Finding Direction for Safety Investments in Local Roads: System Diagnostics and Countermeasure Focus

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Abstract

Local rural road travel has the highest injury crash incidence in North Dakota. Crashes on these roads were determined to differ in contributing factors and characteristics when compared to those on other rural roads. Crash data from 2006 to 2010 was studied to quantify factor magnitude in predicting injury crash likelihood on High Risk Rural Road Program eligible roads, considering on driver and road factors. Driver behaviors, including impaired driving and seat belt use, have the largest role in likelihood for injury outcomes. Intersections and unpaved road surfaces are found to be most significant in increased likelihood for injury outcomes among the road factors. Findings provide insight for resource and policy decisions that may be most effective in increasing travel safety for users of these rural roads.

Disclaimer

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INTRODUCTION

Local roads are essential to economic and social connectivity. While principle and arterial roads function as the catchment corridors to move goods and people, the most basic class of road – rural local roads – are wide-reaching in providing accessibility for rural areas. Local roads are typified as narrow two-lane road with limited or no shoulder, which often have unpaved surfaces. The significance of these roads in North Dakota travel evident, accounting for 1 in 5 rural travel miles beyond the interstate system (NDDOT 2011).

Road investment and management attention flows naturally to the major, higher-traffic roadways such as rural principal arterials. It is, however, important to recognize that rural local roads often provide the first point of entry into the transportation network for natural-resource based products and local residents. A basic entitlement for these road users is a safe and reliable driving environment. Statistics suggest that there is room for improvement in local road safety based on the travel exposure and crash incident illustrated in Figure 1. Local roads accounted for 21% of travel and nearly half of serious crashes between 2006 and 2010. Serious crashes are defined here to include fatal and disabling injury crash events. The practices and standards established to promote goals for local roads may vary based on resources and priorities, but should be recognizable as a priority in organized and ongoing efforts geared to increase safety.

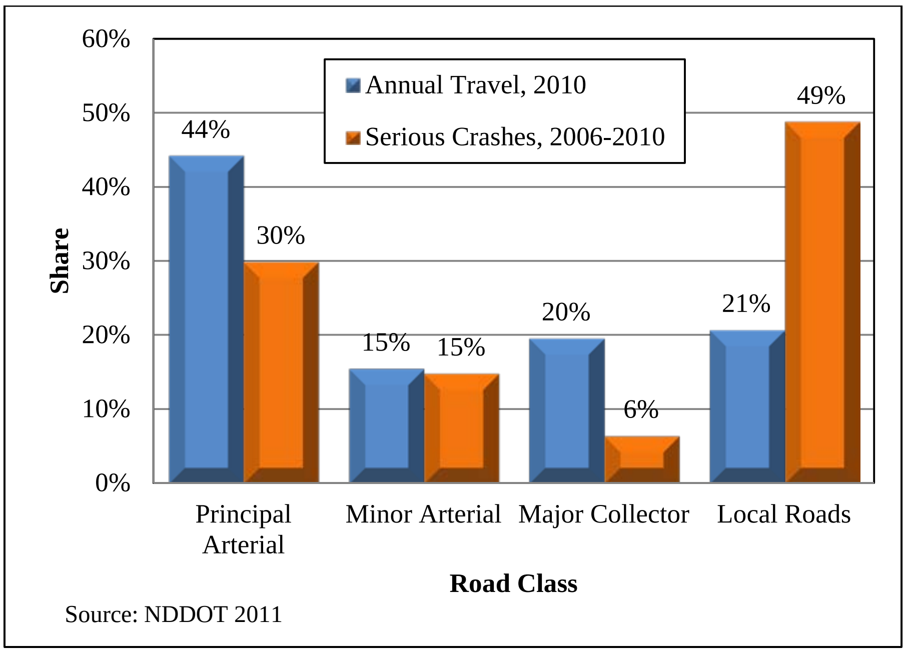


Figure 1 North Dakota Travel and Serious Crashes, by Road Class

The structure of the funding decisions and asset management for roads at the state level is heavily influenced by federal programs. This is driven by the ongoing requisite for interconnecting the federal interstate system and focus on the National Highway System as primary state road corridors for efficient interstate movements. Decisions with regard to lesser state roads and the local road system, however, are treated non-uniformly among states. The focus here is on understanding local roads' safety needs and potential to address these in North Dakota. First, hypotheses are tested to determine if it is appropriate to treat local road crash separately from than other rural road crashes. Work then shifts to understanding the role of these factors in contributing to crash injury likelihood.

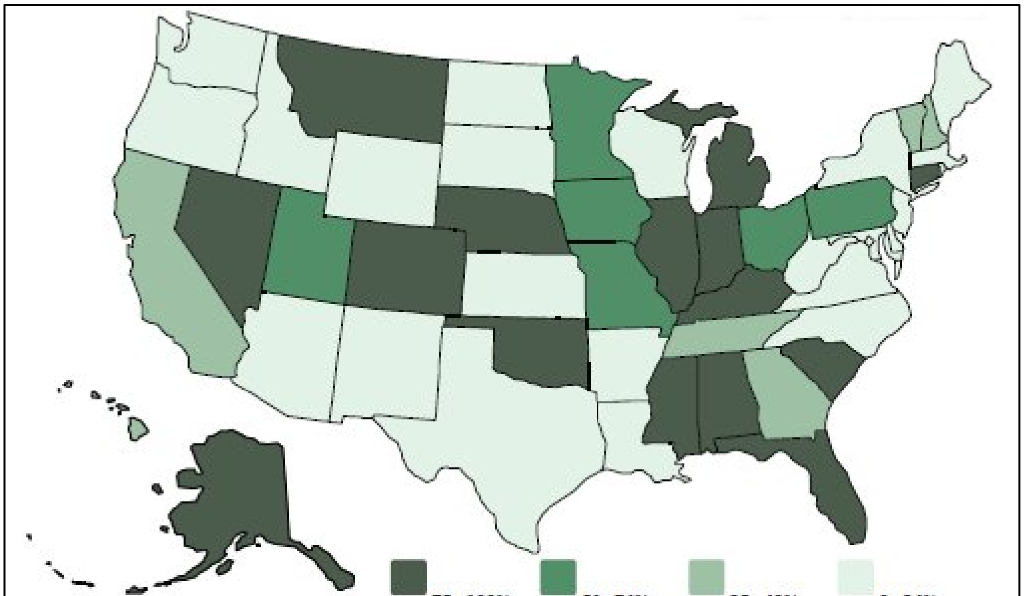
Background

Over recent years federal programs have heightened safety emphasis. While safety has always had consideration in road design and management standards, it is recognized that the United States lags behind other developed nations in controlling economic and social loss attributed to motor vehicle crashes – which are largely preventable. For instance, the United States reported 1.13 road deaths per billion passenger car kilometers, compared to 0.73 and 0.65 for Canada and Australia, respectively (World Health Organization 2011). Interest and ability of states to transfer this heightened federal safety emphasis to local roads, where crash risk is high, varies (Chandler and Anderson 2010, Burgess 2005).

In a 2009 survey of state departments of transportation, 10 of the respondent states indicated they were active in local road safety with data and funding (McDonald and Welch 2009). The data efforts were largely focused on crash data but some did mention local traffic initiatives. The funding used in these efforts was primarily High Risk Rural Roads Program (HRRRP), along with varying levels of Highway Safety Improvement Program (HSIP) and state funds. For example, California law requires all federal safety funds be divided equally between state and local roads. Five states indicated that 100% of the HRRRP funds were dedicated to local roads. Half of the states provided road safety audits as a part of their work with local road programs. Key elements in programs appear to be dedicated and ongoing funding, along with state support for tools that local road managers may use in making local investment and asset management decisions.

An overt signal of federal recognition of the local road safety problem was the aforementioned dedicated funding in the HRRRP. This program was authorized as spending on construction, operational improvements, and the planning, preliminary engineering and road safety audit activities on high-risk rural roads in each state's HSIP to start in FY2006. HSIP was established as a core federal aid program administered by the Federal Highway Administration (FHWA) under the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).

States devised individual plans for implementing the HRRRP within federal guidelines and definitions. One key definition was that 'high risk rural roads are those classified as rural major collectors, rural minor collectors, or rural local roads with fatal and incapacitating injury crash rates above the statewide average for those functional classes of roadway, or likely to experience an increase in traffic volume that leads to a fatal and incapacitating injury crash rates in excess of the average statewide rate' (Chandler and Anderson 2010). Five years after the program was introduced, obligation levels vary widely among the states (Figure 2).

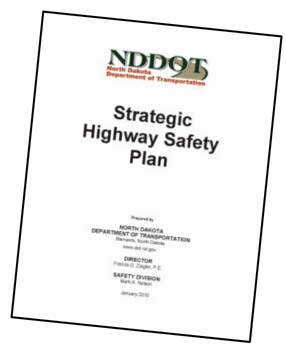


Source: FHWA 2011

Figure 2 Percent of Available HRRRP Funds Obligated as of September 2009

Another notable safety initiative implemented under SAFETEA-LU, which has had implications for the local rural roads in some states, was a requirement for states to develop and implement a Strategic Highway Safety Plan (SHSP) for all roads. The plan developed by North Dakota provided focus for discussing traffic safety issues. Originally adopted in 2006, a revised version was published in 2010. 'The purpose of this Strategic Highway Safety Plan (SHSP) is to identify North Dakota's key safety problems/needs and guide investment decisions to achieve significant reductions in highway fatalities and serious injuries on all public roads. It was developed by the state DOT in a collaborative process including a wide range of safety stakeholders including Federal, State, local, and private sector entities' (NDDOT 2010b). Top priorities are to:

- Reduce Alcohol Impaired Driving
- Increase Seat Belt Use
- Advance Teen and Older Driver Safety Initiatives
- Curb Aggressive Driving
- Reduce Lane Departure Crashes
- Enhance Emergency Medical Capabilities to Enhance Survivability
- Improve Intersection Safety



The SHSP encompasses a foundation for system-wide safety advancement. The nature of travel and risk, however, are different for geographic strata in the system such as rural and urban networks. Rural travel is characterized more often than urban as having high speeds, uncontrolled intersections, lower traffic densities, and fewer roadway safety design/operation features (Burgess 2005). Therefore, while a system-wide approach is desirable as an overarching theme – it is appropriate to distinguish substrata to more effectively study and address road safety within the system.

