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16. Abstract

Although pedestrian fatalities have decreased by 16 percent over the past decade, the United States experienced nearly 4,749 pedestrian fatalities in 2003. The conventional wisdom has been that this is primarily an urban problem, where pedestrians are subject to numerous conflicts with vehicular traffic. The fact that 28 percent of pedestrian fatalities occur in rural areas has largely been ignored, despite the fact that pedestrian impacts in rural areas, while relatively rare, are much more likely to result in fatalities or serious injuries.

The research described in this paper sought to identify the characteristics of rural pedestrian fatalities in ten states with above-average rates of rural pedestrian fatalities. The most prominent characteristics of rural pedestrian fatalities in these states were clear weather, hours of darkness, weekends, non-intersection locations, and level, straight roads. The project also examined all rural pedestrian accidents in New Mexico for a three-year period. Improved visibility and selected application of pedestrian amenities such as walkways, crosswalks, and warning signs appear to have the best potential for enhancing rural pedestrian safety. The excessive incidence of alcohol-involved pedestrians deserves additional attention.

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NOTICE

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INTRODUCTION

Pedestrians are extremely vulnerable in crashes with the faster moving and much more massive motor vehicles. Although pedestrians made up only 2 percent of highway crash injuries, in 2003 they constituted 11 percent of the highway fatalities in the United States and 85 percent of all non-occupant fatalities in motor vehicle crashes (*1*). Analysis of pedestrian crash experience can help identify engineering, educational and enforcement treatments. A proper understanding of pedestrian needs and characteristics and the factors that contribute to pedestrian crashes is essential for the proper design and operation of roadways and pedestrian facilities.

Despite the tremendous progress made in US highway safety, which has seen the highway fatality rate drop from 5.5 fatalities per 100 million vehicle-miles (100 mvm) in 1966 to approximately 1.48 in 2003, there were 4,749 pedestrians killed and approximately 70,000 pedestrians injured in motor vehicle crashes in 2003. Overall, pedestrian fatality rates continue to decline compared to the previous years. There was a 13.5 percent decrease in pedestrian fatalities from 1994 to 2003. In 1994, pedestrians accounted for 13.5 percent of all motor vehicle fatalities; by 2003, the corresponding value was just over 11 percent (*2*). The reduction in pedestrian fatalities is even more pronounced when considering the growth in population, which increased from 250 million in 1994 to over 285 million in 2003 (*3*). It is possible, of course, that part of the decline in pedestrian fatalities may be due to a reduction in walking as a travel mode rather than an improvement in pedestrian safety, but data are not available to support this contention. Even though population-based fatality rates are declining, pedestrian safety remains an important concern to the engineering community, which has the potential to enhance pedestrian safety through application of suitable design and operational standards.

Fig. 1 Typical Road Profile in rural areas – encourages high speeds with no pedestrian facilities.

Most pedestrian fatalities in 2003 occurred in urban areas (72 percent), at non-intersection locations (79 percent), in normal weather conditions (89 percent), and at night (65 percent) (*1*). The 2003 Fatality Analysis Reporting System (FARS) showed that more than two-thirds (69 percent) of the 2003 pedestrian fatalities were males. One-fourth of all children between the ages of five and nine years old killed in traffic crashes were pedestrians (*4*). Alcohol involvement for either the driver or pedestrian was reported in 46 percent of the traffic crashes that resulted in pedestrian fatalities. Of the pedestrians involved, 34 percent were intoxicated, whereas the intoxication rate for the drivers was 13 percent; in 6 percent of the crashes, both the pedestrian and driver were intoxicated. Because most pedestrian activity occurs in urban areas, primary attention has been given to the development and implementation of countermeasures in urban areas such as sidewalks, crosswalks, pedestrian signs and signals. However, pedestrian fatality rates are higher in rural areas because of higher driving speeds, which have a greater impact during a crash when compared to crashes on urban streets.

The research described in this paper:

- Identifies fatal pedestrian crash characteristics in a sample of rural states
- Evaluates all rural pedestrian crashes in one state
- Suggests potential safety engineering countermeasures

LITERATURE REVIEW

In general, traffic accidents are rare events; this is especially true for pedestrian impacts, which account for less than 2 percent of all reported crashes. One study of urban pedestrian accidents (*5*) found that high-volume intersections with more than 80 multiple-vehicle crashes per year rarely experienced pedestrian accidents, possibly because pedestrians avoided these locations. The study found that few intersections averaged more than three pedestrian impacts per year, and the majority of these were not at the intersection but were simply referenced to the intersection (i.e., on Y Boulevard, 500 feet east of Z Street) for purposes of identifying the site. The situation becomes more difficult to assess in rural areas, where pedestrian collisions are less frequent and further removed from intersections.

The technical literature suggests that some pedestrian traffic safety issues can be addressed by engineering treatments, while others can be resolved only by recognizing and addressing the non-engineering aspects of these crashes. For example, Johnson (*6*) found that pedestrian fatalities on Interstate highways constitute more than 10 percent of all pedestrian fatalities even though pedestrians would not be expected on these roads. Though the study was restricted to Interstate highways, the characteristics of pedestrian fatalities it identified may resemble pedestrian fatalities across all highway systems. Some of the most common contributing factors for pedestrian fatalities in the report are driver characteristics, alcohol and drugs, and lighting conditions. The safety countermeasures recommended by the study include alerting drivers to the presence of pedestrians, assisting unintended pedestrians, roadway lighting and keeping pedestrians off of Interstate highways.

Hall's 1981 study (*7)* collected highway design and traffic engineering data at the sites of 95 pedestrian crash sites (66 percent involving a fatality) on rural, non-Interstate, state-administered roads in northwest New Mexico. Average daily traffic volumes at the study sites ranged from 600 to 20,000 vehicles per day (vpd). The study found that motorists at 85 percent of the sites had a daytime sight distance of at least 1000 feet to a pedestrian with an assumed height of 4 feet. The good sight distance assumes less importance when considering that 80 percent of the pedestrian impacts occurred during the hours of darkness. Although pavement markings were present at 95 percent of the crash sites, signs warning of pedestrians were present at less than 20 percent of the sites. The study also found that nearly 30 percent of the crashes involved hit-and-run motorists. Approximately 60 percent of the pedestrians had blood-alcohol levels of at least 0.10 percent. The study recommended improvements on a site-by-site basis; the most commonly suggested countermeasures were shoulder improvements, improved signing, and improved roadway illumination at selected locations with high concentrations of nighttime pedestrian crashes.

