Safety Analysis of Low-Volume Rural Roads in Iowa

Final Report
December 2010

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16. Abstract

Iowa features an extensive surface transportation system, with more than 110,000 miles of roadway, most of which is under the jurisdiction of local agencies. Given that Iowa is a lower-population state, most of this mileage is located in rural areas that exhibit low traffic volumes of less than 400 vehicles per day. However, these low-volume rural roads also account for about half of all recorded traffic crashes in Iowa, including a high percentage of fatal and major injury crashes.

This study was undertaken to examine these crashes, identify major contributing causes, and develop low-cost strategies for reducing the incidence of these crashes. Iowa's extensive crash and roadway system databases were utilized to obtain needed data. Using descriptive statistics, a test of proportions, and crash modeling, various classes of rural secondary roads were compared to similar state of Iowa controlled roads in crash frequency, severity, density, and rate for numerous selected factors that could contribute to crashes.

The results of this study allowed the drawing of conclusions as to common contributing factors for crashes on low-volume rural roads, both paved and unpaved. Due to identified higher crash statistics, particular interest was drawn to unpaved rural roads with traffic volumes greater than 100 vehicles per day. Recommendations for addressing these crashes with low-cost mitigation are also included. Because of the isolated nature of traffic crashes on low-volume roads, a systemic or mass action approach to safety mitigation was recommended for an identified subset of the entire system. In addition, future development of a reliable crash prediction model is described.

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1. INTRODUCTION AND PROBLEM IDENTIFICATION

Each year in the United States, about 40,000 people lose their lives in highway crashes. Many of these fatal crashes occur on high-speed, higher-volume roads. It is on these roads that most efforts have been targeted, particularly by the engineering and enforcement communities. Also, most previous crash mitigation strategies have targeted high-crash locations or "black spots." Naturally, because vehicular traffic, or exposure, is the greatest predictor of a road's crash performance, it has been logical to focus on higher-volume roads and intersections that, statistically speaking, have many more crashes than their lower-volume road (LVR) counterparts. These higher-volume roads were, and, in some cases, still are, the greatest "sites with promise" for improvement.

The focus of this study is a crash analysis of low-volume roads in Iowa. Low-volume roads are defined as roads located in rural areas with daily traffic volumes of less than or equal to 400 vehicles per day (vpd). Low-volume roads are typically undivided, two-lane roads, either paved or unpaved. As the vast majority of state-owned and maintained (primary) rural roads in Iowa have daily volumes greater than 400 vpd, primary roads are not considered to be low-volume roads in this study. LVRs in Iowa and in similar rural states experience a greater proportion of the total statewide number of severe crashes than do Rural LVRs in more populous states.

During a seven-year period (2001–2007), more than 6,000 fatal and major injury crashes were observed on undivided, two-lane rural roads in Iowa. More than 4,000 of these crashes occurred on local roads, while less than 2,000 took place on primary roads. Half of the rural local road crashes were on facilities with 400 vpd or less traffic. Local roads in Iowa comprise the majority of the rural surface transportation system, or about 90,000 miles of roads, of which almost 80% are unpaved (source: Iowa Department of Transportation (DOT) Office of Transportation Data). Most of these roads experience very low traffic volumes. Because of the roads' low volumes, fewer crashes can be expected at given low-volume road locations. As a result, the traditional "black spot" approach to addressing safety problems on these low-volume roads is not as cost-effective as on other roads. "Chasing fatals" can be the outcome of deploying such a strategy. Due to the random nature of low-volume road crashes, a more systematic or mass-action approach is necessary.

While much work has been done to identify safety problems and develop mitigation strategies for higher-volume roads, less effort has gone toward rural LVR safety issues, especially in Iowa. However, interest in rural LVR safety is increasing nationally. Iowa is in a unique position to study rural LVR safety, primarily due to the state's detailed crash and roadway feature databases.

Therefore, this project was proposed to investigate low-volume rural road safety in Iowa, identify safety concerns, and propose safety mitigation strategies to address the identified problems. The study focused on both paved and unpaved low-volume local roads (or secondary roads) and compares the safety performance of these types of roads to each other and to the state-maintained, paved, two-lane roads that carry mostly higher volumes and generally benefit from a more consistent maintenance and traffic control policy. While the study focuses only on Iowa, results are extensible to other states and regions.

Historically, most of the attention paid to safety improvements has been directed toward higher-volume roadways. However, current crash data reveal that more than half of all fatal and serious injury crashes on Iowa's local rural roads occur on facilities with less than 400 vpd. More information is needed to identify potential problem areas on these low-volume roads and devise mitigation strategies to address this serious public safety concern.

This project addressed the problem of rural low-volume road safety by initiating an in-depth database investigation of the history of total and serious crashes on very low-volume rural roads, paved and unpaved, over the most current years on record. Contributing cause, driver characteristics, and crash location were characterized to identify any areas of commonality among these crashes. Statistical tests (tests of proportions) were applied to identify the unique safety concerns on rural low-volume roads. Site-specific conditions were evaluated from video and still photography, and individual crash records and narratives were reviewed. Finally, a crash-based model was developed to investigate key causal factors.

Background

Iowa is among the most rural states in the United States. It has the ninth largest network of rural local roads and the fifteenth highest fatality rate, as shown in Table 1. (Note: The Federal Highway Administration (FHWA) uses a different definition of local road than is used in this report, and, as such, numbers from this table are used to compare states only). The table also shows that some other Midwestern states demonstrate similarly high rankings and large rural local roads networks.

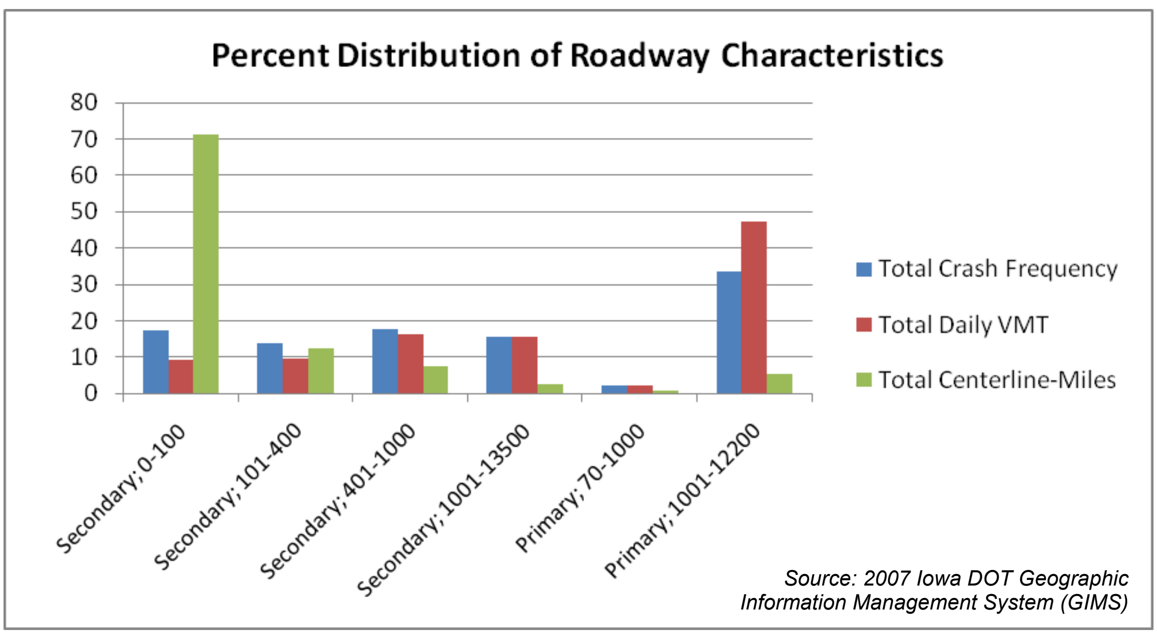


Figure 1. Percent distribution of roadway characteristics of undivided two-lane rural roads in Iowa by road category

Table 1. Nationwide summary of fatality rate and density on rural local roads by state

State	Number of Fatalities	Travel (MVMT)	Length (miles)	Rate (Fatality/MVMT)	Rank by Rate	Density (Fatality/Miles)	Rank by Density
Grand Total	**4,263**	**133,378**	**2,046,806**	**0.032**	**19**	**0.002**	**23**
U.S. Total	**4,219**	**133,282**	**2,044,508**	**0.032**	**20**	**0.002**	**24**
Texas	346	7,043	148,526	0.049	8	0.002	19
Kansas	64	1,642	87,448	0.039	14	0.001	42
Missouri	113	3,766	76,898	0.030	24	0.001	34
Minnesota	65	2,813	76,442	0.023	33	0.001	41
Illinois	109	4,020	72,940	0.027	29	0.001	32
Oklahoma	127	2,757	67,548	0.046	10	0.002	26
North Dakota	28	923	67,514	0.030	23	0.000	48
Wisconsin	98	3,613	64,570	0.027	28	0.002	31
Iowa	**59**	**1,552**	**64,394**	**0.038**	**15**	**0.001**	**39**
Arkansas	101	1,947	62,682	0.052	6	0.002	30
Nebraska	35	1,089	59,634	0.032	18	0.001	45
Ohio	174	6,012	57,236	0.029	26	0.003	9
Michigan	110	2,360	56,976	0.047	9	0.002	25
South Dakota	32	510	56,062	0.063	4	0.001	46
Pennsylvania	151	7,291	54,350	0.021	36	0.003	12
Georgia	109	7,225	52,301	0.015	42	0.002	22
California	117	2,814	51,451	0.042	12	0.002	21
North Carolina	302	5,067	51,366	0.060	5	0.006	4
Alabama	133	6,679	49,859	0.020	38	0.003	14
Indiana	151	3,338	49,162	0.045	11	0.003	8
Tennessee	79	3,223	48,355	0.025	31	0.002	29
Colorado	32	1,543	47,726	0.021	35	0.001	43
Montana	53	1,026	47,531	0.052	7	0.001	37
Kentucky	107	3,429	46,166	0.031	21	0.002	20
New York	167	4,646	44,513	0.036	17	0.004	7
New Mexico	21	3,538	44,164	0.006	48	0.000	47
Mississippi	7	6,684	43,569	0.001	50	0.000	50
Washington	36	1,157	42,011	0.031	22	0.001	40
Louisiana	102	2,685	34,027	0.038	16	0.003	10
Virginia	85	3,181	33,213	0.027	30	0.003	16
South Carolina	0	2,310	31,986	0.000	53	0.000	53
Oregon	35	1,699	30,219	0.021	37	0.001	36
Idaho	19	2,274	29,060	0.008	46	0.001	44
Arizona	69	3,983	27,819	0.017	39	0.002	17
Florida	707	6,641	26,735	0.106	2	0.026	1
Utah	29	1,009	23,049	0.029	27	0.001	35
West Virginia	52	1,309	21,855	0.040	13	0.002	18
Nevada	0	487	19,615	0.000	51	0.000	51
Maine	32	1,454	12,267	0.022	34	0.003	15
Wyoming	11	726	10,546	0.015	41	0.001	38
Maryland	49	1,668	9,225	0.029	25	0.005	6
Vermont	16	1,295	8,743	0.012	44	0.002	27
New Hampshire	14	572	7,693	0.024	32	0.002	28
Alaska	3	511	7,670	0.006	49	0.000	49
Massachusetts	8	688	5,384	0.012	45	0.001	33
New Jersey	15	1,014	5,287	0.015	43	0.003	11
Connecticut	12	781	4,363	0.015	40	0.003	13
Delaware	28	425	2,304	0.066	3	0.012	3
Puerto Rico	44	96	2,298	0.458	1	0.019	2
Hawaii	7	840	1,191	0.008	47	0.006	5
Rhode Island	0	23	863	0.000	52	0.000	52

Source: Adapted from Highway Statistics developed by the FHWA 2006

Figure 1, Table 2, and Table 3present information on various characteristics of undivided two-lane rural roads in Iowa. As shown in Table 2, the crash rate per 100 million vehicle miles traveled (100MVMT) is disproportionately high for the lowest-volume secondary roads being investigated. As shown graphically in Figure 1, the reason for the extremely low crash density is clearly based on the vast mileage of the low-volume system.

Table 2. Characteristics of rural undivided two-lane roads in Iowa 2001-2007 total

Road Category (Road System; AADT Range)	Weighted Average of ADT	Total Crash Frequency	%	Total Daily VMT	%	Total Centerline-Miles	%	Crash Rate (per 100M VMT)	Crash Density (crash per 100 miles)
Secondary; 0-100	37	16,510	17	2,519,000	9	67,963	71	257	24
Secondary; 101-400	220	13,105	14	2,588,000	10	11,766	12	198	111
Secondary; 401-1000	630	16,684	18	4,443,000	16	7,053	7	147	237
Secondary; 1001-13500	1,700	14,784	16	4,217,000	15	2,547	3	137	580
Primary; 70-1000	770	1,995	2	583,600	2	761	1	134	262
Primary; 1001-12200	2,500	32,045	34	12,880,000	47	5,202	5	97	616

Source: 2001-2007 Iowa DOT Crash Database and 2007 GIMS

Table 3. Geometric features of undivided two-lane rural roads in Iowa by centerline miles and percent distribution

Road System; AADT Range		Secondary; 0-100		Secondary; 101-400		Secondary; 401-1000		Secondary; 1001-13500		Primary; 70-1000		Primary; 1001-12200		Grand Total		Secondary; 0-400	
		Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%	Length	%
Grand Total:		67,963	**71**	11,766	**12**	7,053	**7**	2,547	**3**	761	**1**	5,202	**5**	**95,291**		79,729	
Surface Type	Paved	1,063	**2**	7,421	**63**	6,986	**99**	2,537	**100**	761	**100**	5,202	**100**	**23,970**	**25**	8,484	**11**
	Unpaved	66,900	**98**	4,345	**37**	66	**1**	10						**71,321**	**75**	71,245	**89**
Surface Width	>= 24 ft	35,070	**52**	4,372	**37**	1,382	**20**	1,047	**41**	417	**55**	4,532	**87**	**46,821**	**49**	39,442	**49**
	< 24 feet	32,893	**48**	7,394	**63**	5,670	**80**	1,500	**59**	344	**45**	669	**13**	**48,470**	**51**	40,286	**51**
Shoulder	Yes	63,044	**93**	11,720	**100**	7,027	**100**	2,534	**99**	760	**100**	5,186	**100**	**90,271**	**95**	74,764	**94**
	No	4,919	**7**	45		26		13	**1**	1		16		**5,020**	**5**	4,965	**6**
Terrain	Flat	20,878	**31**	3,996	**34**	2,626	**37**	940	**37**	290	**38**	2,219	**43**	**30,948**	**32**	24,873	**31**
	Rolling	43,351	**64**	7,046	**60**	4,090	**58**	1,501	**59**	420	**55**	2,819	**54**	**59,228**	**62**	50,397	**63**
	Hilly	3,344	**5**	722	**6**	336	**5**	107	**4**	51	**7**	164	**3**	**4,723**	**5**	4,066	**5**
	N/A	390	**1**	2										**392**		392	**0**

Source: 2001-2007 Iowa DOT GIMS

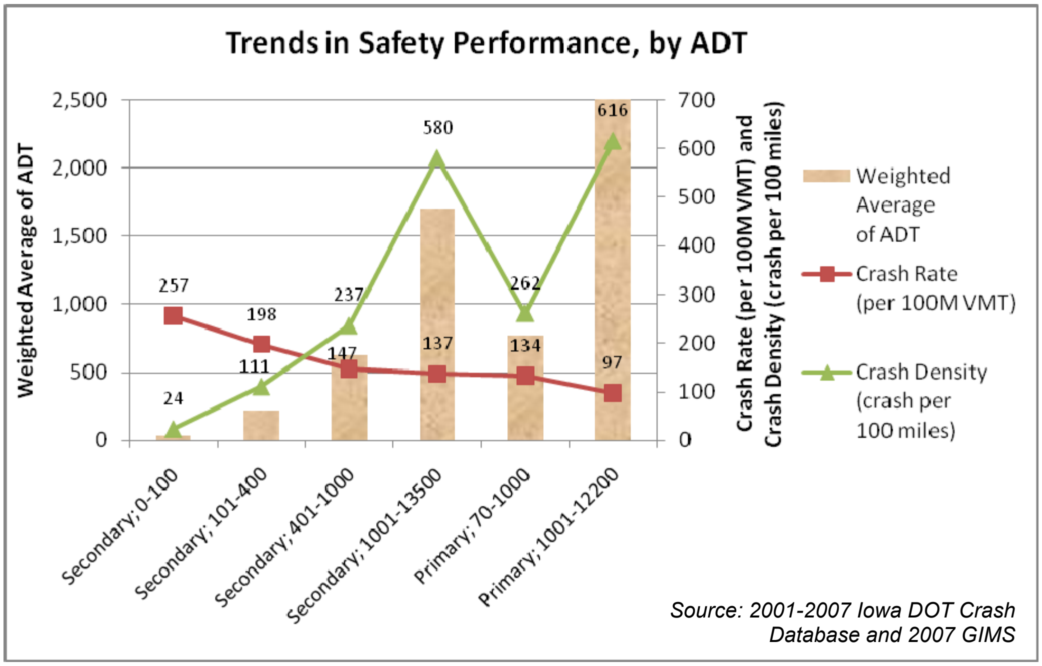


Figure 2. Trends in safety performance of undivided two-lane rural roads in Iowa, by road category and average annual daily traffic

As shown in Figure 2, the crash *density* of secondary roads with traffic volumes greater than 1,000 vehicles per day (VPD) is similar to that of state highways with the same volumes, although the crash *rate* for the secondary roads is nearly one and a half times that of primary roads. The road characteristics in Table 3 provide a partial explanation, as early design standards for secondary roads were not as high as those used for paving primary highways.

Figures 3 through 5 summarize historical trends for fatal, fatal and injury, and total crash rates on roads belonging to three rural jurisdictional classes.

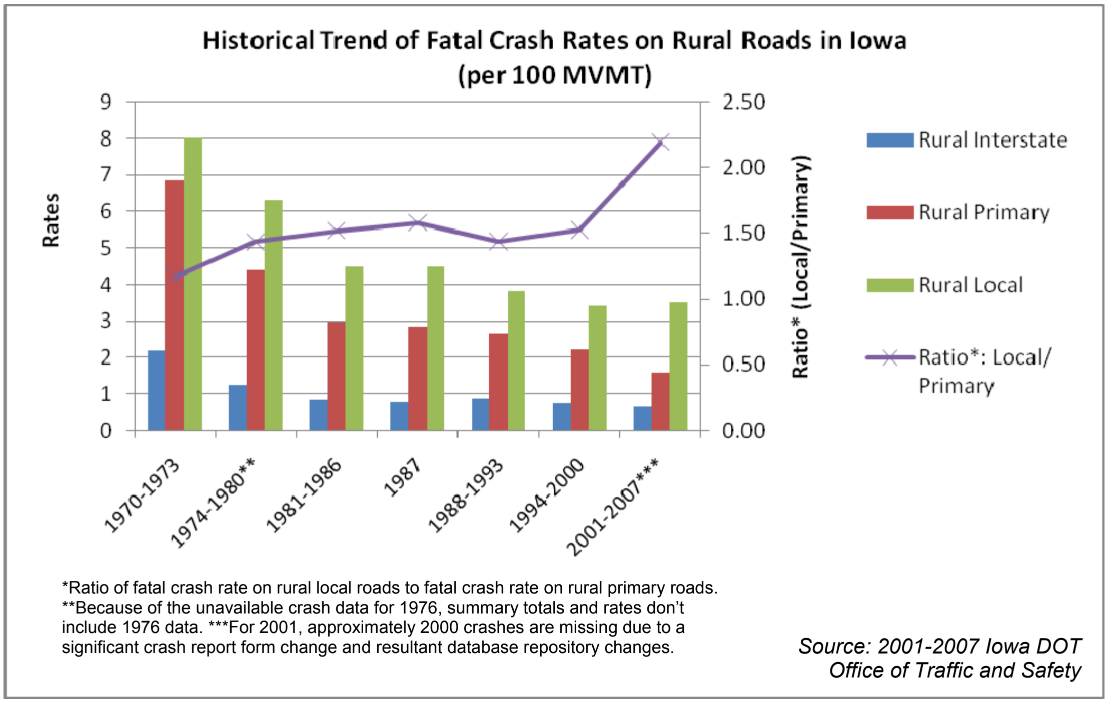
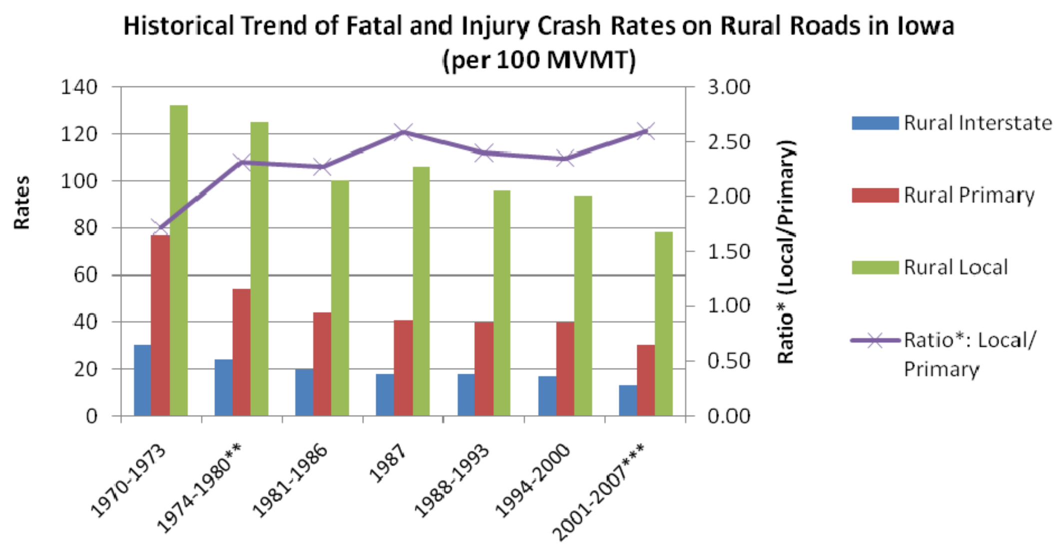


Figure 3. Historical trend of fatal crash rates on Iowa rural roads

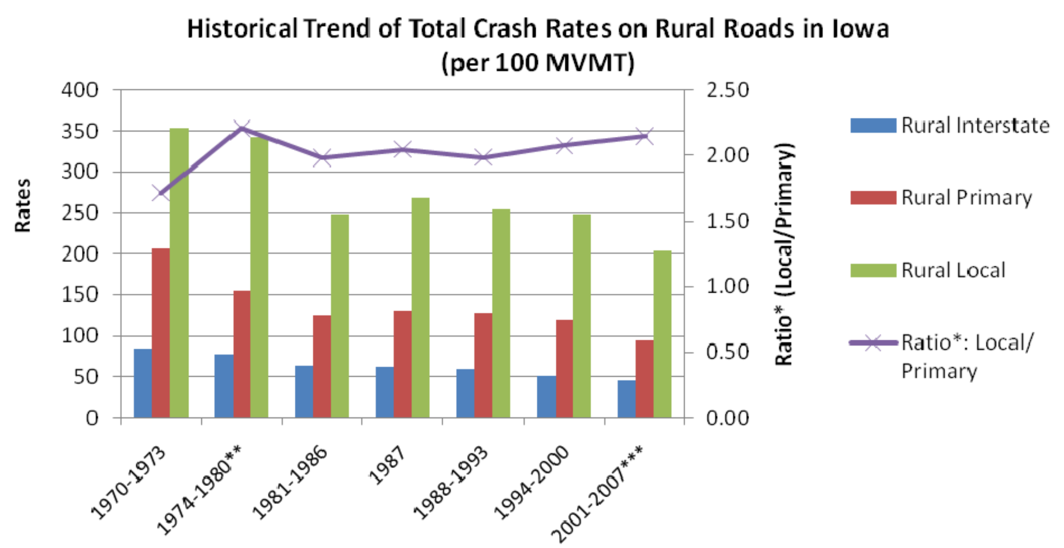
Figure 3 shows a significant increase in the ratio of local to primary crash rates in the past few years. Figure 4 and Figure 5 show a similar increasing trend, although to a lesser degree. These trends may be explained partially by the success of improvements made to the primary system. Potentially contributing to the trend was the transfer of more than 850 miles of rural roads from state to local jurisdiction beginning in 2005. While lower in volume, compared to other primary roads, these "TJed" roads carry greater average daily traffic than most local roads in Iowa (See Appendix 1. *Historical Summary of Rural Crash and Fatality Rates* for details).



*Ratio of fatal and injury crash rate on rural local roads to fatal and injury crash rate on rural primary roads. **Because of the unavailable crash data for 1976, summary totals and rates don't include 1976 data. ***For 2001, approximately 2000 crashes are missing due to a significant crash report form change and resultant database repository changes.

Source: 2001-2007 Iowa DOT Crash Database and 2007 GIMS

Figure 4. Historical trend of fatal and injury crash rates on Iowa rural roads



*Ratio of total crash rate on rural local roads to total crash rate on rural primary roads. **Because of the unavailable crash data for 1976, summary totals and rates don't include 1976 data. ***For 2001, approximately 2000 crashes are missing due to a significant crash report form change and resultant database repository changes.

Source: 2001-2007 Iowa DOT Crash Database and 2007 GIMS

Figure 5. Historical trend of total crash rates on Iowa rural roads

Figure 6 illustrates low-volume (<400 VPD) road crash frequency, density, and rate, by county, for all crashes (top) and serious or fatal and major injury crashes (bottom). Relative crash risk in each county is represented by a color. (Black represents the highest 5% risk group, red the next

10% highest, yellow the next 20%, light green the next 25%, and dark green the lowest 40%.) Five years of crash data (2002-2006) are depicted. Crashes at intersections with primary roads and other secondary roads carrying higher (>400 VPD) volumes were excluded.

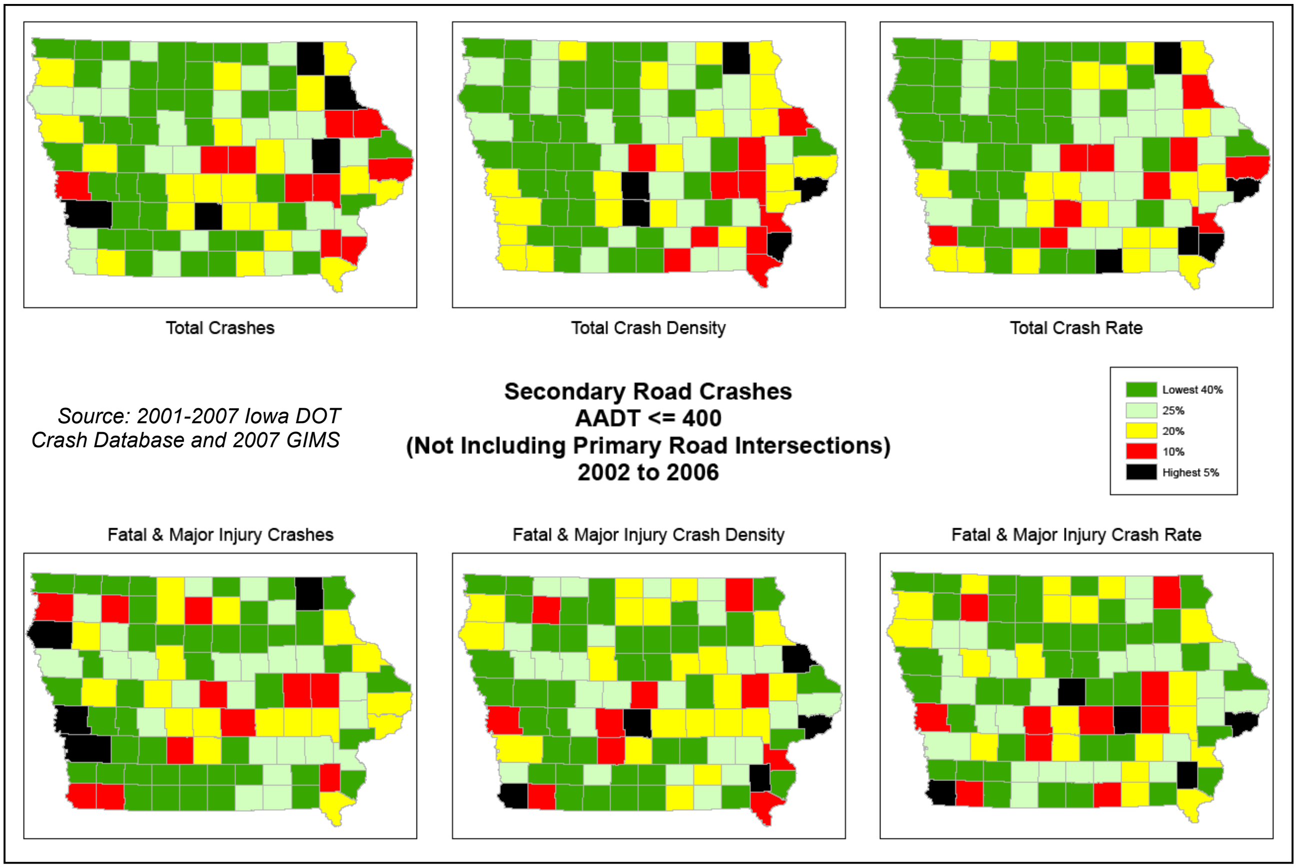


Figure 6. Thematic maps showing crash frequency, density, and rate by county

Survey of County Engineers

An informal survey of county engineers was conducted during by the Institute for Transportation (InTrans) County Traffic Safety Liaison to assess initial perceptions of the major causes of crashes on low-volume roads. The survey also included questions about the county's utilization of DOT safety programs and assistance. Engineers were asked about county policies and practices with respect to signing, maintenance, traffic operations, safety awareness, and training.

Full responses were received from 73 counties:

- 16% of counties have stops or yields at all railroad crossings (90% of Iowa's counties have railroad crossings)
- 52% of counties have control at all rural intersections
- 20% of counties do *not* use Iowa's crash mapping analysis tool (CMAT) in their offices
- All counties have safety brochures and pamphlets on best practices in their office libraries
- 29% of counties have not been active in the past few years in DOT safety programs, nor have county representatives attended fall safety seminars
- Most counties have Roadside Safety Programs in existence to remove obstructions from the clear zones; several degrees of activity were noted, with most counties being reactive to new placements
- Only 8% of counties have no existing sign inventory, and all are working on developing one (or improving the one they do have) to ease the burden of future record keeping for sign retroreflectivity

After the commencement of this project, 41 surveys were conducted. For these, the number of responses indicating perceptions of various crash causes for low-volume roads included:

- Distractions/ inattention 19
- Young/inexperience 12
- Alcohol/drugs 11
- Speed 10
- Road geometry 9
- Farm related 7

More complete survey details are presented in Appendix 2. *Summary of County Engineers Survey.*

2. PREVIOUS WORK

Low-volume roads are defined in the 2003 Manual on Uniform Traffic Control Devices (MUTCD) Part-5 as follows:

Standard: A low-volume road shall be defined for this Part of the Manual as follows:

A. A low-volume road shall be a facility lying outside of built-up areas of Cities, towns, and communities, and it shall have a traffic volume of less than 400 AADT.

B. A low-volume road shall not be a freeway, expressway, interchange ramp, freeway service road, or a road on a designated State highway system. In terms of highway classification, it shall be a variation of a conventional road or a special purpose road as defined in Section 2A.01.

