December	1083	10
TOTAL	**10,798**	**100**

To examine the characteristics of animal crashes in depth, researchers obtained a subset of the animal crashes. The subset contained all the animal crashes for a selected district on rural population, two-lane highways. Table 5 lists the distribution of crashes for the 279 animal crashes. For comparison, the table also contains the rural, two-lane animal crashes for the state and all rural two-lane crashes for the state. Animal crashes have several different characteristics as compared to all rural crashes. These differences include that the majority of the animal crashes occurred:

- at night with no street lights (72 percent as compared to 32 percent),
- at non-intersections (98 percent as compared to 60 percent), and
- on straight sections (82 percent as compared to 71 percent).

Other characteristics of animal crashes that are similar to rural crashes include the following:

- on dry surface (animal: 92 percent, rural: 82 percent) and
- in clear weather (animal: 94 percent, rural 86 percent).

Table 5. Distribution of Animal Crashes for 1997 to 1999.

	Rural Animals Two-Lane Crashes in a District[1]		Rural Animal Two-Lane Crashes in the State[2]		Rural Two-Lane Crashes in the State[3]	
	Num	**%**	**Num**	**%**	**Num**	**%**
Overall Crashes	**279**		**8573**		**86,032**	
Intersection-Related Crashes						
Intersection	2	1	67	1	13,729	16
Intersection-Related	1	0	77	1	10,013	12
Driveway Access	2	1	132	2	11,065	13
Non-Intersection	274	98	8297	97	51,225	60
First Harmful Event						
Overturned	37	13	957	11	13,801	16
Pedestrian	0	0	0	0	508	1
Another Vehicle in Transport	5	2	157	2	38,764	45
RR Train	0	0	0	0	119	0
Parked Car	0	0	10	0	739	1
Pedal Cyclist	0	0	0	0	229	0
Animal	191	68	5921	69	5921	7
Fixed Object	45	16	1506	18	24,523	29
Other Object	0	0	2	0	386	0
Other Non-Collision	1	0	0	0	1042	1
Injury Severity						
Incapacitating	13	5	429	5	9296	11
Non-Incapacitating	55	20	1575	18	19,969	23
Possible Injury	56	20	1835	21	22,507	26
Fatal	2	1	52	1	2838	3
Not Injured	153	55	4682	55	31,422	37
Number of Vehicles Involved						
1	272	97	8296	97	45,978	53
2	6	2	254	3	36,544	42
3 or More	1	0	22	0	3505	4
Light Conditions						
Daylight	45	16	1591	19	51,659	60
Dawn	16	6	294	3	1736	2
Dark-No Lights	202	72	6266	73	27,617	32
Dark-Street Lights	4	1	264	3	3392	4
Dusk	12	4	158	2	1628	2
Surface Conditions						
Dry	256	92	7684	90	70,486	82
Wet	22	8	881	10	14,146	16
Muddy	0	0	0	0	42	0
Snowy/Icy	1	0	8	0	1358	2

Table 5. Distribution of Animal Crashes for 1997 to 1999 (continued).

	Rural Animals Two-Lane Crashes in a District[1]		Rural Animal Two-Lane Crashes in the State[2]		Rural Two-Lane Crashes in the State[3]	
	Num	**%**	**Num**	**%**	**Num**	**%**
Weather Conditions						
Clear	262	94	7860	92	74,238	86
Raining	10	4	433	5	8940	10
Snow	0	0	7	0	357	0
Fog	6	2	266	3	2028	2
Blowing Dust	0	0	0	0	24	0
Smoke	1	0	1	0	26	0
Other	0	0	2	0	64	0
Sleeting	0	0	4	0	355	0
Degree of Curve						
0.1-1.9	13	5	368	4	4586	5
2.0-3.9	17	6	566	7	6658	8
4.0-5.9	8	3	324	4	4519	5
6.0-7.9	4	1	113	1	1866	2
8.0-9.9	0	0	48	1	945	1
10.0-11.9	3	1	78	1	1633	2
12.0-13.9	2	1	16	0	317	0
14.0-15.9	1	0	10	0	373	0
16.0-17.9	0	0	4	0	102	0
18.0 and Over	0	0	30	0	1115	1
No Curve	230	82	6871	80	61,171	71
Unknown	1	0	143	2	2697	3

Notes:
1 = 1997 to 1999, 2-lane, rural population, selected district
animal crashes (first harmful = animal or other factor = "swerved, animal" or "slowed, animal").
2 = 1997 to 1999, 2-lane, rural population, entire state, animal crashes.
3 = 1997 to 1999, 2-lane, rural population, entire state.

The narratives for the animal crashes within the selected district were obtained to identify the contributing factors to the animal crashes. The narratives could be used to answer questions such as "what types of animals are being struck" and "were driver errors a significant contributor to the crashes?" The narratives showed that deer are the animal most frequently involved in crashes, although cows are still heavily represented. For the set of animal crashes for the selected Texas district, 62 percent of the crashes were with deer, and 25 percent of the crashes were with cows. Table 6 lists the distribution of crashes by type of animal.

Table 7 lists the distribution of contributing factors identified by officers for the 279 crashes reviewed. In almost every crash, the contributing factor was an animal on the road, although several of the crashes were with domestic animals (28 percent) rather than wild animals (58 percent). Faulty evasive action was attributed to 7 percent of the animal crashes.

Table 6. Animal Crashes on Rural Two-Lane Highways in a Selected Texas District Occurring in 1997 to 1999 by Type of Animal.

Type of Animal	Number of Crashes	Percent
Deer	174	62
Cow	70	25
Feline	2	1
Horse	6	2
Dog	9	3
Opossum	1	0
Turkey	1	0
Raccoon	3	1
Rabbit	1	0
Goat	2	1
Bird	1	0
Hog	1	0
Unknown	8	3
TOTAL	**279**	**100**

Table 7. Animal Crashes on Rural Two-Lane Highways in a Selected Texas District Occurring in 1997 to 1999 by Contributing Factor.

Contributing Factor	Number of Crashes that Listed the Contributing Factor*	Percent
Animal on Road-Domestic	86	28
Animal on Road-Wild	184	58
Driver Inattention	5	2
Failed to Control Speed	2	1
Faulty Evasive Action	22	7
Followed Too Closely	3	1
Impaired Visibility	1	0
Speeding Unsafe (Under Limit)	6	2
Speed-Over Limit	1	0
Turned When Unsafe	1	0
Under Influence-Alcohol	3	1
Under Influence-Drug	1	0
TOTAL	**316**	**100**
*Note: More than one contributing factor can be associated with a crash.		

WILDLIFE/VEHICLE CRASH COUNTERMEASURES

A number of countermeasures have been used to decrease the likelihood of a wildlife/vehicle crash. In July 2001, the Deer Vehicle Collision Information Clearinghouse (DVCIC) was officially started at the University of Wisconsin-Madison (*4*). The focus of the DVCIC project is the study, summary, and exchange of existing information and data related to DVCs (e.g., vehicle flow, deer population, and crashes) in the upper midwest. Its objectives include:

- the compilation of current DVC-related knowledge (e.g., a countermeasure toolbox);
- the development and promotion of standard DVC-related research, and DVC data collection and information management approaches;
- the collection, evaluation, and analysis of regional DVC-related data;
- the creation and/or update of a DVC-related data information system (e.g., the developing webpage – www.deercrash.com);
- the distribution of useful DVC-related information/findings (e.g., a countermeasure toolbox, reviews, standards proposal, presentations, workshops, seminars, and data summaries); and
- long term – contribute to the decrease in the frequency and severity of DVCs by providing useful information and monitoring.

A toolbox is being developed by the DVCIC and will consider several countermeasures. These countermeasures try to influence the behavior of either the driver or the deer. Neither of these goals is easily accomplished. The objective of any DVC countermeasure, of course, is to reduce the probability that a deer and vehicle will be at the same location at the same time (*4*).

Within TxDOT Project 0-4048, researchers identified several countermeasures as potential treatments for use within Texas. Following is a summary of the different countermeasures identified, along with their pros and cons.

Wildlife Reflectors

Application: Reflectors are mounted at intervals of 100 to 125 ft (30.5 to 38.1 m) at a height of 24 to 30 in (61.0 to 76.2 cm) from the crown of the pavement. When headlights hit the reflector, an infrared beam "creates a fence" that is only seen by animals (see Figures 3 and 4).

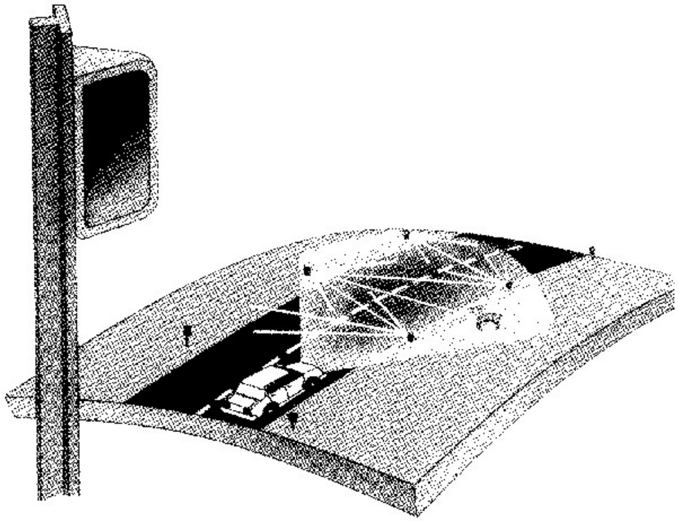


Figure 3. Example of a Wildlife Reflector.

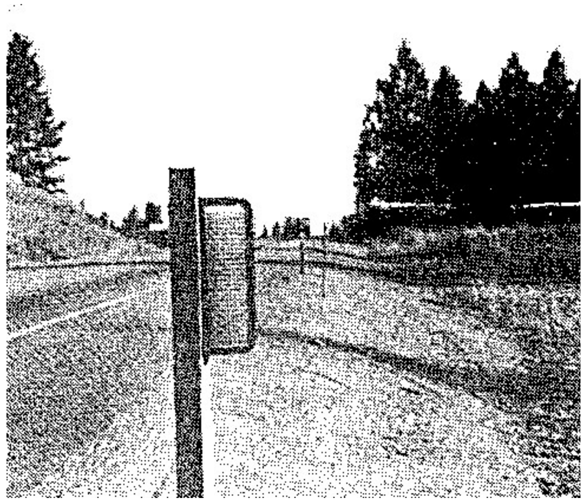


Figure 4. Close-up of Wildlife Reflector.

