GUARDRAIL END ACCIDENT ANALYSIS

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16. ABSTRACT

This study documented attributes associated with guardrail end accidents on Oklahoma Department of Transportation (ODOT) roadways. The database which the researchers studied included accidents at a variety of guardrail end types, but most ends were either exposed or turned-down. The severity of exposed and of turned-down guardrail end accidents in relation to lateral location of the guardrail, to vehicle rolling and vaulting, and to vehicle weight was investigated. Each accident report was read carefully to obtain relevant information for analyses.

The results showed that on divided roads, vehicles struck median guardrail ends as often as right-side ends. On undivided roadways, right-side ends were struck 60% of the time. Fatalities or incapacitating injuries occurred in 1/6 of the end accidents. The vehicle vaulted or rolled in about 1/4 of the guardrail end accidents. The research indicated that turned-down guardrail end accidents had more vehicle rolling and/or vaulting than did exposed end accidents. Driver inattention was a factor in 1/3 of all guardrail end accidents. The majority of guardrail end accidents on the state system occurred on a small portion of the system, namely the higher volume roadways.

The researchers suggested that accident reporting methods be enhanced, and that rumble strips be tested as a means to reduce guardrail end strike accidents. If newer, more expensive end treatments were installed, locating the new guardrail ends on a small portion of the system could address a majority of the end accident sites.

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PARTIAL LIST OF ABBREVIATIONS

ADT	average daily traffic
BCT	breakaway cable terminal
DPS	Department of Public Safety
FHWA	Federal Highway Administration
ft	feet
in	inches
NASS	National Accident Sampling System
NHTSA	National Highway Traffic Safety Administration
ODOT	Oklahoma Department of Transportation
OTIC	Oklahoma Transportation and Infrastructure Center
P	presumed guardrail end accident
P+Q	presumed-plus-questionable guardrail end accident
PDO	property damage only
POI	point-of-impact
SwRI	Southwest Research Institute
TTI	Texas Transportation Institute
VMT	vehicle miles of travel

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CHAPTER I

INTRODUCTION

This report documents the methods and results of a study conducted to gain greater insight into certain characteristics of guardrail end accidents. The two predominant types of guardrail ends currently used on highways operated by the Oklahoma Department of Transportation (ODOT) are the exposed ends and the turned-down or buried ends. The police reports of individual guardrail end accidents which occurred on Oklahoma state highways from 1988 through 1991 were studied to evaluate the performance of the guardrail end treatments when struck by vehicles.

1.1 THE NEED FOR GUARDRAIL ENDS

There are many physical features along the road that need to be shielded from errant vehicles. One of the most common means to shield embankments, sign poles, bridge ends, etc. from traffic is to install a guardrail.

Most guardrail installations include one or more guardrail ends. Traffic safety professionals have cautioned that under certain circumstances, the ends themselves can make accidents worse, by causing the vehicle to vault or roll, or by spearing the vehicle. An effective guardrail end should be capable of decelerating the vehicle without causing undesirable effects. Trying to address these concerns, inventors have developed many alternative guardrail end treatments.

Accumulated experience and technological changes have led to changed perspectives in the roadside safety field. Years ago, highway safety experts preferred the turned-down twist or buried guardrail end, developed from a combination of concepts from the General Motors Proving Grounds and Texas *(1)*. These guardrail ends had been developed to prevent the errant vehicle from being impaled on the then-commonly used exposed guardrail ends. Early turned-down end designs caused vehicles striking the end to go out of control, so the design was modified in an attempt to eliminate this undesirable side effect. The modified design allowed the vehicle to "ride down the rail" and decelerate at a rate that would increase the vehicle occupant's chances of survival.

1.02 Introduction

Since the turned-down ends were first adopted, there has been a change in the composite vehicle fleet, and there is now a higher proportion of smaller, lightweight vehicles on the road. Some in the highway safety field feel that newer guardrail end designs should replace the turned-down ends, because some vehicles, especially lightweight vehicles, have flipped when they ride up on a turned-down guardrail end.

1.2 CURRENT ISSUES

Thousands of turned-down guardrail ends were installed when they were a Federal Highway Administration (FHWA)-approved standard design. These turned-down ends are still in place on many of the nation's roadways, including those in Oklahoma. The following appeared in a recent FHWA memorandum:

* Turned-down terminals should not be used on new installations of guardrails for freeway, expressway, or other high speed, high volume facilities.
* Safety improvement projects, hazard elimination projects, or 3R/4R projects on high speed, high volume facilities should require replacement of turned-down end terminals with approved terminals.
* Use of turned-down terminals on projects involving high speed, but moderate traffic carrying facilities should be considered on a case-by-case basis or an approved State developed policy.
* Development of adequate recovery area behind the terminal and sufficient distance from protected piers, abutments or other fixed hazards is necessary to prevent tragic "vault into object" accidents from occurring.
* Use of turned-down terminals on low speed or any low volume facility may be allowed based on reasonable risk management considerations.

FHWA has asked states to act on this policy.

ODOT is understandably reluctant to incur the cost of replacing existing turned-down ends unless they can be assured that these ends, currently in place, are in fact causing problems. The newer guardrail end treatments, which would be used in lieu of turned-down ends, are more costly than the turned-down ends.

1.3 PURPOSE OF THIS RESEARCH

With reference to the previously-mentioned memorandum, the Oklahoma Department of Transportation wanted an evaluation of the recent experiences with guardrail end accidents on its highways. The guardrail accidents occurring on Interstate, U.S., and State highways in Oklahoma (excluding turnpikes) from 1988 through 1991 were analyzed.

An initial stated study objective was to determine if, and to what degree, the turned-down guardrail ends used on Oklahoma state highways were associated with

1. vehicle overturning,
2. vehicle vaulting, or
3. accidental death and injury.

The original plans called for a study of accidents occurring from June 1, 1987 to May 31, 1990. It was assumed that not all police would describe a certain type of accident with the same terms, and guardrail end accidents possibly could be found in more than one "Object Struck First" category. Therefore, the initial study pool was to have included accidents in the "Object Struck First" categories of barrier, bridge rail, guard post, as well as guardrail. However, the final study considered only the "guardrail" category, but an extra year of data were obtained and studied.

This study documents the attributes associated with accidents where vehicles struck guardrail ends. The data base which the researchers studied included accidents at a variety of guardrail end types, but most ends were either exposed or turned-down. The severity of exposed and of turned-down guardrail end accidents in relation to lateral location of the guardrail, vehicle rolling and vaulting, and vehicle weight was investigated. Each accident report was read carefully to determine if the investigating officer indicated driver inattention as a factor contributing to the accident. In addition, analyses were made by urban/rural location, posted speed limit, and vehicle miles of travel to determine if these factors were related to the frequency of guardrail end strikes.

1.04 Introduction

CHAPTER II

BACKGROUND

This chapter outlines an abbreviated history of the development of guardrail end issues, and reports the contents of two recent related publications. Some of the more common types of guardrail ends are described. This chapter also briefly discusses some of the limitations present in the analysis of accident data.

2.1 A BRIEF HISTORY

Before the 1960s, highway engineers generally held the concept that the people who ran vehicles off the roadway deserved what they got *(2)*. However, in the 1960s it was realized that many innocent people were killed by hostile roadside environments.

The clear-roadside or the forgiving roadside concept evolved in the late 1960s. This concept stated that it is desirable to provide a roadside clear of hazardous objects or conditions for a distance consistent with the speed, traffic, volume, and geometric conditions of the site. According to this concept, the number of accidents resulting in severe consequences could be reduced if a traversable recovery area were provided at the side of the road. This recovery area or "clear zone" should be free of obstacles which would prevent a safe recovery after a vehicle runs off the road. Studies have indicated that on high speed highways, a width of 30 feet or more from the edge of the traveled way permits about 80 percent of the vehicles leaving a roadway out of control, to recover *(2)*. However, in some situations where the embankment slope is steeper than 3-to-1, a 30 feet recovery area might be inadequate. On most low volume or low speed facilities, a 30 feet clear zone distance may be excessive.

Since the 1960s, roadside safety designers have attempted to provide devices such as breakaway signs and crash cushions in attempts to improve safety. Although guardrails had long been installed to improve safety, it became recognized that exposed guardrail ends were lethal roadside hazards, because vehicles were sometimes impaled upon hitting these exposed guardrail ends. When struck by an errant vehicle, the then-standard exposed guardrail ends sometimes allowed the beam element to penetrate the passenger compartment and bring the vehicle to an abrupt stop. To be crashworthy, the end treatment should not spear, vault, or roll a vehicle after a head-on or angled impact. Also, the end section must be capable of developing the full tensile strength of the standard rail element *(3)*.

Flaring and anchoring the end into an embankment or turning the end of the rail down and slowly ramping it up to full height were the recommended end treatments. The turned-down alternative was adopted by the state of Texas and given the name "Texas Twist" *(4)*.

The problem of a vehicle vaulting or rolling when it hit turned-down terminals was becoming known through observations made by the California Division of Highways *(4)*, and in part due to a series of tests run by Southwest Research Institute (SwRI) in 1969 *(5)*. After evaluation tests by the California Division of Highways, there were modifications to the turned-down end.

The SwRI developed the breakaway cable terminal (BCT). However, when small vehicles hit the breakaway cable terminal it did not perform well *(5)*. New guardrail end treatments like the eccentric loader BCT and controlled releasing terminal turndowns were developed at the Texas Transportation Institute (TTI), but these devices did not make the breakthrough that was hoped for *(5)*.

A design called Sentre was developed in the 1980s. Although this end treatment performed well in crash tests, its cost was high. Three new devices came on the market, in efforts to fill the gaps between performance and costs. These were the BRAKEMASTER, Crash-cushion Attenuating Terminal (CAT), and Extruder Terminal-2000 (ET-2000).

2.2 TWO RECENT STUDIES

There have been recent articles about guardrail end safety studies. The following material presents excerpts from two of them, by Griffin et al., and by Troxel et al.

2.2.01 GRIFFIN'S STUDY

Griffin *(6)* studied the accidents involving turned-down guardrail ends in the state of Texas. A total of 4047 guardrail accidents that occurred in 1989 were considered for the study. One hundred of these accidents were fatal. Of the remaining 3947 non-fatal guardrail accidents, a 25% sample was drawn by selecting every fourth accident in the data file. In the 25% sample, there were 987 non-fatal accidents, of which 152 involved turned-down guardrail ends.

Of the 100 fatal accidents, 87 were guardrail accidents and the remaining 13 accidents were non-guardrail accidents. Of the guardrail accidents, 32 collisions were at the guardrail end, 46 were not at the end of the rail, and 9 had undetermined impact points.

It was found that fatalities and injuries on a per accident basis were relatively more common for turned-down ends. Table 2.1 summarizes some of the findings.

TABLE 2.1 Events per 100 accidents

	Not a turned-down end	turned-down end
Fatalities per 100	1.90	5.84
A-injuries per 100	11.2	11.55
Non-fatal accident with overturning	12	36
Fatal accident with overturning	54	72

About 60 percent of all vehicles involved in single-vehicle guardrail accidents were passenger cars. After striking a turned-down end, 39 percent of passenger cars overturned, while eight percent of passenger cars overturned when they struck the guardrail away from the turned-down end.

Ten percent of the non-fatal guardrail accidents at turned-down ends were associated with driver inattention. Twelve percent of the non-fatal guardrail accidents that were not at turned-down ends were associated with driver swerving to avoid something on the road. One in five drivers striking a turned-down guardrail end was found fatigued or asleep, while for drivers striking guardrails at points off the turned-down end, one in twelve was found to be asleep. Driving while intoxicated was cited for one in four drivers striking a turned-down end, while for drivers striking a guardrail not at the turned-down end, the ratio was one in five. Approximately 25% of all non-fatal guardrail accidents on turned-down ends were associated with wet, icy, snowy, or muddy pavements, while for non-fatal, guardrail accidents it was 30 percent. Speeding was involved in over 40 percent of all guardrail accidents.

2.2.02 TROXEL'S STUDY

In a 1991 analysis of National Accident Sampling System (NASS) data for 1982 to 1985, Troxel et al. *(7)* found that there were more than 14,000 occupant involvements with guardrail midsections and fewer than 2000 with end sections and transitions. There was not a single fatality for the estimated 14,000 involvements with guardrail midsections. All the fatalities involving guardrails were caused by collisions with end sections and transitions. Table 2.2 gives a summary of these accidents.

2.3 COMMON GUARDRAIL ENDS

The following material discusses some of the common end treatments, emphasizing those used on Oklahoma highways. An early ODOT response to the exposed end was to flare the end outward. Next, there was a time when BCT's were used. Then Oklahoma adopted the "Type A" turned-down end, which has undergone some changes over time.

2.04 Background

TABLE 2.2 Guardrail collisions by injury severity

Guardrail type	No, Possible, or Minor Injury(0+B+C)		Incapacitating Injury A		Killed		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Non-Median	11,402	75	374	60	0	0	11,776	74
Median	2,185	14	60	10	0	0	2,245	14
Bridge transition	352	2	0	0	22	41	374	2
End w/o median	1,309	9	61	10	18	33	1,388	9
End w/ median	14	0	127	20	14	26	155	1
Totals	15,262	100	622	100	54	100	15,938	100
Missing							58	

2.3.01 EXPOSED END TREATMENT

Figure 2.1 shows an example of an exposed end treatment. This was the old standard end treatment. When hit by a vehicle, these older end treatments may penetrate the front or side of a vehicle, snag the vehicle, or get under the vehicle. Any of these situations may increase the severity of the accident.

FIGURE 2.1 Exposed end treatment

2.3.02 BREAKAWAY CABLE TERMINAL

A breakaway cable terminal is shown in Figure 2.2. The first two posts are intended to fracture for an end impact, allowing the rail element to bend away from the vehicle. This bending of rail away from the vehicle is encouraged by the curvature in the rail itself and by having post bolt washers on the first post. For side impacts where redirection is needed, tensile strength is developed rapidly by the cable which transfers tensile forces from W-Beam to the base of the end post. The parabolic flare is critical for proper impact performance.

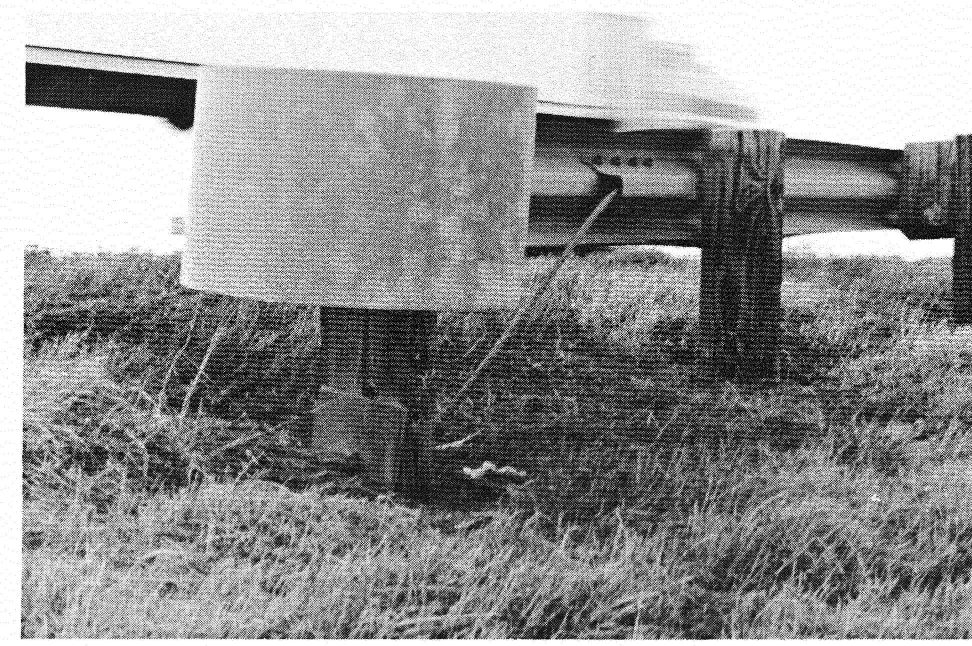


FIGURE 2.2 Breakaway Cable Terminal

2.3.03 TURNED-DOWN OR BURIED GUARDRAIL TERMINAL

Figure 2.3 shows a turned-down guardrail end. This treatment effectively eliminated the impalement problems. However, it gradually came into disfavor because of experiences with vehicle rolling and vaulting after impact.

A modified Oklahoma turned-down end terminal, designed and developed by Texas Transportation Institute for the Oklahoma Department of Transportation, is shown in Figure 2.4. The design specified 25 feet (ft) from the embedded anchor to the initial post, and 12.5 ft between the first two posts. When possible, ends were slightly flared. Posts were wooden, with blockouts. One change to the initial design was modifying the first eight posts by drilling a two-inch hole near ground level parallel to the railing.

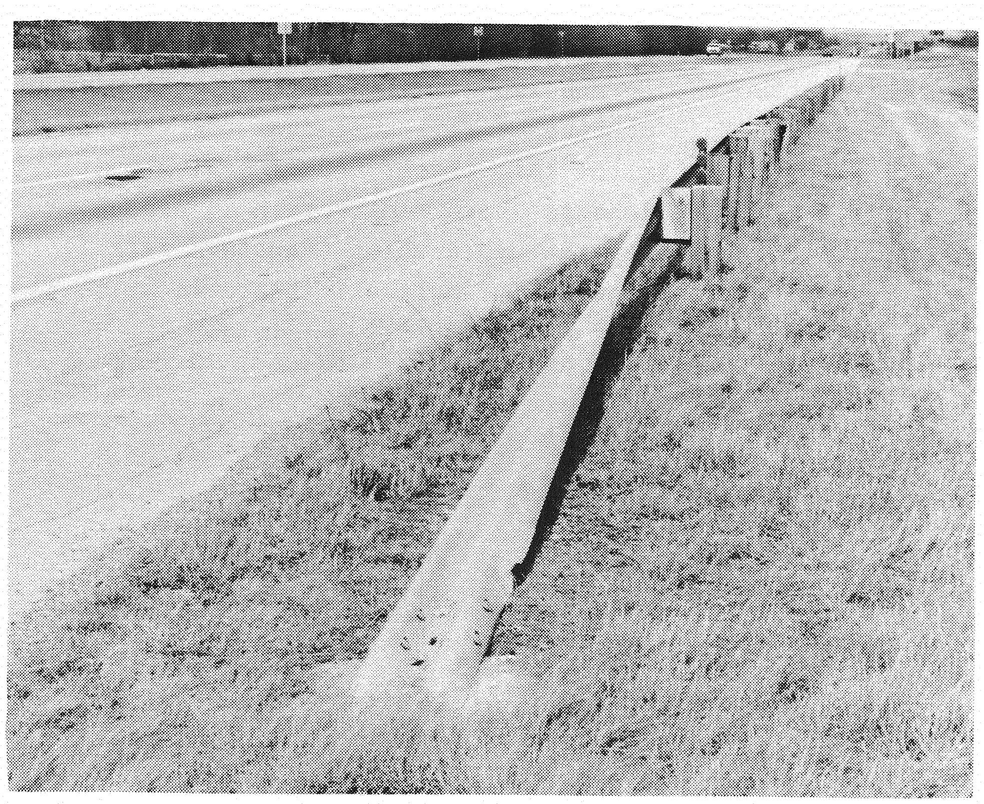


FIGURE 2.3 Turned-down end treatment

FINAL MODIFIED OKLAHOMA GUARDRAIL END TREATMENT

RAIL OFFSET	
POST NO.	OFFSET
ANCHOR	2'-0"
1	0'-10 1/2"
2	0'-7"
2A	0'-5 1/4"
3	0'-3 1/2"
4	0'-1 3/4"
5-35	0'-0"

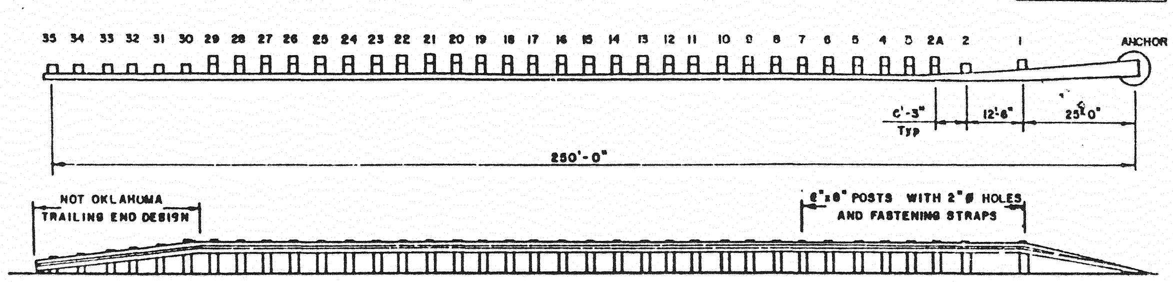


FIGURE 2.4 Modified Oklahoma turned-down end treatment

At some narrow medians, double-faced guardrails with turned-down ends have been used to protect fixed objects like light poles, sign posts, etc. An example is shown in Figure 2.5.

FIGURE 2.5 Double-faced turned-down end treatment

2.3.04 SENTRE

Sentre is a trade name of Energy Absorption Systems, Inc; an example is shown in Figure 2.6. The Sentre provided a combination of guardrail redirection and impact attenuation. The Sentre unit consists of telescoping thrie-beam fender panels, slip base support posts, and sand filled plastic containers which dissipate a portion of collision energy. For head-on impacts, a redirecting cable guides the vehicle behind the barrier, thus allowing the vehicle to avoid the hard part of the system. Major components can supposedly be reused after a typical impact.

Figure 2.7 shows a 1992 Sentre impact on the Turner Turnpike. From the tire marks, it appeared that the impact was not fully head-on, but rather had a right-to-left force component. The bolts at the base did not shear upon impact, but rather pulled out of the base.

FIGURE 2.6 Sentre

FIGURE 2.7 Sentre impact on Oklahoma turnpike

2.3.05 PARABOLIC END

A parabolic end is shown in Figure 2.8. These ends can be found in some medians, protecting vehicles from fixed objects like bridge pillars or sign posts in the median.

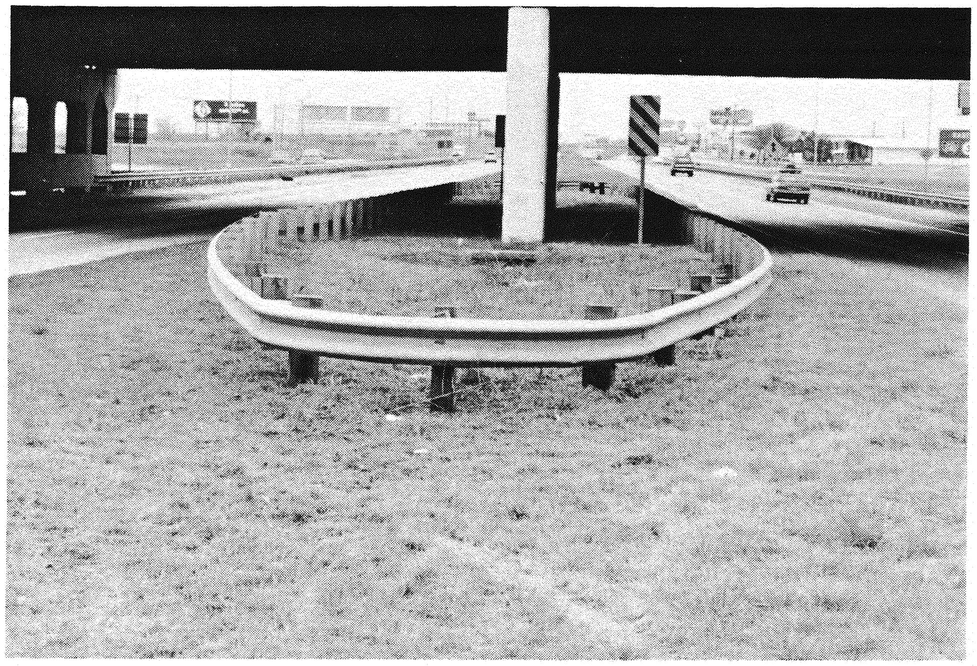


FIGURE 2.8 Parabolic end

2.3.06 ROUNDED END

Some rounded ends have been installed on Oklahoma highways. With this treatment, the end is rounded to reduce the chances of a vehicle being impaled. Figure 2.9 shows a rounded end.

2.3.07 ET-2000

One new guardrail end treatment which seems to be gaining favor is the ET-2000. ET-2000 is a brand name of Syro Steel, Inc. Figure 2.10 shows an ET-2000 near Kyle, Texas.

2.10 Background

FIGURE 2.9 Rounded end

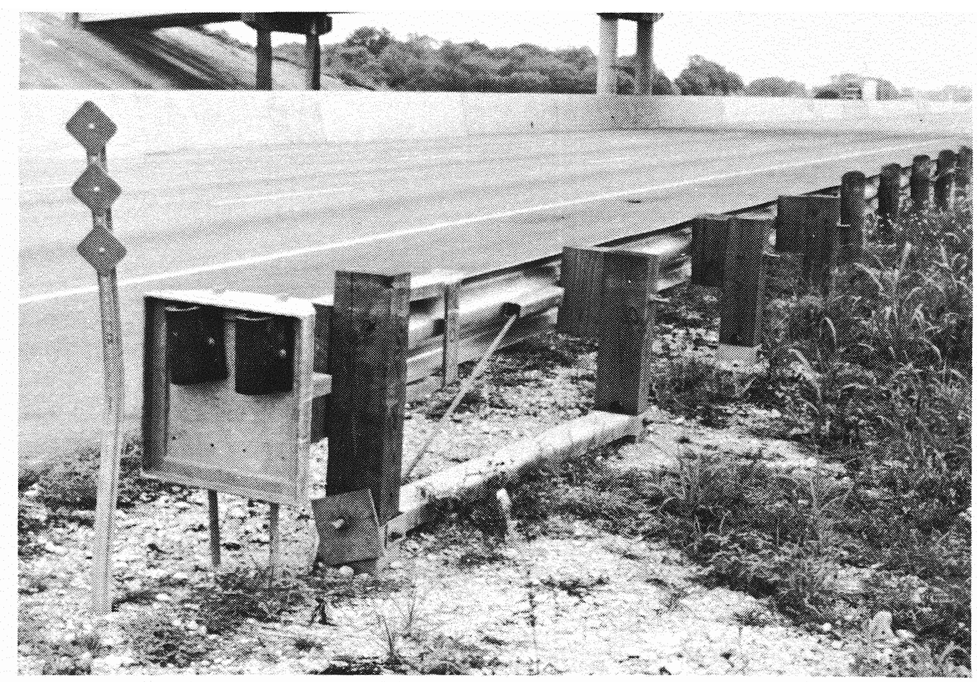


FIGURE 2.10 ET-2000

2.4 ACCIDENT RESEARCH LIMITATIONS

One of the major accident research objectives is to get the best possible information from a set of data. The specific relationships to be studied must be kept in mind. In accident research, one has to consider alternative ways of grouping data and analysis methods, and choose those groupings and methods which will give the fairest and most objective chance for defining relationships. The conclusion-making process can be clouded by factors like exposure, data biases, etc. *(8)*.

Accident data must be used with caution, because accident data are far from perfect. Some accidents may be unreported, so the accidents contained in a given official file may not comprise all the accidents that have occurred in that area or of a particular type. Minor collisions are sometimes not reported.

There can be biases in certain reported variables based on an officer's judgement about a situation. For example, an officer arriving at the scene after an accident may assign a too-high or a too-low injury type to the victims. All officers may not use the same terms to indicate similar events. There may be biases due to shortcomings in the accident report form itself or poor definition of the reporting variables.

One type of bias error is the failure of officers to correctly report the accident mileposts. Officers may merely estimate the distance from an accident site to the nearby milepost. Officers may round off the distance estimate to a convenient distance, which causes the reported accident location milepoint location to be erroneous. The failure to correctly milepoint an accident would in turn cause a subsequent user of the accident data to associate roadway characteristics or video log information from another location with the accident location.

A related problem is that actual field conditions, as either found in an on-site inspection or as viewed on a video tape log, may have changed from the time of the accident to the time of a later data study. If the accident occurred in a construction zone, it may not be possible to determine actual field conditions at a later date.

There is controversy about "delayed death," because sometimes a delayed death after an accident may not be recorded on the collision report. While the American National Standards has recently approved a 90-day rule for reporting delayed deaths, the National Highway Traffic Safety Administration (NHTSA) and FHWA have chosen a 30-day rule in publishing data on fatalities *(8)*.

Those who use traffic accident data need to be aware that the data and subsequent data analyses are imperfect. Those who make decisions from accident data should read accident-study reports critically.

2.12 Background

CHAPTER III

METHODOLOGY

This chapter discusses the research methodology used. The various stages in building the database and the problems that were encountered are described. A brief discussion of the analytical procedures is discussed. Some of the limitations the researchers encountered are also mentioned.

3.1 OBJECTIVES AND WORK PLAN

The overall objective of the study was to define certain characteristics of guardrail end accidents. A "guardrail accident" database was created and analyses were performed so the researchers could gain insight into certain issues. The initial research database included a number of various types of guardrail accidents. By incorporating additional data sources, the researchers addressed the issues listed below.

1. The researchers had to segregate the guardrail end accidents: for a given accident, was the guardrail end or some other guardrail point hit?
2. The researchers sorted the end accidents according to lateral locations (i.e., right side, median, etc.), and further identified the portion of accidents at each lateral location related to the driver inattention.
3. If a guardrail end was hit, then what type of end was it: buried, exposed, etc.? What type of post was present at the end?
4. What type of shoulder and median were present?
5. What was the accident severity? Did the vehicle roll, vault, or strike a fixed object?
6. Relationships between guardrail end accident frequency and miles of highway, vehicle miles of travel, posted speed, and urban or rural locations were examined.
7. The researchers investigated relationships among vehicle rolling and/or vaulting, end type, severity, lateral location, and vehicle weight.

Figure 3.1 presents the overall work plan. Each of the tasks listed in the figure is described in the following sections.

3.2 DATA SOURCES AND THEIR USE

The main sources of data used in the analysis were accident reports, video tape logs of state highways, state highway written inventories, state highway traffic volume maps, and reference books listing vehicle weights. In addition, various reference maps were needed.

3.02 Methodology

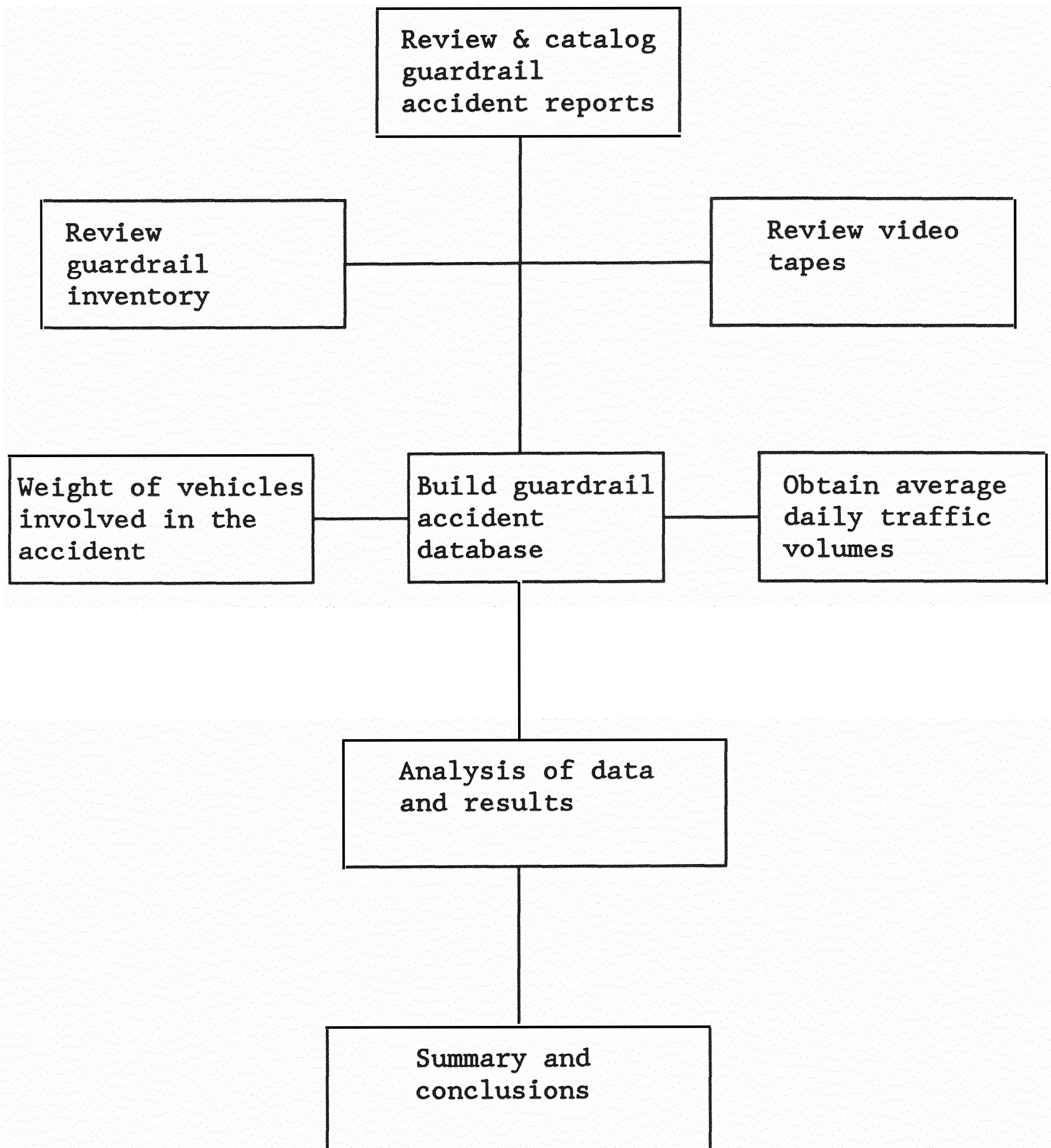


FIGURE 3.1 Work plan

The pertinent accident data from these sources was added to the existing ODOT-supplied accident database in codes. Figure 3.2 lists the codes used and the fields they were entered into.

