2004-22

Final Report

Accident Analysis of Significant Crash Rates for Low to Very Low Volume Roadways in 10 Minnesota Counties

Minnesota Department of Transportation

LRRB Local Road Research Board

Research

Technical Report Documentation Page

<table>
<tr><td>1. Report No.
MN/RC – 2004-22</td><td>2.</td><td colspan="2">3. Recipients Accession No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
ACCIDENT ANALYSIS OF SIGNIFICANT CRASH RATES FOR LOW TO VERY LOW VOLUME ROADWAYS IN 10 MINNESOTA COUNTIES</td><td colspan="2">5. Report Date
March 2004</td></tr>
<tr><td colspan="2">6.</td></tr>
<tr><td colspan="2">7. Author(s)
Michael G. Wade, Curtis Hammond, ChungGon Kim</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
University of Minnesota
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<tr><td colspan="2">11. Contract (C) or Grant (G) No.
(c) 81655 (wo) 15</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Organization Name and Address
Minnesota Department of Transportation
Office of Research Services
395 John Ireland Boulevard Mail Stop 330
St. Paul, Minnesota 55155</td><td colspan="2">13. Type of Report and Period Covered
Final Report</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">15. Supplementary Notes
http://www.lrrb.org/PDF/200422.pdf</td></tr>
<tr><td colspan="4">16. Abstract (Limit: 200 words)
Traffic data from 1996 and continuing through the first half of 2001 were analyzed for roadways with low to very low traffic volumes in ten southwestern Minnesota counties resulting in information about the causes of crashes.
Three sets of analysis were carried out on the database. First was a descriptive analysis of the data to determine the general frequency rates of accidents. A second identified dangerous roadways. Counting the number of crashes on specific roadways and dividing this number by the average daily traffic (ADT) on a roadway generated crash rates for those roadways, including county state aid highways (CSAHs), county highways, and township roads. Roadways with the highest five percent were considered significantly dangerous. Crash rates were generated for specific locations. This method identified 15 dangerous locations, nine on CSAHs, three on county highways, and two on township roads.
There were only 235 cases where no improper driving was indicated. The remaining 1,554 cases suggested that driver error was the major cause. The most likely factor in causing an accident on a highway with an ADT of less than 400 is a crash involving an animal. Road design factors such as number of lanes and the speed limit seem to be the factors related to these accidents.</td></tr>
<tr><td>17. Document Analysis/Descriptors
Low volume roads
Township Road
County State Aid Highways</td><td>
Crash analysis
County highways
CSAH</td><td colspan="2">18.Availability Statement
No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161</td></tr>
<tr><td>19. Security Class (this report)
Unclassified</td><td>20. Security Class (this page)
Unclassified</td><td>21. No. of Pages
27</td><td>22. Price</td></tr>
</table>

Accident Analysis of Significant Crash Rates for Low to Very Low Volume Roadways in 10 Minnesota Counties

Final Report

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March 2004

Published by

Minnesota Department of Transportation
Research Services Section
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Executive Summary

Data for 5 ½ years of traffic information beginning in 1996 and continuing through the first six months of 2001 were analyzed for roadways with low to very low traffic volumes in ten southwestern Minnesota counties. Three sets of analysis were carried out on the database. First was a descriptive analysis of the data to determine the general frequency rates and occurrence of accidents. A second analysis was designed to identify statistically dangerous roadways. This was achieved by counting the number of accident cases on specific roadways within each county and dividing this number by the average ADT on a roadway (data was included for any low-volume roads that had an ADT of less than 400). This analysis generated crash rates for those roadways. Crash rates for the roadways were standardized into z-scores, which were calculated for all the road types, including county state aid assisted highways (CSAHs), county highways, and township roads. When the crash rate of the roadway was within the highest five percent (z-score greater than or equal to 1.65 in each category of analysis), that roadway was considered to be significantly dangerous. Further analysis sought to identify the dangerous locations on each of the roadways. The number of accidents at a specific location was divided by a matched ADT, generating a crash rate at that location. When a location reported an accident but did not provide a matched ADT, the case was eliminated from the analysis. Thus, all crash rates were standardized using z-scores for each of the three types of roadways and if the crash rate of a location was within the high five percent in each category of analysis, then that location was considered to be significantly dangerous. This method identified a total of 15 dangerous locations, nine on CSAHs, three on county highways, and two on township roads. Further analysis sought to identify the most statistically likely contributing factors other than driver error, which yielded a total of 235 cases where no improper driving was indicated. The remaining 1,554 cases suggested that driver error was the major cause.

Analysis suggests that there are many factors other than improper driving that are closely related with these accidents. Other than driver error, the most likely factor in causing an accident on a highway with an ADT of less than 400 is a crash involving an animal. This suggests that such factors as lane and shoulder widths, changing of signage material, seasonal issues, and other factors presumed to be the underlying cause of accident occurrence appears to not be true in this data set. Instead, road design factors such as number of lanes (and whether or not they are separated) and the speed limit seem to be the environmental factors most related to these accidents. These factors, however, may not be modifiable.