Cost per device: $16.50 to $17.90

Cost per mile: $7,000 to $10,000

Current or Recent Studies, New Jersey Turnpike: The New Jersey Turnpike Authority installed a reflector system as a pilot program (*5*, *6*). The Authority selected the system to address vehicle crashes resulting from deer attempting to cross the mainline. Installed in September 1999, the system was evaluated over a two-year period to determine its effectiveness. Located between mileposts 14.5 and 15.4, this system discourages deer from crossing the roadway by reflecting the headlights of oncoming vehicles onto the side of the roadway. The unit cost per mile was $10,247 ($6367.19 per km), with an annual maintenance cost of $1,255 per yr/per mile ($779.82 per yr/per km). The deer-vehicle after dark accident history prior to installation was 19 crashes over three years. The deer-vehicle after dark accident history for the 19 months after installation was zero crashes for the 0.9 mi (1.4 km) where the system was installed. Note that the before and after periods differed in this study. The before period included approximately 29 miles (46.7 km) over a 36-month period, while the 19-month after period included only the 0.9 mi (1.4 km) where the system was installed.

Pro:

- It is an active device that works only when headlights are present.
- It is not visible to motorists.
- The device may be eligible for funding through Federal Hazard Elimination funds.

Con:

- The success of the reflectors is in dispute. Studies by California DOT and Wyoming Cooperative Fish and Wildlife found no effectiveness of reflectors. Five of eight studies on one brand of reflectors found the reflectors not effective. Other studies indicate deer are not inherently frightened by the color red (*7*).
- Broken or misaligned reflectors can cause gaps, where animals will cross.
- Animals may become familiar with the reflectors and disregard the beam.

Infrared Detection Technology

Application: Infrared detectors are mounted at the roadside. When the detector senses a deer or other large animal is present near the roadway, a signal triggers a flashing warning sign.

Cost per device: $50 to $595

Cost per mile: $1,000 to $5,000

Current or Recent Studies, St. Paul, Minnesota: A deer alert system installed in Minnesota consisted of traditional deer warning signs, with an amber beacon mounted on top (*8*). Motion sensors were placed at the far edge of the ditch to create a sensory perimeter. When a deer or other large animal crosses the path of the sensor, a transmitter activates the amber warning lights for about one minute. This serves as a visual caution to drivers to slow down to avoid animals approaching the roadway. The system installed along both sides of the roadway detects deer approaching from either direction. After the systems are operational, additional advisory signs notify drivers when they are entering a test area and that deer or other animals may be present when lights are flashing. The new deer alert systems will be installed at three locations:

- Highway 23 at Camden State Park southwest of Marshall (underway),
- Highway 63 south of Racine, and
- Highway 43 southeast of Winona.

Minnesota Department of Transportation's (MnDOT) two-year trial of the new warning system and signs is the first in the nation. Each site being tested was selected based on a large deer population in the area and the number of crashes reported. Following the test period, MnDOT will analyze the data to determine if the system decreases the number of large animal/vehicle collisions. If successful, the deer alert signs could be installed at additional locations around the state.

Pro:

- The device is relatively inexpensive.
- It can be either passive or active and is not selective as to animal type, only to body heat.
- It could be extremely effective if used in areas of known accidents or wildlife trails.
- It is more of a site fix (rather than a long segment).
- Signs would only flash when wildlife is present.

Con:

- It needs maintenance.
- Sensors need to be replaced every two years.
- Sensitivity is 60 to 100 ft (18.3 to 30.5 km) with adjustable width.
- It is relatively new technology for this use. It may have some unknown difficulties.

Wildlife Warning Signs

Application: Signs are mounted to alert drivers of wildlife in the area (see Figure 5).

Figure 5. Example of Wildlife Sign.

Cost per device: $100 to $500

Cost per mile: $200 to $1,000

Current or Recent Studies: When an area is known to have significant deer activity or a deer-vehicle crash history, an advance deer crossing warning sign may be installed. The *Manual on Uniform Traffic Control Devices* (*MUTCD)* states that "advance crossing signs should be used to alert vehicle operators to unexpected entries into the roadway by pedestrians, trucks, bicyclists, animals, and other potential conflicts" (*9*). The effectiveness of advance warning signs is unknown. A concern with their use is that overuse of the deer crossing warning signs may result in a lack of attention to the message on the part of the motorists.

Pro:

- They are relatively inexpensive.

Con:

- Their effectiveness is not known but is suspected to be minimal.

Roadway Animal Detection System

Application: This system uses low power level radio frequencies to detect deer or other animals near or in the roadway. The system then triggers a warning device (sign with flashers) to warn drivers. The system can detect any size animal in all weather and light conditions. The system consists of sensors (including a communications network and cellular phone capability), power system, and warning device.

Cost per mile: The average cost is $57,100 per standard mile ($35,480 per km) (10 sensors and warning devices). Solar power costs are $9500 per mile ($5903 per km), and line power costs are $1500 per mile ($932 per km). Installation costs are $11,000. Maintenance and operational costs are extra.

Current or Recent Studies: A system was installed in the fall of 2002 for a two-year trial study. This system was partially designed by the Western Transportation Institute at Montana State University and is funded by 15 state Departments of Transportation, including the Montana Department of Transportation (*10*).

Pro:

- The device is motion activated.
- It is waterproof and weather hardened.
- It activates on demand, so deer are startled and do not become used to the sound.
- The device operates on solar power or line power.

Con:

- The cost is prohibitive for large-scale use.

Wildlife Warning System

Application: These systems consist of detection of cars through sensors in the roadway. The sensors then trigger a device that "scares or alarms" the deer. These alarms may consist of lights, whistles, repellent, and/or noisemakers.

Cost per device: The average cost is $50 per device (covers approximately 4000 sq ft [371.6 m^2]). Maintenance is required.

Current or Recent Studies: A 2000 study (*11*) tested the implementation of a prototype design of a wildlife warning system in Saskatchewan. This system contained detectors and warning devices that operated and communicated in series to cover a larger distance of roadway. Oncoming vehicles were detected by an audio sensor; the warning devices consisted of built-in deer-repelling horns and flashing light-emitting diodes (LEDs). The study, which was substantially funded and conducted by the system's manufacturer, was incomplete and inconclusive at the time the study's technical report was written. However, the Saskatchewan government has continued to implement similar systems on a trial basis. The latest trial is a 30-month pilot project, estimated to cost $100,000 ($67,000 US), begun in the summer of 2002. This project will cover a 3.1-mi (5-km) section of highway that is particularly prone to deer-vehicle crashes (*12*).

Pro:

- The device is motion or heat activated.
- It is waterproof and weather hardened.
- It activates on demand, so deer are startled and do not become used to the sound.
- Since the device operates on a 9-volt battery, it may be convertible to solar power.

Con:

- It has not proven effective, and it may not be alarming to deer that are used to vehicle noise.

Established Feeding Areas

Application: A feeding area is established to discourage deer from approaching or crossing the roadway.

Cost per mile: Varies

Current or Recent Studies: Feeding areas have been used with fences to encourage the deer to remain on one side of the roadway. Providing deer with areas away from the right-of-way to forage has been shown to reduce deer-vehicle crashes. Feeding areas have also been used in conjunction with planting unpalatable plants near the edge of the right-of-way to further discourage deer from approaching the roadway (*13*).

Pro:

- It has shown short-term effectiveness in reducing deer-vehicle crashes in areas of high concentrations of deer.

Con:

- It is not a long-term solution.
- It requires landowner participation in Texas.

Fences

Application: A high fence is built between the woods and the roadway. In some cases, a complex system of fences, underpasses, and/or one-way gates are used.

Cost per mile: Average cost of $1.00 per ft ($0.31 per m). Installation is extra.

Current or Recent Studies: Previous studies have found that the use of fencing and underpasses has resulted in fewer deer crossing the roadway and fewer crashes. The treatment cost, however, is high both in design and construction, along with maintenance (*12*).

Pro:

- A properly installed deer-proof fence of 7.2 ft (2.2 m) to 8.9 ft (2.7 m) in height is effective.

Con:

- The fence must be maintained, or deer will go under or through it.
- Deer learn to go around if the fence is not long enough.
- Alternative passages must be provided.

POTENTIAL TEXAS STUDY SITES

Animal crashes are and will continue to be a concern, especially in rural Texas districts. An effort within Project 0-4048 was to identify potential study locations for the testing of an animal crash countermeasure. The animal crash data for a district, as described in the opening section, were used to identify potential sites. Researchers calculated the animal crashes per million vehicle miles driven. The highest rates were 6.22, 5.25, 5.02, 2.46, and 2.19 animal crashes per million vehicle miles driven (3.86, 3.26, 3.12, 1.53, and 1.36 animal crashes per million vehicle km driven).

Straight line diagrams were developed for several of these control sections, along with control sections with a high number of animal crashes. For many sites, the straight line diagrams revealed sections with multiple animal crashes that occurred within a half-mile segment. Members of the research team visited several of these sites in the field. The field visits revealed sites that would be associated with deer movement by having trees and shrubs on one side of the road and grain fields on the other. Figure 6 is an example of the trees and shrubs along one side of a roadway where several animal crashes have occurred. Deer crossed the road to move from their sleeping areas to grazing areas. As the opportunity becomes available, one or more of the animal crash countermeasures will be installed at selected sites for testing.

Figure 6. Photograph of a Potential Site for an Installation of an Animal Crash Countermeasure.

CHAPTER 3

ADDITIONAL CHARACTERISTICS OF LOW-VOLUME, RURAL TWO-LANE HIGHWAY CRASHES

FOUR-COUNTY EVALUATION

KAB crashes are fatal (K), incapacitating injury (A), or non-incapacitating injury (B) crashes. Part of the first year efforts of TxDOT Project 0-4048 determined the KAB crash rates for low-volume, rural two-lane highways in Texas. The *Characteristics of and Potential Treatments for Crashes on Low-Volume, Rural Two-Lane Highways in Texas* (report 4048-1) (*1*) presented the findings from investigations into the characteristics of KAB crashes for the state and by county. A plot of crash rates by county showed a definite pattern of areas with high rates versus areas with lower rates. The counties with the higher crash rates are located in the eastern portion of Texas. With only a few exceptions, most of the lower crash rates were found in west Texas. A sample of counties was selected to investigate which characteristics are associated with high and low crash rates.

