

Highway Safety Challenges on Low-Volume Rural Roads

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Abstract

Most highway-safety related research in the United States over the past 40 years has focused on major facilities (freeways, arterials, interchanges or intersections), or on specific treatments (traffic control devices, roadside barriers, rumble strips). Little effort has been devoted to a systematic assessment of potential safety improvements on low-volume rural roads, such as those administered by most counties, some states, and certain federal agencies. Although treatments that are safety effective on higher traffic volume facilities should also improve safety on low-volume roads, they may not be cost-effective.

This paper analyzes the crash occurrence and potential safety treatments on low-volume rural roads. A safety survey was developed and distributed to a sample of those officials responsible for these roads. Using traffic volume data and traffic accidents for 1998-2001, potential field study sites were identified on rural state highways in New Mexico with average traffic volumes of less than 400 vehicles per day. Computer analyses of the accident data identified some common patterns among crashes on these roads. Field studies, somewhat less rigorous than road safety audits, were undertaken on nearly 300 miles of these highways for the purpose identifying potential low-cost countermeasures that could be effectively deployed at spot locations. The findings and recommendations from this research may be of interest to those responsible for enhancing safety on low-volume rural roads.

Background

Motorists expect that an Interstate highway serving tens of thousands of vehicles each day will meet certain standards of design and maintenance, as well as provide them with abundant information regarding regulations, warning of hazards, and guidance. However, financial constraints limit the ability of many local jurisdictions to design and maintain smaller, lesser-traveled roadways in the same manner as Interstate highways. Nevertheless, motorists should rightly expect all roadways to provide a level of maintenance and information adequate for safe travel. Highway and traffic engineers are responsible for providing motorists with facilities whose design (geometrics, roadsides, and surfacing) and operations (signing, marking, and signalization) are conducive to safe travel.

Engineers traditionally improve highway safety by identifying problem locations, selecting and implementing treatments, and monitoring crash experience after implementation to see if the problem has been ameliorated. On high-volume routes, the before-and-after accident studies often have sufficient sample sizes to provide statistical grounds for evaluating treatment effectiveness. On low-volume rural roads (LVRR), however, this method of identifying and correcting problems may be impractical. The before-and-after accident studies on these facilities are difficult to assess statistically, and treatments suggested by similar conditions on a high-volume roadway are often economically impractical.

Three-quarters of the public roadway mileage in the United States – over three million miles of designated road – is considered rural. Although the categorization of low-volume roads varies from those having average daily volumes of less than 200 to those with less than 1000, it is clear that many rural roads would fall into a low volume classification. (See Figure 1.) The purpose of this research (1) was to assess the safety conditions on these roads and develop a set of potentially cost-effective highway safety treatments for these roads. The project reviewed the technical literature, sought input on the state-of-the-practice for these roads, performed an analysis of LVRR crash characteristics, and conducted field studies on a set of LVRR with unusually high crash rates.



Figure 1. Typical Low-Volume Rural Road

State of the Art

The Transportation Research Board (TRB) sponsors a quadrennial Conference on Low-Volume Roads that attracts a large number of engineers and planners responsible for these roads. The majority of the research reported at this conference is focused on road surface materials and maintenance; few papers address traffic operations or safety. One exception is the conference paper by Calvert and Wilson (2), which indicates that full conformance to acceptable minimum criteria is not reasonable, viable, or necessary with regard to unpaved rural roads.

Primary guidance on the design and operation of LVRR comes from relatively recent policies and standards promulgated by the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), state departments of transportation, the US Forest Service, and the National Association of County Engineers (NACE). The MUTCD (3) is the official national standard specified by the Code of Federal Regulations for traffic control on public streets, highways and bicycle trails. Chapter 5 of the MUTCD Millennium Edition presents material on the use of traffic control devices on low-volume roads. For the purposes of the MUTCD, a low-volume road:

- has a daily traffic volume less than 400 vehicles per day
- lies outside of built-up areas
- is not on a state-designated system

Like the rest of the MUTCD, this chapter emphasizes the importance of exercising informed engineering judgment. However, it does not introduce any unique or modified warrants for device usage. The only significant modifications in Chapter 5 are:

- permission to use smaller sign sizes
- reduction in lateral placement of signs
- permission to use the new NO TRAFFIC SIGNS sign on unpaved low-volume rural roads

AASHTO (formerly AASHO) began publishing highway design pamphlets in 1938. Over the years, these evolved into policies that became widely accepted as examples of good practice. A

Policy on Geometric Design of Highways and Streets (4), the “Green Book,” is the authoritative source document on roadway design. Even though it contains a chapter on local roads, this document is primarily oriented toward high-speed, high-volume roads. AASHTO’s Roadside Design Guide (5) targets issues such as clear zones, sideslopes, roadside objects, and barriers. According to this guide, clear zone widths for the lowest volume road category (under 750 ADT) with a design speed of 55 mph range from 8 to 18 feet. The RGD admits that its barrier warrants may not be cost-effective on low-volume roads and recommends that highway agencies “develop similar warranting based upon their own cost-effectiveness evaluations.”