Chapter 1: Introduction

This study analyzes traffic accidents on low to very low volume roadways (< 400 ADT) located in the southwestern region of Minnesota. The analysis is divided into three basic sections: first, the identification of common contributing factors to traffic accidents; second, the identification of the specific roads with significantly high crash rates; and third, the analysis of which factors play a significant role.

Chapter 2: Common Factors Contributing to Accidents

The first analysis sought to identify common contributing factors to traffic accidents that reported during the calendar year of 1996, 1997, 1998, 1999, 2000, and the first half of 2001 on low to very low volume roadways. The low to very low volume roadways are defined to the roadways that measured Average Daily Traffic (ADT) of less than 400.

The total number of data points employed in the study was 3,190 from 10 Counties located in the southwestern part of the Minnesota. The initial number of accident cases on County State Aid Highways (CSAHs) was 2,944, County Roads 194, Township Roads 51, and one case was not identified (see Table 2.1).

Table 2.1 The total number of data cases that was initially received to analyze.

County	County State Aid Highway	County Road	Township Road	Unidentified Road Type	Total
Brown	376	3	5	1	385
Cottonwood	200	16	6		222
Faribault	253	24	3		280
Jackson	248	19	1		268
Martin	302	24	10		336
Murray	193	8	5		206
Nobles	483	16	4		503
Pipestone	203	34	3		240
Rock	417	9	8		434
Watonwan	269	41	6		316
Total	2944	194	51	1	3190

Because this analysis addressed only the accidents that occurred on roadways with low or very low traffic volume, the accident cases that occurred on the roadways at which year-average ADT was 400 or higher were truncated. The year-average ADT was calculated by averaging ADT across 5 ½ years at a given roadway. Also, any accident case missing Road Type was eliminated. After completion of this process, we obtained a new data set that comprised only the accident cases that occurred on low to very low volume roadways. The new data are summarized in Table 2.2 according to Road Type and County.

Table 2.2 The total number of data cases that was actually analyzed (ADT < 400)

County	County State Aid Highway	County Road	Township Road	Total
Brown	142	3	5	150
Cottonwood	156	16	6	178
Faribault	137	19	3	159
Jackson	235	19	1	255
Martin	154	21	9	184
Murray	159	7	5	171
Nobles	138	15	3	156
Pipestone	125	34	3	162
Rock	176	9	8	193
Watonwan	124	41	6	171
Total	1546	184	49	1779

Analysis 1 – Descriptive statistics of accident data

There appears to be a slight decrease in the pattern of the frequency of accidents from 1996 to 2000. However, considering that year 2001 includes only the data from first six months of the year, the trend disappears (see Figure 2.1).

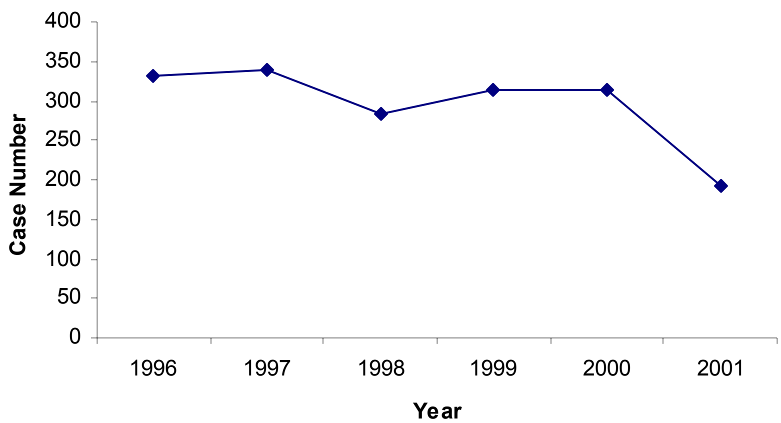

Figure 2.1 Number of accident cases drawn from each study for the years 1996 to 2001.
*Data for year 2001 include only the first 6 months of the year.

Monthly distribution of the number of cases indicates that accidents are more likely to occur during October and winter seasons (Figure 2.2).

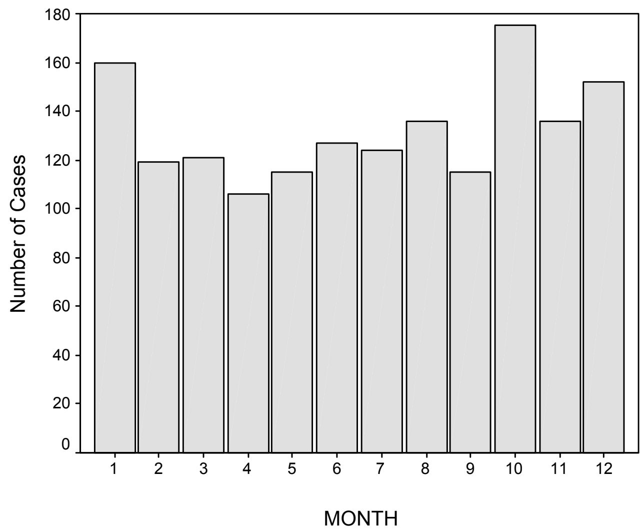

Figure 2.2 Monthly distribution of the accident cases
*The data from year 2001 were eliminated from this graph because the year 2001 data include only the first 6 months of cases. Including these data would increase only the number of cases of from January to June in this graph.