The four counties studied for the task include two counties with high KAB rates (Angelina and Travis) and two counties (Martin and El Paso) with lower KAB rates. Angelina and Martin Counties had a similar number of miles of low-volume, rural two-lane highway, as did Travis and El Paso Counties. Angelina County had the highest KAB crash rate, as well as the highest number of crashes overall. The previous evaluation, documented in 4048-1, found that among the four counties, there is a distinct difference between eastern counties and western counties. The eastern counties had the higher crash totals and rates, and they contained all of the fatal crashes for the sites used in the evaluation. In general, sites in the eastern counties had fewer driver-friendly characteristics, with more horizontal and vertical curves, narrower lanes and/or shoulders, less forgiving roadside development, higher access density, and higher roadside development scores. Eastern counties also had more crashes at intersections than western counties.

The previous evaluation led to the question "... were the causes of these crashes primarily associated with the roadway or with the driver?" To investigate this question, research team members requested and obtained the individual narratives for the crashes from the Department of Public Safety. In addition to the data stored in the electronic database, the crash report provides the officer's written statement on the crash. The officer also has the ability to select from a list of factors or conditions contributing to the crash. Researchers used a combination of a review of the written narrative and the factors selected by the officer to identify the contributing factors for the crashes.

Table 8 lists the factors or conditions contributing to the crash for the 113 crashes reviewed. These findings are split into east and west regions. For all low-volume, rural two-lane highway crashes reviewed, officers selected the "Driver Inattention" factor the most. Officers selected this factor in one of every four crashes (each crash could have more than one contributing factor, and "Driver Inattention" was selected in 28 of the 113 crashes reviewed). Other factors that were frequently selected included "Failed to Control Speed," "Failed to Yield ROW" (Stop Sign), and "Unsafe Speeding" (Under Limit).

The crashes that occurred in the west had the same top two contributing factors as for all crashes: "Driver Inattention" and "Failed to Control Speed." Officers selected "Failed to Control Speed" in 27 percent of the 41 crashes reviewed. The next factor for western crashes was "Speeding Over the Limit." Overall, western crashes are associated with driver inattention and speed.

Similar to all low-volume, rural two-lane highway crashes, the top contributing factor for crashes in eastern counties is "Driver Inattention." This contributing factor was selected in 28 percent of the 72 crashes reviewed. In contrast to the western county contributing factors, eastern county crashes are more often associated with "Failure to Yield at a Stop Sign," "Unsafe Speed – Under Limit" (which tends to be associated with wet pavement or on horizontal curves), and "Faulty Evasive Action." The faulty evasive action can be associated with horizontal curves or narrow lanes/shoulders – all previously identified characteristics of roadways located in the eastern counties.

Table 8. Contributing Factors for Crashes in Four-County Evaluation.

Contributing Factor (CF)	Total			West			East		
	Freq	% CF	% Crashes	Freq	% CF	% Crashes	Freq	% CF	% Crashes
Driver Inattention	28	15	25	8	12	20	20	16	28
Failed to Control Speed	22	11	19	11	16	27	11	9	15
Failed to Yield ROW-Stop Sign	22	11	19	5	7	12	17	14	24
Speeding-Unsafe (Under Limit)	19	10	17	5	7	12	14	11	19
Faulty Evasive Action	18	9	16	2	3	5	16	13	22
Distraction in Vehicle	10	5	9	3	4	7	7	6	10
Under Influence-Alcohol	9	5	8	4	6	10	5	4	7
Speeding-Over Limit	8	4	7	7	10	17	1	1	1
Fatigued or Asleep	6	3	5	4	6	10	2	2	3
Failed to Yield ROW-Turning Left	6	3	5	4	6	10	2	2	3
Failed to Yield ROW-Field Sign	5	3	4	0	0	0	5	4	7
Had Been Drinking	5	3	4	0	0	0	5	4	7
Failed to Drive in Single Lane	4	2	4	4	6	10	0	0	0
Failed to Yield ROW-Open Intersection	3	2	3	0	0	0	3	2	4
Other Factor	3	2	3	0	0	0	3	2	4
Wrong Side-Not Passing	3	2	3	1	1	2	2	2	3
Followed Too Closely	3	2	3	2	3	5	1	1	1
Defective Steering Mechanism	2	1	2	0	0	0	2	2	3
Disregard Stop Sign or Light	2	1	2	0	0	0	2	2	3
Animal on Road-Wild	2	1	2	1	1	2	1	1	1
Improper Start from Parked Position	2	1	2	2	3	5	0	0	0
Animal on Road-Domestic	1	1	1	0	0	0	1	1	1
Defective or No Vehicle Brakes	1	1	1	0	0	0	1	1	1
Defective or Slick Tires	1	1	1	0	0	0	1	1	1
Disabled in Traffic Lane	1	1	1	0	0	0	1	1	1
Failed to Yield ROW-Emergency Vehicle	1	1	1	0	0	0	1	1	1
Taking Medication	1	1	1	0	0	0	1	1	1
Failed to Stop at Proper Place	1	1	1	1	1	2	0	0	0
Failed to Yield ROW-Private Drive	1	1	1	1	1	2	0	0	0
Passed in No Passing Zone	1	1	1	1	1	2	0	0	0
Turned Improperly–Wrong Lane	1	1	1	1	1	2	0	0	0

Notes:
Each crash can have more than one contributing factor.
Percentages based on 113 crashes (41 west and 72 east) and 192 contributing factors (67 west and 125 east).

In summary, the primary contributing factor for crashes on low-volume, rural two-lane highway is driver related – “Driver Inattention.”

IN-DEPTH EVALUATION FOR A RAPIDLY DEVELOPING DISTRICT

Researchers conducted additional investigations on low-volume, rural highways in a rapidly developing district located in the eastern portion of the state. To increase the pool of crash data, the research team used all crashes (i.e., property damage only, possible injury, and KAB crashes) occurring on the roadways of interest in the study. A total of 1795 crashes occurred on low-volume, rural two-lane highways in the selected district between 1997 and 1999. Research team members obtained the electronic records for these crashes from the database maintained at the Texas Transportation Institute (TTI).

Determine Overall Characteristics

The distributions of crash characteristics were determined for the 1795 low-volume, rural two-lane highway crashes that occurred in the district. Table 9 lists the distribution along with the distributions for KAB rural crashes and all rural crashes within the state. Differences between the characteristics of the crashes in the district and the distribution of crashes in the state include the following (see Table 9):

- The district had slightly more crashes at intersections or intersection-related areas (total of 33 percent) than the state KAB rural crashes for low-volume highways (24 percent). The First Harmful Event data supports the observation that a larger percentage of crashes are occurring at intersections or driveways – another vehicle in transport is the most common First Harmful Event.

- When the district low-volume rural roads are compared to the entire state, a slightly higher percentage of crashes occur at or near intersections or driveways than for the entire state (43 percent compared to 39 percent). Rural roads are typically associated with run-off-road crashes; therefore, finding that such a high percentage of this eastern district's low-volume, rural two-lane crashes correlates with intersections or driveways is noteworthy.

- The fixed object and overturned categories of First Harmful Event were the categories with the second and third highest distribution (35 and 20 percent, respectively, as compared to 37 percent for another vehicle in transport). Therefore, run-off-road crashes are still a concern.

Table 9. Distributions of Crashes in Selected District and the State.

DISTRIBUTIONS		District*		Low-Volume, KAB Rural*		State*	
		Total Num	%	Num	%	Num	%
Overall Crashes		**1795**		**14,622**		**142,007**	**28**
Intersection-Related Crashes							
Intersection	1	361	20	2248	15	23,872	17
Intersection-Related	2	242	13	1346	9	16,537	12
Driveway Access	3	177	10	1269	9	15,087	10
Non-Intersection	4	1015	57	9759	67	86,511	61
First Harmful Event							
Overturned	0	366	20	4209	29	22,823	16
Pedestrian	1	4	0	145	1	881	1
Another Vehicle in Transport	2	664	37	4548	31	68,303	48
RR Train	3	3	0	35	0	132	0
Parked Car	4	7	0	72	0	1619	1
Pedal Cyclist	5	6	0	71	0	334	0
Animal	6	106	6	637	4	7328	5
Fixed Object	7	620	35	4739	32	37,610	26
Other Object	8	6	0	44	0	807	1
Motor Vehicle on Other Road	9	0	0	0	0	0	0
Other Non-Collision	-	13	1	122	1	2170	2
Injury Severity							
Incapacitating	1	239	13	4348	30	14,555	10
Non-Incapacitating	2	417	23	8930	61	31,868	22
Possible Injury	3	435	24	0	0	38,274	27
Fatal	4	62	3	1344	9	4310	3
Not Injured	5	642	36	0	0	53,000	37
Number of Vehicles Involved							
1		1125	63	NA	NA	70,831	50
2		637	35	NA	NA	64,172	45
3		30	2	NA	NA	5816	4
4 and more		3	0	NA	NA	1188	1
Light Conditions							
Daylight	1	1030	57	8338	57	88,528	62
Dawn	2	36	2	269	2	2908	2
Dark-No Lights	3	645	36	5344	37	40,919	29
Dark-Street Lights	4	53	3	389	3	7049	5
Dusk	5	31	2	282	2	2603	2

Table 9. Distributions of Crashes in Selected District and the State (continued).