Ivan (*8)* used a probit model to evaluate the effect of roadway and area type features on injury severity of pedestrian crashes in rural Connecticut. His study concluded that the variables that significantly influenced pedestrian injury severity were clear roadway width, vehicle type, driver alcohol involvement and pedestrian alcohol involvement. He found that different area types experienced significantly different injury severity levels, and concluded that pedestrian injury severity was low in highly developed areas, such as business districts, but was high in low population-density areas.

DATA COLLECTION

The primary data source for this study of rural pedestrian collisions was the Fatality Analysis Reporting System database administered and maintained by the National Highway Traffic Safety Administration (*4*). Agencies in each state collect and report detailed information on all fatal motor vehicle crashes to this database. Relevant data from the states' own source documents, including police accident reports, state vehicle registration files, state driver licensing files, state highway department data, vital statistics, death certificates, medical examiner reports, hospital medical records, and emergency medical service reports, are coded on standard FARS forms. A second source of information used in this study was the New Mexico computerized accident record database, maintained by the University of New Mexico's Division of Government Research. Demographic and other statistical data were obtained from the websites maintained by the United States Census Bureau (*3*) and others (*9, 10*).

Querying FARS Crash Data

The FARS query system provides interactive public access to fatality data through a web interface (*4*). The data for fatal pedestrian crashes was obtained by preparing on-line queries for selected variables of interest and cross-tabulating the results. The common selection parameters for all of the studies were:

- Year = 2003
- Person Type = Pedestrian or Other Pedestrian
- Injury Severity = Fatality
- Roadway Function Class = all seven rural roadway classes in the FARS database

The initial step in the data screening was to select a set of ten predominantly rural states with a meaningful occurrence of rural pedestrian fatalities. This was accomplished by using census data and rural land area to determine the population density in the rural areas of all states. This information was combined with rural pedestrian fatality data from FARS to determine the annual average ratio of rural pedestrian fatalities in a state to its rural population, expressed as fatalities per million population. A screening of the national FARS database detected several anomalies, such as one state that reported that all of its 122 pedestrian fatalities, (and indeed, 99.7 percent of all its highway fatalities) occurred in rural areas, which led to its exclusion from the study sample. Other predominately rural states were dropped from consideration due to their low number of rural pedestrian fatalities. Table 1 shows the rural characteristics of the ten states ultimately chosen for further study.

Table 1. Rural Characteristics of the Selected Study States, 2003

State	*Population (1000's)*	*Area (mi^2,1000's)*	*Density (per/mi^2)*	*Pedestrian Fatalities*[a]	*Fatalities/year/ 10^6 persons*
AZ	607	111	5.5	28	46.1
CA	1882	147	12.8	71	37.7
CO	668	102	6.6	10	14.97
FL	1712	46	37.0	150	87.6
LA	1223	41	29.5	44	35.97
MT	414	145	2.9	10	24.15
NM	456	121	3.8	27	59.2
OR	727	95	7.7	11	15.1
TX	3648	253	14.4	121	33.16
WY	172	97	1.8	4	23.25

With these exceptions (CO, MT, OR and WY), all the study states have rural pedestrian fatality rates in excess of 30 per million persons living in rural areas. This is an admittedly imperfect statistic, because some (perhaps many) pedestrians fatally injured in rural accidents may actually live in urban areas of the state or even in other states. Nevertheless, it is the most realistic rural indicator that can be developed from readily available databases. The data set from these ten states consists of 470 rural pedestrian crashes resulting in 476 pedestrian fatalities (1.01 fatalities per crash). As shown in Appendix A, Table A1, 10 percent of the rural crashes that resulted in a pedestrian fatality also resulted in one or more non-fatal pedestrian injuries. Four of the study states (Arizona, California, Florida, and New Mexico), have statewide pedestrian rates in excess of 2.0 fatalities per 100,000 population.

GENERAL CRASH CHARACTERISTICS

The characteristics discussed in this section address some general concerns about rural pedestrian fatalities that are relatively consistent among the states and, in many cases, beyond the control of the engineer. Approximately 18.3 percent (range 7 to 30 percent among the ten study states; see Table A2) of the pedestrian fatalities involved hit-and-run drivers. The most important consequence of this sad statistic is that motorist information is unavailable for one-sixth of rural pedestrian crashes. Table A2 also shows that school buses are associated with only 0.4 percent (range 0 to 1.0 percent) of these fatalities, which suggests that pedestrian safety in the vicinity of rural school bus loading zones is very good. Considerable attention is being devoted to traffic safety in construction zones, and rightly so, but only 2.2 percent (see Table A2) of these fatalities occur in construction areas. In conventional thinking, a pedestrian collision involves a single vehicle impacting a single pedestrian. In fact, specific rural crashes in the ten study states included a couple involving six or seven vehicles. Among all rural fatal pedestrian crashes in the

Fig. 2 Typical Work zone with limited worker protection

study states, 86.6 percent involved a single vehicle, 7.5 percent involved two vehicles, and the remainder involved three or more motor vehicles. Table A3 shows the variation by state in the number of vehicles involved in rural fatal pedestrian crashes. The erroneous belief regarding a single vehicle/single pedestrian collision also applies to the number of pedestrians involved in these crashes. Recent nationally publicized urban pedestrian incidents have involved as many as ten fatalities. For the ten states, 97.2 percent (range 89 to 100 percent; see Table A4) of the crashes involved a single pedestrian fatality.