In addition to establishing common ground for a systematic approach to road safety in the state, the SHSP also opens the door for an additional funding source – HSIP – for local roads and behavioral programs such as education and enforcement (FHWA 2011, GAO 2008). The HSIP funds were apportioned to states for safety-related infrastructure improvements in SAFETEA-LU. A state may opt to 'flex' or reallocate up to 10% of its HSIP funds to non-infrastructure projects if they have written certification with FHWA that infrastructure and railway-highway crossing safety needs have been met for the year. The flexibility to redirect the funds may be approved if larger safety gains, in terms of lives saved as identified in the state's SHSP, are expected from investment in a non-infrastructure effort. The flex does have railway-highway grade crossing and infrastructure safety-need provision requirements.

Several states have successfully implemented flex-funded initiatives to address safety priorities such as speeding, road departure, child passenger safety, and impaired driving (FHWA 2011). The Alabama DOT reports successful flexing of HSIP funds for increased enforcement was successful in that state as it was associated with a 30% reduction in fatal crashes related to speeding. The Michigan DOT flex-funded its "Ice and Snow" road, and experienced a sustained public awareness resulting in 30% reduction in snow-related serious injury crashes. The Nevada DOT credits a flex-funded education and outreach program with reducing serious crashes among two high-risk driver groups in that state – teens and Latinos. The program touched several SHSP target areas, including seat belts, impaired driving, lane departures, intersections, and pedestrians. In a final example, Utah has used flex funding to strengthen public awareness, education, and enforcement under the Zero Fatalities Program it initiated in 2005. Three in four Utah residents were aware of the program in 2009, when traffic fatalities were reported to be the lowest in 34 years.

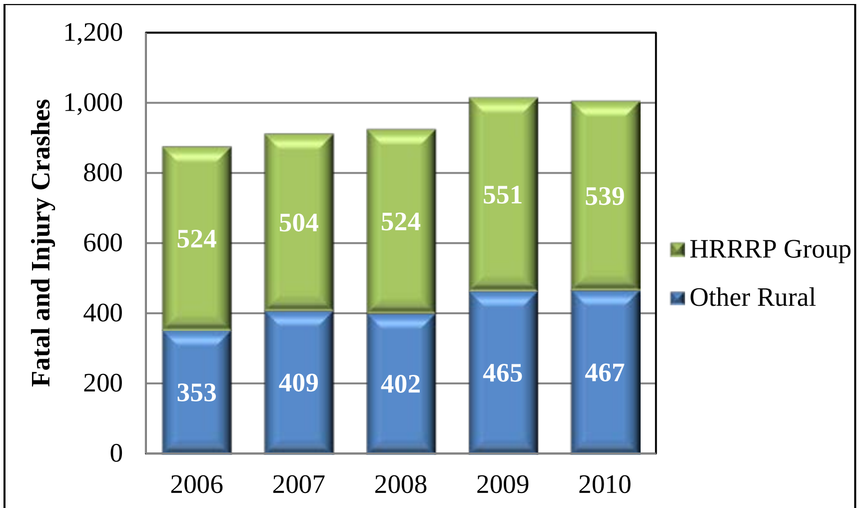
Flexing of HSIP funding enabled NDOT to support multiple education and outreach programs related to the SHSP that would not have received funding or support otherwise. Included with efforts targeting the general population are programs to reduce fatalities and serious injuries among two high-risk groups – young drivers and Latinos. The successful PACE program was expanded from just one area to students all over the state. The proven effective Click It or Ticket and Over the Limit Under Arrest campaigns were also expanded. The RTC free ride program provided 7,326 rides between 7 p.m. and 4 a.m. on New Year's Eve in 2009. While data is not available for the specific day, the number of crashes involving driving under the influence (DUI) in December 2009 was 30 percent lower than in December 2008.

Since 2000 Utah has experienced a reduction in fatal crashes of 34 percent. In 2009, fatalities were the lowest in 34 years. Overall, flex funding has been used to strengthen the Zero Fatalities Program, the overarching safety effort in Utah. Since Zero Fatalities was initiated in 2005, all of the safety campaigns in the State have been branded with the logo. The last market survey in 2009 showed that Utah residents had a 75 percent awareness rate of the Zero Fatalities campaign and the related safety programs. In addition, the flex funded Traffic Safety Prosecutor has helped cities and counties without experience in impaired driving-related court cases reduce the number of dismissals or reduced charges.

Addressing Local Road Safety

While SAFETEA-LU programs provided some latitude for states to address rural local road safety, crash figures suggest that North Dakota has made little progress in transferring its safe travel environment from higher traffic corridors to rural local roads. The importance of improved safety on rural roads is evident in facts reported by the state. Annual reports show that 88% of fatal and injury crashes occurred on rural roads between 2005 and 2009 (NDDOT 2010a). Crash event reports show that safety problems include both infrastructure and behavior elements. Beyond the rural and urban delineation in the crash anatomy, additional detail is available with the FHWA classification system to categorize roads into functional classes based on population and traffic densities. A major class division is made between urban and rural systems. In North Dakota, about 9 of every 10 fatal crashes are on the rural road system.

Within the rural system, road functional classes are interstate, other principal arterial, minor arterial, major collector, minor collector, and local. Interstate rural roads are distinct in the rural category in that these roads are designed, built, and maintained to a high federal standard that ensures safe and reliable interstate travel. Class distinctions show that among non-interstate rural roads, the HRRRP road group – which includes the lowest population/traffic density roads – accounted for a 56% of the fatal and injury crashes over the past five years (Figure 3).[1] The majority of the HRRRP group crashes, 91%, are attributed to the local road system with the other 9% to the major collector system.



Source: NDDOT Crash Data

Figure 3 Rural Road Crash Location

[1] Crashes reported to have occurred within city or town jurisdictions are not included in these figures due to distinct differences in road environments such as speed and intersection maneuvers.

Local roads are typically two-lane, including paved and unpaved surfaces. Roadway features such as shoulder width, ditch slope, pavement markings, and surface condition can vary widely within and across counties. Local resources for road safety were considered in a 2009 survey of North Dakota county road managers (Berwick et. al 2010). Traffic exposure, in terms of vehicle miles traveled, is not routinely collected at the local level by surface type. The extent of local roads system within a county, in terms of distance, ranged from 150 to 1,700 miles. On average, about 18% of the roads managed by the county, which included county system and some township roads, were paved surface. Although it seems reasonable to assume that the paved roadways are more often higher traffic corridors, it is still important to recognize the unpaved road resource demands. Addressing these demands have become more problematic with increasing truck and grain terminal densities, and even more challenging during the recent oil and bioenergy industries' expansions.

Assuming the level of resources and expertise available is related to a local population tax base, a relationship between population and road miles was used as a resource metric. A wide range was found. The median number of local road miles per 100 rural population was 8.3, ranging from a high of 97.9 to a low of 3.9 miles per 100 rural residents. Although maintenance and operations are more commonly discussed as local road management activities, the safety focus in the survey attempted to establish a baseline of knowledge of localized safety issues and practices in North Dakota. With regard to investing in safety, a first step in to improving local roads safety is in identifying common problems. Discussions with local roads managers and a scan of rural road safety publications identified:

- Inadequate sight distance
- Insufficient signage
- Faded pavement markings
- Poor sign retroreflectivity
- Edge drop-offs/shoulder deterioration
- Missing/outdated features (eg. guardrails)
- Short turn lane lengths
- Improper speed limits
- Poor lighting

The next step is identifying reasonable solutions to these problems. A problem exists here in the limited guidance and existing safety countermeasures available for countermeasures and safety improvements on unpaved roads. This is concerning given the relatively high crash associated with the roads. Some immediate, low-cost improvements may be attained by clearing vegetation or improving delineation in the clear zone, or improving signage to provide more advance warning or other valuable driver signals. Among other proven measures recommended by the FHWA for improving safety, few have relevance for unpaved rural roads. Rumble strips/stripes, roundabouts, safety edge, and curve treatment are possible countermeasures when paved rural roads are considered. The Nine Proven Safety Countermeasures include (FHWA 2012):

- Safety Edge
- Roundabouts
- Corridor Access Management
- Backplates with Retroreflective Borders
- Longitudinal Rumble Strips/Stripes on 2-Lane Roads
- Enhanced Delineation and Friction for Horizontal Curves
- Medians and Pedestrian Refuge Areas in Urban and Suburban Areas
- Pedestrian Hybrid Beacon
- "Road Diets" (Roadway Reconfiguration)

The previous sections have provided context for understanding issues, decision-making processes, and resource availability for rural local road safety. The next section discusses data and methods used in the empirical research. Section four provides broad system diagnostics, in terms of descriptive statistics. The hypothesis of interest here is: $H_{o:}$ Local road crash events are similar to other rural road crashes. The following section presents findings for multivariate analysis, including both behavior and engineering parameters. Another premise: $H_{o:}$ Crash prevention should focus on a single element among the driver, road, vehicle, and environment vectors, is addressed here. The model is developed to gain a better understanding of local road safety issues and potential to maximize benefits from safety investments. The analysis is focused on roads that are potentially eligible for HRRRP funding, as discussed in the background section. A final section is comprised of a summary of findings and related discussion.