ACCIDENT CODES

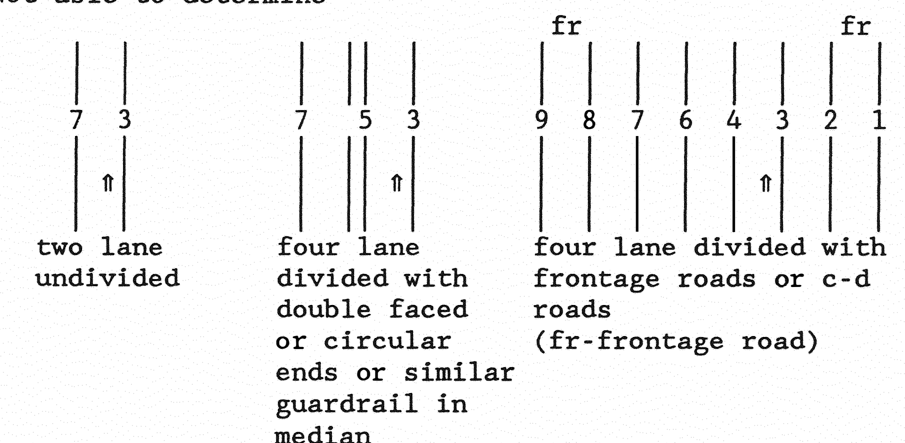
FIELD **F79**
AR-GDACC CL 0140 002 N
CLASSIFICATION OF GUARDRAIL ACCIDENT

0 - Not able to determine
1 - Not guardrail end accident
2 - Questionable guardrail trailing end accident
3 - Questionable near guardrail front end accident
4 - Trailing end (from driver's perspective) of guardrail accident
5 - Head end vehicle-guardrail front end (from driver's perspective) accident
6 - Side of vehicle-guardrail front end (from driver's perspective) accident
7 - Rear end of vehicle-guardrail front end (from driver's perspective) accident
8 - End hit from behind guardrail
19 - Connection-point front
20 - Connection-point trailing
99 - Not a guardrail accident

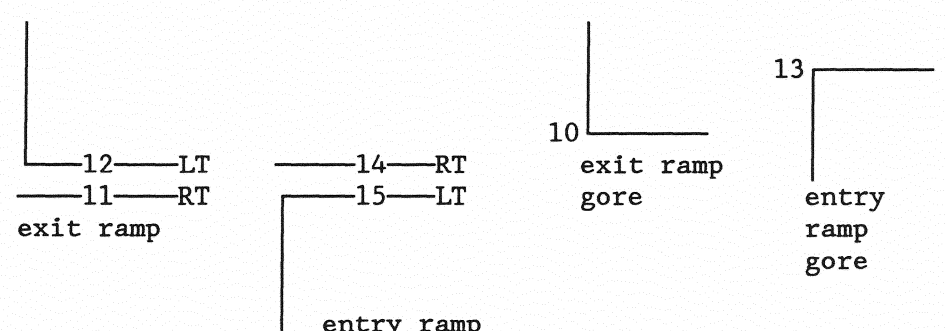
NOTE: If vehicle crossed over into oncoming side and hit oncoming trailing end, was coded head-end from perspective of the driver.

FIELD **F80**
AR-LAT LOC 0142 002 N
LATERAL LOCATION OF THE GUARDRAIL

0 - Not able to determine
1 -
2 -
3 -
4 -
5 -
6 -
7 -
8 -
9 -



10 -
11 -
12 -
13 -
14 -
15 -



20 - other type (guardrail on cross roads, intersecting driveways)
99 - not a guardrail end accident

FIGURE 3.2 Accident codes used to build guardrail accident database

FIELD **F81**
AR-VEH DOING 0144 002 N
WHAT VEHICLE WAS DOING WHEN IT HIT GUARDRAIL
0 - Not able to determine
1 - Ran off road right
2 - Ran off road left (on same direction roadway)
3 - Abrupt cross median left into oncoming lane
4 - Abrupt cross undivided roadway left into oncoming lane
5 - Prolonged wrong way on other than ramp
6 - Prolonged wrong way on ramp
9 - Not a guardrail end accident

FIELD **F82**
AR-PRI/SEC HIT 0146 001 N
WAS GDRL END HIT PRIMARY OR SUBSEQUENT ?
0 - Not sure
1 - Initial hit
2 - Subsequent hit
9 - Not a guardrail end accident

FIELD **F83**
AR-END TYPE 0147 001 N
TYPE OF END TERMINAL
0 - Not able to determine
1 - Exposed end with little or no lateral flare
2 - Turned-down end with little or no lateral flare
3 - Turned-down end with significant lateral flare
4 - Exposed end with significant lateral flare
5 - Parabolic end
6 - Rounded
8 - Other end type
9 - Not a guardrail end accident

FIELD **F84**
AR-POST TYPE 0148 001 N
TYPE OF POST AT THE GDRL END
0 - Not able to determine
1 - Steel posts
2 - Wood posts
9 - Not a guardrail end accident

FIELD **F85**
AR-ROLL\VAULT 0149 001 N
DID VEHICLE ROLL, VAULT OR BOTH IN CONJUNCTION WITH END HIT ?
0 - Not sure if end caused vault or roll
1 - Did not vault nor roll
2 - Vehicle rolled, did not vault
3 - Vehicle vaulted, did not roll
4 - Vehicle vaulted and rolled
5 - Vehicle rolled, not sure if vaulted
6 - Vehicle did not roll, not sure if vaulted
7 - Vehicle vaulted, not sure if rolled
8 - Vehicle did not vault, not sure if rolled
9 - Not a guardrail end accident

FIGURE 3.2 con't Accident codes used to build guardrail accident database

FIELD **F86**
AR-FO HIT 0151 001 N
<u>WAS FIXED OBJECT HIT AFTER END WAS HIT?</u>
0 - Not able to determine
1 - Did not hit fixed object
2 - Did hit fixed object being shielded or connected to
3 - Went down embankment or down grade, but hit nothing
9 - Not a guardrail end accident
FIELD **F87**
AR-SHOULDER TYPE 0152 001 N
<u>TYPE OF SHOULDER</u>
0 - Not able to determine if shoulder is present
1 - No shoulders
2 - Grass, Graded or gravel shoulder
4 - Paved shoulder
5 - other
9 - Not a guardrail end accident
FIELD **F88**
AR-MEDIAN 0153 003 N
<u>MEDIAN DETAILS</u>
0 - No able to determine
1 - Median present but width not determinable
2 to 997 - Width of median in feet
998 - Not sure if does/doesn't have median
999 - Not a guardrail end accident
1000 - No median
FIELD **F89**
AR-INJURY 1 0156 001 N
AR-INJURY 2 0157 001 N
AR-INJURY 3 0158 001 N
AR-INJURY 4 0159 001 N
<u>INJURY TYPE IN GDRL END HIT</u>
0 - Not able to determine
1 - No injury
2 - Injury type A
3 - Injury type B
4 - Injury type C
9 - Not a guardrail end accident
FIELD **F90**
AR-GDSETBACK
<u>GUARDRAIL SETBACK FROM EDGE</u>
0 - Not able to determine width
1 - None or 1 feet
2 - 2 to 7 feet
8 - 8 feet or wider
9 - Not a guardrail end accident

FIGURE 3.2 con't Accident codes used to build guardrail accident database

3.06 Methodology

3.2.01 REVIEWING AND CATALOGING ACCIDENT REPORTS

The Figure 3.3 flow chart shows the general steps taken to review and catalog accident reports.

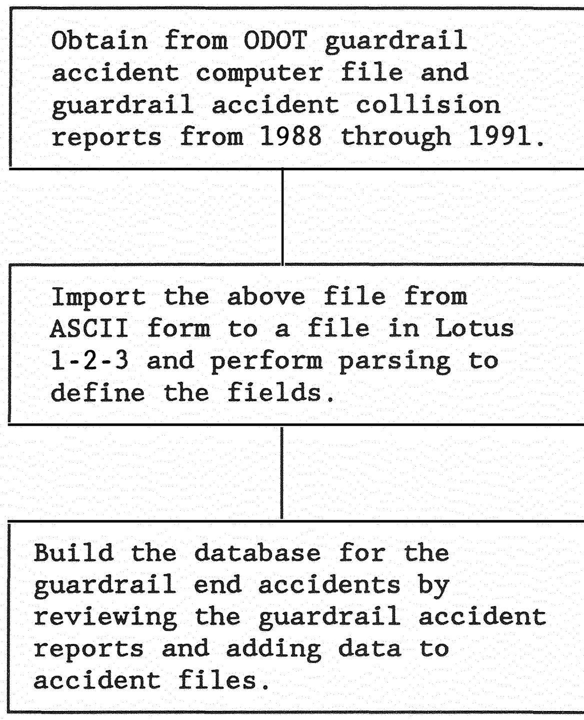


FIGURE 3.3 Flow chart to review and catalog accident reports

The raw material for accident research was the "Official Police Traffic Collision Report," shown in Appendix A. Whenever an accident is reported to the police, the investigating officer records the information pertaining to the accident on this form. All police agencies in the state are supposed to forward these reports to the Department of Public Safety (DPS) headquarters office in Oklahoma City.

The DPS in turn sends copies of the reports to the Oklahoma Department of Transportation, which encodes data from each "Official Police Traffic Collision Report" into a database. The accident coding guide used by ODOT is shown in Appendix B. This accident coding guide lists the codes used to indicate the location, time, driver, vehicle and road conditions, weather, time, severity, causes of the accident, etc. The guide also describes the type and width of the computer data fields used for the codes.

ODOT furnished an ASCII computer file, **GDRAIL.ACC**, containing details of guardrail accidents occurring on Oklahoma non-toll highways from 1989 through 1991. This file was imported into Lotus 1-2-3 and saved as **GDRAILAC.WK1**. With the help of the accident coding chart, columns were defined per their appropriate field widths. This was done by using the software "Parse" operation. The following fields were retained in the GDRAILAC.WK1 file:

Field 2	AR-COUNTY/CITY
Field 5	AR-CONTRL-SEC
Field 7	AR-HIGHWAY REFERENCE MILEPOINT
Field 16	AR-SEVERITY
Field 65	AR-LEGAL SPEED-1
Field 66	AR-LEGAL SPEED-2
Field 71	AR-RURMUN
Field 76	AR-DEPT. OF PUBLIC SAFETY CASE NUMBER

The remaining fields were deleted.

The Department of Public Safety retrieved the accident reports for accidents which had been encoded as "guardrail" accidents. DPS sent the reports to ODOT, who in turn forwarded them to the researchers. The research team reviewed and gleaned information from these accident reports in three iterations. The first iteration involved study by a group of three graduate students. The second iteration consisted of study by a graduate student supervisor, and the third iteration involved a review by the principal investigator and the graduate student supervisor.

Details from the accident reports judged relevant were added to the GDRAILAC.WK1 database by using the codes shown in Figure 3.2. The methodology the researchers used to select a particular code is described later. Appendix C presents an example printout from the researcher's accident file.

3.2.02 REVIEWING VIDEO TAPES AND CATALOGING OBSERVATIONS

ODOT made video tapes of most Oklahoma state highways in the late 1980's and early 1990's. Fortunately, the accidents which the researchers reviewed occurred in that general time period, from 1988 through 1991.

The researchers viewed video tapes to identify the guardrail end type and post type at the accident locations. Both the graduate students and the principal investigator viewed portions of the video tapes. Attributes which were often not determinable from the accident reports, like the type of shoulder in front of the guardrail, or the guardrail offset from road edge, were determined while viewing the video tapes. It was assumed that guardrail end types, post types, shoulder types and site conditions at the accident locations, had not changed between the time the video was taken and the time the accidents occurred. Figure 3.4 shows the steps taken to view the video tapes and add data to the accident database.

3.08 Methodology

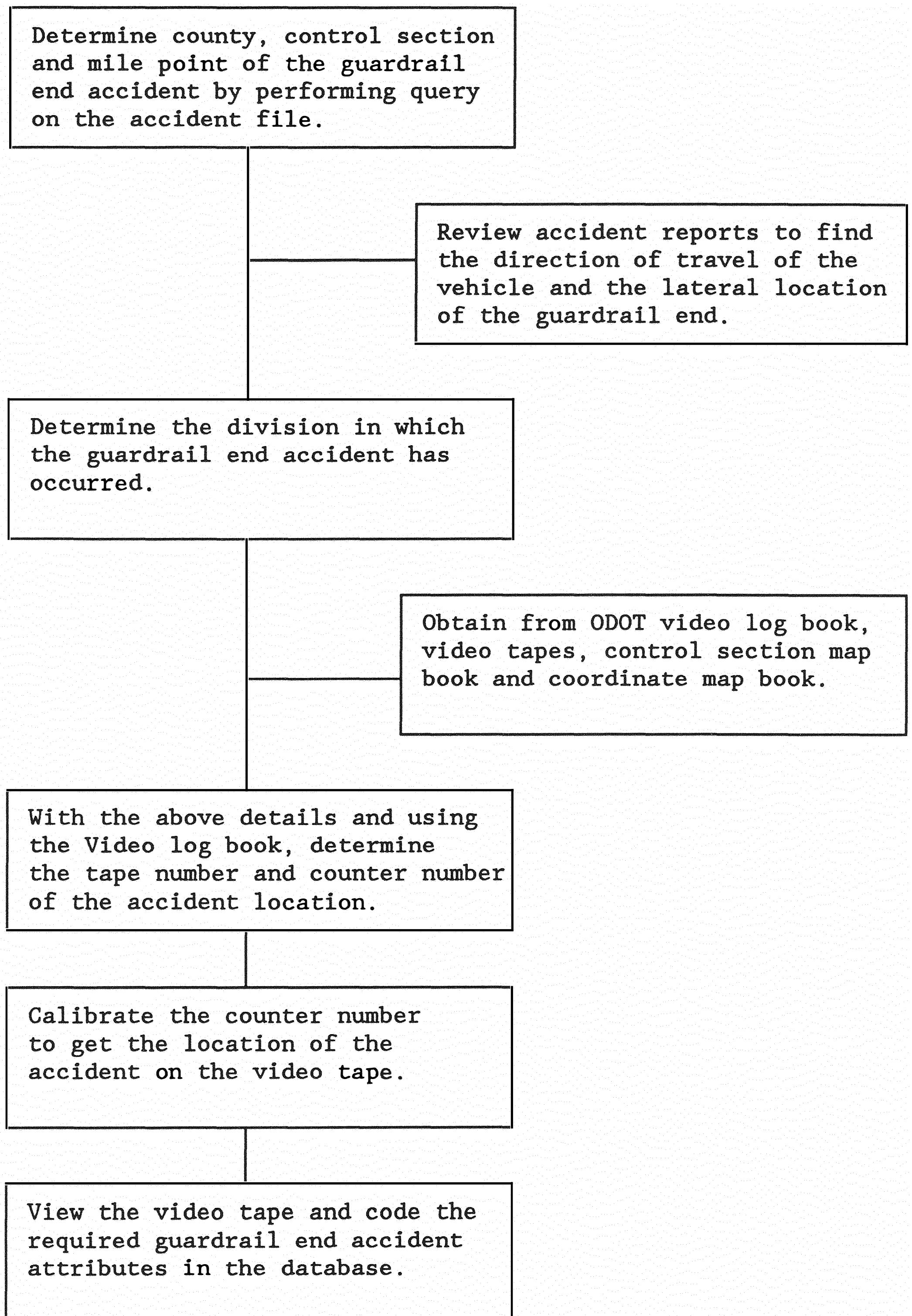


FIGURE 3.4 Flow chart to review video tapes

3.2.02.01 Aids for Using Video Tapes

The state highway system videos occupy about one-hundred tapes. To find a tape for a particular section of roadway, the researchers needed various references such as the video tape log book, the control section maps, and the county coordinate map books.

ODOT has compiled a video tape log book which cross-references the tapes and counter numbers with a given division (an ODOT administrative district), county, and highway control section. For each location there will be two video tapes, one for each direction.

ODOT publishes control section maps every two years. These maps show the various highway control sections in a county. For each control section, the left group of digits gives the highway number, the middle digit-group gives the county number, and the right digits give the control section. The length of the control section is printed by the section.

ODOT furnished maps with all the counties in Oklahoma divided into a coordinate grid corresponding to the land-section lines. Most accident reports contain the grid coordinates which pinpoint the accident location.

The county in which the accident took place was first determined from field 2 of GDRAILAC.WK1. The control section number and milepoint location were determined from field 5 and field 7 respectively. The accident report was then reviewed, to find the direction in which the vehicle that hit the guardrail was travelling. For each accident, the researchers needed the division number, county number, and control section number in order to identify the video tape and counter numbers which would show the section of road where the accident took place.

3.2.02.02 Using the Video Tapes

Viewing the video tapes allows a person to see many roadway features without having to actually visit the site. However, viewing the video tapes did not always allow the researchers to find information they were looking for.

In some accident reports the police officer apparently made an error in recording the direction of travel of the vehicle that hit the guardrail end. In such cases, the coordinate map book, the collision diagram, and the narration were studied to find clues which would identify the guardrail location and correct direction of travel of the vehicle. If it was still not possible to identify the correct direction, the video tapes of both directions were viewed. If both the directions had the same end type, post types, and shoulder type, then these attributes were coded. If the end type, post type, or shoulder pavement type were different for the two directions, then the required attributes were considered as not determinable.

In some cases the video tape did not show a guardrail at the milepoint listed in the accident report. This could be because the reporting officer made an error or was unclear in identifying the milepoint, or because the guardrail may not have been installed at the time the video run was taken. In some cases the researchers inferred another location using details in the accident report, the control section map, and the tapes. In a few cases the researchers called local officials to determine local street name practice, or made field visits to clear up questions.

In a few cases the accident report listed a shoulder-type or guardrail offset from road edge that did not agree with what the reviewers saw in the video. In such cases the information viewed from the video tape was taken to be correct.

The researchers were not always able to determine from viewing the video tape the guardrail end type or the end-post type at the guardrail end section. Impediments included roadside shrubs and plants at the accident location, or an unclear video. At a few accident locations, the guardrail was not in the field-of-vision in the video tape; guardrails located in the median on sharp horizontal curves were especially susceptible to this problem.

3.2.03 REVIEWING GUARDRAIL INVENTORY

ODOT furnished the researchers with a guardrail inventory of its highways, taken in 1987 and 1988. The inventory gives the type of guardrail end at approach end of the guardrail and its location with reference to the division county, control section and mile point. The inventory also lists the video tape and counter number corresponding to the guardrail location. A flow chart showing the steps involved to review guardrail inventory is shown in Figure 3.5.

The code number of the county in which the accident took place was first determined from field 2 in GDRAILAC.WK1. The control section and milepoint were found in field 5 and field 7 respectively. This data allowed the researchers to find a given guardrail end on the list. "GR-1" indicates a twisted, buried or turned down end while "GR-2" indicates blunt or other than turned down end. Code "1" was entered for GR-2 and code "2" was entered for GR-1. This was entered in the GDRAILAC.WK1 file under the column "Inventory".

The researchers employed the inventory as a check of the guardrail end type that was hit by the vehicle. The end type obtained from the inventory sometimes differed from the tape viewed in the video. This could have been due to an error in milepoint recording or because the end may have been replaced after the inventory was taken. The video log record proved to be more usable than the inventory, so the inventory review did not end up contributing to the analysis. In all instances the end type obtained from the video was the one used in the analysis.

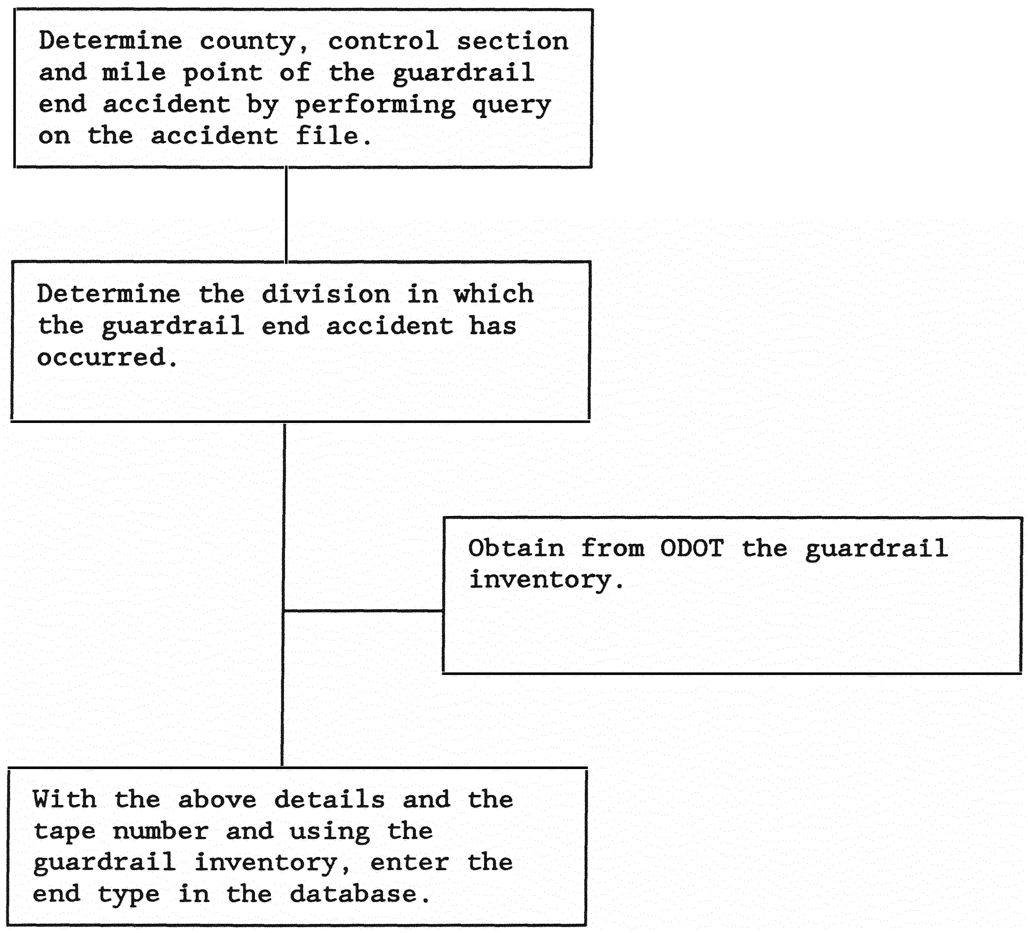


FIGURE 3.5 Flow chart to review guardrail inventory

In some cases the trailing end type is different from the head end type of the guardrail. In such cases, if the vehicle hit the trailing end or if the vehicle crossed the road and hit the trailing end of the oncoming direction, then the guardrail inventory was of no use.

3.2.04 AVERAGE DAILY TRAFFIC VOLUMES

The researchers needed the average daily traffic (ADT) to relate guardrail end hits with the level of exposure to traffic. Figure 3.6 is a flow chart showing the steps taken to determine average daily traffic volumes.

ODOT prints maps showing the ADT for all its highways every two years. The 1987 and 1988 ADT maps were obtained from ODOT. The 1987 ADT map was used to determine the volumes for the guardrail end accidents occurring during 1988 and 1989, while the 1989 ADT map was used to determine the volumes for the accidents occurring during 1990 and 1991.

3.12 Methodology

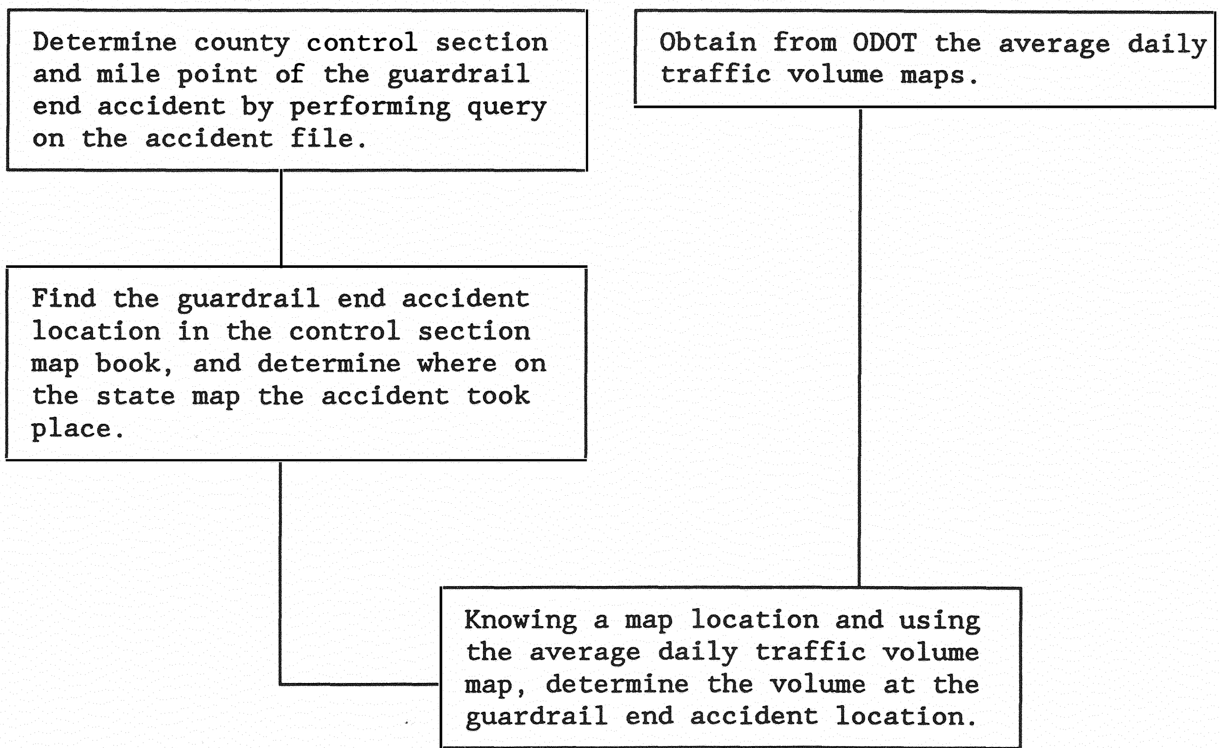


FIGURE 3.6 Flow chart to determine average daily traffic volumes

The number assigned to the county in which the accident occurred was first determined from field 2 of GDRAILAC.WK1. The researchers obtained the control section and milepoint at the accident location from field 5 and field 7 respectively. Using the county number, control section number, and milepoint, the location of the accident on the control section map book was found. With this information as a guide, the accident site was located on the ADT map. The volume nearest to the accident location was taken as the average daily traffic volume for that accident location. This was entered in the GDRAILAC.WK1 file under the column "Volumes".

3.2.05 WEIGHT OF VEHICLES

The year, make, model, and style of the vehicles involved in the guardrail end accidents were determined from the accident reports. This information was entered in the GDRAILAC.WK1 file "Weights" column. Using these details and the vehicle identification number (VIN) from the accident report, the weights of the vehicles involved in the guardrail end accidents were found by referring to publications such as *Standard Catalog of American Cars from 1976 to 1986 (9)*, the *Standard Catalog of American Cars from 1946 to 1975 (10)*, the *Standard Catalog of American Light Duty Trucks from 1896 to*

1986 (11), the *N.A.D.A. Official Used Car Guide (12)*, and *Consumer Reports (13)* for the month of April.

If a vehicle was pulling a trailer, it's weight was unknown and was coded as "dk". Some vehicle models came in many variations, and the weights of each ranged over many hundreds of pounds; therefore, sometimes a vehicle weight could not be pinned-down. Each vehicle was assigned to one of the following weight categories:

1750 - vehicle weight in the range of 1500 to 2000 lbs;
2250 - vehicle weight in the range of 2001 to 2500 lbs;
2750 - vehicle weight in the range of 2501 to 3000 lbs;
3250 - vehicle weight in the range of 3001 to 3500 lbs;
3750 - vehicle weight in the range of 3501 to 4000 lbs;
4250 - vehicle weight in the range of 4001 to 4500 lbs;
4750 - vehicle weight in the range of 4501 to 5000 lbs;
dk - vehicle weight not determinable;
tt - tractor trailer;
mul - more than one possible weight class;
mh - motor home; or
cab - cab.

All vehicles in the "dk", "tt", "mul", "mh", and "cab" categories were called "Other". Therefore, a vehicle in an accident whose weight was listed between 1500 and 2000 pounds was coded as "1750"; a vehicle weighing 3320 pounds was coded as "3250", etc.

3.3 PROCEDURES FOR ADDING DATA TO GUARDRAIL ACCIDENT FILE

The preceding sections described the types of data gleaned form the various sources. The following sections describe in detail the procedures for entering the data into the computer data file.

3.3.01 DETERMINING LONGITUDINAL LOCATION AND DIRECTION

The primary purpose of this classification was to separate the guardrail end and questionable end accidents from the other types of guardrail accidents. The classification also helped determine the points on the longitudinal section of the guardrail where the impacts took place.

3.3.01.01 General Principles for Coding Guardrail End Accidents and Directions

According to NASS coding manual *(14)*, guardrail ends are defined as sections within 25 feet of the upstream guardrail end -- the end upstream from the direction of travel regardless of which side of the road the guardrail is located. However, the accident report did not always indicate how far upstream from the end that the impact took place. This is because the reporting police officers' drawings were usually in schematic form, and not to scale or even in proportion. Therefore, the researchers had to make a judgement as to whether each accident involved an actual guardrail end strike. If the accident report drawing and other information in the accident report led the researchers to presume that the vehicle struck the guardrail end, then the accident was coded as a "presumed end hit." If the accident report information led the researchers to assume that the impact was possibly but not likely near the end, then the accident was coded as a "questionable end hit."

The accidents were initially coded with respect to the direction in which the vehicle was travelling. If a vehicle crossed over into the oncoming side and hit the oncoming trailing end, it was considered head-in from perspective of the vehicle. Later, sorting routines were employed to identify those vehicles that crossed over the median or centerline and had a head-on hit with a trailing end.

When the accidents were later categorized into groups, the terms "approach end" and "trailing end" were employed with respect to the normal or intended direction of travel on a lane or lanes. The "approach end" is the guardrail end initially encountered at the beginning on the right side of an undivided road. On a divided road, the "approach ends" are those on the right or left of the lanes intended for one direction of travel. A "trailing end" is the one encountered last at the end of a guardrail installation. When a driver crossed the centerline or the median, the vehicle was said to have struck the trailing end. Later categorizations were made to group accidents as:

"end hits" -- all guardrail end accidents; and

"approach end/same side and trailing end/cross over/undivided" accidents, only those in which a vehicle hit the approach end, or crossed over the centerline of an undivided roadway and struck the trailing end on the driver's left side, excluding ends struck from behind.

The various data sets eventually created were:

End hits -- presumed (P);

End hits -- presumed-plus-questionable (P+Q);

Approach end/same side and trailing end/cross over/undivided -- presumed;

Approach end/same side and trailing end/cross over/undivided -- presumed-plus-questionable;

If the vehicle hit more than one guardrail end, then each end hit was treated as a separate accident by entering it twice. Where it was not possible to identify a particular attribute, the code "0" was entered in the respective fields of the GDRAILAC.WK1 file.

3.3.01.02 Specific Codes for Guardrail End Accidents and Direction

The accident reports were studied and the guardrail accidents were coded as one of ten different accident types. These codes were entered in field 79 of the GDRAILAC.WK1 file.

The researchers did not classify some accidents. Causes for non-classification include absence of a collision diagram or the duplication of an accident report. A code "0" was assigned to those accidents not classified. If the researchers concluded from studying the accident report that the vehicle did not strike the guardrail at or near the end point, then the accident was classified as "Not a guardrail end hit accident" and code "1" was given to the accident.

If the researchers concluded that the vehicle had struck the guardrail close to the trailing end point, then the accident was classified as a "Questionable guardrail trailing end accident" and code "2" was given to the accident. If the vehicle had struck the guardrail close to the front end point, then the accident was classified as a "Questionable near front end accident" and code "3" was given to the accident.

Some accidents involved a vehicle striking the trailing end point or end section of the guardrail. These were classified as "Trailing end of guardrail accident" and code "4" was given to the accident.