C. A low-volume road shall be classified as either paved or unpaved. (p. 5A-1)

The manual supplements the above definition with the following:

> Support: Low-volume roads typically include farm-to-market, recreational, resource management and development, and local roads.
>
> Guidance: The needs of unfamiliar road users for occasional, recreational, and commercial transportation purposes should be considered. (p. 5A-1)

To better understand the safety issues and possible mitigation strategies for roads of this classification, a review of low-volume rural road literature was conducted. Relevant studies about safety problems and improvement solutions are presented in the following two subsections.

Low-Volume Road Safety Problems

The Rural Transportation Initiative of the United States Department of Transportation (USDOT 2006) has reported that factors, such as rural terrain, faster -vehicle speeds, relatively high alcohol involvement, and relatively long emergency response times, make rural road crashes more likely than urban crashes to result in fatalities.

Additionally, crash rates have been found to be higher on low-volume roads than on other roads. In a study on a sample of nearly 5,000 miles of paved two-lane rural roads in seven states (Alabama, Michigan, Montana, North Carolina, Utah, Washington, and West Virginia), Zegeer et al. (1994) computed a crash rate of 3.5 per million vehicle miles (MVM) on low-volume roads (defined in the study as roads with ≤2,000 average daily traffic [ADT]), versus a crash rate of 2.4 per MVM on all high-volume roads. Zegeer et al. determined that fixed object crashes, rollover crashes, and other run-off-road crashes were more frequent on the lower-volume roads. However, these roads were found to experience fewer multi-vehicle crashes, including rear-end, angle, and turning collisions (SeeTable 4).

Table 4. Summary of accident types and characteristics for low-volume road sites

Accident Type	Primary Database on Low-Volume Roads		Cross-Section Database	
	Number of Accidents	Percent of Total Accidents	Number of Accidents	Percent of Total Accidents
Total	14,888	100.0	62,676	100.0
Property Damage Only	8,973	60.3	38,857	62.0
Injury	5,632	37.8	22,944	36.6
Fatal	283	1.9	875	1.4
Injuries*	8,768	N/A	37,321	N/A
Fatalities*	328	N/A	1,068	N/A
Daylight	8,050	54.1	37,402	59.7
Dawn/Dusk	820	5.5	2,888	4.6
Dark with Lights	160	1.1	2,770	4.4
Dark without Lights	5,809	39.0	19,496	31.1
Light Unknown	49	0.3	120	0.2
Dry	10,306	69.2	41,957	66.9
Wet	2,442	16.4	13,487	21.5
Snow/Ice	1,952	13.1	6,657	10.6
Unknown Pavement	188	1.3	575	0.9
Run-Off-Road - Fixed Object	4,017	27.0	12,091	19.3
Run-Off-Road - Rollover	1,999	13.4	4,245	6.8
Run-Off-Road - Other	2,287	15.4	2,840	4.5
Head-On	475	3.2	2,113	3.4
Opposite Direction Sideswipe	642	4.3	2,997	4.8
Same Direction Sideswipe	330	2.2	2,288	3.7
Rear-End	893	6.0	12,420	19.8
Parking/Backing	264	1.8	1,155	1.8
Ped/Bike Moped	117	0.8	655	1.0
Angle & Turning	1,773	11.9	14,730	23.5
Train	20	0.1	47	0.1
Animal	1,404	9.4	5,212	8.3
Other or Unknown	667	4.5	1,883	3.0

* The data for these variables represent the number of people injured or killed, and not the number of accidents.
N/A = Not applicable.

Source: Zegeer et al. 1994

This was to be expected due to the lower traffic volumes, which offered less of a chance that two vehicles would be in the same place at the same time. However, it should be noted that the Zegeer et al. study defined low-volume as less than 2,000 VPD. In Iowa, many primary roads fall into this category, and 2,000 VPD is not considered to be particularly low-volume in some states. The present study defines low-volume as less than 400 VPD, which is a volume consistent with the 2003 MUTCD definition.

Zegeer et al. (1994) also investigated the relationship between roadway width and crash occurrence on low-volume (≤2,000) rural roads. Estimation results of covariance models showed that the significant estimators of "related accidents," which were defined as single-vehicle and opposite-direction crashes, included lane and shoulder width (or total roadway width), roadside hazard rating and roadside recovery distance, number of driveways per mile, terrain, and state. Roads with relatively wider shoulders or lanes demonstrated lower "related accident" rates, while shoulders being paved or unpaved made no statistically-significant difference. However, narrow, unpaved roads, 20 ft wide or less, demonstrated lower rates, perhaps because of reduced vehicle speeds.

One of the findings of Zegeer et al. was that no significant difference was observed between the crash rates on paved and unpaved roads with 250 VPD or less. Above a daily traffic of 250 VPD, paved roads were found to be significantly safer than unpaved (dirt and gravel) roads. Therefore, the authors recommended that unpaved rural roads with traffic volumes higher than 250 VPD be paved.

Additionally, some studies have found that crash severity is relatively high on low-volume roads. Caldwell and Wilson (1997) compared the injury crash rates on unpaved county road sections in Albany County, Wyoming, to injury crash rates on all roads in the state. Injury risk on county roads was determined to be more than five times higher than on all roads (See Table 5). However, this report was based on a very small sample of road sections and crashes.

These low-volume road safety problems have been recognized by driver education instructors. The National Education Center for Agricultural Safety (2008) conducted a survey in which driver education teachers were asked about their experience, observations, and opinions on a variety of topics related to rural road driving. 87% of the teachers spent one or more class periods teaching about the hazards of driving on rural roads. 98% indicated that their students had an opportunity to drive on rural roads during their behind-the-wheel training time. The teachers consider the highest risk to young drivers to be caused by the following factors (in order of decreasing importance): 1. Speed, 2. Cell phone usage, 3. Passengers 4. Loose gravel surface, and 5. Impaired nighttime driving.

Interestingly, 89% of the surveyed teachers supported the need for a new optional module with additional materials focusing on rural roadway safety. Several instructors also indicated that there should be a requirement to drive on rural roads, especially gravel, during the behind-the-wheel time. However, some noted that their cars were leased and therefore driving students were not able to drive on gravel roads.

Table 5. Wyoming injury crash rates for selected unpaved road sections vs. all roads

Roadway Section or System	Number of Injury Crashes	Daily No. Veh. (Sept. 1995)	Road Section Length (miles)	Number of Days in Study (3 yr. 3 mo.)	VMT (Vehicle Miles Traveled)	**Injury Crash Rate per 1,000,000 VMT**
Albany Co. #234 (0-1.6 miles)	2	158	1.6	1186	299,821	**6.67**
Albany Co. #234 (1.6-10 miles)	1	35	8.4	1186	348,684	**2.87**
Albany Co. #47 (0 - 8 miles)	3	108	8	1186	1,024,704	**2.93**
Albany Co. #61 (0-15 miles)	3	73	15	1186	1,298,670	**2.31**
Four Albany Co. Sections Combined	9				2,971,879	**3.03**
1992-1993 All Wyoming	7121				12,969,000,000	**0.55**

Source: Caldwell and Wilson 1997

Low-volume rural roads can also be hazardous due to the variety of vehicle types that use them. While not specifically examining low-volume roads, Madsen (2008) presented a summary of farm equipment crashes on upper Midwest roads at the 2008 Midwest Rural Agricultural Safety and Health (MRASH) forum. Using the information available in the Fatality Analysis Reporting System (FARS) database, Madsen summarized five years of recent crash history from nine Midwest states (Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin). He emphasized two hazardous situations: rear-end crashes over a crest vertical curve, and broadside/sideswipe crashes where a farm vehicle driver attempted to make a left turn without noticing a vehicle that was attempting to pass. Madsen concluded that 75% of the injured persons and 60% of those killed in these types of crashes were occupants of the non-farm vehicles. The lack of retroreflective signs and taillights on slow-moving vehicles was identified as a major contributing factor for farm equipment crashes.

Vehicle speeds can also present safety concerns on low-volume roads. In a study on speed limits on gravel roads in Kansas, Liu and Dissanayake (2007) collected speed data, performed a survey of county agencies, and statistically analyzed crash data for gravel roads. The authors recorded the speed and type of 7,175 vehicles under normal weather conditions and the speed of 373 vehicles under bad weather conditions on gravel county and township roads in the state. Table 6 and Table 7 show the mean and 85th percentile speeds by road type and weather condition.

Table 6. Speed data based on road types

Road type	Road Width (ft)	Total Volume Observed (vehs)	Heavy Vehicle (%)	ADT (vehs/day)	Mean Speed (mph)	Pace (mph)	% in Pace	85th Speed (mph)	% of Vehicles > 55 mph
County	24.2	3,787	19.9	55.5	41.7	37-46	45.5	51.1	9.2
Township	20.8	3,388	18.7	66	36	31-40	47.4	43.9	8.4
Combined	22.4	7,175	19.3	61	38.7	34-43	46.4	47.3	5.2

Source: Liu and Dissanayake 2007

Table 7. Speed data under different weather conditions

Weather	Mean Speed (mph)	Pace (mph)	% in Pace	85th Speed (mph)	% of Vehicles > 55 mph
Snow (snowpacked)	36	26-35	55.6	46	0
Rain	33	31-40	38.6	43	0
Fog*	35	N/A	N/A	N/A	0
Clear	38.7	34-43	46.4	47.3	5.2

* Only mean speed was computed due to the small number of observations under fog condition.

Source: Liu and Dissanayake 2007

Liu and Dissanayake also considered whether lower speed limits would help decrease severe crashes on these roads. Contrary to what a majority of county road professionals believed, the results shown in Table 8 exhibited no statistical evidence supporting the hypothesis that lowering the speed limit from 55 mph to 45 or 50 mph would improve road safety performance. Lack of posting and enforcement (too expensive for many counties) was given as a possible reason for the lack of correlation between speed policy and safety performance.

Table 8. Percentage of crashes on gravel roads for different speed limits and crash severities

Speed limit (mph)	Crash severity					
	Fatal	Disabled	Non-incapacitating	Possible Injured	Not Injured	Total
30	0.0%	1.4%	10.7%	10.3%	77.5%	100%
35	0.6%	3.2%	16.3%	9.8%	70.1%	100%
40	0.0%	3.9%	11.7%	13.6%	70.9%	100%
45	1.2%	6.6%	12.6%	8.9%	70.7%	100%
50	1.5%	2.3%	18.8%	15.0%	62.4%	100%
55	1.3%	3.5%	16.9%	11.5%	66.8%	100%

Source: Liu and Dissanayake 2007

To determine relationships between crash severity on gravel roads and twelve variables (Table 9), Liu and Dissanayake applied contingency table analysis testing. Each variable, including speed limit, was found to be related to crash severity. However, all but one of these variables (gender) was also found to be correlated with speed limit.

Table 9. Categories of the variables for crashes on gravel roads

Variables	Categories
Speed limit	30 mph, 35 mph, 40 mph, 45 mph, 50 mph, and 55 mph.
Crash severity	Fatal, Disabled, Non_incapacitating, Possible injured, and Not injured.
Accident class	Non-collision, Overturned, Collision with other vehicle, Animal, and Fixed Object.
Contributing circumstances	Driver, Environment, Road, and Vehicle.
Collision with other vehicles	Head on, Rear end, Angle-side impact, Sideswipe, and Backed-into.
Collision with fixed object	Utility devices, Fence/gate, Ditch, Embankment, and Tree.
Driver age group	Old (65 years), Middle (>25&<65 years), and Young (25 years).
Driver factor	Too fast for conditions, Inattention, Under the influence of alcohol, Avoidance/Evasive action, Fail to yield the right of way, and Exceeding posted speed limit.
Driver gender	Female and male.
Light condition	Daylight, Dawn, Dusk, and Dark.
Road characteristics	Straight and Curve.
Surface condition	Dry, Wet, Snow/Slush, Ice/Snowpacked, and Mud/Dirt/Sand.
Weather condition	No adverse conditions, Rain, Snow, Fog/Smoke, and Strong Wind.

Source: Kansas Accident Records System (KARS), Kansas Department of Transportation (KDOT) 2007

In a subsequent study, Liu and Dissanayake (2008) developed logistic regression models to identify factors affecting the severity of injury crashes on gravel roads in Kansas. The results revealed that failure to use safety equipment, driver ejection, alcohol involvement, failure to yield right-of-way, inattentive driving, driving too fast for conditions or exceeding speed limit, older driver involvement, and ruts/potholes on surfaces increased the probability of a more severe crash occurring. The authors also found a correlation between higher crash severity and crashes involving an overturned vehicle, head-on collisions, and collisions with fixed objects. A breakdown of crashes in their sample by various characteristics is shown inTable 10.

Local policy may also affect low-volume road crashes. Souleyrette et al. (2005) conducted a study to establish guidelines for removing unnecessary traffic control devices at low-volume rural intersections. The study's survey of county engineers revealed much variation among the policies Iowa counties adopted and procedures they utilized to establish stop control at low-volume rural intersections. Sight distance and crash history were found to be the main criteria that a majority of county engineers used for installing stop control.

The study also concluded that, above a threshold daily entering vehicle (DEV) value of 150 vehicles, uncontrolled intersections tended to have higher crash rates than intersections with two-way stop control. No statistically significant difference was observed below the threshold.

There appeared to be no direct relation between the fraction of stop-controlled intersections and crash rate in a given jurisdiction.

Table 10. Characteristics of gravel road crashes in Kansas (1996-2005)

	Factors	Crash Severity					Total	Percent
		Fatal	Incapac-itating	Non-Incapaci-tating	Possible	PDO		
Enviro-nment	Good weather	252	658	3,038	1,891	11,003	16,842	90.4%
	Adverse weather	13	39	266	184	1,291	1,793	9.6%
	Dark/Unlit	97	251	1,267	663	5,014	7,292	39.1%
	Day/Light	168	446	2,037	1,412	7,280	11,343	60.9%
Road	Off roadway	60	115	612	310	1,281	2,378	12.8%
	Ruts	5	30	135	81	250	501	2.7%
	Slippery	26	82	460	327	2,498	3,393	18.2%
	Straight& Level	166	356	1,744	1,108	7,171	10,545	56.6%
	Curve/Grade	99	341	1,560	967	5,123	8,090	43.4%
Driver	Alcohol involved	81	147	467	176	546	1,417	7.6%
	Old driver involved	44	67	288	215	1,451	2,065	11.1%
	Young driver involved	132	405	2,082	1,280	5,988	9,887	53.1%
	Male driver involved	168	411	1,865	1,029	7,535	11,008	59.1%
	Safety equipment not used	36	224	1,761	1,367	10,168	13,556	72.7%
	Driver Ejected	142	145	190	37	22	536	2.9%
	Failed to yield right-of-way	46	95	262	178	766	1,347	7.2%
	Disregarded traffic control devices	17	36	110	58	191	412	2.2%
	Exceeded speed limit	15	49	153	80	206	503	2.7%
	Too fast for conditions	116	331	1,567	864	2,965	5,843	31.4%
	Inattention	133	317	1,408	908	3,700	6,466	34.7%
	Avoidance/evasive action	13	33	310	193	752	1,301	7.0%
Crash Type	Pedestrian involved	1	3	20	12	2	38	0.2%
	Two-vehicle	79	188	539	390	2,509	3,705	19.9%
	Overturned	97	170	916	546	1,404	3,133	16.8%
	Vehicle-animal	1	7	44	48	3,450	3,550	19.1%
	Vehicle-fixed-object	86	318	1,717	1,050	4,431	7,602	40.8%
	Head-on	8	38	81	36	159	322	1.7%
	Rear-end	4	14	62	62	353	495	2.7%
	Angle-side	49	120	328	240	1,245	1,982	10.6%
	Sidewipe	1	4	37	42	417	501	2.7%
	Back-into	0	0	3	4	292	299	1.6%

Source: Liu and Dissanayake 2008

Souleyrette et al. drew several conclusions for both stop-controlled and uncontrolled ultra-low-volume (<150 DEV) unpaved intersections. One conclusion was that broadside/right angle crashes were the most prominent multi-vehicle crash types. The major contributing circumstance at these intersections was failure to yield the right-of-way, though this was not because drivers ignored the STOP sign but because they tended to misjudge gaps and proceeded into the path of oncoming vehicles. Older driver involvement in crashes was underrepresented, perhaps because older drivers either drive with more caution at these intersections or avoid these types of intersections. In contrast, younger driver involvement was somewhat overrepresented at these intersections.

However, other studies have found older drivers to experience more severe injuries. Khattak et al. (2002) estimated an ordered probit model to isolate the factors that contribute to more severe injuries to older drivers (age 65 and older) involved in crashes. Modeling results revealed that the severity of crashes involving older drivers was correlated to the involvement of farm vehicles, more so than for other vehicle types. The model also indicated more severe injuries to older drivers in rural areas, where dark and unlit conditions were found to contribute to injury severity. The authors suggested that older drivers should be made aware of the aforementioned risks when they consider a reduction in their driving.

The following common safety problems for low-volume roads were identified in the *Guide to Safety Features for Local Roads and Streets* (FHWA and NHI 1992):

- Narrow lanes and inadequate shoulders (or no shoulder)
- Sharp horizontal and/or vertical curves
- Inadequate passing, stopping, and horizontal sight distance
- Narrow bridges
- Limited right-of-way
- Inadequate sight distances at intersections
- Frequent roadside obstacles
- Lack of clear roadside recovery area
- Inadequate signing , markings, and delineation

Literature was also reviewed in reference to the identification of high-crash locations on local rural roads. Russell et al. (1996) reported that one or more of the following measures can be applied to identify high-accident locations: accident number, accident severity, accident rate, number rate, severity rate, number quality control, and/or rate quality control. Russell et al. pointed to the actual number of accidents as the basic measure. To account for the severity of crashes, the authors suggested the equivalent property damage only (EPDO) number, which is produced by assigning weights to each severity level.

Ksaibati and Evans (2008) assigned crashes to single-mile strips of roadway in Wyoming and stored the crash data associated with each road segment in an Excel spreadsheet. The authors considered 10 potential procedures for identifying high-risk locations (which were very similar to the measures suggested by Russell et al.):

1. Total number of crashes (based on 10 years)
2. Total number of crashes/mile (based on 10 years)
3. Fatal and injury crashes/mile (based on 10 years)

4. EPDO method (based on 10 years)
5. Total number of crashes/mile (based on three-year moving average)
6. Fatal and injury crashes/mile (based on three-year moving average)
7. Total crash rate (based on 10 years)
8. Fatal and injury crash rate (based on 10 years)
9. Total crash rate (based on three-year moving average)
10. Fatal and injury crash rate (based on three-year moving average)

Ksaibati and Evans ranked the road segments by each of these measures and observed only a minor shift in the ranking of the high-risk locations. For the identification process, the authors utilized the ranking by actual number of crashes on respective one-mile segments. They also considered an EPDO method. However, they did not use this method, because fatal crashes were too limited in number, and, therefore, the EPDO method could skew the analysis.

In their report, Ksaibati and Evans provided a sample table that shows the ranking of sections from Laramie County, Wyoming. There were repeated crash frequencies of up to nine crashes per one -mile segment in the county. In a separate study, Zegeer et al. (1994) similarly chose sections with a minimum length of one mile to ensure stability of crash rates by avoiding over/underrepresentation due to too-short of segments. Moreover, Russell et al. emphasized that choosing road segments with low numbers of crashes might provide too many locations to analyze.

To demonstrate the severity weighting, Russell et al. presented an example in which fatal and all injury crashes were considered equivalent to six personal damage only (PDO) crashes.

Low-Volume Road Safety Solutions

Several studies have been conducted to explore mitigation strategies for low-volume roads. The MUTCD provides the following basic recommendations on prioritizing traffic control devices (p. 5A-1):

> Support: It is possible, in many cases, to provide essential information to road users on low-volume roads with a limited number of traffic control devices. The focus might be on devices that:
>
> A. Warn of conditions not normally encountered;
>
> B. Prohibit unsafe movements; or
>
> C. Provide minimal destination guidance.
>
> As with other roads, the application of traffic control devices on low-volume roads is based on engineering judgment or studies.

A guide prepared by Russell et al. (1996) for personnel at Local Technical Assistance Program (LTAP) centers in Kansas suggests specific mitigation strategies. The main focus of the report was on specific safety problems and deficiencies on low-volume roads. The researchers presented basic common solutions from the available literature at the time. They provided design criteria for roadway geometric features, including cross-section elements, clear-zone roadside obstacles, and safe drainage features. Other topics in the guide included the influence of road surface on safety, surface and drainage conditions with respect to safety, sight distance issues, access control, and some principles of good operating practice with emphasis given to driver expectancy, positive guidance, and consistency issues. The report included practical tools for county engineers, such as establishing a maintenance check and sign inventory system, a complaint system, and information deficiency checklists. Guidelines on process-based problem identification and low-cost safety improvements were also provided.

Caldwell and Wilson (1997) similarly conducted research to develop a safety improvement program (SIP) tailored specifically for low-volume unpaved rural roads. The project employed a modified Delphi procedure to obtain input from unpaved road experts and other professionals representing federal and local agencies (FHWA, Wyoming DOT (WYDOT), Wyoming Association of County Engineers and Road Superintendents, Wyoming County Commissioners Association, and regional universities). Crash data and road user assessments were examined to identify safety needs on these roads. The resulting program consisted of the following five steps:

1. System-wide prioritization of unpaved roads
2. Identification of safety improvements on individual road sections
3. Prioritization of safety improvements
4. Scheduling and implementing safety improvements
5. Program evaluation and update process

Caldwell and Wilson concluded that limitations with local funding and staff must be taken into account before developing an SIP for unpaved roads. The authors also recommended that changes in policies and practices should be considered to evaluate and prioritize unpaved road safety needs.

In addition, Tate and Wilson (1998) conducted research to design a road safety audit (RSA) program specifically for rural local roads. A modified Delphi procedure was used to survey a focus group of experts (county road superintendents and county engineers) from the states in FHWA Region VIII. The members in the group represented the FHWA, Bureau of Land Management, WYDOT, LTAPs, and selected counties. Rural local roads were classified into the following four groups: rural primary, rural secondary, rural local, and rural low-volume local. Tate and Wilson concluded the following:

- Functional classification of rural local roads must be established to structure the safety needs identification process and incremental improvements.
- Most local jurisdictions do not have an adequate safety needs identification process.
- Development of a safety needs identification process for rural roads must account for limited local resources.
- The rural local road safety survey indicated a region-wide belief that an RSA program is justified and useful for rural local jurisdictions as a safety needs identification process.

- Pilot studies demonstrated that RSAs are a simple, yet beneficial, method for evaluating safety needs.

More recently, NCHRP Synthesis 321 (2003), *Roadway Safety Tools for Local Agencies: A Synthesis of Highway Practice*, introduced reactive and proactive safety tools. In the report, two proactive safety tools utilizing an independent team approach to address safety concerns on local roads were defined: the RSA and the road safety audit review (RSAR). The report described the steps in planning an RSAR program and provided a functional classification of rural roads (See Table 11). The RSA was defined as an advanced and systematic process that can be modified for an agency's specific organizational culture and safety priorities. The following were listed as the steps of an RSA:

- Select the road safety audit team
- Provide the relevant data and documentation
- Hold a kickoff meeting
- Assess the data and documents
- Inspect the site
- Discuss audit safety issues with the designer or internal client
- Write the RSA report
- Hold a completion meeting
- Respond to the report
- Implement agreed-on changes
- Share lessons learned

Table 11. A proposed approach for functional classification of rural local roads

Rural Major High Speed	Rural Minor	Rural Local	Rural Major Medium Speed	Rural Low-Volume Local
Serves larger towns and other traffic generators not served by higher functional classification systems and serves more important intracounty travel corridors. Typically • Paved surfaces • Traffic volumes up to 400 vpd • Operating speed 40–65 mph • Limited intersections and accesses	Accumulates traffic from local roads, brings all developed areas within reasonable distances of collector roads, provides service to the remaining smaller communities, and links the locally important traffic generators within their rural region. Typically • Unpaved surfaces but some may be paved • Traffic volumes 250–400 vpd • Operating speed 30–60 mph	Provides access to land adjacent to the higher functional classification network and serves travel into isolated areas over relatively short distances. Typically • Unpaved surfaces • Traffic volumes 100–250 vpd • Operating speed 20–45 mph	Serves smaller towns and other traffic generators not served by higher functional classification systems, links these places with nearby cities and larger towns or with higher systems, and serves more important intracounty travel corridors. Links to rural major and collector classifications. Typically • Paved surfaces but some may be unpaved • Traffic volumes up to 400 vpd • Operating speed 30–45 mph • Frequent accesses	Provides access to adjacent land and serves travel over relatively short distances. Typically • Unimproved surfaces and some may be considered improved, but unpaved • Traffic volumes 0–100 vpd • Operating speed variable

Notes: vpd = vehicles per day. [*Source*: Local RSAR training materials developed by Eugene M. Wilson, 2001 (see Appendix I).]

Source: Roadway Safety Tools for Local Agencies - A Synthesis of Highway Practice, NCHRP Synthesis 321, 2003

The report provided a sample RSAR report of rural local roads from an undisclosed county in the form of an “RSAR Tool Kit.” Reactive analysis tools discussed in the report covered a broad compilation of key points identified in several important publications. The reactive safety tools approach was supplemented by a checklist for before-and-after analysis decisions and by suggestions for local agencies to consider in applying basic reactive safety tools. The report included a summary table that integrates the safety tools presented and enables local agencies to readily reach the desired solutions. Both a rural and an urban example of developing local safety improvement programs were briefly explained.

In addition to offering mitigation strategies, NCHRP Synthesis 321 presented common types of crashes, possible contributing factors, and potential countermeasures. Russell et al. (1996) also included general countermeasures for crash patterns and their probable causes.

Proposed mitigation strategies have been shown to have benefits. The *Low-Cost Local Roads Safety Solutions* (2006) publication of the American Traffic Safety Services Association reports that sign and pavement marking improvements result in a 42% reduction in crashes, yielding benefit-cost ratios of 159:1 to 299:1. The publication also points out that studies have determined reductions in run-off-road crashes of up to 31% after deployment of post-mounted chevrons.

However, Russell et al. (1996) have emphasized that operational control devices cannot always compensate for inappropriate road geometry. Use of signs, signals, and markings should be minimized by designing a road to the highest standards possible. Russell et al. provided tables displaying decision sight distance values for speed intervals, radii, and superelevation limit values for different design speeds, maximum grades, and design control values for vertical curves to support this approach. Detailed guidelines for determining advisory safe speeds and checking superelevation at horizontal curves by means of a ball bank indicator were also included in the report.

Addressing the links between maintenance problems and safety concerns on low-volume roads, Zegeer et al. (1994) noted that these links may be over-emphasized due to the fact that a vast majority of low-volume roads are unpaved. The report provided recommendations on designing roadway width with special consideration given to safety and maintenance.

2006 CHSP Local Roads Team Strategy Plan

In 2006, Iowa developed its first Comprehensive Highway Safety Plan (CHSP). Teams were developed to address many safety areas of importance to the state. Among these was a Local Roads team. The team met and reviewed crash data from the Iowa DOT. Following are the trends identified from these data (for rural and urban areas).

Rural Local Road Trends

Inspection of Iowa crash data for local rural roads indicates a significant number of fatal and serious injury crashes occur on very low-volume roads (<400 vpd), with many of them unpaved.[1] Tables 12 through 15 summarize various characteristics of these crashes for Iowa.

The CHSP Local Roads Team identified several crash issues as being noteworthy for rural local roads in Iowa. For example:

- Single-vehicle run-off road
- Multi-vehicle cross centerline/cross median
- Driver's age 15 to 24 years
- Time-of-day
- Driver contributing circumstances:
    - Lost control
    - Driving too fast
    - Ran stop sign
    - Failure to yield right of way (FTYROW)

Table 12. Serious single-vehicle run-off road and multiple-vehicle cross centerline crashes

SVROR & MVCCCM Fatal & Major Injury Crashes on County Roads (2001-2005)

AADT	Rural Secondary Unpaved	
0-49	338	(42.30%)
50-99	240	(30.04%)
100-149	106	(13.27%)
150-199	50	(6.26%)
200-299	47	(5.88%)
300-449	15	(1.88%)
450 +	3	(0.38%)
Total	**799**	**(100.00%)**

AADT	Rural Secondary Paved	
0-199	83	(6.36%)
200-399	190	(14.55%)
400-599	228	(17.46%)
600-799	190	(14.55%)
800-999	141	(10.80%)
1000-1199	119	(9.11%)
1200-1399	80	(6.13%)
1400-1599	51	(3.91%)
1600-1799	40	(3.06%)
1800-1999	41	(3.14%)
2000-2499	48	(3.68%)
2500-2999	20	(1.53%)
3000-3499	24	(1.84%)
3500-3999	19	(1.45%)
4000-4999	7	(0.54%)
5000-5999	8	(0.61%)
6000-7999	13	(1.00%)
8000 +	4	(0.31%)
Total	**1306**	**(100.00%)**

[1] Of the 90,000 miles of secondary roads in Iowa, more than 80,000 miles have traffic volumes of less than 400 vpd. About 48,000 miles have daily traffic volumes less than 50. In addition, almost 72,000 miles of very low-volume (<400 vpd) roads are unpaved.

Table 13. Iowa rural local roads – serious crashes by age 2001-2005

Driver Age	# Drivers
14 yrs & Under	38
15 to 24 yrs	*1612*
25 to 34 yrs	870
35 to 44 yrs	956
45 to 54 yrs	829
55 to 64 yrs	511
65 to 74 yrs	253
75 to 84 yrs	249
85 to 94 yrs	88
95 yrs & Over	4
Unknown	106
Total	5516

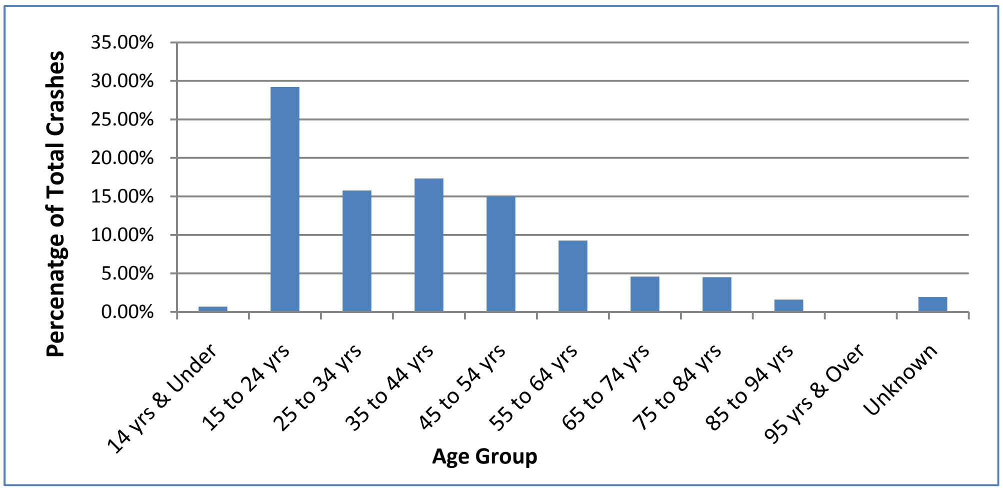


Table 14. Iowa rural local roads – serious crashes by time of day 2001-2005

Hour of Day	# of Crashes
0	114
1	108
2	140
3	62
4	58
5	72
6	104
7	171
8	163
9	131
10	147
11	157
12	180
13	202
14	228
15	286
16	284
17	257
18	190
19	140
20	175
21	154
22	133
23	118
Unknown	27
Total	3801

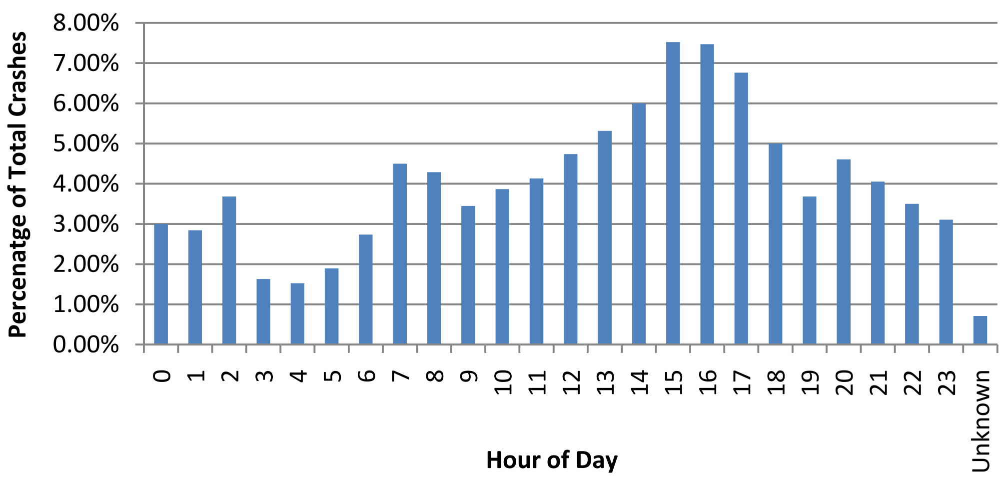


Table 15. Iowa rural local roads serious crashes – driver contributing circumstances 2001-2005

Driver Contributing Circumstance	# Drivers
Ran traffic signal	25
Ran stop sign	276
Exceeded authorized speed	184
Driving too fast for conditions	315
Made improper turn	40
Traveling wrong way or on wrong side of road	74
Crossed centerline	280
Lost Control	1243
Followed too close	40
Swerved to avoid: vehicle/object/non-motorist/or animal in roadway	155
Over correcting/over steering	44
Operating vehicle in an erratic/reckless/careless/negligent/aggressive manner	68
FTYROW: From stop sign	309
FTYROW: From yield sign	41
FTYROW: Making left turn	91
FTYROW: From driveway	15
FTYROW: From parked position	9
FTYROW: To pedestrian	5
FTYROW: At uncontrolled intersection	79
FTYROW: Other	72
Inattentive/distracted by: Passenger	5
Inattentive/distracted by: Use of phone or other device	9
Inattentive/distracted by: Fallen object	5
Inattentive/distracted by: Fatigued/asleep	35
Other: Vision obstructed	49
Other: Improper action	158
Other: No improper action	1441
Unknown	449
Total	5516

On *rural* local roads, there were 594 (15.6%) alcohol-related[2] fatal and major injury crashes from 2001 to 2005.