DISTRIBUTIONS		District*		Low-Volume, KAB Rural*		State*	
		Total Num	%	Num	%	Num	%
Overall Crashes		**1795**		**14,622**		**142,007**	**28**
Surface Conditions							
Dry	1	1496	83	12,539	86	114,514	81
Wet	2	283	16	1909	13	23,902	17
Muddy	3	1	0	7	0	63	0
Snowy/Icy	4	15	1	167	1	3528	2
Weather Conditions							
Clear	1	1588	88	13,054	89	120,995	85
Raining	2	154	9	1057	7	16,085	11
Snow	3	12	1	57	0	797	1
Fog	4	35	2	395	3	2964	2
Blowing Dust	5	0	0	5	0	45	0
Smoke	6	0	0	5	0	45	0
Other	7	1	0	11	0	132	0
Sleeting	8	5	0	38	0	944	1
Degree of Curve							
0.1-1.9	1	80	4	695	5	9929	7
2.0-3.9	2	70	4	1384	9	8981	6
4.0-5.9	3	91	5	1195	8	5108	4
6.0-7.9	4	79	4	566	4	2013	1
8.0-9.9	5	64	4	284	2	976	1
10.0-11.9	6	90	5	456	3	1629	1
12.0-13.9	7	22	1	107	1	340	0
14.0-15.9	8	22	1	110	1	382	0
16.0-17.9	9	6	0	31	0	103	0
18.0 and Over	-	130	7	340	2	1215	1
No Curve	0	1066	59	8853	61	107,456	76
Unknown	+	73	4	601	4	3797	3

*Notes:
District = 1997 to 1999, two-lane, rural (urban-rural functional classification = rural), low volume (< 2000 ADT), all crashes (i.e., KAB, PDO, etc.), includes all intersection crashes.
Low-volume, KAB rural = 1997 to 1999, two-lane, rural, < 2000 ADT, KAB crashes only, includes all intersection crashes.
State = 1997 to 1999, rural, all crashes.
NA = Not available.

- The crashes within the district occur under similar conditions as crashes throughout the state for light condition (slight majority in daylight), surface condition (most on dry surface), and weather conditions (most in clear weather). The district low-volume, rural two-lane highway crashes did occur more often in dark-no light condition (36 percent) than for all rural crashes (29 percent).

- More of the district's low-volume, rural two-lane highway crashes occurred on horizontal curves (37 percent) than the state rural crashes (21 percent).

Select Subset of Roadway Segments

Researchers identified a subset of roadway segments within the district, selecting six control sections with the highest values for (a) the number of crashes and (b) the increase in KAB crashes from 1998 to 1999. Identifying potential control sections for use in this study required the following work:

- Obtaining the electronic crash records for: the district, 1997 through 1999, rural, two-lane highways, and ADT < 2000.
- Obtaining both KAB and non-KAB crashes.
- Ensuring that the database includes crashes at the intersections where a higher functional class road intersects with the roadway of interest (these crashes are assigned to the higher functional class road, and a separate search must be used to identify them).
- Obtaining average daily traffic to be used for rate computations.
- Developing a completed database that included KAB and non-KAB crashes from all three years.
- Determining the number of crashes and the increase in crash frequency for KAB crashes for each control section and selecting the top six control sections from each. Table 10 lists the sites selected for study.
- Gathering a summary of crash information. Information found for each control section that met the criteria included: collision type, road surface condition, weather, object struck, number of vehicles involved, light condition, first harmful event, alignment, curve, intersection related, crash number, and milepoint of crash.
- Comparing the distribution for each site to the district and statewide distributions (see Table 9), and forming generalizations about possible situations that could contribute to the crashes at a site.
- Obtaining narrative reports for the crashes at the selected sites.

Table 10. Control Sections for Study.

Site	ADT Average	Distance Sum	Crashes for 1997-1999	KAB Crashes for 1997-1999	Sum KAB Rate for 1997-1999	Increase in KAB Crashes from 1998-1999	Reason for Selection*
A	940	5.62	11	6	1.04	6	Increase
B	1345	4.33	36	17	2.66	6	Freq / Increase
C	1646	7.29	39	22	1.68	6	Freq / Increase
D	788	5.23	16	9	1.99	5	Increase
E	1327	11.26	39	15	0.92	-2	Freq
F	878	2.62	7	5	1.99	3	Increase
G	856	20.63	65	18	0.93	-2	Freq
H	1636	9.41	48	11	0.65	3	Freq
I	927	15.76	34	15	0.94	4	Freq / Increase

*Freq = control section had one of the six highest crash frequencies.
Increase = control section had one of the six highest increases in number of crashes from 1998 to 1999.

Review Crash Data

Researchers requested the reports for the crashes on the selected control sections. Reviews of these crash reports determined the contributing factors for each crash. The following were developed for each site:

- a generalized summary of each crash report,
- a table listing items to consider while in the field, and
- rankings of high to low for the purpose of priority when collecting data in the field.

Visit Selected Segments

The control sections identified were visited to gain more in-depth information. Video, still photography, and general observations were the main techniques used in data collection. The following steps were performed:

- recorded conditions using a digital video camera and 35mm still photography camera;
- visited high priority sites first, followed by medium and low priority sites;
- drew intersection layouts; and
- recorded notes for each section.

Tasks Completed upon Return from Data Collection Trip

Raw data compiled during the collection task needed to be reduced. Also, a better representation of concerns, if any, at each control section were to be developed from the information gathered during the data collection trip. The following objectives were completed upon return from a data collection trip:

- review video data and note additional observations;
- capture stills through the digital video camera;
- develop, organize, and distribute photographic stills from the 35mm camera into the control section file folders;
- create and distribute a general field observations page for each control section to the individual control section folders;
- create a contributing factors distribution spreadsheet for each control section and distribute each to the individual file folders;
- complete crash diagrams for intersections of interest; and
- complete a document summarizing database distributions, mile point observations, contributing factors distributions, field observations, crash narratives, additional potential investigations, and possible treatments.

The preliminary findings indicated that the width of the lane or shoulder could be a factor in several of the crashes. Researchers estimated the lane width and shoulder width for the selected sites using data contained in the TxDOT roadway inventory file. Lane width was calculated as being the surface width divided by the number of lanes. Shoulder width was calculated as the roadbed width minus the surface width, divided by two. Table 11 lists the calculated values. The lane width for the study section was similar to the lane width for the entire district; however, the shoulder width was much less. The district averages a 6.3 ft (1.9 m) shoulder width for the low-volume, rural two-lane highways while the sites selected for investigation only averaged 1.3 ft (0.4 m).

Table 11. Estimated Average Shoulder and Lane Widths.

	Low-Volume, Rural Two-Lane Highways in District	Selected Control Sections
Lane Width, ft (m)	11.3 (3.4)	11.1 (3.4)
Shoulder Width, ft (m)	6.3 (1.9)	1.3 (0.4)

FINDINGS

Researchers used the review of available data for each site to identify the crash characteristics for the site; from that data, they derived potential treatments for each control section. Potential treatments were identified through research team meetings, individual analysis, and during field data collection.

The distribution of crashes on the district's low volume, rural two-lane highways revealed that crashes occur more often at intersections as compared with the rest of the state. As expected for a rural highway, run-off-road crashes are also a concern. The district had more crashes occurring on horizontal curves than the state rural crashes. A subset of nine roadway segments within the district was identified for additional study. These sites included 118 KAB crashes that represented 17 percent of the KAB crashes for the 1997 to 1999 study period. Overall, the potential treatments frequently suggested were:

- resurfacing due to a high percent of wet surface condition crashes,
- installing intersection treatments to better inform drivers of the downstream intersection, or
- widening shoulders to provide additional recovery room.

CHAPTER 4

BEFORE-AND-AFTER EVALUATION METHODOLOGY

INTRODUCTION

This chapter contains a description of the methodology used in conducting before-and-after (B&A) evaluations of selected sites on highways that have received roadway or intersection improvements. The following text outlines the intended purpose of these evaluations, the steps necessary to conduct the evaluations, details about each step, sample evaluation forms and communications, and progress to date.

OVERVIEW

A large number of improvements are made to highways in the state of Texas each year, and many of them are on rural, low-volume, two-lane highways. Unfortunately, the exact benefits of these improvements are not often known, because there is no comparison of conditions on the roadway prior to and following the installation of the improvement. In many cases, improvements are performed as part of maintenance activities, and detailed records are not kept for these improvements, making evaluation even more difficult. By conducting a before-and-after evaluation of a cross-section of improvements across the state, researchers anticipated that the effectiveness of various improvements can be realized, thereby improving the information available to TxDOT for utilizing these improvements in the future.

The evaluation started with gathering information from TxDOT district and area engineers about improvements in their jurisdictions. Based on the information received in an initial survey of these engineers, researchers prioritized a number of sites for follow-up efforts consisting of the collection of more detailed information about the improvements made. Compiling a record of the crash history at the site and visiting the site for a visual record of the improvements were also part of the evaluation plan. The steps in the evaluation process are listed below.

1. Conduct the initial mail-out survey of TxDOT engineers.
2. Process findings from the survey.
3. Assign an initial B&A score to each improvement.
4. Attempt to determine the location and exact nature of each improvement.
5. Contact the survey respondents to confirm information and add details.
6. Identify a potential comparison site.
7. Revise the B&A score and other information based on contact information.
8. Obtain electronic crash records for each site being evaluated.
9. Reduce crash records by control section, milepoint, and time period for analysis.
10. Obtain/confirm the ADT information for each site.
11. Write an initial overview or summary for the information obtained for each site.
12. Visit the site to take pictures, confirm information on file, and locate a comparison site.
13. Request crash narratives for the specific sites for a detailed analysis.
14. Follow-up with survey respondents to obtain remaining details necessary for analysis.
15. Complete B&A evaluation for the site.
16. Draw conclusions.

A more detailed explanation of the steps taken to compile B&A evaluation information follows.

STEP 1: CONDUCT INITIAL MAIL-OUT SURVEYOF TxDOT ENGINEERS

Researchers conducted a mail-out survey to gather information on relatively low-cost safety improvements on low-volume roads (*1*). Surveys were mailed to all 25 district engineers in the state of Texas, with copies to forward to the area engineers in each district. Respondents were asked to:

- check those safety improvements they have installed to address safety concerns on low-volume, two-lane roads (by checking the items on the list provided);
- list the three to five most recent safety improvements used on a low-volume two-lane road to address a safety concern;

- list candidate sites for the improvements listed in the first question;
- provide additional comments or suggestions; and
- indicate if they would like to receive a copy of the survey results.

STEP 2: PROCESS FINDINGS FROM SURVEY

The survey yielded 75 respondents, with many providing more than one recent safety improvement. The 217 improvements provided were classified by their likelihood of being a good before-and-after site:

- High potential – 67 sites
    - easy to identify location, one of the higher priority treatments set at the panel meeting (animal, flashing beacons, approach rumble strips)
- Moderate potential – 65 sites
    - may be easy to locate if more information is available or may not be a high priority treatment
- Low or no potential – 85 responses
    - not easy to locate, incomplete information, or respondents wrote "various roadways" comment as opposed to providing a specific location

When the high and moderate potential sites were combined with potential sites obtained from personal visits to various districts, researchers selected a total of 153 sites with improvements as having potential for further evaluation. For each site, the information on the county, district, specific roadway and location (if given), and date of installation (if given) was compiled and entered into a spreadsheet database.