Virtually all studies of pedestrian fatalities have found that males are overrepresented based on their proportion of the population. This is also true for rural pedestrian fatalities in the ten study states, where males account for over 74 percent of the fatalities. As shown in Table A5, the percent of male fatalities range from 45 to 82 percent. Particularly in urban areas, considerable attention has been devoted to pedestrian safety for school-aged children. Based on FARS data for the ten study states, this appears to be less of a concern for rural pedestrian collisions. Table 2 shows the age distribution for rural pedestrian fatalities in the study states. On the average in these states, pedestrians under the age of 16 account for about 8 percent of the rural fatalities, while those over the age of 64 account for about 13 percent. There are multiple indications from previous studies (*7*) that alcohol involvement is underreported in rural pedestrian crashes; hit-and-run drivers make it impossible to obtain this information, and it appears that investigating officers may be reluctant to report pedestrian alcohol involvement. Indeed, investigating officers report “unknown”, “test refused”, or “blank” for alcohol involvement for 44 percent of rural fatal pedestrian collisions in the study states. In the minority of crashes where the officer cites an opinion, over 32% of crashes indicate alcohol involvement, (as shown in Table A6).

Fig. 3 Typical School Signing in Rural Areas.

TABLE 2. Ages of Fatally Injured Pedestrians

State	***<=15 (%)***	***16-24 (%)***	***25-44 (%)***	***45-64 (%)***	***>=65 (%)***
AZ	7.1	32.1	42.8	14.3	3.6
CA	18.5	14.1	40.8	18.3	14.1
CO	0.0	10.0	30.0	40.0	20.0
FL	10.3	16.5	31.7	24.8	16.6
LA	6.8	18.2	38.6	27.3	9.1
MT	0.0	10.0	20.0	40.0	30.0
NM	4.0	20.0	56.0	20.0	0.0
OR	9.1	27.3	27.3	9.1	27.3
TX	6.7	23.5	34.5	24.4	10.9
WY	0.0	0.0	100.0	0.0	0.0
TOTAL	7.7	19.7	36.6	23.1	12.8

Crash frequency is known to vary by day of the week and month, but the engineer can control neither. Nevertheless, Saturday (21 percent) accounts for the greatest proportion of rural pedestrian fatalities, while Monday (10.7 percent) has the least. The commonly accepted weekend period, Friday through Sunday, accounts for half of these fatalities (53 percent). The results by state are given in Table A7. If all months accounted for equal shares, then each month would experience 8.3 percent of the annual rural pedestrian fatalities. Overall, months in study states range from a low of 6.6 percent in May to a high of 11.8 percent in September. Table A8 shows the monthly distribution of pedestrian fatalities for the ten study states.

Fig. 4 Unpaved shoulders provide space for pedestrian to walk, but don't offer physical protection

Characteristics of Interest to the Engineer

The statistics presented in the previous section characterize the who, when, and where of rural pedestrian fatalities, but they provide little basis for the engineer or planner to take corrective action. It is appropriate, therefore, to consider those factors that are more closely associated with the design and operation of rural highways. Two such parameters are roadway alignment and profile. Previous research has shown that rural, single-vehicle crashes are more likely to occur under conditions of adverse geometrics, particularly sharp horizontal curves and steep downgrades. Table 3 shows the geometric conditions at the sites of rural pedestrian fatalities. Overall, 90 percent occur on tangent sections of roadway and 89 percent occur on level roads, as shown in Figure 5. These results are probably consistent with the proportion of rural highway mileage that is straight and level. In the ten study states, 38 percent of the rural fatal pedestrian crashes occurred on divided highways with the remainder on non-divided highways. As shown in Table A9, MT, NM and OR report that over 60 percent of their rural fatal pedestrian crash locations are on divided highways.

Table 3. Roadway Geometrics

State	*Straight (%)*	*Level (%)*
AZ	60.7	75.0
CA	87.3	88.7
CO	100.0	80.0
FL	86.3	85.6
LA	95.5	95.5
MT	80.0	50.0
NM	88.9	77.7
OR	90.1	81.8
TX	97.5	95.9
WY	25.0	0.0
TOTAL	90.3	88.6

Fig. 5 Straight-level roadways where close to 90% of all rural pedestrian crashes occur.

Nearly 8 percent (Table A10) of the rural fatal pedestrian impacts took place on the shoulder while virtually all of the remainder took place on the roadway itself (87%). It is not clear from the records if the higher incidence of impacts on the shoulders in these states represents their more extensive use of shoulders on rural highways. Of course, impacts on the roadway could involve pedestrians actually walking along the roadway or crossing the roadway. As noted earlier, over 84 percent of all pedestrian rural fatalities do not occur at intersections; for the rural pedestrian accidents in the ten study states, the corresponding figure is 88 percent. As indicated by Table A11, Colorado and Montana report that one-fifth of their rural pedestrian fatalities occur at intersections.

Adverse roadway surface conditions limit motorists' ability to decelerate and may be accompanied by conditions that limit visibility. Nearly 90 percent of the rural fatal pedestrian crashes occurred on dry pavement. However, in Montana and Oregon, at least 15 percent occurred on wet pavement, perhaps reflecting the climatic conditions in these states. Snow or ice was present at over 10 percent of the crashes in Colorado and Wyoming, (Table A12).

One primary factor in fatal pedestrian accidents is the speed of the impacting vehicle. This is rarely available in the crash records, but the speed limit, which might be considered as a surrogate for roadway travel speeds, is included in the FARS database. The reported speed limits at the rural sites of pedestrian fatalities ranged from 50 mph to 75 mph. The speed limit range 55 to 60 mph accounted for 34 percent of the crash sites, and an additional 28 percent had speed limits of 65 mph or more. Speed limits were 40 mph or less at 23 percent of the sites. Table A13, shows that 40 percent of FL, MT, NM and OR rural pedestrian fatalities occurred on roadways with posted speed limits of 40 mph or less.

Fig. 6 Pedestrian with Advisory Speed

According to the 2003 FARS data, there was no traffic control present at 85 percent of the crash sites. However, this certainly misstates the situation from the engineering perspective, because most locations would, in fact, have centerlines, lane lines and edge lines. However, pavement markings, including crosswalks, are not listed as options under the FARS variable Traffic Control Devices. Another variable in the database indicates that only 1.3 percent of the impacts occurred in a crosswalk. Regulatory signs (e.g., STOP, YIELD, speed limit) were present at 10 percent of the crash sites, warning signs (pedestrian crossing, school) were present at less than 1 percent of the sites, and other controls (primarily traffic signals) were present at just over 1 percent of the sites.