Urban Local Road Trends

By comparison, on urban streets, most fatal and serious injury crashes occur at intersections. Tables 16, 17, and 18 summarize various characteristics of these crashes in Iowa.

The Iowa CHSP Local Roads Team identified several crash issues as being noteworthy for urban local roads in Iowa. For example:

[2] Alcohol-related defined as at least one driver per crash either refusing alcohol test or BAC > 0.00

- Driver contributing circumstances:
  - Ran traffic signal
  - Ran stop sign
  - FTYROW
  - Excessive speed
- Driver's age 15 to 24 years
- Time-of-Day

Table 16. Iowa urban local roads serious crashes – driver contributing circumstances 2001-2005

Driver Contributing Circumstance	# Drivers
Ran traffic signal	409
Ran stop sign	229
Exceeded authorized speed	197
Driving too fast for conditions	191
Made improper turn	86
Traveling wrong way or on wrong side of road	55
Crossed centerline	84
Lost Control	397
Followed too close	136
Swerved to avoid: vehicle/object/non-motorist/or animal in roadway	51
Over correcting/over steering	9
Operating vehicle in an erratic/reckless/careless/negligent/aggressive manner	74
FTYROW: From stop sign	349
FTYROW: From yield sign	33
FTYROW: Making left turn	373
FTYROW: Making right turn on red signal	7
FTYROW: From driveway	50
FTYROW: From parked position	21
FTYROW: To pedestrian	65
FTYROW: At uncontrolled intersection	58
FTYROW: Other	104
Inattentive/distracted by: Passenger	9
Inattentive/distracted by: Use of phone or other device	10
Inattentive/distracted by: Fallen object	5
Inattentive/distracted by: Fatigued/asleep	21
Other: Vision obstructed	52
Other improper action	289
Other: No improper action	3123
Unknown	363
Total	6850

Table 17. Iowa urban local roads – serious crashes by time of day 2001-2005

Hour of Day	# of Crashes	Hour of Day	# of Crashes
0	76	13	234
1	80	14	226
2	78	15	369
3	37	16	306
4	18	17	299
5	41	18	214
6	63	19	146
7	159	20	151
8	180	21	142
9	143	22	120
10	169	23	89
11	210	Unknown	15
12	233	Total	3798

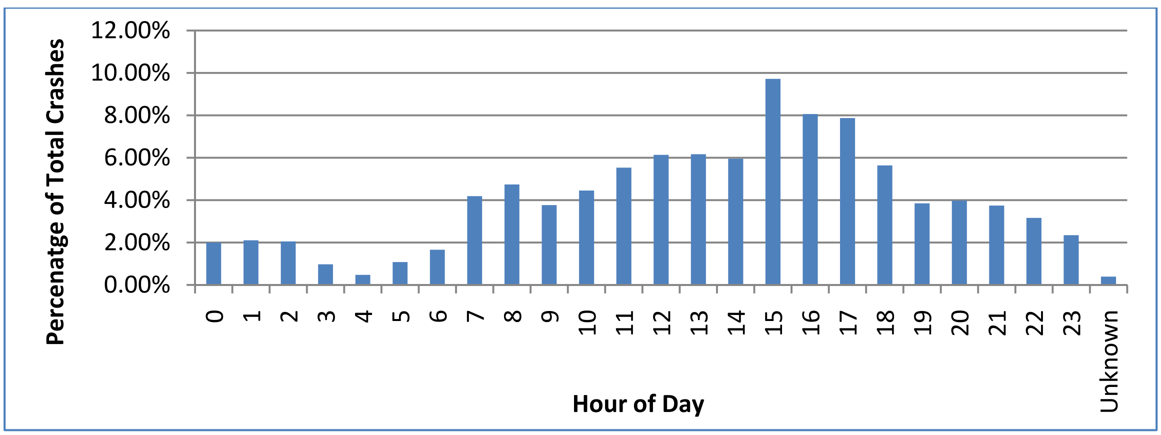
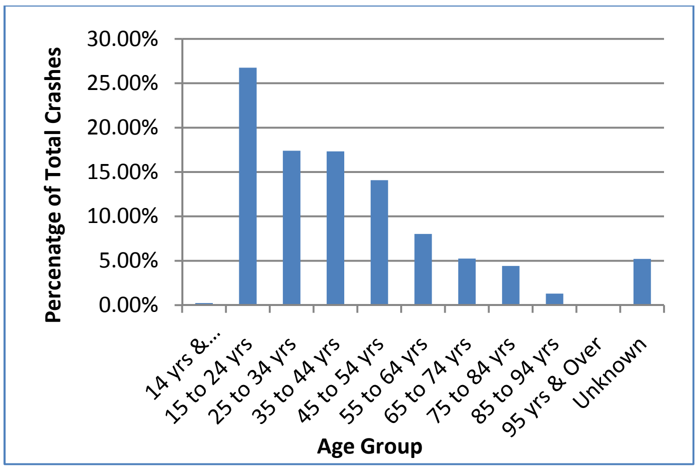


Table 18. Iowa urban local roads – serious crashes by age 2001-2005

Driver's Age	# Drivers
14 yrs & Under	16
15 to 24 yrs	1833
25 to 34 yrs	1192
35 to 44 yrs	1187
45 to 54 yrs	964
55 to 64 yrs	549
65 to 74 yrs	359
75 to 84 yrs	303
85 to 94 yrs	89
95 yrs & Over	1
Unknown	357
Total	6850



On *urban* local roads, there were 325 (8.6%) alcohol-related fatal and major injury crashes from 2001 to 2005.

General Trend Observations

The highest numbers of serious crashes occur in daylight hours, for both urban and rural local roads. Alcohol-related serious crashes are almost twice as common in rural areas than in urban areas. Serious crashes are distributed somewhat evenly for driver ages 15-45 in urban areas, but younger drivers, 15-24, are more commonly involved in rural locations.

The 2006 Iowa CHSP Local Roads team identified the following general goals and specific objectives for improving local road safety.

General Goals:

- Effectively share crash data and interpretation with local agencies
- Promote cooperation between disciplines in local agencies:
  - Engineering
  - Enforcement
  - Educators
  - Emergency responders
- Develop strategies for improving safety on lower-volume rural roads and at urban intersections
- Reduce fatalities and serious injuries by 10% on local roads and streets over the next 10 years

Specific Objectives:

- Promote and support efforts to provide crash data and interpretation assistance to local agencies by the Iowa DOT and/or Center for Transportation Research and Education (CTRE), possibly as an enhancement to the 3R program.

- Assist in development of and support efforts in building multi-disciplinary teams at the local level to consider and address perceived traffic safety concerns.

- Identify and provide educational outreach on the most cost-effective measures to mitigate identified traffic safety concerns on local rural roads and city streets, emphasizing an all-discipline approach. Communication through existing professional organizations, such as the Iowa County Engineers Association and American Public Works Association, should be emphasized.

- Study and identify feasible methods of improving response times for emergency responders in rural areas.

Proposed Strategies

The 2006 Iowa CHSP Local Roads team proposed the following strategies for addressing local road safety issues, listed in order of team preference. Tier One Strategies, shown in **boldface**, are expected to yield the most significant results and work to change the culture of safety. Tier Two Strategies, in normal print, also present potential opportunities to improve safety on local roads and streets.

1. Undertake an in-depth study of fatal and serious injury crashes on very low-volume rural roads, examining where and when these incidents occur and who is involved.

2. Study and promote the use of paved shoulders and "rumble stripes" on paved local rural roads to reduce run-off-road crashes and promote more visible, longer-lived edge line markings, particularly at potentially higher risk locations, such as curves.

3. Provide GIS-based crash data to local agencies and planning organizations on cyclical basis to identify locations of potential concern.

4. Support programs of concentrated enforcement on low-volume rural roads and high-crash intersections with initiatives such as “Safety Zones.”

5. Provide support and analysis information for enhanced enforcement efforts at urban intersections, such as automated enforcement.

6. Support and provide instructional materials for driver educators through class materials, teaching aids, and pertinent crash information, with particular emphasis for driving on unpaved rural roads, seat belt use, speed, and alcohol consumption.

7. Urge local rural agencies to examine very low-volume roads for possible needed safety improvements that can be accomplished at low cost, such as signing upgrades.

8. Promote a reduction in the statutory speed limit on unpaved rural roads from 55 mph to 50 mph, day and night.

9. Encourage local agencies to employ public information efforts to advise of safety initiatives and to acquaint drivers with potential safety concerns, such as red light running and high speed travel on unpaved surfaces.

10. Work with local agencies to establish and support multi-disciplinary traffic safety teams similar to the successful Citizen Awareness on Roadway Safety (CARS) group in the Quad Cities.

11. Establish communication network with emergency responders in local areas to determine feasible methods of improving response times to serious crash sites.

Recommended Programs and Projects

Finally, the Local Roads team recommends the following programs and projects to support interdisciplinary efforts to improve local road safety in Iowa:

1. Complete a research study of serious crashes on very low-volume roads which will provide an excellent reference for identifying mitigation steps with a high benefit probability and also provide a resource for outreach and educational efforts.

2. Document efforts to promote effective use of paved shoulders and/or “rumble stripes” and record miles of implementation on an annual basis.

3. Crash data for serious crashes should be provided to larger cities and metropolitan planning agencies, followed by data for speed-, alcohol-, seat belt-, etc.-related crashes to enforcement agencies, and rural-related crash data to counties and regional planning agencies. This distribution should be repeated on a three-year cycle.

4. Develop and support a program for concentrated enforcement on low-volume rural roads and problem intersections similar to the successful effort on primary roads. An annual report of accomplishment should be prepared.

5. Web-based information of successful enforcement efforts at urban intersections should be provided to include research studies, cities with programs, etc. Documentation of crash analyses and advice provided should be maintained.

6. In addition to a web-based reference, driver educators should be provided with class handouts, training aids, and pertinent crash data. Volume and content of materials provided should be documented annually.

7. Develop and present training for local agencies to inspect and identify potential safety concerns on very low-volume roads and select low-cost but proven mitigation measures.

8. Provide crash analysis support for reduced speed limits on unpaved roads and build support for this legislative initiative with agencies having a vested interest, such as law enforcement, schools, and engineers.

9. Advice, support, and pertinent information should be offered to local agencies for public information initiatives regarding local roads safety issues. Documentation of information provided should be maintained.

10. Expand the number of communities with multi-disciplinary safety teams across the state and provide support as needed.

11. Establish communication network with emergency responders to share concerns and identify impediments for decreasing response time in rural areas.

3. METHODOLOGY

This project consisted of three principal tasks: statewide statistical assessment, statistical modeling, and site-specific field review. Unfortunately, while the site-specific field review consumed significant project resources of time and effort, only one meaningful conclusion could be drawn from the analysis (See subsection titled *Three-Leg Intersections* in Section 5. *Supplemental Analyses*). Further work is recommended to follow this study as discussed in the Section 6. *Conclusions and Recommendations*. Details of the site-specific field review may be found in Appendix 3. *Detailed Study of Crash Records and Field Conditions* and Appendix 4. *Preliminary Characteristics of Interest for Site Visits (Desired Data for Crash Site Review)*.

The methodologies followed for the statistical assessment and modeling tasks are given below.

1. Descriptive Statistics and Statistical Tests

Descriptive statistics for seven years of available crash data (2001-2007, later updated to 2008), were prepared for rural low-volume (≤400 ADT) secondary road crashes, as well as for all other two-lane rural road crashes for comparison purposes. The descriptive statistics included a broad range of both crash- and driver/vehicle-level attributes. Iowa DOT Geographic Information Management Systems (GIMS) roadway data were integrated with crash data for analysis. System-wide crash data were utilized to investigate trends in frequency, rate, and severity with respect to the various crash characteristics and general road types.

Descriptive statistics were developed for low-volume and other road categories on 22 major crash characteristic categories. The categories are comprised of some 240 crash characteristic values, each describing the specific conditions present during a given crash. Appendix 5. *Sample Table Showing the Test of Proportions Results (0-100 Unpaved Secondary vs. Two-Lane Primary)* lists the 240 crash characteristics examined, and is followed by Appendix 6. *Summary of Results from Test of Proportions* . The 22 major crash characteristic categories are:

1. Crash Severity
2. Crash TYPE
3. Manner of Crash/Collision
4. Speed/Weather-Surface Relation
5. Light Conditions
6. Younger and Older Driver Involvement
7. Drug/Alcohol Involvement
8. Terrain
9. Farm Vehicle Involvement
10. Month
11. Day
12. Hour
13. Location of First Harmful Event
14. First Harmful Event
15. Major Cause

16. Drug or Alcohol Related
17. Environment Contributing Circumstances
18. Weather Conditions
19. Light Conditions
20. Surface Conditions
21. Roadway Contributing Circumstances
22. Type of Roadway/Junction/Feature

Test of Proportions

Distribution of low-volume rural secondary road crashes were compared to that of rural primary roads to find the main factors that increase risk for low-volume roads as compared to primary two-lane roads. A test of proportions was employed to determine various crash characteristics which were overrepresented on different low-volume road categories. The comparison group was primary road crashes.

The proportion of various characteristics of crashes on roads of different jurisdictions, traffic volume ranges, and surface types were computed. These proportions were then statistically tested to determine if differences between pairs of proportions were statistically significant. Given adequate sample sizes and assumptions of independence of the proportions, the z-statistic for a standard Normal random variable was utilized for the test. The following steps describe this procedure.

1. The null hypothesis was defined as "the difference between two proportions being tested is zero," or, H_0: $p_1 = p_2$ and, H_1: $p_1 \neq p_2$
   Where p_1 represents the first proportion being tested and p_2 represents the second proportion.
2. The level of confidence was selected as 95%; consequently, the significance level was 0.05.
3. The differences between sample proportions ($|p_1 - p_2|$) were computed.
4. Weighted average of the two sample proportions were computed using the formula:
   $$p = \frac{n_1 p_1 + n_2 p_2}{n_1 + n_2}$$
   where n_1 and n_2 are the respective number of observations sampled from the two populations.
5. Estimated standard error of the difference between proportions was computed by:
   $$s_{p_1 - p_2} = \sqrt{\frac{p(1-p)}{n_1} + \frac{p(1-p)}{n_2}}$$
6. The Z-statistic was computed by the standard formula:
   $$z = \frac{|p_1 - p_2|}{s_{p_1 - p_2}}$$
7. The probability value (p-value) was then computed.
8. The probability computed in Step 7 is compared to the significance level stated in Step 2. A probability value which is equal or less than the significance level of 0.05 would mean that the difference tested is significant. When the difference is significant, the null hypothesis "the two population proportions are equal, or not different" is rejected.

A test of proportions for all 240 crash characteristic values was performed comparing various groups of low-volume roads to other (primary) two-lane roads. The results point to the types of crashes that are particularly problematic for low-volume roads. These characteristics were also used to develop a crash-based statistical model.

2. Crash Model Development

The objective of this task was to create a system-level model for secondary, low-volume road crashes. This model isolated crash, driver and/or roadway variables that are the best predictors of the severity of low-volume road crashes.

A number of disparate data sets were integrated at many stages of the study. Table 19 provides a summary of the sources utilized to gather these data.

Table 19. Data sources utilized in the study

Type of Data	Source/Database	Uses
Crash locations and attributes	Iowa DOT/Iowa Traffic Safety Data Service (2001-2007, 2008)	• Descriptive statistics of crash-, vehicle/driver-, and occupant/injury-level crash characteristics • Road and environmental circumstances
Road shape lines and attributes	Iowa DOT Geographic Information Management System (GIMS) Data (2007, 2008)	• Roadway geometric characteristics • Average annual daily traffic (AADT) on road sections • Terrain information
Aerial images	USDA National Agriculture Imagery Program orthophotos for Iowa (2006 and 2007)	• Crash site evaluation (contribution to locate crashes)
Road images	Videos and photos (2008-2009)	• Crash site evaluation
Water stream shape lines	Iowa Geological Survey (NRGIS) Library	• Crash site visits (contribution to locate crashes)
Railroad shape lines	Iowa Geological Survey (NRGIS) Library	• Crash site visits (contribution to locate crashes)
Census	US Census Bureau web site	• Demographic features of the rural population in Iowa

AADT and road system type were the two basic criteria utilized in setting up groups of roads. State-wide GIMS road data provided both of these data fields. Three thresholds of daily volume and two types of jurisdictional road systems were used to categorize roads and assign crashes to them, respectively. AADT values were also used in the process to determine candidate crash sites to review and evaluate. The main resource for traffic volumes was the GIMS road database, which is maintained and updated by the Iowa DOT Office of Transportation Data (http://www.dot.iowa.gov).

To find the most significant factors of all crashes on rural roads with 400 vpd or less between 2001 and 2007, an ordered probit model was estimated. The model was based on crashes rather than locations, so application is limited to the identification of important contributing factors to low-volume roads in general, rather than the identification of high-crash locations. A location-based model is the subject of a follow-up study of low-volume roads in Iowa.

The Nlogit 4.0 extension of the LIMDEP software was utilized for building the model. The dependent variable was selected as crash severity and a 90% confidence level was used for determining relevant independent variables. Three severity levels were considered: fatal and major injury (serious), minor or possible injury, and property damage only crashes. The model was designed to predict the marginal effects of independent variables on each of the three crash severity levels.

4. ANALYSIS AND RESULTS

Statewide Descriptive Statistics and Statistical Tests

To compare the performance of rural low-volume roads to other selected road types, a statewide analysis was performed. Low-volume rural roads, the majority of which are unpaved, perform differently than state-owned primary highways, which have higher volumes and more-advanced design features. To identify the main factors that influence crash risk on low-volume roads, a test of proportions was employed to determine various crash characteristics that might be overrepresented for different categories of low-volume roads.

Descriptive Statistics

Descriptive statistics were developed for all undivided two-lane rural roads in Iowa (See Table 20 for a sample, and Appendix 7. for all results.) Proportions of various crash characteristics were computed for low-volume rural secondary road crash types of various road volume/surface-type categories and compared to those of rural two-lane rural primary (Iowa DOT) roads. This also facilitated a test of proportions analysis. *Note: In* Table 20 and Appendix 7, orange and blue grouping lines indicate the same crashes broken out into different categories. Some rows are shaded for ease of reading.

Table 20. Partial summary of descriptive statistics for two-lane rural Iowa roads

VARIOUS CHARACTERISTICS OF CRASHES ON TWO-LANE RURAL ROADS BY JURISDICTION, VOLUME, State of Iowa (2001-2007)						
	SECONDARY 0-100					
Road System	Secondary		Secondary		Secondary	
AADT Range	0-100		0-100		0-100	
Surface Type	Unpaved		Paved		All	
Total Crashes	16,040	-	470	-	16,510	-
Total Daily VMT	2,447,000	-	72,080	-	2,519,000	-
Total Centerline-Miles	66,900	-	1,063	-	67,963	-
Weighted Average of ADT	37	-	68	-	37	-
Crash Rate (per 100M VMT)	257	-	255	-	257	-
Crash Density	0.24	-	0.44	-	0.24	-
CRASH SEVERITY	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
Fatal	235	1.5%	9	1.9%	244	1.5%
Major Injury	933	5.8%	29	6.2%	962	5.8%
Minor Injury	2,750	17.1%	65	13.8%	2,815	17.1%
Possible/Unknown	2,929	18.3%	68	14.5%	2,997	18.2%
Property Damage Only	9,193	57.3%	299	63.6%	9,492	57.5%
CRASH TYPE						
MV (No Ani/Obj on Road)	2,940	18.3%	104	22.1%	3,044	18.4%
SV ROR (No Ani/Obj on Road)	9,121	56.9%	199	42.3%	9,320	56.5%
SV Other (No Ani/Obj on Road)	507	3.2%	24	5.1%	531	3.2%
SV ROR (Ani/Obj on Road)	984	6.1%	22	4.7%	1,006	6.1%
SV Other (Ani/Obj on Road)	35	0.2%		0.0%	35	0.2%
Hit Animal	2,453	15.3%	121	25.7%	2,574	15.6%
MANNER OF CRASH/COLLISION						
MV Head-on	378	2.4%	8	1.7%	386	2.3%
MV Read-end	524	3.3%	29	6.2%	553	3.3%
MV Oncoming left turn	206	1.3%	5	1.1%	211	1.3%
MV Broadside	1,007	6.3%	27	5.7%	1,034	6.3%
MV Sideswipe-Same Dir.	217	1.4%	17	3.6%	234	1.4%
MV Sideswipe-Oppos. Dir.	391	2.4%	12	2.6%	403	2.4%
MV Other	217	1.4%	6	1.3%	223	1.4%
SV Coll. with Fixed Obj.	4,050	25.2%	108	23.0%	4,158	25.2%
SV Overturn/Rollover	3,332	20.8%	58	12.3%	3,390	20.5%
SV Collw/FixObj+Over/Roll	2,574	16.0%	43	9.1%	2,617	15.9%
SV Other	691	4.3%	36	7.7%	727	4.4%
Hit Animal	2,453	15.3%	121	25.7%	2,574	15.6%
SPEED/WEATHER-SURFACE RELATION						
Speed Rel	6,894	43.0%	159	33.8%	7,053	42.7%
Weather-Surface Rel	1,143	7.1%	31	6.6%	1,174	7.1%
Speed&Weather-Surface Rel	1,619	10.1%	38	8.1%	1,657	10.0%
Other/Unknown	6,384	39.8%	242	51.5%	6,626	40.1%

Test of Proportions

To identify crash characteristics that are overrepresented on rural low-volume roads, 10 secondary road categories were compared as shown in Table 21. A sample sheet documenting the procedure and a summary of results of the 10 comparisons can be seen in Appendix 5. *Sample Table Showing the Test of Proportions Results (0-100 Unpaved Secondary vs. Two-Lane Primary)* and Appendix 6. *Summary of Results from Test of Proportions* . Differences in proportions of crashes for 240 crash characteristics were evaluated for statistical significance.

Table 21. Road category comparison

GROUPS BEING COMPARED				COMPARISON GROUP		
Comparison Pairs	Road System (Jurisdiction)	AADT Range	Surface Type	Road System (Jurisdiction)	AADT Range	Surface Type
1	Secondary	0-100	Unpaved	All undivided two-lane rural primary roads (All are paved)		
2	Secondary	0-100	Paved			
3	Secondary	100-400	Unpaved			
4	Secondary	100-400	Paved			
5	Secondary	0-400	Unpaved			
6	Secondary	0-400	Paved			
7	Secondary	0-400	All			
8	Secondary	0-100	Unpaved	Secondary	100-400	Unpaved
9	Secondary	0-100	Paved	Secondary	100-400	Paved
10	Secondary	0-400	Unpaved	Secondary	0-400	Paved

Results

The preliminary analysis of 2001-2007 data yielded results which may be seen in Appendix 6. *Summary of Results from Test of Proportions* and Appendix 7. . However during the course of the project, 2008 crash data became available and analysis for the following two selected road classes were updated and compared to data for two-lane rural primary roads:

- All secondary low-volume roads 0-400 AADT (paved and unpaved), and
- Unpaved secondary roads with volumes greater than *or equal to* 100 AADT

The first of these two road classes was chosen for analysis as it represents the target group of roads (low-volume rural roads). However, due to the significant mileage of this class of road in Iowa and the lack of statistically significant high crash locations, a subset of roads was identified for potential application of mass action (systemic) programs. These are represented by the second group, unpaved with traffic volumes greater that 100 vpd.

The following two tables compare historical crash data for 0-400 vpd rural roads to similar rural Iowa DOT (primary) roads. Table 22. Highest relative differences (>3.0) in crash proportions, low-volume (0-400 AADT) rural roads summarizes the results of the test of proportions for this group. These results show only the factors or characteristics for which the proportion of crashes on low-volume roads was significantly higher (statistically) than the corresponding proportion of similar crashes on primary roads. These factors may be considered those that most differentiate the safety performance of low-volume rural roads from primary two-lane roads.

Table 22. Highest relative differences (>3.0) in crash proportions, low-volume (0-400 AADT) rural roads compared to primary two-lane rural roads 2001-2008

CRASH TYPE/FACTOR	Secondary rural LVR Frequency (32,361 total crashes)	Secondary rural LVR percent	Primary 2-lane Frequency (35,175 total crashes)	Primary 2-lane percent	Relative difference in proportion (secondary ÷ primary)
Sand/mud/dirt/oil/gravel	7,732	23.9%	97	0.3%	86.6
Farm vehicle only	125	0.4%	6	0.0%	22.6
Ruts/holes/bumps	340	1.1%	23	0.1%	16.1
Collision with: Railway vehicle/train	107	0.3%	10	0.0%	11.6
Ran off road - straight	539	1.7%	57	0.2%	10.3
Flat	9,115	28.2%	1,066	3.0%	9.3
Physical obstruction	1,045	3.2%	183	0.5%	6.2
FTYROW: At uncontrolled intersection	590	1.8%	133	0.4%	4.8
SV ROR (Ani/Obj on Road)*	926	2.9%	243	0.7%	4.1
SV CollwFixObj+Over/Roll*	4,196	13.0%	1,172	3.3%	3.9
Gore	167	0.5%	49	0.1%	3.7
Collision with fixed object: Ditch/embankment	7,224	22.3%	2,162	6.1%	3.6
Age 14 or below involved	299	0.9%	94	0.3%	3.5
Shoulders (none/low/soft/high)	342	1.1%	109	0.3%	3.4
Intersection: Y - intersection	275	0.8%	89	0.3%	3.4
Non-collision events: Overturn/rollover	7,247	22.4%	2,362	6.7%	3.3
SV Overturn/Rollover*	5,650	17.5%	1,895	5.4%	3.2
Roadside	4,695	14.5%	1,601	4.6%	3.2

Table 23 shows where selected crash types or factors for secondary rural LVR roads are largest in absolute terms compared to primary two-lane roads. These factors may be considered the most problematic aspects of low-volume rural roads.

Table 23. Highest absolute differences in crash proportions (>10%), secondary low-volume (0-400 AADT) rural roads compared to primary two-lane rural roads 2001-2008

CRASH TYPE/FACTOR	Secondary rural LVR Frequency (32,361 total crashes)	Secondary rural LVR percent	Primary 2-lane Frequency (35,175 total crashes)	Primary 2-lane percent	% Absolute difference in proportion (secondary – primary)
SV ROR (No Ani/Obj on Road)*	14,015	43.3%	5,613	16.0%	27.4%
Rolling	20,331	62.8%	12,847	36.5%	26.3%
Flat	9,115	28.2%	1,066	3.0%	25.1%
Sand/mud/dirt/oil/gravel	7,732	23.9%	97	0.3%	23.6%
Speed Rel	12,168	37.6%	6,284	17.9%	19.7%
Collision with fixed object: Ditch/ embankment	7,224	22.3%	2,162	6.1%	16.2%
Non-collision events: Overturn/rollover	7,247	22.4%	2,362	6.7%	15.7%
SV Coll. with Fixed Obj.*	7,220	22.3%	3,424	9.7%	12.6%
Ages 15-19 involved	9,856	30.5%	6,456	18.4%	12.1%
SV Overturn/Rollover*	5,650	17.5%	1,895	5.4%	12.1%
Dark - roadway not lighted	10,523	32.5%	7,390	21.0%	11.5%
Roadside	4,695	14.5%	1,601	4.6%	10.0%

The next two tables summarize the results of the test of proportions for the second group (unpaved rural roads with AADT >100 AADT). Again, these results show only the factors or characteristics for which the proportion on the unpaved low-volume roads was significantly higher (statistically) than the corresponding proportion of crashes on primary roads.

Table 24 indicates where crash types or factors for unpaved roads are largest relative to primary two-lane roads. These factors may be considered those that most differentiate the safety performance of unpaved >100 ADT rural roads from primary two-lane roads.

Table 24. Highest relative differences (>3.0), secondary unpaved (>= 100 AADT) rural roads compared to primary two-lane rural roads 2001-2008

CRASH TYPE/FACTOR	Secondary rural unpaved >=100 Frequency (6,736 total crashes)	Secondary rural unpaved >=100 percent	Primary 2-lane Frequency (35,175 total crashes)	Primary 2-lane Frequency	Relative difference in proportion (secondary ÷ primary)
Sand/mud/dirt/oil/gravel	2,066	30.7%	97	0.3%	111.2
Ruts/holes/bumps	145	2.2%	23	0.1%	32.9
Farm vehicle only	21	0.3%	6	0.0%	18.3
Collision with: Railway vehicle/train	23	0.3%	10	0.0%	12.0
Ran off road - straight	101	1.5%	57	0.2%	9.3
Flat	1,762	26.2%	1,066	3.0%	8.6
Physical obstruction	170	2.5%	183	0.5%	4.9
Gore	45	0.7%	49	0.1%	4.8
SV CollwFixObj+Over/Roll*	1,033	15.3%	1,172	3.3%	4.6
Collision with fixed object: Ditch/embankment	1,702	25.3%	2,162	6.1%	4.1
SV ROR (Ani/Obj on Road)*	191	2.8%	243	0.7%	4.1
Age 14 or below involved	68	1.0%	94	0.3%	3.8
Collision with fixed object: Tree	188	2.8%	263	0.7%	3.7
Non-collision events: Overturn/rollover	1,680	24.9%	2,362	6.7%	3.7
Intersection: Y - intersection	62	0.9%	89	0.3%	3.6
SV Overturn/Rollover*	1,274	18.9%	1,895	5.4%	3.5
Roadside	1,072	15.9%	1,601	4.6%	3.5
Other (explain in narrative)	294	4.4%	479	1.4%	3.2
Shoulders (none/low/soft/high)	66	1.0%	109	0.3%	3.2
FTYROW: At uncontrolled intersection	80	1.2%	133	0.4%	3.1

Table 25 indicates those crash types or factors for unpaved roads >100ADT that are largest in absolute terms compared to primary two-lane roads. These factors may be considered the most problematic for unpaved >100 ADT rural roads.