STEP 3: ASSIGN INITIAL B&A SCORE TO EACH IMPROVEMENT

Each of the 153 sites was assigned a before-and-after score based on the researchers' judgment of the potential of each site for further follow-up. Sites were given scores from zero to two, as follows:

- 0.0 Not installed yet
- 0.5 Very high potential
- 1.0 High potential
- 1.5 Average potential
- 2.0 Low potential

The completeness of information provided by the survey respondents, the ability to pinpoint a specific intersection or section of roadway that had been improved, the ability to adequately evaluate a particular site, and the estimated value of evaluating a particular type of improvement determined the scores.

STEP 4: ATTEMPT TO DETERMINE LOCATION AND EXACT NATURE OF EACH IMPROVEMENT

Researchers focused efforts on sites given a score of 0.5 or 1.0. The site pool eventually expanded to include some sites with scores of 1.5, resulting in 78 sites selected for greater consideration. Team members also examined the sites to evaluate the probability of determining the exact nature and location of each improvement, based on the information provided. The survey requested respondents to provide the location of improvement installation; however, the location information was often limited to only a route number or county. Therefore, determining the exact location of these improvements would need significant follow-up effort.

Accurately obtaining the crash history for the site required a site description by control section and milepoint. In many cases, the proper control section could be identified from TxDOT district control section maps, particularly if the improvement was at the intersection of two highways. However, for roadway segments, determining the specific control section milepoint was difficult, as that is only one method of providing location information on a roadway. Other methods are by roadway milepost or by project station, both of which were often given by survey respondents. Correlating those descriptions to a control section milepoint often was not possible using available maps, and required contacting the respondents, as described in Step 5. In some cases, it was possible to make an estimate by calculating distances from other known reference points, but it was still necessary to confirm those estimates with the survey respondents.

In addition, for a number of sites, even the confirmation with respondents was initially insufficient, because many of the respondents either did not understand the distinction between control section milepoint and highway milepost/reference marker, or they were unfamiliar with milepoints and had to be educated as to their definition and usage. For some sites, respondents confirmed the initial description provided by researchers, thinking that they understood what information was being requested, when in fact the description was incorrect and needed to be changed. Unfortunately, few respondents had significant previous experience with control section milepoints, especially on a regular basis. In fact, it appears the control section milepoint functions primarily as an identification of crashes, and most survey respondents do not work with crash data to an extent requiring such detail. As a result, the simple act of confirming the exact location of an improvement became a multiple-step task that could be very time-consuming to ensure accuracy.

Similar refinements were necessary for the improvement information. In a number of cases, the meaning of the abbreviations or descriptions of the improvement installed was unclear. It was often possible to determine the majority of the descriptions given, but some were sufficiently unclear as to require contacting the respondents for further clarification.

STEP 5: CONTACT SURVEY RESPONDENTS TO CONFIRM INFORMATION AND ADD DETAILS

For each site selected for in-depth evaluation, staff members contacted the survey respondent of that particular site for further explanation, clarification, and/or expansion of answers. Initial contact was by e-mail. It included the information currently in the database and requested survey respondents to confirm or provide more specific information where appropriate. Respondents were asked to provide or verify the exact control section and milepost location of the improvement and the date of completion, explain whether there were any other improvements made at the site during the six-year study period, confirm or provide the ADT at the site, and recommend a comparison site that had been unchanged during the study period. Figure 7 is a sample e-mail sent to survey respondents in this initial contact.

Most respondents replied or were contacted again for their answers within 10 days of the initial e-mail being sent. For sites where replies were not obtained, the respondent received a second e-mail or phone call. In some situations, research team members made a third and fourth attempt at contact to complete the information needed. Of the 78 sites selected for further evaluation, 54 had replies with further information, four were reviewed during site visits to districts, and 20 had no response.

STEP 6: IDENTIFY POTENTIAL COMPARISON SITE

The purpose of a comparison site is to gain an appreciation of how effective an improvement really was. A comparison site is a site as similar as possible to the study site in geometrics, ADT, section length, location, traffic control, and other characteristics without having any changes to impact driver behavior during the six-year study period. By comparing the crash history of the study site and the comparison site, there is a better understanding of what changes were direct results of the improvement and what changes were simply routine variations that occurred at other locations in the area.

From: Researcher, John
Sent: Wednesday, December 12, 2001 10:52 AM
To: Engineer, Bob
Subject: FW: Safety Improvements on US-123

Dear Mr. Engineer:

Last fall you completed a survey for **TxDOT Project 4048: Low-Cost Design Safety Improvements for Rural Highways**. The purpose of the 4048 project is to investigate the effectiveness of countermeasures and to provide information that discusses the safety improvement options for low-volume rural roadways. A site you identified in the survey shows potential as a candidate for a before-and-after study to evaluate its effectiveness. This e-mail contains the information we have to date and the additional information we will need to conduct the before-and-after study. I would like to talk to you about this site. *Please call me when convenient, or I can call you on December 19.*

On the survey that you completed in the fall of 2000, you provided information for this treatment installed in your district: **Bridge widened on US 123 in Lone Star County at Reference Marker 471 + 0.0, Station 0 + 472.646.**

1. To perform a complete crash analysis, we need to know the exact location of the improvement by its control section and milepost. According to our records, this improvement is located on **control section 123-4 at an unknown milepoint**. Please provide the correct milepoint location.

2. To ensure an appropriate evaluation of the benefits of the treatment, we need to know the exact date (to the month) of when the treatment was installed. In your survey, you stated the date of installation was: **September 1999.** Please confirm that date, along with information on where you obtained the date (e.g. signal agreement, maintenance diary, etc.).

3. Have there been any other changes at this location that could impact driver behavior, specifically within the six-year period of three years before to three years after the improvement was installed?

4. According to the ADT maps, the ADT for this location would be: **ADT for US 123 = 4567**. Does this ADT value appear to be appropriate for this location? If not, please provide the more representative value.

5. Do you have suggestions for a similar, unimproved site to use as a comparative/control site? (This site should be as similar as possible to the improved site in geometrics, ADT, section length, location, etc. without having any changes to impact driver behavior during the six-year study period.)

Thank you once again for your assistance. We greatly appreciate your continued support in this project. I look forward to talking with you next week.

John Researcher
Transportation Operations Group -- CE/TTI Building, Suite 301
Texas Transportation Institute -- Texas A&M University System
3135 TAMU
College Station, TX 77843-3135
(979) 845-7321 (Phone)
(979) 845-6481 (Fax)
johnresearcher@tamu.edu

Figure 7. Sample E-mail Sent to Survey Respondents for Initial B&A Contact.

Identifying a comparison site for each study site is a difficult task. Many of the sites under consideration are unique in their geometry or other characteristics, and it is those characteristics that are being addressed by the improvements under consideration. For other sites, the improvements were part of a change in policy or a district-wide series of improvements, which eliminates similar sites for comparison because all sites received the same improvement. Researchers requested that the survey respondents provide suggestions for comparison sites. If survey respondents did not provide sites, then the researchers attempted to identify sites as part of Step 12.

STEP 7: REVISE B&A SCORE AND OTHER INFORMATION BASED ON CONTACT INFORMATION

Based on the information received from the respondents, the B&A score for each of the 78 sites was reviewed and revised to a new value between 10 and 20, based on the following scale:

10	No potential
11	No response
12	Cannot pinpoint location
13	Still under construction
14	Policy-driven improvement
15	Average potential, need more detailed information
16	Average potential, high volume or multi-lane
17	High potential, need control/comparison site, need visit/pictures
18	High potential, need control/comparison site, have visit/pictures
19	Very high potential, pursue further, need visit/pictures
20	Very high potential, pursue further, have visit/pictures

The sites' scores were again revised to reflect the most current status after staff members established contact and gathered additional information.

STEP 8: OBTAIN ELECTRONIC CRASH RECORDS FOR EACH SITE BEING EVALUATED

The crash data for the potential before-and-after study sites were obtained using the control section and milepost information available from the respondents. For sites where this information was available, researchers requested the crash records from 1994 through 1999 from the DPS computer database maintained at TTI. Data for 1999 were the most current records available at the time of the study, which allows the use of a full three-year after period only for those sites with an improvement installed in 1996. For sites where the milepoint information was not available, researchers requested the crash records for the entire control section.

STEP 9: REDUCE CRASH RECORDS BY CONTROL SECTION, MILEPOINT, AND TIME PERIOD FOR ANALYSIS

The research team requested relevant information for the crashes that occurred on the sites of interest from the DPS database. Because the crash records were available by individual year, staff members merged the data into one master file of all crashes occurring on the studied control sections. Sorting these crashes by control section, milepoint, and accident number provided an orderly method of reviewing the data. Next, researchers converted some of the coded and abbreviated information to text to facilitate the readability of the data. Also, some of the data fields were entered in different units than used for analysis and had to be converted to new units. For example, control section milepoint is reported in tenths of miles, and was converted to whole miles with one decimal place. Therefore, the data better reflected the units and terms used in the analysis (i.e., MP 507 was converted to Control Section Milepoint 50.7).

After completing the conversions, research staff copied records for crashes on specific control sections from the master file into a separate file for analysis on a site-specific level. This resulted in a file that contained all crashes on a control section from 1994 to 1999. It was then necessary to reduce this set of records to only those that were relevant to the analysis – that is, those that occurred within the appropriate before or after time period and those that were within the section or intersection that received the improvement.

STEP 10: OBTAIN AND CONFIRM ADT INFORMATION FOR EACH SITE

Data on traffic volumes are necessary to calculate accurate crash rates. ADT information can be obtained from a variety of sources, such as district traffic maps, crash records, and district or area personnel. Each of these sources was used to a certain extent. The district traffic maps, used where available, provided an initial estimate of the traffic volumes at each site. In Step 5, survey respondents either verified or revised these values, which the research team then recorded as the current ADT for the site. After receiving the crash records, research staff used the imbedded ADTs associated with the previous years of the crash history to calculate specific crash rates for each of those years.