Data and Methods

Analysis is conducted in a two phases. Initially, descriptive statistics are presented to establish facts about crashes on ND roads. More extensive data was developed for the local rural road system, defined here as the HRRRP candidate roads. Systematic consideration of crash factors is emphasized in the study. Because terrain, traffic patterns, and other factors differ across the state, a geographic perspective is also offered in the descriptive statistics. County boundaries were used as the geographic unit of analysis since the HRRRP candidate roads are often under township and county jurisdiction. In subsequent analysis, multivariate regression is used to model HRRRP road crash factors. Results provide insight regarding the role of engineering and behavioral factors in severity of driver injuries on the local rural road system.

State crash reports from 2006 to 2010 were used in the analysis. The crash reports are completed by law enforcement for all reported crashes – there are to include the population of crashes resulting in any injury or in property damage over $1,000. The crash reports include information about the injury level, driver, environment, vehicle, and roadway. Interest here is primarily in the driver and roadway data related to injury crashes, with variables defined to control for other factors.

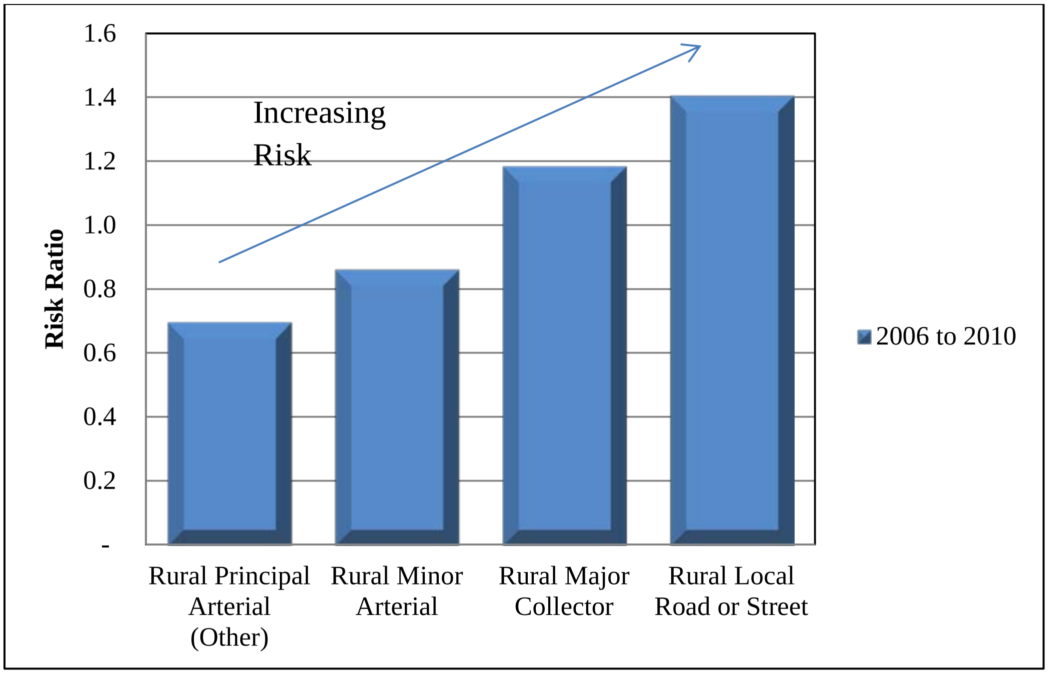


Figure 4 Injury Crash Risk Ratio, AVMT and Crash Distribution by Road Type

Approximately 16,000 crashes occur annually in North Dakota, with about 20% resulting in occupant injury. The injuries are described in a range of severity as possible injury, non-disabling, disabling, or fatal. Among rural roads injury crashes, over 43% occur on local roads (NDDOT 2011). The local rural roads accounted for about 15% of annual state travel so higher risk is evident (NDDOT 2011). Injury crash risk is about 3 times greater on rural local roads than on the state's heavily traveled rural principal arterial roads (Figure 4). The risk ratio is defined as the share of injury (including fatal injuries) crashes to share of vehicle miles traveled for the state.

Injury crashes are distinguished from the larger crash population in this analysis for focus on reducing the most serious incidents and associated economic loss. Annual economic loss from traffic crashes has averaged over $500 million over the past five years (NDDOT 2010a). Injury crashes account for over 80% of the loss, with of total losses 53% attributed to non-fatal injury crashes. Common practice is to focus solely on the fatal incidents when conducting crash analysis. In more rural areas, however, where crashes tend to be episodic in nature this may yield skewed results that fail to represent the large crash population. Therefore, diligence was taken in identifying a preferred study group by testing the relationship between potential crash study groups (Table 1). Crash group association analysis, based on county location, shows a strong relationship between all injury crashes and total crashes. The Pearson's r correlations show that over 99% of the variation in all crashes can be explained by the injury crashes, while only 66% of the variation in all crashes can be explained by studying fatal crashes. These calculations, and the larger investigation here, is limited to the non-interstate rural roads beyond city limits due to the distinct nature of towns and interstates in terms of users, travel speeds, traffic patterns, land use, law enforcement visibility, and safety features.

Table 1 Strength of Relation between Crash Types Based on County-Level Incidents, 2006 to 2010

Crash Group 1/ Crash Group 2	Rural Crashes by County (Pearson's r Correlation)[1]
Fatal/All	0.6620
Fatal/Injury[2]	0.6755
Fatal/Serious Injury[3]	0.8451
Serious Injury/All	0.8165
Serious Injury/Injury	0.8362
Injury/All	0.9989

[1]Note: Less than 0.70 moderate, 0.70 to 0.89 high, over 0.89 very high;
[2]Injury includes Fatal Injury and Other Injury Types [3]Serious Injury includes Fatal and Disabling Injury Types
Source: NDDOT Crash Data

Table 2 Strength of Relation between Exposure Measures and Crash Events, Based on County-Level Incidents from 2006-2010

Crash Group[2,3]/ Exposure Measure	Rural Crashes by County (Pearson's r Correlation)[1]
Serious Injury/ Rural Population	0.6982
Serious Injury/Rural VMT	0.6035
Serious Injury/Rural Lane Mile	0.6435
All Injury/Rural Population	0.7526
All Injury/VMT	0.7247
All Injury/Lane Miles	0.7451
All/Rural Population	0.7341
All/Rural VMT	0.7101
All/Rural Lane Miles	0.7378

[1]Note: Less than 0.70 moderate, 0.70 to 0.89 high, over 0.89 very high;
[2]Serious Injury includes Fatal and Disabling Injury Types [3]All Injury includes Fatal Injury and Other Injury Types
Source: NDDOT Crash Data, U.S. Census, U.S. Department of Transportation

A second effort in diligence to most accurately representing and discussing rural local road safety, given the current available data, was in selecting an exposure measure. Table 2 looks at the relationship between potential travel exposure measures and crash incidents, at the county level. Vehicle miles traveled (VMT) is a common unit used for exposure in crash analysis, but this information is very limited for local rural roads. Therefore, two other potential measures were tested – lane miles and population. Results for correlation between the travel and crashes show that injury crashes and rural population have stronger relationships than other potential study units. Therefore, county unit population is employed as the exposure measure for this study in descriptive analysis since it is readily available.

Regression analysis, a more powerful tool, offers a means to assess the role of driver, road, vehicle, and environment elements in predicting crash severity. In addition, it provides an understanding of often confounding factors in rural local road safety. Logistic regression measures the relationship between dependent and independent variables, while recognizing effects of simultaneous effects among terms in relation to the dependent variable. Results cannot be used to discuss causation, but do produce log-odds ratios for understanding relative effects of individual factors associated with crash outcomes. This methodology has been applied in other traffic safety assessments and provides valuable quantitative information that may be used in prioritizing activities and guiding policy-making to improve public safety (Gonzales et. al 2005, Chandraratna et. al 2006, Lui and Dissanayake 2009, Gkritzaa et. al 2010). The model is generally defined as follows:

$$P_n = \frac{e^{g(x)}}{1+e^{g(x)}}, \text{ so} \qquad \text{Equation 1}$$

$$P_s = 1 - P_n = 1 - \pi(x) = \frac{1}{1+e^{g(x)}} \qquad \text{Equation 2}$$

P_n = probability of driver incurring injury in crash, and

P_s = probability of driver not incurring injury in crash,

where g(x) includes a set of independent variables related to driver and environment in

$$g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_n x_n \qquad \text{Equation 3}$$

The maximum-likelihood technique was used to determine the coefficients that make the observed set of outcomes most likely. This type of model allows multiple independent factors to be considered in understanding the roles of operators, roads, vehicles, and environment in local road safety. Model definition and results are presented in the Empirical Analysis section.

Local Roads Crash Diagnostics

Crash causes and mitigation, such as crash modification factors, are generally discussed around four major components, human, roadway, vehicle, and environment (FHWA 2010). Within these four areas, data elements discussed here will be selected from information available in the state crash reports. Driver characteristics include age, gender, and behavior. Information regarding the roadway is available from fields such as curve, hill, intersection, and surface type. Limited descriptors for the vehicle can be used to show if the vehicle was equipped with airbags or anti-lock brakes, along with the age and type of vehicle. The final component, environment, is a catchment for elements such as time and weather.

A first step in understanding the crashes on local rural roads, and potential differentiation from other rural crashes, is identifying common elements, with attention given to special interest events such those involving occupant injury or lane departure. Occupant injury crashes is an obvious critical area. The lane departure crashes are of special interest due to incidence and prominence in the state's safety planning. Understanding crash types and factors is a fundamental step in work to reduce crash injury and death.