Table 25. Highest absolute differences (>10%), secondary unpaved (> 100 AADT) rural roads compared to primary two-lane rural roads 2001-2008

CRASH TYPE/FACTOR	Secondary rural LVR Frequency (32,361 total crashes)	Secondary rural LVR percent	Primary 2-lane Frequency (35,175 total crashes)	Primary 2-lane percent	% Absolute difference in proportion (secondary – primary)
SV ROR (No Ani/Obj on Road)*	3,230	48.0%	5,613	16.0%	32.0%
Sand/mud/dirt/oil/gravel	2,066	30.7%	97	0.3%	30.4%
Rolling	4,207	62.5%	12,847	36.5%	25.9%
Speed Rel	2,932	43.5%	6,284	17.9%	25.7%
Flat	1,762	26.2%	1,066	3.0%	23.1%
Collision with fixed object: Ditch/embankment	1,702	25.3%	2,162	6.1%	19.1%
Non-collision events: Overturn/rollover	1,680	24.9%	2,362	6.7%	18.2%
Ages 15-19 involved	2,389	35.5%	6,456	18.4%	17.1%
SV Coll. with Fixed Obj.*	1,657	24.6%	3,424	9.7%	14.9%
None apparent	4,092	60.7%	16,579	47.1%	13.6%
SV Overturn/Rollover*	1,274	18.9%	1,895	5.4%	13.5%
Non-intersection: No special feature	4,169	61.9%	17,017	48.4%	13.5%
SV CollwFixObj+Over/Roll*	1,033	15.3%	1,172	3.3%	12.0%
Clear	3,586	53.2%	14,565	41.4%	11.8%
Roadside	1,072	15.9%	1,601	4.6%	11.4%
Dark - roadway not lighted	2,130	31.6%	7,390	21.0%	10.6%
Swerving/Evasive Action	1,200	17.8%	2,553	7.3%	10.6%

5. SUPPLEMENTAL ANALYSES

Younger Drivers

Time-of-day and day-of-week analysis for young driver crashes requires a more intensive system of data manipulation than was used in the previous combinations. Results indicate a higher proportion of young driver crashes occurring in the 3 p.m. to 5 p.m. time period on school days when compared to the proportion of crashes for middle-aged drivers. Also, young drivers were more likely to be involved in crashes between 9 p.m. and midnight throughout the week. Both of these results may reflect times when young drivers are proportionally more likely to be driving than their adult counterparts. Assessing the significance of these data is difficult due to the lack of exposure data for driver age (e.g., when persons of various ages drive).

Based on these findings in relation to the expected risk factors, two mitigation strategies could be considered. Both options relate to young driver education: increase the emphasis on providing young drivers with practical experience driving on unpaved roads and focus on the dangers of excessive speed. In addition, sharing of crash data involving younger drivers may be beneficial. Young drivers need more supervised practice driving on unpaved roads to learn the differences of vehicle control and handling between paved and unpaved surfaces. Additionally, young drivers who have relatively strong thrill-seeking motivations will often drive faster than road conditions or their own capabilities can support. In light of these facts, young drivers need to be instructed how to avoid and/or recover from loss of control incidents on both paved and unpaved roads.

Crashes Involving Agricultural Equipment

In rural Iowa conflicts with slow moving agricultural equipment can be a potential hazard for drivers of automobiles and pickups, especially during planting and harvesting seasons. During the study period of 2001 through 2007, a 682 crashes were recorded on the secondary road system in Iowa with 242 of these on unpaved roads. Two-lane primary roads recorded an additional 270 farm vehicle crashes with other motorized vehicles. In addition, 141 crashes involving only farm equipment occurred on secondary roads and 12 of this crash type were reported on two-lane primary roads. When compared to the total number of crashes of all types during this period on all two-lane rural roads (95,123), the percentage involving farm equipment seems quite low, but the frequency of these crashes is not insignificant.

It is interesting to compare farm equipment crashes by traffic volume on the secondary road system. For secondary roads with traffic volumes less than 100 vpd, 202 farm equipment collisions occurred with other vehicles with 196 of these on unpaved roads. But when examining higher volume secondary roads, more of these crashes are observed. For example, secondary roads with 401-1000 vpd exhibited 243 farm equipment crashes with other vehicles and for secondary roads with 101-13,500 vpd, 480 farm vehicle crashes with other vehicles were noted. Clearly traffic volume is a distinct predictor for this type of crash as with other crashes.

From a strictly frequency of occurrence standpoint, it would appear that it is much more probable that a farm equipment crash may occur on a higher volume secondary road than any other road class in this study, including primary roads. In addition to higher traffic volumes and speed, other factors may include narrow shoulders and inadequate sight distance in many locations. Drivers and farm equipment operators alike would be advised to pay additional attention to safe operating procedures and driving techniques during higher times of exposure such as those that occur during planting and harvesting seasons.

Crash Level Model

To supplement the test of proportions analysis and to account for the effect of multiple causal factors and explanatory variables, a crash-level statistical model was developed. For low-volume rural roads (400 vpd or less, excluding intersections with roads carrying any higher traffic) the following factors were found to increase the severity of crashes:

1. Paved surfaces
2. Spring/summer months (April through September)
3. Weekends
4. Fixed objects struck
5. Overturn/rollover crashes are more severe
6. Multi-vehicle broadside collisions are more severe
7. Impaired driving, including both alcohol and/or drug involvement
8. Daytime
9. Speeding
10. Younger (≤19) and older (≥65) driver involvement
11. Counties with lower total rural populations and less VMT per capita
12. Counties with positive traffic control at intersections (information was available for 73 of the 99 counties)

The following factors were found *not* to increase the severity of crashes

1. Animal collisions
2. Weather, environment, and surface-related factors

While a crash-level model is useful in identifying and verifying the effect of variables on crash severity, it is not able to identify specific locations of potential problems. For that, a road- or segment-based model is required. Development of a segment-based model is the subject of a follow-on project currently being conducted at InTrans. See Appendix 8. *limdep Model* for full details about the development of the segment-level model.

Three-Leg Intersections

Crashes were identified as being intersection-related based on the ROADTYPE information from the Iowa crash database. Selected crashes were then reviewed using data from crash narratives and diagrams, aerial imagery, and the crash database to determine any relationship between the intersections and local features for each crash.

An initial assessment of crash and road files of three-leg intersections for the study area counties suggested that these intersection types were overrepresented in the crash data. However, no consistent relationship between crashes and intersection configuration was concluded.

In the five-county study area, for the years reviewed, 85 serious crashes occurred at T or Y intersections. Of those, 44 crashes occurred at locations for which video or still images were available for review. Of those, 25 or 57% of crashes were determined to have no causal factor related to the intersection. While intersection locations were found to vary in geometry, signage, and apparent maintenance level, problems suggesting the need for systemic corrective actions at three-leg intersections could not be identified.

6. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to perform an in-depth analysis of crash history for a specific class of roadway in Iowa, rural roads with traffic volumes of 400 vehicles per day (vpd) or less, and from those data, devise and recommend mitigation to improve safety on those roadways. Note that almost the entire low-volume network is under the jurisdiction of local agencies in Iowa.

The study divided rural roads into several classes by traffic volume and surface type for the purpose of comparing safety performance among classes and with Iowa DOT-controlled two-lane primary roads. The classes of low-volume local agency roads include 0-100 vpd *paved and unpaved*, 0-100 vpd *all*,101-400 vpd *paved and unpaved,* 0-400 *paved and unpaved*, and *all* local rural roads with traffic volumes of 0-400. The DOT primary comparison roads ranged in traffic volume of 70-12,200 vpd and are all paved.

Conclusions

From the tables in Appendices 5 and 6, it can be seen (and is no surprise) that crash frequency is strongly related to traffic volume. But other factors are also in play, such as type of surface. Unpaved roads exhibit higher crash rates than paved roads. However rural paved roads in Iowa are almost always designed and constructed to higher standards than unpaved roads, exhibiting a wider roadway, shoulders and right-of-way, flatter slopes, and more forgiving clear zones. All of these factors improve safety performance.

In addition to the relationships described above, the study conducted other comparisons of performance using about 100 attributes of Iowa's extensive crash data base. Crash data from the years of 2001 through 2007 were analyzed. Many of the findings could be concluded as intuitive and others confirmed details that have been opined; however, several potentially beneficial aspects for rural road safety were determined. Comparing the frequency of several crash attributes in each local road class to those in the primary road group and testing for statistical significance using a test of proportions, we found:

1. In crash severity, almost all local road classes exhibit a higher frequency of injury crashes than primary roads.

2. Single vehicle, run-off-road crashes occur at a higher frequency on local roads, lower for multi-vehicle events, although multi-vehicle broadside crashes occurred more often on local roads.

3. Animal-related crash frequencies were lower on local roads than primary roads.

4. Speed-related crash frequency was higher for all classes of local roads but lower for weather-related crashes.

5. Younger driver involvement in local road crashes was higher for most local road classes but older driver crash frequency was lower.

6. Impaired driving crashes occurred more frequently on local roads than on primary roads.

7. As might be expected, crashes in rolling or hilly terrain were more frequent on local roads, but less on flat terrain.

8. When farm vehicles were involved, crash frequency was higher on local roads than primary roads.

9. Local road crashes occurred at a higher frequency in the summer and fall but lower in winter months. Also local roads crashes had a higher frequency on weekends but lower during the week than primary roads.

10. In general, local road crashes were more frequent during nighttime hours and higher on unpaved roads during the day in general, but all classes of local road crashes were lower from about 5 p.m. to 9 p.m. and from 4 a.m. to 7 a.m.

11. Non-collision crashes involving a roll-over or overturn showed a higher frequency for all local road classes, especially on unpaved roads.

12. On local roads, collisions with fixed objects involved culverts, ditch/embankment, trees, or poles indicated a higher frequency of occurrence on local roads, but lower than primary for guard rail collisions.

13. Major cause of crashes on local roads was higher than primary roads for failure to yield at uncontrolled intersections and driveways. Too fast for conditions and swerving or evasive action also showed a higher frequency on local roads, but left turn crashes, following too close, and crossed centerline crashes had a lower frequency on local roads.

14. In general, lower-volume roads exhibited less contribution to crashes from adverse weather or undesirable pavement surface conditions than did primary roads. However, roadway contributing circumstances such as ruts/holes/bumps showed a higher frequency as did deficient traffic control devices on local roads, although the latter category was quite low in occurrence. Shoulder conditions also contributed to local road crashes at a higher frequency than on primary roads.

15. Finally, crashes on local roads occurred at a higher frequency at bridges, railroad crossings, farm or residence driveways, as well as T or Y configuration intersections but at a lower frequency at four-way intersections.

In addition to the comparison in performance between local road classes and primary roads, a comparison between LVR classes was also performed using both crash rates and crash densities (See Appendix 7). In general, when comparing crash rates, higher values are found for unpaved local roads, regardless of traffic volume. This can be found for single-vehicle run-off-road crashes as well as multi-vehicle broadside, speed related, younger driver involvement, impaired driving, rolling or hilly terrain, farm vehicles, overturn/rollover, collisions with culverts, trees, and poles, uncontrolled intersections, swerving or evasive action, overcorrecting/oversteering, lost control, weather or road surface related, non-intersection crashes, bridges, farm/residence driveways, and almost all configurations of intersections. However, this finding was not always true when comparing very low-volume (<100 ADT) paved roads to unpaved, possibly impacted by the very low mileage on paved roads in this category.

An exception to the above findings can be seen with animal crashes. Crash rates for animal crashes are almost always higher for paved roads than unpaved.

As can be expected, crash densities varied with traffic volumes in general but not always in direct relation. For very low-volume classes, less than 100 vpd, higher crash densities were observed on paved roads versus unpaved; however, the weighted traffic volume is also higher (almost double) on those paved roads (See Appendix 7 *Comparison Data for Various Road Classes*).

In contrast, the opposite finding was exhibited for unpaved local roads with a traffic volume of 101-400 vpd. Almost all crash categories displayed a higher crash density on unpaved roads within this traffic range than with paved roads carrying similar or even higher volumes. Some of these differences were substantial ,such as younger driver involvement, speed related, and vehicle control related crashes. An exception was found with animal crashes, where paved roads displayed a higher density than unpaved.

When local roads with a traffic volume range of 0-400 vpd were examined, paved roads again mostly displayed higher densities for most crash categories than unpaved.

When comparing all seven classes of low-volume local roads as defined by this study, the 101-400 vpd traffic volume, unpaved class stands out in all three measures utilized, crash frequency, rate, and density with most crash categories displaying higher values (in some cases substantially higher). About 4,300 miles of this road class exist in Iowa divided among 99 counties, so concentration on needed safety improvements on these roads may pay beneficial results. Unpaved roads with even higher traffic volumes do not display similar results, but the very low mileage in these volume classes undoubtedly impact those results.

Finally, while little was learned from the field visits conducted in this study, the approach and findings are reported in Appendices 3 and 4 and may be of some use to future researchers conducting a more extensive field assessment.

Recommendations

The findings from this study confirmed several commonly held assumptions regarding younger driver involvement, speed related, and impaired driving on local roads, especially unpaved roads. But the findings also allow several recommendations to be made based on the results and conclusions discussed previously.

Low-volume rural roads exhibit differing crash history characteristics from two-lane rural primary roads. The findings of this study should permit local agencies to rank mitigating action in the most cost effective manner.

County engineers, law enforcement, and educators should consider safety needs on unpaved local roads with traffic volumes of 101-400 AADT on a priority basis with other road classes, while not ignoring the concerns on those other roads. If even higher volume unpaved roads exist in a jurisdiction, examination of crash history for those roads would be beneficial. By considering safety needs on these relatively limited mileage roads, agencies can achieve the most beneficial results for employing low-cost safety improvements such as signing upgrades, better road edge delineation, higher maintenance levels, and spot improvements. To facilitate identification of these roads, a tiled PDF map of >100 AADT unpaved local roads is available from the ITSDS (www.itsds.iastate.edu) at the Institute for Transportation (InTrans), as shown in Figure 7.

Based on the results of this study, law enforcement agencies should direct appropriate surveillance to local roads where the highest level of driver infraction crashes are found, such as impaired or speed-related incidents.

A similar recommendation could be made for driver educators. Younger drivers could benefit from instruction for driving on unpaved surfaces, particularly related to speed and vehicle control issues. It is also recommended that additional research be undertaken to determine and develop specific educational tools and materials for younger drivers, such as videos and demonstrations.

Due to the random nature of crashes on low-volume rural roads, a systemic approach to crash mitigation has the potential for an effective and efficient benefit. Using the results from this study, major common crash contributing factors can be determined and mitigative steps taken without relying on the development of a crash history. Examples might include improved signing at shorter radii horizontal curves, delineation of roadsides, education of younger drivers to address unique safety concerns on unpaved roads, and focused enforcement for undesirable driver behavior, such as speeding and/or impaired driving.

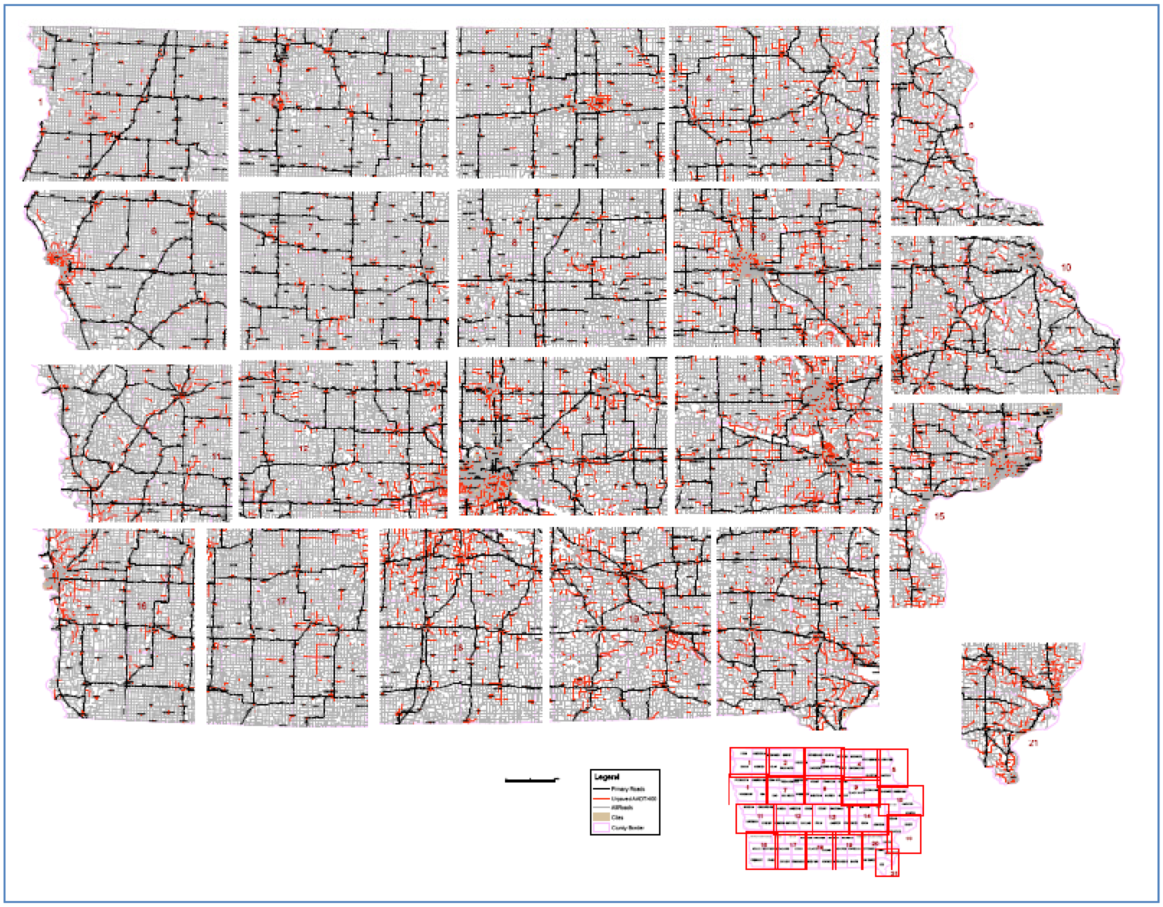


Figure 7. Unpaved roads > 100 AADT

For particularly problematic roadway sections or spot locations, road safety audits can be an effective means to identify safety needs. Local officials can arrange for audits or assessments of identified sections by contacting the Institute for Transportation at Iowa State University.

More information regarding recent crash history in specific locations or jurisdictions should be sought through resources such as the Crash Mapping Analysis Tool, CMAT, Safety Analysis, Visualization, and Exploration Resource (SAVER), the Crash Analysis web site: http://www.iowadot.gov/crashanalysis/ or Iowa Traffic Safety Data Service (ITSDS) at InTrans.

It is recommended that average operational speed on unpaved roads be studied for the potential effectiveness of reduced statutory speed limits.

Additional research should be considered to develop a reliable road segment or system-based crash prediction tool for low-volume rural roads.

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APPENDIX 1. HISTORICAL SUMMARY OF RURAL CRASH AND FATALITY RATES

By Jurisdiction, State of Iowa (per 100MVMT)

		Rural Interstate				Rural Primary				Rural Local							Rural Total			
Years	Changes in Legislation, Regulations, and Technology	Fatality Rate	Fatal Crash Rate	Fatal + Injury Crash Rate	Total Crash Rate	Fatality Rate	Fatal Crash Rate	Fatal + Injury Crash Rate	Total Crash Rate	Fatality Rate	Fatal Crash Rate	Fatal + Injury Crash Rate	Total Crash Rate	Ratio*: Local/ Primary	Ratio**: Local/ Primary	Ratio***: Local/ Primary	Fatality Rate	Fatal Crash Rate	Fatal + Injury Crash Rate	Total Crash Rate
1970-1973	~Minimum Property Damage Threshhold: $100 ~Speed Limits: Interstate, 75 MPH Day/65 MPH Night - Primary, 70 MPH Day/60 MPH Night	1.76	2.18	30	84	5.35	6.85	77	206	6.69	8	132	353	1.17	1.71	1.71	5.07	6.32	84	225
1974-1980 ****	~January 1, 1974 - Maximum Speed Limit Lowered to 55 MPH on all Road Systems ~July 1, 1975 - Property Damage Threshhold Raised to $250	1.03	1.24	24	78	3.55	4.4	54	155	5.53	6.31	125	342	1.43	2.31	2.21	3.64	4.35	69	195
1981-1986	~July 1, 1981 - Property Damage Threshhold Raised to $500 ~July 1, 1982 - OWI Administrative License Revocation ~July 1, 1984 - Child Restraint Law	0.65	0.82	20	64	2.48	2.96	44	125	3.96	4.5	100	248	1.52	2.27	1.98	2.55	2.98	56	151
1987	~January 1, 1987 - Iowa Seat Belt Law ~May 12, 1987 - Rural Interstate Speed Limit Raised to 65 MPH	0.71	0.78	18	62	2.51	2.84	41	131	3.91	4.49	106	268	1.58	2.59	2.05	2.49	2.83	54	154
1988-1993	~December 28, 1987 - Rural Non-Interstate Freeway Speed Limits Raised to 65 MPH	0.72	0.86	18	60	2.17	2.66	40	128	3.41	3.82	96	254	1.44	2.40	1.98	2.16	2.53	50	147
1994-2000	~Beginning in 1996 Speed Limits on Selected Sections of Rural Four-Lane Divided Expressways Raised to 65 MPH ~July 1, 1997 - Property Damage Threshhold Raised to $1,000	0.58	0.73	17	51	1.84	2.23	40	120	3.07	3.4	94	249	1.52	2.35	2.08	1.84	2.15	49	137
2001-2007 *****	~January 1, 2001 - New Crash Report Form ~July 1, 2002 - Driver Reporting Requirements Changed - No Driver Report Required if Officer On Scene and Reported ~July 1, 2005 - Rural Interstate Speed Limits Raised to 70 MPH ~April 15, 2007 - Database Changed from DBF to SQL	0.5	0.65	13	45	1.38	1.6	30	95	3.15	3.51	78	204	2.19	2.60	2.15	1.46	1.67	35	103

* Ratio of fatal crash rate on rural local roads to fatal crash rate on rural primary roads.
** Ratio of fatal and injury crash rate on rural local roads to fatal and injury crash rate on rural primary roads.
*** Ratio of total crash rate on rural local roads to total crash rate on rural primary roads.
**** Because of the unavailable crash data for 1976, these summary totals and ratesdo not include 1976 data.
***** For 2001, due to a significant crash report form change and resultant databaserepository changes, an unknown number of crashes are missing (approximately 2000?).

Source: Iowa DOT
Office of Traffic and Safety

APPENDIX 2. SUMMARY OF COUNTY ENGINEERS SURVEY

Questions:	Stop signs at all railroad crossings?	Traffic control at all intersections?	Have access to up-to-date crash data?	Crash Mapping Analysis Tool (CMAT) user?	Has/uses Traffic Studies Manual?	Uses the Low Cost Safety Improvement guide?	Uses the Best Practices guide?
Choices:	Yes, No	Yes, No	Yes, No	Yes, No	Have/Like, Maybe, No	Have/Like, Maybe, No	Liked the idea, Sht. Contrib., Yes (Has)
Adair	N	N	N	N	L	H	L
Adams	N	Y	Y	Y	L	H	L
Allamakee	N	Y	Y	Y	Y	Y	Y
Appanoose							
Audubon	N	Y	Y	N	H	H	L
Benton	Y	Y	Y	Y	H	H	Y
Blackhaw k							
Boone	N	N	Y	Y	H	U	S
Bremer							
Buchanan							
Buena Vista							
Butler							
Calhoun	N	N	Y	Y	Y	Y	Y
Carroll	N	N	Y	Y	H	H	H
Cass	N	N	N	N	H	H	L
Cedar	N	Y	08	Y	H	H	Y
Cerro Gordo	N	N	Y	Y	H	H	S
Cherokee	Y	N	N	N	H	M	Y
Chickasaw	N	N	Y	Y	Y	Y	Y
Clarke	Y	Y	N	N	H	H	L
Clay							
Clayton	N	Y	Y	Y	H	M	Y
Clinton	N	N	Y	Y	H	H	S
Craw ford							
Dallas	Y	N	Y	Y	Y	Y	Y
Davis	None	Y	N	N	N	N	L
Decatur	N	**Y**	Y	N	H	H	L
Delaw are							
Des Moines							
Dickinson	N	N	N	Y	H	H	Y
Dubuque	N	Y	Y	Y	H	H	Y
Emmet							
Fayette							
Floyd	N	N	Y	Y	Y	Y	Y
Franklin							
Fremont	N	Y	Y	Y	H	M	L
Greene	N	Y	Y	Y	H	H	L
Grundy	N	N	Y	Y	H	H	S
Guthrie	N	N	N	N	Y	M	Y
Hamilton	Y	Y	Y	N	L	H	L
Hancock							
Hardin	N	N	N	N	L	H	L
Harrison							
Henry	N	N	Y	Y	M	H	L
How ard							
Humboldt	N	N	Y	Y	H	H	Y
Ida							
Iow a	N	N	8	Y	H	H	H
Jackson							
Jasper	Y	Y	Y	Y	L	H	L

Questions:	DOT T&S user?	Has attended safety seminars?	Road Safety Audits (RSAs)	Roadside safety obstructions	Has a sign inventory?	Sign inventory type
Choices:	Yes, No	Yes, Some, No	Liked the idea, Requested/ing, Not interested	Yes, Holding, No	Yes, Starting, Unknown, Changed/ing, No	Paper;Custom, CartSign, ArcV, SimpSign, None
Adair	N	N	L	H	U	
Adams	Y	S	L	H	Y	P
Allamakee	N	N	L	H	Y	CS
Appanoose						
Audubon	N	N	L	H	Y	CU
Benton	N	Y	N	H	N	
Blackhawk						
Boone	N	S	L	Y	N	
Bremer						
Buchanan						
Buena Vista						
Butler						
Calhoun	Y	S	L	H	Y	P
Carroll	N	Y	L	H	Y	CS
Cass	N	N	L	H	U`	
Cedar	N	S	L	H	S	CS
Cerro Gordo	Y	N	L	H	Y	C
Cherokee	N	S	L	N	Y	P
Chickasaw	N	N	L	H	Y	SS
Clarke	N	S	L	H	U	
Clay						
Clayton	N	N	L	H	Y	AV
Clinton	N	S	L	H	CHG	P
Crawford						
Dallas	Y	Y	N	Y	Y	CS
Davis	N	N	N	N	N	N
Decatur	N	S	L	H	S	N
Delaware						
Des Moines						
Dickinson	Y	N	L	H	Y	C
Dubuque	N	N	L	H	Y	CS
Emmet						
Fayette						
Floyd	N	N	L	H	Y	SS
Franklin						
Fremont	N	N	L	H	Y	C
Greene	N	S	L	H	Y	C
Grundy	N	N	L	H	U	
Guthrie	N	N	N	H	Y	CS
Hamilton	Y	S	L	H	Y	C
Hancock						
Hardin	N	N	L	H	U	
Harrison						
Henry	N	N	N	H	Y	SS
Howard						
Humboldt	N	N	N	H	S	SS
Ida						
Iowa	N	S	L	H	Y	P
Jackson						
Jasper	Y	S	L	H	Y	C

Questions:	Conducts night retroreflectivity surveys?	How frequently?	Has own retroreflectometer?	Initial perceptions of county engineers on traffic safety concerns
Choices:	Yes, Usually, No	Annually, Biennially, Sometimes	Yes, No	
Adair	U		N	
Adams	Y	S	N	
Allamakee	N		N	Curves ;Speed
Appanoose				
Audubon	N		N	
Benton	N		N	inattention, young drivers,
Blackhawk				
Boone	Y	B	N	Alcohol,inexperience
Bremer				
Buchanan				
Buena Vista				
Butler				
Calhoun	N		N	Alcohol, Inexperience, older drivers
Carroll	U	S	N	Animals, Alcohol & inattention
Cass	N		N	
Cedar	N		N	Speeding
Cerro Gordo	Y	A	N	Inattention of drivers
Cherokee	Y	A	N	Speed, overwidth vehicles, weeds
Chickasaw	Y	B	N	Sight distances
Clarke	N		N	
Clay				
Clayton	N		N	Speed; Animals
Clinton	N		Y	Animal;driver related-distraction
Crawford				
Dallas	Y	A	Y	Steering committee member
Davis	N		N	Cell phones,drinking,inexperience,speed
Decatur	N		N	
Delaware				
Des Moines				
Dickinson	Y	A	N	Inattention
Dubuque	N		N	Curves
Emmet				
Fayette				
Floyd	Y	B	N	Sight distances
Franklin				
Fremont	Y	S	N	
Greene	Y	A	N	Speed , inattention
Grundy	N		N	
Guthrie	N	S	N	Not paying attention, alcohol
Hamilton	Y	S	N	
Hancock				
Hardin	N		N	
Harrison				
Henry	Y	A	N	
Howard				
Humboldt	N		N	Alcohol, Animals, weather
Ida				
Iowa	N		N	Blind hills & intersections
Jackson				
Jasper	N		Y	

Questions:	Stop signs at all railroad crossings?	Traffic control at all intersections?	Have access to up-to-date crash data?	Crash Mapping Analysis Tool (CMAT) user?	Has/uses Traffic Studies Manual?	Uses the Low Cost Safety Improvement guide?	Uses the Best Practices guide?
Choices:	**Yes, No**	**Yes, No**	**Yes, No**	**Yes, No**	**Have/Like, Maybe, No**	**Have/Like, Maybe, No**	**Liked the idea, Sht. Contrib., Yes (Has)**
Jefferson	Y	N	N	N	N	N	L
Johnson	N	N	8	Y	H	H	Y
Jones	N	Y	Y	Y	Y	Y	Y
Keokuk	N	Y	Y	N	H	H	L
Kossuth							
Lee	N	N	Y	Y	H	H	S
Linn	N	N	Y	Y	Y	Y	Y
Louisa	N	N	Y	Y	N	Y	L
Lucas	N	Y	N	N	M	H	L
Lyon	N	N	Y	Y	H	H	Y
Madison	N	Y	Y	Y	H	H	L
Mahaska	N	Y	Y	Y	M	M	Y
Marion	Y	Y	Y	Y	H	H	S
Marshall	N	N	Y	Y	H	H	S
Mills	N	Y	N	N	L	H	L
Mitchell							
Monona							
Monroe	N	Y	Y	Y	H	H	S
Montgomery	N	Y	N	N	H	H	L
Muscatine	N	N	Y	Y	H	H	L
O'Brien	N	N	Y	Y	H	H	L
Osceola	N	N	Y	Y	H	H	L
Page							
Palo Alto							
Plymouth	N	N	Y	Y	H	H	L
Pocahontas							
Polk	Y	Y	Y	Y	H	H	L
Pottaw attamie	N	Y	Y	Y	L	H	L
Pow eshiek	Y	Y	Y	Y	H	H	L
Ringgold	None	Y	Y	N	H	H	L
Sac	N	Y	Y	Y	H	H	Y
Scott	Y	N	Y	Y	H	H	L
Shelby	N	Y	N	N	H	H	L
Sioux	N	N	Y	Y	H	H	S
Story	N	N	Y	Y	H	H	S
Tama	N	Y	Y	Y	H	H	Y
Taylor	N	Y	N	N	M	H	L
Union	N	N	N	N	H	H	L
Van Buren	N	Y	Y	Y	H	H	S
Wapello	N	Y	Y	Y	H	M	Y
Warren	N	Y	Y	Y	H	H	L
Washington	Y	Y	Y	Y	H	H	L
Wayne	N	Y	Y	Y	M	H	L
Webster	N	N	Y	Y	L	H	L
Winnebago							
Winneshiek	N	N	Y	Y	H	H	Y
Woodbury	N	Y	Y	Y	H	H	Y
Worth							
Wright	N	Y	N	N	H	H	L