STEP 11: WRITE INITIAL SITE OVERVIEW OR SUMMARY FOR INFORMATION OBTAINED FOR EACH SITE

Researchers compiled and summarized all of the information obtained to this point for each site. This initial summary contains the description of the site, the nature of the improvement, the answers to the questions asked during the initial contact with the respondents, and the record of contacts made. Figure 8 is typical of the summaries completed to date. While a portion of respondents returned their answers within one to two weeks, another portion of respondents were re-contacted at least once to obtain their answers. In most cases, there was no control site suggested, and occasionally some portion of the description was lacking. Eventually, researchers decided to proceed with the information already obtained rather than continue to re-contact respondents for pieces of information that were missing.

STEP 12: VISIT SITE TO TAKE PICTURES, CONFIRM INFORMATION ON FILE, AND LOCATE COMPARISON SITE

To have a visual record of the improvements made and to take measurements and readings of various roadway and roadside characteristics, it was necessary to visit the study sites in person. Research team members conducted three separate trips to visit various sites, primarily in west and north Texas. On these trips, they examined and described the study sites, took photographs and videos, and investigated comparison sites. Figure 9 is a copy of the data worksheet used to record information about a study site at an intersection.

Survey Number: 84f

Location: US 123 RM 471 + 0.0 and Station 0 + 472.646

Improvement: Bridge Widened

District/County: Austin/Lone Star

Ctrl Sec Description: 123-4 at MP 5.6

Original B&A Rating: 0.5

Current B&A Rating: 15

ADT: 250

Date of Completion (Source of Date): 09/99 (maintenance logs)

Other Changes at Location: No

Comparative/Control Site: None provided

Contacts: Bob Engineer [email, phone number]
Jeff Technician [email, phone number]

<u>Contact Record</u>

1. John Researcher sent initial e-mail to BE on 12/12.
2. JR called on 12/19 to follow up with BE; was informed that JT was compiling the information and would contact JR when finished.
3. JR called JT on 1/26 for status; was informed that JT needed more time.
4. JR called JT on 2/24; received information shown above.

Figure 8. Example of Initial Site Overview/Summary.

INTERSECTION DATA WORKSHEET – 4048 B&A

Date: **Intersection:**

District/County: **Ctrl Section(s):**

Improvement:

General Information

- N/S Road: ______________________ • Posted Speed: ________
- E/W Road: ______________________ • Posted Speed: ________

Field Observations

- Roadside Environment
  - N/S Road

    2 ft — 10 ft

    ◊ No fixed objects ◊
    ◊ Yielding objects only ◊
    ◊ Combo of yielding and isolated rigid objects ◊
    ◊ Isolated rigid objects only ◊
    ◊ Many or continuous rigid objects ◊
  - E/W Road

    2 ft — 10 ft

    ◊ No fixed objects ◊
    ◊ Yielding objects only ◊
    ◊ Combo of yielding and isolated rigid objects ◊
    ◊ Isolated rigid objects only ◊
    ◊ Many or continuous rigid objects ◊

	N/S	E/W
• Roadside Dev		
• Shoulder Width		

  - Type of Shoulder ________
- Median
  - ◊ Raised .. width __________
  - ◊ Grass .. width ___________
  - ◊ Turn Bay .. width _________
  - ◊ None

Traffic Control Devices (TCDs)

- Traffic Signal? _______
- Stop Signs? ________
  - 2-Way or 4-Way?
- *Advisory Speed(s)? ________
- Pavement Markings
  - Centerline Type ________
  - Edgeline Type ________
  - Lane Line Type ________
- General Condition of TCDs: Excellent Good Fair Poor

Miscellaneous

- Shoot video on all approaches of intersection (tape #______)
- Take pictures on all approaches of intersection and various views of improvement (roll #_______)
- Draw site diagram, including lane assignments and widths
- *Note any sight distance restrictions, unusual features, and unique characteristics
- Complete data sheet for comparison/control site
- **Use back of page for notes.**
- ***Note location of advisory speeds and any unique features on site diagram**

Figure 9. Data Worksheet for an Intersection Study Site.

The technicians completed the following steps in the field to record data from the site visits:

- verified the location and existence of the improvement – the location of the improvement should also have referred to an intersection or other identifiable feature on a control-section map to pinpoint the location of the crashes (for example, a bridge that has had new guardrails installed could be identified as being on FM 1234, 6.2 mi [10 km] south of SH 123);
- shot video and still pictures of the improvement and site;
- measured the dimensions (lane and shoulder widths, number of lanes, etc.);
- diagrammed the location, including the approximate angle of the intersection and lane assignments, accompanying development, traffic control, other signs, etc.;
- finished completing the remainder of the data worksheet;
- located the comparison site, if provided, and repeated steps;
- if not provided, searched for a comparison site – this site should have been as similar as possible in geometry, length, ADT, class, etc. to the study site; and
- noted anything else that had significance or importance to understanding the characteristics of the sites.

Each study site visited required about two to three hours to complete a data worksheet, and another two to three hours for the comparison site. This time estimate is for sites with a good description of the location and the nature of the improvement. Roadway sections required more time than intersections because of their increased length. Completing a video drive-through record, taking pictures, evaluating the roadside characteristics, and accurately sketching a diagram of the site, required several round trips through the site. Furthermore, compared to an intersection, roadway sections required collecting more pieces of information, such as the number of vertical curves, total number and type of traffic control devices, and number of access points along the entire length of the section.

Of the 78 study sites, 52 have been visited as of the summer of 2002, either for viewing with district or area personnel, or to collect information on site characteristics and take pictures.

STEP 13: REQUEST CRASH NARRATIVES FOR SPECIFIC SITES FOR DETAILED ANALYSIS

For sites that had a complete crash history available, researchers requested copies of the crash narratives from DPS for further review. Copies of the actual crash reports from the various reporting agencies greatly aid in completing the comprehension of the crash history at a location. Possession of the narratives allows for creation of a crash diagram, which helps to recognize crash patterns at the sites.

STEP 14: FOLLOW-UP WITH SURVEY RESPONDENTS TO OBTAIN REMAINING DETAILS NECESSARY FOR ANALYSIS

After compiling all of the available information, it is necessary to contact the respondents again to confirm that information and to gather any other information that is still missing. This follow-up also allows a further review of any conditions that might have affected traffic and crash patterns at the site besides the improvement under consideration.

STEP 15: COMPLETE BEFORE-AND-AFTER EVALUATION FOR SITE

With the information collected and confirmed by the respondents, the final portion of analysis can be completed. This is done by calculating and comparing crash rates, types of crashes, behavior at the study site and comparison site, and roadway and roadside characteristics. When all calculations and analyses have been completed, a more thorough overview and summary are written for each site.

STEP 16: DRAW CONCLUSIONS

A complete before-and-after evaluation is a very thorough and comprehensive review of a site and its improvements. It provides a clearer total picture of what has been done and its effectiveness. However, it is also a very time-consuming and labor-intensive process, requiring input from many different sources: researchers and staff, survey respondents and their staff, and keepers of crash records and narratives and their staff. Each of these parties has a part in completing the evaluation process; if any of the steps outlined above are incomplete, the evaluation cannot proceed as planned. A before-and-after evaluation is a tool with great potential, but it requires significant time and effort for proper use.

CHAPTER 5

BEFORE-AND-AFTER EVALUATIONS

INTRODUCTION

This chapter discusses the before-and-after evaluations of selected sites. The number of sites available for completion of a full B&A evaluation is dependent on the date of installation of the improvement as well as the quality of site data available. To have three years worth of after-crash data, an improvement must have been completed in 1996. (Currently, crash data up to December 1999 are available for analysis.) Available from the mail-out survey completed in the initial year of Project 4048 along with information available from contacts with TxDOT districts, researchers identified two sites as having a treatment completed in 1996. To expand the number of sites available for evaluation, the after crash history period was shortened to two years from three, allowing sites completed in 1997 to be included in this round of evaluations. Team members identified four sites with improvements in 1997; however, data were not provided for one site, and another site was determined to be a poor candidate for study. This left four sites from 1996 and 1997 available for evaluation. The text in this chapter describes these four sites and the information gathered using the methodology outlined in Chapter 4.

RAISED REFLECTIVE PAVEMENT MARKERS AND ADDITIONAL DELINEATION

Description of Site. This site is on a rural two-lane farm-to-market highway with a 2002 ADT of approximately 2600. The location under evaluation, shown in Figures 10 and 11, is a 1.5-mile (2.4 km) section containing a bridge over a lake that is near a power plant. The power plant feeds into the lake, causing the lake water to be warm, and inducing fog under certain weather conditions. Thus, this section of roadway has been subject to heavy fog, which greatly reduces visibility near the bridge. TxDOT personnel were looking for a low-cost means of providing better information to drivers in the area. They had considered installation of a full-function weather station with variable message signs; however, the cost for such a treatment was prohibitive. A simpler, and less costly, alternative was to increase the visibility of the centerline and edgelines of the roadway through improved delineation.

Figure 10. View of Bridge on Lake.

Description of Treatment. Raised reflective pavement markers and additional delineation along the bridge rails and guardrails were installed throughout the 1.5-mile (2.4 km) section. Raised reflective yellow pavement markers were installed beside the centerline of the road on the outside edge of both solid yellow lines. These markers begin about 100 ft (30.4 m) in advance of the beginning of the guardrail and continue throughout the section to the other side of the bridge. The delineators, rectangular white or yellow reflectors on metal posts, were attached to wooden guardrail posts at regular intervals throughout the length of the guardrail (see Figure 10); white delineators were used throughout the length of the guardrail, while yellow ones were used at the last guardrail post to signify the end of the guardrail.

Installation. Based on maintenance diary records, the installation of the improvements was completed in October 1996, at an estimated cost of $3000-5000.

Figure 11. View of Added Raised Pavement Markers and Delineation.

Comparison Site. No comparison site was suggested; this site is rather unique because of its location on the lake and its foggy conditions. Other than a slight decrease in 1997, the ADT at this site has shown a gradual trend of growth over the study period.