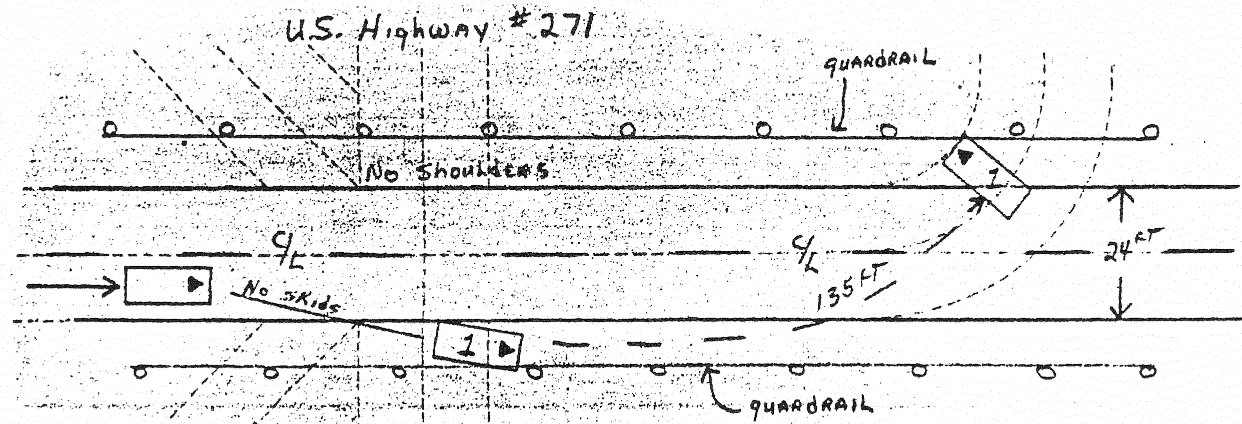
The accident reports show the first point-of-contact made by the vehicle. Points 10, 11, and 12 under the "Point of First Contact of Vehicle" in the accident report were considered head-end impacts. Points 1, 2, 3, 7, 8 and 9 were considered to be on the side of the vehicle. Points 4, 5 and 6 were called the rear of the vehicle. If the front end of the guardrail was struck by the head end of the vehicle, then the accident was placed under "Head end vehicle-front end accident" category and code "5" was given to the accident. If the front end of the guardrail was struck by the side of the vehicle, then the accident was placed under "Side of vehicle-front end accident" category and code "6" was given to the accident. When the front end of the guardrail was struck by the rear of the vehicle, then the accident was categorized as "Rear end of vehicle-front end accident" and code "7" was assigned.

A few vehicles struck the guardrail end from behind the guardrail. These accidents were placed in the "End hit from behind guardrail" category and code "8" was given to the accident.

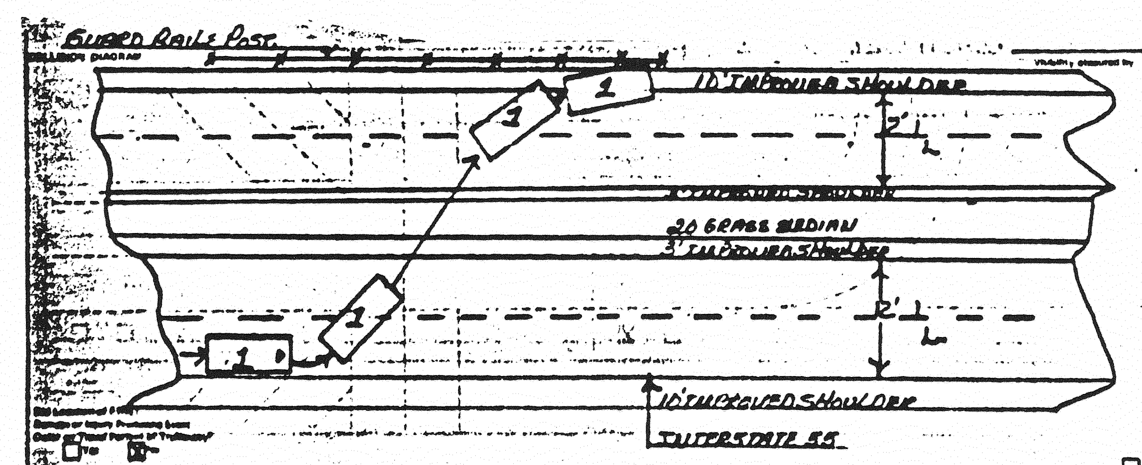
If the vehicle struck the area where the front guardrail section connected to a bridge parapet wall, then the accident was placed under "Connection point front accident" category and code "19" was given to the accident. If the trailing connecting point of the guardrail and bridge parapet wall was struck, then the accident was called a "Connection point trailing accident" and code "20" was given to the accident.

If the vehicle had struck a concrete bridge barrier or concrete guardrail, then the accident was placed under "Not a guardrail accident" category and code "99" was given to the accident. Figure 3.7 shows typical examples of the end accident types. The drawings are from actual accident reports.

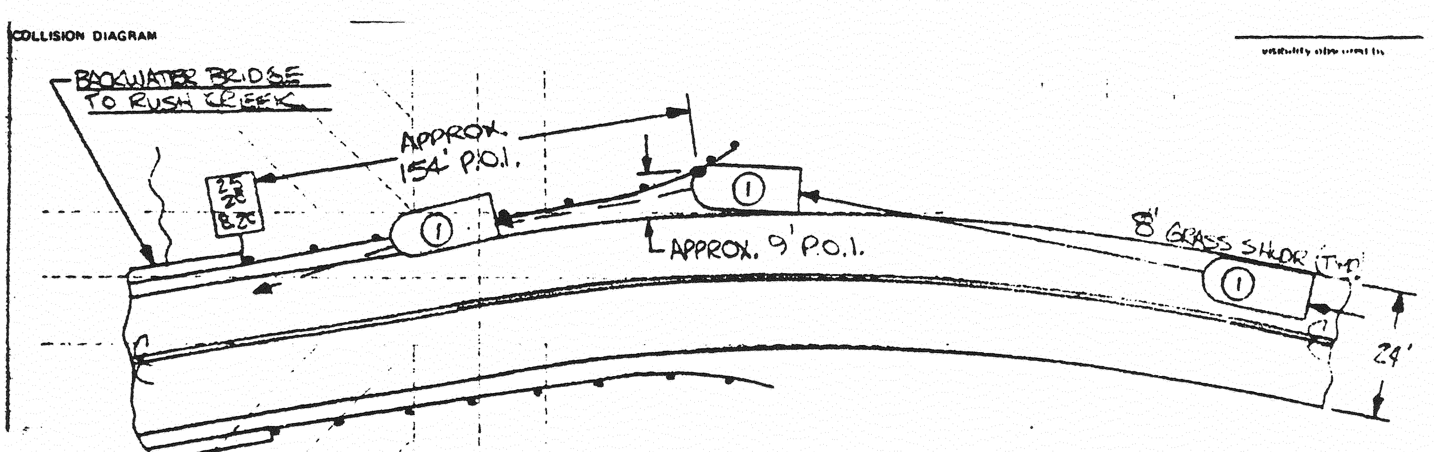
3.16 Methodology



Not a guardrail end accident (DPS # 047712932)

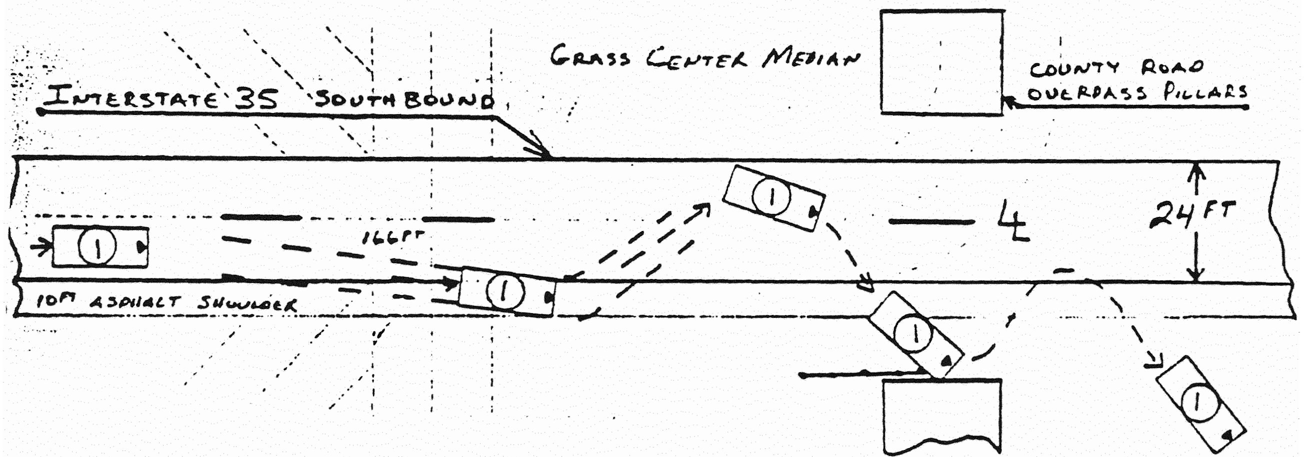


Questionable guardrail trailing end accident (DPS # 047709062)

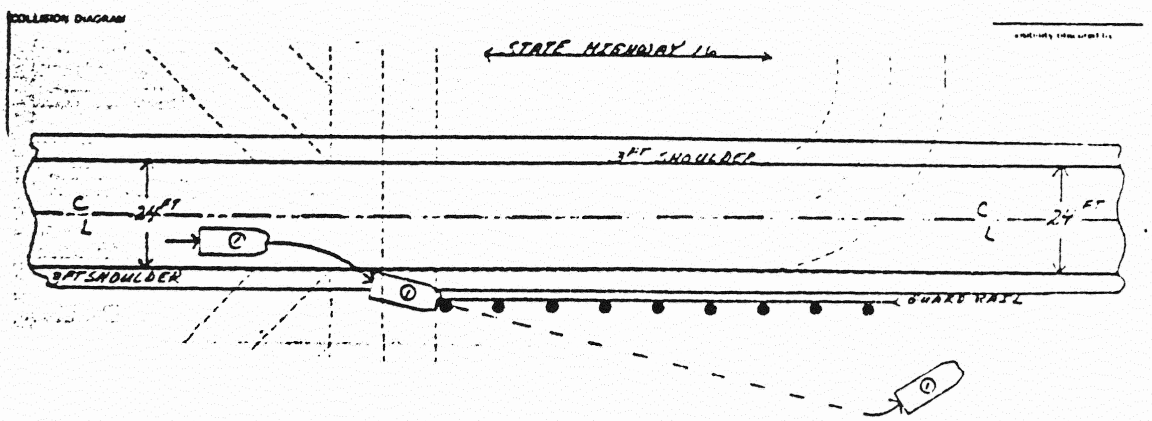


Questionable guardrail front end accident (DPS # 047714627)

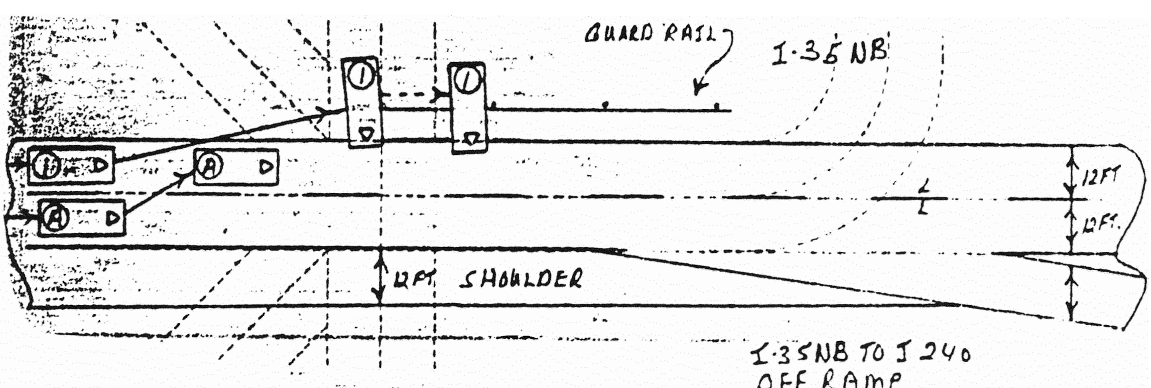
FIGURE 3.7 Example drawings from actual guardrail accident reports



Trailing guardrail end accident (DPS # 049413219)

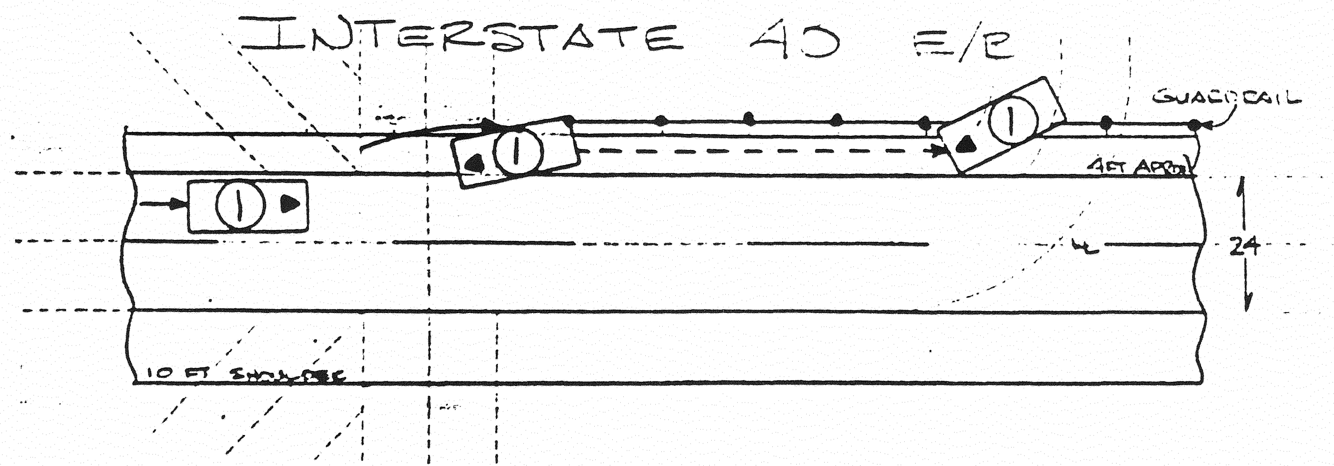


Head end of vehicle-front end accident (DPS # 050109177)

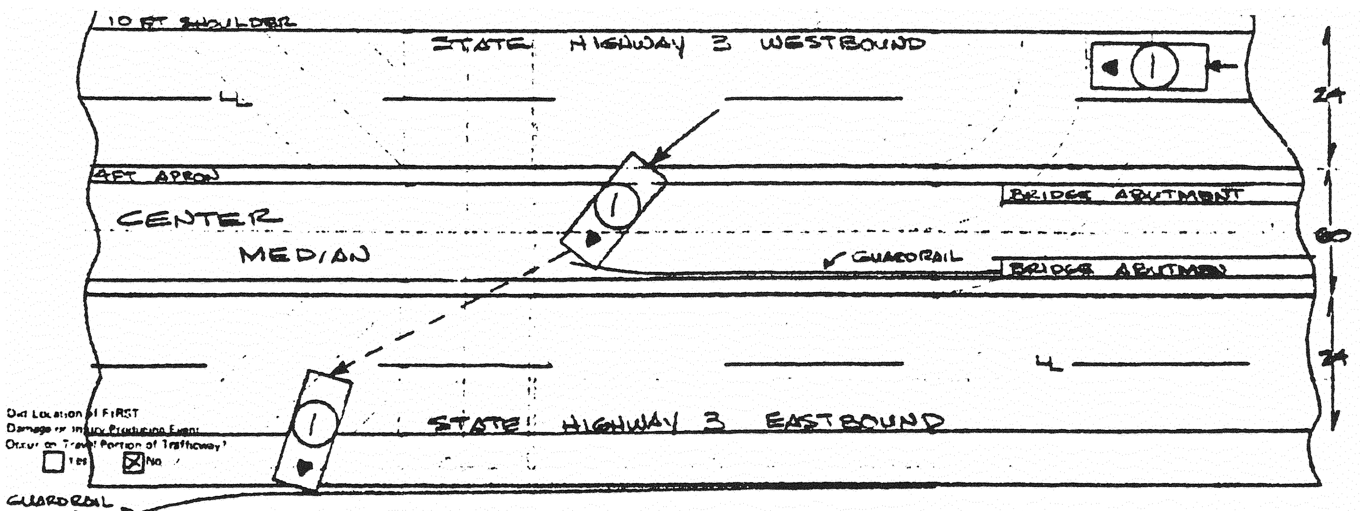


Side end of vehicle-front end accident (DPS # 050103052)

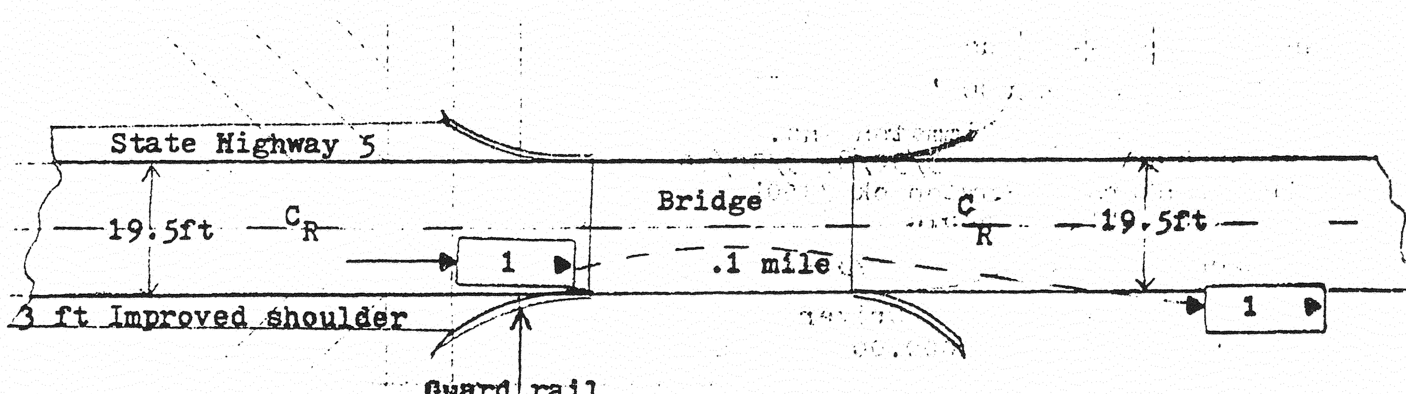
FIGURE 3.7 con't. Example drawings from actual guardrail accident reports



Rear end of vehicle-front end accident (DPS # 049400332)



End hit from behind guardrail (DPS # 055305047)



Connection-point front accident (DPS # 055302260)

FIGURE 3.7 con't. Example drawings from actual guardrail accident reports

3.3.02 LATERAL LOCATION OF THE GUARDRAIL

The researchers classified the guardrail location in order to determine the proportions of accidents occurring at the various lateral locations. These codes were entered in field 80 of the GDRAILAC.WK1 file. If the accident collision diagram was missing, if it was a duplicate accident, or if for some other reason the researchers were not able to determine the guardrail lateral location, then the accident was given a "0" code.

Guardrail lateral positions were numbered front right to left across the roadway section. The right side and left side guardrails on the frontage road or collector-distributor road to the right of the main lanes were given code "1" and code "2" respectively. The guardrail on the right side of the main lanes was given code "3". The guardrail in the median on the left side of the on-going main road and the guardrail in the median on the left side of the on-coming main road of a divided roadway were given code "4" and code "6" respectively. If a pair of median guardrails was connected at the ends, then code "5" was given. The guardrail to the left of oncoming traffic (from the perspective of the subject accident vehicle), whether the roadway was divided or undivided, was called code "7". The right side and left side guardrails on the on-coming frontage road or collector-distributor road were given code "8" and code "9" respectively.

The guardrails at the exit gore and entry gore were given code "10" and code "13" respectively. The guardrail on the right side of an exit ramp was given code "11", while the guardrail on the left side of an exit ramp was given code "12". The guardrail on the right side of an entry ramp was given code "14", while the guardrail on the left side of an entry ramp was given code "15".

Code "20" was assigned to guardrails located on cross streets and driveways. Code "99" was given if it was not a guardrail end accident.

3.3.03 TYPE OF END TERMINAL STRUCK

The researchers assigned codes to reflect the type of guardrail end which had been hit. Only a few accident reports furnished this information. For the most part, the researchers had to review video tapes and field inventory data to determine the type of guardrail end that was hit. These codes were entered in field 83 of the GDRAILAC.WK1 file.

If the collision diagram was missing, if the accident report was a duplicate, or if for some other reason the researchers were not able to determine the type of end, then code "0" was given to the accident. If a flared exposed end was hit, then code "1" was given to the accident. If a turned-down end with little or no lateral flare was hit, then code "2" was given to the accident. Code "3" was given to the accident if a turned-down end with significant lateral flare was hit by the vehicle. Code "4" was given to the accident, if an flared exposed end with significant lateral flare was hit by the vehicle. Code "5" was given to the accident if a parabolic end was hit by the vehicle.

The researchers used judgement to categorized guardrail ends as to whether they were flared. If the end appeared in the video to be significantly set back, then they called it flared. In the subsequent analysis, flared ends were not analyzed separately because of their small number.

On the video, it was not possible to differentiate breakaway cable terminals with rounded ends from "normal" rounded exposed ends; both were classified as rounded ends. Code "6" was given to the accident if a rounded end was hit. Code "8" was given to the accident if a Sentre was hit. If the accident was not a guardrail end hit, then code "9" was given to the accident.

3.3.04 TYPE OF INITIAL POST

Very few of the accident reports describe whether the first post at the guardrail end section was wood or metal. The researchers had to review video tapes to determine the type of end post that was hit. The researchers assigned a code in field 84 of the GDRAILAC.WK1 file to indicate whether the first post at the guardrail end section was steel or wooden.

Code "0" was given if there was no collision diagram, if the accident report was a duplicate, or if for some other reason it was not possible to determine the type of post present. Code "1" was given to the accident if the first post at the guardrail end section was steel; Code "2" was given for a wooden post. Code "9" was assigned if the accident was not a guardrail end accident.

3.3.05 TYPE OF SHOULDER

The classification was done as a part of building the database and was not used in the analysis. The researchers assigned codes to the accident according to the type of shoulder immediately preceding the guardrail end. These codes were entered in field 87 of the GDRAILAC.WK1 file.

Some accident reports mentioned shoulder type, while others did not. The video tapes were used to both confirm and augment accident report information.

If there was no collision diagram or if it was a duplicate accident report, then code "0" was given to the accident. Code "0" was also given to the accident if it was not possible to determine the type of shoulder, even after viewing the video tape.

Code "1" was given to the accident if there was no shoulder. If there was grass, graded or gravel shoulder, then code "2" was assigned to the accident. Accidents where there were hard-surfaced shoulders (usually asphalt) were coded as "4". If the accident report mentioned the term "improved shoulder" and the road was an interstate, then paved shoulder was assumed; the video tapes confirmed this assumption. Code "5" was given to the accident if the shoulder was of other than the above mentioned types. Code "9" was given to the accident if it was not a guardrail end accident.

3.3.06 GUARDRAIL SETBACK FROM EDGE OF ROAD

This task was done as a part of building the database and was not used in the analysis. The accident reports and video tape were studied to find the guardrail setback from the edge of the road. In some of the accident reports, the point-of-impact (POI) from the road edge was given. Codes were given depending on the guardrail setback from the roadway edge. These codes were entered in field 90 of the GDRAILAC.WK1 file.

If it was not able to determine the guardrail setback distance, then code "0" was given to the accident. If there were only one feet offset or if there were no offset, then code "1" was given to the accident. If the offset were between two to seven feet, then code "2" was given to the accident. If the offset were eight feet or wider, then code "8" was given to the accident. If the accident were not a guardrail end accident, then code "99" was given to the accident.

3.3.07 MEDIAN DETAILS

This classification was done to determine if there were any relation between guardrail end accidents and presence of median. Codes were given to indicate the width in feet of the median at the accident site. These codes were entered in field 88 of the GDRAILAC.WK1 file. The researchers used both the accident reports and the video tapes to make this classification.

If there were no collision diagram or if it were a duplicate accident report, then code "0" was given to the accident. The accident reports give information under "Type of road" whether the road is divided or undivided. If the road were a undivided road, then there is no median and code "1000" was given to the accident. Accidents on a ramp were also coded this way.

Some accident reports showed that the accident occurred along a section of a divided road. In such cases code "1" was given to the accident if the width were not determinable. If the width were mentioned, then codes "2" to "997" were used to enter the width of the median, after rounding the width to the nearest whole foot.

Sometimes the accident occurred in a construction zone and it was not possible to conclude whether a median existed at the accident site. In such cases code "998" was given to the accident. If the accident were not a guardrail end hit, then code "999" was given to the accident.

3.3.08 WHAT VEHICLE WAS DOING WHEN IT HIT THE GUARDRAIL

The researchers assigned codes to indicate what the vehicle was doing when it hit the guardrail, with reference to direction of travel. These codes were entered in field 81 of the GDRAILAC.WK1 file.

3.22 Methodology

If the collision diagram were missing, if the accident report were a duplicate, or if for some other reason the researchers were unable to determine what the vehicle was doing when it hit the guardrail, then the accident was given code "0". Code "1" was given to the accident if the vehicle ran off road to the right and then hit the guardrail end. Code "2" was assigned if the vehicle ran off of a divided roadway to the left, did not cross the median, and then hit the guardrail end. If the vehicle abruptly crossed the median towards the left side into oncoming lanes and hit the guardrail end, the accident was given code "3". If the vehicle abruptly crossed undivided roadway towards the left side into oncoming lanes and hit the guardrail end, the accident was given code "4". Code "5" was given when the vehicle experienced prolonged wrong way travel before hitting the guardrail end. Code "6" was given when the vehicle experienced prolonged wrong way travel on a ramp before hitting the guardrail end. Code "9" was given if the accident were not a guardrail end accident.

3.3.09 WAS THE GUARDRAIL END HIT INITIAL OR SUBSEQUENT?

Codes were assigned to reflect whether the guardrail end was the first object the vehicle struck (initial hit), or if another object was struck before the guardrail end was (subsequent hit). These codes were entered in field 82 of the GDRAILAC.WK1 file.

If the collision diagram were missing, if the accident report were a duplicate, or if for some other reason it were not possible to determine whether the impact with the guardrail end was a initial or subsequent hit, then the accident was given code "0". If the vehicle first hit the guardrail end, then the accident was given code "1". If the vehicle hit another vehicle, the guardrail midsection, or any other object before hitting the guardrail end, then the accident was given code "2". Code "9" was given if it were not a guardrail end accident.

3.3.10 DID VEHICLE ROLL OR VAULT IN CONJUNCTION WITH THE END HIT?

The purpose of this classification was to determine the frequency of rolling or vaulting associated with particular types of guardrail. The researchers assigned codes in field 85 of the GDRAILAC.WK1 file to indicate whether vaulting, rolling, or both vaulting and rolling occurred.

The researchers relied upon the accident report wording and drawings to determine if the vehicle rolled or vaulted. They found many of the accident reports contained wording which did not clearly indicate whether the vehicle vaulted. For instance, a description of a vehicle "going down the guardrail" could mean that the vehicle vaulted and rode the top of the guardrail, or that the vehicle impact could have sheared off the posts, allowing the vehicle to stay in contact with the road.

After reviewing the police accident report, the researchers concluded that the vehicle was said to have vaulted in conjunction with striking the guardrail end if the vehicle went airborne, went over guardrail, or slid on top of the guardrail. If the language in the report was such that the researchers were not sure whether the vehicle vaulted, then the accident was classified as not sure to have vaulted. If the vehicle did not do any of the preceding, then the classification of "vehicle did not vault" was made.

If, after hitting the guardrail end, the vehicle immediately turned on its side or top, then it was said to have rolled. Researchers categorized the accident as "Rolling was not sure to have occurred" in some instances, such as when an embankment was close to the end and the researchers could not determine from the report whether the guardrail end or the embankment caused the rolling. If no roll occurred, then the accident was classified as "Did not roll".

Code "0" was given to the accident if the researchers were not sure if the guardrail end caused the vehicle to vault or roll. Code "1" was given to the accident if the guardrail end did not cause the vehicle to vault or roll. Code "2" was given to the accident if the vehicle rolled but did not vault after hitting the guardrail end. Code "3" was given to the accident if the vehicle vaulted but did not roll after hitting the guardrail end. Code "4" was given to the accident if the vehicle both vaulted and rolled after hitting the guardrail end.

If the vehicle rolled, but it was not clear if it vaulted, then code "5" was given to the accident. If the vehicle did not roll, but it was not clear if it vaulted, then code "6" was given to the accident. Code "7" was given to the accident if the vehicle vaulted but it was not clear if it rolled after hitting the guardrail end. If the vehicle did not vault but it was not clear if it rolled, then code "8" was given to the accident. Code "9" was given if the accident was not a guardrail end hit.

3.3.11 ACCIDENT SEVERITY -- TYPE OF INJURY

The purpose of this task was to determine the type of injuries that were being suffered by the occupants of the vehicle that hit the guardrail end. The existing database categorized accidents as fatal, injury, or property-damage-only. The researchers wanted to further define the severity of injury accidents, and used field 89 of the GDRAILAC.WK1 file to enter the type of injury sustained by each occupant.

The three injury types are: A, B, or C. Injury A is incapacitating, injury B is non-incapacitating, and injury C is a complaint of injury. Injury A is the most severe and injury C is the least severe. The accident report lists the type of injury sustained by each occupant. Codes were given to type of injury sustained.

3.24 Methodology

If the collision diagram was missing, if the accident report was a duplicate, or if for some other reason the type of injury was not determined, then code "0" was given to the accident. Code "9" was given to the accident if it were not a guardrail end accident. If no injury occurred, then code "1" was given to the accident. Code "2", code "3" and code "4" were given for injury A, B, and C respectively.

Because field 89 was four columns wide, injury severities for up to four occupants could be entered. For example, if two occupants sustained injuries A and B, then code "2" and code "3" were entered in the first two columns and code "1" was entered in the remaining two columns of field 89. Some accident reports listed two types of injuries for an individual; in such a case the most severe was listed. In the subsequent analysis, the accident was classified according to the most severe injury. If there were both an "A" and a "C" injury in a single accident, the "A" was used as the severity.

3.3.12 WAS FIXED OBJECT HIT AFTER END WAS HIT?

The purpose of this classification was to determine if the guardrail did not prevent the vehicle from hitting a fixed object it was shielding or connected to. This task was done as part of building the database and was not used in the analysis. Codes were entered in field 86 of the GDRAILAC.WK1 file to indicate whether the fixed object was hit after the vehicle struck the guardrail end.

Code "0" was given to the accident when the collision diagram was missing or when it was a duplicate accident report. Code "1" was given to the accident when the accident report made no mention of the vehicle hitting the fixed object or the connecting bridge or overpass wall. When the vehicle hit the fixed object or the bridge or overpass wall after hitting the guardrail end, code "2" was given to the accident. When the vehicle went down the embankment or downgrade but hit nothing, code "3" was given to the accident. When the guardrail was connected to a bridge or overpass and was also shielding a fixed object and the vehicle struck only the fixed object, then code "2" was given to the accident, even if it didn't hit the bridge wall. Code "9" was given if the accident were not a guardrail end hit.

3.3.13 VEHICLE DESCRIPTION

The guardrail end accident reports were studied to find the year, make, model and style of the vehicles that were involved in the guardrail end and questionable end accidents. These were entered in separate columns in the GDRAILAC.WK file. This information was needed in order to find vehicle weights.

3.3.14 DRIVER ALERTNESS

The researchers studied the wording of the guardrail end accident reports to identify the accidents in which the driver was sleepy or not alert. This information was obtained by reading the citation and "Condition of drivers and Pedestrians" details in the accident report. When the wording led the researchers to conclude that driver inattention or drowsiness contributed to the accident, the code "U" was entered in column "dri" in the GDRAILAC.WK1 file. The "U" was not assigned if seizures or driving-under-the-influence were mentioned, except in the few cases in which the accident report wording led the researchers to conclude that the driver was not significantly impaired.

3.4 ANALYSIS OF DATA

After building the database, the researchers performed a number of analyses. In some cases it was desirable or necessary to combine some data categories.

In some analyses, the lateral guardrail locations on the road were combined into three categories. These were left side guardrails, right side guardrails, and median guardrails.

The guardrail end accidents were classified according to the longitudinal location of the crash on the guardrail and according to the type of end that was hit by the vehicle. The end types were combined into turned-down, exposed, and other ends.

The various categories for vehicle rolling and/or vaulting after it hit the guardrail end were also combined. The resulting combined categories were "no roll or vault", "roll and/or vault", and "not sure if roll or vault".

In some analyses, the accidents were grouped into three categories, based on accident severity. These combined categories were fatal + injury A; injury B + injury C; and property damage only (PDO) accidents. Some vehicle weight categories were combined.

The frequency of accidents at lateral locations due to driver inattention was determined. The frequency and percentage of accidents with respect to urban/rural location and with respect to posted speed were also determined.

Regression equations were derived for the percent of accidents versus percent vehicle miles of travel, and for percent of accidents versus miles of highway. A brief description of linear regression is given in section 3.4.04.

Two-factor and three-factor contingency tables for the following classifications were formulated from the "presumed" data sets.

end type vs. roll and/or vault;
end type vs. lateral location vs. severity;
end type vs. rolling and/or vaulting vs. severity;
vehicle weight vs. rolling and/or vaulting;
end type vs. rolling and/or vaulting vs. vehicle weight;

vehicle weight vs. severity; and
end type vs. vehicle weight vs. severity.