Questions:	Iowa Traffic Safety Data Service user?	DOT T&S user?	Has attended safety seminars?	Road Safety Audits (RSAs)	Roadside safety obstructions	Has a sign inventory?	Sign inventory type
Choices:	Yes, No	Yes, No	Yes, Some, No	Liked the idea, Requested/ing, Not interested	Yes, Holding, No	Yes, Starting, Unknown, Changed/ing, No	Paper;Custom, CartSign, ArcV, SimpSign, None
Jefferson	N	N	N	N	N	Y	C
Johnson	N	N	S	L	Y	S	SS
Jones	Y	Y	Y	N	H	Y	CS
Keokuk	N	N	N	N	H	N	
Kossuth							
Lee	Y	Y	Y	L	H	U	
Linn	Y	Y	Y	N		U	C
Louisa	Y	Y	Y	R	H	Y	CS
Lucas	N	Y	S	L	H	Y	C
Lyon	N	N	S	L	H	Y	SS
Madison	T	N	S	L	H	U	
Mahaska	N	N	N		H	Y	C
Marion	N	N	S	L	Y	Y	CU
Marshall	Y	Y	S	R	Y	U	
Mills	N	Y	N	L	H	Y	CU
Mitchell							
Monona							
Monroe	Y	Y	S	L	H	U	
Montgomery	N	N	S	L	H	Y	C
Muscatine	N	N	N	L	H	Y	CU
O'Brien	N	N	S	L	H	Y	SS
Osceola	N	N	S	L	H	Y	P
Page							
Palo Alto							
Plymouth	N	N	S	L	H	Y	P
Pocahontas							
Polk	Y	Y	S	L	H		
Pottaw attamie	N	Y	S	L	H	U	
Pow eshiek	N	N	Y	L	H	Y	P
Ringgold	T	N	N	L	H	S	SS
Sac	N	N	S	L	H	Y	P
Scott	U	Y	N	Y	H	Y	CU
Shelby	N	N	N	L	H	Y	P
Sioux	N	N	N	L	H	Y	C
Story	Y	Y	S	L	Y	Y	SS
Tama	N	N	Y	L	Y	Y	CS
Taylor	N	N	S	L	H	U	
Union	N	N	N	L	H	Y	SS
Van Buren	N	N	N	L	H	Y	P
Wapello	N	N	S	L	H	Y	CS
Warren	N	Y	S	L	H	Y	CU
Washington	Y	Y	Y	R	H	Y	SS
Wayne	N	N	N	L	H	N	
Webster	Y	N	S	L	H	Y	C
Winnebago							
Winneshiek	N	N	S	L	H	Y	SS
Woodbury	N	Y	N	L	H	N	
Worth							
Wright	Y	Y	S	L	H	Y	P

Questions:	Conducts night retroreflectivity surveys?	How frequently?	Has own retroreflectometer?	Initial perceptions of county engineers on traffic safety concerns
Choices:	Yes, Usually, No	Annually, Biennially, Sometimes	Yes, No	
Jefferson	N	A	N	Inexperience, speed, inattention
Johnson	Y	A	Y	Sight distance; access location
Jones	Y	A	N	inexperienced drivers, large farm equip, alcohol
Keokuk	N		N	sight distance;foggy;4 way Int; road conditions
Kossuth				
Lee	Y	B	N	Visibility, animals, cell phones
Linn	N		N	driver inexperience, inattention, alcohol
Louisa	N	S	N	youth, inattention
Lucas	N		N	
Lyon	N		N	
Madison	N		N	
Mahaska	Y	S	N	
Marion	N		B	
Marshall	Y	S	N	Inexperience, alcohol, cell phones, visibility
Mills	N		Y	
Mitchell				
Monona				
Monroe	Y	B	N	
Montgomery	N		Y	
Muscatine	N		N	speed- "lost urbanites" per David @ Washington Co
O'Brien	Y	A	N	Distration Speed younger
Osceola	Y	A	N	Distraction - ROR
Page				
Palo Alto				
Plymouth	Y	A	N	inexperienced drivers, speed animals
Pocahontas				
Polk	Y	A	N	
Pottawattamie	Y	A	N	
Poweshiek	Y	A	N	Speed; falling asleep;poor seat belts usage
Ringgold	N		N	
Sac	N		N	Farm related (getting around);youger drivers don't understand yield to the right
Scott	N	A	Y	Unfamiliarity w / road;distractions
Shelby	N		N	
Sioux	N		N	
Story	Y	A	N	distractions, alcohol
Tama	Y	A	N	late night crashes - falling asleep;drunkenness
Taylor	N		N	
Union	N		N	
Van Buren	N		N	
Wapello	Y	A	N	speed, alcohol, animals
Warren	N		N	
Washington	N		N	alcohol,distractions,inexperience
Wayne	N		N	
Webster	Y	A	N	
Winnebago				
Winneshiek	N		N	Terrain; Older drivers; College and tourism - Unfamiliar
Woodbury	N		N	Driver inexperience; Inattention to signs;Snow and Ice
Worth				
Wright	Y	A	N	

APPENDIX 3. DETAILED STUDY OF CRASH RECORDS AND FIELD CONDITIONS

Selection of Candidate Counties for Detailed Study

Five candidate counties were selected based on the assessment of a combination of risk measures, including rural low-volume (<400 VPD) road crash frequency (number of crashes per unit of time), density (crashes per length of roadway segment), and rate (crashes per vehicle mile traveled). Rural population trends, some other demographic features of the counties, terrain, land use, and local knowledge and experience were also taken into consideration.

Selected Counties

Five candidate counties were selected for further in-depth analysis based on the aforementioned factors. The five counties and the reasons they were selected are as follows:

- Story County, for a relatively high fatal and major injury crash rate and especially for the county's proximity to the research center, which allowed preliminary field reviews and videotaping to be more efficiently conducted. The preliminary site visits were performed early to develop a final methodology for field data gathering before visits to the sites in the more distant counties.
- Dallas County, for the highest growth rate in rural neighborhoods, population, and corresponding traffic volumes. Potential novice drivers in the area were considered as a group representing related crash factors.
- Winneshiek County, for a relatively higher number of crashes.
- Ringgold County, for its relatively lower population density and traffic volumes. This county reflects the crash characteristics specific to a county where less maintenance is expected to take place due to a lower population and accordingly limited funds.
- Henry County, for its relatively high crash rate and density.

Selection of Candidate Sites and Routes for Detailed Study

Candidate sites within the five counties identified in the previous step were selected for more detailed analysis. Several criteria were employed to identify preliminary sites, including crash distribution (frequency, density, and rate), crash type(s), and roadway characteristics.

Large-format maps for each of the five selected counties were used in the site selection process. The maps displayed all low-volume rural secondary road crashes that occurred between 2001 and 2007, inclusive. Crashes were represented by severity and "stacked" where they were so close as to obscure one another. Low-volume sections of interest (≤400 AADT) were mapped thematically. Railroads and streams were added to the maps after a pilot study of Story County indicated that they may contribute to the location of crashes. Similarly, urban areas and towns were also indicated and labeled. A sample working map of Winneshiek County used for the preliminary identification of candidate sites can be seen in Figure 8.

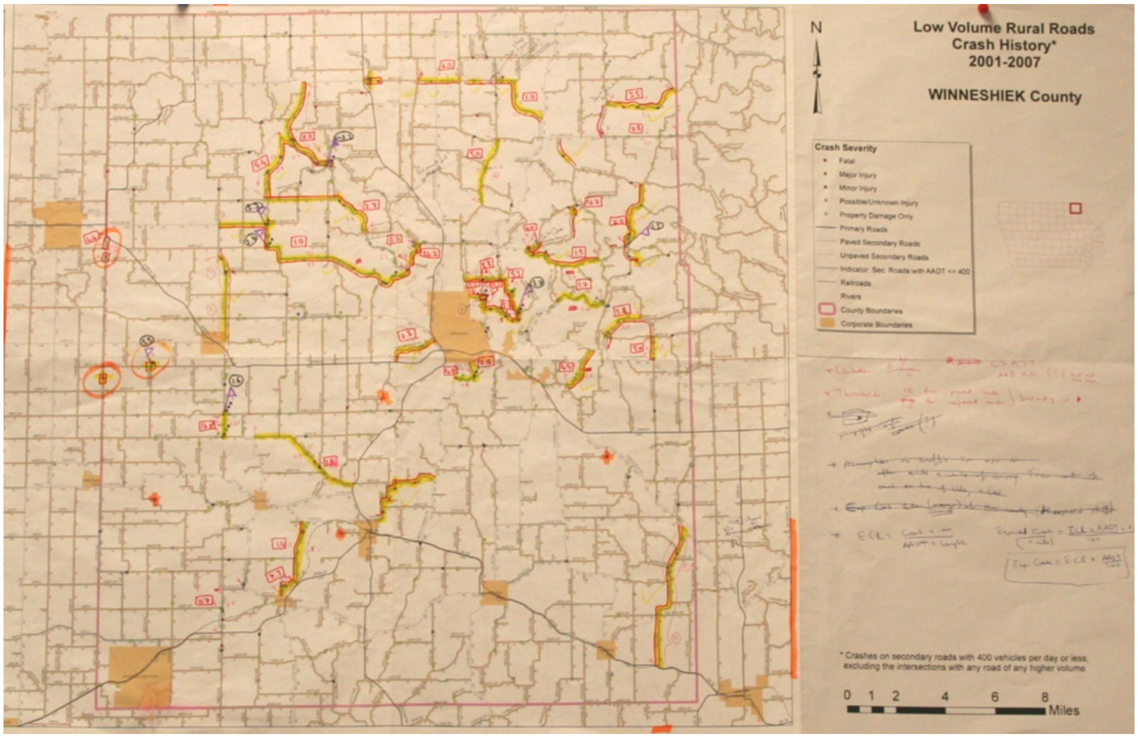


Figure 8. Site visit map for Winneshiek County

The following steps describe the crash analysis-based selection process for refinement of candidate sites.

Road Segment Selection

Because county roads in Iowa have relatively few crashes per mile, the methods identified in previous studies required some modifications to be used in this study. These modifications included considering longer road segments and measuring the safety performance of road segments and intersections separately. As the rural local road network in Iowa has chiefly been designed on grids of one mile in the north-south and east-west directions, the use of a GIS process to systematically select high-crash locations was somewhat complicated. Because crashes on low-volume rural roads in Iowa are generally random, analysis segment of more than one mile were created.

When considering crashes on particular road segments, intersection crashes were excluded. The following steps describe the selection process for high-crash segments:

1. Maps were thoroughly scanned for segments where a relatively high number of crashes had accumulated.

2. Special consideration was given to each of these possible situations:
    a. Relatively high number of crashes per mile
    b. Relatively more severe crashes
    c. Fatal (and major injury crashes in some sites) crashes.
3. Locations were noted where a segment could be extended to adjacent roads with similar AADT (+/- 10%) (See Figure 9).

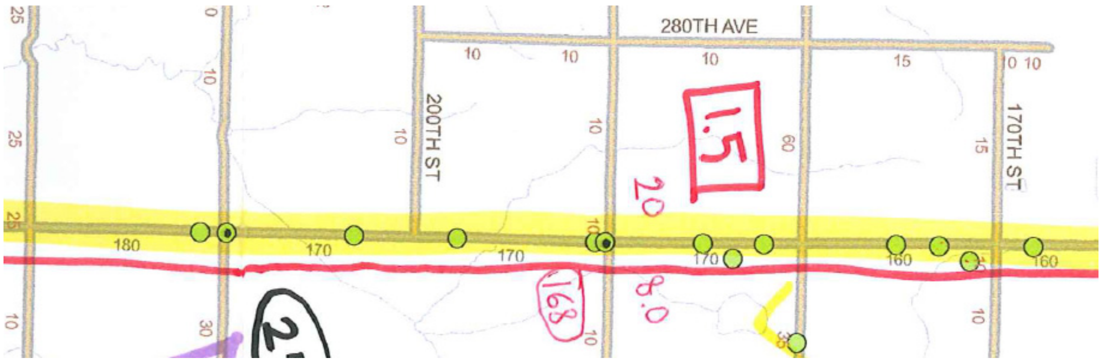


Figure 9. Sample "AADT-consistent" corridor

4. Crashes within sections were counted using the equivalent property damage only (EPDO) method of accounting. Next, equivalent crash (EC) numbers (for the seven-year analysis period) were computed. Intersection crashes were not included in the segment analysis.
5. The length of the identified corridor was measured.
6. If the section was extended to cover adjacent segments with similar AADT, the approximate weighted average of the AADT values was computed.
7. The above steps were repeated for all sections of interest.
8. A crash rate was computed for each of the sections:

$$Crash\ Rate\ (Segment) = \frac{Crashes \times 10^8}{AADT \times 365 \times Years \times Length}$$

9. A number of segments were selected for detailed analysis based on crash rates. Consideration was given to the period of time allocated to visit each of the counties (See Figure 10).

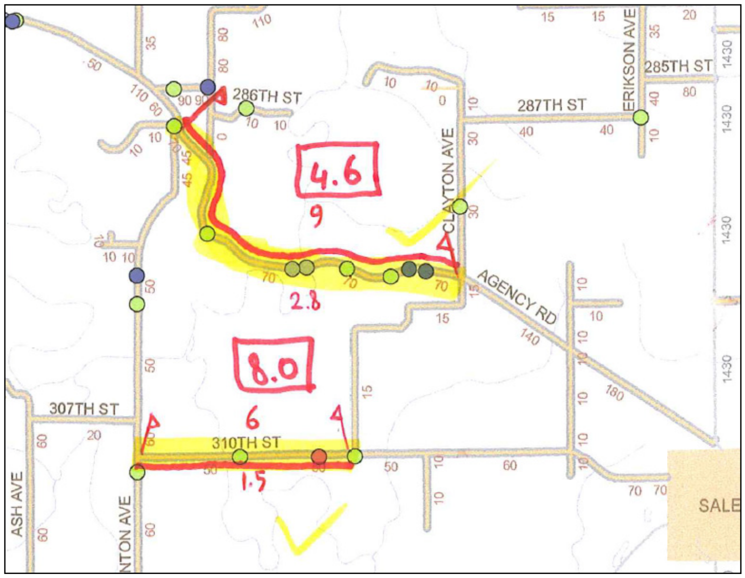


Figure 10. Map marking style for segments

Intersection Selection

The following steps describe the selection process for high-crash intersections:

1. Maps were thoroughly scanned for intersections where multiple crashes had been recorded.
2. The number of crashes located at intersections was adjusted to Equivalent Property Only Damage crashes. This adjusted number of crashes is referred to as "Equivalent Crashes" or "EC."
3. The above steps were repeated for all intersections of interest.
4. An empirical crash rate was computed for each of the intersections.

$$Empirical\ Crash\ Rate\ (Intersection)(per\ 100\ entering\ EC) = \frac{EC \times 100}{\left(\frac{AADT}{2}\right) * 365 * \#\ Years}$$

5. A number of intersections (and sections) beginning from the highest ECR were selected, with consideration given to the period of time allocated to visit each of the counties. (See Figure 11).

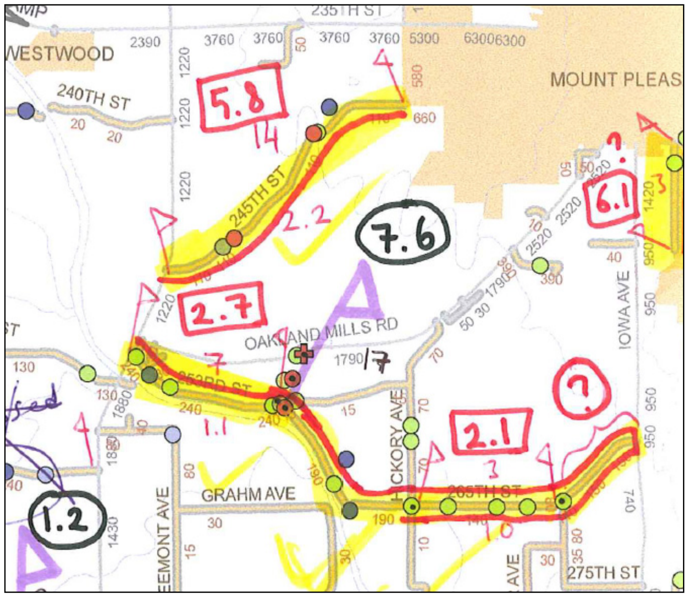


Figure 11. Map marking style for intersections

Field and Detailed Evaluation

Sites and routes identified in previous steps were visited for videotaping and/or photographing. Supplemental information about the environment of crash locations that may not be available in the crash and road databases was obtained. During the visits, characteristics of some sites with potential risk factors were documented for consideration in the succeeding analyses. These video records and photographs were reviewed in an attempt to better understand potential causes of particular crashes. The supplemental data gathered in this task were also intended to be integrated with the existing data for a descriptive statistical analysis of selected crash sites. During the process, it was observed that deriving crash attributes using this method would consume more time and effort than estimated and give potentially biased results due to subjectivity. Therefore, the research team decided to use video clips and photos for evaluating only the top crash factors determined in the descriptive statistical analysis.

An in-depth analysis of the characteristics of crashes at the candidate sites was conducted, and inferences were documented. A primary objective of this task was to identify common site characteristics that may have impacted safety performance. Special consideration was given to the five to 10 highest risk factors determined in the test of proportions analysis. Video records and photographs obtained in the site visits were tied with statewide aerial imagery available through geographic information systems (GIS) tools. Crash-, driver/vehicle-, and injury-level attributes of each crash were also inspected. Simultaneous review of individual crash reports, focusing on narratives and diagrams, was a key component of this analysis. A comprehensive listing of the preliminary characteristics of interest can be seen in Appendix 4. *Preliminary Characteristics of Interest for Site Visits (Desired Data for Crash Site Review)*.

Field Visits and Imaging

Visiting the actual site of a crash helps supplement and confirm the information in the database. For this reason, visits to selected crash sites were conducted to videotape and photograph individual crash locations for subsequent evaluation. Travel routes between sites were determined using the maps prepared previously.

For a comprehensive field evaluation, information may be integrated from as many sources as available. These sources can include detailed crash and roadway databases, aerial imagery (to help locate crash sites), and narratives and diagrams from the original crash reports. For a thorough analysis of candidate crash sites, two procedures were considered:

1. Each crash site of interest is visited, and each site and its surroundings are inspected to identify general safety deficiencies. The aforementioned sources of information associated with each particular crash are reviewed to understand the underlying factors. This procedure would require having all these resources readily available in the research vehicle, and stopping at each site would be time consuming. Furthermore, it would be difficult to summarize the common characteristics found at the sites of particular crash types and then draw conclusions.

2. Crash sites of interest are visited rapidly by videotaping and/or photographing, as appropriate and necessary. These visual media are subsequently processed and organized into easily accessible and reviewable sections. Because all types of information are gathered on a single computer and all the available sources can be accessed instantly and simultaneously, this type of evaluation is much easier to perform. For instance, the aerial imagery; the crash database with crash-, driver/vehicle-, and injury-level information; the videos; the photos; the narratives; and the crash diagrams can be tied together to get a full understanding of the crash's background.

The second procedure was chosen. Therefore, the evaluation of crash sites took place in the office rather than in the field. Resources (including aerial imagery, the crash database with crash, driver/vehicle, and injury-level information, videos, photos, narratives; and crash diagrams) were reviewed simultaneously using dual computer monitors. Figure 12 illustrates the working environment during the crash site evaluation process.

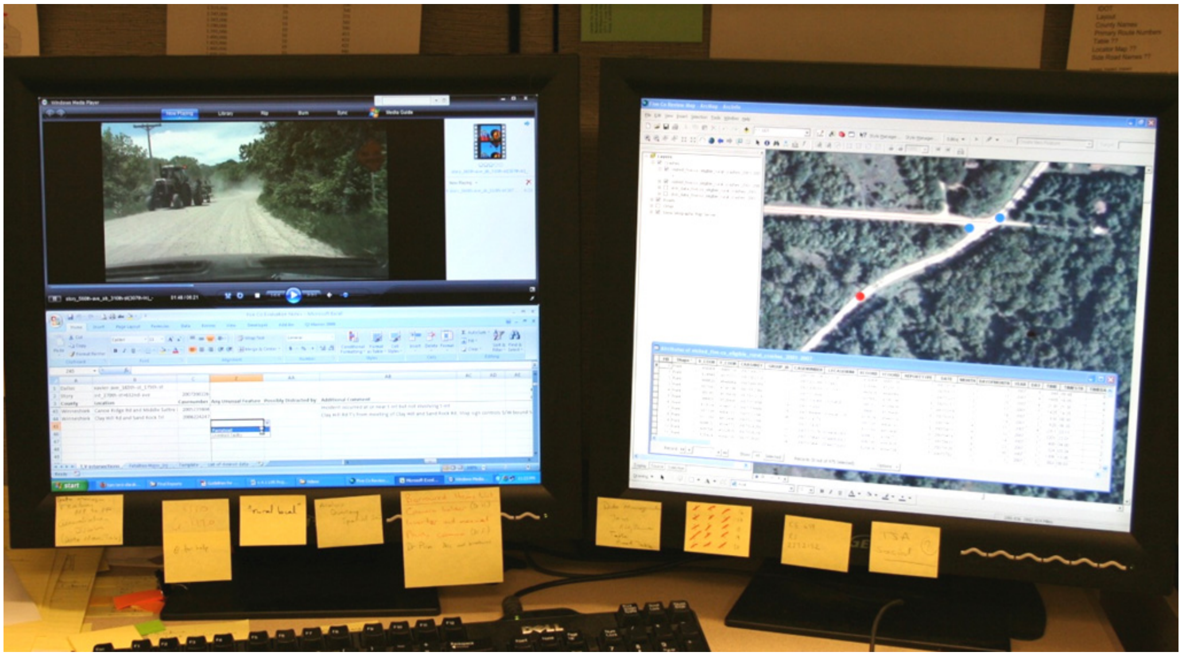


Figure 12. Screen snapshot of the resources used in the evaluation procedure

A hard disc camcorder and a still-photo camera were used to capture the video and images of the crash sites. The camcorder was mounted inside the windshield of the vehicle used for site visits and was tested for image quality, zoom level, and voice capturing level. The videotaping method was tested and improved in Story County due to that site's proximity to the research center.

For most sites, roadway sections were videotaped while intersections were photographed from different directions. However, both techniques were applied in some cases. Video records covered only one direction of the road section, but signs for the opposite direction were narrated by voice to the camcorder.

Video and Photo Processing

The videos and photos were transferred to a computer and stored after each visit. Video editing software was used to trim the records into reviewable and easily accessible clips. A consistent format was used to label the video clip files. The label included, in order, the name of the county, the name of the road videotaped, the direction of travel, and the intersecting roads at the start and end points. For example, a road in Story County was labeled "story_100th-st_eb_590th-ave_600th-ave." Most video clips covered more than one crash location.

Photos were labeled using the names of the intersecting roads or special features in the vicinity. For example, "story_int_19th-st+260th-st(south-of-Nevada)_eb" includes, in order, the name of the county, the type of site (intersection), names of intersecting roads, special features (in brackets), and the direction of the view.

Video Evaluation

Video evaluation of crash locations can be useful to assess location-based potential contributing factors and to validate or supplement crash reports and the crash database. Site factors that may be examined in videos may include sight distance, visibility of signage, and visual clutter.

In this study, video analysis was used to assess three-leg intersections that have experienced crash problems. Video of the selected intersections was evaluated, paying special attention to sight distance, clutter (distractions) or obstructions, presence and location of appropriate signage, and grade changes.

APPENDIX 4. PRELIMINARY CHARACTERISTICS OF INTEREST FOR SITE VISITS (DESIRED DATA FOR CRASH SITE REVIEW)

1. Location: intersection-distance; Section, Township, Range; coordinates (GPS), etc.
2. Any restricted speed limits, (< 55 mph)
3. Traffic control in place and general condition; signs, chevrons, delineators, etc.
4. Surface type and general condition
5. If paved
    a. Lane width
    b. Shoulder type & width
    c. Pavement marking condition, centerline and edge lines

    If unpaved

    d. Top width
    e. Washboarding
    f. Loose rock
    g. Windrows
6. Approx. lane cross slope
7. General terrain
    a. Flat
    b. Gently rolling
    c. Severely rolling(hilly)
8. Curvature
    a. Vertical
    b. Horizontal (measurement or approximation of degree?)
9. Roadside conditions
    a. Approximate width (66 feet, other)
    b. Ditches; V, flat bottom, etc.
    c. Fore and back slopes, approx. % and height of fill or cut
    d. Obstructions in ROW: trees, utility poles, etc. or near ROW, (buildings, etc.)
10. Structures, if any
    a. Large culverts (+6 feet opening)
    b. Bridges
        i. Clearance width
        ii. Handrail type and condition
        iii. Guardrail type and condition
11. Pictures, electronic
12. Any unusual features in area
    a. farmsteads
    b. livestock facilities
    c. etc
14. Sight distance restrictions, especially for intersections

APPENDIX 5. SAMPLE TABLE SHOWING THE TEST OF PROPORTIONS RESULTS (0-100 UNPAVED SECONDARY VS. TWO-LANE PRIMARY)

VARIOUS CHARACTERISTICS OF CRASHES ON UNDIVIDED RURAL ROADS BY ROAD SYSTEM, VOLUME RANGE, AND SURFACE TYPE

Statistical Comparison of Proportions

State of Iowa (2001-2007)

Top 20 highlighted in each column

			Comparison Group	
Road System:	**Secondary**		**Primary-ALL**	
AADT Range:	**0-100**		**70-12200**	
Surface Type:	**Unpaved**		**All Paved**	
Total Crashes	16,040	-	34,040	-
Total Daily VMT	2,447,000	-	13,460,000	-
Total Centerline-Miles	66,900	-	5,963	-
Weighted Average of ADT	37	-	2,300	-
Crash Rate (per 100M VMT)	257	-	99	-
Crash Density (crash per mile)	0.24	-	5.71	-

Notes:

- Level of Confidence: 95 %
- p-values smaller than 0.000001are displayed as "0.000001".
- Ratio of proportions, ranking of ratios, difference between proportions, and ranking of differences are displayed only where the the p-value <= 0.05 and the proportion in the lower-volume road class is higher.
- The total number of crashes with an asterisk (*) under 'Crash Type' category and 'Manner of Crash/Collision' category are equal. The same rule also applies to those with two asterisks (**).