AASHTO recently published Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT # 400) (6). Defining very LVRR as those whose “primary function is to provide access to residences, farms, businesses or other abutting property,” the document suggests guidelines for several functional subclasses of local roads based primarily on user type. The guide generally assumes that most motorists are familiar with the roadway and its geometries. Separate guidelines are provided for the following roadway distinctions:

- low speed (0 to 45 mph) vs. high speed (> 45 mph)
- newly constructed vs. reconstructed
- paved vs. unpaved
- three ADT levels: 100 vehicles per day (vpd) or less, 100 to 250 vpd, 250 to 400 vpd

AASHTO now permits the use of different design parameters on low-volume roads, particularly at low-risk locations, defined as those not near intersections, narrow bridges, railroad-highway grade crossings, sharp curves, or steep downgrades. For example, allowable stopping sight distances are shortened in low-risk locations by using a perception-reaction time of 2.0 sec, rather than the Green Book value of 2.5 sec, and a deceleration rate of 13.4 ft/s², rather than 11.2 ft/s².

The Forest Service Handbook (7) and Sign and Poster Guidelines for the Forest Service (8) are intended to aid that agency’s personnel in maintaining its roads. The Handbook provides extensive detail on the designation of various roadway maintenance levels based on volume, type, class and composition of traffic, surface type, travel speed, user comfort and convenience, and environmental protection needs. The Sign and Poster Guidelines provide signing information relevant to the special needs of Forest Service roads. For example, speed warrants for use of Turn and Curve warning signs are reduced (from the MUTCD) by 10 mph due to the lower speeds on these roads. In addition, the USFS places traffic signs on dead-end roads only for the inbound motorist. This practice is based on the assumption that motorists who traversed the inbound road know where curves and other hazards are located, thus obviating the need for signs on the outbound traverse.

The National Association of County Engineers (NACE) produces the Action Guide Series, a collection of 19 manuals intended to assist county engineers and county public works agencies with the various aspects of their duties. Safety Improvements (9) recognizes that rural counties have limited resources for locating and improving hazardous spots on their roadways, and that the nature of problems is often quite different in rural and urban locations. The guide encourages proper signing, along with the more expensive roadway realignment and major reconstruction. Providing adequate sight distance is cited as the most cost-effective improvement at

intersections, though use of oversized signs and rumble strips is also suggested. Standard 12-ft lanes and 10-ft clear zones are repeatedly suggested, and installation of guardrail is encouraged even on low-speed roads. Signs and markings are given more extensive treatment in the NACE Action Guide Traffic Operations (10). Procedures for some typical traffic studies are abbreviated versions of procedures detailed in the Manual of Traffic Engineering Studies (11).

Several states have developed their own manuals for LVRR operations. The most complete example is Kansas' Handbook of Traffic Control Practices for Low Volume Rural Roads (12). This handbook, which is not a legal document in Kansas, is intended for use by county and city engineers and county road supervisors. The handbook defines low-volume rural roads as "county and township roads carrying less than 400 vehicles per day." The intent of the manual is to balance safety and cost, so that "a reasonably prudent driver, even a stranger to the area, will be able to safely travel the roads." The suggested practices are, therefore, highly dependent on the principles of driver expectancy, positive guidance (13), and consistency in the nature of the road from one section to another. The cornerstone of the manual is the implementation of the Commentary Driving Procedure for evaluation of the safety conditions on LVRR. The procedure involves a trained observer driving the roadway being evaluated, recording his expectations of the road (such as "it appears to curve to the left up ahead"), noting locations that violate his expectations and further examining these locations to develop potential safety treatments.

Idaho (14) and New York (15) have similar manuals for low-volume roads. New York, for example, permits the use of a "MINIMUM MAINTANCE ROAD" sign on an unpaved, low-volume road. The Washington State Modifications to the MUTCD (16) includes a provision to use the "PRIMITIVE ROAD" (see Figure 2) sign on a portion of a county road that:

- Is not classified as part of the county primary road system,
- Has a gravel or earth driving surface, and
- Has an average annual daily traffic of one hundred or fewer vehicles

An accompanying "CAUTION – NO WARNING SIGNS" sign may also be posted, with or without a "NEXT XX MILES" plaque.



Figure 2. Washington Sign

Local Agency Survey

The documents cited in the previous section consistently note that decisions about using traffic control devices are left to engineering judgment. Although this is reasonable for larger highway agencies with a trained staff, it is appropriate to ask how public works directors, engineers, or road superintendents responsible for LVRR operation and maintenance develop a basis for making informed engineering judgment. To address this issue, this project conducted a survey of officials responsible for low-volume rural roads. The survey instrument (1, Appendix), consisting of 11 questions that could be answered by the respondents with no additional research, was distributed to 48 individuals representing county agencies, USFS, and the Bureau of Indian Affairs (BIA); the survey response rate was 40%.