Some of classifications were combined to obtain a sufficient number of occurrences per cell and for better numerical stability.

The following statistical tests were performed on contingency tables:

1. the Chi-square test of independence;
2. the Games-Howell (GH) procedure of multiple comparisons on cell means; and
3. the test to compare binomial proportions.

These tests are described in the following sections. A severity index, probability index and collision index for exposed and turned-down end terminals was determined.

3.4.01 CHI-SQUARE TEST OF INDEPENDENCE

The Chi-square test of independence is a test of hypotheses concerning category probabilities. It determines if the multinomial count data categories, classified by either two or three factors, are independent of each other. This involves a comparison of "actual" data with "expected" data.

The symbols representing the cell counts and the corresponding row and column probabilities for a two-way or contingency table are shown in Table 3.1. In the table, n_{11} represents the actual count data of classifications '1' and 'A' and p_{11} represents the corresponding excepted cell probability.

TABLE 3.1 Observed counts and probabilities for a two-factor contingency table

		COLUMN				ROW TOTALS
		A	B	C	D	
OBSERVED						
ROW	1	n_{11}	n_{12}	n_{13}	n_{14}	r_1
	2	n_{21}	n_{22}	n_{23}	n_{24}	r_2
	3	n_{31}	n_{32}	n_{33}	n_{34}	r_3
COLUMN TOTALS		c_1	c_2	c_3	c_4	n
EXPECTED						
ROW	1	p_{11}	p_{12}	p_{13}	p_{14}	p_1
	2	p_{21}	p_{22}	p_{23}	p_{24}	p_2
	3	p_{31}	p_{32}	p_{33}	p_{34}	p_3
COLUMN TOTALS		p_A	p_B	p_C	p_D	

The row and column totals are designated as r_1, r_2, r_3 and c_1, c_2, c_3 and c_4 respectively, and the corresponding row and column probabilities or marginal probabilities are designated p_1, p_2, p_3 and p_A, p_B, p_C and p_D respectively. Marginal probabilities are $p_1 = p_{11} + p_{12} + p_{13} + p_{14}$ and $p_A = p_{11} + p_{21} + p_{31}$.

The ith row marginal probability p_i is,

$$\hat{p}_i = \left(\frac{r_j}{n}\right)$$

where r_j is the row i total. Similarly, the best estimate of the jth column probability p_j is,

$$\hat{p}_j = \left(\frac{r_i}{n}\right)$$

where r_i is the column j total. The estimated expected cell count for the cell in the ith row and jth column of the contingency table is

$$\hat{E}(n_{ij}) = nxp_i xp_j$$

If two events A and B are independent, the probability of the intersection of A and B equals the product of the probabilities of A and B, i.e.,

$$P(A \cap B) = P(A)P(B)$$

Similarly, in the contingency table analysis, if two variables are independent of each other, the expected probability of a particular cell of the table is the product of the corresponding row and column marginal probabilities. Thus, if the hypothesis of independence is substantiated, in Table 3.1 we must have
$p_{11} = p_1\ p_A$, $p_{12} = p_1\ p_B$,
and so forth. If the actual data disagree with the expected cell counts computed from these probabilities, there is evidence to indicate that the two variables are dependent.

The null hypothesis (H_0) that the variables are independent is equivalent to the hypothesis that every cell probability in the contingency table is equal to the product of its respective row and column marginal probabilities. Rejecting the null hypothesis when it is true is a Type I error. The probability of making a Type I error is denoted by the symbol α. $(1-\alpha)$ is also called as the confidence coefficient.

When n is large, the test statistic

$$X^2 = \sum_{j=1}^{c} \sum_{i=1}^{r} \frac{[n_{ij} - \hat{E}(n_{ij})]^2}{[\hat{E}(n_{ij})]}$$

will possess approximately a Chi-square distribution *(15)*. The rejection region for the test will be

$$X^2 \geq X^2_\alpha$$

The degrees of freedom for the Chi-square will be

df = rc - (the number of linearly independent restrictions on the cell count)
= (r -1)(c-1)

where, r is the number of rows and c is the number of columns in the contingency table.

The Chi-square test of independence is based on the assumption that the n observed counts are a random sample from the population of interest. For the Chi-square approximation to be valid, the estimated expected counts should be greater than or equal to 5 in all cells.

In a three-way table, several hypotheses of partial association or partial independence of the three variables (factors) can be constructed. Table 3.2 shows an example of a three way contingency table, where the levels of the first factor are X and Y, the levels of the second factor are 1 and 2, and the levels of the third factor are A and B.

In this analysis the complete independence model was considered. In the complete independence model, the classification of any factor has no influence on the classification of any other factor or combination of factors. If complete independence is rejected, then some form of association is present.

TABLE 3.2 Observed counts and probabilities for a three-factor contingency table

		X					Y		
		COLUMN		total			COLUMN		total
		A	B				A	B	
ROW	1	l_{11}	l_{12}	l_1	ROW	1	m_{11}	m_{12}	m_1
	2	l_{21}	l_{22}	l_2		2	m_{21}	m_{22}	m_2
total		l_A	l_B	l	total		m_A	m_B	m

The estimated expected cell count for the cell l_{11} in X - contingency table is *(16)*

$$\hat{E}(l_{11}) = ((l_A + m_B) * (l_1 + m_1) * (l)) / (l + m)^2$$

Similarly the expected counts for the other cells in the X and Y contingency tables are calculated.

When n is large, the test statistic

$$X^2 = \sum_{j=1}^{c} \sum_{i=1}^{r} \frac{[l_{ij} - \hat{E}(l_{ij})]^2}{[\hat{E}(l_{ij})]} + \sum_{j=1}^{c} \sum_{i=1}^{r} \frac{[m_{ij} - \hat{E}(m_{ij})]^2}{[\hat{E}(m_{ij})]}$$

will possess approximately a Chi-square distribution. The rejection region for the test will be

$$X^2 \geq X_\alpha^2$$

The degrees of freedom will be

$$df = abc-a-b-c+2$$

where, a is the number of levels of the first factor, b is the number of levels of the second factor, and c is the number of levels of the third factor of the three-factor contingency table.

3.4.02 GAMES-HOWELL (GH) PROCEDURE OF MULTIPLE COMPARISONS ON CELL MEANS

This multiple comparison method uses the test statistic

$$t_{jk}=\overline{Y}_j-\overline{Y}_k/\sqrt{((s_j)^2/(n_j)+(s_k)^2/(n_k))}$$

where, Y-bar is the sample mean, s^2 is the unbiased sample variance, and n is the sample size for each pair of means, j being equal to k (17).

The null hypothesis H_o is rejected if

$$p(t_{df_{jk}} \geq |t_{jk}|) \leq \alpha$$

Otherwise, the null hypothesis is not rejected.

$$df_{jk}=(s_j^2/n_j+s_k^2/n_k)^2/[(s_j^2/n_j)^2/(n_j-1)]+[(s_k^2/n_k)^2/(n_k-1)]$$

where df_{jk} is the degrees of freedom for the observed t_{jk}.

3.4.03 TEST FOR COMPARING TWO BINOMIAL PROPORTIONS

Inferences about two proportions are usually phrased in terms of their difference. The sampling distribution can be approximated by a normal distribution. A summary of the comparison test procedure follows (18).

$$H_0: p_1-p_2=0$$

$$H_{alt}: p_1-p_2 \neq 0$$

Test Statistic :

$$z=(p_1-p_2)/\sqrt{(p*q*(1/n_1+1/n_2))}$$

where H_0 is the Null hypothesis
H_{alt} is the alternate hypothesis
p_1 and p_2 are sample proportions
where $p_1 = x_1/n_1$ and $p_2 = x_2/n_2$
$p = (x_1 + x_2)/(n_1 + n_2)$
$q = (1 - p)$

Reject H_0 if $|z| \geq z_{\alpha/2}$, where $z_{\alpha/2}$ is the α-level critical value from the standard normal distribution.

3.4.04 LINEAR REGRESSION ANALYSIS

Linear regression analysis finds a model in which the dependent variable (y) is approximated by a linear combination of the independent variables (x), with a constant term. Mathematically speaking, regression analysis finds values of $A_1, \ldots, A_k$ and C for each y such that the values of $A_1x_1 + \ldots + A_kx_k + C$ are as close to the values of y in a least squares sense. These values of $A_1, \ldots, A_k$ and C are the values that minimize the sum of squares $A_1x_1 + \ldots + A_kx_k + C - y$. The regression analysis was done using spreadsheet software. The output included the following:

1. The "No. of Observations" is the total number of dependent (y) values.
2. The "Degrees of Freedom" equals (number of observations)-(number of independent x variables +1).
3. The "Constant" is the y-axis intercept of the regression.
4. The "Std Err of Y Est" is the estimated standard error of the y values and represents the deviation of the observed y values from the values of the linear combinations.
5. The "X Coefficient(s)" are the coefficients $A_1, \ldots, A_k$ of the independent (x) variables in the model.
6. The "Std Err of Coef." gives the error estimate of the coefficients.
7. The coefficient of determination (R^2) is a statistic that measures the validity of the model. It ranges up to 1, with 1 being optimal.

3.5 LIMITATIONS OF THIS ACCIDENT RESEARCH

There were certain difficulties and limitations encountered while relating the accident report data with the video tapes and the guardrail inventory. The reports, tapes, and inventory were recorded at different times, which could cause them to disagree if there had been changes in the field between the time of the accident and the time the tape or inventory was made.

3.5.01 LIMITATIONS WITH ACCIDENT REPORTS

The quality of the accident reports varied. The conditions in the field may not be conducive to filling out precise accident reports, and some officers may not possess well-developed "map and drawing" skills needed to convey locational information to others. The drawings usually are not in proportion, and may not include distance measurements, which makes it more difficult to ascertain the relative position of the guardrail end to the point of impact.

Some reported accident locations seemed to be incorrect. There were a few cases of very vague locational references and the absence of any milepoint or grid coordinate locations on the accident report. In a few other instances, a guardrail was not present at or near the reported accident location.

While reviewing the accident reports, the researchers found a few reports that appeared to contain incorrect information. Three problems with accident reports are highlighted in the accompanying drawings and photographs. Figure 3.8 shows excerpts from three accident reports.

The first shows that the accident was reported to have occurred in Osage County at a guardrail end. If the two intersecting highways at which the accident occurred are correctly recorded, then the accident actually took place in Pawnee County. A field visit showed that there was no guardrail end at the site; instead, the guardrail curves continuously around the intersection radius as shown in the photo.

The second illustration shows an accident report drawing indicating the presence of a guardrail end. The photograph of the site shows that there is no exposed end, but rather a parabolic end section.

The third illustration shows an accident report drawing indicating the presence of a guardrail. The site photograph shows a concrete barrier, not a metal guardrail, in place.

3.5.02 LIMITATIONS WITH THE VIDEO TAPES

Viewing the video tapes did not always answer all the questions the researchers had about a particular accident site, and there were some difficulties with tape-viewing. When winding roads changed direction often, it was more difficult to relate the direction of travel given in the accident report with directions on a map or video log. Another limitation was the quality of super-long play video, especially at the edges of the frame. When proceeding through a sharp curve, the video camera sometimes missed roadside features.

3.5.03 COMMENTS ABOUT LIMITATIONS

The researchers resolved most of these data problems with patient study. The researchers made a few field visits to the accident site area and made telephone calls to local officials to obtain more information.

The small number of some guardrail accident types caused numerical instability; i.e., the number of a particular type of occurrence was to small to analyze. To address this limitation, the researchers combined some of the data categories.

3.32 Methodology

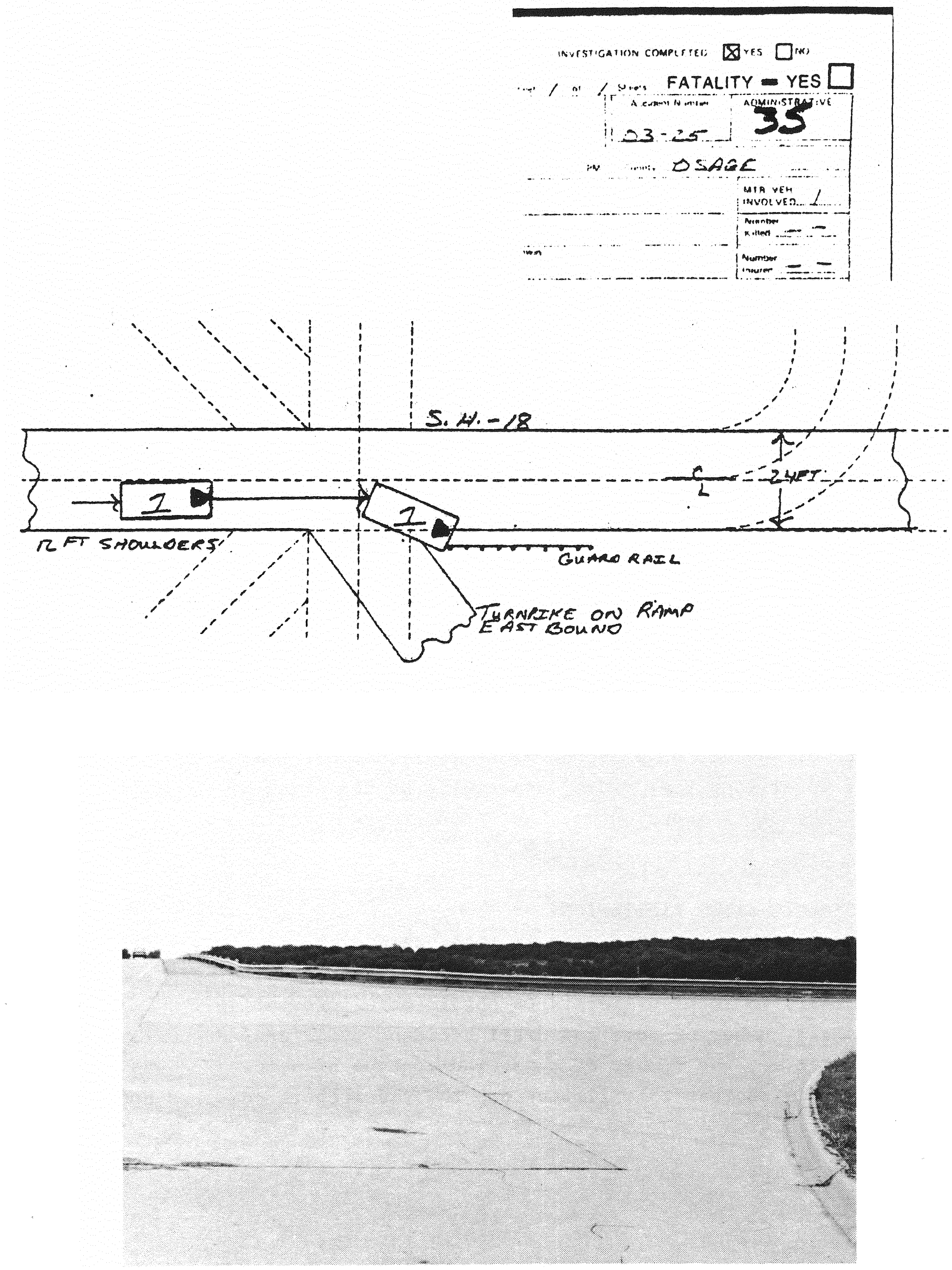
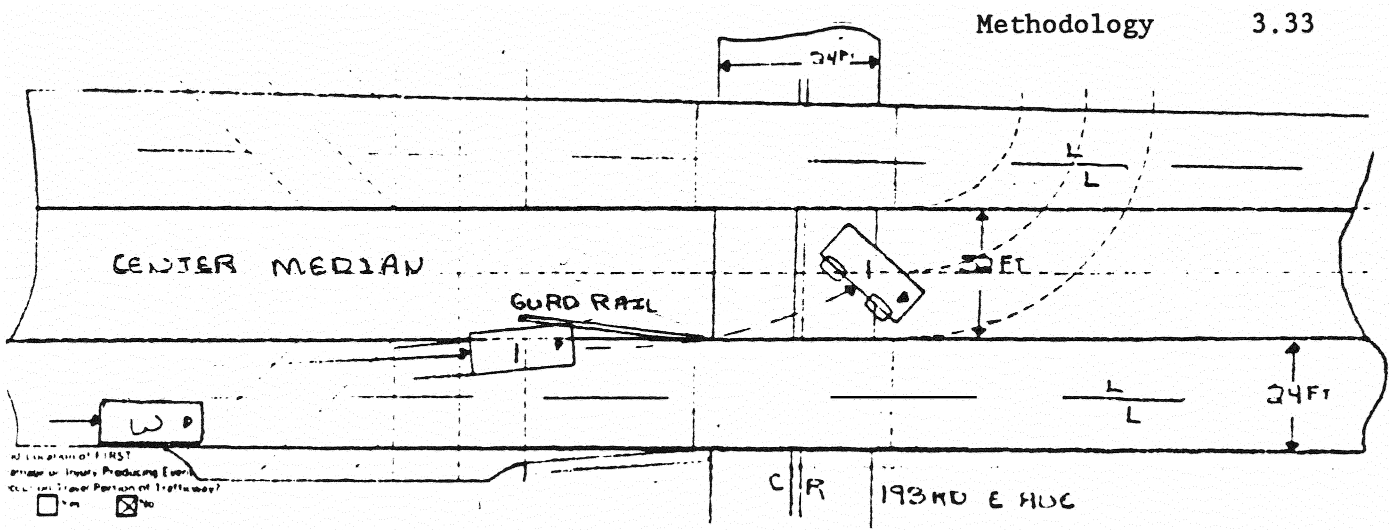


FIGURE 3.8 Examples of accident report limitations



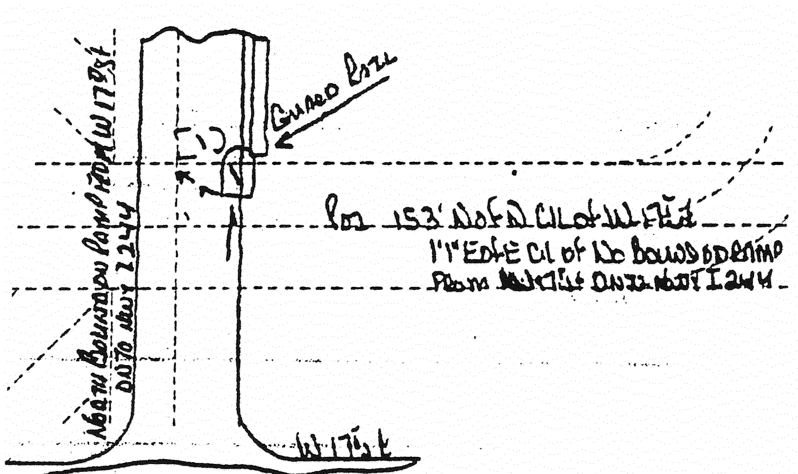


FIGURE 3.8 con't. Examples of accident report limitations

3.34 Methodology

CHAPTER IV

ANALYSIS OF DATA AND RESULTS

This chapter presents the data analysis and the results. The results provide insight into various attributes associated with guardrail end accidents, and highlight factors associated with elevated frequency or severity of guardrail end accidents.

The guardrail accident spreadsheet file GDRAILAC.WK1 was imported into a database file. The researchers performed ask and query operations in order to find numbers of guardrail end accidents exhibiting certain traits. The following issues were examined.

1. Longitudinal location of guardrail accidents
2. Lateral location of the guardrail end
3. Type of end which was struck
4. Type of initial post
5. Shoulder attributes
6. Guardrail setback
7. Median attributes
8. What vehicle was doing
9. Was the end-hit the initial impact or a subsequent event?
10. Occurrence of vehicle rolling or vaulting
11. Accident severity
12. Whether vehicle subsequently struck fixed object
13. Weight of vehicles striking guardrail ends
14. Number of unalert drivers involved in guardrail end accidents
15. Rural vs. urban location of guardrail end accidents
16. Posted speed at guardrail end accident sites
17. Relationship of accident frequency with miles of road and VMT
18. Combined-factor relationships: various combinations of end type, lateral location, severity, rolling and/or vaulting, and weight
19. Severity index, probability index and collision index for exposed and turned-down ends

4.1 LONGITUDINAL LOCATION OF GUARDRAIL ACCIDENT

Because the initial database included both guardrail end and non-end accidents, the researchers used the ask and query operations on fields 79, 80, 81, and 88 of the database file to separate the accidents into various longitudinal location categories. Table 4.1 shows the summary of guardrail accident longitudinal locations.

4.02 Analysis & Results

TABLE 4.1 Longitudinal location of guardrail accidents

Classification	Code	Number	Same Side	Cross-over	Percent
ALL GUARDRAIL ACCIDENTS					
Not able to determine	0	23			1.33
Not guardrail end accident	1	1064			61.36
Questionable guardrail end accident	2,3	118			6.80
Presumed guardrail end accidents	4-8	435			25.09
Guardrail connection with fixed object	19,20	67			3.86
Not a guardrail accident (e.g.,concrete barriers)	99	27			1.56
Total		1734			100.0%
ONLY GUARDRAIL END ACCIDENTS					
Questionable trailing end	2	27	17	10	4.88
Trailing guardrail end--undivided road				9	
Questionable approach end	3	91	81	10	16.46
QUESTIONABLE		118			
Trailing guardrail end	4	89	19	70	16.09
Trailing guardrail end--undivided road				62	
Approach guardrail end		336		5	0.90
Head end of vehicle--approach end	5		234		42.32
Side of vehicle--approach end	6		92		16.64
Rear of car--approach end	7		5		0.90
Approach or trailing guardrail end hit from behind	8	10	4	6	1.81
PRESUMED		435			
TOTAL PRESUMED PLUS QUESTIONABLE		553			100.0%

To analyze the different accident categories, various data sets were created during the project. The guardrail end data sets included:

End hits -- presumed (P);

End hits -- presumed-plus-questionable (P+Q);

Approach end/same side and trailing end/cross over/undivided -- presumed (AP);

Approach end/same side and trailing end/cross over/undivided -- presumed-plus-questionable (AP+Q);

To control the scope of the work and the size of the report, not all analyses were performed on all data sets.

The terms "approach end" and "trailing end" were used with respect to the normal or intended direction of travel on a lane or lanes. The "approach end" is the guardrail end on the right side of an undivided road. For a divided road, the "approach ends" are those on the right or left of the lanes intended for one direction of travel. A "trailing end" is the one at the end of a guardrail installation. When a driver crosses the centerline of an undivided road or the median of a divided road, the vehicle was said to strike the trailing end. The following matrix may help explain the data set combinations.

	Presumed	Presumed-plus-questionable
1. End hits	P	P+Q
2. Approach end/same side and trailing end/cross over/undivided	AP	AP+Q

To review, the

1. "questionable" data included those guardrail end hits where the researchers concluded that there was a slight chance that the accident involved a guardrail end;
2. the "presumed" set consisted of those accidents that were judged from the reports to probably involve a guardrail end;
3. the "end hits" group included all guardrail end accidents; and
4. the "approach end/same side and trailing end/cross over/undivided" accidents included only those end hits in which a vehicle hit the approach end, or crossed over the centerline of an undivided roadway and struck the trailing end on the driver's left side -- ends struck from behind were not included.

ODOT had furnished a total of 1731 guardrail accident reports. In three of the accidents a vehicle struck two guardrail ends, so there were 1734 entries in the database file. Of these 1734, the researchers did not classify

1.3% because of missing data or the accident report was a duplicate. The researchers determined that 61.4% of the accidents were not guardrail end accidents. They categorized 6.8% of the accidents as either questionable approach end or questionable trailing end guardrail accidents, and called 25.1% of the accidents probable guardrail end accidents. The researchers found that 3.9% of the accidents involved impacts where the guardrail was connected to a rigid object, such as a bridge; these included both the fixed object-approach connection point and the fixed object-trailing connection point accidents. In 1.6% of the accidents, the vehicle hit a concrete barrier, not a metal guardrail.

The number of presumed guardrail end accidents plus questionable guardrail end accidents was 553. From Table 4.1, **it can be concluded that most of the guardrail accidents occurred along the guardrail midsection. The end accidents constituted less than 32% of the total number of reported guardrail accidents. The approach end of the guardrail was struck more often than the trailing end. In most of the end accidents, the front or side of the vehicle struck the guardrail.**

4.2 LATERAL LOCATION OF GUARDRAIL END STRIKES

The researchers analyzed the guardrail end accident data to find the relative frequency with which various guardrail lateral locations (i.e., right side, left side) were being struck. The ask and query operations were performed on field 79 and field 81 of the database file to arrive at the number of accidents in each lateral location category. Table 4.2 gives a summary of the guardrail end accident lateral locations. The codes used to classify the guardrail location were shown in Figure 3.2.

4.2.01 LATERAL LOCATION WITHOUT CONSIDERING EFFECT OF MEDIANS

Of the presumed guardrail end hit accidents, the vehicle struck the right side guardrail on the main road in over half (code 3) of the accidents. In 15.4% of the accidents the vehicle crossed the road and hit the guardrail to the right of the oncoming traffic (code 7). The vehicle hit the guardrail on the right side of the median (code 4) in 21.8% of the accidents. In 3.7% of the accidents the vehicle crossed the road and hit the extreme left side guardrail on the median (code 6), while in 2.5% of the accidents the vehicle hit the double faced or narrow circular guardrail or similar guardrail in the median (code 5). There were few accidents in which a vehicle struck the guardrail on the same direction or the opposite direction frontage roads, gores, entry ramps, exit ramps, or guardrail ends on cross roads or drives. The lateral location percentages for the presumed guardrail end hit accident data set were similar to those of the other three accident data sets.

TABLE 4.2 Lateral location of guardrail end accidents

Lateral location code		END HITS Presumed #	%	END HITS Presumed-plus-Questionable #	%	APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED Presumed #	%	APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED Presumed-plus-Questionable #	%
1	Rt. Frontage rd-far right	1	0.23	2	0.36	1	0.25	1	0.21
2	Rt. Frontage rd-near rt.	0	0.00	0	0.00	0	0.00	0	0.00
3	Right side	230	52.87	291	52.62	214	54.45	264	54.66
4	Median - same direction	95	21.84	126	22.79	90	22.90	117	24.22
5	Median - both	11	2.53	13	2.35	10	2.55	12	2.49
6	Median - oncoming	16	3.68	18	3.26	1	0.25	1	0.21
7	Left side	67	15.40	85	15.37	62	15.78	71	14.70
8	Lt. Frontage rd-near left	0	0.00	0	0.00	0	0.00	0	0.00
9	Lt. Frontage rd-far left	0	0.00	0	0.00	0	0.00	0	0.00
10	Exit ramp gore	4	0.92	5	0.91	4	1.02	5	1.04
11	Exit ramp - right	2	0.46	2	0.36	2	0.51	2	0.41
12	Exit ramp - left	5	1.15	6	1.08	5	1.27	6	1.24
13	Entry ramp gore	0	0.00	0	0.00	0	0.00	0	0.00
14	Entry ramp - right	2	0.46	2	0.36	2	0.51	2	0.41
15	Entry ramp - left	0	0.00	1	0.18	0	0.00	0	0.00
20	Cross road, other	2	0.46	2	0.36	2	0.51	2	0.41
Total		435	100.0%	553	100.0%	393	100.0%	483	100.0%

It can be concluded from Table 4.2 that **the most predominant guardrail end accidents involves the vehicle hitting the guardrail end on the right side of the main road. A sizeable number of accidents involved crashes with guardrail ends in the median.**

4.2.02 LATERAL LOCATION CONSIDERING EFFECT OF MEDIANS

After viewing the lateral location data, the researchers suspected that the presence or absence of a median was affecting the results. The researchers then used the ask and query operations on field 79, field 80, and field 88 to determine if the presence of median affected the relative frequency of guardrail end accident lateral locations.

In order to concentrate on lateral locations with the most accidents, the researchers combined some lateral location groups for analysis. Accidents involving guardrail located on the right side of the road (code 3), the far side median (code 6), and accidents involving guardrail located on oncoming traffic's right side (code 7) remained uncombined. Accidents involving guardrail located in the middle and the near side of the median (codes 4 and 5) were combined into one classification. Accidents involving all other guardrail locations were combined into one classification. Table 4.3 shows the number of accidents under these classifications for both the presumed and presumed plus questionable guardrail end accident data sets. Again, the proportions of accidents in the various categories did not greatly differ between the presumed and the presumed-plus-questionable data groups.

The data showed that 55% to 60% of guardrail end accidents on the state highway system occurred on divided roads. **On divided roads, the chances of a vehicle hitting the guardrail on the right side of the road or in the median were almost the same.** On a divided roadway, the probability of vehicles crossing the median and hitting the guardrail on the far left side (i.e., the oncoming main road's right side) was small. **About 60% of accidents on undivided roads involved the vehicle striking the guardrail end on the right side.**

4.3 TYPE OF GUARDRAIL END STRUCK

The researchers utilized ask and query operations on field 79 and field 83 of the database file to find the number of accidents which occurred at various guardrail end types. The researchers were not able to determine a few of the end types, possibly because the guardrail at the location had been removed or due to an inadequate description of the location. All four data sets exhibited similar end-type category proportions. Table 4.4 presents the results, and shows that **the number of accidents at turned-down ends was greater than the number at exposed ends.**

4.3.01 COMBINING END TYPES

As the percent of accidents occurring on "other than exposed or turned-down ends" was very small, the researchers did not perform analyses on the "other" group. For the analysis, the researchers combined the turned-down ends and turned-down ends with significant flare to form one category, the turned-down ends. They also combined the exposed ends and exposed ends with significant flare to form one category, the exposed end category. Table 4.5 shows the number and percentage of accidents under these categories for all four data sets. The difference between the proportions of exposed and of turned-down guardrail end types in the four accident data sets was small.

TABLE 4.3 Combined lateral location of guardrail end accidents

		Left side	Median left	Median middle/ right	Right side	Other	Total
PRESUMED END HITS							
Roadway with median							
	Frequency	2	16	105	119	5	247
	Percentage	0.81	6.48	42.51	48.18	2.02	100.0
Roadway without median							
	Frequency	65	na	na	111	9	185
	Percentage	35.13	na	na	60.00	4.87	100.0
Not Sure	Frequency						3
PRESUMED-PLUS-QUESTIONABLE END HITS							
Roadway with median							
	Frequency	3	18	138	161	7	327
	Percentage	0.92	5.50	42.20	49.24	2.14	100.0
Roadway without median							
	Frequency	82	na	na	131	10	223
	Percentage	36.77	na	na	58.74	4.49	100.0
Not Sure	Frequency						3
PRESUMED -- APPROACH END/SAME SIDE and TRAILING END/CROSSOVER/UNDIVIDED							
Roadway with median							
	Frequency	0	1	99	110	5	215
	Percentage	0.0	0.46	46.05	51.16	2.33	100.0
Roadway without median							
	Frequency	62	na	na	105	9	176
	Percentage	35.23	na	na	59.66	5.11	100.0
Not Sure	Frequency						2

TABLE 4.4 Type of guardrail end struck

Type of end	Code	END HITS Presumed #	%	END HITS Presumed-plus-Questionable #	%	APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED Presumed #	%	APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED Presumed-plus-Questionable #	%
Not able to determine	0	13	2.99	17	3.07	11	2.80	14	2.90
Exposed end	1	140	32.18	168	30.38	126	32.06	143	29.61
Turned-down end	2	241	55.40	316	57.14	218	55.47	280	57.97
Exposed end with significant flare	4	17	3.91	22	3.98	17	4.33	21	4.35
Turned-down with significant flare	3	8	1.84	10	1.81	6	1.53	7	1.45
Parabolic end	5	5	1.15	7	1.27	5	1.27	7	1.45
Rounded end	6	8	1.84	9	1.63	7	1.78	8	1.65
Other end type	8	3	0.69	4	0.72	3	0.76	3	0.62
Total		435	100.0%	553	100.0%	393	100.0%	483	100.0%

TABLE 4.5 Type of guardrail end hit -- categories combined

Type of end hit	END HITS Presumed #	%	END HITS Presumed-plus-Questionable #	%	APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED Presumed #	%	APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED Presumed-plus-Questionable #	%
Exposed end	157	38.67	190	36.82	143	38.96	164	36.36
Turned-down end	249	61.33	326	63.18	224	61.04	287	63.64
Total	406	100.0%	516	100.0%	367	100.0%	451	100.0%

4.3.02 COMPARING VIDEO OBSERVATIONS WITH INVENTORY

As a check, the researchers compared the end types logged from the video viewing and field inspections with those listed in the ODOT inventory. The ask and query operations were performed on field 79, field 83, and the "Inventory" column to determine whether the end type obtained from the video tapes and field visits agreed with the end type listed in the inventory. Table 4.6 presents the results of this comparison.

TABLE 4.6 Video tape and inventory comparison

END HITS	Presumed		Presumed-plus-Questionable	
	#	%	#	%
Agreeing	252	57.93	311	56.24
Not Agreeing	34	7.82	44	7.96
Not able to determine	149	34.25	198	35.80
Total	435	100.0%	553	100.0%

It can be concluded from Table 4.6 that about 8% of the end-type classifications made from the video tapes did not match the inventory classifications. Some disagreement is to be expected for accidents involving trailing end hits, because the inventory describes only the end-type on the leading-end of the guardrail, which at many locations differs from the end-type at the trailing end. Other disagreement could be due to the inventory showing only exposed and turned-down guardrail end types, and due to difference in time between making the inventory and making the video tapes. In about 35% of the accidents, the end type could not be determined from the inventory.