Effectiveness. Researchers obtained crash records for this site for a total of six years and divided the records into periods before and after the date of installation. The before period lasted from January 1994 through September 1996 (33 months). The after period began with November 1996 and ran through December 1999 (38 months). During the before period, four crashes occurred in the 1.5-mile (2.4 km) section (three non-injury, one incapacitating injury), with a crash rate of 1.46 crashes per million vehicle miles traveled (0.91 crash per million vehicle kilometers traveled [MVKT]). In the after period, only one (non-incapacitating injury) crash occurred, resulting in a crash rate of 0.29 crash/MVMT (0.18 crash/MVKT). The four crashes in the before period consisted of two fixed-object crashes, one head-on crash, and one striking a parked vehicle; the rear-end crash in the after period happened as the lead vehicle avoided an animal in the road. In addition to the reduction in crashes on this section, TxDOT personnel report fewer complaints from motorists since the installation of this improvement.

APPROACH RUMBLE STRIPS AND STROBES IN SIGNAL HEADS

Description of Site. This site is an intersection of two US highways. One highway is the major east-west route through the county and intersects with the other highway within the limits of a small city. The primary highway is a four-lane arterial with a continuous center two-way left-turn lane (TWLTL) having a 2002 ADT of approximately 14,000. The secondary highway at the intersection is also a four-lane arterial with an ADT of approximately 4000. This site, a signalized intersection surrounded on all sides by commercial development, is the highest-volume intersection in the city in which it is located. This site was originally given a lower priority within this project because of its high ADT and non-rural, multi-lane status; however, there have been multiple improvements made at the site that can be studied and evaluated for use at other locations.

This intersection is the first signalized intersection encountered by eastbound drivers as they approach the west side of the city on the primary highway. There is also a high percentage of truck traffic on the primary highway. Those two factors were attributed to a high occurrence of vehicles "running the red." Eastbound drivers have a low expectation of seeing a signalized intersection, and westbound drivers may be eager to proceed through the final signal and enter the open highway west of town. The occurrences of red-light violations produce a high number of right-angle and left-turn crashes. TxDOT engineers were looking to increase drivers' awareness of the upcoming signal. They selected a combination of measures implemented over a period of time.

Description of Treatment. One of the treatments to be installed at this site was approach rumble strips, shown in Figure 12. These thermoplastic strips are installed in two places across the lanes of the eastbound approach to the intersection. The second treatment at this site is the installation of white strobe lights in the red signal heads facing west, shown in Figure 13. These strobe lights flash at regular intervals when the red signal is lit. Because the primary highway is almost directly east-west through the city, visibility at dusk and dawn can be impeded due to the rising and setting sun. Engineers in the district felt the strobe lights would especially aid drivers during these times of day. Additionally, engineers theorized that these devices would give travelers a better recognition of a change in the roadway environment.

Note that the high-intensity strobe device is experimental. When considering new technologies not included in the TMUTCD, a request for experimentation is to be submitted to the Traffic Operations Division of TxDOT and approved before installation of the device.

Figure 12. View of Approach Rumble Strips.

Figure 13. Strobes in Signal Heads.

Installation. The rumble strips, installed in August 1997, were placed in two sets. Each set consisted of 10 strips, 24 ft × 4.5 inches (7.3 m × 11.4 cm), with a space of 9.5 inches (24.1 cm) between each strip. A close-up view of the rumble strips is shown in Figure 14. The first set is 1236 ft (377 m) from the traffic signal, and the second set is 480 ft (146.3 m) from the traffic signal. There is also a 36 ft × 36 ft (91.4 cm × 91.4 cm) "RUMBLE STRIPS AHEAD" sign located 985 ft (300 m) west of the first set of rumble strips. The cost to install the rumble strips and advance sign amounted to approximately $500. The strobe lights, installed in March 1997, are mounted to the red lenses of the traffic signals. The cost of purchasing and installing the strobe lights was approximately $3200.

Figure 14. Close-Up View of Approach Rumble Strips.

Comparison Site. No comparison site was submitted because no other intersection in the district possesses volumes as high as at this site. The district did compare the findings at this site to other sites with signals in the city, as discussed in the Effectiveness section below.

Effectiveness. Researchers obtained crash data from 1994 through 1999 for this intersection, then divided the data into before and after periods relative to the installation of both treatments. The before period consists of January 1, 1994, to February 28, 1997, while the after period continues from September 1, 1997, to December 31, 1999. There were 18 crashes at this intersection during the before period, with a crash rate of 1.20 crashes per million entering vehicles (MEV). Of those 18 crashes, 13 were right-angle crashes, and four were left-turn crashes. In the after period, six crashes (two right-angle, two left-turn, and two rear-end) occurred, with a crash rate of 0.46 crash/MEV. Thus, the crash rate greatly reduced after treatment, as did the number of the predominant types of crashes caused by red-light-running. One caveat, however, may be the increase in rear-end crashes from zero to two. As more vehicles stop for the red signal, the opportunity for rear-end crashes increases. Not enough crash data are present to determine if this is a developing trend at the intersection, but it may be an issue to examine further in the future.

ADT is the strongest predictor of crashes. As ADT increases at a site, it would be expected that crashes would also increase. At this intersection, fewer crashes occurred in the after period, even with an increase in the number of vehicles entering the intersection (see Figure 15).

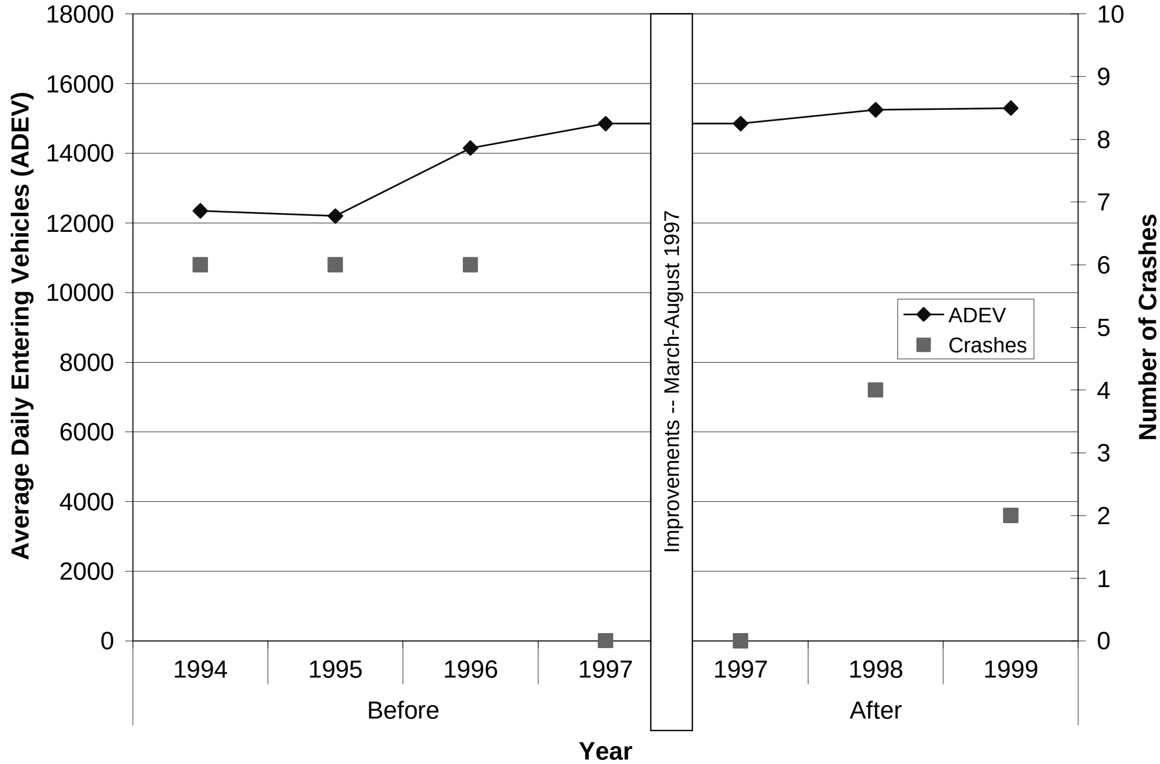


Figure 15. Annual ADT and Number of Crashes at Study Site with Approach Rumble Strips and Strobes in Signal Heads.

The district also conducted their own effectiveness study, consisting of approximately 44 months of crash data. When compared to signals in the city that did not have the safety devices installed, there was as much as an 85 percent reduction in crashes at the sites with the devices. In the opinion of district personnel, these devices have significantly reduced accidents at this site.

ROADWAY WIDENING

Description of Site. This site is a 2.8-mi (4.5-km) section of a rural, two-lane farm-to-market highway with a number of vertical and horizontal curves. Before improvements, the cross-section of this site consisted of two 10-ft (3.1-m) lanes with no shoulders, for a total pavement width of 20 ft (6.2 m). The 2002 ADT is approximately 200. The sections of the highway on either end of the 2.8-mi (4.5-km) study site were wider and caused a "bottleneck" as vehicles approached the change in cross-section. District personnel wanted to eliminate this bottleneck.

Description of Treatment. The roadway was widened to match the width of the adjacent sections. An additional 3 ft (0.9 m) of lane width and 2 ft (0.6 m) of shoulder width on either side of the roadway augmented this segment, for a total pavement width of 30 ft (9.2 m).

Installation. Recycled asphalt pavement was used for the paving material, with the intent of adding a seal coat in the future. Completion of the installation occurred in May 1997; approximate cost of installation was not available.

Comparison Site. Another section of the same highway south of the study site was chosen for a comparison site. This site consists of a 2.8-mi (4.5-km) section where no improvements took place during the six-year crash history evaluation period. The comparison site section is similar to the study site in terrain and volume. A view of the comparison site is shown in Figure 16.

Figure 16. View of Comparison Site near Site with Roadway Widening.

Effectiveness. Crash data showed two crashes in the section during the 40 months prior to improvement (January 1994 through April 1997). Both of these crashes were single-vehicle, fixed-object crashes, and the crash rate was 2.79 crashes/MVMT (1.73 crashes/MVKT). In addition, according to crash narratives, one of these crashes involved a driver who was driving while intoxicated, and the other involved a driver who fell asleep. In the period after improvement (June 1, 1997, through December 31, 1999), there were three crashes in this section, for a crash rate of 6.07 crashes/MVMT (3.77 crashes/MVKT). As in the before period, all three crashes in the after period were single-vehicle crashes; two involved overturned vehicles, and the third was a fixed-object crash. One of these crashes involved avoidance of an animal. Because of the low number of crashes and the similarities between crashes in the two periods, determining the effectiveness of the improvement from the crash history has been inconclusive. However, district personnel say that people feel more comfortable driving the new section and have not lodged any complaints since completing the installation.