Several questions solicited information on the respondents' management of their LVRR system. Only 35% of the departments indicated that they currently use a classification scheme. Although 90% of the departments are receptive to citizen complaints, only 60% have a TCD inventory, and only 65% have a program for identifying and correcting safety problems; 45% of the departments have both. The respondents employed various techniques for identifying and correcting safety problems. The most common methods for hazardous location identification were regular maintenance checks, accident history reviews, and/or user complaints. The USFS has one of the most comprehensive policies for maintaining roadway safety, outlined in its Handbook (7).

State motor vehicle laws establish statutory speed limits, which specify an enforceable limit if limits are not established through the speed zoning process. For example, New Mexico's statutory speed limit is 55 mph on rural highways. The lack of speed enforcement on LVRR may cause motorists to rely on roadway appearance in selecting their speed rather than a posted or statutory speed limit. Because some LVRR are subject to variable conditions – rutting and erosion, especially on unpaved roads – setting speed limits can be problematic. Only 20% of the responding agencies indicated that they post speed limits on all their LVRR. Forty-five percent indicated they post speed limits on some LVRR, while the remainder indicated they rarely post speed limits. The principal factors used by agencies to determine an appropriate speed are sight distance and roadway alignment. Roadway surface and function are considered by about half the agencies; less than half take crash experience into consideration. Five agencies listed the 85 percentile speed study as an important parameter.

For counties with extensive LVRR systems and limited roadway budgets, deciding which roads to improve and what improvements to make are difficult tasks. Roadway user complaints, unsafe conditions found by a field evaluation, and high maintenance costs were factors cited by most agencies in making their improvement decisions. Crash experience was listed as an important selection factor by less than half of the respondents. Respondents indicated that recent litigation has minimal impact on the decision to improve LVRR.

To determine which standards agencies use in making highway design and traffic improvements to their LVRR, respondents were asked to identify the references. The MUTCD (80%) and the three AASHTO publications (75%, with the Low-Volume Road Guide being the most popular) are the most helpful. NACE publications were used by about 40%; the lone respondent from Kansas reported using that state's manual. With respect to the standards they do utilize, only 35% of the respondents indicated they always achieve standard design criteria, while 10% almost never reach that goal. Moreover, 68% felt that the effective safety treatments used on higher volume roadways are possibly applicable but not economically justified for use on LVRR; 11% felt that these treatments are not applicable to LVRR at all.

Few agencies responsible for a significant mileage of LVRR have solid studies documenting countermeasure effectiveness. Respondents were asked to identify what they felt were the top two or three most cost-effective safety improvements on LVRR. The most common responses were:

- (55%) Signs: more, better, more consistent.

- (50%) Geometrics: improve sight distance, eliminate geometric problem areas, use proper roadway width, use appropriate cross slope.
- (45%) Road surface: general surface condition, oil and chipping of gravel roads, caliche.
- (20%) Inspection and maintenance programs.

New Mexico LVRR

Field Study Site Selection

One purpose of this research was to assess the characteristics of traffic accidents on a sample of low-volume rural roads. New Mexico has extensive mileage of roads that can be properly categorized as rural and low-volume. The analysis was accomplished in two phases:

- The characteristics of a large sample of accidents on these roads were compared to those on all roads.
- Field visits were conducted on selected low-volume roads at the locations of traffic accidents to determine the potential for their amelioration through the deployment of highway design or traffic engineering treatments.

Although the state-of-the-practice surveys focused on county-administered roads, these roads are not necessarily the best choice for detailed analysis of crashes. Many county roads have poor traffic volume data; state-administered roads, with potentially better volume and crash location information, were used for accident analyses and site visits. The following criteria were used to cull a set of 40 potential sites from the large pool of rural, state-administered, low-volume roads in New Mexico:

- Average daily traffic volumes between 150 and 400 vehicles per day
- Segment length in excess of 15 miles (to give a meaningful sample size)
- Paved roads, typically with a 55-mph speed limit over the whole route (except maybe terminals)

To further simplify analysis, routes with significant lengths in more than one county were dropped. To facilitate field visits, segments beyond about 225 miles from Albuquerque were also dropped from the list of analysis sites. This paring yielded 17 road segments, shown in Figure 3, in north-central New Mexico. Accidents reported on these route segments but with unknown mileposts were excluded from the analyses because they would be impossible to locate in the field. The accident sample consisted of 447 accidents that took place on these segments in the four years between January 1, 1998, and December 31, 2001. The computerized accident records contained information of interest to the engineer, including:

- Report number

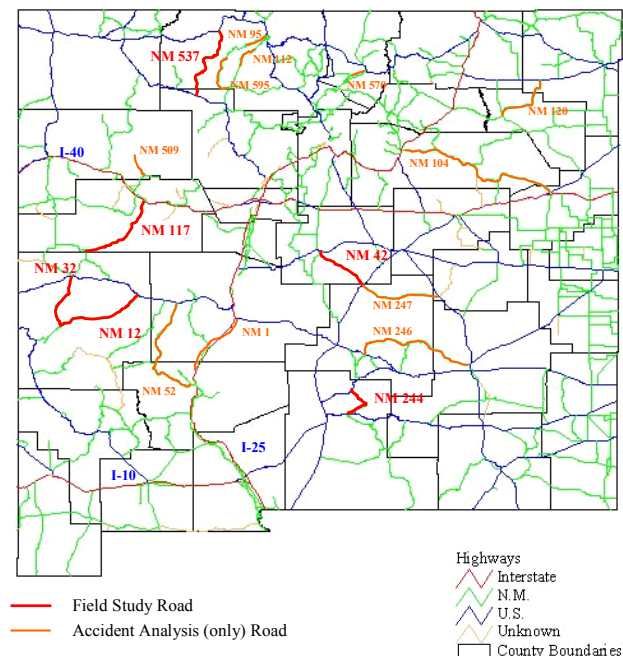


Figure 3 New Mexico LVRR Accident Analysis and Field Survey Sections

- Date and hour of accident
- Location (county, route, milelog^a and direction of travel)
- Crash severity (fatality, injury, property damage only)
- Road element (intersection, non-intersection, intersection-related, driveway)
- Road characteristic (straight, curve)
- Road grade (level, hillcrest, grade)
- Road condition (dry, wet, snow-covered, icy, loose material)
- Road surface (unpaved, paved, center stripe only, center and edge lines)
- Traffic control (none, no passing zone, STOP sign, signal, flasher)
- Number and Type(s) of vehicle(s) (passenger, pickup, semi, bus, or motorcycle)
- Collision classification (overturn, other vehicle, parked vehicle, animal, fixed object)
- Highest contributing factor to the accident (alcohol, speed, improper overtake, inattention)

^aOn New Mexico's rural highways, milelog is the administrative equivalent of milepost.

Using reported AADT for 2000, and the four-year accident number for 1998-2001, an estimate of the accident rate was calculated for each of the LVRR segments. Accident rates ranged from 0.30 accidents/mvm (on NM 112) to 5.56 accidents/mvm (on NM 244). The average accident rate for these 17 segments was 1.39 accidents/mvm. Because of the methods by which these segments were selected, the calculated average certainly exceeds the average for all New Mexico's rural low-volume roads.

New Mexico LVRR Crash Characteristics

The 447 accident reports cited earlier were used to generate some general accident characteristics for New Mexico's LVRR. There are some important caveats associated with these statistics.

- This is not a complete set of accident records for these 17 roads for the four-year period. Besides crashes with unknown locations, some crashes are never reported.
- Mistakes are made when transferring information from written accident reports to the computerized database.
- New Mexico had serious accident data reporting and computer coding problems in 1999, particularly the last three months; this certainly resulted in a reduced sample for that year.

Data for New Mexico's 17 road segments were compared to data from the National Highway Traffic Safety Administration's "Traffic Safety Facts 2000" (17). The TSF 2000 data are estimates of the national statistics, based on the Fatality Analysis Reporting System and the National Automotive Sampling System General Estimates System. TSF 2000 data represent accidents on all roads, urban and rural, and all traffic volume levels. A comparison of accident characteristics on New Mexico LVRR to roadways nationwide can serve as a base point for analysis. Table 1 indicates that the overall accident rate for New Mexico's LVRR is below the national average, while the fatal accident rate is almost four times as high.

Table 1. NM LVRR and National Accident Rates		
Rates	NM LVRR	TSF 2000 (all roads)
Accident rate (per mvm)	1.4	2.3
Fatality rate (per 100 mvm)	5.3	1.4

Table 2 compares the distribution of by crash type and severity between the New Mexico sample and the national estimates. The low volume of traffic on NM LVRR obviously reduces the potential for multiple vehicle accidents.

Table 2. NM LVRR and National Crash Distributions		
Characteristic	NM LVRR	TSF 2000
Single vehicle accidents	89.0%	30.0%
Fatal accident	3.8	0.6
Non-fatal injury accidents	36.5	32.0
Overtuning accidents	28.4	2.0
Collision with fixed object	20.6	15.0
Collision with animals	34.7	4.0

Figure 4 shows the distribution of NM LVRR accidents by collision classification. Over one-third of the accidents involve an animal struck by a vehicle, and 80% of these animals are either deer or elk. There were no reported accidents involving a pedestrian on any of these LVRR.