Previous studies have documented that a significant proportion of pedestrian crashes occur during the hours of darkness. For the ten study states, 28 percent of the crashes occurred between midnight and 6:00 am, 16 percent between 6:00 am and noon, 10 percent between noon and 6:00 pm, and 46 percent between 6:00 pm and midnight. There are variations among the study states, as shown by Table A14. Table 4 summarizes the light condition at the times of the fatal pedestrian crashes. Dark, unlighted conditions existed for 64 percent of the crashes; only 20 percent occurred during daylight hours. The table demonstrates that at least 60 percent of rural pedestrian fatalities occur under dark, unlighted conditions in Arizona, California, Louisiana, New Mexico, and Texas. Figure 8 shows the hourly distribution of rural pedestrian fatalities and highlights the particular problem in the evening and early morning hours.

Fig. 7 Rural Road at Nighttime – no overhead illumination

TABLE 4 Light Conditions at Crash Times

State	***Daylight (%)***	***Dark (%)***	***Dark, Light (%)***	***Dawn (%)***	***Dusk (%)***
AZ	23.0	73.0	0.0	4.0	0.0
CA	19.7	71.8	5.6	2.9	0.0
CO	30.0	40.0	20.0	0.0	10.0
FL	23.3	54.6	18.0	0.0	4.4
LA	15.9	65.9	15.9	2.3	0.0
MT	20.0	40.0	20.0	10.0	10.0
NM	14.8	70.3	11.1	3.8	0.0
OR	30.0	40.0	30.0	10.0	10.0
TX	15.7	74.4	7.4	2.5	0.0
WY	25.0	50.0	0.0	25.0	0.0
TOTAL	20.0	64.4	11.9	2.1	1.6

The FARS database provides limited guidance on possible contributing factors for crashes. For the rural fatal pedestrian crashes in the study states, 16 percent reportedly involved persons improperly crossing the roadway or intersection, and another 7 percent involved failure to yield the right of way. Approximately 4 percent of the crashes were associated with a previous accident nearby.

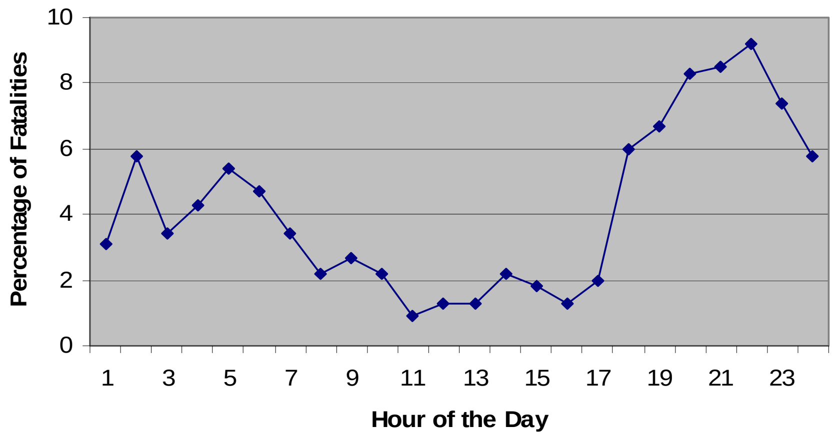

Figure 8. Variation of Rural Pedestrian Fatalities by Time of Day

DISCUSSION

From the statistics developed for this project, it is clear that rural pedestrian crashes remain a serious issue. Although urban pedestrian crashes outnumber those in rural areas, the potential for fatalities and serious injuries is greater on rural, high-speed highways. The geographical dispersion of rural pedestrian crashes can hamper the application of remedial measures. A similar situation exists for vehicle-deer impacts, even though they are much more numerous and somewhat more concentrated.

The critical period for rural pedestrians in the ten study states was between 6pm and 6am, which accounted for 73 percent of the fatalities. Related statistics from Table 4 show that 64 percent of the rural pedestrian fatalities occurred on dark, unlighted highways and an additional 12 percent occurred on lighted roadways during the hours of darkness. Evidently, limited visibility plays a major role in the occurrence of rural pedestrian fatalities. But in most cases, the situation does not lend itself to correction through standard programs of sight distance enhancements such as improving horizontal or vertical alignment. The incidence of impaired driving is also known to peak during the hours of darkness, further exacerbating the situation.

Fig. 9 High-Speed Rural Road (38% of rural pedestrian fatalities occur)

Over 38 percent of the fatalities occurred on divided highways. Posted speed limits, and in turn, actual vehicle speeds, are higher on rural highways, especially when they are divided. The speed limit at 63 percent of the sites of rural pedestrian fatalities was 55 mph or higher, although the role of vehicular speed in the causation of the crash, as opposed to the consequences of the impact, is less obvious. Nevertheless, it is evident that the close proximity of vulnerable pedestrians and fast moving vehicles is undesirable. The physical separation of pedestrians and vehicles commonly provided in urban areas is rare along rural roads, as demonstrated by the fact that 86 percent of rural pedestrian fatalities occurred on the highway itself. Although intersections account for only 11 percent of rural pedestrian fatalities, they might benefit from remedial treatments.

Weather and adverse roadway surface conditions appear to seem a minor role, if any, in the occurrence of rural pedestrian fatalities. Indeed, the percent of the incidents that happen on wet roadways may be less than the percent of vehicular travel that occurs under this condition. The parameters of construction zones and school buses have an almost negligible role in rural pedestrian fatalities.

The results from the analyses of all New Mexico rural pedestrian accidents closely parallel the results from FARS. It is noteworthy that the rural areas of San Juan and McKinley counties in northwest New Mexico contain 46 percent of all accidents in the three-year study period. These two counties, which account for 9.0 percent of the state's land area and 10.4 percent of the state's population, were examined in an earlier study (*7*). Although selected spot improvements have been implemented, it appears that these counties warrant even more attention.