CRASH SEVERITY	**Frequency**	**%**	**Frequency**	**%**	**P-Value**	**Ratio**	**Rank: Ratio**	**Diff.**	**Rank: Diff.**
Fatal	235	1.5%	563	1.7%					
Major Injury	933	5.8%	1,410	4.1%	0.000001	1.40	68	1.7%	44
Minor Injury	2,750	17.1%	3,433	10.1%	0.000001	1.70	50	7.1%	20
Possible/Unknown	2,929	18.3%	5,142	15.1%	0.000001	1.21	85	3.2%	31
Property Damage Only	9,193	57.3%	23,492	69.0%					
CRASH TYPE	**Frequency**	**%**	**Frequency**	**%**					
MV (No Ani/Obj on Road)**	2,940	18.3%	9,539	28.0%					
SV ROR (No Ani/Obj on Road)*	9,121	56.9%	7,366	21.6%	0.000001	2.63	29	35.2%	1
SV Other (No Ani/Obj on Road)*	507	3.2%	1,460	4.3%					
SV ROR (Ani/Obj on Road)*	984	6.1%	491	1.4%	0.000001	4.25	12	4.7%	24
SV Other (Ani/Obj on Road)*	35	0.2%	109	0.3%					
Hit Animal	2,453	15.3%	15,075	44.3%					
MANNER OF CRASH/COLLISION	**Frequency**	**%**	**Frequency**	**%**					
MV Head-on**	378	2.4%	855	2.5%					
MV Read-end**	524	3.3%	3,211	9.4%					
MV Oncoming left turn**	206	1.3%	692	2.0%					
MV Broadside**	1,007	6.3%	1,896	5.6%	0.001555	1.13	94	0.7%	68
MV Sideswipe-Same Dir.**	217	1.4%	1,377	4.0%					
MV Sideswipe-Oppos. Dir.**	391	2.4%	1,035	3.0%					
MV Other**	217	1.4%	473	1.4%					
SV Coll. with Fixed Obj.*	4,050	25.2%	3,841	11.3%	0.000001	2.24	36	14.0%	10
SV Overturn/Rollover*	3,332	20.8%	2,279	6.7%	0.000001	3.10	19	14.1%	9
SV CollwFixObj+Over/Roll*	2,574	16.0%	1,519	4.5%	0.000001	3.60	13	11.6%	14
SV Other*	691	4.3%	1,787	5.2%					
Hit Animal	2,453	15.3%	15,075	44.3%					
SPEED/WEATHER-SURFACE RELATION	**Frequency**	**%**	**Frequency**	**%**					
Speed Rel	6,894	43.0%	4,991	14.7%	0.000001	2.93	23	28.3%	3
Weather/Surface Rel	1,143	7.1%	3,053	9.0%					
Speed&Weather/Surface Rel	1,619	10.1%	3,739	11.0%					
Other/Unknown	6,384	39.8%	22,257	65.4%					
LIGHT CONDITIONS	**Frequency**	**%**	**Frequency**	**%**					
Day	7,829	48.8%	12,891	37.9%	0.000001	1.29	75	10.9%	15
Dark, dusk or dawn	6,559	40.9%	12,552	36.9%	0.000001	1.11	97	4.0%	27
Other/Unknown	1,652	10.3%	8,597	25.3%					

YOUNGER AND OLDER DRIVER INVOLVEMENT	Frequency	%	Frequency	%					
Age 14 or below involved	205	1.3%	102	0.3%	0.000001	4.27	11	1.0%	60
Ages 15-19 involved	5,499	34.3%	5,234	15.4%	0.000001	2.23	37	18.9%	5
Age 65 or above involved	865	5.4%	4,374	12.8%					
Other/Unknown	9,471	59.0%	24,330	71.5%					
DRUG/ALCOHOL INVOLVEMENT	**Frequency**	**%**	**Frequency**	**%**					
Impaired	1,329	8.3%	1,444	4.2%	0.000001	1.95	47	4.0%	26
Unimpaired	14,711	91.7%	32,596	95.8%					
TERRAIN	**Frequency**	**%**	**Frequency**	**%**					
Flat	4,407	27.5%	13,266	39.0%					
Rolling	10,438	65.1%	19,117	56.2%	0.000001	1.16	89	8.9%	18
Hilly	1,173	7.3%	1,657	4.9%	0.000001	1.50	62	2.4%	40
Other/Unknown	22	0.1%							
FARM VEHICLE INVOLVEMENT	**Frequency**	**%**	**Frequency**	**%**					
Farm vehicle and other	196	1.2%	270	0.8%	0.000003	1.54	56	0.4%	81
Farm vehicle only	83	0.5%	12	0.0%	0.000001	14.68	3	0.5%	77
No farm vehicle	15,761	98.3%	33,758	99.2%					
MISCELLANEOUS									
Month									
January	1,231	7.7%	2,992	8.8%					
February	930	5.8%	2,508	7.4%					
March	877	5.5%	2,388	7.0%					
April	981	6.1%	2,072	6.1%					
May	1,202	7.5%	2,324	6.8%	0.006523	1.10	98	0.7%	70
June	1,398	8.7%	2,572	7.6%	0.000007	1.15	91	1.2%	53
July	1,517	9.5%	2,313	6.8%	0.000001	1.39	69	2.7%	37
August	1,410	8.8%	1,970	5.8%	0.000001	1.52	59	3.0%	33
September	1,477	9.2%	2,218	6.5%	0.000001	1.41	66	2.7%	36
October	1,638	10.2%	3,308	9.7%					
November	1,749	10.9%	5,174	15.2%					
December	1,630	10.2%	4,201	12.3%					
Day									
Sunday	2,568	16.0%	4,468	13.1%	0.000001	1.22	83	2.9%	34
Monday	2,106	13.1%	4,576	13.4%					
Tuesday	1,918	12.0%	4,506	13.2%					
Wednesday	2,007	12.5%	4,518	13.3%					
Thursday	2,037	12.7%	4,714	13.8%					
Friday	2,437	15.2%	5,836	17.1%					
Saturday	2,967	18.5%	5,422	15.9%	0.000001	1.16	88	2.6%	38

Hour									
Midnight	626	3.9%	834	2.5%	0.000001	1.59	54	1.5%	49
1	515	3.2%	660	1.9%	0.000001	1.66	51	1.3%	50
2	441	2.7%	567	1.7%	0.000001	1.65	52	1.1%	57
3	296	1.8%	418	1.2%	0.000001	1.50	61	0.6%	73
4	227	1.4%	549	1.6%					
5	337	2.1%	1,283	3.8%					
6	480	3.0%	1,901	5.6%					
7	661	4.1%	1,680	4.9%					
8	614	3.8%	1,187	3.5%					
9	435	2.7%	992	2.9%					
10	527	3.3%	994	2.9%	0.026178	1.13	95	0.4%	87
11	541	3.4%	1,023	3.0%	0.027364	1.12	96	0.4%	86
12	585	3.6%	1,087	3.2%	0.008344	1.14	93	0.5%	79
13	686	4.3%	1,182	3.5%	0.000009	1.23	81	0.8%	66
14	724	4.5%	1,345	4.0%	0.003166	1.14	92	0.6%	75
15	941	5.9%	1,692	5.0%	0.000028	1.18	87	0.9%	64
16	977	6.1%	1,656	4.9%	0.000001	1.25	78	1.2%	51
17	1,021	6.4%	2,994	8.8%					
18	1,091	6.8%	2,856	8.4%					
19	880	5.5%	2,222	6.5%					
20	845	5.3%	1,949	5.7%					
21	855	5.3%	2,249	6.6%					
22	802	5.0%	1,397	4.1%	0.000005	1.22	84	0.9%	63
23	739	4.6%	1,047	3.1%	0.000001	1.50	64	1.5%	48
Unknown	194	1.2%	276	0.8%					
Location of First Harmful Event									
On roadway	9,400	58.6%	21,205	62.3%					
Shoulder	1,291	8.0%	1,985	5.8%	0.000001	1.38	71	2.2%	41
Median	20	0.1%	36	0.1%					
Roadside	2,793	17.4%	1,953	5.7%	0.000001	3.03	20	11.7%	13
Gore	76	0.5%	45	0.1%	0.000001	3.58	14	0.3%	90
Outside trafficway	907	5.7%	651	1.9%	0.000001	2.96	22	3.7%	29
Unknown	1,553	9.7%	8,165	24.0%					
First Harmful Event									
Non-collision events: Overturn/rollover	4,209	26.2%	2,860	8.4%	0.000001	3.12	18	17.8%	6
Non-collision events: Jackknife	30	0.2%	151	0.4%					
Non-collision events: Other non-collision (explain in narrative)	458	2.9%	648	1.9%	0.000001	1.50	63	1.0%	62
Collision with: Non-motorist (see non-motorist type)	23	0.1%	67	0.2%					
Collision with: Vehicle in traffic	2,320	14.5%	8,105	23.8%					
Collision with: Vehicle in/from other roadway	426	2.7%	845	2.5%					
Collision with: Parked motor vehicle	145	0.9%	127	0.4%	0.000001	2.42	34	0.5%	76
Collision with: Railway vehicle/train	65	0.4%	16	0.0%	0.000001	8.62	5	0.4%	88
Collision with: Animal	2,403	15.0%	14,950	43.9%					
Collision with: Other non-fixed object (explain in narrative)	164	1.0%	351	1.0%					
Collision with fixed object: Bridge/bridge rail/overpass	259	1.6%	260	0.8%	0.000001	2.11	39	0.9%	65
Collision with fixed object: Underpass/structure support	4	0.0%	4	0.0%					
Collision with fixed object: Culvert	170	1.1%	143	0.4%	0.000001	2.52	33	0.6%	72
Collision with fixed object: Ditch/embankment	3,879	24.2%	2,613	7.7%	0.000001	3.15	17	16.5%	7
Collision with fixed object: Curb/island/raised median	3	0.0%	19	0.1%					
Collision with fixed object: Guardrail	32	0.2%	222	0.7%					
Collision with fixed object: Concrete barrier (median or right side)	3	0.0%	6	0.0%					
Collision with fixed object: Tree	372	2.3%	241	0.7%	0.000001	3.28	16	1.6%	46
Collision with fixed object: Poles (utility, light, etc.)	291	1.8%	396	1.2%	0.000001	1.56	55	0.7%	71
Collision with fixed object: Sign post	70	0.4%	238	0.7%					
Collision with fixed object: Mailbox	52	0.3%	80	0.2%					
Collision with fixed object: Impact attenuator	1	0.0%	4	0.0%					
Collision with fixed object: Other fixed object (explain in narrative)	225	1.4%	319	0.9%	0.000003	1.50	65	0.5%	78
Miscellaneous events: Fire/explosion	8	0.0%	6	0.0%	0.043985	2.83	27	0.0%	98
Miscellaneous events: Immersion	2	0.0%	2	0.0%					
Miscellaneous events: Hit and run	1	0.0%							
Unknown	425	2.6%	1,367	4.0%					

Major Cause									
Animal	2,526	15.7%	15,362	45.1%					
Ran Traffic Signal	24	0.1%	75	0.2%					
Ran Stop Sign	277	1.7%	569	1.7%					
Crossed centerline	397	2.5%	1,413	4.2%					
FTYROW: At uncontrolled intersection	480	3.0%	164	0.5%	0.000001	6.21	7	2.5%	39
FTYROW: Making right turn on red signal	1	0.0%	1	0.0%					
FTYROW: From stop sign	148	0.9%	1,147	3.4%					
FTYROW: From yield sign	26	0.2%	12	0.0%	0.000002	4.60	9	0.1%	95
FTYROW: Making left turn	98	0.6%	446	1.3%					
FTYROW: From driveway	177	1.1%	142	0.4%	0.000001	2.65	28	0.7%	69
FTYROW: From parked position	28	0.2%	88	0.3%					
FTYROW: To pedestrian	2	0.0%	6	0.0%					
FTYROW: Other (explain in narrative)	262	1.6%	589	1.7%					
Traveling wrong way or on wrong side of road	184	1.1%	195	0.6%	0.000001	2.00	46	0.6%	74
Driving too fast for conditions	1,897	11.8%	1,561	4.6%	0.000001	2.58	31	7.2%	19
Exceeded authorized speed	183	1.1%	243	0.7%	0.000001	1.60	53	0.4%	82
Made improper turn	85	0.5%	262	0.8%					
Followed too close	127	0.8%	980	2.9%					
Disregarded RR Signal	4	0.0%	7	0.0%					
Disregarded Warning Sign	12	0.1%	12	0.0%					
Operating vehicle in an erratic/reckless/careless/negligent/aggressive manner	358	2.2%	347	1.0%	0.000001	2.19	38	1.2%	52
Swerving/Evasive Action	2,870	17.9%	2,883	8.5%	0.000001	2.11	40	9.4%	17
Over correcting/over steering	427	2.7%	384	1.1%	0.000001	2.36	35	1.5%	47
Downhill runaway	26	0.2%	19	0.1%	0.000213	2.90	25	0.1%	96
Equipment failure	67	0.4%	157	0.5%					
Ran off road - right	2,067	12.9%	2,092	6.1%	0.000001	2.10	41	6.7%	21
Ran off road - straight	311	1.9%	81	0.2%	0.000001	8.15	6	1.7%	43
Ran off road - left	1,289	8.0%	1,078	3.2%	0.000001	2.54	32	4.9%	23
Lost Control	436	2.7%	677	2.0%	0.000001	1.37	72	0.7%	67
Inattentive/distracted by: Passenger	6	0.0%	32	0.1%					
Inattentive/distracted by: Use of phone or other device	7	0.0%	53	0.2%					
Inattentive/distracted by: Fallen object	8	0.0%	24	0.1%					
Inattentive/distracted by: Fatigued/asleep	19	0.1%	63	0.2%					
Other (explain in narrative): Vision obstructed	134	0.8%	141	0.4%	0.000001	2.02	44	0.4%	83
Oversized Load/Vehicle	2	0.0%	7	0.0%					
Cargo/equipment loss or shift	4	0.0%	55	0.2%					
Other (explain in narrative): Other improper action	165	1.0%	692	2.0%					
Other (explain in narrative): No improper action	267	1.7%	578	1.7%					
Unknown	639	4.0%	1,403	4.1%					
Drug or Alcohol Related									
Drug-related	73	0.5%	141	0.4%					
Alcohol-related (under 0.08)	121	0.8%	123	0.4%	0.000001	2.09	42	0.4%	84
Alcohol-related (0.08 or over)	689	4.3%	728	2.1%	0.000001	2.01	45	2.2%	42
Drug- and alcohol-related (under 0.08)	14	0.1%	9	0.0%	0.003026	3.30	15	0.1%	97
Drug- and alcohol-related (0.08 or over)	23	0.1%	35	0.1%					
Refused	124	0.8%	174	0.5%	0.000377	1.51	60	0.3%	91
A driver indicated as under the influence of alcohol/drugs/medications	285	1.8%	234	0.7%	0.000001	2.58	30	1.1%	56
Not drug- or alcohol-related	14,711	91.7%	32,596	95.8%					

Environment Contributing Circumstances									
None apparent	9,046	56.4%	12,487	36.7%	0.000001	1.54	57	19.7%	4
Weather conditions	762	4.8%	3,421	10.0%					
Physical obstruction	699	4.4%	149	0.4%	0.000001	9.96	4	3.9%	28
Pedestrian action	16	0.1%	26	0.1%					
Glare	131	0.8%	211	0.6%	0.012568	1.32	74	0.2%	92
Animal in roadway	1,510	9.4%	4,404	12.9%					
Previous accident	7	0.0%	49	0.1%					
Other (explain in narrative)	722	4.5%	507	1.5%	0.000001	3.02	21	3.0%	32
Unknown	3,147	19.6%	12,786	37.6%					
Weather Conditions									
Clear	8,720	54.4%	13,598	39.9%	0.000001	1.36	73	14.4%	8
Partly cloudy	2,500	15.6%	3,760	11.0%	0.000001	1.41	67	4.5%	25
Cloudy	1,336	8.3%	2,447	7.2%	0.000007	1.16	90	1.1%	54
Fog/smoke	204	1.3%	491	1.4%					
Mist	175	1.1%	521	1.5%					
Rain	397	2.5%	1,001	2.9%					
Sleet/hail/freezing rain	93	0.6%	475	1.4%					
Snow	346	2.2%	2,040	6.0%					
Severe winds	115	0.7%	234	0.7%					
Blowing sand/soil/dirt/snow	143	0.9%	560	1.6%					
Other (explain in narrative)	17	0.1%	34	0.1%					
Unknown	1,994	12.4%	8,879	26.1%					
Light Conditions - More Detail									
Daylight	7,829	48.8%	12,891	37.9%	0.000001	1.29	75	10.9%	15
Dusk	506	3.2%	1,035	3.0%					
Dawn	299	1.9%	1,074	3.2%					
Dark - roadway lighted	173	1.1%	729	2.1%					
Dark - roadway not lighted	5,516	34.4%	9,553	28.1%	0.000001	1.23	82	6.3%	22
Dark - unknown roadway lighting	65	0.4%	161	0.5%					
Unknown	1,652	10.3%	8,597	25.3%					
Surface Conditions									
Dry	6,382	39.8%	18,421	54.1%					
Wet	582	3.6%	2,300	6.8%					
Ice	851	5.3%	1,833	5.4%					
Snow	655	4.1%	1,604	4.7%					
Slush	98	0.6%	372	1.1%					
Sand/mud/dirt/oil/gravel	5,411	33.7%	200	0.6%	0.000001	57.42	1	33.1%	2
Water (standing/moving)	14	0.1%	24	0.1%					
Other (explain in narrative)	127	0.8%	150	0.4%	0.000001	1.80	49	0.4%	89
Unknown	1,920	12.0%	9,136	26.8%					
Roadway Contributing Circumstances									
None apparent	9,980	62.2%	16,816	49.4%	0.000001	1.26	77	12.8%	11
Road surface condition	2,133	13.3%	3,263	9.6%	0.000001	1.39	70	3.7%	30
Debris	37	0.2%	80	0.2%					
Ruts/holes/bumps	181	1.1%	25	0.1%	0.000001	15.36	2	1.1%	59
Work Zone (construction/maintenance/utility)	44	0.3%	168	0.5%					
Worn/travel-polished surface	5	0.0%	7	0.0%					
Obstruction in roadway	70	0.4%	112	0.3%					
Traffic control device inoperative/missing/obscured	32	0.2%	11	0.0%	0.000001	6.17	8	0.2%	94
Shoulders (none/low/soft/high)	230	1.4%	113	0.3%	0.000001	4.32	10	1.1%	55
Non-highway work	37	0.2%	53	0.2%					
Non-contact vehicle	153	1.0%	262	0.8%	0.033886	1.24	80	0.2%	93
Unknown	3,138	19.6%	13,130	38.6%					

Type of Roadway/Junction/Feature										
Non-intersection: No special feature	10,026	62.5%	17,132	50.3%	0.000001	1.24	79	12.2%	12
Non-intersection: Bridge/overpass/underpass	499	3.1%	692	2.0%	0.000001	1.53	58	1.1%	58
Non-intersection: Railroad crossing	109	0.7%	79	0.2%	0.000001	2.93	24	0.4%	80
Non-intersection: Business drive	31	0.2%	402	1.2%					
Non-intersection: Farm/residential drive	889	5.5%	907	2.7%	0.000001	2.08	43	2.9%	35
Non-intersection: Alley intersection	7	0.0%	16	0.0%					
Non-intersection: Crossover in median	5	0.0%	9	0.0%					
Non-intersection: Other non-intersection (explain in narrative)	398	2.5%	296	0.9%	0.000001	2.85	26	1.6%	45
Intersection: Four-way intersection	1,016	6.3%	3,251	9.6%					
Intersection: T - intersection	989	6.2%	1,766	5.2%	0.000008	1.19	86	1.0%	61
Intersection: Y - intersection	130	0.8%	150	0.4%	0.000001	1.84	48	0.4%	85
Intersection: Five-leg or more	4	0.0%	15	0.0%					
Intersection: Offset four-way intersection	12	0.1%	62	0.2%					
Intersection: Intersection with ramp	1	0.0%	11	0.0%					
Intersection: On-ramp merge area	6	0.0%	4	0.0%					
Intersection: Off-ramp diverge area	1	0.0%	6	0.0%					
Intersection: On-ramp	1	0.0%							
Intersection: Off-ramp	2	0.0%	12	0.0%					
Intersection: With bike/pedestrian path	4	0.0%	2	0.0%					
Intersection: Other intersection (explain in narrative)	209	1.3%	387	1.1%					
Unknown	1,701	10.6%	8,841	26.0%					

APPENDIX 6. SUMMARY OF RESULTS FROM TEST OF PROPORTIONS ON SEVEN COMPARISON PAIRS

Note: Ratio is the proportion of crashes in the low-volume road category divided by the proportion of crashes for rural primary two-lane (only statistically significant differences shown); these ratios are ranked and the top 20 for each LVR category is shaded in pink. Similarly, the differences in proportions are ranked (the second column in each LVR category). The cons. column lists consitency of findings. Where all seven secondary road types for that item are in the top 20, cons. is 7 and is highlighted in pink.

VARIOUS CHARACTERISTICS OF CRASHES ON UNDIVIDED RURAL ROADS BY ROAD SYSTEM, VOLUME RANGE, AND SURFACE TYPE
Statistical Comparison of Proportions
State of Iowa (2001-2007)
Top 20 highlighted in each column

								Comparison Group
Road System:	**Secondary**	**Secondary**	**Secondary**	**Secondary**	**Secondary**	**Secondary**	**Secondary**	**Primary-ALL**
AADT Range:	**0-100**	**0-100**	**101-400**	**101-400**	**0-400**	**0-400**	**0-400**	**70-12200**
Surface Type:	**Unpaved**	**Paved**	**Unpaved**	**Paved**	**Unpaved**	**Paved**	**All**	**All Paved**
Total Crashes	16,040	470	5,502	7,603	21,542	8,073	29,615	34,040
Total Daily VMT	2,447,000	72,080	677,000	1,911,000	3,124,000	1,983,000	5,107,000	13,460,000
Total Centerline-Miles	66,900	1,063	4,345	7,421	71,245	8,484	79,729	5,963
Weighted Average of ADT	37	68	160	260	44	230	64	2,300
Crash Rate (per 100M VMT)	257	255	318	156	270	159	227	99
Crash Density (crash per mile)	0	0	1	1	0	0.95	0	6

	Rank: Ratio	Rank: Diff.	Rank: Ratio	Rank: Diff.	Rank: Ratio	Rank: Diff.	Rank: Ratio	Rank: Diff.	Rank: Ratio	Rank: Diff.	Rank: Ratio	Rank: Diff.	Rank: Ratio	Rank: Diff.	Cons.
CRASH SEVERITY															
Fatal															
Major Injury	68	44	42	40	78	59	56	34	74	48	56	34	68	43	7
Minor Injury	50	20	46	21	54	20	61	20	51	20	59	20	52	20	7
Possible/Unknown	85	31			75	26			82	29			87	31	4
Property Damage Only															
CRASH TYPE															
MV (No Ani/Obj on Road)**															
SV ROR (No Ani/Obj on Road)*	29	1	30	1	26	1	25	1	28	1	25	1	29	1	7
SV Other (No Ani/Obj on Road)*															
SV ROR (Ani/Obj on Road)*	12	24	10	23	13	28	10	27	11	24	10	26	10	26	7
SV Other (Ani/Obj on Road)*							46	84							1
Hit Animal															
MANNER OF CRASH/COLLISION															
MV Head-on**															
MV Read-end**															
MV Oncoming left turn**															
MV Broadside**	94	68			86	64			98	67			98	83	4
MV Sideswipe-Same Dir.**															
MV Sideswipe-Oppos. Dir.**															
MV Other**															
SV Coll. with Fixed Obj.*	36	10	28	4	36	8	26	4	36	9	27	4	34	8	7
SV Overturn/Rollover*	19	9	31	15	23	12	30	12	19	10	30	13	20	10	7
SV CollwFixObj+Over/Roll*	13	14	27	17	12	13	15	11	14	12	17	12	14	13	7
SV Other*			44	29			74	54			69	47			3
Hit Animal															
SPEED/WEATHER-SURFACE RELATION															
Speed Rel	23	3	19	2	18	3	41	3	22	3	36	2	22	3	7
Weather/Surface Rel															
Speed&Weather/Surface Rel															
Other/Unknown															
LIGHT CONDITIONS															
Day	75	15			72	10			77	15			78	15	4
Dark, dusk or dawn	97	27	51	12	91	44	71	6	102	31	70	6	93	24	7
Other/Unknown															
YOUNGER AND OLDER DRIVER INVOLVEMENT															
Age 14 or below involved	11	60	5	48	11	65			10	61			13	65	5
Ages 15-19 involved	37	5	37	9	35	5	54	7	35	5	54	7	38	5	7
Age 65 or above involved															
Other/Unknown															

DRUG/ALCOHOL INVOLVEMENT															
Impaired	47	26	33	24	41	27	31	21	47	26	31	22	43	25	7
Unimpaired															
TERRAIN															
Flat															
Rolling	89	18			87	19	89	14	94	18	84	16	90	17	6
Hilly	62	40			44	24	32	19	54	33	34	21	50	29	6
Other/Unknown															
FARM VEHICLE INVOLVEMENT															
Farm vehicle and other	56	81					47	70	69	90	46	69	66	85	5
Farm vehicle only	3	77			3	86	5	90	3	82	5	85	3	86	6
No farm vehicle															
MISCELLANEOUS															
Month															
January															
February															
March															
April							76	51			77	53			2
May	98	70			88	62	73	38	100	68	74	40	91	63	6
June	91	53			84	54	87	56	93	55			89	55	5
July	69	37	40	20	69	34	81	50	71	36	75	41	71	38	7
August	59	33			61	33	58	30	62	34	58	32	61	32	6
September	66	36			68	35	80	52	70	35	76	48	69	39	6
October							83	41			80	43	99	71	3
November															
December															
Day															
Sunday	83	34			89	56	72	25	90	38	72	25	86	36	6
Monday															
Tuesday															
Wednesday															
Thursday															
Friday															
Saturday	88	38			90	53	90	48	97	39	85	50	92	41	6
Hour															
Midnight	54	49			59	55	70	67	57	51	68	64	60	50	6
1	51	50	26	37	67	68	52	53	56	56	50	49	54	52	7
2	52	57			50	52	39	42	50	57	41	45	48	51	6
3	61	73			58	70	40	55	61	72	40	55	57	66	6
4															
5															
6															
7							79	58							1
8									101	88			97	88	2
9															
10	95	87													1
11	96	86							99	84					2
12	93	79							96	79					2
13	81	66							89	71			94	79	3
14	92	75			83	71			95	73					3
15	87	64			76	46			86	59			95	72	4
16	78	51			65	38			79	50			85	58	4
17															
18															
19															
20															
21							85	59							1
22	84	63					64	39	88	65	63	39	77	59	5
23	64	48			64	49	55	40	64	49	55	38	62	47	6
Unknown															

Location of First Harmful Event															
On roadway															
Shoulder	71	41	41	25	71	39	36	18	73	42	37	18	65	35	7
Median															
Roadside	20	13	22	13	21	15	22	9	20	13	23	10	18	12	7
Gore	14	90			8	81	9	80	13	86	8	77	12	87	6
Outside trafficway	22	29	21	31	22	29	17	26	23	28	19	28	19	28	7
Unknown															
First Harmful Event															
Non-collision events: Overturn/rollover	18	6	34	14	20	6	28	5	17	6	28	5	17	7	7
Non-collision events: Jackknife															
Non-collision events: Other non-collision (explain in narrative)	63	62	35	44	63	63	63	63	63	63	57	57	64	61	7
Collision with: Non-motorist (see non-motorist type)															
Collision with: Vehicle in traffic															
Collision with: Vehicle in/from other roadway															
Collision with: Parked motor vehicle	34	76	3	30	40	82	23	73	34	76	14	68	32	74	7
Collision with: Railway vehicle/train	5	88			6	87	4	86	5	91	3	80	6	90	6
Collision with: Animal															
Collision with: Other non-fixed object (explain in narrative)			20	43											1
Collision with fixed object: Bridge/bridge rail/overpass	39	65			48	73	49	72	43	66	52	70	46	67	6
Collision with fixed object: Underpass/structure support															
Collision with fixed object: Culvert	33	72			46	84	33	77	33	75	32	72	33	73	6
Collision with fixed object: Ditch/embankment	17	7	24	10	16	7	13	2	16	7	16	3	16	6	7
Collision with fixed object: Curb/island/raised median															
Collision with fixed object: Guardrail															
Collision with fixed object: Concrete barrier (median or right side)															
Collision with fixed object: Tree	16	46	6	38	14	42	24	57	15	43	20	56	15	45	7
Collision with fixed object: Poles (utility, light, etc.)	55	71	16	39	51	66	57	71	55	69	53	66	55	69	7
Collision with fixed object: Sign post															
Collision with fixed object: Mailbox					45	88	43	87	60	98	43	82	58	93	5
Collision with fixed object: Impact attenuator															
Collision with fixed object: Other fixed object (explain in narrative)	65	78			66	83	38	62	65	80	39	59	59	75	6
Miscellaneous events: Fire/explosion	27	98													1
Miscellaneous events: Immersion															
Miscellaneous events: Hit and run															
Unknown															

Weather Conditions															
Clear	73	8	48	8	70	9	82	15	75	8	79	15	74	9	7
Partly cloudy	67	25	45	18	74	31	75	32	72	25	71	31	70	27	7
Cloudy	90	54			79	43	78	46	92	52	78	52	88	49	6
Fog/smoke							65	74							1
Mist							68	75			65	71			2
Rain															
Sleet/hail/freezing rain															
Snow															
Severe winds															
Blowing sand/soil/dirt/snow															
Other (explain in narrative)															
Unknown															
Light Conditions - More Detail															
Daylight	75	15			72	10			77	15			78	15	4
Dusk							60	44			61	51			2
Dawn															
Dark - roadway lighted			29	35											1
Dark - roadway not lighted	82	22	47	11	85	25	69	8	87	22	67	9	81	21	7
Dark - unknown roadway lighting															
Unknown															
Surface Conditions															
Dry							91	29			86	29			2
Wet															
Ice					81	58	66	37			66	37	96	76	4
Snow															
Slush															
Sand/mud/dirt/oil/gravel															
Water (standing/moving)															
Other (explain in narrative)	49	89			42	80	34	76	49	85	35	73	47	84	6
Unknown															
Roadway Contributing Circumstances															
None apparent	77	11	49	6	80	14	88	16	81	11	82	14	80	11	7
Road surface condition	70	30			60	22			68	27			72	30	4
Debris															
Ruts/holes/bumps	2	59			2	40	6	85	2	53	7	81	2	57	6
Work Zone (construction/maintenance/utility)			14	47											1
Worn/travel-polished surface															
Obstruction in roadway							42	83			43	79	73	96	3
Traffic control device inoperative/missing/obscured	8	94			9	90	8	91	8	96	9	86	7	95	6
Shoulders (none/low/soft/high)	10	55	11	51	17	69	11	66	12	60	11	65	11	60	7
Non-highway work									59	100			53	98	2
Non-contact vehicle	80	93							85	95					2
Unknown															
Type of Roadway/Junction/Feature															
Non-intersection: No special feature	79	12	50	7	82	17	86	13	84	14	81	11	83	14	7
Non-intersection: Bridge/overpass/underpass	58	58			77	79	62	60	66	62	62	60	67	62	6
Non-intersection: Railroad crossing	24	80			31	85	20	81	25	83	21	78	25	82	6
Non-intersection: Business drive															
Non-intersection: Farm/residential drive	43	35	18	22	52	41	21	23	46	37	22	23	40	34	7
Non-intersection: Alley intersection															
Non-intersection: Crossover in median															
Non-intersection: Other non-intersection (explain in narrative)	26	45	8	36	30	51	16	43	26	46	15	42	21	46	7
Intersection: Four-way intersection															
Intersection: T - intersection	86	61			53	30			76	44			82	54	4
Intersection: Y - intersection	48	85	15	49	24	67	51	82	41	77	45	76	42	78	7
Intersection: Five-leg or more															
Intersection: Offset four-way intersection															
Intersection: Intersection with ramp															
Intersection: On-ramp merge area															
Intersection: Off-ramp diverge area															
Intersection: On-ramp															
Intersection: Off-ramp															
Intersection: With bike/pedestrian path															
Intersection: Other intersection (explain in narrative)			17	41	62	78			83	93			84	92	4
Unknown															

Major Cause															
Animal															
Ran Traffic Signal															
Ran Stop Sign					55	60	44	47	91	92	48	54	76	77	5
Crossed centerline															
FTYROW: At uncontrolled intersection	7	39	13	46	10	50	48	79	7	41	42	74	8	42	7
FTYROW: Making right turn on red signal															
FTYROW: From stop sign															
FTYROW: From yield sign	9	95			7	89	3	88	9	97	3	83	9	94	6
FTYROW: Making left turn															
FTYROW: From driveway	28	69	4	34	28	72	14	64	29	70	12	58	26	68	7
FTYROW: From parked position															
FTYROW: To pedestrian															
FTYROW: Other (explain in narrative)															
Traveling wrong way or on wrong side of road	46	74			43	75			45	74			49	81	4
Driving too fast for conditions	31	19	36	26	19	18	50	28	27	19	51	27	31	19	7
Exceeded authorized speed	53	82	9	42	47	74	7	36	52	78	6	35	39	64	7
Made improper turn															
Followed too close															
Disregarded RR Signal															
Disregarded Warning Sign									38	102					1
Operating vehicle in an erratic/reckless/careless/negligent/aggressive manner	38	52	12	33	32	47	53	69	37	54	47	62	37	53	7
Swerving/Evasive Action	40	17	38	16	38	16	67	31	40	17	64	30	45	18	7
Over correcting/over steering	35	47			34	45	45	61	32	47	49	61	35	48	6
Downhill runaway	25	96			27	91			24	99			23	97	4
Equipment failure															
Ran off road - right	41	21	39	19	49	23	37	17	44	21	38	17	44	22	7
Ran off road - straight	6	43	2	28	4	48	2	49	6	45	2	44	4	44	7
Ran off road - left	32	23	32	27	25	21	29	24	30	23	29	24	30	23	7
Lost Control	72	67			57	57			67	64			75	70	4
Inattentive/distracted by: Passenger															
Inattentive/distracted by: Use of phone or other device															
Inattentive/distracted by: Fallen object															
Inattentive/distracted by: Fatigued/asleep															
Other (explain in narrative): Vision obstructed	44	83							48	87			51	91	3
Oversized Load/Vehicle															
Cargo/equipment loss or shift															
Other (explain in narrative): Other improper action															
Other (explain in narrative): No improper action															
Unknown															
Drug or Alcohol Related															
Drug-related															
Alcohol-related (under 0.08)	42	84			29	76	35	78	39	81	33	75	36	80	6
Alcohol-related (0.08 or over)	45	42	25	32	37	36	27	33	42	40	26	33	41	40	7
Drug- and alcohol-related (under 0.08)	15	97							21	101			27	99	3
Drug- and alcohol-related (0.08 or over)							18	89			24	84			2
Refused	60	91			39	77			53	89			56	89	4
A driver indicated as under the influence of alcohol/drugs/medications	30	56	23	50	33	61	12	45	31	58	13	46	28	56	7
Not drug- or alcohol-related															
Environment Contributing Circumstances															
None apparent	57	4	43	3	56	4	77	10	58	4	73	8	63	4	7
Weather conditions															
Physical obstruction	4	28	7	45	5	37	19	68	4	30	18	63	5	33	7
Pedestrian action															
Glare	74	92							80	94					2
Animal in roadway							84	35			83	36			2
Previous accident															
Other (explain in narrative)	21	32			15	32	59	65	18	32	60	67	24	37	6
Unknown															

APPENDIX 7. COMPARISON DATA FOR VARIOUS ROAD CLASSES

Note: The % columns total to 100% for each crash type heading (severity, type, manner, etc.). Orange and blue grouping lines indicate the same crashes broken out into different categories. Some rows are shaded for ease of reading. Frequencies are seven-year totals.