4.4 TYPE OF INITIAL POST

The researchers found it difficult to determine the type of post at the beginning of the guardrail. The quality of a super-long play video picture is not great, and the post was often in a shadow. Some of the attempted classifications may be incorrect.

The researchers performed the ask and query operation on field 84 of the database file to ascertain the post type of only the "presumed end hit" data set. The results follow.

Could not tell: 218 Metal: 17 Wooden: 200

4.10 Analysis & Results

Of accidents at the 17 guardrail ends supported by metal posts, one was a fatality and two were injury A. These numbers are in proportion to the overall proportions. Due to the small number of metal posts, no further analyses were performed.

4.5 SHOULDER ATTRIBUTES

The researchers performed the ask and query operations on field 87 of the database file to differentiate among accidents at various shoulder types. From accident report comments and video viewing, the researchers could not be confident in distinguishing between "no shoulder" and unpaved shoulders, so these two categories were combined. Table 4.7 shows the results.

TABLE 4.7 Guardrail end accident severity as a function of shoulder type

PRESUMED END HITS

Severity	Don't know (0) #	None or grass (1 or 2) #	None or grass (1 or 2) %	Paved (4) #	Paved (4) %
Fatal	0	2	2.3	13	3.9
Injury A	2	8	9.1	47	14.0
Injury B	2	10	11.4	62	18.5
Injury C	0	13	14.7	43	12.8
PDO	8	55	62.5	170	50.8
Total	12	88	100.0	335	100.0

The shoulder type seemed to make no significant difference in the accident severity.

4.6 GUARDRAIL SETBACK

The researchers estimated the distance from the edge of the traveled lane to the guardrail end from accident report information and from viewing the videos. They performed ask and query on field 90 of the GDRAILAC.DB file to study severity differences for various guardrail end setbacks from the road edge. Table 4.8 shows the results; the end setback distance did not seem to affect the accident severity.

4.7 MEDIAN ATTRIBUTES

The researchers utilized the median data they gathered in other analyses, such as differentiating between proportions of far side guardrail end strikes on a road with and without a median. The data were not collected with the intent of performing a separate median analysis.

TABLE 4.8 Guardrail end accident severity as a function of end setback

PRESUMED END HITS

Severity	Unknown (0) #	0-1 ft (1) #	2-7 ft (2) #	%	8 or more ft (8) #	%
Fatal	0	0	6	3.1	9	3.8
Injury A	0	0	30	15.7	27	11.5
Injury B	0	0	30	15.7	44	18.7
Injury C	0	1	25	13.1	30	12.7
PDO	5	2	100	52.4	126	53.4
Total	5	3	191	100.0	236	100.0

4.8 WHAT VEHICLE WAS DOING

The initial intent of recording this data was to determine if there were any patterns of unusual vehicle movements (such as wrong-way driving) prior to end-collision. From reviewing the accident reports, the researchers found that no such patterns happened, so no analysis was performed.

4.9 PROPORTIONS OF INITIAL AND SUBSEQUENT END STRIKES

The initial impact in an accident may be when the vehicle strikes the guardrail end, or a vehicle may strike a guardrail end after being involved in other impacts. The ask and query operations were performed on field 79 and field 82 to determine the percentage of initial and subsequent guardrail end hits for the presumed, and presumed-plus-questionable accident data sets. The results are shown in Table 4.9.

TABLE 4.9 Number of initial and subsequent guardrail end accidents

END HITS

Type of hit	Presumed #	%	Presumed-plus-Questionable #	%
Initial	421	96.78	529	95.66
Subsequent	14	3.22	24	4.34
Total	435	100.0%	553	100.0%

This analysis showed that the proportion of subsequent hits was small, relative to the total number of guardrail end strikes. One implication of this is that for almost all of the guardrail end accidents studied, the vehicle occupants were not injured before striking the guardrail end. They could have been injured by impacts after striking the guardrail end. Because the "subsequent" group was small, it was not separated in the analysis.

4.10 VEHICLE ROLLING AND VAULTING IN CONJUNCTION WITH END STRIKE

Previous chapters included a discussion of the concerns about vehicles rolling and/or vaulting after striking turned-down guardrail ends. Because Oklahoma has large-scale experience with only the exposed ends and the turned-down ends, it was not possible to compare the performance of turned-down ends with newer guardrail end-types. However, the researchers did use the ask and query operations on database field 79, field 83 and field 85 to examine vehicle rolling and/or vaulting trends in relation to the exposed or the turned-down guardrail end-types.

The roll and vault characteristics encoded into field 85 were combined into three major groups: "No Roll/Vault", "Roll/Vault", and "Not sure". The "No Roll/Vault" category included accident code "1"; the "Roll/Vault" category included accident codes "2", "3", "4", "5", and "7"; the "Not sure" category included accident codes "0", "6", and "8".

Table 4.10 shows the number and percentage of accidents in these categories for both the exposed and turned-down terminals. About 1/4 of guardrail end accidents appear to result in vehicle rolling and/or vaulting. **It can be concluded that in most of the guardrail end accidents, the vehicle did not vault or roll.** All four data sets yielded similar distributions of accidents.

4.11 GUARDRAIL END ACCIDENT SEVERITY

The researchers performed the ask and query operations on field 16, field 79, field 83, and field 89 to find the number of fatal, injury A, injury B, injury C, and property damage only (PDO) accidents. The totals were found separately for exposed and for turned-down end-terminals. Table 4.11 shows the results. The percentages of accidents in each severity category were similar in all four data sets. The percentages of accidents in the fatal plus the Injury A categories was somewhat higher for the turned-down ends than for the exposed ends.

4.11.01 COMBINED END ACCIDENT SEVERITY CATEGORIES

Some "A" injuries are life threatening, while others are not. Factors such as emergency service response time, occupant protection employed, or chance may be the difference between a major injury or a fatality in an automobile accident. Because the "A" injuries are more severe, and the fact that fatalities were rather rare, it was felt that the analyses would be enhanced by combining the fatal category with the injury A category, and by combining the relatively minor injury B and injury C categories. Table 4.12 gives the severity of the combined categories.

TABLE 4.10 Roll/Vault in connection with guardrail end accidents

	END HITS				APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/ UNDIVIDED			
	No Roll/ Vault	Roll/ Vault	Not sure	Total	No Roll/ Vault	Roll/ Vault	Not sure	Total
ALL END TYPES								
PRESUMED								
Number	273	105	57	435	240	96	57	393
Percentage	62.76	24.14	13.10	100.0	61.07	24.43	14.50	100.0
PRESUMED-PLUS-QUESTIONABLE								
Number	354	125	74	553	298	112	73	483
Percentage	64.02	22.60	13.38	100.0	61.70	23.19	15.11	100.0
EXPOSED ENDS								
PRESUMED								
Number	116	24	17	157	104	22	17	143
Percentage	73.88	15.29	10.83	100.0	72.73	15.38	11.89	100.0
PRESUMED-PLUS-QUESTIONABLE								
Number	140	32	18	190	118	28	18	164
Percentage	73.69	16.84	9.47	100.0	71.95	17.07	10.98	100.0
TURNED-DOWN ENDS								
PRESUMED								
Number	133	78	38	249	115	71	38	224
Percentage	53.41	31.33	15.26	100.0	51.34	31.70	16.96	100.0
PRESUMED-PLUS-QUESTIONABLE								
Number	182	90	54	326	153	81	53	287
Percentage	55.83	27.61	16.56	100.0	53.31	28.22	18.47	100.0

TABLE 4.11 Severity of guardrail end accidents

	END HITS				APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED			
	Presumed		Presumed -plus- Questionable		Presumed		Presumed -plus- Questionable	
Severity	#	%	#	%	#	%	#	%
ALL END TYPES COMBINED								
Fatal	15	3.45	19	3.44	14	3.56	17	3.52
Injury A	57	13.10	66	11.93	54	13.74	61	12.63
Injury B	74	17.01	97	17.54	67	17.05	83	17.18
Injury C	56	12.88	70	12.66	52	13.23	64	13.25
PDO	233	53.56	301	54.43	206	52.42	258	53.42
Total	435	100.0%	553	100.0%	393	100.0%	483	100.0%
EXPOSED ENDS								
Fatal	7	4.46	9	4.74	6	4.20	8	4.88
Injury A	17	10.83	21	11.05	16	11.19	19	11.59
Injury B	31	19.74	39	20.53	28	19.58	32	19.51
Injury C	21	13.38	22	11.58	20	13.99	20	12.19
PDO	81	51.59	99	52.10	73	51.05	85	51.83
Total	157	100.0%	190	100.0%	143	100.0%	164	100.0%
TURNED-DOWN ENDS								
Fatal	8	3.21	10	3.07	8	3.57	9	3.14
Injury A	38	15.26	42	12.88	36	16.07	39	13.59
Injury B	40	16.07	54	16.56	36	16.07	48	16.72
Injury C	30	12.05	43	13.19	28	12.59	40	13.94
PDO	133	53.41	177	54.30	116	51.79	151	52.61
Total	249	100.0%	326	100.0%	224	100.0%	287	100.0%

Note: accidents from 1988-1991

TABLE 4.12 Combined-category severity of guardrail end accidents

	END HITS				APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED			
	Presumed		Presumed -plus- Questionable		Presumed		Presumed -plus- Questionable	
Severity	#	%	#	%	#	%	#	%
Fatal + Injury A	72	16.55	85	15.37	68	17.30	78	16.15
Injury B + C	130	29.89	167	30.20	119	30.28	147	30.43
PDO	233	53.56	301	54.43	206	52.42	258	53.42
Total	435	100.0%	553	100.0%	393	100.0%	483	100.0%

Note: accidents from 1988-1991

It was concluded from the preceding tables that **the majority of guardrail end accidents were property-damage-only accidents. For all guardrail end types, about 1/6 of the accidents had fatal or incapacitating injuries.**

4.11.02 GUARDRAIL END ACCIDENTS IN RELATION TO ALL ACCIDENTS

ODOT furnished information presented in Table 4.13. This shows the number and severity of all the accidents on the state highway system from 1988 through 1991.

TABLE 4.13 Accidents on state system by severity, 1988 through 1991

		---- Guardrail end accidents ----				
Severity	Total # of ALL accidents 1988-1991	presumed approach end/same side and trailing/ crossover/ undivided % of ALL	presumed guardrail end hits % of ALL	presumed-plus-questionable end hits % of ALL	fixed object-culvert acc. % of ALL	fixed object-utility pole acc. % of ALL
Fatal	1,315	1.05%	1.14%	1.45%	2.05%	1.22%
Injury A	8,270	0.65%	0.69%	0.80%	1.81%	1.05%
Injury B	9,048	0.74%	0.82%	1.07%	2.01%	1.24%
Injury C	17,773	0.29%	0.32%	0.39%	0.74%	0.77%
PDO	63,757	0.32%	0.37%	0.47%	0.51%	0.84%
Total	100,163	0.39%	0.43%	0.55%	0.82%	0.89%

Viewing Table 4.13, one can see that **guardrail end accidents constitute only a small fraction of the total accidents in any of the accident severity categories.** The table also allows the reader to compare the relative magnitudes of guardrail end accidents with two other types on the state highway system, culvert accidents and utility pole accidents.

<u>4.12 VEHICLE SUBSEQUENTLY STRIKING FIXED OBJECT</u>

One issue pertaining to the efficacy of various guardrail end types is whether the end allows a vehicle, after striking the end, to continue on and strike a fixed object the guardrail was supposed to be shielding. The researchers had recorded any information contained in the accident report about subsequent impacts with fixed objects; it is possible that some police reports may have omitted such details, or that the researchers incorrectly interpreted an accident report. The investigators manipulated field 86 of the presumed end hit file to find the following information.

4.16 Analysis & Results

Vehicle did not strike fixed object	(code 1)	300	69.0%
Vehicle did strike fixed object	(code 2)	77	17.7%
Vehicle went down embankment	(code 3)	58	13.3%

Then the researchers searched fields 86, 83, 16, and 89 to obtain the data by end type (exposed or turned-down) and by severity; Table 4.14 presents this.

Table 4.14 Subsequently striking fixed object

PRESUMED END HITS	EXPOSED END					TURNED-DOWN END				
	Fat	Inj A	F+A	All	F+A/ All	Fat	Inj A	F+A	All	F+A/ All
Vehicle did not strike fixed object	3	8	11	111	0.099	2	14	16	163	0.098
Vehicle did strike fixed object	2	3	5	22	0.227	3	17	20	52	0.385
Vehicle went down embankment				24					34	
Total				157					249	

With exposed ends, 14.0% (22/157) of accidents resulted in the vehicle striking a fixed object after hitting the guardrail end, while with turned-down ends the figure was 20.9%. **It appeared that there was more subsequent striking of fixed objects with turned-down ends, and perhaps a higher severity when such an event did happen.**

4.13 WEIGHT OF VEHICLES INVOLVED IN GUARDRAIL END ACCIDENTS

Vehicle weight was thought to be related to rolling and/or vaulting. The newer, lighter-weight automobiles were supposedly more prone to rolling and/or vaulting after striking turned-down guardrail ends.

The ask and query operations were done on field 79, field 83, and the "Weight" field to get number of accidents in each weight category. The weights of the vehicles involved in the guardrail end accidents were combined into 500-pound (lb) increment categories. Vehicles pulling trailers, large trucks, and a few vehicles whose weights could not be found in the available reference books were categorized as "other" weights.

Table 4.15 shows the number of guardrail end accidents by the different vehicle weight categories. The four data groups all exhibited similar proportions of vehicles in each of the weight categories.

TABLE 4.15 Weights of vehicles involved in guardrail end accidents

Weight group (lbs)	END HITS Presumed #	END HITS Presumed %	END HITS Presumed -plus- Questionable #	END HITS Presumed -plus- Questionable %	APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED Presumed #	APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED Presumed %	APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED Presumed -plus- Questionable #	APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED Presumed -plus- Questionable %
1750	19	4.37	20	3.62	14	3.56	15	3.11
2250	38	8.74	56	10.13	36	9.16	52	10.77
2750	79	18.16	92	16.64	70	17.81	80	16.56
3250	83	19.08	102	18.44	78	19.85	91	18.84
3750	85	19.54	108	19.53	80	20.35	92	19.05
4250	27	6.21	39	7.05	25	6.36	35	7.25
4750	10	2.30	12	2.17	8	2.04	10	2.07
OTHERS	94	21.60	124	22.44	82	20.87	108	22.35
TOTAL	435	100.0%	553	100.0%	393	100.0%	483	100.0%

4.14 DRIVER INATTENTION AND GUARDRAIL END ACCIDENTS

The Official Police Traffic Collision Reports contain information from which the reader can deduce whether the driver was distracted from the driving task, sleepy, or otherwise inattentive. The researchers performed the ask and query operations on field 79, field 80, field 88, and the "dri" field to determine the relation between driver inattention ("unalert") and lateral location of guardrail end accidents. Both the presumed and the presumed-plus-questionable end hit accident data sets were analyzed. Table 4.16 presents these results for end hits.

Table 4.16 indicated, based on information recorded by the police officer who investigated the accident, that **roughly 1/5 of all guardrail end accidents involved an inattentive driver striking the right-side guardrail end.** On divided roads, the chances of an unalert driver hitting the guardrail on the right side were slightly more than the chances of hitting a guardrail in the near-side or center of the median. On undivided roads, the chances of hitting the guardrail on the right side were almost double that of hitting guardrail on the left side. The actual portion of inattentive drivers involved in guardrail end accidents may have been greater; this categorization was made only if the reporting police officer mentioned a form of inattention in the report.

TABLE 4.16 Driver inattention and lateral location of guardrail end hit

END HITS	Lateral location codes	Presumed #	Presumed %	Presumed-plus-Questionable #	Presumed-plus-Questionable %
ROADWAY WITH MEDIAN					
Left side	7	1	0.40	1	0.31
Median - left side	6	2	0.81	2	0.61
Median - right, center	4+5	35	14.17	42	12.84
Right side	3	43	17.41	53	16.21
Other		1	0.41	2	0.61
No mention		165	66.80	227	69.42
Total		247	100.0%	327	100.0%
ROADWAY WITHOUT MEDIAN					
Left side	7	19	10.27	23	10.31
Right side	3	42	22.70	52	23.32
Other		1	0.54	1	0.45
No mention		123	66.49	147	65.92
Total		185	100.0%	223	100.0%

Not able to determine or Not sure if median existed = 3.00

4.15 RURAL VS. URBAN LOCATION OF GUARDRAIL END ACCIDENTS

The researchers performed analyses to determine what portion of accidents occurred on rural and on urban state highways. The ODOT accident file contained a code which assigned a rural or an urban location to each accident.

These calculations were done for the presumed end hit and the presumed-plus-questionable end hit data sets to determine the location of the guardrail end accidents. Only exposed and turned-down ends were considered. The ask and query operations were done on field 71, field 79 and field 83 of the database file. The results are shown in Table 4.17.

TABLE 4.17 Rural/urban location for exposed and turned-down guardrail end accidents.

	Exposed #	Exposed %	Turned-down #	Turned-down %	Total #	Total %
PRESUMED END HITS						
Urban	38	29.92	89	70.08	127	100.0
Rural	119	42.65	160	57.35	279	100.0
PRESUMED-PLUS-QUESTIONABLE END HITS						
Urban	44	27.33	117	72.67	161	100.0
Rural	146	41.13	209	58.87	355	100.0

It can be concluded from Table 4.17, that most of the exposed and turned-down guardrail end accidents on state highways occurred in rural areas. There were few exposed end accidents in urban areas. There may be relatively few exposed ends on urban state highways.

The Federal Highway Administration publishes summary highway statistics. Referring to *Highway Statistics 1990 (19)*, page 125 lists the number of Oklahoma state system rural miles as 12,009, and urban as 991; the tables beginning on page 147 give a rural mileage of 12,028. Using a total of 13,019 miles, the **urban miles constitute 7.6% of the mileage, but over 30% of the end accidents occurred at settings classified as urban.**

4.16 ACCIDENT FREQUENCY AND POSTED SPEED LIMITS

The researchers investigated relationships between the frequency of guardrail end strikes on the state highway system and the posted speed limit. The ODOT accident file already contained the posted speed at the accident site, as recorded by the police officer.

The researchers performed the analysis on both the presumed and the presumed-plus-questionable data sets. The ask and query operations were done on field 65 and field 79 of the database file to obtain the number of guardrail end accidents occurring for various posted speed limits. It must be noted that the posted speed may not the speed at which the vehicle was travelling. The results are shown in Table 4.18.

TABLE 4.18 Number of guardrail end accidents in relation to posted speed

Posted Speed (mph)	≤45	50	55	≥60	Total
PRESUMED END HITS					
Number	19	10	306	100	435
Percent	4.37	2.30	70.34	22.99	100.0
PRESUMED-PLUS-QUESTIONABLE END HITS					
Number	28	14	379	132	553
Percent	5.06	2.53	68.54	23.87	100.0

Table 4.18 indicates that **most of the guardrail end accidents in the study occurred on roads with posted speeds of 55 mph or greater.** The percentages of accidents occurring on roads with given speed limits was about the same for the presumed end hit data set as it was for the presumed-plus-questionable end hit data set.

4.17 ACCIDENT FREQUENCY, MILES OF HIGHWAY, AND TRAVEL

The researchers performed analyses to determine if the frequency of guardrail end strikes was a function of the miles of highway in a volume range or the amount of travel on the roadway. ODOT provided a file containing the number of miles of state highways for each one thousand vehicles per day (ADT) volume increment. Volume data for 1989 were used as representative of the period 1988 through 1991. The analyses were done only for the presumed data set. Table 4.19 displays the results.

The vehicle miles of travel (VMT) is the product of the miles of highway and the volume on those miles of highway. The process of estimating VMT began with letting the midpoint of the volume range be the assumed volume of all roads within that range. For instance, for the 1000 to 1999 volume range, 1500 was assumed to be the volume. Then, for each ADT volume increment, the midpoint of the volume range was multiplied by the miles of road in that volume range to arrive at the VMT. For instance, for the volume range 1000 to 1999, the VMT was calculated as:

1500 vehicles per day * 3117.37 miles of highway = 4,676,055 VMT

The percent VMT for each of the ADT volume groups was also determined.

TABLE 4.19 Number of guardrail end accidents in relation to miles and VMT

PRESUMED END HITS

Volume Range	Assumed volume mid-point	Presumed Accidents		Miles of rd on system		VMT
		#	%	#	%	%
<1000	500	18	4.14	3595.41	29.40	3.54
1000-1999	1500	43	9.89	3117.37	25.49	9.20
2000-2999	2500	45	10.34	1742.41	14.25	8.57
3000-3999	3500	24	5.52	946.17	7.74	6.52
4000-4999	4500	16	3.68	513.61	4.20	4.55
5000-6999	6000	31	7.13	655.25	5.36	7.74
7000-9999	8500	27	6.21	514.78	4.21	8.61
10000-14999	12500	67	15.40	575.87	4.71	14.17
15000-24999	20000	44	10.11	307.94	2.52	12.12
25000-34999	30000	22	5.06	90.37	0.74	5.34
35000-44999	40000	7	1.61	32.57	0.27	2.56
45000-54999	50000	21	4.83	51.33	0.42	5.05
55000-64999	60000	15	3.45	21.54	0.18	2.54
65000-74999	70000	22	5.06	39.75	0.33	5.48
75000-84999	80000	7	1.61	8.56	0.07	1.35
85000-94999	90000	24	5.52	11.11	0.09	1.97
95000-100000	97500	2	0.46	3.69	0.03	0.71
Total		435	100.0%	12227.73	100.0%	100.0%

It can be concluded from Table 4.19 that **around 47% of the guardrail end accidents occurred on 11,085 miles of roads having volumes less than 10,000 ADT. These lower-volume roads constituted over 90% of the miles on the state highway system. Around 53% of guardrail end accidents were concentrated on about 10% of the system miles having the higher ADT's.**

The researchers performed regression analyses to examine the following relationships:

1. the percent of accidents in volume group versus percent miles of highway in volume group; and
2. the percent of accidents in volume group versus percent VMT in the volume group.

The regression terms were explained in Chapter 3.

Figure 4.1 shows plots of the three relationships. There was a **close relation between the proportion of accidents and the proportion of VMT in a volume group**; the R^2 value for the model was 0.86. There was little significance in relationship between the number of accidents and the miles of highway in a volume group.

	x: %VMT y: %Acc	x: %miles y: %Acc
Constant	0.432	5.137
X Coefficient	0.926	0.127
R Squared	0.864	0.089

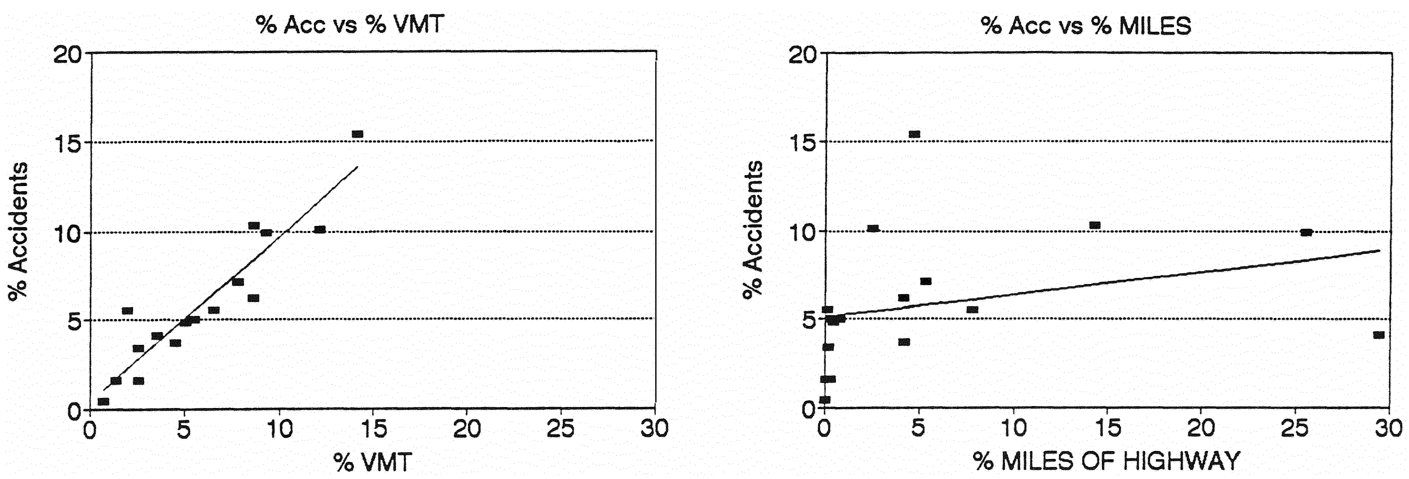


FIGURE 4.1 Guardrail end accidents as a function of miles and VMT

4.18 COMBINED FACTOR RELATIONSHIPS

In addition to investigating the individual attributes of the guardrail end accident problem on state highways in Oklahoma, the researchers studied the impacts of combinations of factors. The contingency tables show the number (#) of accidents having various combinations of attributes. The observed values in the contingency tables were found by performing ask and query operations on fields in the database file. The theoretical or expected values were calculated per the methodology described in Chapter 3.

Because examinations showed similar proportions among the presumed end hit data, the presumed-plus-questionable end hit data, the presumed approach end/same side and trailing end/cross over/undivided data, and the presumed-plus-questionable approach end/same side and trailing end/cross over/undivided data, many of the test were performed on only one or two of the data sets. Subsequent statistical tests were performed on some values in the tables.

4.18.01 END TYPE VS. ROLL AND/OR VAULT

One central question was whether guardrail end accidents with vehicle rolling and/or vaulting were more common at one end type than at another. For accidents at exposed, turned-down, and other end types, the researchers found the observed and expected cell counts. Table 4.20-a presents the presumed end hit and the presumed-plus-questionable end hit data sets.

TABLE 4.20-a End type vs roll/vault

END HITS

END TYPE	Roll/vault		Unsure		No Roll/Vault		TOTAL
	obser	*expec*	obser	*expec*	obser	*expec*	
PRESUMED							
Exposed	24	*37.90*	17	*20.57*	116	*98.53*	157
Turned-down	78	*60.10*	38	*32.63*	133	*156.27*	249
Other types	3	*7.00*	2	*3.80*	24	*18.20*	29
Total	105	*105*	57	*57*	273	*273*	435
PRESUMED-PLUS-QUESTIONABLE							
Exposed	32	*42.95*	18	*25.42*	140	*121.63*	190
Turned-down	90	*73.69*	54	*43.62*	182	*208.69*	326
Other types	3	*8.36*	2	*4.95*	32	*23.69*	37
Total	125	*125*	74	*74*	354	*354*	553

The Chi-square test of independence was done for the presumed end hit values. The calculated test statistic was $X^2 = 23.48$. With df = (r-1)(c-1) =

4, (where r = 3, c = 3), and $\alpha = 0.05$, the critical X^2 was 9.49. Because the test statistic X^2 was greater than the critical X^2, it was concluded that the classifications were not independent. A relationship existed between the type of end and rolling and/or vaulting.

The Chi-square independence test was also done for the presumed-plus-questionable end hit values. The calculated test statistic was $X^2 = 25.34$. With df = (r-1)(c-1) = 4, (where r = 3, c = 3), and $\alpha = 0.05$, the critical X^2 was 9.49. Because the test statistic X^2 was greater than the critical X^2, it was concluded that the classifications were not independent. A relationship existed between the type of end and rolling and/or vaulting.

The tests were also performed on the "approach end/same side and trailing end/cross over/undivided roadway" sets; Table 4.20-b shows these values. The df, α, and critical X^2 were the same. For the presumed values, the calculated test statistic was $X^2 = 22.15$. For the presumed-plus-questionable values, the calculated test statistic was $X^2 = 22.80$. In both cases, the test statistic X^2 was greater than the critical X^2. Again, it was concluded that the classifications were not independent.

TABLE 4.20-b End type vs roll/vault

APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED

END TYPE	Roll/vault		Unsure		No Roll/Vault		TOTAL
	obser	*expec*	obser	*expec*	obser	*expec*	
PRESUMED							
Exposed	22	*34.93*	17	*20.74*	104	*87.33*	143
Turned-down	71	*54.72*	38	*32.49*	115	*136.79*	224
Other types	3	*6.35*	2	*3.77*	21	*15.88*	26
Total	96	*96*	57	*57*	240	*240*	393
PRESUMED-PLUS-QUESTIONABLE							
Exposed	28	*38.03*	18	*24.79*	118	*101.18*	164
Turned-down	81	*66.55*	53	*43.38*	153	*177.07*	287
Other types	3	*7.42*	2	*4.84*	27	*19.74*	32
Total	112	*112*	73	*73*	298	*298*	483

In each of the four Chi-square tests, it was concluded that the factors of end type and rolling and/or vaulting were not independent of each other. To more closely examine the relationships between end type and vehicle rolling and/or vaulting, the binomial proportions test by pairwise comparison was performed on the presumed accident set. These tests compared the proportions of rolling/vaulting at exposed ends with the proportions at turned-down ends, and the proportions of no-rolling/no-vaulting at exposed ends with the proportions at turned-down ends. Table 4.21 presents values used in the tests.

TABLE 4.21 End type vs roll/vault proportions

PRESUMED END HITS

END TYPE	ROLL AND/OR VAULT			NO ROLL/VAULT			TOTAL
	Observ	*Expect*	Propor	Observ	*Expect*	Propor	
Exposed	24	*37.90*	0.1529	116	*98.53*	0.7389	157
Turned-down	78	*60.10*	0.3133	133	*156.27*	0.5341	249
Other types	3	*7.00*		24	*18.20*		29
Total	105	*105*		273	*273*		435

TEST 1. Proportion of exposed end accidents having roll and/or vault compared with proportion of turned-down end accidents having roll and/or vault.

H_0: $P_{exp} = P_{t\text{-}d}$ (p1) H_{alt}: $P_{exp} \neq P_{t\text{-}d}$ (p2)
$P_{exp} = 24/157 = 0.1529$ $P_{t\text{-}d} = 78/249 = 0.3133$
$P = (24+78) / (157+249) = 0.2512$ $q = 1 - P = 0.7488$
$\alpha = 0.05$ critical $z_{\alpha/2} = 1.96$ test statistic $z = 3.629$

As the calculated z exceeded the critical $z_{\alpha/2}$, H_0 was rejected . The proportion of roll/vaults associated with turned-down ends (0.31) was statistically different from the proportion of roll/vaults associated with exposed ends (0.15). The inference from this was that the proportion of accidents with rolling and/or vaulting at turned-down ends was greater than the proportion at exposed ends.

TEST 2. Proportion of exposed end accidents having no roll/vault compared with proportion of turned-down end accidents having no roll/vault.

H_0: $P_{exp} = P_{t\text{-}d}$ (p3) H_{alt}: $P_{exp} \neq P_{t\text{-}d}$ (p4)
$P_{exp} = 116/157 = 0.7389$ $P_{t\text{-}d} = 133/249 = 0.5341$
$P = (116+133) / (157+249) = 0.6133$ $q = 1 - P = 0.3867$
$\alpha = 0.05$ critical $z_{\alpha/2} = 1.96$ test statistic $z = 4.125$

H_0 was rejected, as the calculated z exceeded the critical $z_{\alpha/2}$. The proportion of no roll/vaults associated with turned-down ends (0.738) statistically different from the proportion of no roll/vaults associated with exposed ends (0.534).

Both tests indicated that there were significant differences between the proportions of accidents involving rolling and/or vaulting at exposed and at turned-down ends. The inference from this was that **the proportion of accidents with rolling and/or vaulting at turned-down ends was greater than the proportion at exposed ends.**

4.18.02 END TYPE VS. LATERAL LOCATION VS. SEVERITY

In order to investigate the relationship of end type, guardrail end lateral location, and resulting accident severity, the researchers analyzed data for roadways with and without medians. The contingency tables were obtained by performing ask and query operations on field 16, field 79, field 80, field 83, field 88, and field 89 of the database.

Chapter 3 describes how the expected cell counts were calculated for the exposed and turned-down terminals. The observed and expected cell counts for those accidents on roads with a median are shown in Table 4.22, and the observed and expected cell counts for roads without a median are shown in Table 4.23.