More than half of the accidents resulted only in property damage without human injury (see Table 2.3). Fatal injury was 2.8 percent of all injuries.

Table 2.3 Traffic accident cases classified according to severity of injury

Severity	Case Number	Percent (%)
Property Damage	1034	58.1
Possible Injury	275	15.5
Moderate Injury	287	16.1
Severe Injury	133	7.5
Fatal Injury	50	2.8
Total	1779	100.0

More than half of the accidents occurred without the involvement of an intersection or interchange area; a quarter of the accidents involved an intersection or interchange area (see Table 2.4).

Table 2.4 Traffic accident cases classified according to junction relation

Junction Relation	Case Number	Percent (%)
Interchange Area	52	2.9
Intersection	364	20.5
Intersection Related	105	5.9
Alley Driveway Access	90	5.1
School Crossing	3	.2
Not an intersection	938	52.7
Unknown	227	12.8
Total	1779	100.0

Among the drivers primarily involved in the accidents, teenagers comprised the highest frequency group. Age group 16-18 recorded the peak frequencies of accidents (see Figure 1.3). After peaking in the teen years, the frequency of accidents decreases as the driver's age increases. Among the first drivers, 62.8 percent were male, 35.5 percent female, and 1.6 percent were unspecified.

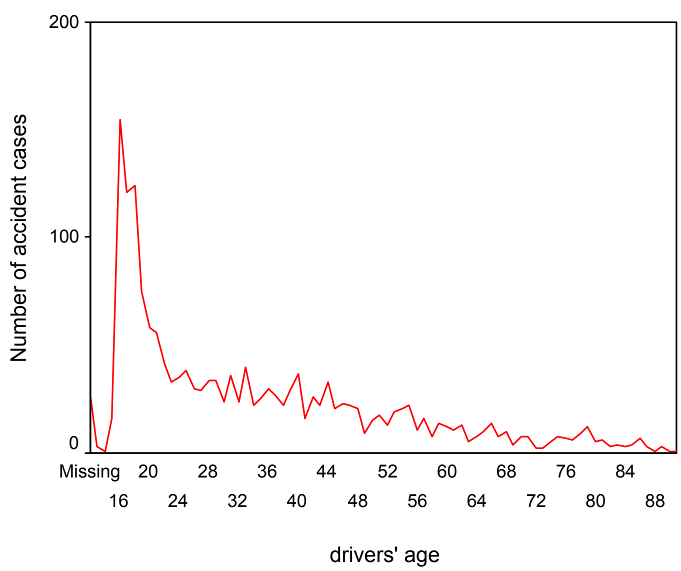

Figure 2.3 Accident distribution according to driver age.
*The number of missing data was 27.

Among the type of accidents, collision with other motor vehicle was the most frequent (33.4 %) followed by overturn (26.2 %), collision with fixed object (16.7 %), and collision with deer (11.0 %) in the order of frequency (see Table 1.5).

Table 2.5 Classification of accidents according to type of accident

Type of Accident	Case Number	Percent (%)
Collision w/ another motor vehicle	594	33.4
Overturn	466	26.2
Collision w/ fixed objects	297	16.7
Collision w/deer	195	11.0
Collision w/ parked vehicle	66	3.7
Collision w/ animal (not deer)	47	2.6
Collision w/ railroad train	26	1.5
Collision w/ bicyclist	5	.3
Fire or explosion	5	.3
Collision w/ pedestrian	4	.2
Collision w/ falling objects	3	.2
Submersion	3	.2
Other	63	3.5
Unknown	5	.3
Total	1779	100.0

Among the factors that may affect the first driver in the occurrence of accidents (see Table 1.6), no improper driving was the most common (22.1 %) followed by driver inattention or distraction (12.8 %), illegal or unsafe speed (11.2 %), failure to yield right of way (9.7 %), and weather (6.7 %).

Table 2.6 Factors that may affect the first driver[1] in the occurrence of the accidents

Factors	Case Number	Percent (%)
No improper driving	394	22.1
Driver inattention or distraction	228	12.8
Illegal or unsafe speed	200	11.2
Failure to yield right of way	173	9.7
Weather	119	6.7
Skidding	81	4.6
Physical impairment	66	3.7
Driver inexperience	64	3.6
Vision obscured	38	2.2
Disregard traffic control device	24	1.3
Human violation	24	1.3
Vehicle defect	24	1.3
Improper passing or overtaking	18	1.0
Driving left of center (not passing)	15	.8
Improper or unsafe lane use	15	.8
Improper parking/starting/stopping	14	.8
Unsafe backing	14	.8
Following too closely	13	7
Improper turn	12	.7
No signal or improper signal	3	.2
Oversize, overweight vehicle	2	.1
Other	61	3.4
Unknown	176	9.9
Missing Data	1	.1
Total	1778	99.9

[1] Presumably the driver responsible for an accident

In 71.6 percent of the cases, the first driver's involved in accidents did not report any physically harmful conditions. The accidents that occurred under the influence of alcohol or drug constituted 9.9 percent (see Table 1.7).