State of Iowa (2001-2007)	SECONDARY 0-100						SECONDARY 101-400					
Road System	Secondary		Secondary		Secondary		Secondary		Secondary		Secondary	
AADT Range	0-100		0-100		0-100		101-400		101-400		101-400	
Surface Type	Unpaved		Paved		All		Unpaved		Paved		All	
Total Crashes	16,040	-	470	-	16,510	-	5,502	-	7,603	-	13,105	-
Total Daily VMT	2,447,000	-	72,080	-	2,519,000	-	677,000	-	1,911,000	-	2,588,000	-
Total Centerline-Miles	66,900	-	1,063	-	67,963	-	4,345	-	7,421	-	11,766	-
Weighted Average of ADT	37	-	68	-	37	-	160	-	260	-	220	-
Crash Rate (per 100M VMT)	257	-	255	-	257	-	318	-	156	-	198	-
Crash Density	0.24	-	0.44	-	0.24	-	1.27	-	1.02	-	1.11	-
CRASH SEVERITY	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Fatal	235	1.5%	9	1.9%	244	1.5%	57	1.0%	120	1.6%	177	1.4%
Major Injury	933	5.8%	29	6.2%	962	5.8%	287	5.2%	424	5.6%	711	5.4%
Minor Injury	2,750	17.1%	65	13.8%	2,815	17.1%	911	16.6%	1,014	13.3%	1,925	14.7%
Possible/Unknown	2,929	18.3%	68	14.5%	2,997	18.2%	1,084	19.7%	1,201	15.8%	2,285	17.4%
Property Damage Only	9,193	57.3%	299	63.6%	9,492	57.5%	3,163	57.5%	4,844	63.7%	8,007	61.1%
CRASH TYPE												
MV (No Ani/Obj on Road)	2,940	18.3%	104	22.1%	3,044	18.4%	1,068	19.4%	1,118	14.7%	2,186	16.7%
SV ROR (No Ani/Obj on Road)	9,121	56.9%	199	42.3%	9,320	56.5%	3,156	57.4%	2,973	39.1%	6,129	46.8%
SV Other (No Ani/Obj on Road)	507	3.2%	24	5.1%	531	3.2%	175	3.2%	358	4.7%	533	4.1%
SV ROR (Ani/Obj on Road)	984	6.1%	22	4.7%	1,006	6.1%	295	5.4%	272	3.6%	567	4.3%
SV Other (Ani/Obj on Road)	35	0.2%		0.0%	35	0.2%	9	0.2%	37	0.5%	46	0.4%
Hit Animal	2,453	15.3%	121	25.7%	2,574	15.6%	799	14.5%	2,845	37.4%	3,644	27.8%
MANNER OF CRASH/COLLISION												

MANNER OF CRASH/COLLISION												
MV Head-on	378	2.4%	8	1.7%	386	2.3%	119	2.2%	66	0.9%	185	1.4%
MV Read-end	524	3.3%	29	6.2%	553	3.3%	212	3.9%	235	3.1%	447	3.4%
MV Oncoming left turn	206	1.3%	5	1.1%	211	1.3%	108	2.0%	93	1.2%	201	1.5%
MV Broadside	1,007	6.3%	27	5.7%	1,034	6.3%	353	6.4%	371	4.9%	724	5.5%
MV Sideswipe-Same Dir.	217	1.4%	17	3.6%	234	1.4%	84	1.5%	173	2.3%	257	2.0%
MV Sideswipe-Oppos. Dir.	391	2.4%	12	2.6%	403	2.4%	130	2.4%	103	1.4%	233	1.8%
MV Other	217	1.4%	6	1.3%	223	1.4%	62	1.1%	77	1.0%	139	1.1%
SV Coll. with Fixed Obj.	4,050	25.2%	108	23.0%	4,158	25.2%	1,437	26.1%	1,538	20.2%	2,975	22.7%
SV Overturn/Rollover	3,332	20.8%	58	12.3%	3,390	20.5%	1,055	19.2%	900	11.8%	1,955	14.9%
SV Collw/FixObj+Over/Roll	2,574	16.0%	43	9.1%	2,617	15.9%	914	16.6%	738	9.7%	1,652	12.6%
SV Other	691	4.3%	36	7.7%	727	4.4%	229	4.2%	464	6.1%	693	5.3%
Hit Animal	2,453	15.3%	121	25.7%	2,574	15.6%	799	14.5%	2,845	37.4%	3,644	27.8%
SPEED/WEATHER-SURFACE RELATION												
Speed Rel	6,894	43.0%	159	33.8%	7,053	42.7%	2,491	45.3%	1,802	23.7%	4,293	32.8%
Weather-Surface Rel	1,143	7.1%	31	6.6%	1,174	7.1%	373	6.8%	645	8.5%	1,018	7.8%
Speed&Weather-Surface Rel	1,619	10.1%	38	8.1%	1,657	10.0%	623	11.3%	871	11.5%	1,494	11.4%
Other/Unknown	6,384	39.8%	242	51.5%	6,626	40.1%	2,015	36.6%	4,285	56.4%	6,300	48.1%
LIGHT CONDITIONS												
Day	7,829	48.8%	195	41.5%	8,024	48.6%	2,784	50.6%	2,811	37.0%	5,595	42.7%
Dark, dusk or dawn	6,559	40.9%	206	43.8%	6,765	41.0%	2,125	38.6%	3,292	43.3%	5,417	41.3%
Other/Unknown	1,652	10.3%	69	14.7%	1,721	10.4%	593	10.8%	1,500	19.7%	2,093	16.0%
YOUNGER AND OLDER DRIVER INVOLVEMENT												
Age 14 or below involved	205	1.3%	6	1.3%	211	1.3%	63	1.1%	27	0.4%	90	0.7%
Ages 15-19 involved	5,499	34.3%	119	25.3%	5,618	34.0%	1,983	36.0%	1,620	21.3%	3,603	27.5%
Age 65 or above involved	865	5.4%	38	8.1%	903	5.5%	246	4.5%	595	7.8%	841	6.4%
Other/Unknown	9,471	59.0%	307	65.3%	9,778	59.2%	3,210	58.3%	5,361	70.5%	8,571	65.4%
DRUG/ALCOHOL INVOLVEMENT												
Impaired	1,329	8.3%	35	7.4%	1,364	8.3%	482	8.8%	565	7.4%	1,047	8.0%
Unimpaired	14,711	91.7%	435	92.6%	15,146	91.7%	5,020	91.2%	7,038	92.6%	12,058	92.0%

TERRAIN												
Flat	4,407	27.5%	180	38.3%	4,587	27.8%	1,453	26.4%	2,329	30.6%	3,782	28.9%
Rolling	10,438	65.1%	272	57.9%	10,710	64.9%	3,521	64.0%	4,636	61.0%	8,157	62.2%
Hilly	1,173	7.3%	18	3.8%	1,191	7.2%	528	9.6%	638	8.4%	1,166	8.9%
Other/Unknown	22	0.1%		0.0%	22	0.1%		0.0%		0.0%		0.0%
FARM VEHICLE INVOLVEMENT												
Farm vehicle and other	196	1.2%	6	1.3%	202	1.2%	46	0.8%	91	1.2%	137	1.0%
Farm vehicle only	83	0.5%	1	0.2%	84	0.5%	17	0.3%	9	0.1%	26	0.2%
No farm vehicle	15,761	98.3%	463	98.5%	16,224	98.3%	5,439	98.9%	7,503	98.7%	12,942	98.8%

State of Iowa (2001-2007)

	SECONDARY 401-1000						SECONDARY 1001-13500					
Road System	**Secondary**		**Secondary**		**Secondary**		**Secondary**		**Secondary**		**Secondary**	
AADT Range	**401-1000**		**401-1000**		**401-1000**		**1001-13500**		**1001-13500**		**1001-13500**	
Surface Type	**Unpaved**		**Paved**		**All**		**Unpaved**		**Paved**		**All**	
Total Crashes	158	-	16,526	-	16,684	-	25	-	14,759	-	14,784	-
Total Daily VMT	36,610	-	4,407,000	-	4,443,000	-	20,930	-	4,196,000	-	4,217,000	-
Total Centerline-Miles	66	-	6,986	-	7,053	-	10	-	2,537	-	2,547	-
Weighted Average of ADT	550	-	630	-	630	-	2,000	-	1,700	-	1,700	-
Crash Rate (per 100M VMT)	169	-	147	-	147	-	47	-	138	-	137	-
Crash Density	2.39	-	2.37	-	2.37	-	2.41	-	5.82	-	5.80	-
CRASH SEVERITY	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
Fatal	1	0.6%	275	1.7%	276	1.7%		0.0%	219	1.5%	219	1.5%
Major Injury	8	5.1%	885	5.4%	893	5.4%		0.0%	709	4.8%	709	4.8%
Minor Injury	38	24.1%	2,169	13.1%	2,207	13.2%	1	4.0%	1,721	11.7%	1,722	11.6%
Possible/Unknown	33	20.9%	2,452	14.8%	2,485	14.9%	6	24.0%	2,459	16.7%	2,465	16.7%
Property Damage Only	78	49.4%	10,745	65.0%	10,823	64.9%	18	72.0%	9,651	65.4%	9,669	65.4%
CRASH TYPE												
MV (No Ani/Obj on Road)	41	25.9%	2,732	16.5%	2,773	16.6%	8	32.0%	3,786	25.7%	3,794	25.7%
SV ROR (No Ani/Obj on Road)	93	58.9%	6,207	37.6%	6,300	37.8%	10	40.0%	4,844	32.8%	4,854	32.8%
SV Other (No Ani/Obj on Road)	6	3.8%	739	4.5%	745	4.5%	1	4.0%	652	4.4%	653	4.4%
SV ROR (Ani/Obj on Road)	4	2.5%	471	2.9%	475	2.8%	2	8.0%	312	2.1%	314	2.1%
SV Other (Ani/Obj on Road)		0.0%	58	0.4%	58	0.3%		0.0%	42	0.3%	42	0.3%
Hit Animal	14	8.9%	6,319	38.2%	6,333	38.0%	4	16.0%	5,123	34.7%	5,127	34.7%

MANNER OF CRASH/COLLISION												
MV Head-on	3	1.9%	204	1.2%	207	1.2%	1	4.0%	266	1.8%	267	1.8%
MV Read-end	7	4.4%	637	3.9%	644	3.9%	4	16.0%	1,148	7.8%	1,152	7.8%
MV Oncoming left turn	4	2.5%	254	1.5%	258	1.5%		0.0%	318	2.2%	318	2.2%
MV Broadside	15	9.5%	780	4.7%	795	4.8%	2	8.0%	1,027	7.0%	1,029	7.0%
MV Sideswipe-Same Dir.	4	2.5%	423	2.6%	427	2.6%		0.0%	471	3.2%	471	3.2%
MV Sideswipe-Oppos. Dir.	6	3.8%	258	1.6%	264	1.6%	1	4.0%	332	2.2%	333	2.3%
MV Other	2	1.3%	176	1.1%	178	1.1%		0.0%	224	1.5%	224	1.5%
SV Coll. with Fixed Obj.	45	28.5%	3,224	19.5%	3,269	19.6%	7	28.0%	2,578	17.5%	2,585	17.5%
SV Overturn/Rollover	32	20.3%	1,838	11.1%	1,870	11.2%	4	16.0%	1,367	9.3%	1,371	9.3%
SV Collw/FixObj+Over/Roll	19	12.0%	1,450	8.8%	1,469	8.8%	1	4.0%	1,123	7.6%	1,124	7.6%
SV Other	7	4.4%	963	5.8%	970	5.8%	1	4.0%	782	5.3%	783	5.3%
Hit Animal	14	8.9%	6,319	38.2%	6,333	38.0%	4	16.0%	5,123	34.7%	5,127	34.7%
SPEED/WEATHER-SURFACE RELATION												
Speed Rel	78	49.4%	3,383	20.5%	3,461	20.7%	11	44.0%	2,736	18.5%	2,747	18.6%
Weather-Surface Rel	12	7.6%	1,354	8.2%	1,366	8.2%	1	4.0%	1,329	9.0%	1,330	9.0%
Speed&Weather-Surface Rel	16	10.1%	2,323	14.1%	2,339	14.0%	1	4.0%	2,362	16.0%	2,363	16.0%
Other/Unknown	52	32.9%	9,466	57.3%	9,518	57.0%	12	48.0%	8,332	56.5%	8,344	56.4%
LIGHT CONDITIONS												
Day	97	61.4%	6,082	36.8%	6,179	37.0%	12	48.0%	5,917	40.1%	5,929	40.1%
Dark, dusk or dawn	45	28.5%	6,679	40.4%	6,724	40.3%	9	36.0%	5,379	36.4%	5,388	36.4%
Other/Unknown	16	10.1%	3,765	22.8%	3,781	22.7%	4	16.0%	3,463	23.5%	3,467	23.5%
YOUNGER AND OLDER DRIVER INVOLVEMENT												
Age 14 or below involved	3	1.9%	59	0.4%	62	0.4%		0.0%	49	0.3%	49	0.3%
Ages 15-19 involved	59	37.3%	3,234	19.6%	3,293	19.7%	7	28.0%	3,034	20.6%	3,041	20.6%
Age 65 or above involved	10	6.3%	1,332	8.1%	1,342	8.0%	1	4.0%	1,264	8.6%	1,265	8.6%
Other/Unknown	86	54.4%	11,901	72.0%	11,987	71.8%	17	68.0%	10,412	70.5%	10,429	70.5%
DRUG/ALCOHOL INVOLVEMENT												
Impaired	13	8.2%	1,085	6.6%	1,098	6.6%	1	4.0%	964	6.5%	965	6.5%
Unimpaired	145	91.8%	15,441	93.4%	15,586	93.4%	24	96.0%	13,795	93.5%	13,819	93.5%

TERRAIN												
Flat	39	24.7%	5,218	31.6%	5,257	31.5%	5	20.0%	4,897	33.2%	4,902	33.2%
Rolling	85	53.8%	10,061	60.9%	10,146	60.8%	18	72.0%	9,018	61.1%	9,036	61.1%
Hilly	34	21.5%	1,247	7.5%	1,281	7.7%	2	8.0%	844	5.7%	846	5.7%
Other/Unknown		0.0%		0.0%		0.0%		0.0%		0.0%		0.0%
FARM VEHICLE INVOLVEMENT												
Farm vehicle and other		0.0%	243	1.5%	243	1.5%		0.0%	100	0.7%	100	0.7%
Farm vehicle only		0.0%	24	0.1%	24	0.1%		0.0%	7	0.0%	7	0.0%
No farm vehicle	158	100.0%	16,259	98.4%	16,417	98.4%	25	100.0%	14,652	99.3%	14,677	99.3%

State of Iowa (2001-2007)

	SECONDARY 0-400						SECONDARY 101-13500					
Road System	Secondary		Secondary		Secondary		Secondary		Secondary		Secondary	
AADT Range	0-400		0-400		0-400		101-13500		101-13500		101-13500	
Surface Type	Unpaved		Paved		All		Unpaved		Paved		All	
Total Crashes	21,542	-	8,073	-	29,615	-	5,685	-	38,888	-	44,573	-
Total Daily VMT	3,124,000	-	1,983,000	-	5,107,000	-	734,540	-	10,514,000	-	11,248,000	-
Total Centerline-Miles	71,245	-	8,484	-	79,729	-	4,421	-	16,944	-	21,365	-
Weighted Average of ADT	44	-	230	-	64	-	170	-	620	-	530	-
Crash Rate (per 100M VMT)	270	-	159	-	227	-	303	-	145	-	155	-
Crash Density	0.30	-	0.95	-	0.37	-	1.29	-	2.30	-	2.09	-
CRASH SEVERITY	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Fatal	292	1.4%	129	1.6%	421	1.4%	58	1.0%	614	1.6%	672	1.5%
Major Injury	1,220	5.7%	453	5.6%	1,673	5.6%	295	5.2%	2,018	5.2%	2,313	5.2%
Minor Injury	3,661	17.0%	1,079	13.4%	4,740	16.0%	950	16.7%	4,904	12.6%	5,854	13.1%
Possible/Unknown	4,013	18.6%	1,269	15.7%	5,282	17.8%	1,123	19.8%	6,112	15.7%	7,235	16.2%
Property Damage Only	12,356	57.4%	5,143	63.7%	17,499	59.1%	3,259	57.3%	25,240	64.9%	28,499	63.9%
CRASH TYPE												
MV (No Ani/Obj on Road)	4,008	18.6%	1,222	15.1%	5,230	17.7%	1,117	19.6%	7,636	19.6%	8,753	19.6%
SV ROR (No Ani/Obj on Road)	12,277	57.0%	3,172	39.3%	15,449	52.2%	3,259	57.3%	14,024	36.1%	17,283	38.8%
SV Other (No Ani/Obj on Road)	682	3.2%	382	4.7%	1,064	3.6%	182	3.2%	1,749	4.5%	1,931	4.3%
SV ROR (Ani/Obj on Road)	1,279	5.9%	294	3.6%	1,573	5.3%	301	5.3%	1,055	2.7%	1,356	3.0%
SV Other (Ani/Obj on Road)	44	0.2%	37	0.5%	81	0.3%	9	0.2%	137	0.4%	146	0.3%
Hit Animal	3,252	15.1%	2,966	36.7%	6,218	21.0%	817	14.4%	14,287	36.7%	15,104	33.9%

MANNER OF CRASH/COLLISION												
MV Head-on	497	2.3%	74	0.9%	571	1.9%	123	2.2%	536	1.4%	659	1.5%
MV Read-end	736	3.4%	264	3.3%	1,000	3.4%	223	3.9%	2,020	5.2%	2,243	5.0%
MV Oncoming left turn	314	1.5%	98	1.2%	412	1.4%	112	2.0%	665	1.7%	777	1.7%
MV Broadside	1,360	6.3%	398	4.9%	1,758	5.9%	370	6.5%	2,178	5.6%	2,548	5.7%
MV Sideswipe-Same Dir.	301	1.4%	190	2.4%	491	1.7%	88	1.5%	1,067	2.7%	1,155	2.6%
MV Sideswipe-Oppos. Dir.	521	2.4%	115	1.4%	636	2.1%	137	2.4%	693	1.8%	830	1.9%
MV Other	279	1.3%	83	1.0%	362	1.2%	64	1.1%	477	1.2%	541	1.2%
SV Coll. with Fixed Obj.	5,487	25.5%	1,646	20.4%	7,133	24.1%	1,489	26.2%	7,340	18.9%	8,829	19.8%
SV Overturn/Rollover	4,387	20.4%	958	11.9%	5,345	18.0%	1,091	19.2%	4,105	10.6%	5,196	11.7%
SV Collw/FixObj+Over/Roll	3,488	16.2%	781	9.7%	4,269	14.4%	934	16.4%	3,311	8.5%	4,245	9.5%
SV Other	920	4.3%	500	6.2%	1,420	4.8%	237	4.2%	2,209	5.7%	2,446	5.5%
Hit Animal	3,252	15.1%	2,966	36.7%	6,218	21.0%	817	14.4%	14,287	36.7%	15,104	33.9%
SPEED/WEATHER-SURFACE RELATION												
Speed Rel	9,385	43.6%	1,961	24.3%	11,346	38.3%	2,580	45.4%	7,921	20.4%	10,501	23.6%
Weather-Surface Rel	1,516	7.0%	676	8.4%	2,192	7.4%	386	6.8%	3,328	8.6%	3,714	8.3%
Speed&Weather-Surface Rel	2,242	10.4%	909	11.3%	3,151	10.6%	640	11.3%	5,556	14.3%	6,196	13.9%
Other/Unknown	8,399	39.0%	4,527	56.1%	12,926	43.6%	2,079	36.6%	22,083	56.8%	24,162	54.2%
LIGHT CONDITIONS												
Day	10,613	49.3%	3,006	37.2%	13,619	46.0%	2,893	50.9%	14,810	38.1%	17,703	39.7%
Dark, dusk or dawn	8,684	40.3%	3,498	43.3%	12,182	41.1%	2,179	38.3%	15,350	39.5%	17,529	39.3%
Other/Unknown	2,245	10.4%	1,569	19.4%	3,814	12.9%	613	10.8%	8,728	22.4%	9,341	21.0%
YOUNGER AND OLDER DRIVER INVOLVEMENT												
Age 14 or below involved	268	1.2%	33	0.4%	301	1.0%	66	1.2%	135	0.3%	201	0.5%
Ages 15-19 involved	7,482	34.7%	1,739	21.5%	9,221	31.1%	2,049	36.0%	7,888	20.3%	9,937	22.3%
Age 65 or above involved	1,111	5.2%	633	7.8%	1,744	5.9%	257	4.5%	3,191	8.2%	3,448	7.7%
Other/Unknown	12,681	58.9%	5,668	70.2%	18,349	62.0%	3,313	58.3%	27,674	71.2%	30,987	69.5%
DRUG/ALCOHOL INVOLVEMENT												
Impaired	1,811	8.4%	600	7.4%	2,411	8.1%	496	8.7%	2,614	6.7%	3,110	7.0%
Unimpaired	19,731	91.6%	7,473	92.6%	27,204	91.9%	5,189	91.3%	36,274	93.3%	41,463	93.0%

TERRAIN											
Flat	5,860	27.2%	2,509	31.1%	8,369	28.3%	1,497	26.3%	12,444	32.0%	13,941
Rolling	13,959	64.8%	4,908	60.8%	18,867	63.7%	3,624	63.7%	23,715	61.0%	27,339
Hilly	1,701	7.9%	656	8.1%	2,357	8.0%	564	9.9%	2,729	7.0%	3,293
Other/Unknown	22	0.1%	0	0.0%	22	0.1%	0	0.0%	0	0.0%	0
FARM VEHICLE INVOLVEMENT											
Farm vehicle and other	242	1.1%	97	1.2%	339	1.1%	46	0.8%	434	1.1%	480
Farm vehicle only	100	0.5%	10	0.1%	110	0.4%	17	0.3%	40	0.1%	57
No farm vehicle	21,200	98.4%	7,966	98.7%	29,166	98.5%	5,622	98.9%	38,414	98.8%	44,036

State of Iowa (2001-2007)

	SECONDARY 401-13500						SECONDARY 0-1000					
Road System	Secondary		Secondary		Secondary		Secondary		Secondary		Secondary	
AADT Range	401-13500		401-13500		401-13500		0-1000		0-1000		0-1000	
Surface Type	Unpaved		Paved		All		Unpaved		Paved		All	
Total Crashes	183	-	31,285	-	31,468	-	21,700	-	24,599	-	46,299	-
Total Daily VMT	57,540	-	8,603,000	-	8,661,000	-	3,160,000	-	6,390,000	-	9,550,000	-
Total Centerline-Miles	76	-	9,523	-	9,600	-	71,311	-	15,471	-	86,781	-
Weighted Average of ADT	750	-	900	-	900	-	44	-	410	-	110	-
Crash Rate (per 100M VMT)	124	-	142	-	142	-	269	-	151	-	190	-
Crash Density	2.39	-	3.29	-	3.28	-	0.30	-	1.59	-	0.53	-
CRASH SEVERITY	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
Fatal	1	0.5%	494	1.6%	495	1.6%	293	1.4%	404	1.6%	697	1.5%
Major Injury	8	4.4%	1,594	5.1%	1,602	5.1%	1,228	5.7%	1,338	5.4%	2,566	5.5%
Minor Injury	39	21.3%	3,890	12.4%	3,929	12.5%	3,699	17.0%	3,248	13.2%	6,947	15.0%
Possible/Unknown	39	21.3%	4,911	15.7%	4,950	15.7%	4,046	18.6%	3,721	15.1%	7,767	16.8%
Property Damage Only	96	52.5%	20,396	65.2%	20,492	65.1%	12,434	57.3%	15,888	64.6%	28,322	61.2%
CRASH TYPE												
MV (No Ani/Obj on Road)	49	26.8%	6,518	20.8%	6,567	20.9%	4,049	18.7%	3,954	16.1%	8,003	17.3%
SV ROR (No Ani/Obj on Road)	103	56.3%	11,051	35.3%	11,154	35.4%	12,370	57.0%	9,379	38.1%	21,749	47.0%
SV Other (No Ani/Obj on Road)	7	3.8%	1,391	4.4%	1,398	4.4%	688	3.2%	1,121	4.6%	1,809	3.9%
SV ROR (Ani/Obj on Road)	6	3.3%	783	2.5%	789	2.5%	1,283	5.9%	765	3.1%	2,048	4.4%
SV Other (Ani/Obj on Road)	0	0.0%	100	0.3%	100	0.3%	44	0.2%	95	0.4%	139	0.3%
Hit Animal	18	9.8%	11,442	36.6%	11,460	36.4%	3,266	15.1%	9,285	37.7%	12,551	27.1%

MANNER OF CRASH/COLLISION												
MV Head-on	4	2.2%	470	1.5%	474	1.5%	500	2.3%	278	1.1%	778	1.7%
MV Read-end	11	6.0%	1,785	5.7%	1,796	5.7%	743	3.4%	901	3.7%	1,644	3.6%
MV Oncoming left turn	4	2.2%	572	1.8%	576	1.8%	318	1.5%	352	1.4%	670	1.4%
MV Broadside	17	9.3%	1,807	5.8%	1,824	5.8%	1,375	6.3%	1,178	4.8%	2,553	5.5%
MV Sideswipe-Same Dir.	4	2.2%	894	2.9%	898	2.9%	305	1.4%	613	2.5%	918	2.0%
MV Sideswipe-Oppos. Dir.	7	3.8%	590	1.9%	597	1.9%	527	2.4%	373	1.5%	900	1.9%
MV Other	2	1.1%	400	1.3%	402	1.3%	281	1.3%	259	1.1%	540	1.2%
SV Coll. with Fixed Obj.	52	28.4%	5,802	18.5%	5,854	18.6%	5,532	25.5%	4,870	19.8%	10,402	22.5%
SV Overturn/Rollover	36	19.7%	3,205	10.2%	3,241	10.3%	4,419	20.4%	2,796	11.4%	7,215	15.6%
SV Collw/FixObj+Over/Roll	20	10.9%	2,573	8.2%	2,593	8.2%	3,507	16.2%	2,231	9.1%	5,738	12.4%
SV Other	8	4.4%	1,745	5.6%	1,753	5.6%	927	4.3%	1,463	5.9%	2,390	5.2%
Hit Animal	18	9.8%	11,442	36.6%	11,460	36.4%	3,266	15.1%	9,285	37.7%	12,551	27.1%
SPEED/WEATHER-SURFACE RELATION												
Speed Rel	89	48.6%	6,119	19.6%	6,208	19.7%	9,463	43.6%	5,344	21.7%	14,807	32.0%
Weather-Surface Rel	13	7.1%	2,683	8.6%	2,696	8.6%	1,528	7.0%	2,030	8.3%	3,558	7.7%
Speed&Weather-Surface Rel	17	9.3%	4,685	15.0%	4,702	14.9%	2,258	10.4%	3,232	13.1%	5,490	11.9%
Other/Unknown	64	35.0%	17,798	56.9%	17,862	56.8%	8,451	38.9%	13,993	56.9%	22,444	48.5%
LIGHT CONDITIONS												
Day	109	59.6%	11,999	38.4%	12,108	38.5%	10,710	49.4%	9,088	36.9%	19,798	42.8%
Dark, dusk or dawn	54	29.5%	12,058	38.5%	12,112	38.5%	8,729	40.2%	10,177	41.4%	18,906	40.8%
Other/Unknown	20	10.9%	7,228	23.1%	7,248	23.0%	2,261	10.4%	5,334	21.7%	7,595	16.4%
YOUNGER AND OLDER DRIVER INVOLVEMENT												
Age 14 or below involved	3	1.6%	108	0.3%	111	0.4%	271	1.2%	92	0.4%	363	0.8%
Ages 15-19 involved	66	36.1%	6,268	20.0%	6,334	20.1%	7,541	34.8%	4,973	20.2%	12,514	27.0%
Age 65 or above involved	11	6.0%	2,596	8.3%	2,607	8.3%	1,121	5.2%	1,965	8.0%	3,086	6.7%
Other/Unknown	103	56.3%	22,313	71.3%	22,416	71.2%	12,767	58.8%	17,569	71.4%	30,336	65.5%
DRUG/ALCOHOL INVOLVEMENT												
Impaired	14	7.7%	2,049	6.5%	2,063	6.6%	1,824	8.4%	1,685	6.8%	3,509	7.6%
Unimpaired	169	92.3%	29,236	93.5%	29,405	93.4%	19,876	91.6%	22,914	93.2%	42,790	92.4%

TERRAIN												
Flat	13,941	31.3%	44	24.0%	10,115	32.3%	10,159	32.3%	5,899	27.2%	7,727	31.4%
Rolling	27,339	61.3%	103	56.3%	19,079	61.0%	19,182	61.0%	14,044	64.7%	14,969	60.9%
Hilly	3,293	7.4%	36	19.7%	2,091	6.7%	2,127	6.8%	1,735	8.0%	1,903	7.7%
Other/Unknown	0	0.0%	0	0.0%	0	0.0%	0	0.0%	22	0.1%	0	0.0%
FARM VEHICLE INVOLVEMENT												
Farm vehicle and other	480	1.1%	0	0.0%	343	1.1%	343	1.1%	242	1.1%	340	1.4%
Farm vehicle only	57	0.1%	0	0.0%	31	0.1%	31	0.1%	100	0.5%	34	0.1%
No farm vehicle	44,036	98.8%	183	100.0%	30,911	98.8%	31,094	98.8%	21,358	98.4%	24,225	98.5%

State of Iowa (2001-2007)

	SECONDARY 0-13500						PRIMARY					
Road System	Secondary		Secondary		Secondary-ALL		Primary		Primary		Primary-ALL	
AADT Range	0-13500		0-13500		0-13500		70-1000		1001-12200		70-12200	
Surface Type	Unpaved		Paved		All		All Paved		All Paved		All Paved	
Total Crashes	21,725	-	39,358	-	61,083	-	1,995	-	32,045	-	34,040	-
Total Daily VMT	3,181,000	-	10,590,000	-	13,770,000	-	583,600	-	12,880,000	-	13,460,000	-
Total Centerline-Miles	71,321	-	18,007	-	89,328	-	761	-	5,202	-	5,963	-
Weighted Average of ADT	45	-	590	-	150	-	770	-	2,500	-	2,300	-
Crash Rate (per 100M VMT)	267	-	146	-	174	-	134	-	97	-	99	-
Crash Density	0.30	-	2.19	-	0.68	-	2.62	-	6.16	-	5.71	-
CRASH SEVERITY	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Fatal	293	1.3%	623	1.6%	916	1.5%	28	1.4%	535	1.7%	563	1.7%
Major Injury	1,228	5.7%	2,047	5.2%	3,275	5.4%	80	4.0%	1,330	4.2%	1,410	4.1%
Minor Injury	3,700	17.0%	4,969	12.6%	8,669	14.2%	189	9.5%	3,244	10.1%	3,433	10.1%
Possible/Unknown	4,052	18.7%	6,180	15.7%	10,232	16.8%	301	15.1%	4,841	15.1%	5,142	15.1%
Property Damage Only	12,452	57.3%	25,539	64.9%	37,991	62.2%	1,397	70.0%	22,095	68.9%	23,492	69.0%
CRASH TYPE												
MV (No Ani/Obj on Road)	4,057	18.7%	7,740	19.7%	11,797	19.3%	308	15.4%	9,231	28.8%	9,539	28.0%
SV ROR (No Ani/Obj on Road)	12,380	57.0%	14,223	36.1%	26,603	43.6%	527	26.4%	6,839	21.3%	7,366	21.6%
SV Other (No Ani/Obj on Road)	689	3.2%	1,773	4.5%	2,462	4.0%	87	4.4%	1,373	4.3%	1,460	4.3%
SV ROR (Ani/Obj on Road)	1,285	5.9%	1,077	2.7%	2,362	3.9%	53	2.7%	438	1.4%	491	1.4%
SV Other (Ani/Obj on Road)	44	0.2%	137	0.3%	181	0.3%	14	0.7%	95	0.3%	109	0.3%
Hit Animal	3,270	15.1%	14,408	36.6%	17,678	28.9%	1,006	50.4%	14,069	43.9%	15,075	44.3%