TABLE 4.22 End type vs. lateral location vs. severity - median present

PRESUMED END HITS

	Left side		Median		Right side		Total	
	Obs	*Exp*	Obs	*Exp*	Obs	*Exp*	Obs	*Exp*
EXPOSED ENDS								
Fatal + Injury A	0	*0.06*	2	*3.45*	3	*3.49*	5	*7.00*
Injury B + Injury C	1	*0.12*	5	*6.41*	8	*6.47*	14	*13.00*
PDO	0	*0.22*	7	*12.34*	19	*12.44*	26	*25.00*
Total	1	*0.40*	14	*22.20*	30	*22.40*	45	*45.00*
TURNED-DOWN ENDS								
Fatal + Injury A	0	*0.25*	18	*13.81*	12	*13.94*	30	*28.00*
Injury B + Injury C	1	*0.46*	24	*25.66*	26	*25.88*	51	*52.00*
PDO	0	*0.89*	55	*49.33*	44	*49.78*	99	*100.00*
Total	1	*1.60*	97	*89.80*	82	*89.60*	180	*180.00*

4.26 Analysis & Results

The Chi-square test of independence with df= abc-a-b-c+2=12 (where a=2, b=3, and c=3) and α = 0.05 was performed on the "median present" values. The test statistic X^2 was 19.16 and critical X^2 was 21.03. From this it was concluded that the variables were independent; i.e., **on roads with a median, there was not a relationship between the type of end, severity, and lateral location.** Inspection of the data showed that there were relatively few exposed end hits on roads with medians, and a disproportionately high number of exposed end hits on the right side. A comparison of observed and expected row subtotals for both the exposed and for the turned-down ends suggests that the accident severity experience was as expected for either end type.

TABLE 4.23 End type vs. lateral location vs. severity - median absent

PRESUMED END HITS

	Left side		Right side		Total	
	Obs	*Exp*	Obs	*Exp*	Obs	*Exp*
EXPOSED						
Fatal + Injury A	9	*7.72*	10	*13.42*	19	*21.14*
Injury B + Injury C	15	*12.17*	20	*21.15*	35	*33.32*
PDO	13	*19.19*	40	*33.35*	53	*52.54*
Total	37	*39.08*	70	*67.92*	107	*107.00*
TURNED-DOWN						
Fatal + Injury A	3	*4.33*	11	*7.53*	14	*11.86*
Injury B + Injury C	7	*6.82*	10	*11.86*	17	*18.68*
PDO	14	*10.76*	15	*18.70*	29	*29.46*
Total	24	*21.92*	36	*38.08*	60	*60.00*

The Chi-square test of independence with df= abc-a-b-c+2=7 (where a=2, b=2, and c=2) and α = 0.05 was done for "median absent" values. The test statistic X^2 was 8.80 and X^2 critical was 14.07. It was concluded that the classifications were independent; i.e., **on roads without a median, there was no relationship between the type of end, severity, and lateral location.**

4.18.03 **END TYPE VS. ROLL/VAULT VS. SEVERITY**

The researchers continued the investigations of various factors acting together with a study of the relationship of end type, occurrence of rolling and/or vaulting, and resulting accident severity. The contingency tables were obtained by performing ask and query operations on field 16, field 79, field 83, field 85 and field 89.

The expected cell counts were calculated for the exposed and turned-down terminals as described in Chapter 3. Table 4.24 presents the observed and expected cell counts.

TABLE 4.24 End type vs. roll/vault vs. severity

PRESUMED	END HITS								APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED							
	No Roll/ Vault		Roll/ Vault		Not sure		Total		No Roll/ Vault		Roll/ Vault		Not sure		Total	
	Obs	*Exp*	Obs	*Exp*	Obs	*Exp*	Obs	*Exp*	Obs	*Exp*	Obs	*Exp*	Obs	*Exp*	Obs	*Exp*
EXPOSED																
Fat + Inj A	12	*16.6*	9	*6.8*	3	*3.7*	24	*27.1*	11	*14.9*	8	*6.3*	1	*3.7*	20	*24.9*
Inj B+ Inj C	41	*28.9*	7	*11.9*	4	*6.4*	52	*47.2*	37	*26.5*	7	*11.3*	6	*6.7*	50	*44.4*
PDO	63	*50.8*	8	*20.8*	10	*11.2*	81	*82.8*	56	*43.9*	7	*18.7*	10	*11.0*	73	*73.6*
Total	116	*96.3*	24	*39.4*	17	*21.3*	157	*157*	104	*85.3*	22	*36.2*	17	*21.4*	143	*143*
TURNED-DOWN																
Fat + Inj A	21	*26.3*	18	*10.8*	7	*5.8*	46	*42.9*	20	*23.3*	17	*9.9*	7	*5.9*	44	*39.1*
Inj B+ Inj C	31	*45.9*	31	*18.8*	8	*10.1*	70	*74.8*	27	*41.5*	29	*17.6*	8	*10.4*	64	*69.6*
PDO	81	*80.5*	29	*33.0*	23	*17.8*	133	*131.3*	68	*68.8*	25	*29.2*	23	*17.3*	116	*115.4*
Total	133	*152.7*	78	*62.6*	38	*33.7*	249	*249*	115	*133.7*	71	*56.8*	38	*33.7*	224	*224*

The Chi-square test of independence with df= abc-a-b-c+2=12 (where a=2, b=3, and c=3) and an α of 0.05 was performed on the presumed end hit values. The test statistic X^2 was 42.34 and X^2 critical was 21.03. It was concluded that the classifications were not independent; i.e., **some kind of relationship between the end type, roll/vault, and severity existed.**

The Games-Howell (GH) procedure for comparing two means was done as described in Chapter 3. The following weights were assigned to the severity classes.

Type of Severity	Weight
Fatal + Injury A	5
Injury B + Injury C	3
PDO	1

Thus, each accident which had severity classification of fatal or injury A received a score of 5 for severity, etc. Using severity as the dependent variable, the mean value for each combination of the factors (end type and roll/vault) was then calculated. The standard deviation was also calculated. The results are shown in Table 4.25.

TABLE 4.25 Mean severity of end type and roll/vault

		END HITS		APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED	
	Group	Mean	Standard deviation	Mean	Standard deviation
EXPOSED (EX)					
No Roll/Vault	EX-N	2.12	1.35	2.13	1.36
Roll/Vault	EX-RV	3.08	1.72	3.09	1.69
Not sure	EX-NS	2.18	1.59	1.94	1.25
TURNED-DOWN (TD)					
No Roll/Vault	TD-N	2.10	1.51	2.17	1.54
Roll/Vault	TD-RV	2.72	1.54	2.77	1.53
Not sure	TD-NS	2.16	1.59	2.16	1.59

Note- N:No roll/vault RV:roll/vault NS:not sure

The pairwise comparisons were then made; they are shown in Appendix D. The t-statistic and degrees-of-freedom for the comparisons were then calculated using the GH procedure. The four comparisons shown in Table 4.26 were found to be statistically significant.

TABLE 4.26 Pairwise comparison of severity means

	END HITS			APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED		
For Groups	t-statistic	df	p	t-statistic	df	p
TD-N vs. TD-RV	-2.8504	158.8743	0.0049	-2.6271	149.2597	0.0095
EX-N vs. EX-RV	-2.5853	29.1839	0.0150	-2.4923	27.0481	0.0191
TD-N vs. EX-RV	-2.6345	29.7348	0.0132	-2.3884	28.1324	0.0239
EX-N vs. TD-RV	-2.7837	150.7217	0.0061	-2.8390	138.2259	0.0052

The p values were less than the α value of 0.05. It was concluded that the severity associated with roll and/or vault accidents for both exposed and

turned-down ends was significantly higher than the severity associated with no roll/vault accidents.

The statistical test for comparing proportions was done for presumed end hits to determine if any significant differences existed in the proportions of roll/vault and the severity associated with it, for the exposed and turned-down ends. This test was explained in Chapter 3. Three comparisons were made. The raw values were obtained from Table 4.24.

TEST 1. Compare the proportion of exposed end Fatal+Injury A accidents having roll/vault with the proportion of turned-down end Fatal+Injury A accidents having roll/vault.

$H_0: p_{exp} = p_{td}$ $\qquad$ $H_{alt}: p_{exp} \neq p_{td}$

$p_{exp} = 9/24 = 0.375$ $\qquad$ $p_{td} = 18/46 = 0.391$

$p = 0.386$ $\qquad$ $q = 0.614$

$\alpha = 0.05$ $\qquad$ critical $z_{\alpha/2} = 1.96$ $\qquad$ test statistic $z = 0.131$

H_0 was not rejected as the observed z did not exceed the critical $z_{\alpha/2}$. From the comparisons of exposed with turned-down ends, **it was concluded that there was no significant difference in the proportions of Fatal+Injury A accidents which had rolling and/or vaulting.** It should be pointed out that the sample size for exposed ends resulted in relatively low power for this test.

TEST 2. Compare the proportion of exposed end roll/vault having Fatal+Injury A to the proportion of turned-down end roll/vault accidents having Fatal+Injury A.

$H_0: p_{exp} = p_{td}$ $\qquad$ $H_{alt}: p_{exp} \neq p_{td}$

$p_{exp} = 9/24 = 0.375$ $\qquad$ $p_{td} = 18/78 = 0.231$

$p = 0.265$ $\qquad$ $q = 0.735$

$\alpha = 0.05$ $\qquad$ critical $z_{\alpha/2} = 1.96$ $\qquad$ test statistic $z = 1.399$

H_0 was not rejected as the observed z did not exceed the critical $z_{\alpha/2}$. Given that a roll/vault accident had occurred, the proportion of the accidents that were Fatal+Injury A was higher for exposed ends ($p_{exp} = 0.375$) than for turned-down ends ($p_{td} = 0.231$), but the difference was not statistically significantly. Again, it should be pointed out that the sample size for exposed ends results in relatively low power for this test; a larger sample size could have produced a finding of statistical significance.

TEST 3. Compare the proportion of exposed end Fatal+Injury A accidents out of total exposed end accidents to the proportion of turned-down end

Fatal+Injury A accidents out of total turned-down end accidents.

H_0: $p_{exp} = p_{td}$ H_{alt}: $p_{exp} \neq p_{td}$
$p_{exp} = 24/157 = 0.153$ $p_{td} = 46/249 = 0.185$
$p = 0.186$ $q = 0.814$
$\alpha = 0.05$ critical $z_{\alpha/2} = 1.96$ test statistic $z = 0.81$

H_0 was not rejected as the observed z did not exceed the critical $z_{\alpha/2}$. **The proportion of Fatal+Injury A associated with turned-down ends was not significantly different than the proportion of Fatal+Injury A associated with exposed ends.**

The preceding three tests showed no significant differences between accident severity proportions at exposed ends and at turned-down ends. A higher proportion of exposed end roll/vault accidents resulted in serious injury, but the difference was not statistically significant.

4.18.04 **VEHICLE WEIGHT VS. ROLL/VAULT**

The researchers investigated the frequency of rolling and/or vaulting as a function of vehicle weight. Needed information was gleaned by performing ask and query operations on fields 16, 79, 83, 85, and "Weight". The expected cell counts were calculated for the exposed and the turned-down terminals as described in Chapter 3. The observed and expected cell counts for the presumed data set are shown in Table 4.27.

TABLE 4.27 Vehicle weight vs. roll/vault

PRESUMED END HITS

WEIGHT CLASS (lbs)	ROLL/VAULT Obser	ROLL/VAULT *Expec*	UNSURE Obser	UNSURE *Expec*	NO ROLL/VAULT Obser	NO ROLL/VAULT *Expec*	TOTAL
1750 - 2250	27	*13.8*	4	*7.5*	26	*35.8*	57
2750	23	*19.1*	6	*10.4*	50	*49.6*	79
3250	12	*20.0*	12	*10.9*	59	*52.1*	83
3750	12	*20.5*	16	*11.1*	57	*53.3*	85
4250 - 4750	5	*8.9*	8	*4.8*	24	*23.2*	37
OTHER	26	*22.7*	11	*12.3*	57	*59.0*	94
TOTAL	105	*105*	57	*57*	273	*273*	435

The calculated statistic from the Chi-square independence test was $X^2 = 34.33$. From the statistical tables, for an $\alpha = 0.05$, and df= $(r-1)*(c-1) = 10$ (where r=6 and c=3), the critical value X^2 was 18.31. Because the test statistic X^2 was found to be greater than the critical X^2, it was concluded that the classifications were not independent. **Some type of statistical relationship existed between the vehicle weight and rolling and/or vaulting.**

4.18.05 END TYPE VS. VEHICLE WEIGHT VS. ROLL/VAULT

The researchers evaluated the frequency of rolling and/or vaulting as a function of vehicle weight concurrently with the end type, by sorting on field 76, field 79, field 83, field 85, and "Weight". The expected cell counts were calculated for the exposed, turned-down, and other end types as described in Chapter 3. Table 4.28 presents the observed and expected cell counts.

TABLE 4.28 End type vs. vehicle weight vs. roll/vault

PRESUMED	END HITS							APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED						
WEIGHT CLASS (lbs)	ROLL/ VAULT		UNSURE		NO ROLL/ VAULT		TOTAL	ROLL/ VAULT		UNSURE		NO ROLL/ VAULT		TOTAL
	Obs	*Exp*	Obs	*Exp*	Obs	*Exp*	Obs	Obs	*Exp*	Obs	*Exp*	Obs	*Exp*	Obs
EXPOSED ENDS														
1750-2250	7	*5.0*	1	*2.7*	15	*12.9*	23	7	*4.4*	1	*2.5*	11	*11.0*	19
2750	5	*6.9*	2	*3.7*	20	*17.9*	27	5	*5.7*	0	*3.2*	18	*14.3*	23
3250	1	*7.2*	3	*3.9*	29	*18.8*	33	1	*7.1*	3	*4.0*	27	*17.7*	31
3750	4	*7.4*	5	*4.0*	24	*19.2*	33	3	*7.2*	5	*4.1*	22	*17.9*	30
4250-4750	2	*3.2*	3	*1.7*	7	*8.3*	12	2	*2.8*	3	*1.6*	7	*7.1*	12
Other	5	*8.2*	3	*4.4*	21	*21.2*	29	4	*7.3*	3	*4.1*	19	*18.1*	26
Total	24	*37.9*	17	*20.6*	116	*98.5*	157	22	*34.8*	15	*19.8*	104	*86.4*	141
TURNED-DOWN ENDS														
1750-2250	20	*7.9*	3	*4.3*	7	*20.5*	30	18	*7.0*	3	*4.0*	6	*17.4*	27
2750	17	*10.9*	3	*5.9*	25	*28.4*	45	15	*9.1*	3	*5.2*	20	*22.8*	38
3250	10	*11.5*	9	*6.2*	24	*29.8*	43	10	*11.3*	9	*6.4*	22	*28.1*	41
3750	8	*11.7*	11	*6.4*	29	*30.5*	48	7	*11.4*	11	*6.5*	28	*28.5*	46
4250-4750	3	*5.1*	4	*2.8*	17	*13.3*	24	3	*4.5*	4	*2.6*	13	*11.4*	20
Other	20	*13.0*	8	*7.0*	31	*33.8*	59	18	*11.6*	8	*6.6*	26	*28.8*	52
Total	78	*60.1*	38	*32.6*	133	*156.3*	249	71	*55.3*	38	*31.4*	115	*137.3*	224
OTHER ENDS														
1750-2250	0	*0.9*	0	*0.5*	4	*2.4*	4	0	*0.6*	0	*0.3*	3	*1.5*	3
2750	1	*1.3*	1	*0.7*	5	*5.3*	7	1	*0.8*	1	*0.4*	1	*2.0*	3
3250	1	*1.3*	0	*0.7*	6	*5.5*	7	1	*1.0*	0	*0.5*	6	*2.5*	7
3750	0	*1.4*	0	*0.7*	4	*5.7*	4	0	*1.0*	0	*0.5*	4	*2.5*	4
4250-4750	0	*0.6*	1	*0.3*	0	*2.5*	1	0	*0.4*	0	*0.2*	0	*1.0*	0
Other	1	*1.5*	0	*0.8*	5	*6.3*	6	0	*1.0*	0	*0.5*	3	*2.5*	3
Total	3	*7.0*	2	*3.8*	24	*18.2*	29	2	*4.9*	1	*2.8*	17	*12.3*	20

There were relatively few accidents at the "other" end types. There were fewer than expected rolls and/or vaults "other" end types.

4.32 Analysis & Results

For analysis, "other" end types, "other" vehicle weights, and "unsure" roll/vault categories were removed from the data. This allowed the Chi-square test to focus on those accidents involving turned-down and exposed ends, vehicles weighing between 1500 and 5000 pounds, and those accidents where the accident report gave a clearer indication whether rolling and/or vaulting resulted from the end hit. The expected cell counts were calculated for the exposed and turned-down terminals as described in Chapter 3. Table 4.29 shows the observed and expected cell counts for presumed accidents.

TABLE 4.29 Modified end type vs. vehicle weight vs. roll/vault

WEIGHT CLASS (lbs)	ROLL/VAULT Observ	ROLL/VAULT *Expect*	ROLL/VAULT Propor	NO ROLL/VAULT Observ	NO ROLL/VAULT *Expect*	NO ROLL/VAULT Propor	TOTAL
PRESUMED -- END HITS							
EXPOSED							
1750 & 2250	7	*5.73*	0.318	15	*14.66*	0.682	22
2750	5	*7.83*	0.200	20	*20.04*	0.800	25
3250	1	*7.48*	0.033	29	*19.14*	0.967	30
3750	4	*7.60*	0.143	24	*19.44*	0.857	28
4250 & 4750	2	*3.39*	0.222	7	*8.67*	0.778	9
Total	19	*32.04*		95	*81.96*		114
TURNED-DOWN							
1750 & 2250	20	*8.04*	0.741	7	*20.57*	0.259	27
2750	17	*10.99*	0.405	25	*28.13*	0.595	42
3250	10	*10.50*	0.294	24	*26.87*	0.706	34
3750	8	*10.67*	0.216	29	*27.29*	0.784	37
4250 & 4750	3	*4.76*	0.150	17	*12.18*	0.850	20
Total	58	*44.96*		102	*115.04*		160
PRESUMED -- APPROACH END/SAME SIDE and TRAILING END/CROSS OVER/UNDIVIDED							
EXPOSED							
1750 & 2250	7	*5.12*	0.389	11	*12.54*	0.611	18
2750	5	*7.07*	0.217	18	*17.32*	0.783	23
3250	1	*7.31*	0.036	27	*17.91*	0.964	28
3750	3	*7.31*	0.120	22	*17.91*	0.880	25
4250 & 4750	2	*3.05*	0.222	7	*7.46*	0.778	9
Total	18	*29.85*		85	*73.15*		103
TURNED-DOWN							
1750 & 2250	18	*7.05*	0.750	6	*17.29*	0.250	24
2750	15	*9.74*	0.429	20	*23.87*	0.571	35
3250	10	*10.08*	0.313	22	*24.70*	0.688	32
3750	7	*10.08*	0.200	28	*24.70*	0.800	35
4250 & 4750	3	*4.20*	0.188	13	*10.29*	0.813	16
Total	53	*41.15*		89	*100.85*		142

The Chi-square independence test was done. The calculated test statistic for presumed end hits was X^2 was 49.71; X^2 was 45.98 for the presumed approach end/same side and trailing end/cross over/undivided data set. From the statistical tables, for an $\alpha = 0.05$, and df = abc-a-b-c+2 = 13 (where a=2,b=5, c=2), the critical value X^2 was 22.36. Because both test statistic X^2 were greater than the critical X^2, it was concluded that the classifications were not independent. **A statistical relationship existed between the end type, vehicle weight, and rolling and/or vaulting.**

To determine which vehicle-weight groups exhibited significantly higher rates of roll/vault at either exposed or at turned-down ends, the binomial proportions test explained in Chapter 3 was employed. Comparisons were made from Table 4.29 data. It excluded "other" weight class, "other" end types, and the "unsure" roll/vault category. The binomial proportions tests involved pair-wise comparisons of accidents at exposed and turned-down ends, given that they belonged to the same weight class and rolled and/or vaulted, or they belonged to the same weight class and did not roll and/or vault. Tests were made on presumed end hit and on presumed approach end/same side-and-trailing end/cross over/undivided data sets.

TEST 1. The proportion of the accidents involving rolling and/or vaulting at exposed ends compared with the proportion at turned-down ends, given that the weights of the vehicles fell in the 1750 lb or 2250 lb weight classes.

H_0: $P_{exp} = P_{t-d}$ H_{alt}: $P_{exp} \neq P_{t-d}$ $\alpha = 0.10$ critical $z_{\alpha/2} = 1.645$

PRESUMED END HITS

$P_{exp} = 7/22 = 0.3182$
$P_{t-d} = 20/27 = 0.7407$
$P = 0.5510$ $q = 0.4490$
test statistic $z = 2.9579$

PRESUMED APP/S S and TRAIL/X OVER/UNDIV

$P_{exp} = 0.3889$
$P_{t-d} = 0.75$
$P = 0.5952$ $q = 0.4048$
test statistic $z = 2.359$

H_0 was rejected as the observed or test z exceeded the critical $z_{\alpha/2}$. There was a significant difference between the proportions of vehicles in the combined 1750-2250 lb weight class that rolled and/or vaulted at exposed ends and that rolled and/or vaulted at turned-down ends. The proportion of rolling/vaulting at turned-down ends was greater.

TEST 2. The proportion of the accidents involving rolling and/or vaulting at exposed ends compared with the proportion at turned-down ends, given that the weights of the vehicles fell in the 2750 lb weight class.

4.34 Analysis & Results

H_0: $P_{exp} = P_{t\text{-}d}$ H_{alt}: $P_{exp} \neq P_{t\text{-}d}$ $\alpha = 0.10$ critical $z_{\alpha/2} = 1.645$

PRESUMED END HITS	PRESUMED APP/S S and TRAIL/X OVER/UNDIV
$P_{exp} = 5/25 = 0.20$	$P_{exp} = 0.2174$
$P_{t\text{-}d} = 17/42 = 0.405$	$P_{t\text{-}d} = 0.4286$
$P = 0.32836$ $q = 0.6716$	$P = 0.3448$ $q = 0.6552$
test statistic $z = 1.7261$	test statistic $z = 1.655$

H_0 was rejected as the observed z exceeded the critical $z_{\alpha/2}$. There was a significant difference between the proportions of vehicles in the 2750 lb weight class that rolled and/or vaulted at exposed ends and that rolled and/or vaulted at turned-down ends. More rolled and/or vaulted at turned-down ends.

TEST 3. The proportion of the accidents involving rolling and/or vaulting at exposed ends compared with the proportion at turned-down ends, given that the weights of the vehicles fell in the 3250 lb weight class.

H_0: $P_{exp} = P_{t\text{-}d}$ H_{alt}: $P_{exp} \neq P_{t\text{-}d}$ $\alpha = 0.10$ critical $z_{\alpha/2} = 1.645$

PRESUMED END HITS	PRESUMED APP/S S and TRAIL/X OVER/UNDIV
$P_{exp} = 1/30 = 0.0333$	$P_{exp} = 0.0357$
$P_{t\text{-}d} = 10/34 = 0.2941$	$P_{t\text{-}d} = 0.3125$
$P = 0.1719$ $q = 0.8281$	$P = 0.1833$ $q = 0.8167$
test statistic $z = 2.760$	test statistic $z = 2.764$

Ho was rejected, as the observed or test z exceeded the critical $z_{\alpha/2}$. There was a significant difference between the proportions of vehicles in the 3250 lb weight class that rolled and/or vaulted at exposed ends and that rolled and/or vaulted at turned-down ends.

TEST 4. The proportion of the accidents involving rolling and/or vaulting at exposed ends compared with the proportion at turned-down ends, given that the weights of the vehicles fell in the 3750 lb weight class.

H_0: $P_{exp} = P_{t\text{-}d}$ H_{alt}: $P_{exp} \neq P_{t\text{-}d}$ $\alpha = 0.10$ critical $z_{\alpha/2} = 1.645$

PRESUMED END HITS	PRESUMED APP/S S and TRAIL/X OVER/UNDIV
$P_{exp} = 4/28 = 0.1429$	$P_{exp} = 0.120$
$P_{t\text{-}d} = 8/37 = 0.2162$	$P_{t\text{-}d} = 0.200$
$P = 0.1846$ $q = 0.8154$	$P = 0.1667$ $q = 0.8333$
test statistic $z = 0.755$	test statistic $z = 0.82$

H_0 was not rejected, as the observed z did not exceed the critical $z_{\alpha/2}$. There was no significant difference between the proportions of vehicles in the 3750 lb weight class that rolled and/or vaulted at exposed and at turned-down ends.

TEST 5. The proportion of the accidents involving rolling and/or vaulting at exposed ends compared with the proportion at turned-down ends, given that the weights of the vehicles fell in the 4250 or 4750 lb weight classes.

H_0: $P_{exp} = P_{t\text{-}d}$ H_{alt}: $P_{exp} \neq P_{t\text{-}d}$ $\alpha = 0.10$ critical $z_{\alpha/2} = 1.645$

PRESUMED END HITS	PRESUMED APP/S S and TRAIL/X OVER/UNDIV
$P_{exp} = 2/9 = 0.2222$	$P_{exp} = 0.2222$
$P_{t\text{-}d} = 3/20 = 0.1500$	$P_{t\text{-}d} = 0.1875$
$P = 0.1724$ $q = 0.8276$	$P = 0.200$ $q = 0.800$
test statistic $z = 0.476$	test statistic $z = 0.208$

H_0 was not rejected, as the observed z did not exceed the critical $z_{\alpha/2}$. There was no significant difference between the proportions of vehicles in the combined 4250-4750 lb weight class that rolled and/or vaulted at exposed ends and that rolled and/or vaulted at turned-down ends.

The binomial proportions tests were also performed for the presumed end hit no roll and/or vault accidents for the 1750/2250 lbs, 2750 lbs, 3250 lbs, 3750 lbs, 4250/4750 lbs weight classes. The tests showed the same pattern of significance as did the roll/vault tests. Table 4.30 presents the pattern of significance for both sets of tests.

TABLE 4.30 Significance pattern for tests

PRESUMED END HITS	WT CLASS (lbs)	ROLL/VAULT	NO ROLL/VAULT
	1750 & 2250	S	S
	2750	S	S
	3250	S	S
	3750	Not S	Not S
	4250 & 4750	Not S	Not S

Note: S = Significant Not S = Not significant

The Chi-square test suggested that a relationship existed between guardrail end type, vehicle weight, and vehicle rolling and/or vaulting. The conclusion from the binomial proportions tests was that, as a group, those **vehicles in the 1500 to 3500 pound weight ranges had a greater tendency to roll and/or vault in accidents at turned-down ends that at exposed ends.**

4.18.06 VEHICLE WEIGHT VS. SEVERITY

The researchers derived contingency tables by performing ask and query operations on field 16, field 79, the "Weight" field, and field 89 to investigate the interrelation between vehicle weight and accident severity. The expected cell counts were calculated for the exposed, turned-down and other end types as described in Chapter 3. Table 4.31 shows the observed and expected cell counts for the presumed-plus-questionable data set, and for the presumed data.

TABLE 4.31 Vehicle weight vs severity

END HITS

WEIGHT CLASS	Fatal + Inj A		Injury B + C		PDO		TOTAL
(lbs)	Observ	*Expect*	Observ	*Expect*	Observ	*Expect*	
PRESUMED							
1750 - 2250	9	*9.36*	22	*17.22*	26	*30.42*	57
2750	17	*12.97*	26	*23.86*	36	*42.16*	79
3250	12	*13.63*	29	*25.07*	42	*44.30*	83
3750	12	*13.96*	15	*25.67*	58	*45.37*	85
4250 - 4750	6	*6.08*	11	*11.18*	20	*19.75*	37
Total	56	*56*	103	*103*	182	*182*	341
PRESUMED-PLUS-QUESTIONABLE							
1750 - 2250	11	*12.05*	28	*23.21*	37	*40.75*	76
2750	18	*14.58*	31	*28.09*	43	*49.32*	92
3250	14	*16.17*	34	*31.15*	54	*54.69*	102
3750	15	*17.12*	21	*32.98*	72	*57.90*	108
4250 - 4750	10	*8.08*	17	*15.57*	24	*27.34*	51
Total	68	*68*	131	*131*	230	*230*	429

The Chi-square independence test was done only on the presumed data. The calculated test statistic X^2 was 13.5. From the statistical tables, for an $\alpha = 0.10$, and df= $(r-1)*(c-1) = 8$ (where r=3 and c=5), the critical value X^2 was 13.36. Because the test statistic X^2 was slightly greater than the critical X^2, it was concluded that the classifications were marginally dependent. The closeness of the test statistic and of the critical statistic values causes the result to be less conclusive than some of the other results in this study. Examination of the table shows that one large difference between observed and expected values was in the 3750 lb class; end accidents involving these vehicles had more PDO and fewer minor injuries that expected.

4.18.07 END TYPE VS. VEHICLE WEIGHT VS. SEVERITY

To examine possible relationships among guardrail end type, vehicle weight, and guardrail end accident severity, the researchers derived contingency tables by performing ask and query operations on field 16, field 79, field 83, the "Weight" field, and field 89. The expected cell counts were calculated for the exposed, turned-down, and other end types as described in Chapter 3. Table 4.32-a shows the observed and expected cell counts for the presumed data set, and Table 4.32-b shows values for the presumed-plus-questionable data set.

TABLE 4.32-a End type vs. vehicle weight vs. severity

PRESUMED END HITS

WEIGHT CLASS (lbs)	Fatal + Inj A		Injury B + C		PDO		TOTAL	
	Observ	*Expect*	Observ	*Expect*	Observ	*Expect*	Observ	*Expect*
EXPOSED								
1750-2250	3	*3.41*	7	*6.15*	13	*11.02*	23	*20.57*
2750	7	*4.72*	12	*8.52*	8	*15.27*	27	*28.51*
3250	2	*4.96*	15	*8.95*	16	*16.05*	33	*29.96*
3750	5	*5.08*	7	*9.17*	21	*16.43*	33	*30.68*
4250-4750	1	*2.21*	5	*3.99*	6	*7.15*	12	*13.35*
Other	6	*5.62*	6	*10.14*	17	*18.17*	29	*33.93*
Total	24	*25.99*	52	*46.92*	81	*84.09*	157	*157.00*
TURNED-DOWN								
1750-2250	5	*5.40*	13	*9.75*	12	*17.48*	30	*32.63*
2750	9	*7.48*	12	*13.51*	24	*24.22*	45	*45.22*
3250	10	*7.86*	11	*14.20*	22	*25.45*	43	*47.51*
3750	7	*8.05*	7	*14.54*	34	*26.06*	48	*48.66*
4250-4750	5	*3.51*	6	*6.33*	13	*11.34*	24	*21.18*
Other	10	*8.91*	21	*16.08*	28	*28.82*	59	*53.81*
Total	46	*41.21*	70	*74.41*	133	*133.37*	249	*249.00*
OTHER ENDS								
1750-2250	1	*0.63*	2	*1.14*	1	*2.04*	4	*3.80*
2750	1	*0.87*	2	*1.57*	4	*2.82*	7	*5.27*
3250	0	*0.92*	3	*1.65*	4	*2.96*	7	*5.53*
3750	0	*0.94*	1	*1.69*	3	*3.04*	4	*5.67*
4250-4750	0	*0.41*	0	*0.74*	1	*1.32*	1	*2.47*
Other	0	*1.04*	0	*1.87*	6	*3.36*	6	*6.27*
Total	2	*4.80*	8	*8.67*	19	*15.53*	29	*29.00*

4.38 Analysis & Results

The researchers compared the proportions within cell categories of presumed-plus-questionable end hits with the proportions of presumed end hits to determine if the two shared a similar distribution of data. To explain the following Table 4.33, for exposed ends, the proportion of the presumed-plus-questionable (P+Q) accidents resulting in a fatality or injury-A out of the total number of presumed-plus-questionable accidents was compared with the proportion of the presumed (P) accidents resulting in a fatality or injury-A out of the total number of presumed (P) accidents. The proportions were calculated along the same lines for the remainder of the cells in the matrix of end type versus severity.

TABLE 4.32-b End type vs vehicle weight vs severity

PRESUMED-PLUS-QUESTIONABLE END HITS

WEIGHT CLASS (lbs)	Fatal + Inj A		Injury B + C		PDO		TOTAL	
	Observ	*Expect*	Observ	*Expect*	Observ	*Expect*	Observ	*Expect*
EXPOSED								
1750-2250	3	*4.01*	9	*7.89*	16	*14.21*	28	*26.11*
2750	7	*4.86*	12	*9.55*	11	*17.21*	30	*31.61*
3250	2	*5.39*	16	*10.58*	20	*19.08*	38	*35.05*
3750	7	*5.70*	9	*11.21*	24	*20.20*	40	*37.11*
4250-4750	4	*2.69*	8	*5.29*	7	*9.54*	19	*17.52*
Other	7	*6.55*	7	*12.87*	21	*23.19*	35	*42.60*
Total	30	*29.20*	61	*57.38*	99	*103.42*	190	*190.00*
TURNED-DOWN								
1750-2250	6	*6.89*	17	*13.53*	19	*24.39*	42	*44.80*
2750	10	*8.34*	17	*16.38*	28	*29.52*	55	*54.24*
3250	12	*9.24*	15	*18.16*	28	*32.73*	55	*60.13*
3750	8	*9.79*	10	*19.23*	44	*34.65*	62	*63.67*
4250-4750	6	*4.62*	9	*9.08*	15	*16.36*	30	*30.07*
Other	10	*11.24*	29	*22.08*	43	*39.79*	82	*73.10*
Total	52	*50.11*	97	*98.45*	177	*177.44*	326	*326.00*
OTHER ENDS								
1750-2250	2	*0.7*	2	*1.54*	2	*2.77*	6	*5.08*
2750	1	*0.95*	2	*1.86*	4	*3.35*	7	*6.16*
3250	0	*1.05*	3	*2.06*	6	*3.71*	9	*6.82*
3750	0	*1.11*	2	*2.18*	4	*3.93*	6	*7.23*
4250-4750	0	*0.52*	0	*1.03*	2	*1.86*	2	*3.41*
Other	0	*1.28*	0	*2.51*	7	*4.52*	7	*8.30*
Total	3	*5.69*	9	*11.17*	25	*20.14*	37	*37.00*

TABLE 4.33 Proportions

	Fatal + Inj A		Injury B + C		PDO		TOTAL	
	P+Q	P	P+Q	P	P+Q	P	P+Q	P
Exposed	0.05	0.05	0.11	0.12	0.18	0.19	0.34	0.36
Turned-down	0.09	0.11	0.17	0.16	0.32	0.31	0.59	0.57

The values showed that there was little difference between the corresponding-category proportions of presumed-plus-questionable (P+Q) accidents and presumed (P) accidents. Because the proportions were similar, the Chi-square test of independence was conducted on only the presumed accident data set. In addition, the "other" end types were omitted, and the 4250-4750 and 3750 weight classes were combined; this focused on the differences between the two predominant end types, and strengthened the Chi-square test results. The expected cell counts were calculated for the exposed and turned-down terminals as described in Chapter 3. Table 4.34 presents the observed and expected cell counts for the presumed data set, used to investigate the interrelation among end type, vehicle weight, and accident severity.