Even though rural pedestrian crashes are relatively rare, they are in some ways much simpler than their urban counterparts. Urban pedestrian safety programs face a number of challenges, including higher pedestrian densities, persons with mobility limitations, jaywalking, intersections, crosswalks, and left-turning vehicles. Common crash patterns include pedestrians darting out from between parked vehicles, dashing to get across an intersection, or reacting to multiple threats. A broad range of urban pedestrian treatments have been developed, including marked crosswalks, safe routes to school, in-roadway lights, grade separations, and traffic calming to help address urban pedestrian problems. Most of these issues don't exist or are of lesser importance along rural highways, where the common factor in many of the accidents is simply that the motorist doesn't see the pedestrian until it is too late to initiate and complete an evasive maneuver.

RECOMMENDATIONS

The initial step in addressing rural pedestrian collisions is to identify any spot locations with crash concentrations. These could be in the vicinity of intersections or near rural roadside attractions, such as stores, parks, or tourist attractions. Potential treatments are more likely to become cost-effective at these spots.

Fig. 10 Typical Pedestrian Tourist Attraction Signing

It is well established that pedestrians overestimate their visibility to motorists during the nighttime. On an unlit roadway at night, a motorist traveling faster than 50 mph with low beam headlights is certainly overdriving the visibility limits, especially where the object that needs to be seen is a pedestrian in normal clothing. The urban solution to this situation is the installation of new roadway illumination or the enhancement of existing illumination. In the 1980s, Federal Highway Administration reports consistently found that, when warranted, roadway illumination had one of the highest benefit-cost ratios for safety projects (*13*). One source suggests that roadway lighting is warranted when the ratio of nighttime to daytime accidents exceeds 2.0 (14). It is clearly not feasible or desirable to install, operate, and maintain roadway illumination on extensive segments of rural highway. However, at locations with a continuing incidence of nighttime pedestrian accidents or concentrations of nighttime pedestrian activity, serious consideration should be given to installing roadway illumination and monitoring its effect.

If it is not practical to enhance rural pedestrian visibility with improved roadway illumination, the potential for making pedestrians more visible to motorists through the use of retroreflective clothing or armbands should be considered. A Swedish pedestrian safety study (*15*) suggested the use of fluorescent caps for school children. Many joggers and walkers in the United States voluntarily use some form of retro reflective material to enhance their visibility at nighttime. Reflective materials could be made available to individuals through rural school districts, rural post offices, or other locations that attract potential nighttime pedestrians. Outreach Materials should be developed in multiple languages (eg. Of Porter) and made available in rural areas as indicated above. The Swedish study is also recommended the use of ultraviolet light for vehicles. UV headlights, an Intelligent Transportation System concept, help the motorist to see pedestrians better during darkness. The UV light reportedly gives good reflection on clothing washed with most detergents.

One well-established countermeasure to reduce pedestrian-vehicle conflicts is to physically separate pedestrians and vehicles. Sidewalks or walkways provide pedestrians with a dedicated space to travel within the public right-of-way that is removed from motor vehicles. While Portland cement concrete sidewalks are commonly used in urban areas, less expensive walkways constructed of asphalt, crushed stone, or other all-weather surfaces are appropriate for rural areas if they are properly maintained. Existing AASHTO guidelines for sidewalks are rather weak, although they recommend that sidewalks “be constructed along any highway or street not provided with shoulders, even though pedestrian traffic may be light.” (*16*) Under some conditions, it might be desirable to provide fencing or another form of barrier between the walkway and the roadway. AASHTO recommends all-weather shoulders for rural arterials: at least 6 feet wide for traffic volumes between 400 and 2000 vpd, and at least 8 feet wide on multi-lane highways. Pedestrian grade separations are extremely expensive and difficult to justify in urban areas; only in rare cases (e.g., major traffic generator on one side of the rural road with parking on the opposite side) would they deserve consideration in rural areas.

Marked crosswalks indicate preferred locations for pedestrians to cross roadways, alert motorists to the location of a crossing point and remind them of their duty to yield the right-of-way to pedestrians. The Manual on Uniform Traffic Control Devices (*17*) recommends that they be installed only after an engineering study supports their need, particularly at non-intersection locations. Crosswalk markings must be visible to motorists both day and at night. It is imperative for the crosswalk material to be highly reflective, long lasting, slip-resistant, and relatively maintenance free. In special cases, they can be installed in conjunction with other enhancements that physically reinforce crosswalks and reduce vehicle speeds. Where motorists would not expect crossing pedestrians, the markings should be supplemented with W11-2 warning signs or S1-1 school crossing signs. In accord with good traffic control practice, it is clearly not desirable to mark or sign every location where a pedestrian might cross. On 4-lane roads, with ADT in excess of 15,000 vehicles and vehicles speeds greater than 35 mph, crosswalk installation must be accompanied by other treatments.

Fig. 11 Rural Pedestrian Concentration

Intelligent Transportation Systems (ITS) and Geographic Information Systems (GIS) technologies show promise for ameliorating vehicle-pedestrian conflicts along rural highways. Innovative ITS methods such as pedestrian detection, relevant warning systems, and dynamic signs are currently deployed in urban areas and could be considered for implementation at selected locations on rural roads (*18*). The systems allow motorists to detect pedestrians earlier, affording them an opportunity to avoid an impact with a pedestrian or at least reduce the speed at impact. The finding from FARS analyses that 4 percent of rural fatal collisions with pedestrians were associated with a previous accident could be also be addressed by ITS through the prompt detection and clearance of previous incidents/accidents, thus minimizing the opportunity for secondary crashes.

This study would be remiss in concluding without commenting on the significant role that alcohol impairment plays in rural pedestrian collisions. The highway safety community has made a good effort since the passage of the Highway Safety Act of 1966 to address the problem of driving while intoxicated; the success of these efforts is well-documented, but there is clearly room for additional progress. The less publicized fact is that alcohol plays an even more significant role in rural pedestrian fatalities. While engineers and planners are ill-equipped to address the problem of impaired pedestrians, the fact remains that any highway design or traffic engineering remedial action should benefit both sober and impaired pedestrians. If selected deployment of roadway lighting helps sober pedestrians, it should likewise help impaired ones. The engineering community must actively support the efforts of other safety specialists in addressing the significant alcohol aspects of pedestrian crashes.