MANNER OF CRASH/COLLISION												
MV Head-on	501	2.3%	544	1.4%	1,045	1.7%	14	0.7%	841	2.6%	855	2.5%
MV Read-end	747	3.4%	2,049	5.2%	2,796	4.6%	67	3.4%	3,144	9.8%	3,211	9.4%
MV Oncoming left turn	318	1.5%	670	1.7%	988	1.6%	29	1.5%	663	2.1%	692	2.0%
MV Broadside	1,377	6.3%	2,205	5.6%	3,582	5.9%	85	4.3%	1,811	5.7%	1,896	5.6%
MV Sideswipe-Same Dir.	305	1.4%	1,084	2.8%	1,389	2.3%	58	2.9%	1,319	4.1%	1,377	4.0%
MV Sideswipe-Oppos. Dir.	528	2.4%	705	1.8%	1,233	2.0%	30	1.5%	1,005	3.1%	1,035	3.0%
MV Other	281	1.3%	483	1.2%	764	1.3%	25	1.3%	448	1.4%	473	1.4%
SV Coll. with Fixed Obj.	5,539	25.5%	7,448	18.9%	12,987	21.3%	273	13.7%	3,568	11.1%	3,841	11.3%
SV Overturn/Rollover	4,423	20.4%	4,163	10.6%	8,586	14.1%	185	9.3%	2,094	6.5%	2,279	6.7%
SV Collw/FixObj+Over/Roll	3,508	16.1%	3,354	8.5%	6,862	11.2%	109	5.5%	1,410	4.4%	1,519	4.5%
SV Other	928	4.3%	2,245	5.7%	3,173	5.2%	114	5.7%	1,673	5.2%	1,787	5.2%
Hit Animal	3,270	15.1%	14,408	36.6%	17,678	28.9%	1,006	50.4%	14,069	43.9%	15,075	44.3%
SPEED/WEATHER-SURFACE RELATION												
Speed Rel	9,474	43.6%	8,080	20.5%	17,554	28.7%	341	17.1%	4,650	14.5%	4,991	14.7%
Weather-Surface Rel	1,529	7.0%	3,359	8.5%	4,888	8.0%	162	8.1%	2,891	9.0%	3,053	9.0%
Speed&Weather-Surface Rel	2,259	10.4%	5,594	14.2%	7,853	12.9%	151	7.6%	3,588	11.2%	3,739	11.0%
Other/Unknown	8,463	39.0%	22,325	56.7%	30,788	50.4%	1,341	67.2%	20,916	65.3%	22,257	65.4%
LIGHT CONDITIONS												
Day	10,722	49.4%	15,005	38.1%	25,727	42.1%	636	31.9%	12,255	38.2%	12,891	37.9%
Dark, dusk or dawn	8,738	40.2%	15,556	39.5%	24,294	39.8%	825	41.4%	11,727	36.6%	12,552	36.9%
Other/Unknown	2,265	10.4%	8,797	22.4%	11,062	18.1%	534	26.8%	8,063	25.2%	8,597	25.3%
YOUNGER AND OLDER DRIVER INVOLVEMENT												
Age 14 or below involved	271	1.2%	141	0.4%	412	0.7%	3	0.2%	99	0.3%	102	0.3%
Ages 15-19 involved	7,548	34.7%	8,007	20.3%	15,555	25.5%	275	13.8%	4,959	15.5%	5,234	15.4%
Age 65 or above involved	1,122	5.2%	3,229	8.2%	4,351	7.1%	245	12.3%	4,129	12.9%	4,374	12.8%
Other/Unknown	12,784	58.8%	27,981	71.1%	40,765	66.7%	1,472	73.8%	22,858	71.3%	24,330	71.5%
DRUG/ALCOHOL INVOLVEMENT												
Impaired	1,825	8.4%	2,649	6.7%	4,474	7.3%	93	4.7%	1,351	4.2%	1,444	4.2%
Unimpaired	19,900	91.6%	36,709	93.3%	56,609	92.7%	1,902	95.3%	30,694	95.8%	32,596	95.8%

TERRAIN												
Flat	5,904	27.2%	12,624	32.1%	18,528	30.3%	633	31.7%	12,633	39.4%	13,266	39.0%
Rolling	14,062	64.7%	23,987	60.9%	38,049	62.3%	1,161	58.2%	17,956	56.0%	19,117	56.2%
Hilly	1,737	8.0%	2,747	7.0%	4,484	7.3%	201	10.1%	1,456	4.5%	1,657	4.9%
Other/Unknown	22	0.1%	0	0.0%	22	0.0%		0.0%		0.0%	0	0.0%
FARM VEHICLE INVOLVEMENT												
Farm vehicle and other	242	1.1%	440	1.1%	682	1.1%	24	1.2%	246	0.8%	270	0.8%
Farm vehicle only	100	0.5%	41	0.1%	141	0.2%	1	0.1%	11	0.0%	12	0.0%
No farm vehicle	21,383	98.4%	38,877	98.8%	60,260	98.7%	1,970	98.7%	31,788	99.2%	33,758	99.2%

ALL	
ALL	Road System
0-13500	AADT Range
All	Surface Type

95,123	-	Total Crashes
27,230,000	-	Total Daily VMT
95,291	-	Total Centerline-Miles
290	-	Weighted Average of ADT
137	-	Crash Rate (per 100M VMT)
1.00	-	Crash Density

Frequency	%	CRASH SEVERITY
1,479	1.6%	Fatal
4,685	4.9%	Major Injury
12,102	12.7%	Minor Injury
15,374	16.2%	Possible/Unknown
61,483	64.6%	Property Damage Only

		CRASH TYPE
21,336	22.4%	MV (No Ani/Obj on Road)
33,969	35.7%	SV ROR (No Ani/Obj on Road)
3,922	4.1%	SV Other (No Ani/Obj on Road)
2,853	3.0%	SV ROR (Ani/Obj on Road)
290	0.3%	SV Other (Ani/Obj on Road)
32,753	34.4%	Hit Animal

		MANNER OF CRASH/COLLISION
1,900	2.0%	MV Head-on
6,007	6.3%	MV Read-end
1,680	1.8%	MV Oncoming left turn
5,478	5.8%	MV Broadside
2,766	2.9%	MV Sideswipe-Same Dir.
2,268	2.4%	MV Sideswipe-Oppos. Dir.
1,237	1.3%	MV Other
16,828	17.7%	SV Coll. with Fixed Obj.
10,865	11.4%	SV Overturn/Rollover
8,381	8.8%	SV Collw/FixObj+Over/Roll
4,960	5.2%	SV Other
32,753	34.4%	Hit Animal
		SPEED/WEATHER-SURFACE RELATION
22,545	23.7%	Speed Rel
7,941	8.3%	Weather-Surface Rel
11,592	12.2%	Speed&Weather-Surface Rel
53,045	55.8%	Other/Unknown
		LIGHT CONDITIONS
38,618	40.6%	Day
36,846	38.7%	Dark, dusk or dawn
19,659	20.7%	Other/Unknown
		YOUNGER AND OLDER DRIVER INVOLVEMENT
514	0.5%	Age 14 or below involved
20,789	21.9%	Ages 15-19 involved
8,725	9.2%	Age 65 or above involved
65,095	68.4%	Other/Unknown
		DRUG/ALCOHOL INVOLVEMENT
5,918	6.2%	Impaired
89,205	93.8%	Unimpaired

		TERRAIN
31,794	33.4%	Flat
57,166	60.1%	Rolling
6,141	6.5%	Hilly
22	0.0%	Other/Unknown
		FARM VEHICLE INVOLVEMENT
952	1.0%	Farm vehicle and other
153	0.2%	Farm vehicle only
94,018	98.8%	No farm vehicle

APPENDIX 8. LIMDEP MODEL

Variables

			The factor "increasing" the probability of a more severe crash:
X3	SRFCTYPE_	-	Paved surface
X9	FLATTRRN	-	Flat terrain
X10	RLLGTRRN	-	Rolling terrain
X11	HLLYTRRN	-	Hilly terrain
X15	SUMMER	-	Months April, May, June, July, Aug, Sep
X16	WEEKEND	-	Saturday and Sunday
X19	NIGHT	+	(Not the hours 10pm-3am)
X31	COLFIXOB	-	Collision with fixed object
X32	HITANIML	+	Non-animal crashes
X33	OVERROLL	-	Overturn and/or rollover crashes
X34	MVBRDSID	-	Multi-vehicle broadside collisions
X35	IMPAIRED	-	Impaired driving
X36	ENVCOCIR_	+	(No apparent environmental contribution)
X37	DARK	+	Daytime
X39	SPEEDREL	-	Speed
X40	WESURREL	+	(No apparent weather or surface contribution)
X41	YOUNGINV	-	Younger driver (?19) involvement
X42	OLDERINV	-	Older driver (?65) involvement
X43	TOTRUPO	+	Less total rural population
X47	VMTPRUPO	+	Less VMT per rural population
X50	CONATINT	-	Existence of traffic controls at intersections throughout the county
X55	**CRSHORDT**		
Num. Obsrv.	16942		
Iterations	34		
Num. Var.	22		
L.L.F.	-14828.75		
R.L.L.F.	-15802.50		
Ro-sqrd	0.0616200		
Corr. Ro-sqrd	0.0602278		
Chi-sqrd	1947.508		

TRIAL	1	2	3	4	5	6	7	8	9	10	11	(7)12	13	14	(7)15	7	
X1	CRSHDENS_																
X2	CRSHRATE_																
X3	SRFCTYPE_	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X4	SRFCWDTH	+	+	+	+	+	+										
X5	SHLDR																
X6	SHLDRTYP	+															
X7	SHLDRWDH																
X8	NUMCRSHS																
X9	FLATTRRN	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X10	RLLGTRRN	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X11	HLLYTRRN	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X12	AADT_	+	+	+													
X13	LANLNGTH																
X14	DAILYVMT_																
X15	SUMMER	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X16	WEEKEND	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X17	AMPEAK	+	+	+													
X18	PMPEAK	+	+	+	+	+											
X19	NIGHT	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X20	FHEVONRD	+	+														
X21	CRASHSEV																
X22	FATALITY																
X23	INJURY																
X24	MAJORINJ																
X25	MINORINJ																
X26	POSSINJ																
X27	UNKWNINJ																
X28	FATMAJIN																
X29	PROPDMG_																
X30	MULTIVEH	+	+														
X31	COLFIXOB	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X32	HITANIML	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X33	OVERROLL	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X34	MVBRDSID	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X35	IMPAIRED	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

X36	ENVCOCIR_	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X37	DARK	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X38	INTRSCTN	+	+	+	+												
X39	SPEEDREL	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X40	WESURREL	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X41	YOUNGINV	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X42	OLDERINV	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
X43	TOTRUPO	+	+	+	+	+	+	+				+	+	+	+	+	+
X44	~~RUFARMPO~~								+								
X45	~~RUPOPCLM~~									+							
X46	~~RUFPPCLM~~										+	+					
X47	VMTPRUPO	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
X48	CRSPRUPO															+	
X49	KAPRUPO																
X50	CONATINT	+	+	+	+	+	+	+	+	+	+	+				+	+
X51	~~RETROSUR~~												+				
X52	CRSHDATA													+			
X53	STOPRAIL														+		
X54	DRIVEWAY	+	+	+	+												
X55	**CRSHORDT**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**
X56	CRSHORDS																
	Num. Obsrv.	16942	16942	16942	16942	16942	16942	16942	16942	16942	16942	16942	16936	15996	16546	16942	16942
	Iterations	51	51	50	40	36	38	34	36	87	95	37	35	36	35	36	34
	Num. Var.	31	30	28	26	24	23	22	22	22	22	23	22	22	22	22	22
	L.L.F.	-14824.72	-14824.72	-14824.83	-14827.04	-14827.22	-14827.85	-14828.75	-14833.23	-14830.24	-14830.37	-14828.25	-14834.67	-14037.25	-14548.31	-14832.41	-14828.75
	R.L.L.F.	-15802.50	-15802.50	-15802.50	-15802.50	-15802.50	-15802.50	-15802.50	-15802.50	-15802.50	-15802.50	-15802.50	-15766.20	-14966.31	-15507.57	-15802.50	-15802.50
	Ro-sqrd	0.0619	0.0619	0.0619	0.0617	0.0617	0.0617	0.0616	0.0613	0.0615	0.0615	0.0617	0.0591	0.0621	0.0619	0.0614	0.0616
	Corr. Ro-sqrd	0.0599	0.0600	0.0601	0.0601	0.0602	0.0602	0.0602	0.0599	0.0601	0.0601	0.0602	0.0577	0.0606	0.0604	0.0600	0.0602
	Chi-sqrd	1955.56	1955.56	1955.34	1950.92	1950.57	949.297	1947.50	1938.53	1944.51	1944.25	1948.50	1863.06	1858.12	1918.50	1940.17	1947.508

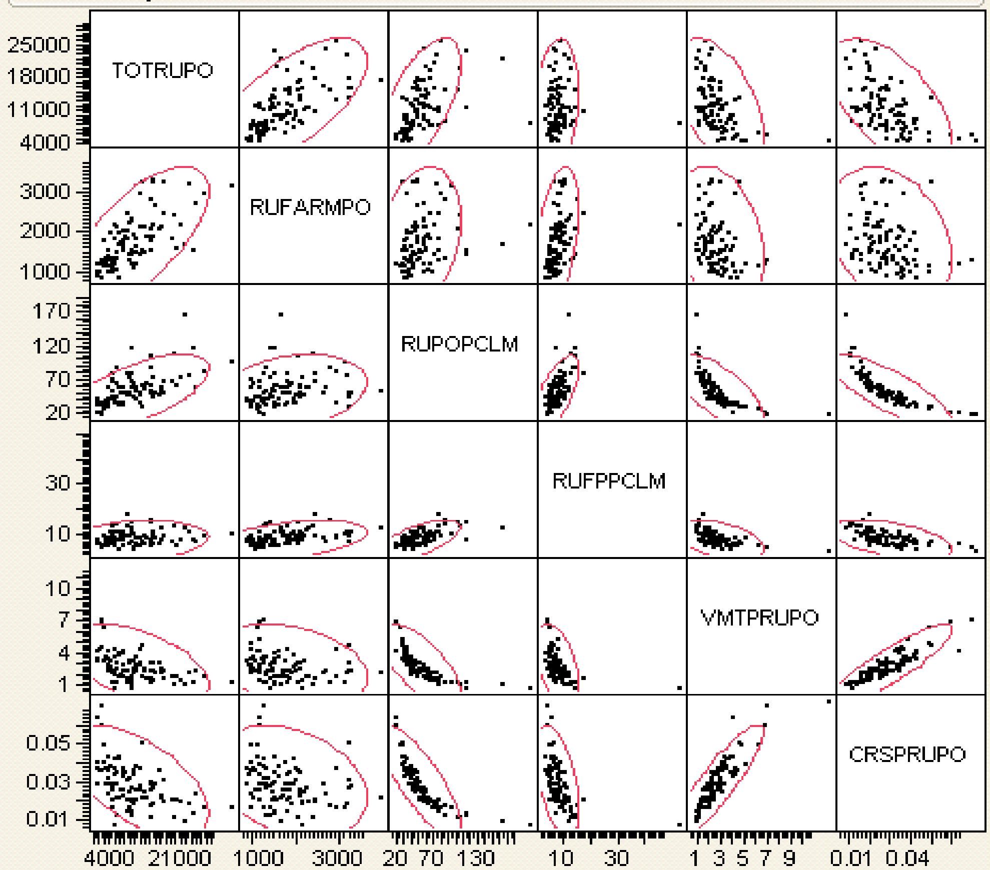
model_input_1_total- Multivariate

Multivariate

Correlations

	TOTRUPO	RUFARMPO	RUPOPCLM	RUFPPCLM	VMTPRUPO	CRSPRUPO
TOTRUPO	1.0000	0.6641	0.6220	0.1654	-0.5032	-0.5778
RUFARMPO	0.6641	1.0000	0.2621	0.4235	-0.2941	-0.3007
RUPOPCLM	0.6220	0.2621	1.0000	0.6344	-0.6833	-0.8045
RUFPPCLM	0.1654	0.4235	0.6344	1.0000	-0.4690	-0.5188
VMTPRUPO	-0.5032	-0.2941	-0.6833	-0.4690	1.0000	0.8731
CRSPRUPO	-0.5778	-0.3007	-0.8045	-0.5188	0.8731	1.0000

Scatterplot Matrix



County Data

COUN TYNO	TOT RUPO	RUFA RMPO	RUPO PCLM	RUFP PCLM	VMTP RUPO	CRSP RUPO	KAP RUPO	CONA TINT	RETR OSUR	CRSH DATA	STOP RAIL
1	8243	1341	41.09	6.68	2.01	0.0289	0.0015	0	1	0	0
2	4482	948	38.69	8.18	2.82	0.0341	0.0011	1	1	1	0
3	10543	2021	47.90	9.18	2.37	0.0304	0.0012	1	0	1	0
4	8141	1304	34.95	5.60	3.53	0.0425	0.0031	9999	9999	9999	9999
5	6830	1375	40.43	8.14	2.39	0.0316	0.0028	1	0	1	0
6	17817	2456	65.76	9.06	1.61	0.0189	0.0021	1	0	1	1
7	19825	2424	107.15	13.10	1.09	0.0111	0.0007	9999	9999	9999	9999
8	13591	1536	61.10	6.90	1.70	0.0210	0.0015	0	1	1	0
9	15807	2144	72.88	9.89	1.46	0.0180	0.0009	9999	9999	9999	9999
10	15283	2784	86.36	15.73	1.16	0.0172	0.0014	9999	9999	9999	9999
11	9730	1603	32.95	5.43	4.15	0.0331	0.0021	9999	9999	9999	9999
12	15305	2080	105.43	14.33	1.15	0.0115	0.0012	9999	9999	9999	9999
13	11115	1435	73.15	9.44	1.58	0.0166	0.0022	0	0	1	0
14	11513	2306	59.36	11.89	1.69	0.0194	0.0013	0	1	1	0
15	7801	1274	77.85	12.71	1.24	0.0167	0.0018	0	0	0	0
16	15178	1763	50.34	5.85	2.23	0.0289	0.0012	1	0	9999	0
17	9888	1509	36.14	5.52	4.00	0.0351	0.0023	0	1	1	0
18	8051	1833	35.00	7.97	4.30	0.0334	0.0026	0	1	0	1
19	9729	1745	57.31	10.28	2.31	0.0222	0.0019	0	1	1	0
20	4758	1210	21.94	5.58	4.07	0.0633	0.0034	1	0	0	1
21	6383	1344	30.84	6.49	3.63	0.0367	0.0044	9999	9999	9999	9999
22	17812	3236	50.13	9.11	2.37	0.0308	0.0012	1	0	1	0
23	16020	2627	49.85	8.18	2.10	0.0284	0.0019	0	0	1	0
24	9790	2012	35.90	7.38	2.88	0.0368	0.0027	9999	9999	9999	9999
25	19271	1798	68.04	6.35	1.71	0.0209	0.0016	0	1	1	1
26	8541	2093	43.53	10.67	2.58	0.0350	0.0025	1	0	0	9999
27	8689	1059	63.72	7.77	2.48	0.0213	0.0022	1	0	1	0
28	13028	2951	35.96	8.15	4.29	0.0369	0.0015	9999	9999	9999	9999
29	12068	1085	43.59	3.92	3.25	0.0355	0.0015	9999	9999	9999	9999
30	4956	894	40.74	7.35	3.18	0.0282	0.0020	0	1	0	0
31	22926	3188	76.87	10.69	2.17	0.0186	0.0011	1	0	1	0
32	4440	813	16.67	3.05	12.36	0.0721	0.0027	9999	9999	9999	9999
33	15552	3274	50.64	10.66	2.25	0.0273	0.0013	9999	9999	9999	9999
34	9440	1711	50.82	9.21	2.01	0.0255	0.0012	0	1	1	0
35	7097	1543	29.83	6.49	3.44	0.0426	0.0010	9999	9999	9999	9999
36	8010	1035	38.87	5.02	3.61	0.0373	0.0041	1	1	1	0
37	5921	1124	26.04	4.94	6.27	0.0495	0.0046	1	1	1	0
38	12369	1456	52.89	6.23	2.41	0.0205	0.0015	0	0	1	0
39	11353	1164	66.35	6.80	1.33	0.0205	0.0017	0	0	0	0

40	8550	1463	43.85	7.50	2.98	0.0282	0.0022	1	1	1	1
41	8986	1670	58.40	10.85	1.85	0.0213	0.0032	9999	9999	9999	9999
42	13983	1459	55.53	5.79	2.24	0.0247	0.0013	0	0	0	0
43	12503	1612	40.91	5.27	3.63	0.0378	0.0029	9999	9999	9999	9999
44	12035	1205	44.60	4.47	2.51	0.0343	0.0027	0	1	1	0
45	6237	1761	33.16	9.36	3.25	0.0396	0.0024	9999	9999	9999	9999
46	5322	1010	32.43	6.15	4.30	0.0357	0.0028	0	0	1	0
47	7837	1068	42.72	5.82	2.40	0.0260	0.0019	9999	9999	9999	9999
48	15671	1864	50.97	6.06	2.29	0.0284	0.0015	0	0	9999	0
49	10794	2441	78.12	17.67	1.59	0.0205	0.0019	9999	9999	9999	9999
50	20928	2180	73.63	7.67	1.39	0.0191	0.0016	1	0	1	1
51	6830	1150	33.53	5.65	4.16	0.0436	0.0028	0	0	0	1
52	25825	2924	82.64	9.36	1.76	0.0165	0.0011	0	1	9999	0
53	11310	2244	57.11	11.33	1.81	0.0269	0.0021	1	1	1	0
54	11400	1443	116.03	14.69	0.66	0.0119	0.0018	1	0	1	0
55	11265	2186	45.77	8.88	3.16	0.0244	0.0025	9999	9999	9999	9999
56	15370	1530	51.69	5.15	3.13	0.0295	0.0020	0	1	1	0
57	31262	3146	95.16	9.58	1.28	0.0160	0.0009	0	0	1	0
58	12183	1185	57.65	5.61	2.81	0.0252	0.0015	0	0	1	0
59	5001	894	37.80	6.76	3.19	0.0372	0.0024	1	0	0	0
60	11763	1906	62.52	10.13	2.18	0.0180	0.0008	0	0	1	0
61	9161	1944	34.92	7.41	3.76	0.0421	0.0044	1	0	1	0
62	10234	1884	50.26	9.25	2.36	0.0350	0.0018	1	1	1	0
63	15198	1873	62.06	7.65	1.54	0.0254	0.0012	1	0	1	1
64	13189	1443	47.04	5.15	2.82	0.0281	0.0014	0	1	1	0
65	8972	866	33.26	3.21	3.94	0.0431	0.0025	1	0	0	0
66	7494	1954	41.63	10.86	2.69	0.0288	0.0028	9999	9999	9999	9999
67	7308	1301	40.14	7.15	3.25	0.0380	0.0025	9999	9999	9999	9999
68	4503	987	28.40	6.22	4.89	0.0495	0.0033	1	1	1	0
69	5680	871	34.55	5.30	4.53	0.0361	0.0023	1	0	0	0
70	12179	1816	56.82	8.47	2.37	0.0254	0.0016	0	0	1	0
71	10543	1800	78.20	13.35	1.20	0.0139	0.0023	0	1	1	0
72	4258	1192	29.85	8.36	5.17	0.0385	0.0012	0	1	1	0
73	5778	1301	19.15	4.31	7.01	0.0694	0.0069	9999	9999	9999	9999
74	6547	1238	39.36	7.44	3.37	0.0287	0.0029	9999	9999	9999	9999
75	15831	3208	42.95	8.70	3.02	0.0271	0.0032	0	1	1	0
76	8662	1336	87.93	13.56	1.31	0.0125	0.0013	9999	9999	9999	9999
77	21736	1677	163.66	12.63	1.06	0.0092	0.0008	1	1	1	1
78	23801	2682	57.97	6.53	2.40	0.0233	0.0018	1	1	1	0
79	9700	1788	49.01	9.03	1.70	0.0252	0.0035	1	1	1	1
80	5469	1169	20.55	4.39	6.79	0.0592	0.0031	1	0	1	9999
81	11529	1534	78.83	10.49	1.12	0.0145	0.0021	1	0	1	0
82	23559	1536	116.06	7.57	1.18	0.0128	0.0009	0	0	1	1

83	8144	2140	202.46	53.20	0.62	0.0066	0.0007	1	0	0	0
84	17201	3966	52.61	12.13	2.14	0.0210	0.0021	0	0	1	0
85	20113	1594	62.18	4.93	1.79	0.0206	0.0015	0	1	1	0
86	13102	2107	50.63	8.14	3.02	0.0260	0.0011	1	1	1	0
87	6958	971	38.78	5.41	2.92	0.0358	0.0020	1	0	0	0
88	4831	990	33.30	6.82	3.45	0.0404	0.0037	0	0	0	0
89	7809	1339	51.65	8.86	2.20	0.0269	0.0010	1	0	1	0
90	10905	1303	50.03	5.98	2.98	0.0313	0.0018	1	1	1	0
91	16858	2059	47.09	5.75	3.03	0.0361	0.0016	1	0	1	0
92	13880	2095	60.58	9.14	2.48	0.0244	0.0015	1	0	1	1
93	6730	993	57.72	8.52	2.53	0.0233	0.0021	1	0	1	0
94	14543	1865	63.19	8.10	1.64	0.0218	0.0016	0	1	1	0
95	7804	987	70.62	8.93	2.09	0.0167	0.0024	9999	9999	9999	9999
96	13701	3216	29.79	6.99	4.65	0.0507	0.0026	0	0	1	0
97	17176	2130	58.02	7.19	2.56	0.0229	0.0013	1	0	1	0
98	7909	1212	67.15	10.29	2.10	0.0206	0.0019	9999	9999	9999	9999
99	8295	1168	43.87	6.18	2.17	0.0291	0.0019	1	1	0	0

Limdep Output

```
--> SAVE;file="C:\_projects\ITSDS\working\4000-
LVRR\Analysis\Version2\Statewi...
--> skip$
--> ordered;lhs=x55;rhs=one,x3,x9,x10,x11,x15,x16,x19,
    x31,x32,x33,x34,x35,x36,x37,x39,x40,x41,x42,x43,x47,x50;
    marginal effects$

 ***********************************************************************
 * NOTE: Deleted  12595 observations with missing data. N is now  16942 *
 ***********************************************************************

Line search does not improve fn. Exit iterations. Status=3
Check derivatives (with ;OUTPUT=3). This may be a solution
if several iterations have been computed, not if only one.

  Error   806: (The log likelihood is flat at the current estimates.)
+---------------------------------------------+
| Ordered Probability Model                   |
| Maximum Likelihood Estimates                |
| Model estimated: Aug 25, 2009 at 03:42:45PM.|
| Dependent variable                   X55    |
| Weighting variable                  None    |
| Number of observations             16942    |
| Iterations completed                  34    |
| Log likelihood function        -14828.75    |
| Number of parameters                  24    |
| Info. Criterion: AIC =           1.75336    |
|   Finite Sample: AIC =           1.75337    |
| Info. Criterion: BIC =           1.76433    |
| Info. Criterion:HQIC =           1.75698    |
| Restricted log likelihood      -15802.50    |
| McFadden Pseudo R-squared       .0616202    |
| Chi squared                     1947.508    |
| Degrees of freedom                    21    |
| Prob[ChiSqd > value] =          .0000000    |
| Underlying probabilities based on Normal    |
+---------------------------------------------+

+---------------------------------------------+
| Ordered Probability Model                   |
| Cell frequencies for outcomes               |
|  Y Count Freq  Y Count Freq  Y Count Freq   |
|  0    43 .002  1  1435 .084  2  6741 .397   |
|  3  8723 .514                               |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Index function for probability					
Constant	5.87037782	.58250690	10.078	.0000	
X3	-.12024630	.02241116	-5.365	.0000	.22665565
X9	-1.97323771	.57906332	-3.408	.0007	.24135285
X10	-1.96505205	.57889248	-3.395	.0007	.67046394
X11	-1.78939521	.57947013	-3.088	.0020	.08747491
X15	-.10993743	.01929299	-5.698	.0000	.51174596
X16	-.03873581	.01956040	-1.980	.0477	.33160194
X19	.08403488	.02852121	2.946	.0032	.18622359
X31	-.09105320	.02078142	-4.381	.0000	.45502302
X32	.53941032	.04408067	12.237	.0000	.08853736
X33	-.17820311	.02078692	-8.573	.0000	.38614095
X34	-.28390287	.03890489	-7.297	.0000	.07201039
X35	-.61787974	.03131171	-19.733	.0000	.09868965
X36	.04403534	.02233710	1.971	.0487	.30893637
X37	.07936555	.02322816	3.417	.0006	.44174242
X39	-.12859173	.02250844	-5.713	.0000	.59910282
X40	.19794681	.02508203	7.892	.0000	.20623303
X41	-.03616464	.01945617	-1.859	.0631	.36140951
X42	-.00053713	.356204D-04	-15.079	.0000	37.7330303
X43	.598189D-05	.183741D-05	3.256	.0011	13521.4125
X47	.03662743	.00988500	3.705	.0002	2.63381871
X50	-.07149960	.01855369	-3.854	.0001	.50076732
Threshold parameters for index					
Mu(1)	2.38039631	.01492415	159.500	.0000	
Mu(2)	3.78842872	.01494155	253.550	.0000	

Summary of Marginal Effects for Ordered Probability Model (probit)								
Variable	Y=00	Y=01	Y=02	Y=03	Y=04	Y=05	Y=06	Y=07
*X3	.0000	.0179	.0300	-.0479				
*X9	.0102	.4863	.1255	-.6220				
*X10	.0008	.2116	.4307	-.6430				
*X11	.0145	.5080	-.0036	-.5189				
*X15	.0000	.0156	.0282	-.0438				
*X16	.0000	.0056	.0099	-.0154				
*X19	.0000	-.0115	-.0220	.0335				
*X31	.0000	.0130	.0233	-.0363				
*X32	-.0001	-.0555	-.1506	.2062				
*X33	.0001	.0261	.0449	-.0710				
*X34	.0001	.0477	.0645	-.1124				
*X35	.0005	.1220	.1145	-.2370				
*X36	.0000	-.0062	-.0114	.0176				
*X37	.0000	-.0112	-.0204	.0316				
*X39	.0000	.0179	.0332	-.0512				
*X40	.0000	-.0259	-.0526	.0786				
*X41	.0000	.0052	.0092	-.0144				
X42	.0000	.0001	.0001	-.0002				
X43	.0000	.0000	.0000	.0000				
X47	.0000	-.0052	-.0094	.0146				
*X50	.0000	.0102	.0183	-.0285				

Cross tabulation of predictions. Row is actual, column is predicted.
Model = Probit . Prediction is number of the most probable cell.

Actual	Row Sum	0	1	2	3	4	5	6	7	8	9
0	43	37	6	0	0						
1	1435	2	0	682	751						
2	6741	2	1	2386	4352						
3	8723	0	0	1719	7004						
Col Sum	16942	41	7	4787	12107	0	0	0	0	0	0

The estimation equation for crash severity was as follows:

Z = 5.8704 – 0.1202 X3(SRFCTYPE) – 1.9732 X9(FLATTRRN) …

The thresholds for outputs of crash severity levels:

y = 1 (fatal or serious injury crash)	$Z \leq 2.38039631$
y = 2 (minor or possible injury crash)	$2.38039631 < Z \leq 3.78842872$
y = 3 (property damage only crash)	$Z > 3.78842872$