TABLE 4.34 Modified end type vs. vehicle weight vs. severity

WEIGHT CLASS (lbs)	Fatal + Inj A		Injury B + C		PDO		TOTAL	
	Observ	*Expect*	Observ	*Expect*	Observ	*Expect*	Observ	*Expect*
EXPOSED								
1750-2250	3	*3.62*	7	*6.37*	13	*11.34*	23	*21.33*
2750	7	*4.92*	12	*8.66*	8	*15.40*	27	*28.98*
3250	2	*5.19*	15	*9.14*	16	*16.26*	33	*30.59*
3750-4750	6	*8.00*	12	*14.07*	27	*25.03*	45	*47.09*
Total	18	*21.73*	46	*38.24*	64	*68.02*	128	*128*
TURNED-DOWN								
1750-2250	5	*5.38*	13	*9.46*	12	*16.83*	30	*31.67*
2750	9	*7.31*	12	*12.85*	24	*22.86*	45	*43.02*
3250	10	*7.71*	11	*13.57*	22	*24.13*	43	*45.41*
3750-4750	12	*11.87*	13	*20.88*	47	*37.15*	72	*69.91*
Total	36	*32.26*	49	*56.76*	105	*100.97*	190	*190*

The Chi-square test was performed on the values. The calculated test statistic was $X^2 = 20.03$. For $\alpha = 0.05$, and df= abc-a-b-c+2 (where a=2, b=3, c=4), the X^2 critical was 27.59. Because the test statistic X^2 was less than the critical X^2, this test indicated that the classifications were independent; **i.e., there was no statistical relationship between the end type, vehicle weight, and severity.**

4.19 SEVERITY INDEX, PROBABILITY INDEX AND COLLISION INDEX FOR EXPOSED AND TURNED-DOWN GUARDRAIL ENDS.

The researchers performed a mathematical exercise to evaluate accident severity, accident frequency, and to compare the relative safety of the guardrail ends. This procedure was based on the methodology of Glennon et al. *(20)*.

The severity index was used to compare the severity of the accidents at turned-down ends with accidents at exposed ends. The accident severity class for each accident is shown in field 16 of the database file. Code "1", code "2" and code "3", represent fatal accident, injury accident and property damage accident respectively. Weighted severity values were assigned to the three accident severity classes: fatal, injury, and property damage only accidents.

The weighted severity values used by ODOT *(21)* were assigned to the severity classes. The severity values used for the three classes of accidents were as follows:

Accident type	Value
Fatal accident	4
Injury accident	4
Property Damage accident	2

Therefore accidents with severity classes "1", "2" and "3" were given severity values "4","4" and "2" respectively.

The severity index chosen for comparison purposes is the average severity value for all accidents for a given condition *(20)*. The severity index was calculated using equation given below.

$$\text{Severity index} = \frac{\text{Sum of the severity values}}{\text{Number of accidents}}$$

The severity index alone is not sufficient for comparing the relative safety of the guardrail end types. The number of accidents that occurred in relation to the number of vehicles exposed to the condition is necessary for comparison purposes. The probability index is the number of accidents pertaining to each end type divide by the sum of the average daily traffic volumes for the accidents under that particular end type *(20)*. The probability index was calculated using the following equation.

$$\text{Probability index} = \frac{\text{Number of accidents}}{\text{Sum of the Average daily traffic volumes}}$$

The collision index is used as the measure for comparing the relative safety of the guardrail end terminals. It is the product of the severity index and the probability index. The collision index was calculated using the following equation.

$$\text{Collision index} = \text{Severity index} * \text{Probability index}$$

$$= \frac{\text{Sum of the severity values}}{\text{Number of accidents}} * \frac{\text{Number of accidents}}{\text{Sum of the ADT volumes}}$$

$$= \frac{\text{Sum of severity values}}{\text{Sum of ADT volumes}}$$

The probability index and collision index were calculated for the exposed and turned-down ends. The analysis was done only for the presumed accident data set. Table 4.35 shows the calculated severity index, the probability index and the collision index of exposed and turned-down ends hits.

TABLE 4.35 Severity, probability and collision index for exposed and turned-down ends

PRESUMED END HITS

End Type	Severity Index	Probability Index	Collision Index
Exposed	2.97	6.19E-05	0.000183
Turned-down	2.93	4.02E-05	0.000118

It can be concluded that **the severity index of exposed ends was higher than that of turned-down ends. The probability index and collision index of exposed ends was also higher than both indices for turned-down ends.**

4.42 Analysis & Results

CHAPTER V

SUMMARY AND CONCLUSIONS

This report documented the methods and results of a study conducted to gain greater insight into certain characteristics of guardrail end accidents. The Oklahoma Department of Transportation wanted to investigate the performance of buried guardrail ends on its highways, because the Federal Highway Administration's Office of Highway Safety had discouraged the use of turned-down guardrail end terminals on highways. Upon impact, the turned-down ends were said to cause vehicle rolling and vaulting. ODOT contracted with The University of Oklahoma to study certain attributes of guardrail end accidents.

5.01 SUMMARY OF METHODS

The main data sources were the police accident reports and the video tapes logs showing highway features. Other data were also needed. The accident reports requested for study were those which had been coded with "guardrail" being the first object struck. The police reports of individual guardrail end accidents which occurred on Oklahoma state highways from 1988 through 1991 were scrutinized to evaluate how the guardrail end treatments performed when struck by vehicles. The researchers added codes to the initial guardrail database which ODOT furnished so as to include relevant attributes which were gleaned from the various data sources.

The study focused on the two predominate types of guardrail ends currently found on ODOT highways, the exposed ends and the turned-down or buried ends. Analyses were performed to define characteristics of guardrail end accidents. Those accidents which the researchers were fairly sure had involved impacts with a guardrail end were termed "presumed" end hits. If the researchers were more uncertain that an accident actually involved an end strike, then the accident was termed a "questionable" end hit. Also, data sets were created for all "end hits" and for "approach end/same side and trailing end/cross over/undivided" accidents. This "2 x 2" matrix resulted in creating four data sets. Not all analyses were performed on all data sets. The numbers of accidents in each of the four data sets differed, but the researchers found the proportions of accidents exhibiting certain traits to be about the same in all four sets.

A few guardrail end accidents could have been excluded from the dataset. For instance, an end accident may have been erroneously recorded and coded as a "guard post" accident. Some guardrail end accidents may have been unreported, improperly coded, omitted in the retrieval process, or overlooked by the researchers.

5.02 Summary

5.02 SUMMARY OF FINDINGS AND CONCLUSIONS

Chapters 3 and 4 discuss the methodologies used to arrive at the following findings. The following findings are "general summaries" of the more detailed results of Chapter 4.

1. 1.7% of the accidents reported on the ODOT system from 1988 through 1991 involved a guardrail as the first point of impact.

2. Most of these guardrail accidents occurred along the guardrail midsection; 1/4 of the total number of reported guardrail accidents were presumed end accidents. Less than 5% of end accidents in the data set involved a guardrail end strike after another impact had occurred.

3. The number of accidents at turned-down ends was greater than the number at exposed ends; over 60% were at turned-down ends.

4. 56% of guardrail end accidents on the state highway system occurred on divided roads. On divided roads, the chances of a vehicle hitting the guardrail on the right side of the road or in the median were almost the same. 60% of accidents on undivided roads involved the vehicle striking the guardrail end on the right side.

5. 70% of the exposed plus turned-down guardrail end accidents on state highways occurred in rural areas. Urban miles constitute 8% of the mileage, but 30% of the end accidents occurred at urban settings.

6. Over 90% of the guardrail end accidents occurred on roads with posted speeds of 55 mph or greater.

7. 47% of the guardrail end accidents occurred on 11,085 miles of roads having volumes less than 10,000 ADT; these lower-volume roads constituted over 90% of the miles on the state highway system. 53% of guardrail end accidents were concentrated on about 10% of the system miles having the higher ADT's. Regression analysis showed a close relation between the number of accidents and the VMT in a volume group ($R^2 = 0.86$).

8. 1/3 of all guardrail end accidents involved an inattentive driver. For roads with and without medians, the right-side guardrail end was the one struck most when inattention was mentioned in the accident report.

9. The majority of guardrail end accidents were property-damage-only accidents. For all guardrail end types, 1/6 of the accidents had fatal or incapacitating injuries (Injury A).

10. Vehicles striking ends subsequently went down an embankment in 13% of the accidents. 14% of exposed end accidents resulted in the vehicle striking a fixed object after hitting the guardrail end, while 21% of turned-down ends accidents did.

11. About 10% of accidents involved death or incapacitating injury when the vehicle did not subsequently strike a fixed object. When a vehicle did subsequently strike a fixed object, 23% of exposed end and 38% of turned-down end accidents involved death or incapacitating injury.

12. 1/4 of guardrail end accidents resulted in vehicle rolling and/or vaulting; in most of the guardrail end accidents, the vehicle did not vault or roll.

13. The proportion of accidents with fatalities or A-injuries was higher for roll and/or vault accidents (26%) than for non-roll/vault accidents (13%).

14. Accidents at turned-down ends had more vehicle rolling and/or vaulting (31%) than those at exposed ends (15%). When a roll/vault did occur, the results were more severe with exposed ends than with buried ends, although the difference was not statistically significant.

15. At turned-down ends, 16% of the no roll/vault accidents had fatal or A-injuries, while 23% of the roll/vault accidents had fatal or A-injuries.

16. Lighter-weight vehicles experienced more rolling and/or vaulting. The vehicles in the 1500 to 3500 weight range had more rolling and/or vaulting at turned-down ends than at exposed ends.

The data from 1988 through 1991 suggested that the following numbers of events resulting from guardrail end accidents can be approximated:

4 fatal guardrail end accidents and fatalities per year;
15 A-type injury accidents per year; and
20 A-injuries per year.

The turned-down ends accounted for just under 60% of the fatalities (slightly more than 60% of all end accidents were at turned-down ends). About 60% of the A injuries occurred at turned-down ends. The studied accident reports indicated that at 3/4 of exposed and turned-down end accidents where there was or may have been rolling and/or vaulting, the vehicle occupants suffered either B, C, or no injuries.

5.04 Summary

5.03 ACCIDENT REPORTING SUGGESTIONS

Accident study quality is constrained by database quality, in this case the quality of individual police accident reports. While the majority of the reports were very adequate, some were not. Because police may not have experience with using accident reports to find solutions to traffic safety problems, it may be difficult for police in the field to always appreciate the needs of other accident report users. Police may be able to improve the quality of their reports if they participate in training sessions in which police are given actual examples of unclear accident reports, asked to identify accident details, and then discuss the missing or unclear aspects on which other users of the reports rely.

The researchers do offer some particular suggestions for improving the accident reports.

1. The arrangement of certain data boxes which the police check appeared to contribute to mistakes. Arrangements such as
   N ☐ S ☐ E ☐ W ☐
   sometimes result in the officer checking the wrong box; an officer in a hurry may check the third box, intending to indicate "west", but in fact indicating "east". Revisions to the form could help.
2. Some officers do not differentiate among metal guardrails, concrete barriers, and bridge rails. The forms could be revised to list these categories separately, as well as including newer safety appurtenances, such as crash cushions.
3. The police need to provide a distance from the point-of-impact to a nearby geometric feature or roadside appurtenance, so future users of the data can better reconstruct events.
4. Police sometimes describe a shoulder as "improved". This is ambiguous; it would be better to say "gravel" or "paved."

Accident report quality would be improved if police had global positioning devices to report accident locations while physically at the accident site. With the proper codes, police could report to within a few feet the first "point of error" and the final resting place of vehicles in accidents. This would reduce the amount of time later spent in offices, trying to figure out where the accident took place. It would also enhance the ability of office staff to identify locations with elevated accident frequencies or rates.

5.04 RECOMMENDATIONS

Based on the analysis of four years of Oklahoma data and the experiences of the study, the researchers offer the following comments and recommendations.

1. Over the four year study period, less than 2% of the fatalities and less than 1% of the incapacitating injuries on the ODOT system were associated with guardrail end accidents.

2. Turned-down guardrail ends seemed to produce more vehicle rolling and vaulting after being struck than did exposed ends. However, if rolling or vaulting did occur after striking a turned-down end, the severity may have been less than that of striking an exposed end, and the aggregate severity for either end type was about the same. The vast majority of occupants in vehicles which rolled and/or vaulted after striking guardrail ends did not incur fatal or incapacitating injuries.
3. If guardrail ends are to be replaced in an effort to improve safety on roads with medians, the ends on the right side of the main lanes and in the middle and right of the median should be targeted. On undivided roads, the first priority should be to replace ends on the drivers' right; although not unimportant, it is of secondary importance to replace the end of the drivers' left (i.e., a trailing end).
4. Other factors being equal, it is more probable that a guardrail end on a higher volume road will be struck than an end on a lower volume road. The indication that urban roads had a disproportionate share of end hits may simply reflect higher volumes on urban portions of state highways. Since almost 60% of the end accidents took place on less than 15% of the system miles, one concludes that if an agency had new guardrail end products which were safer than the ends currently in the field, it would be more cost-effective to target the newer end type replacement program along the roads with the higher volumes.
5. Roughly 1/3 of all guardrail end accidents involved an inattentive driver striking a guardrail end. Inattentive drivers leaving the road most often struck the right-side guardrail end. Recent research, conducted mainly in western states, suggests that rumble or chatter strips constructed on the shoulder at the lane edge may reduce the number of run-off-the-road accidents. These strips create an unusual noise when car tires traverse them, so the strips warn a driver that they are headed off the road. After construction of indented rumble strips, stretches of highway in studies have experienced dramatic reductions in run-off-the-road accidents. The indented rumble strips were relatively inexpensive, and offered impressive benefit-to-cost ratios. At sites with lesser probabilities of end strikes, highway agencies may wish to test rumble strips as an inexpensive method of reducing the number of guardrail end impacts. Agencies may wish to examine alternative rumble strip patterns to identify methods of getting "more rumble from the strip".

5.05 CLOSING

One of the major current guardrail end treatment issues is replacing the existing ends with, and specifying on new projects, the newer, more expensive end treatments. Unfortunately, one cannot compare turned-down end with newer end performance on ODOT roads, because ODOT has little experience with the newer types. Given that turned-down ends were once considered acceptable but now are discouraged, it would be prudent to conduct controlled long term field studies of various newer end types before embarking upon a costly, extensive guardrail end replacement program.

In relation to all accidents on state highways, guardrail end accidents constituted only a small fraction of the total accidents in any of the accident severity categories. Officials should consider the cost of the more expensive, newer guardrail end treatments in relation to expected reductions in accident severity. Could the same money be spent on other safety items and yield greater benefit to the traveling public in terms of lowered injury and death totals? Officials charged with the oversight of the public highways should evaluate data in this report critically, and consider other relevant studies before deciding upon a course of action.

REFERENCES

1. N. J. Rowan et al. *Safety Design and Operational Practices for Streets and Highways*, TS 80-228, May 1980. Federal Highway Administration, Washington, D.C.
2. *Roadside Design Guide*, 1989. American Association of State Highway and Transportation Officials, Washington, D.C.
3. *Development of New Guardrail End Treatments*, Research Report 404-1F, 1988. Texas Transportation Institute, College Station, Tex.
4. N. J. Rowan et al. "An Update on Highway Safety Hardware," *Traffic Engineering Journal*, Vol 47, No. 7, pp. 38-39, May 1977. Institute of Transportation Engineers, Washington, D.C.
5. D. L. Ivey et al. "Guardrail End Treatments in the 1990s", paper No.920910, presented at 71st annual meeting, January 1992, Transportation Research Board, Washington, D.C.
6. L.I. Griffin. *An Analysis of Accidents on Turned Down Guardrail Ends in the State of Texas*, Report 9901-H, May 1991. Texas Transportation Institute, College Station, Tex.
7. L.A. Troxel et al. "Side Impact Collisions with Roadside Obstacles", *Transportation Research Record No. 1302*, 1991, pp. 34-37. Transportation Research Board, Washington, D.C.,
8. *Accident Research Manual*, Report No. FHWA/RD-80/016, February 1980. Federal Highway Administration, Washington, D.C.
9. *Standard Catalogue of American Cars from 1976 to 1986*, Second Edition, 1989. Krause Publications, Inc., Iola, Wis.
10. *Standard Catalogue of American Cars from 1946 to 1975*, Second Edition, 1987. Krause Publications, Inc., Iola, Wis.
11. *Standard Catalogue of American Light Duty Trucks from 1896 to 1986*, First Edition, 1987. Krause Publications, Inc., Iola, Wis.
12. *Official Used Car Guide*, Southwestern Ed., Vol. 58, No. 10, October 1991. National Automobile Dealers Used Car Guide Co., McLean, Va.
13. "Mechanical Specifications," *Consumer Reports*, Vol. 56, No.4, pp. 280-284, April 1991. Consumers Union of USA, Inc., Mt. Vernon, N.Y.
14. *National Accident Sampling System - Coding, Validation, and Editing Manual*. Technical Report, 1979-1985 version. National Highway Traffic Safety Administration, Washington, D.C.
15. W. Mendenhall et al. *Statistics for the Engineering and Computer Sciences*, 1988. Dellen Publishing Company, San Francisco, Cal.
16. T. D. Wickens. *Multiway Contingency Tables Analysis for Social Sciences*, 1989. Lawrence Erlboum Assoc., Hillsdale, N.J.

17. L.E. Toothaker. *Multiple Comparisons for Researchers*, 1991. Sage Publications, Newbury Park, Cal.
18. Lyman Ott. *An Introduction to Statistical Methods and Data Analysis*, Second Edition, 1984. PWS Publishers, Boston, Mass.
19. *Highway Statistics 1990*. Federal Highway Administration, Washington, D.C.
20. J. C. Glennon et al. "Objective Criteria for Guardrail Installation," *Highway Research Record 174*, pp. 185-205, 1967, Washington, D.C.
21. "Procedures Manual of Oklahoma's Highway Safety Improvement Program," October 1978. Oklahoma Department of Transportation.

APPENDIX A Official Police Traffic Collision Report

TYPE OR PRINT LEGIBLY

[DO NOT WRITE IN THIS SPACE]

☐ INCIDENT REPORT
☐ REVISED REPORT

INVESTIGATION COMPLETED ☐ YES ☐ NO

Sheet ___ of ___ Sheets

FATALITY = YES ☐

OKLAHOMA

OFFICIAL POLICE TRAFFIC COLLISION REPORT

Reporting Agency: ______

Accident Number | ADMINISTRATIVE

Date: ______ Day of Week: ______ Hour: ______ AM ______ PM County: ______

Name of Nearest City (If outside city limits) ______

Distance From Nearest City Limits: ______ N ☐ S ☐ E ☐ W ☐

Hwy. Class ☐

STATE HIGHWAY CODES

Control No. | Int. I.D. | Location

County No.

County Section Line Grids Or City Street Codes

East | North

City No.

Spec. Feat. | Collision Codes | Inter. Pop. Cl.

LOCATION

IN ______ city or town

ON ______ Name or number of street or highway

AT ______ name of intersecting road

NOT AT INTERSECTION

______ ft. / ______ mi. North ☐ South ☐ East ☐ West ☐ OF ______ show nearest intersecting street or highway

OF Control Location ☐

MTR. VEH. INVOLVED ______

Number Killed ______

Number Injured ______

Time Notified: Date: ______ Hour: ______ AM ______ PM

Arrived At Scene: Date: ______ Hour: ______ AM ______ PM

UNIT 1 Occupants ______ RAD. DET. ☐

Driver: ______ last first middle ______ phone no.

Address: ______ street or RFD city and state zip code

License: ______ exp. yr. state number

Age: ______ Sex: ______ Race: ______ Date of Birth: ______ mo. day year

Operator's Report given to driver – ☐ Yes ☐ No

☐ Operator ☐ Chauffeur ☐ Other

Driver Injury Type K A B C — Head ☐ Trunk – External ☐ Trunk – Internal ☐ Arm Leg ☐

	Equipped		In Use	
Lap belt	Yes	No	Yes	No
Shoulder belt	Yes	No	Yes	No
Crash Helmet			Yes	No
Pinned? Yes No		Ejected?	Yes	No

Taken To: ______

By: ______

VIN ______ (__) size = { towed vehicle

Vehicle ______ color year make model style

CHEMICAL TEST Refused ☐ ______ AC Blood Kit No.

License Plate ______ mo/year state number

Sec. Verifi: ☐ No ☐ Owner ☐ Oper. Ins. Co. ______

Policy No. ______ From ______ mo day year to ______ mo day year

Agent: ______ Address: ______

Owner's Name ______ last first middle

Address: ______ city and state zip code

Veh. removed to: ______ by: ______

______ MPH legal speed ______ MPH estimated speed before contact ______ MPH contact $ ______ estimated damages Burned? ☐ Yes ☐ No

UNIT 2 Occupants ______ RAD. DET. ☐

Driver ☐ Pedestrian ☐ Animal ☐ Train, etc. ☐

______ last first middle ______ phone no.

Address: ______ street or RFD city and state zip code

License: ______ exp. yr. state number

Age: ______ Sex: ______ Race: ______ Date of Birth: ______ mo. day year

Operator's Report given to driver – ☐ Yes ☐ No

☐ Operator ☐ Chauffeur ☐ Other

Driver Injury Type K A B C — Head ☐ Trunk – External ☐ Trunk – Internal ☐ Arm Leg ☐

	Equipped		In Use	
Lap belt	Yes	No	Yes	No
Shoulder belt	Yes	No	Yes	No
Crash Helmet			Yes	No
Pinned? Yes No		Ejected?	Yes	No

Taken To: ______

By: ______

VIN ______ (__) size = { towed vehicle

Vehicle ______ color year make model style

CHEMICAL TEST Refused ☐ ______ AC Blood Kit No.

License Plate ______ mo/year state number

Sec. Verifi: ☐ No ☐ Owner ☐ Oper. Ins. Co. ______

Policy No. ______ From ______ mo day year to ______ mo day year

Agent: ______ Address: ______

Owner's Name ______ last first middle

Address: ______ city and state zip code

Veh. removed to: ______ by: ______

______ MPH legal speed ______ MPH estimated speed before contact ______ MPH contact $ ______ estimated damages Burned? ☐ Yes ☐ No

INJURED or WITNESSES or INJ. PEDESTRIAN

#	Injured – ☐ Witness – ☐	last	first	middle	address	Phone Number	age	sex	race	veh. no	Position in vehicle
1	K Injury Type: A B C	Head ☐	Trunk – External ☐	Trunk – Internal ☐	Arm Leg ☐	Lap Belt / Child Rest. Equipped Yes No, In Use Yes No	Shoulder Belt Equipped Yes No, In Use Yes No	Crash Helmet Yes No	Pinned? Yes No ped. / Ejected? Yes No		1 2 3 / 4 5 6
2	K Injury Type: A B C	Head ☐	Trunk – External ☐	Trunk – Internal ☐	Arm Leg ☐	Lap Belt / Child Rest. Equipped Yes No, In Use Yes No	Shoulder Belt Equipped Yes No, In Use Yes No	Crash Helmet Yes No	Pinned? Yes No ped. / Ejected? Yes No		1 2 3 / 4 5 6
3	K Injury Type: A B C	Head ☐	Trunk – External ☐	Trunk – Internal ☐	Arm Leg ☐	Lap Belt / Child Rest. Equipped Yes No, In Use Yes No	Shoulder Belt Equipped Yes No, In Use Yes No	Crash Helmet Yes No	Pinned? Yes No ped. / Ejected? Yes No		1 2 3 / 4 5 6

Injured Taken To:

1. ______ By: ______
2. ______ By: ______
3. ______ By: ______

Damage to property Other than vehicles: ______ $ ______ Owner – ______ Address – ______

Name: last first middle	Citation:	Citation No.
1		
2 last first middle	Citation:	Citation No.

SIGN HERE – ______

Troop or Division | Reviewed by: *(Initials & Badge No.)* | Date of report:

Unit 1	Unit 2	WHAT VEHICLES WERE GOING TO DO
		1. Go ahead
		2. Turn left
		3. Turn right
		4. Make 'U' turn
		5. Stop
		6. Slow for cause
		7. Start from park
		8. Change lanes
		9. Overtake / Pass
		10. Back
		11. Remain stopped parked
		12. Other

Unit 1	Unit 2	WHAT VEHICLES DID
		1. Went ahead
		2. Turned left/right
		3. Swerved left/right
		4. Entered 'U' turn
		5. Stopped
		6. Slowed
		7. Started from park
		8. Entered other lane
		9. Overtaking/Passing
		10. Backed
		11. Remained stopped parked
		12. Ran off roadway
		13. Other

Unit 1	Unit 2	TYPE OF ROAD
		1. Oneway road
		2. Alley
		3. Two lanes
		4. Three lanes
		5. Four or more divided
		6. Four or more not divided
		7. Driveway
		8. Turn bay
		9. On ramp
		10. Off ramp
		11. Const. zone
		12. Other

Unit 1	Unit 2	TRAFFIC CONTROL
		1. Stop sign
		2. Traffic signal
		3. Flashing signal
		4. Yield Sign
		5. Warning sign
		6. RR gates, signals
		7. No-passing zone
		8. Officer
		9. No control
		10. Abnormal control
		11. Other

Unit 1	Unit 2	ROAD CHARACTER
		1. Straight-level
		2. Straight-upgrade
		3. Straight-downgrade
		4. Straight-hillcrest
		5. Curve-level
		6. Curve-upgrade
		7. Curve downgrade
		8. Curve-hillcrest
		9. Sharp curve (add to above as applicable)
		10. Other

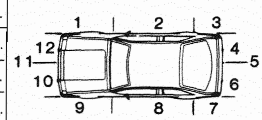
Unit 1	Unit 2	Ped.	CONDITION OF DRIVERS AND PEDESTRIANS
			1. Apparently normal
			2. Drinking-ability impaired
			3. Odor of alcoholic beverage
			4. Drug use indicated
			5. Very tired
			6. Sleepy
			7. Sick
			8. Condition not known
			9. Body defects (arm, leg, eyes, etc.)
			10. Other

Unit 1	Unit 2	VEHICLE CONDITION	TIRE CHECK U-1	U-2
		1. Apparently normal		
		2. Brakes		
		3. Steering	RF	RF
		4. Headlights	LF	LF
		5. Rearlight	RR	RR
		6. Tires	LR	LR
		7. Other		

Ped.	WHAT PEDESTRIAN WAS DOING
	1. Crossing/at intersection
	2. Crossing/not at intersection
	3. Crossing/at other crosswalk
	4. Getting on/off vehicle
	5. Walking with traffic
	6. Walking against traffic
	7. Push/work on vehicle
	8. Playing
	9. Other working
	10. Other

POINT OF FIRST CONTACT ON VEHICLE

Unit 1		Top ______ Bottom ______	Unit 2	
1.	7.		1.	7.
2.	8.		2.	8.
3.	9.		3.	9.
4.	10.		4.	10.
5.	11.		5.	11.
6.	12.		6.	12.



OBJECT STRUCK BY VEHICLE OR LOAD ON FIRST CONTACT

Unit 1	Unit 2		Unit 1	Unit 2	
		1. Fence pole			11. Ditch
		2. Utility pole			12. Embankment
		3. Guard rail			13. Tree
		4. Guard post			14. Dividing strip
		5. Culvert			15. Retaining wall
		6. Traffic signal			16. Fence
		7. Barrier			17. Bridge______ (pier, abuttment, etc.)
		8. Curb			18. Other highway structure
		9. Island			19 Other
		10. Traffic control sign			

	WEATHER
	1. Clear
	2. Partly cloudy
	3. Overcast
	4. Raining
	5. Snowing
	6. Other

	LIGHT
	1. Daylight
	2. Darkness
	3. Lighted
	4. Dawn
	5. Dusk
	6. Other

	LOCALITY
	1. Residential
	2. Business
	3. Industrial
	4. School
	5. Not built-up
	6. Other

Unit 1	Unit 2	ROAD SURFACE
		1. Concrete
		2. Asphalt
		3. Gravel
		4. Dirt
		5. Other

Unit 1	Unit 2	ROAD CONDITION
		1. Dry
		2. Wet
		3. Ice/Snow
		4. Muddy
		5. Other

Indicate North By Arrow ◯

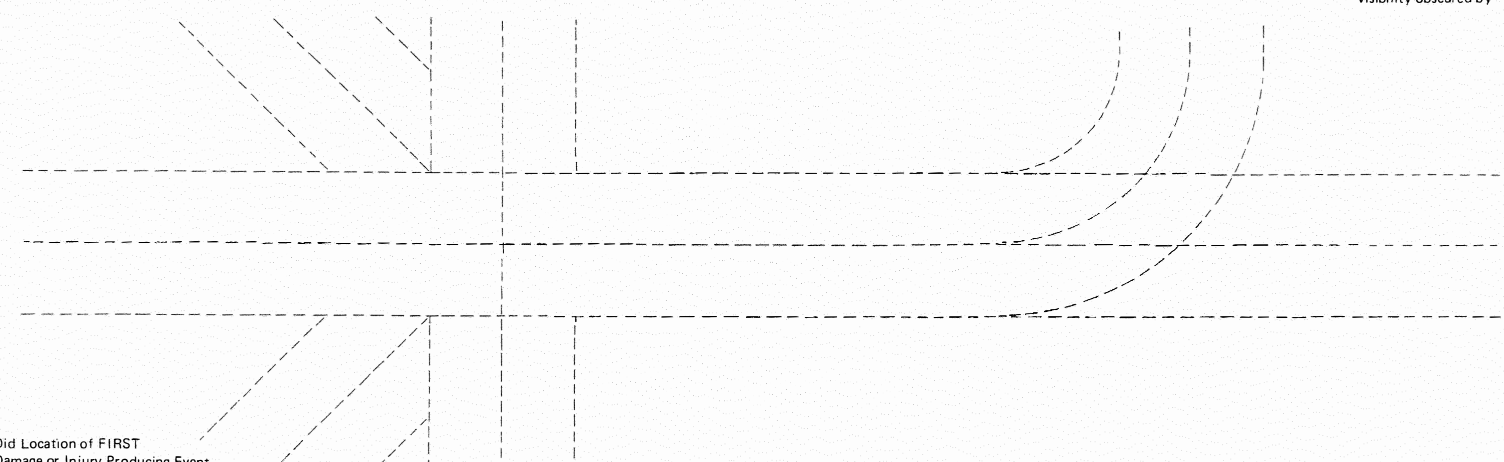
DIRECTION OF TRAVEL

Veh. 1 N☐ S☐ E☐ W☐

Veh. 2 N☐ S☐ E☐ W☐

COLLISION DIAGRAM

______________ visibility obscured by



Did Location of FIRST Damage or Injury Producing Event Occur on Travel Portion of Trafficway?
☐ Yes ☐ No

Investigation made at Scene? ☐ Yes ☐ No   Hit & Run ☐ Yes ☐ No   Photos Taken? ☐ Yes ☐ No   ______ Oversize Vehicle ☐ P ☐ E

REMARKS: *(COMMENTS THAT WILL CLARIFY REPORT)* Refer to vehicle by number.

UNSAFE, UNLAWFUL, OR OTHER ACTION (this section — primarily for general statistics and administrative purposes)   Blocks 1 thru 10 must be described when checked.