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APPENDIX A

Rural Pedestrian Fatality Data by State 2003

Data obtained from queries of FARS http://www.fars.nhtsa.dot.gov/

FARS records meeting the following criteria

- Year = 2003
- Person Type = Pedestrian or Other Pedestrian
- Injury Severity = Fatality
- Roadway Function Class = all seven rural roadway classes in the FARS database

Table A1. Pedestrian Injury Level

State	*Fatal (%)*	*Non-Fatal (%)*
AZ	87.2	12.8
CA	90.1	9.9
CO	65.6	34.4
FL	93.0	7.0
LA	86.3	13.7
MT	100.0	0.0
NM	90.6	9.4
OR	93.6	6.4
TX	91.7	8.3
WY	100.0	0.0
TOTAL	90.2	9.8

Table A2. Selected Crash Characteristics

State	*Construction (%)*	*Hit & Run (%)*	*School Bus (%)*
AZ	2.6	7.1	0.0
CA	0.0	29.6	0.6
CO	0.0	10.0	0.0
FL	1.0	16.0	0.5
LA	0.0	13.6	1.0
MT	1.7	10.0	0.0
NM	2.3	7.4	0.0
OR	4.5	0.0	0.0
TX	4.5	24.8	0.4
WY	7.7	0.0	0.0
TOTAL	2.2	18.3	0.4

Table A3. Number of Vehicles in Crash

State	*1 Vehicle (%)*	*2 Vehicles (%)*	*>=3 Vehicles (%)*
AZ	90.0	3.3	6.6
CA	83.0	12.6	4.4
CO	90.0	10.0	0.0
FL	89.3	8.0	2.7
LA	90.9	9.1	0.0
MT	90.0	10.0	0.0
NM	100.0	0.0	0.0
OR	75.0	16.6	8.4
TX	81.6	10.7	7.7
WY	100.0	0.0	0.0
TOTAL	86.6	7.5	5.9

Table A4. Number of Pedestrian Fatalities

State	*1 Fatality (%)*	*2 Fatalities (%)*
AZ	97.4	2.6
CA	100.0	0.0
CO	88.9	11.1
FL	98.6	1.4
LA	95.8	4.2
MT	100.0	0.0
NM	97.4	2.6
OR	91.3	8.7
TX	96.5	3.5
WY	100.0	0.0
TOTAL	97.2	2.8

Table A5. Sex of Pedestrian

State	*Male (%)*	*Female (%)*
AZ	82.15	17.85
CA	71.9	28.1
CO	70.0	30.0
FL	74.0	26.0
LA	79.55	20.45
MT	50.0	50.0
NM	81.5	18.5
OR	45.5	54.5
TX	76.3	23.7
WY	75.0	25.0
TOTAL	74.1	25.6

Table A6. Pedestrian Alcohol Involvement

State	*No Alcohol (%)*	*Yes Alcohol (%)*
AZ	81.8	18.2
CA	57.7	42.3
CO	70.0	30.0
FL	66.7	33.3
LA	86.4	13.6
MT	50.0	50.0
NM	33.3	66.7
OR	63.6	36.4
TX	76.0	24.0
WY	50.0	50.0
TOTAL	68.0	32.0

Table A7. Day of the Week

State	*Sun(%)*	*Mon(%)*	*Tue(%)*	*Wed(%)*	*Thu(%)*	*Fri(%)*	*Sat(%)*
AZ	3.6	19.2	19.2	11.5	11.5	19.2	14.1
CA	25.4	8.4	7.0	9.9	14.0	16.9	18.3
CO	10.0	30.0	30.0	0.0	9.5	10.0	20.0
FL	11.3	12.7	13.3	8.0	12.7	20.0	20.6
LA	13.4	11.4	4.5	15.9	11.4	15.9	16.8
MT	10.0	0.0	0.0	30.0	20.0	30.0	10.0
NM	3.7	3.7	14.8	29.6	7.4	11.1	17.2
OR	0.0	9.1	9.1	36.4	0.0	27.3	13.6
TX	21.5	12.4	9.9	14.0	6.6	16.5	25.8
WY	0.0	0.0	0.0	50.0	25.0	0.0	25.0
TOTAL	15.0	11.6	11.0	13.3	10.5	17.7	20.9

Table A8. Month

State	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
AZ	10.7	14.3	10.7	0.0	7.1	7.1	10.7	7.1	7.1	7.1	0.0	17.9
CA	9.9	8.5	7.0	9.9	9.9	5.6	8.5	4.2	12.7	8.5	8.5	7.0
CO	0.0	0.0	20.0	10.0	10.0	20.0	10.0	0.0	20.0	10.0	0.0	0.0
FL	8.0	5.3	7.3	10.0	4.7	7.3	8.7	10.0	14.0	6.7	12.0	6.0
LA	6.8	15.9	13.6	6.8	6.8	13.6	2.3	6.8	6.8	2.3	4.5	13.6
MT	10.0	0.0	0.0	0.0	0.0	10.0	10.0	0.0	10.0	50.0	10.0	0.0
NM	7.4	18.5	7.4	11.1	0.0	7.4	14.8	3.7	11.1	7.4	7.4	3.7
OR	0.0	9.1	0.0	0.0	9.1	0.0	18.2	0.0	9.1	9.1	0.0	45.5
TX	9.9	5.8	5.0	8.3	7.4	8.3	8.3	6.6	11.6	7.4	10.7	10.7
WY	0.0	50.0	25.0	0.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8.4	8.4	7.6	8.2	6.3	8.2	8.6	6.7	11.8	7.8	8.8	9.2

Table A9. Roadway Cross Section

State	*Not-Divided (%)*	*Divided (%)*
AZ	60.7	39.3
CA	71.8	28.2
CO	50.0	50.0
FL	65.0	35.0
LA	68.2	31.8
MT	30.0	70.0
NM	22.3	77.7
OR	36.4	63.6
TX	69.5	30.5
WY	75.0	25.0
TOTAL	62.4	37.6

Table A10. Relation to Roadway

State	*On Roadway (%)*	*Shoulder (%)*	*Other (%)*
AZ	67.9	3.6	0.0
CA	87.3	9.9	1.9
CO	20.0	10.0	20.0
FL	88.7	8.7	0.0
LA	95.5	0.0	1.0
MT	91.0	0.0	10.0
NM	96.3	0.0	1.8
OR	81.2	9.4	9.4
TX	84.3	10.7	0.8
WY	75.0	0.0	2.5
TOTAL	86.5	7.7	5.8