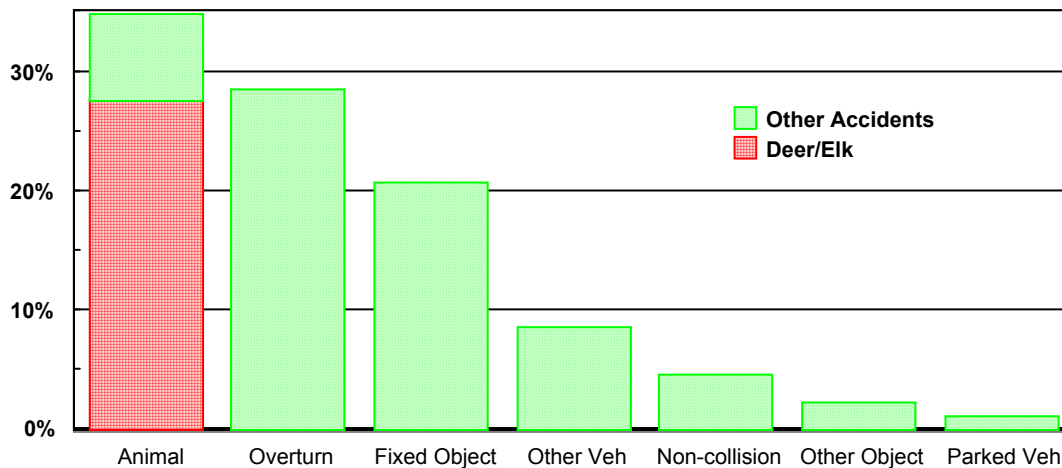


Figure 4. NM LVRR Crash Type Distribution, 1998-2001

About 9.6% of New Mexico’s LVRR accidents occur on Monday. This steadily increases throughout the week to 15.4% on Friday, jumps to 22% on Saturday, and drops to 17% on Sunday. This contrasts with the national daily distribution of accidents, where Saturday and Sunday account for the smallest percentage of accidents. Increased recreational travel on LVRR during the weekends is the most likely explanation for the greater proportion of weekend accidents. The monthly distribution of accidents on New Mexico’s LVRR range from 3-4% in January and February to 12% and 16% in August and September, respectively.

Figure 5 shows the hourly distribution of 124 deer/elk accidents and 323 other accidents on New Mexico’s LVRR. The most troublesome time for deer/elk impacts is between 6 pm and 2 am with 62% of the crashes. Other accidents show a peak between 2 and 5 pm, which accounts for 25% of the crashes. The period from 7 am to 1 pm accounts for another 30% of the LVRR accidents. Approximately 44% New Mexico’s LVRR accidents occurred between 6:00 pm and 6:00 am; according to TSF 2000, only 31% of all accidents nationwide occur during this time span.

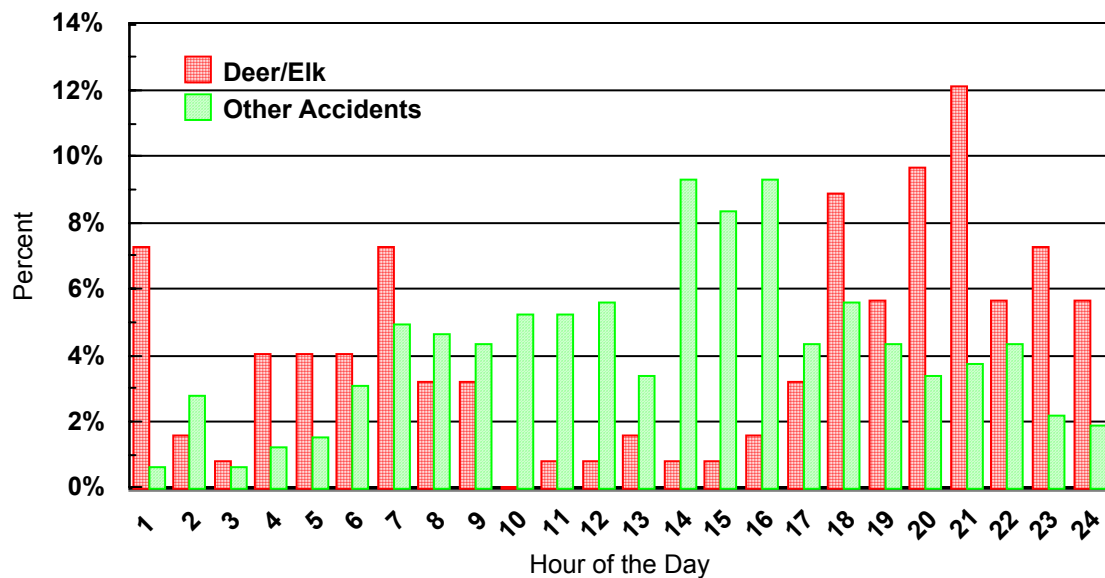


Figure 5. Hourly Distribution of NM LVRR Accidents, 1998-2001

Over 90% of New Mexico’s reported accidents on LVRR occurred on dry pavement; this figure, which obviously depends on weather conditions, is virtually identical to the pavement condition reported for all of the state’s traffic accidents. On the New Mexico traffic accident form, the investigating officer is asked to identify the factors that contributed to the accident. This is a challenge because 90% of the crashes involve a single vehicle, so the officer probably didn’t witness the accident and the chances are high that there are no witnesses besides the motorist involved. In the process of developing computerized accident files, factors cited by the officer are evaluated on an importance scale (e.g., driving while intoxicated is more serious than speed to fast for conditions, which in turn is more serious than driver inattention), with the most serious defect selected as the “highest contributing factor.” Figure 6 plots the highest contributing factor for three crash types on New Mexico’s LVRR for 1998-2001:

- all accidents
- all animal accidents (includes deer, elk, cattle, and others)
- all non-animal accidents

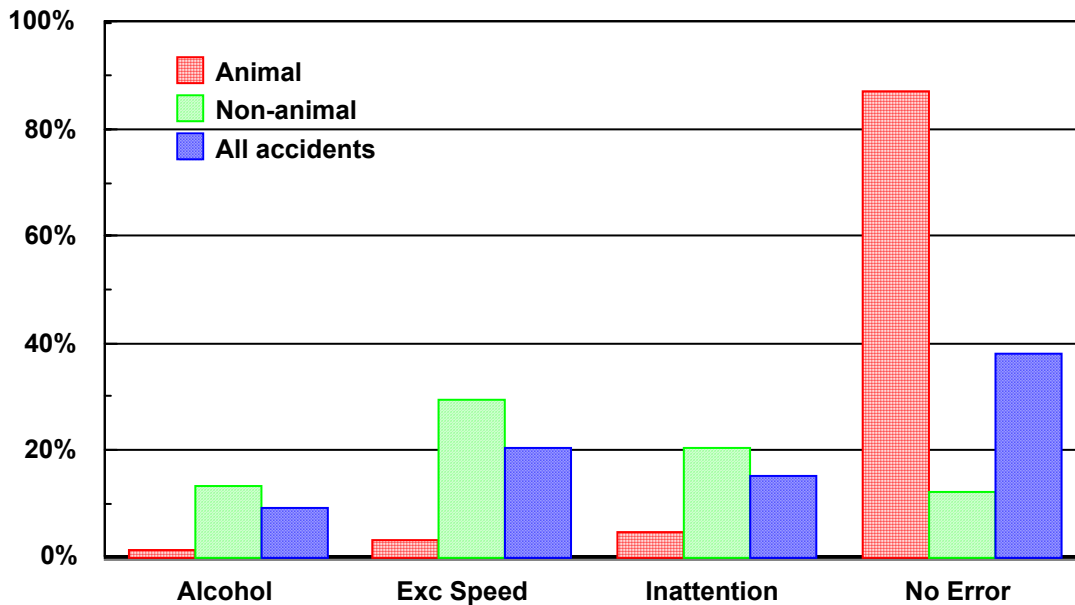


Figure 6 Highest Contributing Factor to NM LVRR Accidents, 1998-2001

Alcohol, excessive speed, driver inattention, and no driver error account for 82% of the highest contributing factors to the accidents on these roads. The importance of speed as a contributing factor reinforces previous work on higher volume roads showing a relationship between speed and single vehicle accidents. Although no driver error was reported for 87% of the animal impacts, it is quite possible that driver inattention or excessive speed could have been involved in these collisions. Alcohol was cited in 9% of the crashes.

Field Site Visits

Field studies were conducted on six roads highlighted in Figure 3; the characteristics of these study sections are given in Table 3. All of the roads are low-volume rural arterials or collectors; access is permitted from residences and ranches. All are paved, two-lane, asphaltic concrete roads with both centerline and edge line markings; the right-of-way (ROW) is typically fenced. Most of the sections had 55 mph speed limits, although limited segments had speed limits ranging from 30 to 65 mph; the only stop locations along the routes were at the termini.

The entire low-volume section of each road was driven; stops were made at each location where an accident was reported to have occurred. Numerous measurements of lane width, shoulder width, side-slope and cross-slope were taken in an effort to determine if any engineering treatments could be applicable. Some locations did not match their accident description (e.g., no guardrail at the milelog location where “hit rail” was reported), while others showed no apparent defect that might contribute to the accident.

Table 3. Characteristics of the Low-volume Field Study Sites				
Route	Length, mi	ADT	Accidents in 4 years	Accident Rate
NM 12	55.1	313	37	1.47 acc/mvm
NM 32	41.3	262	36	2.28
NM 42	35.5	278	27	1.87
NM 117	56.8	287	34	1.43
NM 244	29.4	293	70	5.56
NM 537	55.9	302	75	3.04

The final report for this project (1) provides detailed discussion of each route, with particular attention to those factors that might be addressed using highway or traffic engineering techniques. The most common shortcomings are listed below:

- lack of certain warning signs and object markers
- existing warning signs inconsistent with roadway features (see Figure 7)
- signs in need of maintenance
- need for larger STOP and Stop Ahead signs
- problems with signing isolated, low-speed curves on 55-mph highway
- concentrations of deer/elk accidents with no nearby signing
- excessive vegetation in ROW attracts animals
- cattle on the ROW (see Figure 8)
- travel lanes less than 10 feet wide
- absence of any shoulders
- overturning and fixed object accidents on the outside of horizontal curves
- excessive superelevation on roads with the potential for ice
- steep sideslopes without guardrail
- need for guardrail maintenance