Table 2.7 Classification of accidents according to the first driver's physical conditions

Physical conditions	Case Number	Percent
No drugs or drinking	1274	71.6
Under the influence of alcohol or drugs	176	9.9
Asleep	12	.7
Fatigued	8	.4
Ill	2	.1
Other	6	.3
Unknown	301	16.9
Total	1779	100.0

Sixty-two percent of the cases occurred in dry conditions followed by ice or packed snow (20.3 %) condition and wet condition (7.0 %) (see Table 1.8).

Table 2.8 Classification of accidents according to road surface conditions

Surface conditions	Case Number	Percent
Dry	1103	62.0
Ice or packed snow	362	20.3
Wet	124	7.0
Snow or slush	99	5.6
Debris	6	.3
Muddy	4	.2
Oily	1	.1
Others	30	1.7
Unknown	50	2.8
Total	1779	100.0

When analyzed by road surface condition, more than half of the accidents (54 %) occurred during clear weather. Cloudy (21.4 %) and blowing sand or dust (5.6 %) weather also appeared to contribute to the occurrence of the accidents (see Table 1.9).

Table 2.9 Classification of accidents according to weather conditions

Weather conditions	Case Number	Percent
Clear	961	54.0
Cloudy	380	21.4
Blowing sand or dust	100	5.6
Snow	79	4.4
Rain	65	3.7
Fog/Smog/Smoke	50	2.8
Sleet/Hail/Freezing snow	43	2.4
Severe cross winds	10	.6
Others	7	.4
Unknown	84	4.7
Total	1779	100.0

More than two thirds (71.1 %) of the accidents occurred without involvement of a traffic control device. All approaching stop sign (.7 %) may be safer than two-way or other kinds of stop signs (12.1 %) (see Table 1.10).

Table 2.10 Classification of accidents according to traffic control devices

Traffic Control Devices	Case Number	Percent
Not applicable	1264	71.1
Stop sign (others)	215	12.1
Yield sign	61	3.4
Traffic signals	20	1.1
No passing zone	13	.7
Rail road crossing (cross buck)	16	.9
Stop sign (all approaches)	12	.7
Rail road crossing (stop sign)	5	.3
School bus stop arm	5	.3
Officer/Flagman/School patrol	3	.2
Rail road crossing (flashing lights)	2	.1
Rail road crossing (gates)	1	.1
Others	31	1.7
Unknown	131	7.4
Total	1779	100.0

More than half of the cases (54.2 %) occurred during daylight, while dark conditions without street lights may contribute to the occurrence of accidents (26.9 %) (see Table 1.11).

Table 2.11 Classification of accidents according to light condition

Light conditions	Case Number	Percent
Daylight	964	54.2
Dark (no light)	479	26.9
Dark (light on)	80	4.5
Dusk (evening)	79	4.4
Dawn (morning)	73	4.1
Dark (light off)	17	1.0
Others	2	.1
Unknown	85	4.8
Total	1779	100.0

Chapter 3: Identification of dangerous accident locations

In order to identify highly dangerous roadways and reference points on a roadway, the total number of traffic accidents on a roadway at a reference point on the roadway was divided by mean ADT. A reference point is defined as a certain location on a roadway in terms of mileage. The same reference point on the same roadway is assumed to be the same location throughout this analysis. This method yielded crash rates on each roadway and each reference point.

The analysis comprised two parts. First was an analysis of crash rates on roadways. This analysis enabled us to identify which roadways were statistically dangerous. The statistical unit in this part of the analysis was a within county value. For example, the roadways that run through two or more counties were divided into two or more roadways according to which county they belong. Therefore, the number of accidents on the same roadway in a county was not the same as the same roadway in another county. The ADT for the roadway in each county divided the number of accidents in that county to generate a crash rate. We expect that dividing the statistical unit into within county value minimized the engagement of error.

Second, we identified statistically dangerous reference points. Even a safe roadway may have a dangerous region, although the number of accidents at a specific region is not high enough to make the roadway completely unsafe.

The statistical decision rule used for both parts of analysis was alpha at $p \leq .05$. The crash rates for each of the roadways and reference points were converted into z-score. In the z-score distribution, zero represents mean crash rate. Therefore, below zero crash rates indicate the roadways are safer than average in terms of crash rate.

The same logic is applied to the above zero crash rate. A high z-score on a roadway indicates that there was relatively high incidence of traffic accidents on the roadway. Because we were concerned only with the high crash rates, the decision point used in this analysis was one-tailed test. Therefore, when the $z \geq 1.65$ on a roadway, a roadway is considered to be statistically dangerous. For the roadway to have such a high crash rate by chance occurs less than 5% of the time. Therefore, other conditions being equal across all roadways, there might be a factor that contributed to the high crash rate. Throughout the analysis, the crash rates on roadway and on reference points were independent from each other.

3.1 Crash rate by route number within counties

This analysis sought to identify the roads that reported significantly high crash rates across all roadways of less than 400 ADT. The total number of roadways incorporated in this analysis was 352. It was assumed that even the same roadway separated by the County borders would be different in terms of crash rate. Therefore, the statistical unit used in this analysis was roadways within each County.