For the comparison site, there was one crash during the corresponding before period, and no crashes during the after period, for crash rates of 1.39 and 0.00 crashes/MVMT (0.86 and 0.00 crash/MVKT), respectively. The before period crash was a single-vehicle crash that involved avoidance of an animal. As with the study site, the low number of crashes and the consistency in the number and type of crashes among all periods and sites make a crash analysis comparison inconclusive between the two sites.

Traffic volume history reveals a fluctuating, but downward, trend in volume (from 230 to 180). However, the absolute differences in annual ADT are not very large. The changes in the number of crashes from year to year are also small. Given the low ADT values and the low number of crashes, it is difficult to attribute any effective results to the treatment with any level of confidence.

ALL-WAY STOP AND ADVANCE WARNING

Description of Site. This site is an intersection of two two-lane rural highways, with a 2002 ADT of approximately 1000 on the primary highway and 500 on the secondary highway (see

Figure 17). Prior to improvements, this intersection was two-way stop-controlled on the secondary highway. The westbound approach on the primary highway has a crest vertical curve approximately 1000 ft (305 m) prior to the intersection; this curve limits the line of sight between drivers approaching the intersection on the primary highway and drivers stopped on the secondary highway. District personnel decided to address this safety concern with an all-way stop control at the intersection.

Description of Treatment. Four-way stop control was installed at this intersection, along with advance warning signs. This consisted of symbolic STOP AHEAD signs and HIGHWAY INTERSECTION 1500 FT (457.5 m) signs on each approach. A view of these signs on one approach is shown in Figure 18.

Installation. According to the maintenance diary, district maintenance personnel completed installation of signs in September 1996.

Comparison Site. No comparison site was suggested by the survey respondents.

Figure 17. All-Way Stop Controlled Intersection, Looking East.

Effectiveness. An analysis of available crash data revealed that during the 32 months prior to installation of the improvement (January 1994 through August 1996), there was one rear-end crash at this intersection, resulting in a crash rate of 0.65 crash/MEV. In the 39 months following installation (October 1996 through December 1999), there were no crashes. While this represents a 100 percent reduction in crashes following the installation of the improvement, the number of crashes is too small to make a definitive analysis based on the crash history.

A comparison of crashes and volume trends revealed that both values have remained consistent over the six-year study period. The number of vehicles entering the intersection ranged between 1500 and 1610, while there was only one crash during the study period.

Figure 18. Advance Warning Signs for Approach to Intersection.

FUTURE EFFORTS

As time passes, more sites will become available for evaluation, and more information can be obtained from survey respondents and site visits. Additional sites will provide a greater cross-section of improvements and geographical variation than is available with the current four sites.

CHAPTER 6

SUMMARY AND CONCLUSIONS

The majority of the highway system in Texas, as well as the United States, consists of two- and three-lane rural roads. A substantial mileage of these roads carries relatively low traffic volumes. These low-volume rural roadways generally have high speeds, and crashes can be severe due to the high speeds. Following are summaries of some of the causes and characteristics of these crashes, as well as the methodology and results of before-and-after evaluations of selected treatments to reduce these crashes.

ANIMAL CRASHES

A notable portion of rural two-lane highway crashes involve animals. Following are some key findings about animal crashes in Texas:

- About 3800 animal crashes occurred in 1999 on rural highways in Texas.
- Non-PDO animal crashes occurred at a rate of about 0.02 to 0.03 crashes/MVMT (0.012 to 0.019 crashes/MVKT) each year from 1990 to 1999.
- Nearly three-fourths (73 percent) of all animal crashes in Texas occur at night.
- More than one-third (35 percent) of all animal crashes occur during October, November, and December.
- Sixty-two percent of all animal crashes in a selected district in Texas involved deer; another 25 percent involved cows.

Researchers identified several countermeasures within this project as being potential treatments for use within Texas. These countermeasures and some of their pros and cons are identified in Table 12.

Research team members identified potential study locations using animal crash data. As the opportunity becomes available, one or more of the animal crash countermeasures will be installed at selected sites for testing.

Table 12. Potential Countermeasures to Animal Crashes.

Countermeasure	Application	Pros	Cons
Wildlife Reflectors	Reflectors mounted at regular intervals; create an optical fence	• Active device • Invisible to motorists	• May have "gaps" • Animals may become accustomed to fences not really being present
Infrared Detection Technology	Infrared detectors activate flashing warning sign when animal is detected	• Only warns motorist when animal is present	• Requires maintenance and replacement • Sensitivity needs adjustment
Wildlife Warning Signs	Signs are mounted to alert drivers of wildlife in area	• Low cost	• Effectiveness is suspected to be minimal
Roadway Animal Detection System	Low-power radio detects animals and triggers warning device	• Motion-activated • Waterproof • Can use solar power	• Prohibitive cost for large-scale use
Wildlife Warning System	Roadway sensors detect vehicles, then scare animals away	• Motion- or heat-activated • Waterproof • Can use solar power	• Not proven effective
Established Feeding Areas	Feeding area is established to discourage animals from crossing roadway	• Short-term reduction in crashes	• Not a long-term solution • Requires landowner participation
Fences	High fence is built along roadside	• Effective if properly installed	• Maintenance • Proper length • Routes of passage

CHARACTERISTICS OF LOW-VOLUME, RURAL TWO-LANE HIGHWAY CRASHES

A review of narratives for 113 crashes in four Texas counties revealed the following characteristics about crashes on low-volume, rural two-lane highways:

- One of every four crashes (25 percent) involved "Driver Inattention" as a contributing factor. Other factors greater than 15 percent included "Failed to Control Speed," "Failed to Yield ROW (Stop Sign)," "Unsafe Speeding (Under Limit)," and "Faulty Evasive Action."
- Overall, crashes in western counties are associated with driver inattention and speeding over the limit.
- Overall, crashes in eastern counties are associated with driver inattention, failure to yield, and driving too fast for conditions.

Researchers conducted an additional in-depth evaluation for a rapidly developing district in the eastern part of Texas. They identified a subset of nine roadway segments within the district. The research staff requested and reviewed reports for the crashes on the selected control sections to determine the contributing factors for each crash.

The distribution of the district's crashes revealed that crashes occurred more often at intersections compared to the rest of the state. Run-off-road crashes were also a concern. The district had a higher percentage of crashes on horizontal curves than the state rural crashes. Potential treatments frequently suggested were resurfacing, intersection treatments, and wider shoulders.

BEFORE-AND-AFTER METHODOLOGY

Researchers conducted a before-and-after study to determine the effectiveness of various treatments. It is also anticipated that the evaluations can improve the information available to TxDOT for utilizing these improvements in the future. The steps in the evaluation process are listed below.

1. Conduct the initial mail-out survey of TxDOT engineers.
2. Process the findings from the survey.
3. Assign an initial B&A score to each improvement.
4. Attempt to determine the location and exact nature of each improvement.
5. Contact the survey respondents to confirm information and add details.
6. Identify a potential comparison site.
7. Revise the B&A score and other information based on contact information.
8. Obtain electronic crash records for each site being evaluated.
9. Reduce crash records by control section, milepoint, and time period for analysis.
10. Obtain/confirm the ADT information for each site.
11. Write an initial overview or summary for information obtained for each site.
12. Visit the site to take pictures; confirm information on file; and locate a comparison site.

13. Request crash narratives for the specific sites for detailed analysis.
14. Follow-up with the survey respondents to obtain remaining details necessary for analysis.
15. Complete B&A evaluation for the site.
16. Draw conclusions.

Each of the above steps depends on researchers, engineers, record keepers, and their respective staffs. If any of the needed information is missing, the evaluation cannot be completed, is completed at a higher cost of time and resources, or is incomplete. Obtaining and receiving accurate information and data in a timely fashion is of utmost importance in completing the evaluation process.

BEFORE-AND-AFTER EVALUATIONS

Researchers evaluated four sites with treatments for effectiveness. Team members analyzed crash data and traffic volume data from 1994 through 1999 to determine trends and patterns at the four sites. Table 13 contains a summary of the evaluations.

Table 13. Summary of Before-and-After Evaluations.

Treatment(s)	Installation Date	Effectiveness
Raised reflective pavement markers and additional delineation on bridge	October 1996	Reduction in crashes from four to one, despite gradual increase in ADT
Approach rumble strips and strobes in signal heads	March-August 1997	Reduction in crashes from 18 to six, with sizable increase in ADT. Right-angle crashes nearly eliminated
Roadway widening	May 1997	Two crashes before, three crashes after; all single-vehicle. Low ADT, virtually unchanged
All-way stop and advance warning	September 1996	One crash before, no crashes after. Steady ADT throughout study period

The number of sites available for completion of a full B&A evaluation is dependent on the date of installation of the improvement as well as the quality of site data available. To have three years worth of after crash data, an improvement must have been completed in 1996. (Currently, crash data up to December 1999 are available for analysis.) Available from the mail-out survey completed in the initial year of Project 0-4048, along with information available from contacts with TxDOT districts, staff identified two sites with treatment completed in 1996. To expand the number of sites available for evaluation, the after crash history period was shortened to two years from three, allowing sites completed in 1997 to be included in this round of evaluations. Research team members identified four sites with improvements completed in 1997; however, data were not provided for one site, and another site was determined to be a poor candidate for study. This left four sites, completed in 1996 and 1997 and listed in Table 13, available for evaluation.

CONCLUSIONS

Crashes on low-volume, rural two-lane highways are an issue of concern. Large numbers of these crashes occur each year in Texas, but their isolated nature makes traditional improvements impractical or too costly to be effective. Other treatments such as animal warning devices, additional delineation, approach rumble strips, and roadway widening may be effective at reducing crashes in specific locations and at a lower cost. A complete before-and-after evaluation is a very thorough and comprehensive review of a site and its improvements. It provides a clearer total picture of what has been done and its effectiveness. However, it is also a time-consuming and labor-intensive process, requiring input from many different sources: researchers and staff, survey respondents and their staff, and keepers of crash records and narratives and their staff. Each of these parties has a part in completing the evaluation process; if any of the steps outlined above are incomplete, the evaluation cannot proceed as planned. A before-and-after evaluation is a tool with great potential, but requires significant time and effort for proper use.

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