Reports for crash types and factors show that the local rural roads, or HRRRP eligible road group, differ significantly in its profile compared to crashes on other rural roads (Table 3). Thus, the null hypothesis can be rejected to validate the need to distinguish the road groups in discussing crash injury prevention on rural roads. An initial distinction in the two rural crash populations is the greater prominence of single vehicle crashes on the local rural roads. Given the lighter traffic densities associated with these roads, this is expected but may not be a generally recognized fact. Lane departure is reported in about 6 of every 10 injury crashes that occur on local rural roads. The local rural roads incidence is significantly higher than for other rural roads (χ^2=17.4780, p=<.001, n=6,071). Crash reports show these crashes are also more likely to involve road departure and rollovers – 52.2% and 45.9%, compared to 36.0% and 32.8%, respectively, for other rural roads.

On local rural roads, a much higher share of crashes are attributed to unpaved surfaces – nearly half of the crashes occur on unpaved. Given the nature of this road system, it is reasonable to see this difference but it is important to recognize what this means for trying to reduce crashes on rural roads. The traditional focus of federal funds on highways and high-traffic corridors has meant limited investment in understanding unpaved roads construction and management (Kocher et. al 2007, Huntington and Ksaibati 2010). Since unpaved road crashes appear to be largely attributable to local roads, outside resources and expertise would be needed to establish and implement safety-related asset management initiatives. With regard to other road features, about 1 in 4 crashes occur on or are related to a hill – the same for local rural roads and other rural roads. Intersection crashes are more common on other rural roads, while curve-related crashes are more problematic on the local roads.

Several of the subsequent factors among those reported, in terms of injury crash involvement, are related to driver behavior. Drivers on local rural roads are half as likely to be wearing seat belts, based on reported injury crashes. Speeding, including exceeding the posted speed limit and driving too fast for conditions, and impaired driving are also more common in local rural road crashes than on other rural roads. Impaired driving, including drug or alcohol involvement, is substantially great on local rural roads. Nearly one in four local road injury crashes are drug/alcohol related compared to about one in eight on other rural roads.

Teen driver involvement is also flagged as significantly different in treating safety with regard to local roads in the rural road system. Although the degree to which exposure affects teen involvement cannot be determined, the magnitude in the difference suggests that it may be beneficial to focus on teen driver safety in reducing local rural road crashes. Another driver group deemed at higher-risk for injury is older drivers. These drivers, however, are shown to have great involvement in rural crashes on non-local roads.

Table 3 Factors Reported, ND Rural Road Injury Crashes 2006 to 2010

	Local Rural (HRRRP)	Other Rural (No Towns or Interstate)	All Rural (No Interstate or Town)	Local Compared to Other Rural	Significant Difference[1]
Male Driver	68.3%	66.7%	66.6%	+2.4%	n.s.
Single Vehicle	66.0%	44.1%	55.5%	+49.7%	***
Lane Departure	61.4%	56.1%	58.9%	+9.4%	***
Road Departure	52.2%	36.0%	44.4%	+45.3%	***
No Seat Belt	46.5%	30.1%	38.7%	+54.3%	***
Unpaved	46.4%	1.0%	24.7%	+>100.0%	***
Rollover	45.9%	32.8%	39.6%	+39.9%	***
Speed	36.1%	25.4%	31.0%	+42.1%	***
Hill	26.0%	25.0%	25.5%	+4.1%	n.s.
Alcohol/Drug Involved	24.1%	13.6%	19.1%	+77.6%	***
Intersection	22.6%	25.0%	23.8%	-9.6%	*
Curve	18.9%	13.7%	16.4%	+37.5%	***
Teen	14.4%	6.5%	10.6%	+>100.0%	***
Weather Related	11.1%	21.7%	16.2%	-48.6%	***
Failure to Yield	5.3%	6.8%	6.0%	-21.3%	***
Deer	3.3%	4.9%	4.0%	-33.0%	*
Older (>75)	2.1%	6.0%	4.0%	-64.2%	***
Units/Drivers in Crashes	3,167	2,904	6,071		

[1]Significance: ***p=<.001, **p=<0.01, *p=<0.05., n.s. not significant

In addition to systematic consideration of the crash factors, geographic perspectives may also be useful in spurring and deploying local rural roads safety efforts. All counties in the state reported crashes on local rural roads group roads during the past five years. In absolute terms, the lowest number of local rural roads injury crash events was recorded for Logan with 3 crashes. The highest number of injury crashes occurred on Burleigh local rural roads at 212. Total reported local rural roads crashes, including the injury and non-injury events, were lowest in Sioux county[2] at 22 and highest in Burleigh at 1,155. Although these overall crash figures are important, more severe injury events provide focus for understanding factors that may be most relevant in reducing risk for crash injury and death on these roads.

[2]Sioux county crashes may be underreported due to limited tribal government participation in the state crash record system.

Standardizing the number of crash events by some type of exposure factor provides an incidence rate – which is further refined in a measure used to understanding risk. The map in Figure 5 shows the quartile distributions for the number of injury crashes per 1,000 rural residents with

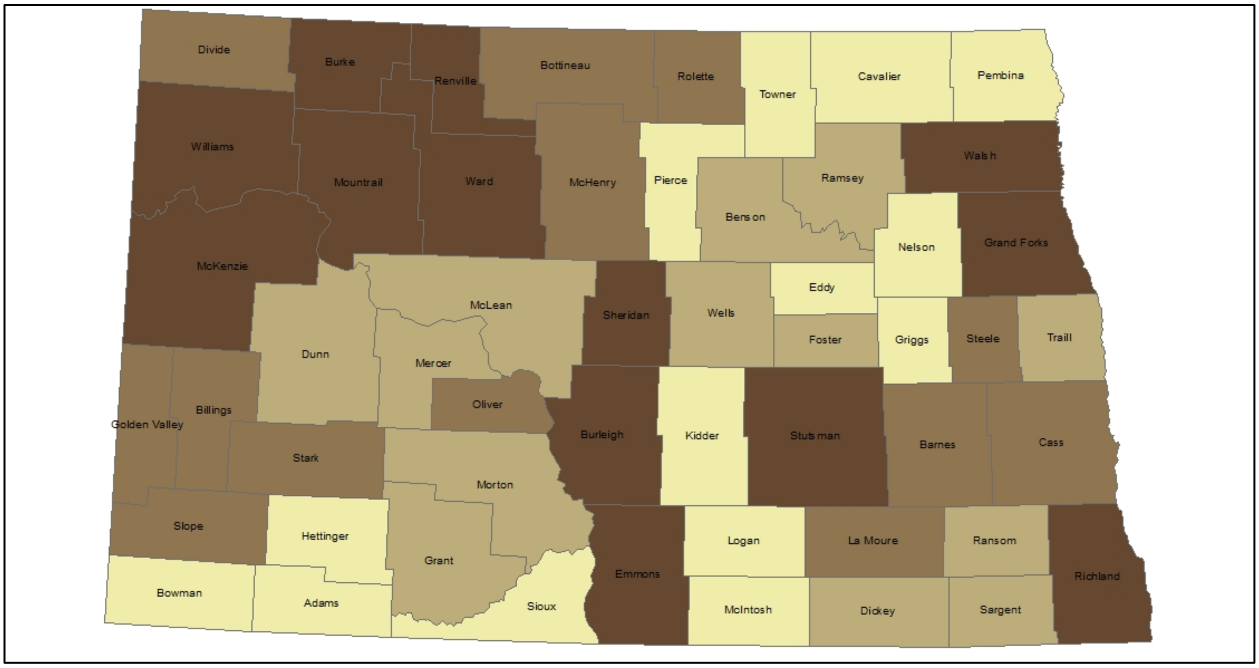


Figure 5 Local Rural Roads Population-Based Injury Crash Incidence from 2006 to 2010, Darker Indicating Higher Risk

counties shaded lightest to darkest colors to indicate risk levels associated with HRRRP roads in the county. Controlling for exposure, in terms of population, the highest crash risk on HRRRP roads are found to be two county clusters and four other counties. The northwest cluster includes Burke, McKenzie, Mountrail, Renville, Ward, and Williams. The south central cluster includes Burleigh, Emmons, and Sheridan. Other counties with relatively high risk for HRRRP crashes include Grand Forks, Richland, Stutsman, and Walsh counties – which are located in the east and south central regions. The population-based crash incidence is highest Williams at 25.8 injury crashes per 1,000 per rural residents. Rates for the yellow counties, which are in the lowest incidence quartile, range from 1.4 to 6.3.

As noted, traffic volumes can also be used as a denominator in standardizing travel exposure among the counties. Rural vehicle-miles-traveled are estimated and reported by the state. As noted previously, the VMT is collected for local roads on an episodic basis rather than systemic. These figures were used to determine non-interstate rural road travel that was used as the VMT exposure. The traffic volume standardization does produce results that differ somewhat from the population-based. The darkest shaded counties in Figure 6 are the highest risk considering VMT exposure. Nine counties were found to be in the highest risk quartile for local rural roads injury crashes looking at results for either incidence measure. These include:

- Burleigh
- Emmons
- Grand Forks
- Mountrail
- Richland
- Renville
- Stutsman
- Walsh
- Williams

With a systematic approach, the geographic perspective may be useful in understanding where initial effort may maximize benefit for a selected issue or intervention.