Among them, 15 routes reported $z \geq 1.65$ (see Table 12). Despite all three road types being incorporated into the analysis, only the CSAHs revealed significantly high crash rate.

Considering that the crash rate was a standardized value, which was crash number over ADT, there might be a contributing factor to this finding.

Road Type was ignored for this analysis. This means that the common features of a certain road type were not incorporated into the analysis when the roads were converted into z-scores according to their crash number and ADT.

However, the common features that might distribute on the same type of roadways would have contributed to the occurrence of the accidents. Therefore, the next part of analysis is devoted to analyzing accidents by road type (Analysis 2, Table 2.1).

Table 3.1 Road Type and Routes that reported z ≥ 1.65 among all roadways

Road Type	Route Num	County	Crash #	ADT	Crash Rate	Z-scores
4-CSAH	22000006	Faribault	22	56	.39	8.47
4-CSAH	46000039	Martin	24	74	.32	6.84
4-CSAH	17000013	Cottonwood	65	235	.28	5.70
4-CSAH	08000008	Brown	17	79	.22	4.27
4-CSAH	17000009	Cottonwood	10	50	.20	3.88
4-CSAH	59000015	Pipestone	28	152	.18	3.54
4-CSAH	83000003	Watonwan	46	262	.18	3.32
4-CSAH	51000010	Murray	16	108	.15	2.69
4-CSAH	51000032	Murray	9	61	.15	2.66
4-CSAH	67000008	Rock	29	202	.14	2.58
4-CSAH	08000003	Brown	22	160	.14	2.43
4-CSAH	32000014	Cottonwood	40	298	.13	2.35
4-CSAH	67000006	Rock	26	196	.13	2.32
4-CSAH	32000009	Jackson	26	241	.11	1.74
4-CSAH	53000016	Nobles	22	206	.11	1.71

3.2 Crash rate by route and road type within counties

3.2.1 County State Aid Highways (CSAHs)

There were a total of 207 CSAHs that reportedly had traffic accidents. Analysis revealed 13 routes that had reportedly significant crash rate (see Table 2.2). The routes listed in Table 2.2 are virtually the same with the ones in Table 2.1. Only the last two routes in Table 2.1 were omitted in Table 2.2.

Table 3.2 Routes of County State Aid Highway's that reported z ≥ 1.65

Road Type	Route Num	County	Crash #	ADT	Crash Rate	Z-scores
4-CSAH	22000006	Faribault	22	56	.39	6.73
4-CSAH	46000039	Martin	24	74	.32	5.41
4-CSAH	17000013	Cottonwood	65	235	.28	4.48
4-CSAH	08000008	Brown	17	79	.22	3.32
4-CSAH	17000009	Cottonwood	10	50	.20	3.01
4-CSAH	59000015	Pipestone	28	152	.18	2.73
4-CSAH	83000003	Watonwan	46	262	.18	2.55
4-CSAH	51000010	Murray	16	108	.15	2.04
4-CSAH	51000032	Murray	9	61	.15	2.01
4-CSAH	67000008	Rock	29	202	.14	1.95
4-CSAH	08000003	Brown	22	160	.14	1.83
4-CSAH	32000014	Cottonwood	40	298	.13	1.76
4-CSAH	67000006	Rock	26	196	.13	1.73

3.2.2 County Roads

A total of 100 County Roads were subjected to analysis. Analysis revealed 8 County roadways that reported z ≥ 1.65 (see Table 2.3). As can be seen in the table, Pipestone and Watonwan counties had the highest cumulative crash rates, respectively. Specifically, Pipestone reported two routes, of which one showed the highest crash rate and the other the third. Watonwan reported four routes out of 8 routes.

Table 3.3 Routes of County Road that reported z ≥ 1.65

Road Type	Route Num	County	Crash #	ADT	Crash Rate	Z-scores
7-CNTY	59000067	Pipestone	10	101	.10	4.1506
7-CNTY	32000063	Jackson	3	37	.09	3.1727
7-CNTY	59000076	Pipestone	2	25	.08	3.0634
7-CNTY	83000116	Watonwan	6	79	.08	2.8476
7-CNTY	83000117	Watonwan	4	57	.07	2.5013
7-CNTY	83000124	Watonwan	1	15	.07	2.3233
7-CNTY	83000113	Watonwan	4	65	.06	2.0149
7-CNTY	67000051	Rock	2	35	.06	1.7480

3.2.3 Township Roads

Forty-six (46) Township Roads were subject to this analysis. Among them, two routes revealed significant high crash rates (see Table 2.4). As seen in the table, Route 51000150 reported only one accident, but is placed the most dangerous route. Obviously, it was because the ADT on the route was very low (10.74) compared to the mean (X = 72.63, SD = 43.90).