Unit 1	Unit 2		Unit 1	Unit 2		Blk	Remarks Unit 1	Blk	Remarks Unit 2
		1. Other (describe)			6. Change Lanes Unsafely				
		2. Failed to Yield/Stop			7. Unsafe Vehicle				
		3. Followed too Closely			8. Left of Center/Passing				
		4. Unsafe Speed			9. Not Known — or — No Improper Action				
		5. Made Improper Turn			10. Pedestrian/Bicycle Action				

THIS REPORT IS BASED ON THE OFFICER'S INVESTIGATION OF THIS ACCIDENT. IT MAY CONTAIN THE OPINION OF THE OFFICER

DPS 67-1 Rev. 1987

APPENDIX B ODOT Accident Coding Guide

OKLAHOMA DEPARTMENT OF TRANSPORTATION

ACCIDENT COD

ACCD-RECORD 0001 140 A

- Not listed in accident fields

AR-HWY-CLASS 0001 001 N

HIGHWAY CLASSIFICATION

0 - Private Property
1 - US Highway - Rural
2 - Interstate Highway
3 - Turnpike - Interstate - Jan 1, '90
4 - State Highway - Rural
5 - County Road
6 - City Street
7 - US Highway - Urban
8 - State Highway - Urban
9 - Non-Interstate Turnpike - Jan 1, '90

AR-COUNTY-CITY 0002 004 N

COUNTY - CITY

- See County - City Number Listing

AR-COUNTY 0002 002 N

COUNTY - See County Number Listing

AR-CITY 0004 002 N

CITY - See County-City Number Listing

AR-REVISED 0006 001 N

TYPE OF REPORT

0 - Not stated
1 - Incident report
2 - Revised report

STREET1 0007 004 N
NS-STREET 0007 004 N

ODD CITY STREET OR GRID NUMBER

- See Map or City Street File

AR-CONTRL-SEC 0007 002 N

HIGHWAY CONTROL SECTION

- See Map or Reference File

AR-INT-ID 0009 002 N

INTERSECTION ID NUMBER

- See Map or Reference File

STREET2 0011 004 N
EW-STREET 0011 004 N

EVEN CITY STREET OR GRID NUMBER

- See Map or City Street Reference File

AR-LOCATION 0011 004 N

HIGHWAY REFERENCE MILE POINT

- See Map or Reference File

AR-INT 0015 001 N

INTERSECTION RELATION CODE

0 - Not Related to Intersection
1 - In Intersection
2 - Related to Intersection
5 - North of Intersection
6 - East of Intersection
7 - South of Intersection
8 - West of Intersection

AR-POP 0016 001 N

URBAN POPULATION CLASS

- See County - City Number Listing

AR-NO-VEH 0017 002 N

NUMBER OF VEHICLES INVOLVED

- Use Actual Number (01 - 99)

AR-NO-INJ 0019 002 N

NUMBER OF PEOPLE INJURED

- Use Actual Number (01 - 99)

AR-NO-FAT 0021 002 N

NUMBER OF PEOPLE KILLED

- Use Actual Number (00-99)

AR-ACC-TYPE 0023 002 N

TYPE OF ACCIDENT

ON RDWY	OFF RDWY	
01	26	Overturning
02	27	Other Non-Collision
03	28	Pedestrian
04	29	Motor Vehicle in Transport
05	30	Motor Vehicle on Other Roadway
06	31	Motor Vehicle Parked
07	32	Railroad Train
08	33	Pedacycle (Bicycle)
09	34	Animal
10	35	Fixed Object
11	36	Other Object
12	37	Motorcycle
13	38	Moped
14	39	All - terrain - vehicle (ATV)
15	40	Airplane
16	41	Motor boat
17	42	Snowmobile
18	43	Golf Cart
19	44	Riding Lawn Mower
20	45	Implements of Husbandry

Non-Traffic Codes

51 Private Property
52 Deliberate Act
53 Heart Attack
54 Legal Intervention
55 Suicide
56 Industrial
57 Drowning
58 Boat Accident
59 Incident
99 Other

AR-SPECIAL FEATURES 0025 001 N

SPECIAL FEATURES - Two Digits

00 - None
01 - Driveway
02 - Median Opening
03 - Two-Way Turn Bay (5th Lane)
04 - Reversible Lane
05 - Construction
06 - Alley
07 - Rest Area
08 - Impact Attenuator Device
09 - R.R. Grade Crossing (Train)
10 - Bridge
11 - Incident
12 - Parks
13 - Dead End (9-1-89)
14 - Cul-de-sac (9-1-89)
15 - Bus Stop (9-1-89)
16 - Lane/Ends Begins (9-1-89)
17 - Toll Plaza (9-1-89)
18 - Impact Attenuator On Bridge (9-1-89)
19 - R.R. Non-Grade Acc. (train) (9-1-89)
20 - Terminal Location Left
21 - Terminal Location Right
22 - Terminal Location Undetermined Side
23 - Ramp - Frontage Road Junction Left
24 - Ramp - Frontage Road Junction Right
25 - Ramp - Frontage Road Junction Undetermined Side
26 - Frontage Road Between Ramp and Terminal Location Left
27 - Frontage Road Between Ramp and Terminal Location Right
28 - Frontage Road Between Ramp and Terminal Location Undetermined Side
30 - Ramp
31 - Ramp Merge
32 - Ramp Gore
33 - Entrance Exit Lane Between Interchanges (9-1-89)
35 - Turning Lane Merge
36 - Turning Lane Gore
40 - Loop
41 - Loop Merge
42 - Loop Gore
50 - Collector - Distributor Road
51 - Collector - Distributor Road Merge
52 - Collector - Distributor Road Gore
60 - Cross-Street Between Terminal Areas
61 - Street Intersecting with Interchange Feature (9-1-89)
70 - Other Interchange Special Feature
80 - Unlocatable Accident - Reference Files Incomplete
81 - Unlocatable Driveway
86 - Unlocatable Alley Accident
88 - Unlocatable Accident - Insufficient Info on Accident Report

UNLOC 0025 001 N

SPECIAL FEATURE "D"

- First Column
Column for Bridge Code, Ramps, Terminals, Loops, Collector-Dist.

AR-WK-DA 0027 001 N

DAY OF THE WEEK

1 - Monday
2 - Tuesday
3 - Wednesday
4 - Thursday
5 - Friday
6 - Saturday
7 - Sunday

AR-SEVERITY 0028 001 N

SEVERITY

1 - Fatal Accident
2 - Personal Injury
3 - Property Damage Only

AR-HOUR 0029 002 N

TIME OF ACCIDENT - Military Time

00 - Not Stated
01 - 1:00 to 1:59 AM
02 - 2:00 to 2:59 AM, etc
12 - 12:00 Noon to 12:59 PM, etc
24 - 12:00 Midnight to 12:59 AM

AR-AGE1 0031 002 N
AR-AGE2 0033 002 N

ACTUAL AGE OF DRIVER

00 - Not Stated

AR-SEX1 0035 001 N
AR-SEX2 0036 001 N

SEX OF DRIVER

0 - Not Stated
1 - Male
2 - Female

AR-VEH-1-TYPE 0037 002 N
AR-VEH-2-TYPE 0039 002 N

TYPE OF VEHICLES

00 - Not Stated
01 - Passenger Car (or Station Wagon)
02 - Passenger Car and Trailer
03 - Single Unit Truck
04 - Truck-Tractor, Semi-Trailer
05 - Truck and Trailer
06 - Bus
07 - School Bus
08 - Motorcycle
09 - Moped
10 - Motor Home
11 - Farm Machinery
12 - "Highway" Equipment
13 - Special Mobilized Machinery
14 - Pickup Truck
15 - Pickup Truck with Camper Body
16 - Pickup Truck with Trailer
17 - Motor Home with Trailer
18 - O.H.P Patrol Unit
19 - Other Police Units
20 - Four-Wheel-Drive
21 - Ambulance
22 - Fire Truck
23 - Other Publicly Owned Vehicle
24 - Military Vehicle
99 - All Others

AR-CONT-SPED1 0041 002 N
AR-CONT-SPED2 0043 002 N

ACTUAL SPEED BEFORE CONTACT - (01-99)

00 - Stopped or Not Stated

AR-VEH1-ACT 0045 002 N
AR-VEH2-ACT 0047 002 N

WHAT VEHICLES DID

00 - Not Stated
01 - Went Straight Ahead
02 - Turned Left
03 - Turned Right
04 - Entered "U" Turn
05 - Stopped
06 - Slowed
07 - Started from Park
08 - Entered Other Lane
09 - Overtaking
10 - Backed
11 - Remained Stopped
12 - Ran Off Road
13 - Remained Parked
14 - Swerved Left
15 - Swerved Right
16 - Passing
99 - Other

AR-RDTYPE1 0049 002 N
AR-RDTYPE2 0051 002 N

TYPE OF ROAD

00 - Not Stated
01 - One Way Road
02 - Alley
03 - Two Lanes
04 - Three Lanes
05 - Four or More Divided
06 - Four or More Not Divided
07 - Driveway
08 - Turn Bay
09 - On Ramp
10 - Off Ramp
11 - Construction Zone
12 - Merging Lanes
13 - Collector Distributor (C-D) Road
14 - Loop
15 - Crossover (Median Opening)
16 - Frontage Road
17 - Traffic Circle (Rotary)
18 - Reversible Lane
19 - Elevated Structure
99 - Other

AR-TRAF1-CONTRL 0053 002 N
AR-TRAF2-CONTRL 0055 002 N

TYPE OF CONTROL

00 - Not Stated
01 - Stop Sign
02 - Traffic Signal
03 - Flashing Signal
04 - Yield Sign
05 - Warning Sign
06 - RR Gates, Signals
07 - No Passing Zone
08 - Officer
09 - No Control
10 - Abnormal Control
11 - Crosswalk Lanes
12 - Flagman
13 - Posted Speed
14 - Stop Lines
15 - Emergency Vehicle
99 - Other

AR-RDCHAR1 0057 002 N
AR-RDCHAR2 0059 002 N

ROADWAY CHARACTERISTICS

00 - Not Stated
01 - Straight - Level
02 - Straight - Upgrade
03 - Straight - Downgrade
04 - Straight - Hillcrest
05 - Curve - Level
06 - Curve - Upgrade
07 - Curve - Downgrade
08 - Curve - Hillcrest
09 - Combination of Sharp Curve and 05
10 - Combination of Sharp Curve and 06
11 - Combination of Sharp Curve and 07
12 - Combination of Sharp Curve and 08
14 - Not Level
15 - Curve
16 - Not Level with Curve
99 - Other

AR-COND-DR1 0061 001 N
AR-COND-DR2 0062 001 N
AR-COND-PED 0063 001 N

CONDITION OF DRIVERS AND PEDESTRIANS

00 - Not Stated
01 - Apparently Normal
02 - Drinking - Ability Impaired
03 - Odor of Alcoholic Beverage
04 - Drug Use Indicated
05 - Very Tired
06 - Sleepy
07 - Sick
08 - Condition Not Known
09 - Body Defects
99 - Other

AR-FIRST-STRUK1 0064 002 N
AR-FIRST-STRUK2 0066 002 N

OBJECT STRUCK - FIRST CONTACT

00 - Not Stated
01 - Fence Pole
02 - Utility Pole
03 - Guard Rail
04 - Guard Post
05 - Culvert
06 - Traffic Signal
07 - Barrier
08 - Curb
09 - Island
10 - Traffic Control Sign
11 - Ditch
12 - Embankment
13 - Tree
14 - Dividing Strip
15 - Retaining Wall
16 - Fence
17 - Bridge - Abutment
18 - Other Highway Structure
19 - Bridge - Rail
20 - Bridge - Post
21 - Bridge - Curbs
22 - Bridge - Superstructure (Beams)
23 - Building
24 - Delineator
28 - Bridge Pier (to be reinstated)
29 - Bridge Parapet (to be reinstated)

AR-CONT1 0068 002 N
AR-CONT2 0070 002 N

POINT OF FIRST CONTACT ON VEHICLE

00 - Not Stated
01 - Rightside - Forward
02 - Rightside - Center
03 - Rightside - Aft
04 - Rear - Right
05 - Rear - Center
06 - Rear - Left
07 - Leftside - Aft
08 - Leftside - Center
09 - Leftside - Forward
10 - Front - Left
11 - Front - Center
12 - Front - Right
13 - Other
14 - Top
15 - Bottom

FRONT - Combinations
REAR - Combinations of
RIGHTSIDE - Combinati
LEFTSIDE - Combinatio
CENTER - Combinations
RIGHT - Combinations o
LEFT - Combinations of
FORWARD - Combinatio
AFT - Combinations of C

AR-LIGHT

LIGHT CONDITIONS

0 - Not Stated
1 - Daylight
2 - Darkness
3 - Lighted
4 - Dawn
5 - Dusk
9 - Other

AR-WEATHER

TYPE OF WEATHER

0 - Not Stated or Other
1 - Clear
2 - Partly Cloudy
3 - Overcast
4 - Raining
5 - Snowing
6 - Fog
9 - Other

AR-PEDACT

PEDESTRIAN ACTIO

00 - Not Stated
01 - In Road Crossing -
02 - In Road Crossing -
03 - In Road Crossing - Crosswalk
04 - In Road Getting On
05 - In Road Walking W
06 - In Road Walking A
07 - In Road Pushing/W
08 - In Road Playing
09 - In Road Other Wor
99 - Other

IN ROADWAY - Comb
CROSSING ROAD - C
CROSSWALK - Combin

AR-RDICOND
AR-RD2COND

ROADWAY CONDITIC

0 - Not Stated
1 - Dry
2 - Wet
3 - Ice, Snow
4 - Muddy
9 - Other

AR-RD-SURF1
AR-RD-SURF2

SURFACE TYPE

0 - Not Stated
1 - Concrete
2 - Asphalt
3 - Gravel
4 - Dirt
9 - Other

AR-LOCAL

LOCALITY

0 - Not Stated
1 - Residential
2 - Business
3 - Industrial
4 - School
5 - Not Built-Up
9 - Other

CODING GUIDE

...ght

...binations of 10 thru 12
...nations of 04 thru 06
... Combinations of 01 thru 03
...Combinations of 07 thru 09
...mbinations of 02, 05, 08, & 11
...inations of 04, & 12
...ations of 06, & 10
...Combinations of 01, & 09
...tions of 03, & 07

0072 001 N

...TIONS

0073 001 N

...ATHER
...or Other

0074 002 N

... ACTION

...Crossing - At Intersection
...Crossing - Not At Intersection
...Crossing - At Other

...etting On/Off Vehicle
...alking With Traffic
...alking Against Traffic
...ushing/Working on Vehicle
...laying
...ther Working

... - Combinations of 01 thru 09
...AD - Combinations of 01 thru 03
... - Combinations of 01 and 03

0076 001 N
0077 001 N

...NDITIONS

0078 001 N
0079 001 N

...PE

0080 001 N

AR-VEHCONDI 0081 001 N
AR-VEHCOND2 0082 001 N

VEHICLE CONDITION
- 0 - Not Stated
- 1 - Apparently Normal
- 2 Brakes
- 3 - Steering
- 4 - Headlights
- 5 - Rearlights
- 6 - Tires
- 7 - Exhaust System
- 8 - Shocks
- 9 Other

AR-DIR1 0083 001 N
AR-DIR2 0084 001 N

DIRECTION OF TRAVEL
- 0 - Not Stated - Blank
- 1 - North
- 2 - East
- 3 - South
- 4 - West
- 5 - Northeast
- 6 - Southeast
- 7 - Southwest
- 8 - Northwest

AR-VIS 0085 002 N

VISIBILITY OBSCURED BY:
- 00 - Not Stated
- 01 - Trees
- 02 - Embankment
- 03 - Building
- 04 - Signs
- 05 - Parked Vehicles
- 06 High Weeds
- 07 - Fences
- 08 - Shrubbery (Bush, Hedge)
- 09 - Ice, Snow or Frost on Windows
- 10 - Smoke
- 11 - Fog
- 12 - Dust
- 13 - Rain
- 99 - Other

FILLER1 0087 001 N

- not referred to in any program

AR-CAUSE 0088 002 N

CAUSE OF ACCIDENT

Failed to Yield: (01-12)
- 01 - From Stop Sign
- 02 - From Yield Sign
- 03 - From Private Drive
- 04 - From County Road, at Through Hwy
- 05 - From Signal Light
- 06 - From Alley
- 07 - To Pedestrian
- 08 - To Vehicle on Right
- 09 - To Vehicle in Intersection
- 10 - To Emergency Vehicle
- 12 - Other

Followed too Closely for: (13-15)
- 13 - Human Element
- 14 - Traffic Condition
- 15 - Weather Condition

Unsafe Speed: (16-29)
- 16 - Drivers Ability - Aged
- 17 - Inexperienced Driver - Young
- 18 - Exceeding Legal Limit
- 19 - For Traffic Conditions
- 20 - For Type of Roadway (Gravel, Dirt, etc.)
- 21 - For Ice or Snow on Roadway
- 22 - Rain or Wet Roadway
- 23 - Wind
- 24 - Other Weather Conditions
- 25 - Vehicle Condition
- 26 - View Obstruction
- 27 - On Curve or Turn
- 28 - Impeding Traffic
- 29 - Other

Improper Turn: (30-37)
- 30 - From Wrong lane
- 31 - From Direct Course
- 32 - Right
- 33 - Left
- 34 - Turn-About
- 35 - To Enter Private Drive
- 36 - In Front of Oncoming Traffic

Changed Lanes Unsafely:
- 38 - Changed Lanes Unsafely

Stopped in Traffic Lane:
- 39 - Stopped in Traffic Lane

Failed to Stop: (40-46)
- 40 - For Stop Sign
- 41 - For Traffic Signal
- 42 - For School Bus
- 43 - For Railroad Gate or Signal
- 44 - For Officer or Flagman
- 45 - At Sidewalk or Stop Line
- 46 - Other

Unsafe Vehicle: (47-57)
- 47 - Brakes
- 48 - Steering
- 49 - Tires
- 50 - Suspension (i.e. Shock Absorbers)
- 51 - Headlights
- 52 - Tail Lights
- 53 - Stop Lights
- 54 - Wheel
- 55 - Exhaust System
- 56 - Windshield Wipers
- 57 - Other Mechanical Defects

Left of Center: (58-61)
- 58 - In Meeting
- 59 - No Passing Zone - Unmarked
- 60 - Marked Zone
- 61 - Other

Improper Overtaking: (62-66)
- 62 - In Marked Zone
- 63 - On Hill or Curve
- 64 - At Intersection
- 65 - Without Sufficient Clearance
- 66 - Other

Improper Parking: (67-69)
- 67 - On Roadway
- 68 - Where Prohibited
- 69 - Other

Inattention: (70-73)
- 70 - Distracted by Passenger in Vehicle
- 71 - Other Distraction in Vehicle
- 72 - Distraction from Outside Vehicle
- 73 - Other

Wrong Way On: (74-77)
- 74 - One Way
- 75 - Exit Ramp
- 76 - Entrance Ramp
- 77 - Other

Improper Start From: (78-79)
- 78 - Parked Position
- 79 - Other

Other Improper Act or Movement: (80-88)
- 80 - Driving Under Influence of Alcohol
- 81 - Driving Under Influence of Drugs
- 82 - Failed to Signal
- 83 - Disregard Warning Signal
- 84 - Improper Use of Lane
- 85 - Improper Backing
- 87 - Failure to Secure Load
- 88 - Other

Not Known or No-Improper-Action: (89-99)
- 89 - Deer
- 90 - Animal on Roadway
- 91 - Avoiding Other Vehicle
- 92 - Avoiding Pedestrian
- 93 - Avoiding Animal
- 94 - Obstruction in Roadway
- 95 - Defect in Roadway
- 96 - Abnormal Traffic Control
- 97 - Improper Bicyclist Action
- 98 - Other Action - No Improper Action by the Driver
- 99 - Pedestrian Action - No Improper Action

ANIMAL: (90-93)

AR-DAM 0090 005 N

DAMAGE ESTIMATE
- Use Total Dollars from Report

AR-CASE NUM 0095 008 N

CASE NUMBER OF REPORT
(See Below)

AR-YR 0095 001 N

CALENDAR YEAR
- Last Number of Year

AR-JULIAN 0096 003 N

DAY - Numerical Day of the Year
(See Julian Date Calendar)
- 001 - January 1
- 002 - January 2, etc.
- 032 - February 1, etc.
- 059 - February 28, etc.
- 365 - December 31 (Except on Leap Years)

AR-SERIAL 0099 004 N

SERIAL NUMBER - Assigned by DPS

AR-COLLISN-CODE 0103 005 N

COLLISION DIAGRAM CODE - See Below

INTERSEC-DESIGN 0103 001 N

INTERSECTION DESIGN
- 0 - Not Stated or Not at Intersection
- 1 - "T" Intersection (Three-Legged)
- 3 - "+" Intersection (Four Legged)
- 4 - Five Legged Intersection

AR-TERMINAL-LOCATION 0104 001 N

TERMINAL LOCATION
- 0 Not Stated or Not Applicable
- 1 - Terminal Location - Left
- 2 - Terminal Location Right
- 3 Terminal Location - Unable to Define

QUADRANT 0105 001 N

QUADRANT
- 0 - Not Stated or Not at Intersection
- 1 - Northeast (or Upper Right of "T" Intersection)
- 2 - Southeast (or Lower Right of "T" Intersection)
- 3 Southwest (or Lower Left of "T" Intersection)
- 4 - Northwest (or Upper Left of "T" Intersection)

AR-COLLISION-CODE 0106 002 N

COLLISION TYPE
- See Collision Diagram Coding Guide
- 00 - Not at Intersection

ANGLE	-01
TURNING LEFT	Comb of 06 thru 10 and 12 and 15
REAR END	Comb of 02 thru 05
TURNING RIGHT	Comb of 11, 13, 14, 24
SIDESWIPE	Comb of 16, 17
PEDESTRIAN	Comb of 21, 23

AR-DECADE 0108 001 N

Not Listed in Accident Fields

TRAFFIC ENGINEERING DIVISION

AR LEGAL-SPD-1 0109 002 N
AR LEGAL-SPD-2 0111 002 N

LEGAL SPEED
- Use Legal Speed on Report (01-99)
- 00 - Stopped or Not Stated

AR-DIV 0113 001 N

DOT FIELD MAINTENANCE DIVISION
- See Map or County Listing

AR-FADATA 0114 007 N

FEDERAL AID AND FUNCTIONAL CLASS
- Federal Aid and Functional Class Info on Roadway Classification

AR-ROUTE 0114 004 N

FEDERAL AID ROUTE NUMBER
- Federal Aid Primary Route Number
- Federal Aid Secondary Route Number

AR FEDSYS 0118 001 N

TYPE OF FEDERAL AID SYSTEM
- 0 - Non-Federal Aid (Rural or Urban)
- 1 - Federal Aid Primary (Rural or Urban)
- 2 - Federal Aid Secondary (Rural)
- 3 - Federal Aid Interstate (Rural or Urban)
- 4 - Toll Roads
- 5 Federal Aid Interstate Travelway (Carries Interstate Detour Traffic)
- 6 - Federal Aid Urban
- 7 - Future Federal Aid Primary
- 8 - Future Federal Aid Secondary
- 9 - Future Federal Aid Urban

AR-FEDCLASS 0119 001 N

TYPE OF FUNCTIONAL CLASSIFICATION
- 1 - Interstate
- 2 - Other Urban Freeways and Expressways
- 3 - Other Principal Arterials
- 4 - Minor Arterials
- 5 - Major Arterials Rural, Collector Urban
- 6 - Minor Collector Rural
- 7 Local Rural Road, Local City Streets

AR-RURMUN 0120 D01 N

URBAN AREA TYPE
- 1 - Rural
- 2 Urban
- 3 - Arkoma Urbanized Area
- 4 Enid Urbanized Area
- 5 Lawton Urbanized Area
- 6 - Oklahoma City Urbanized Area
- 7 - Tulsa Urbanized Area

AR-DATE 0121 008 N

CALENDAR DATE
- Date in Year, Month, and Day Format

AR-CENTURY 0121 002 N

First Two Digits of the Year

AR-YEAR 0123 002 N

Last Two Digits of the Year

AR MONTH 0125 002 N
- 01 - January
- 02 - February
- 12 - December

AR-DAY 0127 002 N
- Day of the Month
- 01 thru 31

AR DPSCASE 0129 009 N

DEPT. OF PUBLIC SAFETY CASE NUMBER
- nine digit case number assigned to document at time of filming

AR COMM DIST 0138 001 N
AR COLLTYPE 0139 002 N

RECAPITULATED COLLISION CODE NUMBER
- 01 OVR-TRN (IN RD)
- 02 PEDESTRIAN
- 03 - PARKED-VEHICLE
- 04 - RAILROAD TRAIN
- 05 BICYCLIST
- 06 - ANIMAL
- 07 FIXED-O(OTHER
- 08 - RAN-OFF ROAD
- 09 S-S (OPP DIR)
- 10 REAR END
- 11 - HEAD-ON
- 12 S-S (OPP DIR)
- 13 - ANGLE (TURN)I
- 14 ANGLE (TURN)NI
- 15 ANGLE (I)
- 16 - ANGLE (NI)
- 17 - BACKING
- 18 - OTHER
- 19 - F-O(FENCEPOLE)
- 20 - F-O(UTIL POLE)
- 21 - F-O(GD RAIL)
- 22 - F-O(GD-POST)
- 23 F-O(CULVERT)
- 24 - F-O(TRAF SIG)
- 25 F-O BARRIER)
- 26 F-O(CURB)
- 27 F-O(ISLAND)
- 28 F-O(TRAF SIGN)
- 29 - F-O(DITCH)
- 30 - F-O(EMBANKMENT)
- 31 F-O(TREE)
- 32 - F-O(DIV STRIP)
- 33 - F-O(RETN WALL)
- 34 F-O(FENCE)
- 35 - F-O(BR ABUTMT)
- 36 - F-O(OTHER STR)
- 37 - F-O(BR RAIL)
- 38 - F-O(BR POST)
- 39 - F-O(BR CURBS)
- 40 - F-O(BR STRUCT)
- 41 - F-O(BUILDING)
- 42 - F-O(DELINEATR)
- 46 - F-O(BR PIER)
- 47 F-O(BR PARAPT)

APPENDIX C Example Printout of Accident Data File

F76	driF2	F5	F7	F16	F65	F66	F71	F79	F80	F81	F82	Inve	F83	F84	F85	F86	F87	F88	F89	F89	F89	F89	F90	volume	F76	year	make	model	style	weight
46712680	72	80	921	2	45	0	7	1	99	9	9	9	9	9	9	9	9	999	9	9	9	9	9		46712680					
47500754	21	6	1350	3	30	0	1	6	3	8	1	1	1	2	1	1	4	1000	1	1	1	1	8	4500	47500754	84	CHEV	KODIAC	TRUCK	N.A
47500962	16	49	1020	2	55	0	5	1	99	9	9	9	9	9	9	9	9	999	9	9	9	9	9		47500962					
47501131	16	49	846	3	55	0	5	1	99	9	9	9	9	9	9	9	9	999	9	9	9	9	9		47501131					
47501637	55	7	977	3	55	0	6	5	11	1	1	0	2	0	6	1	4	1	1	1	1	1	2	56000	47501637	76	CHEV	MONTE CARLO	2-DR	3907

APPENDIX D Pairwise Comparison of Means (Games-Howell Procedure)

END HITS

```
number of groups is        6
number of pairwise comparisons is    15.0000

for groups       1     2
group, n, mean, std dev       1   133        2.0977444000        1.5068765000
group, n, mean, std dev       2   116        2.1206897000        1.3523260000
t=     -.1266 with df=   246.7913 and p=      .8993

for groups       1     3
group, n, mean, std dev       1   133        2.0977444000        1.5068765000
group, n, mean, std dev       3    38        2.1578947000        1.5858550000
t=     -.2085 with df=    57.4794 and p=      .8356

for groups       1     4
group, n, mean, std dev       1   133        2.0977444000        1.5068765000
group, n, mean, std dev       4    17        2.1764706000        1.5904125000
t=     -.1933 with df=    19.8508 and p=      .8487

for groups       1     5
group, n, mean, std dev       1   133        2.0977444000        1.5068765000
group, n, mean, std dev       5    78        2.7179487000        1.5365456000
t=    -2.8504 with df=   158.8743 and p=      .0049

for groups       1     6
group, n, mean, std dev       1   133        2.0977444000        1.5068765000
group, n, mean, std dev       6    24        3.0833333000        1.7173454000
t=    -2.6345 with df=    29.7348 and p=      .0132

for groups       2     3
group, n, mean, std dev       2   116        2.1206897000        1.3523260000
group, n, mean, std dev       3    38        2.1578947000        1.5858550000
t=     -.1300 with df=    55.7100 and p=      .8971

for groups       2     4
group, n, mean, std dev       2   116        2.1206897000        1.3523260000
group, n, mean, std dev       4    17        2.1764706000        1.5904125000
t=     -.1375 with df=    19.5398 and p=      .8920

for groups       2     5
group, n, mean, std dev       2   116        2.1206897000        1.3523260000
group, n, mean, std dev       5    78        2.7179487000        1.5365456000
t=    -2.7837 with df=   150.7217 and p=      .0061

for groups       2     6
group, n, mean, std dev       2   116        2.1206897000        1.3523260000
group, n, mean, std dev       6    24        3.0833333000        1.7173454000
t=    -2.5853 with df=    29.1839 and p=      .0150

for groups       3     4
group, n, mean, std dev       3    38        2.1578947000        1.5858550000
group, n, mean, std dev       4    17        2.1764706000        1.5904125000
t=     -.0401 with df=    30.7671 and p=      .9683

for groups       3     5
group, n, mean, std dev       3    38        2.1578947000        1.5858550000
group, n, mean, std dev       5    78        2.7179487000        1.5365456000
t=    -1.8033 with df=    71.4064 and p=      .0756

for groups       3     6
group, n, mean, std dev       3    38        2.1578947000        1.5858550000
group, n, mean, std dev       6    24        3.0833333000        1.7173454000
t=    -2.1283 with df=    46.1282 and p=      .0387
```

```
for groups       4      5
group, n, mean, std dev      4     17          2.1764706000          1.5904125000
group, n, mean, std dev      5     78          2.7179487000          1.5365456000
t=    -1.2796 with df=    22.9745 and p=      .2134

for groups       4      6
group, n, mean, std dev      4     17          2.1764706000          1.5904125000
group, n, mean, std dev      6     24          3.0833333000          1.7173454000
t=    -1.7399 with df=    36.1766 and p=      .0904

for groups       5      6
group, n, mean, std dev      5     78          2.7179487000          1.5365456000
group, n, mean, std dev      6     24          3.0833333000          1.7173454000
t=     -.9337 with df=    35.0900 and p=      .3569
```

APPROACH END

```
number of groups is       6
number of pairwise comparisons is    15.0000

for groups        1     2
group, n, mean, std dev      1   115        2.1652174000        1.5442618000
group, n, mean, std dev      2   104        2.1346154000        1.3585950000
t=      .1560 with df=   216.8418 and p=      .8762

for groups        1     3
group, n, mean, std dev      1   115        2.1652174000        1.5442618000
group, n, mean, std dev      3    38        2.1578947000        1.5858550000
t=      .0248 with df=    61.8481 and p=      .9803

for groups        1     4
group, n, mean, std dev      1   115        2.1652174000        1.5442618000
group, n, mean, std dev      4    17        1.9411765000        1.2485285000
t=      .6682 with df=    23.8837 and p=      .5104

for groups        1     5
group, n, mean, std dev      1   115        2.1652174000        1.5442618000
group, n, mean, std dev      5    71        2.7746479000        1.5324787000
t=    -2.6271 with df=   149.2597 and p=      .0095

for groups        1     6
group, n, mean, std dev      1   115        2.1652174000        1.5442618000
group, n, mean, std dev      6    22        3.0909091000        1.6877455000
t=    -2.3884 with df=    28.1324 and p=      .0239

for groups        2     3
group, n, mean, std dev      2   104        2.1346154000        1.3585950000
group, n, mean, std dev      3    38        2.1578947000        1.5858550000
t=     -.0804 with df=    58.0066 and p=      .9362

for groups        2     4
group, n, mean, std dev      2   104        2.1346154000        1.3585950000
group, n, mean, std dev      4    17        1.9411765000        1.2485285000
t=      .5847 with df=    22.6612 and p=      .5645

for groups        2     5
group, n, mean, std dev      2   104        2.1346154000        1.3585950000
group, n, mean, std dev      5    71        2.7746479000        1.5324787000
t=    -2.8390 with df=   138.2259 and p=      .0052

for groups        2     6
group, n, mean, std dev      2   104        2.1346154000        1.3585950000
group, n, mean, std dev      6    22        3.0909091000        1.6877455000
t=    -2.4923 with df=    27.0481 and p=      .0191

for groups        3     4
group, n, mean, std dev      3    38        2.1578947000        1.5858550000
group, n, mean, std dev      4    17        1.9411765000        1.2485285000
t=      .5454 with df=    38.7110 and p=      .5886

for groups        3     5
group, n, mean, std dev      3    38        2.1578947000        1.5858550000
group, n, mean, std dev      5    71        2.7746479000        1.5324787000
t=    -1.9576 with df=    73.5197 and p=      .0541

for groups        3     6
group, n, mean, std dev      3    38        2.1578947000        1.5858550000
group, n, mean, std dev      6    22        3.0909091000        1.6877455000
t=    -2.1093 with df=    41.7623 and p=      .0410
```

```
for groups        4      5
group, n, mean, std dev      4     17          1.9411765000          1.2485285000
group, n, mean, std dev      5     71          2.7746479000          1.5324787000
t=    -2.3596 with df=    28.7697 and p=      .0253

for groups        4      6
group, n, mean, std dev      4     17          1.9411765000          1.2485285000
group, n, mean, std dev      6     22          3.0909091000          1.6877455000
t=    -2.4447 with df=    36.9521 and p=      .0194

for groups        5      6
group, n, mean, std dev      5     71          2.7746479000          1.5324787000
 group, n, mean, std dev      6     22          3.0909091000          1.6877455000
t=     -.7844 with df=    32.4646 and p=      .4385
```