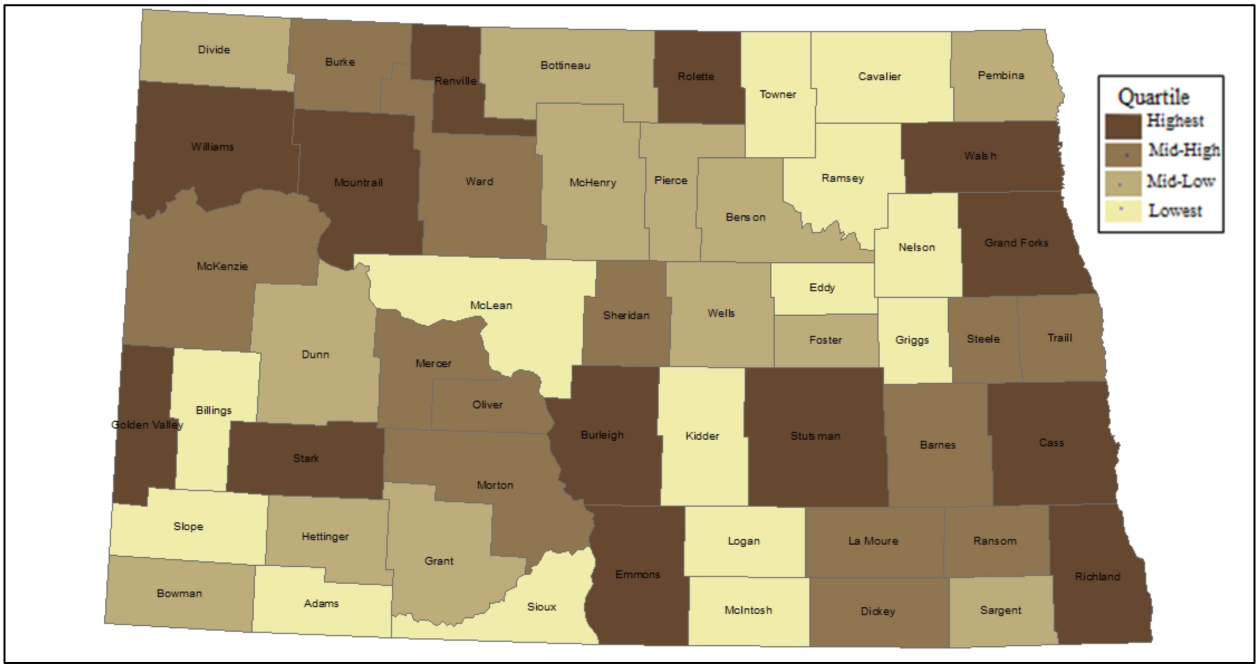


Figure 6 Local Rural Roads VMT-Based Injury Crash Incidence by County, 2006 to 2010

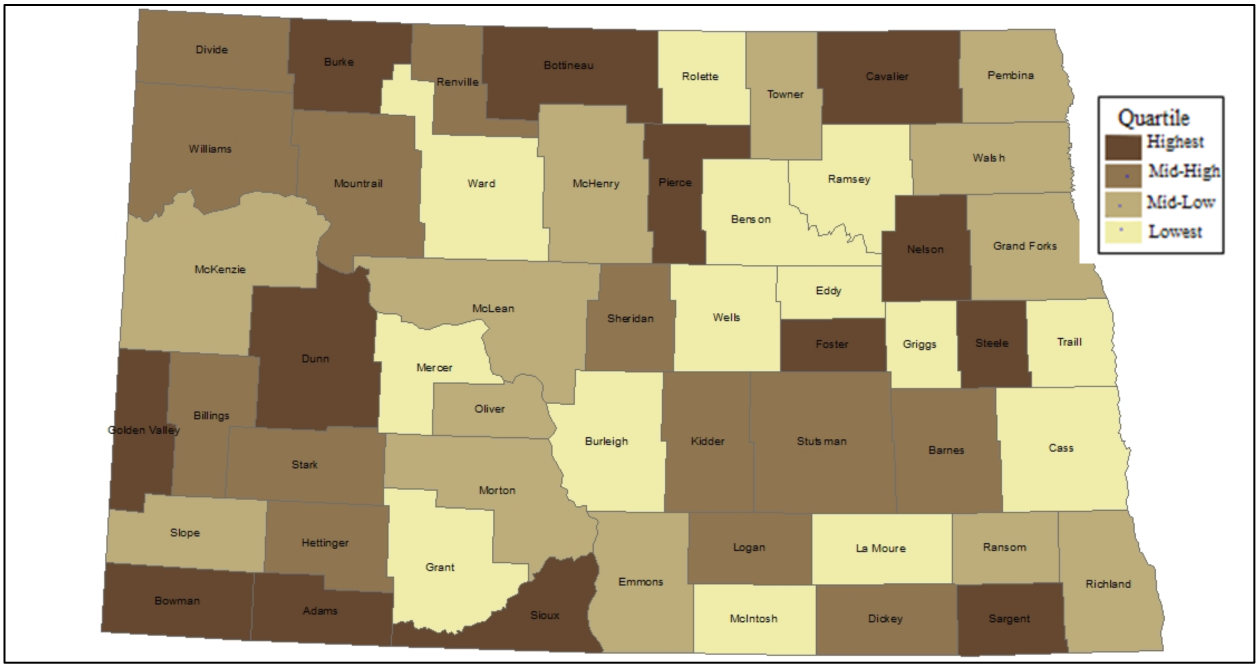


Figure 7 Local Rural Roads Lane Departure Crash Incidence in Injury Crashes by County, 2006 to 2010

In a continuation of the effort to highlight SHSP priorities, lane departure crashes are given special attention as a large injury crash group. Engineering elements related to these events may offer opportunities to reduce crash injury and death through changes to road features such as driver recovery related to pavement edge, ditch slope, roadside hazards, and shoulder width. Driver education related to vehicle steering and braking in these situations may also be beneficial.

Crash reports show 68.9% of lane departure crash injuries involved road departure. Rollover events are associated with serious crashes, which are also often in the lane departure crash group, and especially its road departure segment. When there was lane departure, over half the crashes – 60.1% – had a rollover. When road departure occurs on local rural roads, a rollover is reported in 71.1% of the crashes. This incidence is similar on other rural roads where 71.9% of road departures involve rollovers.

Between 2006 and 2010, 1,346 drivers were involved in rollovers on local rural roads. About 1 in 10 of these crashes was reported as fatal injury – in 91.3% of the 103 fatal injury cases, the driver was not using a seat belt. In the fatal injury cases in the rollovers, 78.7% of unbelted drivers were ejected. In the limited number of rollover fatalities where drivers were using seat belts, 2 of the 9 drivers – 22.2% – were ejected or partially ejected. When the driver was reported ejected or partial ejected in an injury crash, considering all local rural roads crash events between 2006 and 2010, incidence of death was 3.6 times greater than when the driver remained in the vehicle (Figure 8). As with the larger lane departure group, there is potential to reduce rollover outcomes through improvements to the driver recovery zone. In addition, enforcement and education related to increased seat belt use have great potential to reduce severity of these crashes.

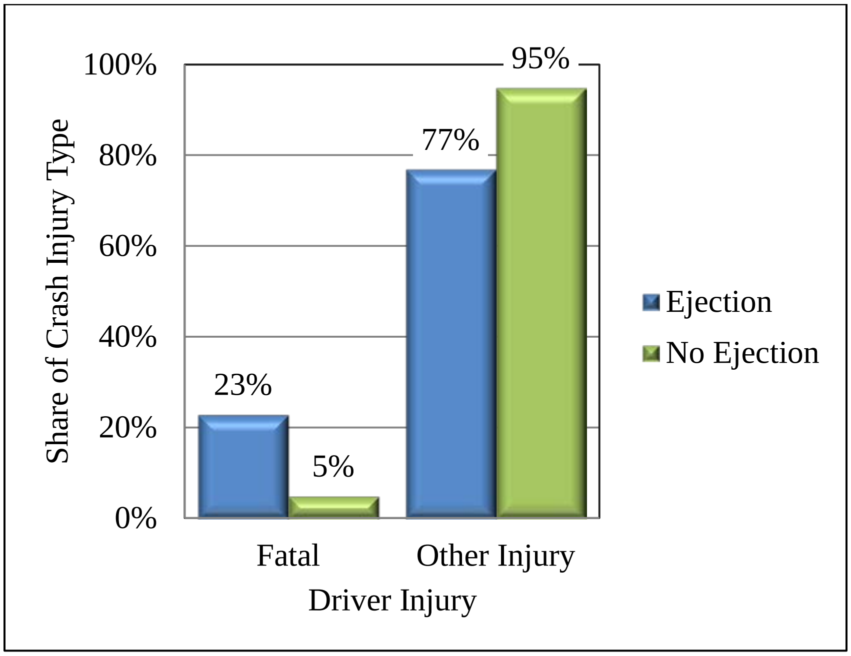


Figure 8 Driver Injury Severity in Local Rural Roads Crashes from 2006 to 2010, Driver Ejection