Table A11. Relation to Intersection

State	*Not Junction (%)*	*Intersection (%)*	*Other (%)*
AZ	64.3	7.1	28.4
CA	87.3	8.5	1.3
CO	80.0	20.0	0.0
FL	78.0	17.3	2.8
LA	91.0	4.5	4.5
MT	60.0	30.0	10.0
NM	88.9	7.4	3.4
OR	81.8	18.2	0.0
TX	87.6	6.6	1.5
WY	75.0	0.0	25.0
TOTAL	82.6	11.1	6.3

Table A12. Roadway Surface Condition

State	*Dry (%)*	*Wet (%)*	*Snow (%)*	*Ice (%)*
AZ	83.3	12.5	4.2	0.0
CA	95.8	2.8	0.0	1.4
CO	90.0	0.0	10.0	0.0
FL	89.3	10.7	0.0	0.0
LA	88.6	11.4	0.0	0.0
MT	80.0	20.0	0.0	0.0
NM	96.3	3.7	0.0	0.0
OR	72.7	27.3	0.0	0.0
TX	93.4	6.6	0.0	0.0
WY	75.0	0.0	0.0	25.0
Total	90.7	8.5	0.4	0.4

Table A13. Posted Speed Limit

State	*<=30 MPH*	*35-40 MPH*	*45-50 MPH*	*55-60 MPH*	*>=65 MPH*
AZ	0.0	17.4	4.3	26.0	52.3
CA	12.7	4.2	12.7	47.9	22.5
CO	20.0	40.0	10.0	10.0	30.0
FL	14.0	20.0	20.7	26.0	19.3
LA	9.1	4.5	15.9	45.6	24.9
MT	30.0	20.0	0.0	0.0	50.0
NM	0.0	27.3	14.8	29.6	28.3
OR	27.3	0.0	18.2	45.5	9.0
TX	6.6	9.0	10.7	35.5	38.2
WY	0.0	0.0	0.0	25.0	75.0
TOTAL	10.7	12.9	14.8	34.0	27.6

Table A14. Time Period

State	*12-6am (%)*	*6-noon (%)*	*Noon-6pm (%)*	*6pm-midnight (%)*
AZ	30.4	3.3	1.3	65.0
CA	34.8	10.1	11.3	43.5
CO	30.0	10.0	10.0	50.0
FL	23.7	16.3	8.9	51.1
LA	22.5	15.0	10.0	52.5
MT	0.0	20.0	0.0	80.0
NM	28.0	8.0	8.0	6.4
OR	20.0	30.0	30.0	20.0
TX	32.2	19.8	9.9	38.1
WY	25	25.0	0.0	50.0
TOTAL	27.5	16.1	10.0	46.4

APPENDIX B

Case Study

Rural Pedestrian Crashes in New Mexico
1998-2000

Data provided by the University of New Mexico
Division of Government Research

EXISTING CASE STUDY
NEW MEXICO DATA ANALYSIS

Fig. 1 Hitchhikers along Rural Road

The National Highway Traffic Safety Administration (NHTSA) reports that for 2001, New Mexico's per capita pedestrian fatality rate of 3.94 fatalities per 100,000 population was over 30 percent higher than Arizona's, the second place state, with a rate of 3.00 (*2*). In 2001, pedestrians accounted for 15.6 percent of the state's highway fatalities, much higher than the national average of 11.6 percent. Over the four-year period 1998-2001, 12.9 percent of the state's fatalities were pedestrians. Because New Mexico is a rural state and pedestrian crashes are more commonly thought to be an urban/suburban problem, it is somewhat surprising that the state's proportion of fatalities involving a pedestrian exceeds the national average.

Summary statistics for the three-year period 1998-2000 were obtained from New Mexico's annual crash statistics reports (*11*). Table 1 presents annual counts and percentage distribution of all pedestrian crashes and fatal rural pedestrian crashes in New Mexico. While almost 70 percent of all New Mexico pedestrian crashes occurred in urban areas, nearly half of fatal pedestrian accidents occurred on rural roads.

TABLE 1. New Mexico Pedestrian Crashes

Year	*Pedestrian Crashes*	*Rural (%)*	*Pedestrian Fatalities*	*Rural (%)*
1998	509	30	58	51
1999	463	29	52	51
2000	421	27	47	34

Analysis of Rural New Mexico Pedestrian Crashes

The database for this evaluation consisted of information collected by investigating officers during 1998-2000 for over 400 rural pedestrian crashes in New Mexico. Variables similar to those used in the FARS evaluation were selected and analyzed using the New Mexico data. Consistent with previous practice, crashes with *unknown* cited for any parameter were excluded from the analysis of that particular parameter.

As suggested by data in Table 5, New Mexico had about 135 rural pedestrian crashes and 25 rural pedestrian fatalities per year during the study period. Although it is possible to reach conclusions based on analyses of this small number of incidents, analyses become more powerful if data from multiple years are combined to create a larger homogeneous database. Contingency tables (*12*) are a commonly used tool for assessing the consistency of data from year to year. This tool permits the analyst to test the pedestrian crash data to determine if a parameter of interest, such as highway element, varies significantly among the study years. If the contingency table analysis accepts the hypothesis that highway element is independent of the crash year, then it is proper to group the data from these three years. The primary effect of this grouping is that a much larger sample of crashes is available for analysis (i.e., three years of pedestrian crashes versus highway element).

An r H c contingency table has r rows and c columns. For the analysis of pedestrian crashes, the columns represent the years and the rows represent a parameter of interest, such as the highway elements of intersection or non-intersection. The actual values in the table represent the number of observations (O_{ij}) for the various combinations of highway element (i) and year (j). If the parameters are statistically independent, then the expected number in each cell (E_{ij}) can be estimated by:

$$E_{ij} = \frac{\sum_{j=1}^{c} O_{ij} \sum_{i-1}^{r} O_{ij}}{\sum_{j=1}^{c}\sum_{i=1}^{r} O_{ij}}$$

Once the E_{ij} values have been calculated for each cell, the Chi-square statistic is calculated as follows:

$$\chi^2 = \sum_{j=1}^{c} \sum_{i=1}^{r} \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

The calculated value of χ^2 is then compared to the tabular value $\chi^2_{\alpha,\gamma}$, where α is the level of significance and γ is the degrees of freedom, given by:

$\gamma = (r-1)(c-1)$

The hypothesis of independence is rejected if the calculated value of χ^2 exceeds the tabular value $\chi^2_{\alpha,\gamma}$ (*12*).