Table 3.4 Routes of Township Roads that reported z ≥ 1.65

Road Type	Route Num	County	Crash #	ADT	Crash Rate	Z-scores
8-TWNS	51000150	Murray	1	11	.09	4.9461
8-TWNS	67000058	Rock	2	39	.05	2.0560

3.3 Crash rates by location

This part of analysis identifies statistically dangerous reference points. In order to obtain crash rates at each reference point, all the reference points where accidents occurred were compared with those of the given ADT. When accident cases at a reference point matched ADT at the same location, the number of accidents was divided by that ADT. This process generated crash rates at each of the reference points.

When accident cases were not provided with matched ADT, the cases were eliminated from the analysis. Because the selection of the reference points at which ADT was measured was independent from the occurrence of accidents at the locations, the elimination of the cases was assumed to be random. However, random elimination does not mean that there are no biases in the interpretation of the results. There is a possibility that the reference points that reported high accident rates were randomly eliminated from the analysis. Because the primary purpose of this part of the data analysis was detecting any dangerous locations in roadways, incorporation of all the data is desirable. However, if a location that reported one or more accident cases does not provide any ADT information, it is impossible to determine crash rate at the location. Therefore, the elimination of the data was inevitable.

3.3.1 County State Aid Highways (CSAHs)

Only 162 accident cases (150 locations) provided matched ADT out of a total of 1546 accidents on CSAHs. Approximately 89.5 % of the data were randomly eliminated.

Among the 150 locations, the analysis identified 9 statistically significant locations (see Table 2.6). As can be seen in the Table 2.5, Rock County and Jackson County have three dangerous locations each.

Table 3.5 The locations on the County State Aid Highways that reported significant crash rates.

Road Type	County	Route Num	Reference Point	Case Num	Mean ADT	z-score
CSAH	Rock	67000016	002+00.010	2	69	5.56
CSAH	Jackson	32000024	019+00.793	1	41	4.44
CSAH	Jackson	32000007	000+00.000	3	131	4.08
CSAH	Faribault	22000004	001+00.500	1	51	3.32
CSAH	Pipestone	59000004	005+00.020	1	60	2.61
CSAH	Murray	51000032	000+00.880	1	60	2.58
CSAH	Jackson	32000032	003+00.810	2	133	2.21
CSAH	Rock	67000019	007+00.120	1	73	1.91
CSAH	Rock	67000019	009+00.120	1	73	1.91

3.3.2 County Roads

The total number of accidents on the County Roads was 184. Among them, only 44 cases (41 locations) provided matching ADT. The remaining 140 cases (24 %) were eliminated from this analysis.

The z-score analysis revealed three statistically dangerous locations (see Table 2.6). It is noteworthy that all the three statistically dangerous locations reported only one accident. Therefore, the high z-scores for the locations are not because of a high number of accidents but because of low ADT.

Table 3.6 The locations on the County Roads that reported significant crash rates.

Road Type	County	Route Num	Reference Point	Case Num	Mean ADT	z-score
CNTY	Martin	46000108	001+00.500	1	29	2.59
CNTY	Jackson	32000063	004+00.010	1	31	2.34
CNTY	Pipestone	59000076	000+00.000	1	31	2.31

3.3.3 Township Roads

The total number of accidents on the Township Roads was 49. Matching ADT was provided for 15 of the accidents. Also, all the 15 locations reported only one accident. Consequently, the crash rates at each location are dependent only on the ADT. The analysis revealed 2 dangerous locations (see Table 2.7).

Table 3.7 The locations on the Township Roads that reported significant crash rates.

Road Type	County	Route Num	Reference Point	Case Num	Mean ADT	z-score
8-TWNS	Rock	67000084	005+00.040	1	11	2.40
8-TWNS	Noble	53000039	003+00.020	1	12	2.13

Chapter 4: Statistically Reliable Contributing Factors

The aim of this analysis was to identify statistically the most likely contributing factors other than driver factors such as failure to yield right of way, driver inattention/distraction, driver inexperience, and physical impairment. To accomplish this we initially classified all the accident cases into two categories: one that had no reported improper driving of all the drivers involved in each of the accident cases, and the other that remained after the first cases. This process yielded a total of 235 cases of no improper driving accidents (NDE) and the remaining 1554 cases (DE) out of 1779 accidents on ADT < 400 roadways. To obtain general overview of the data, the factors that are similar in their characteristics were reduced to one, and then, descriptive statistics were derived for each of the data set. The results are summarized in Table 3.1.

Table 4.1 Comparisons on selected issues between the no improper driving (NDE: no driver error) accident cases and the remaining accident cases (DE: driver error).

		NDE (n = 235) Case number (%)	DE (n = 1544) Case number (%)
Severity	Injury	49 (20.9)	696 (45.1)
		186 (79.1)	846 (54.9)
Junction relation	Not an intersection	184 (78.3)	754 (48.8)
	Intersection	13 (5.5)	351 (22.7)
Speed limit	55 MPH	208 (88.5)	1058 (68.5)
	30 MPH	9 (3.8)	310 (20.1)
Type of accident	w/ other motor vehicle	16 (6.8)	509 (33.0)
	w/ animal	150 (63.8)	92 (6.0)
	w/ fixed object	24 (10.2)	273 (17.7)
	Overturn	31 (13.2)	435 (28.2)
Location of 1st harmful event	On the roadway	197 (83.8)	1002 (64.9)
	Others	38 (16.2)	542 (35.1)
Fixed object struck	Not applicable	172 (73.2)	978 (63.3)
	Embankment / ditch / curb	14 (6.0)	172 (11.1)
Traffic control device	Not applicable	215 (91.5)	1049 (67.9)
	Stop sign at all approaches	5 (2.1)	210 (13.6)
Road design	Two lanes, undivided two-way	220 (93.6)	1321 (85.6)
	Unknown	7 (3.0)	152 (9.8)
Daylight condition	Daylight	67 (28.5)	897 (50.4)
	Dark	156 (66.4)	572 (32.2)