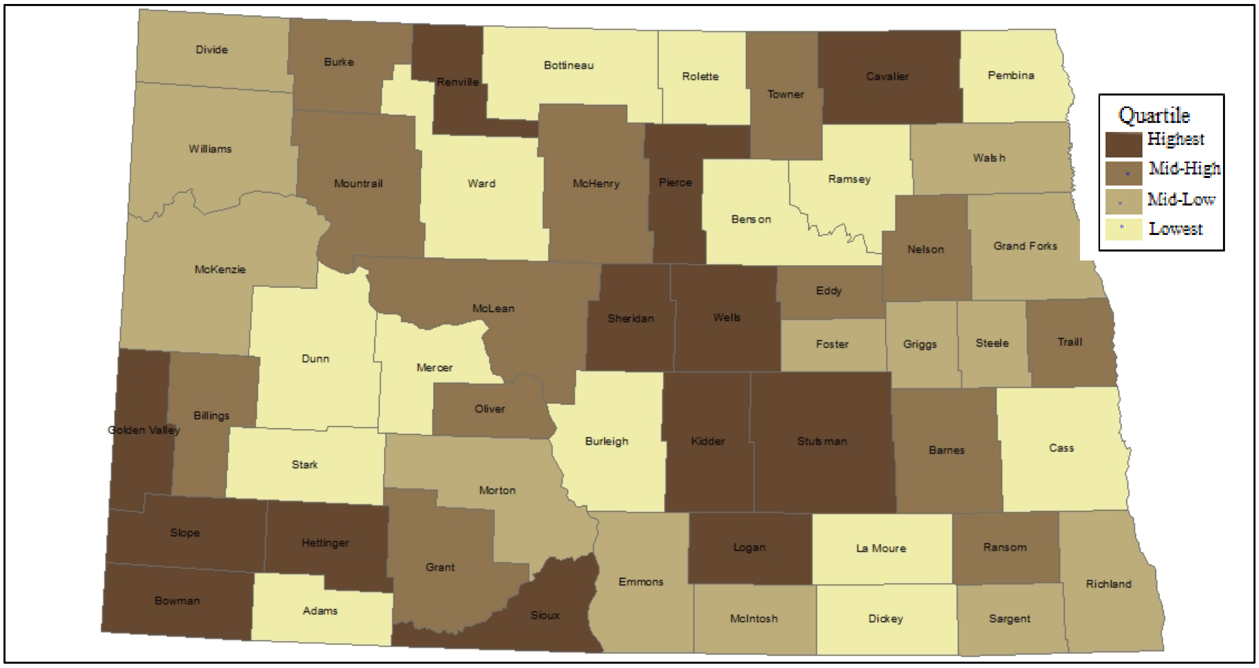


Figure 9 Local Rural Roads Rollover Crash Incidence in Injury Crashes by County, 2006 to 2010

Similar quartile-based distributions county-level incidence for other leading crash factors are illustrated in Figure 10 and Figure 11. The quartile assignments are based on a distribution of the share of injury crashes in the county, between 2006 and 2010, that involve the crash factor. The seat belt use, speed, and impaired driving factors show that Logan and Sioux counties have high incidence of all three factors – considering population-based incidence rates for all counties. In the road factor illustrations of the quartiles, Golden Valley and Billings are in the highest quartile for the crash incidence rates for all factors.

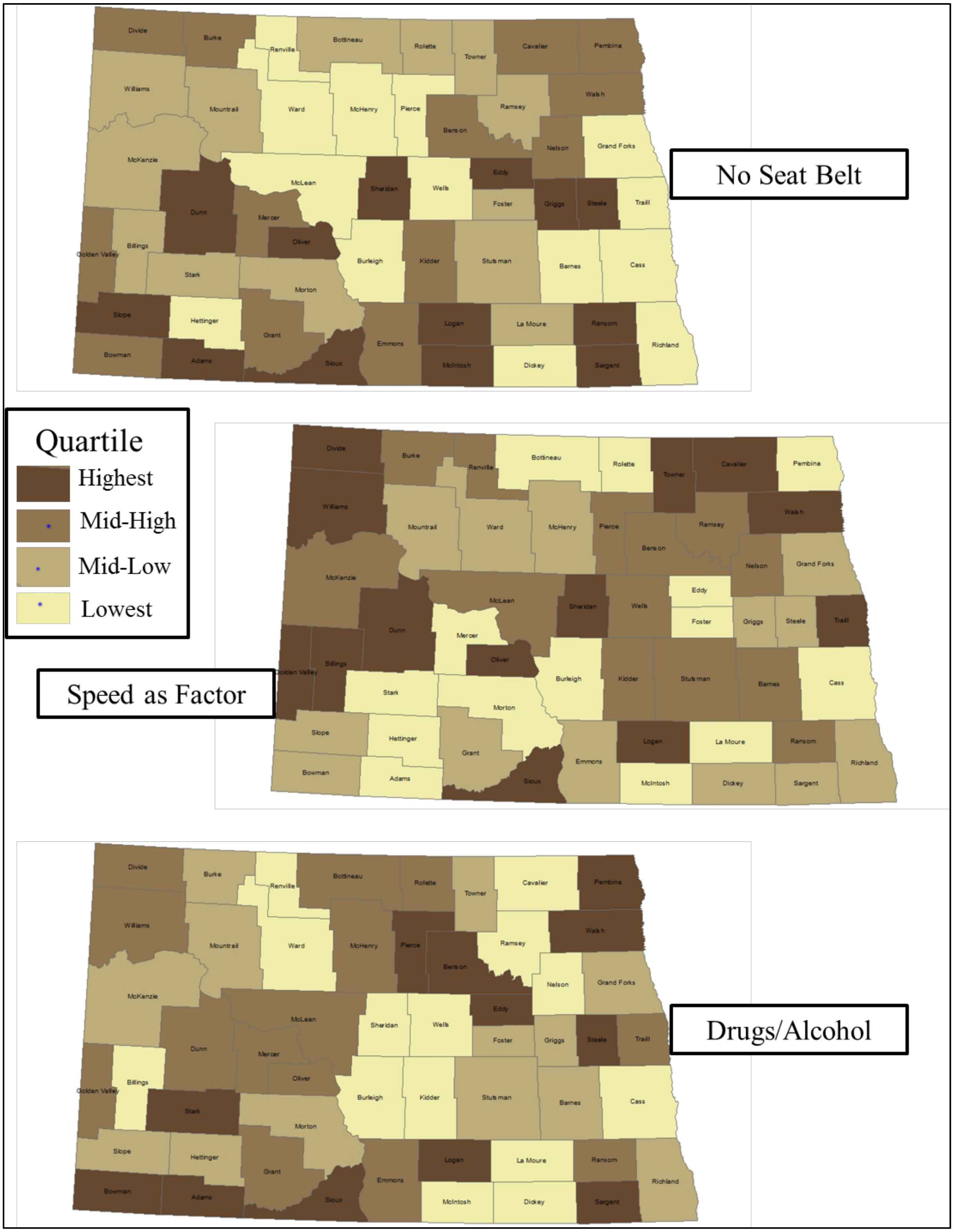


Figure 10 Local Rural Roads Injury Crash Factor Incidence by County. 2006 to 2010

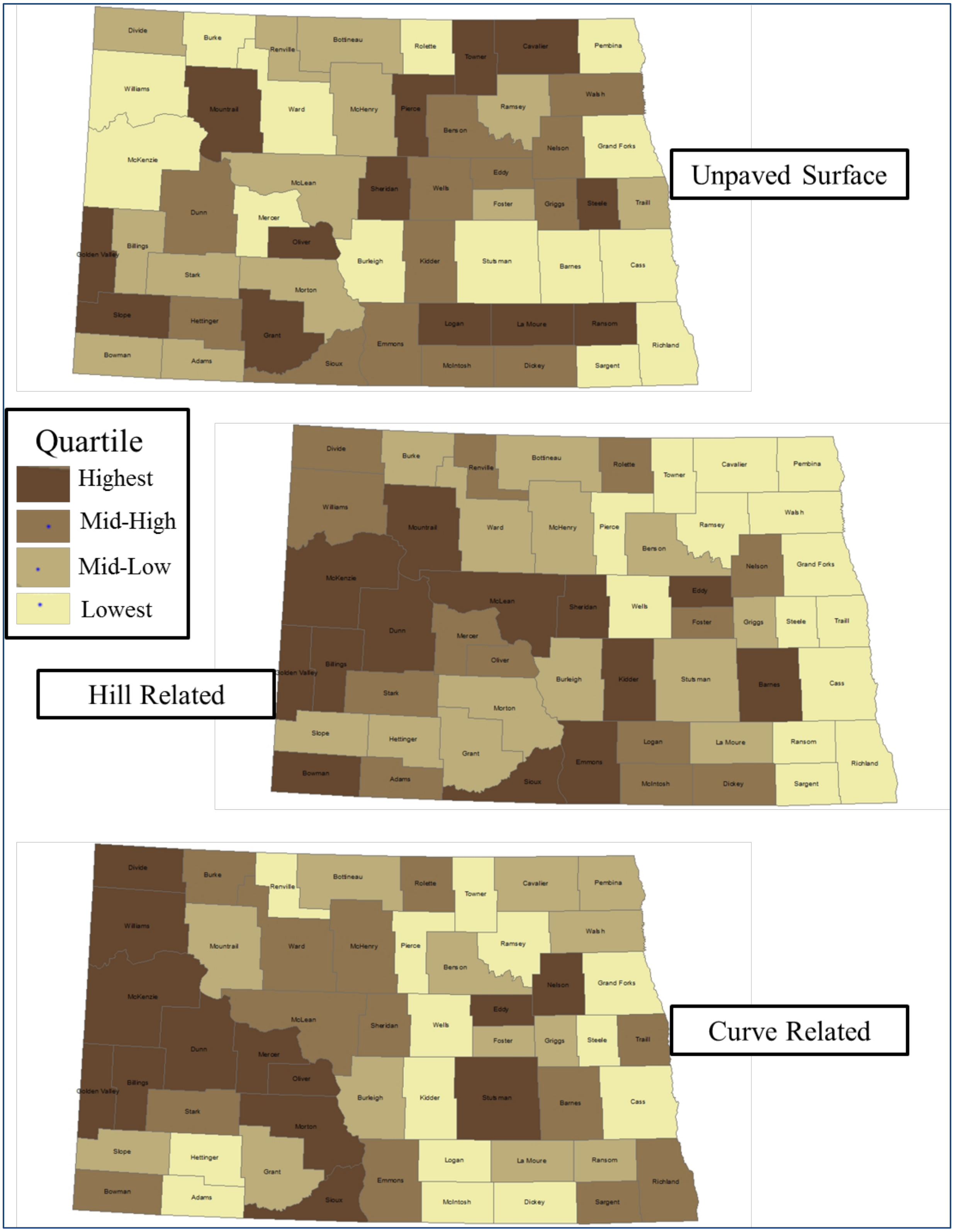


Figure 11 Local Rural Roads Injury Crash Factor Incidence by County, 2006 to 2010 (cont.)