Figure 7. Sign inconsistent with roadway



Figure 8. Cattle grazing on right-of-way

Computerized Accident Database versus Original Forms

Accident sites were identified in the field using the route and milelog information given on the computerized accident record. In several cases, one or more pieces of the additional information provided in the database (e.g., curvature, grade, existence of a guardrail) did not match the field site. After completion of the site visits, the

NMSHTD provided the researchers with 31 hard-copy accident reports from various locations, including some with apparent locational problems. These were reviewed and compared to the computerized database information for accuracy of data transfer. The most common errors involved errors in milepost (48%), traffic control (16%), and manner of collision (10%). Errors in locational information are especially troublesome because the field studies over 300 miles of LVRR encountered very few missing (physical) mileposts.

Deer Accidents

Deer-vehicle collisions are a national problem, amounting to more than \$1 billion in property damage and more than 200 human deaths per year (18). On NM LVRR, animal-vehicle collisions account for nearly 35% of all accidents; 80% of the animals struck are deer and elk. The typical safety treatment is to install warning signs (see Figure 9) occasionally with distance plaques (“Next XX Miles”). Game animals (e.g., deer, elk and moose) are more active at night, an added challenge for motorists due to the decreased visibility. Human instinct causes motorists to attempt to avoid hitting a large animal, though predicting which direction the animal will go is difficult. Swerving to miss an animal can cause a more severe accident than simply hitting the animal.



Figure 9. Typical Deer Warning Application

Several alternatives to deer warning signs have been developed and evaluated. The “Deer Whistle,” a device purchased by the motorist and mounted on a vehicle, in theory makes a noise that wards the deer away from the road when the vehicle passes by. Though they are low cost (about \$25), studies on their effectiveness have shown them to be useless (19, 20).

Several agencies are investigating the effectiveness of roadside reflectors, which reflect the headlights of an approaching vehicle into the nearby woods, causing the animals to “freeze” before they enter the roadway. Although federal funding is available, the cost can be high (\$5000 - \$10,000 per mile) and the results are questionable. Saskatchewan, Canada, is testing a different concept (21), where an approaching vehicle sets off a chain of warning devices each of which randomly either sounds a horn or flashes lights to ward deer away from the roadway. The cost is high – \$100,000 for sensors every 1000 ft along a three-mile stretch of highway.

New methods of alerting motorists of the presence of animals include solar-powered, flashing warning signs. Along US 101 in Washington, 10% of an elk herd have been fitted with radio collars that trigger the flashing “ELK X-ING” signs when they are within ¼ mile of the roadway (22). The \$75,000 cost of fitting elk with collars and installing 12 signs is partially federally-funded. It will be several years before the effectiveness of the warning signs can be assessed.

Fences provide one alternative to static or active warning systems. Most game animals can easily jump 4-ft right-of-way fences and cattle guards; fences intended to keep them off the roads are typically at least 8 ft high. A three-mile fence was erected north of Bloomfield, NM, on US 550 in 2002 in the hopes of reducing deer-vehicle collisions. The \$2 million cost includes installation of several one-way gates and ungulate guards (wide cattle guards with rolling bars). Touted as highly effective, a downside to these fences is that if animals manage to get around the fence, they are stuck in the ROW until they find their way out.

None of the treatments listed above are economically viable for LVRR. There are, however, some less-expensive options. The field studies undertaken as part of this project found numerous concentrations of deer/elk accidents, most lacking any nearby deer warning signs. Proper placement of warning signs is critical for gaining motorist confidence and attention. Ungulate guards can be selectively installed where minor roads intersect LVRR, which will help keep game animals away from the intersection. Although wide clear zones are not always feasible, clearing the ROW of small trees and brush in areas where deer crossings are common will improve motorist visibility of the animals. With respect to cattle-vehicle collisions, keeping grassy areas in the ROW mowed so as not to entice cattle to “greener pastures” should be a priority. Regular inspection of ROW fencing and quickly repairing damaged sections will help keep cattle from straying.

Summary and Conclusions

This project’s survey of county engineers found differences among the protocols used to manage their LVRR systems. Most agencies do not have a classification scheme for LVRR, but 65% have a program for detecting and correcting safety deficiencies. A majority of agencies reportedly used roadway user complaints and field evaluations to identify locations needing improvement. Most local agencies acknowledged that they were unable to achieve AASHTO design standard criteria on their LVRR. A majority of agencies thought that improved signs, geometrics, and road surfaces were the most cost-effective safety improvements on LVRR.

The most prominent reference manuals deemed “helpful” by those surveyed were the MUTCD (3) and AASHTO (4, 5, 6) manuals. Although many of these documents strongly recommend the proper use of signs and markings, decisions of when to use them were often left to “engineering judgment.” Many manuals encourage safety treatments, such as wide clear zones and liberal use of guardrail, that may be economically infeasible on LVRR.