Comparison of accident severity indicates that when there is no driver error, accident severity was likely to be reduced to property damage (79.1 %) compare to human injury (20.9 %). On the contrary, when driver error was involved, the severity tends to increase to human injury (45.1 %). Human injury includes possible injury and moderate to fatal injury. In NDE cases, a greater percent of accidents occurred without involving intersection (78.3%) than in DE cases (48.8). Almost 90 percent of the accidents in NDE occurred on high speed limit roadways (55 MPH). This pattern can be observed in DE cases (68.5 %), but the percentage is lower than NDE cases by about 20 percent. Great percentage of accidents in NDE was crash against animals, while only small percent (6.0 %) of accidents in DE was crash against animals. Instead, the type of accidents in DE distributes evenly among crash against other motor vehicle (33 %), overturn (28.2 %), and crash against fixed object (17.7 %). In both the NDE and DE, most accidents occurred on roadways: 83.8 percent for NDE and 64.9 percent for DE. As can be predicted by the analysis on Junction relation, majority of cases (91.5 %) in NDE was independent to traffic control device compared to DE cases (67.9 %). In both the NDE and DE, most accident exclusively occurred on two lane undivided two-way roadways (93.6 % for NDE and 85.6 % for DE). This is interpreted that most of the Township, County, County State Aid Highways (CSAHs) are two lanes undivided two-way roadways. Compared to DE, greater percentage of accidents in NDE occurred during night or dark (66.4 % for NDE and 32.2 % for DE), half of the accidents (50.4) occurred during day in DE.

Summarizing the descriptive statistics up the finding suggests that many factors other than improper driving are closely interrelated with the accidents. When driver error is absent, most of the accidents are more likely to be inevitable. As can be seen under 'Type of accident' in Table 1, 63.8 percent of the accidents were crashes involving animals. This kind of accident usually occurred during dark condition (66.4 %) when visual field was limited and on relatively high-speed zone (88.5 % at 55 MPH of speed limit). When animals suddenly came into drivers visual field and drivers were unable to stop (as not an intersection by 78.3 % and no traffic control by 91.5 %), the accidents are inevitable regardless of driver error. However, the severity of the accidents is milder than the cases in DE.

These data exclusively demonstrate that when there is minimal or no driver error involved, the most likely factor that causes an accident on ADT < 400 roadway is crash involving an animal. This finding implicates that our initial concern regarding environmental factors, such as lane and shoulder widths, change of signage, sign material, seasonal issues, and others presumed to be underlying causes of the occurrence of the accidents **is not true**. Instead, road design factors such as number of lanes and whether or not they are separated, and speed limit are the environmental factors that appear most related to the occurrence of the accident. However, these factors are hardly modifiable.

4.1 Chi-square (χ^2) analysis

The results of descriptive statistics indicate that there are different patterns of accidents between no engagement of driver error and the remaining cases. In order to test if those patterns are statistically meaningful we ran chi-square analysis on selected issues. Chi-square (χ^2) test is a statistical tool that enables us to test the independence of two variables when each variable can have two or more possible outcomes. When the test result is significant, the null hypothesis concerning their independence is rejected and two variables are considered to be significantly dependent on each other.

(1) Driver error vs. severity of injury

In this analysis, whether or not the engagement of driver error is related with the severity of injury was analyzed. The result indicates that engagement of driver error and severity of injury are reliably dependent from each other.
(see Table 3.2; $\chi^2_1 = 65.81$, $p < .001$)

Table 4.2 Frequency table of the data for each of the engagement of driver error and severity of accident

		NDE	DE	Total
Property damage	Observed	185	648	833
	Expected	128	705	
Injury	Observed	50	646	696
	Expected	107.0	589.0	
Total		235	1294	1529

Number of missing data: 250

(2) Engagement of driver error vs. daylight condition

This analysis determines whether or not engagement of driver error is related with daylight condition. The result showed no significance (see Table 3.3; $\chi^2_1 = .06$, $p > .5$).

Table 4.3 Frequency table of the data for each of the engagement of driver error and daylight condition

		NDE	DE	Total
Daylight	Observed	66	800	866
	Expected	131	735.0	
Dark	Observed	157	451	608
	Expected	92	516.0	
Total		223	1251	1474

Number of missing data: 305

(3) Engagement of driver error vs. location of 1st harmful event

When there is no engagement of driver error, they are more likely to commit accident only on roadways than the case of engagement of driver error. The result showed significant relationship between these two variables (see Table 3.4; $\chi^2_1 = 24.96$, $p < .001$).