While overall and geographic understanding of the prominence of factors in rural road crashes is crucial, it is important to note that crashes often involve multiple factors. The crosstab description of crash factors reported for local rural roads injury events from 2006 to 2010 provides insight regarding the multifactor nature of these crashes (Table 4). For example, consider the lane departure crash group. In these crashes, 49.4% of drivers injured in these crashes were not using proper occupant protection. The role of impairment in these crashes is also evident as 1 in 3 drivers in lane departure crashes is impaired by alcohol or drugs. One in three drivers was driving too fast for conditions. About 7 in 10 driver lane departures will result in a rollover.

Table 4 Crosstab Description of Local Rural Roads Injury Crashes, 2006 to 2010

Crash Factor	Crash Factor: No Occupant Protection	Impaired	Aggressive	Too Fast	Weather	Intersection	Unpaved	Lane Departure	Run off Road	Rollover	Hill	Curve
No OcProt		576	272	447	136	276	753	961	857	737	407	344
Impaired	576		69	272	59	109	359	584	519	440	218	207
Aggressive	272	69		312	67	87	353	481	447	387	168	147
Too Fast	447	272	312		97	109	503	629	611	572	246	259
Weather	136	59	67	97		79	114	233	182	150	92	62
Intersection	276	109	87	109	79		233	279	157	139	130	74
Unpaved	753	359	353	503	114	233		966	908	842	392	224
Lane Deprt	961	584	481	629	233	279	966		1341	1170	563	445
Run off Rd	857	519	447	611	182	157	908	1341		1122	479	426
Rollover	737	440	387	572	150	139	842	1170	1122		426	357
Hill	407	218	168	246	92	130	392	563	479	426		337
Curve	344	207	147	259	62	74	224	445	426	357	337	
Factor n=	1472	763	625	831	353	717	1470	1945	1654	1454	824	597
Total N=	3167	3167	3167	3167	3167	3167	3167	3167	3167	3167	3167	3167
Factor Share=	46.5%	24.1%	19.7%	26.2%	11.1%	22.6%	46.4%	61.4%	52.2%	45.9%	26.0%	18.9%

Cells shaded by Quartile: 1st=no color, 2nd=light shade, 3rd=medium shade to 4th=dark shade.

The crosstab summary of crash factors shows where interconnected issues exist in the local rural roads injury crashes. Understanding these relationships is useful in targeting resources. For instance, investments aimed to reduce crashes related to hills such as driver awareness campaigns or increased signage should also reduce lane departure crashes. A reduction in lane departure injury crashes should also reduce events with high crosstab association such as unpaved, road departure, and rollover crashes. While these crosstab associations may be similar for local rural roads and other rural roads, it is evident that factors such as unpaved surfaces, driving too fast for conditions, and unbelted and impaired drivers are relatively more troublesome issues on local rural roads in the state (Figure 12).

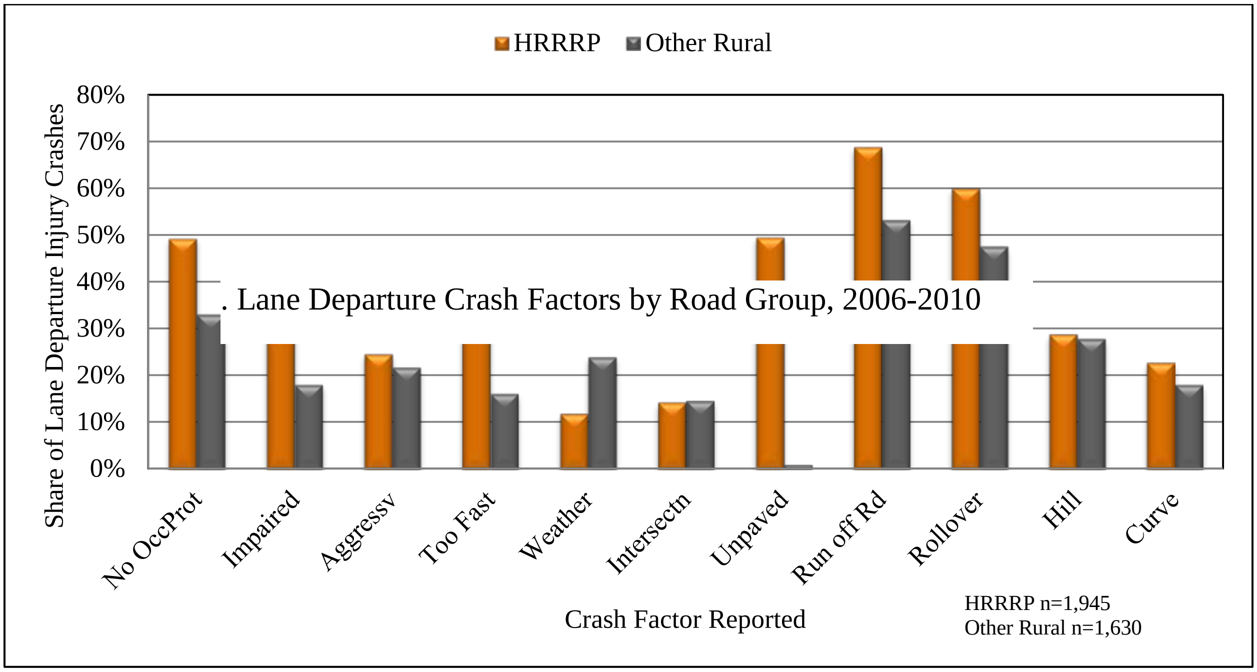


Figure 12 Lane Departure Crash Factors, Local Rural Roads and Other Rural Road Injury Crashes from 2006 to 2010

Mutually beneficial opportunities may also be revealed in targeting behaviors such as seat belt use. Crosstab relations suggest that increased seat belt use should also reduce injury crashes related to impaired driving, unpaved surfaces, lane departure, road departure, and rollover (Table 4). The simultaneous effects among independent factors are addressed in the regression findings in the next section. Coupling the incidence rates and crosstab frequencies with systemic logistic regression will provide a more robust foundation for identifying priorities and understanding potential benefits for investing local rural roads road safety resources.

Systemic Local Rural Roads Injury Crash Analysis

The ability to consider multiple risk factors is key in discussing crash reduction efforts. It is rare that a crash report has a single contributing factor reported throughout the driver, environment, road, and vehicle event profile contained in the crash report. Many applications of multivariate analysis have been used to understand crash factors (Krull et. al 2000, Chandraratna et al. 2006, Morgan and Mannering 2011). This research extends existing knowledge by developing a localized, systemic understanding of local rural roads crashes in North Dakota. It considers the local culture, traffic, legacy, and resource factors that are difficult to address in national studies. A review of research and state crash form elements were used to define an initial logit model for the local rural road crash injury outcomes.

Table 5 Model Variable Definitions

Dependent Variable		
	Serious Injury	Fatal or Disabling Injury=1; Else=0
	Injury	Fatal, Disabling, or Non-disabling Injury=1; Else=0
Driver		
	Gender	Male=1, Female=0
	Occupant Protection	No Seat Belt Used=1; Seat Belt Used=1
	Impaired	Drinking Driver=1, Non Drinking Driver=0
	Young Adult	Age 18-24=1; Over 24=0
	Teen	Age 14-17=1; Over 17=0
	Too Fast	Driving Too Fast for Conditions
Road		
	Hill	Road Geometrics reported as Straight on grade, Hill Crest=1; Else=0
	Curve	Road Geometrics reported as Curve on grade, Curve on Level=1; Else=0
	Intersection	Relation to Junction reported at Intersection, Intersection related=1; Else=0
Environment		
	Pickup	Vehicle Type is Pickup Truck=1; Other Type=0
	Weather	Weather reported as Rain, Snow, Blowing Soil/Snow, Sleet/Hail/Freezing Rain, Fog/Smoke/Dust, or Severe Wind=1; Else Weather=0
	Unpaved	Surface Type reported as Gravel, Scoria, or Dirt=1; Else=0
	Winter Road	Road Surface Snow, Slush, Ice/Compacted Snow, or Frost=1; Else=0
	Dark	Light Condition Dark (not lighted)=1; Else=0;
	Late Night	Time between 11:00 pm to 4:59 am=1; Other=0
Vehicle		
	No Anti-lock Brakes	No=1; Yes=0

Initially, the systemic local rural roads crash model was defined to include the several driver, road, environment, and vehicle elements (Table 5). In addition, two definitions of the dependent variable were tested to assess model rigor in consistency and strength. Both definitions of the dependent variable provided consistent results with regard to their relation to independent variables. Strength of the injury model, however, is evidenced by greater levels of significance with several of the independent variables. The preference of use of all injury crashes is also consistent with the relationships presented in Table 1. Results are presented in Table 6. The model has good explanatory power with a ROC value near 0.80. Concordance is found in 77.5% of the cases, comparing the relationship between actual and predicted dependent variable results.