Highway element is used here as an example to explain chi-square calculations. Table 2 shows the distribution of New Mexico's rural pedestrian accidents based on highway element over the three-year period 1998-2000.

Table 2. Highway Element versus Year, New Mexico Rural Pedestrian Crashes

Highway Element	***1998***	***1999***	***2000***	***Total***
Intersection	10	6	9	25
Non-Intersection	141	120	94	355
TOTAL	151	126	103	380

The observed distribution of variables in this table is compared with the distribution that would be expected if the variables were independent. The tabular chi-square(χ^2) statistic is based on a desired level of significance (assumed α=0.01) and the degrees of freedom ν= (2-1) * (3-1) = 2. In the context of this analysis, independence mathematically means that the ratio of intersection to non-intersection accidents was essentially the same, regardless of the year of occurrence, or that there is no interaction between year and highway element.

The expected frequencies are calculated as the product of row and column totals divided by the table total. For example, the expected number of pedestrian crashes at non-intersections during 1998 is:

e_{21} = (151*355/380) = 141.06

The calculated expected values are shown in Table 3.

Table 3. Calculated Expected Values, Highway Element versus Year

Highway Element	***1998***	***1999***	***2000***
Intersection	$e_{11} = 9.93$	$e_{12} = 8.29$	$e_{13} = 6.78$
Non-Intersection	$e_{21} = 141.06$	$e_{22} = 117.71$	$e_{23} = 96.22$

A comparison of the data in Tables 2 and 3 reveals that the differences between observed and expected values are relatively small. A chi-square test is performed to see if the differences are significant enough. The tabular value of $\chi^2_{0.01,2}$ = 9.21. The calculated value of χ^2 is:

$$\chi^2 = \sum_{j=1}^{c} \sum_{i=1}^{r} \frac{(O_{ij} - E_{ij})^2}{E_{ij}} = 1.46$$

Comparing the calculated value of chi-square to the tabular value, we cannot reject the hypothesis of independence. In simple terms, the distribution of New Mexico's rural pedestrian crashes by highway element is essentially the same for each of the three study years.

As expected, these rural pedestrian crashes were quite severe, with 99 percent resulting in injury, including 38 percent with fatal injuries. Table B1 in Appendix B shows the percentage distribution of New Mexico's rural pedestrian crash severity by year. Officers cited "had been drinking" for 33 percent of the pedestrians; see Table B1. This statistic developed from the information on the crash report certainly understates the problem. An earlier research project (*7*) collected information on actual blood-alcohol levels from the New Mexico Office of the Medical Investigator and determined that the actual alcohol involvement was closer to 60%.

Fig. 2 Innovative Pedestrian Sign

Among parameters of interest to the engineer, horizontal curvature was cited at 9 percent of the crash locations; this is the same value found in the FARS analysis. As shown in Table B3, the New Mexico values ranged from 4 percent in 1998 to 17 percent in 2000. The reason for this variation is not obvious, but the contingency table analyses rejected the hypothesis that alignment and crash year are independent. Table B4 shows that the profile was level at 88 percent of the crash sites, a result that is also consistent with the FARS analysis. Approximately 92 percent of the crashes occurred on the roadway, with the remainder on the shoulder or roadside; see Table B5.

Fig. 3 Typical Low-Volume Rural Road in NM

Weather does not appear to be a contributing factor; Table B6 shows that less than 4 percent of the crashes occurred during adverse weather conditions. The light conditions for New Mexico's rural pedestrian crashes were 58 percent dark (unlighted), 32 percent daylight, and 5 percent each for dark (lighted) and dawn/dusk. Table B7 shows a large amount of variation by year, and the contingency table analyses concluded that crash year and light condition were not independent.

Table B1. Pedestrian Crash Severity versus Year

Severity	*1998(%)*	*1999 (%)*	*2000 (%)*	*Overall (%)*
Fatal	38.2	40.4	32.7	37.4
Non-Fatal	60.5	58.1	65.5	61.1
Property Damage Only	1.3	1.5	1.8	1.5

Table B2. Pedestrian Sobriety versus Year

Sobriety	*1998(%)*	*1999 (%)*	*2000 (%)*	*Overall (%)*
Had been drinking	31.5	37.1	29.8	32.8
Had not been drinking	68.5	62.9	70.2	67.2

Table B3. Roadway Alignment versus Year

Alignment	*1998 (%)*	*1999 (%)*	*2000 (%)*	*Overall (%)*
Straight	96.0	90.6	83.2	90.6
Curve	4.0	9.4	16.8	9.4

Table B4. Road Gradient versus Year

Grade	*1998 (%)*	*1999 (%)*	*2000 (%)*	*Overall (%)*
Level	87.5	90.7	85.8	87.9
Hill crest	12.5	9.3	14.2	12.1

Table B5. Roadway Relation versus Year

Road Relation	*1998 (%)*	*1999 (%)*	*2000 (%)*	*Overall (%)*
On roadway	93.5	95.5	86.7	92.3
Off roadway	6.5	4.5	13.3	7.7

Table B6. Weather versus Year

Weather	*1998 (%)*	*1999 (%)*	*2000 (%)*	*Overall (%)*
Clear	93.0	90.5	98.2	96.2
Not clear	7.0	9.5	1.8	3.8

Table B7. Light Condition versus Year

Light Condition	*1998 (%)*	*1999 (%)*	*2000 (%)*	*Overall (%)*
Daylight	30.9	22.3	43.2	31.5
Dawn and dusk	4.0	6.2	5.4	5.1
Dark (lighted)	5.4	3.1	7.2	5.1
Dark (not lighted)	59.7	68.4	44.2	58.3