Accident analyses on 17 New Mexico LVRR identified the general characteristics of crashes on low-volume roads. Due primarily to low volumes, over 80% of the accidents involved animals struck by a vehicle, single-vehicle rollover crashes, or fixed object collisions. Field studies on six of these roads documented some excellent safety treatments deployed by the NMSHTD, as well as some deficiencies that could be addressed in a cost-effective manner.

The technical literature supports the concept that traffic accidents are more frequent at points where roadway characteristics (e.g., horizontal and vertical alignment, limited sight distance, changes in design speed, absence of necessary warning) are inferior to those conditions the motorist encountered on the approaching roadway. Because the probability of LVRR accidents

occurring is roughly proportional to traffic volume, projects to improve safety on these roads will have a lesser benefit-cost ratio than on higher volume roadways. Recognizing the limited financial resources available to agencies responsible for LVRR systems, blanket application of AASHTO or MUTCD recommended treatments or standards for higher volume roadways is not feasible.

Based on the findings from the state-of-the-practice review, the questionnaire survey, the accident analyses, and the field studies, the following safety treatments may be cost-effective and deserve consideration for application on LVRR.

- Establish a TCD inventory and accident record database.
- Schedule periodic maintenance checks and schedule remedial action.
- Implement the Commentary Driving Procedure (12).
- Replace signs that have been damaged or lost their retroreflectivity.
- Accommodate the growing population of older motorists by ensuring that all traffic control devices meet standards of legibility, standard message, size, and placement.
- Ensure the accuracy of all signs: signs must be consistent with what the driver sees on the road. Remove signs that are no longer applicable.
- Require that Stop Ahead signs be placed in advance of all STOP signs on these routes with approach segment lengths greater than 10 miles.
- Use larger warning signs at sites where getting the drivers' attention is essential.
- Limit sign installations to those necessary. [The NO PASSING ZONE – DO NOT PASS – PASS WITH CARE triplet supplementing pavement markings, used extensively on New Mexico's LVRR at a cost of \$888 per two-directional installation, is unnecessary, especially when motor vehicle laws prohibit passing in areas of limited visibility.]
- Use animal crossing signs judiciously; distance plaques are helpful, but limit distances to less than 7 miles lest the motorists forget.
- To discourage grazing by animals, keep the ROW mowed. Repair damaged fencing promptly. Report deficient cattle guards and gates to land owners.
- Install advisory speed plaques, Large Arrows, and/or properly-spaced Chevrons at curves where the safe speed is 15 mph below the posted speed limit.
- Install Narrow Bridge signs, augmented with object markers, advisory speeds, raised pavement markers, and similar treatments at all narrow bridge locations.
- Consider installing Cross Road, Side Road, Falling Rock, and similar signs to address specific crash patterns.
- Consider using the new NO TRAFFIC SIGNS sign on appropriate, unpaved roadways.
- Use edge line markings on all paved LVRR with a posted speed limit of 45 mph or greater, as well as center line markings where the traveled width exceeds 18 ft.
- Use properly-spaced delineators to outline confusing alignment, and indicate the edge of the roadway when the side slope is precarious but not warranting of a greater treatment.
- Use object markers for obstructions near the roadway and for positive guidance.
- Consider using windsocks with warning signs at sites where accident reports indicate that cross winds were a contributing factor to the crashes.
- Consider using transverse rumble strips on approaches to STOP signs on segments where the distance from the previous stop is more than 10 miles. Also consider placing them in

advance of horizontal curves when the site's accident history suggests more aggressive warnings are necessary.

- Install guardrail if an embankment is extremely deep or steep, or if the site's accident history suggests this more expensive treatment would be beneficial.
- Use New Jersey barriers for containment of falling rocks that would otherwise enter the roadway.
- Design reconstructed roads with at least 10-ft lanes and 2-ft shoulders; 11-12 ft lanes are preferred on those roads with a design speed of 60 mph or more.
- Avoid use excessive superelevation in areas where snow and ice are prevalent.

The Highway Safety Manual (23) chapter on rural, two-lane roads is currently being reviewed by industry professionals. When the initial version is available, it will assist engineers in identifying problem locations and selecting appropriate countermeasures. FHWA, in cooperation with several state DOTs, is developing SafetyAnalyst (24), a set of six software tools designed to assist agencies in making economically sound, site-specific safety improvements. The final software is expected to be released in 2006. Both of these products have the potential to help those responsible for improving highway safety on LVRR.

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Acknowledgments

The research described in this paper was supported by the Federal Highway Administration under its Minority Institutions of Higher Education research program. Access to the computerized accident data files and traffic volume information was provided by James Davis at the University of New Mexico Division of Government Research. Steve Eagan with the NMSHTD provided a sample of hard copy accident reports and typical costs for safety improvements.

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