Table 6 Local Rural Roads Driver Injury Model Results

Parameter	Estimate	S.E.	P-Value	Significance[1]	Log-Odds	95% CI
Teen Driver	0.4654	0.0836	<.0001	***	1.593	1.352-1.876
No Seat Belt	1.0453	0.0491	<.0001	***	2.844	2.583-3.131
Too Fast	0.6861	0.0602	<.0001	***	1.986	1.765-2.234
Impaired	1.7292	0.0749	<.0001	***	5.636	4.866-6.528
Unpaved	0.5953	0.049	<.0001	***	1.814	1.647-1.996
Curve	0.3749	0.0715	<.0001	***	1.455	1.265-1.674
Hill	0.4911	0.0602	<.0001	***	1.634	1.452-1.838
Intersection	0.6598	0.0568	<.0001	***	1.934	1.731-2.162
Antilock Brakes	-0.1785	0.0616	0.0038	**	0.837	0.741-0.944
Dark	-0.6446	0.0507	<.0001	***	0.525	0.475-0.580
Concordant %	77.5					
ROC	0.79					

[1]Significance: ***p=<.001, **p=<0.01, *p=<0.05., n.s. not significant

Not unexpected, the driver factors are critical in understanding and potentially reducing crash injury on local rural roads. Impaired driving has the largest weight among factors in modeling injury likelihood in local rural roads crashes. Impaired driver likelihood for crash involvement is 5.6 times greater than that for unimpaired drivers. Impaired drivers have often been identified as a high-risk driver group. Results here quantify the magnitude of the problem in the likelihood impaired driver crashes will involve injury.

Driver decisions not to use seat belts are also a large factor in the likelihood a crash event will result in injury. Unbelted drivers are nearly three times more likely to be injured when involved in a crash on local rural roads than drivers who are belted – 2.8 times increased likelihood. Speed, defined as driving too fast for conditions, is also found to be linked to driver injury. When drivers are reported to be traveling too fast for conditions, crash risk is also nearly double compared to cases where the driver is traveling at appropriate speeds.

Teen drivers also have a heightened chance for injury outcomes in crash events on local rural roads. It is 59.3% more likely that a crash will involve injury when the driver is between the ages of 14 and 17. Recently enacted graduated driver licensing may reduce this risk to the extent that driving experience, nighttime driving, and age are factors in teen crashes on these roads.

Several road factors are also significant in understanding injury likelihood. Crashes reported to be intersection-related have 93.4% increased likelihood to be associated with driver injury. Unpaved surfaces, including gravel, dirt, and scoria, were associated with increased probability for injury outcome in a crash with 81.4% greater likelihood than other road surfaces such as paved and concrete. Although smaller in magnitude, curve and hill road features are associated with 45.5% and 63.4% higher probability of injury crash events than when crashes occur on flat, straight stretches of road.

The final parameters in the model are the environment and vehicle. Although several variables related to weather and nighttime environments were tested in initial models, only the lighting variable was significant and included in the final model. Local rural roads crashes that occur in the dark are associated with a 47.5% lower injury crash likelihood than those crashes that occurred with daylight or lighted conditions. This may be associated with factors such as differing nighttime and daytime travel speeds or the traffic interaction levels. Vehicles equipped with anti-lock brakes were found 16.3% less likely to be associated with injury crash events than unequipped vehicles. The benefits may be related to the anti-lock brake function itself or to generally enhanced safety systems in vehicles where anti-lock brakes are present.

Results show several potential focus areas for improving rural local road safety. The largest in magnitude among factors that are associated with increase injury probability in a crash event is impaired driving – including drug and alcohol involvement. Occupant protection also has a large overall weight among factors in the relation to likelihood for a driver injury outcome. Among road elements, intersections and unpaved surfaces have the largest magnitude in increased injury crash probability.

Table 7 offers a county-level summary of the model factors for the counties with the crash incidence above the state average. The average crash incidence for HRRR roads is based on the mean of the population and VMT incidence rates for these roads. Most counties are in the highest quartile for frequency of at least one of the factors associated with increased injury crash likelihood in the logit model. Many counties have multiple factors associated with increased crash probability, related to both driver and road. The logit model results with a multitude of factors with similar magnitude and county-level factor identification reinforce notions that local rural roads truly required a combination of interventions related to the driver, road, vehicle, and environment.

Table 7 Highest Incidence of Factors in HRRRP Crashes for Counties with above Average Crash Rates on these Roads, 2006-2010

County (X=Highest Quartile)	Driver Factors				Road Factors				Intervention Area		
	Alcohol/ Drug Involved	No Seat Belt	Speed	Teen	Intersec-tion	Unpav-ed	Hill	Curve	Driver	Comb ined	Road
Barnes							X		0	1	1
Burke									0	0	0
Burleigh					X				0	1	1
Cass					X				0	1	1
Dickey				X					1	1	0
Divide			X					X	1	2	1
Emmons							X		0	1	1
Golden Valley			X			X	X	X	1	4	3
Grand Forks					X				0	1	1
La Moure				X		X			1	2	1
McKenzie					X		X	X	0	3	3
Morton					X			X	0	2	2
Mountrail					X	X	X		0	3	3
Oliver		X	X			X		X	2	4	2
Ransom		X				X			1	2	1
Renville									0	0	0
Richland									0	0	0
Rolette					X				0	1	1
Sheridan		X	X			X	X		2	4	2
Stark	X								1	1	0
Steele	X	X				X			2	3	1
Stutsman								X	0	1	1
Traill			X						1	1	0
Walsh	X		X		X				2	3	1
Ward					X				0	1	1
Williams			X		X			X	1	3	2

X: Indicates 75th percentile, highest quartile, for factor.

Conclusion

Despite recent heighted interest in rural road safety, North Dakota's local rural roads are still among the state's most dangerous – in terms of injury crash incidence. Work here supports the premise that this road group should be given special attention because it has crash factors that are distinct from other, higher traffic rural roads in the state. Managers of these roads, however, face challenges in the lack of data, tools, and management guidance needed to mobilize safety improvements. Systematic analysis of driver injury outcomes in rural local road crashes suggests that reducing impaired driving and increasing occupant protection have the largest potential for increasing rural local road safety. Results also show that a disproportionately large number of rural local road crashes take place on unpaved surfaces, compared to other rural roads – a challenge for safety managers in terms of the lack of resources specific to these roadways. Efforts to improve curve and intersection safety would also pay dividends in terms of reduced probability for crash injury. The large number and diversity of contributing factors in the rural local roads crashes reinforce the need for long-term, dedicated resources in a holistic safety program that address elements related to driver, road, vehicle, and environment. Many states have had success in instituting sustainable rural local road safety programs of this type. Research here may be useful for North Dakota and other rural states in understanding the complexity and priorities in moving forward with a similar program.

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Appendix. Crash Data Definitions

Variable or Measure	Definition
Vehicles	Unit Configuration other than snowmobile, moped, construction, emergency, train, farm, maintenance, or pedestrian
All Injury	Crash Occupant Injury includes Fatal, Disabling, or Possible
Serious Injury	Most Serious Crash Occupant Injury Type Fatal or Disabling
Injury	Most Serious Crash Occupant Injury Type Disabling, Non-disabling, or Possible
Rural	Functional Class 1-9 (area beyond urban)
Urban	Functional Class 10-19 (city limits for population centers ≥5,000)
Occupant Protection	Safety Equipment reported as Lap belt only, Lap and shoulder belts, Automatic belts (used properly), Helmet worn, Child safety restraint used properly
Young Teen Drivers	Drivers ages 14-16
Mature Drivers	Drivers ages 75 and older
Competent & Licensed Drivers	No Drivers Cited for Driving under suspended Class D driver license or no driver license[1]
Impaired	Drug or Alcohol Use reported as Alcohol present, Other drug present, Alcohol or other drugs present
Aggressive	Citation/Warning reported as Care required, Careless driving, and Speeding
Too Fast for Conditions	Contributing Factor reported as Speed/too fast for conditions, Too fast for conditions
Drowsy	Driver Condition reported as Fatigue, Asleep
Distracted	Contributing Factor reported as Attention Distracted, Drove Left of Center, Ran Red Light, Disregard for Road Markings, Vehicle Operation Erratic, Distracted Cell/Palm or Nav Device/Inside Vehicle/Outside
Run off Road	Relation to Road in Shoulder, Median, Gore, Outside Shoulder, Off Roadway, Separator
Lane Departure	If Manner of Collision reported at Head-On, Sideswipe (same direction or opposite direction), Angle (same direction or opposite direction); or Most Harmful Event reported as Parked motor vehicle or Ran off road; or Event sequence includes Roadside Feature; or Vehicle Movement reported as Wrong Side of Road or Changing Lanes
Rollover	Event sequence includes Overturn/Rollover
Intersection	Relation to Junction reported at Intersection, Intersection related
Curve	Road Geometrics reported as Curve on grade, Curve on Level
Hill	Road Geometrics reported as Straight on grade, Hill Crest
Road Side Object	Reported Events include Roadside Feature such as Guardrail, Bridge Pier, Traffic Sign, Utility Pole, Tree, Etc.
Unpaved Roads	Surface Type reported as Gravel, Scoria, or Dirt
Weather	Weather reported as Rain, Snow, Blowing Soil/Snow, Sleet/Hail/Freezing Rain, Fog/Smoke/Dust, or Severe Wind
Deer/Animal	Reported Events include Deer, Other large game, Farm animal, or Small animal
Large Truck	Vehicle Type includes 3 or more axles single unit truck, Single unit truck, Truck tractor, or Unknown heavy truck
Motorcycle	Vehicle Type reported as Motorcycle
Pedestrian	Pedestrian/Vehicle Crashes
Train Crossing	Railroad Grade Crossing

Source: NDDOT Crash Records unless noted as [1]NDDOT Driver Record; Definitions based on ND Crash Form and Overlay, and Crash Form Expert Consultation