Table 4.4 Frequency table of the data for each of the engagement of driver error and location of 1st harmful event

		NDE	DE	Total
On the roads	Observed	196	933	1129
	Expected	166.9	962.1	
Others	Observed	23	329	352
	Expected	52.1	299.9	
Total		219	1262	1481

Number of missing data: 298

(4) Daylight condition vs. severity of accident

There may be a relationship between daylight condition and severity of accident for any reasons. This hypothesis has been tested on chi-square analysis. The result showed non-significance (see Table 3.5; $\chi^2_1 = .18$, $p > .5$).

Table 4.5 Frequency table of the data for each of the daylight condition and severity of accident

		Daylight	Dark	Total
Property damage	Observed	549	422	971
	Expected	553.2	417.8	
Injury	Observed	415	306	721
	Expected	410.8	310.2	
Total		964	728	1692

Number of missing data: 87

(5) Location of 1st harmful event vs. severity of accident

Whether or not the severity of accident is related with the location of 1st harmful event is tested. The result shows no significant relationship between these two variables (see Table 3.6; $\chi^2_1 = .016$, $p > .5$).

Table 4.6 Frequency table of the data for each of the daylight condition and severity of accident

		On the Roads	Others	Total
Property damage	Observed	705	170	875
	Expected	662.3	212.7	
Injury	Observed	494	215	709
	Expected	536.7	172.3	
Total		1199	385	1584

Number of missing data: 195

(6) Summary of chi-square tests

The chi-square test on selected issues yielded significance on two sets of comparison. These include driver error vs. severity of accident and driver error vs. daylight condition (see Tables 3.2 and 3.3). The chi-square test on driver error vs. severity of accident indicates that when there is a driver error the severity of the accident is more likely to be personal injury rather than only property damage. Conversely, when there is no engagement of driver error, the severity of the accident is more likely to involve only property damage (see Table 3.2). Chi-square test on driver error vs. location of 1st harmful event implicates that when there is a driver error, the location of 1st harmful event is likely to be on outside a roadway. Contrary, when there is no driver error, the crash is more likely to happen on a roadway. In other words, a driver was not able to avoid the crash. The remaining chi-square test did not yield any significance. There was no certain pattern in the engagement of driver error on the onset time of accidents classified into daylight and dark condition. Also, the severity of accident was independent of either the onset time of accident or the location of 1st harmful event.

Table 4.7 Summary of the chi-square tests on selected issues

Test items	χ^2 – value	p-value
Driver error vs. severity of accident	65.8	$P < .001$
Driver error vs. daylight condition	.06	$P > .5$
Driver error vs. location of 1st harmful event	24.96	$P < .001$
Daylight condition and severity of accident	.18	$P > .5$
Location of 1st harmful event vs. severity of accident	.016	$P > .5$

Limitations of the study

1. The number of accidents on a roadway may depend on the length of the roadway besides many other factors. If everything except the length of the roadway is equal, a long roadway is more likely to have high number of accidents.

2. In Part II of the data analysis, approximately 88 % (1558 cases out of 1779) of the data were eliminated because they did not provide matched ADT. This part of the data analysis is designed to detect any significantly dangerous locations in roadways. Therefore, missing data, for any reasons, would generate bias in the results of the analysis.

Chapter 5: Summary

Using the database of the 5 ½ years of accident reports provided by the Mn/DOT Office of Research, our analysis identified 15 accidents from the selected counties in Minnesota, which met the criteria for further analysis. It is clear that there are many factors other than improper driving that are related to accidents, and the general conclusion is that other than driver error, the most likely factor for accidents on highways with an ADT of less than 400 is a collision involving an animal.

Five direct comparisons using chi-square analysis compared driver error with the severity of the accident, daylight condition, and location of the first harmful event. The data (accident reports) on the 15 accident sites from the 11 counties identified were sent to county traffic engineers requesting their comments relative to such things as the nature of the highway, whether it was county assisted, county, or township, and other factors relative to the accident locations (e.g. historic lane and shoulder width changes, changing of signage or sign materials, seasonal issues, and time of day). The comments received were spasmodic and at best mixed, and we were unable to produce any conclusive information from them. It would appear overall that the analysis of the 5 ½ years of data suggests that where driver error is not a persuasive factor in the accident, the physical and structural properties of the highways in the categories included in this analysis do not play a significant role in the accidents. The largest factor relative to accidents that do not involve driver error appears to be an animal being involved in the accident.

Appendix

Task 3 reports were originally designed to be based on county engineers' comments to following format regarding to the significant reference points reported in Task 2b.

Suggested format for comments:

Please follow the following format when submitting comments on crash data for your county for the Task 2A and/or Task 2B reports:

1. Provide separate comments for each highway category, i.e. township, county, CSAHs.
2. For each highway category comment on the following issues:
    a. Historic lane and shoulder widths
    b. Change of signage
    c. Sign materials
    d. Seasonal issues: i.e. summer or winter
    e. Time of day or night
    f. Other reasons or issues not covered above

However, some of the comments from county engineers are already included in police reports and other comments are generally short and not sufficiently informative to identify common possible causes for the significant crash rates.