DRIVER ATTITUDES AND CRASH PATTERNS IN WESTERN NORTH DAKOTA OIL COUNTIES: LINKS BETWEEN PERCEPTIONS AND REALITY

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Driver Attitudes and Crash Patterns in Western North Dakota Oil Counties: Links Between Perceptions and Reality

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

DOCTOR OF PHILOSOPHY

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ABSTRACT

Traffic safety conditions in the 17-county oil region of western North Dakota have changed considerably in recent years. Roads previously used for low-volume, agricultural purposes are presently utilized at high volumes to serve expanding oil interest. Traffic volume in the region has grown rapidly since the advent of hydraulic fracturing as a viable technique for extracting oil, especially with regard to the overweight and oversized vehicles needed for oil production. Three studies were conducted to understand how changing traffic conditions are perceived by local drivers.

First, a survey questionnaire was sent to drivers in the region to measure perceptions of traffic safety priorities. County-level crash data were gathered for rural road crashes in North Dakota between 2004 and 2013 to examine statewide crash trends. Survey responses were linked to crash data and found that safety perceptions from drivers are valid: conditions in oil counties are actually more dangerous than elsewhere in North Dakota. Second, using Decision Theory as a theoretical lens to guide decision-making, crash data were queried to establish if driving conditions in certain parts of the oil region are more dangerous. Proximity to oil wells, city limits, and travel on major roadways were found to have an effect on overall crash severity. Third, written survey responses were qualitatively studied via emergent theme content analysis. Crash types relating to these themes were then subjected to cluster analysis using ArcGIS. Respondent zip codes were matched with crash zip codes to provide a mixed methods approach to understanding key traffic safety issues such as perceived danger, large truck danger, and law enforcement presence.

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DEDICATION

For Dr. John Fraser Hart. You challenged me to get out and explore the world to learn firsthand why things are the way they are. Without your guidance I would have never considered continuing my education. If I am lucky enough to accomplish half of what you have in your career, I will consider it a resounding success.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. A FOLLOW-UP STUDY OF OIL COUNTY TRAFFIC SAFETY: PERSPECTIVES FROM WESTERN NORTH DAKOTA RESIDENTS

1.1. Abstract

The sharp increase in travel volumes, shift in traffic mix, and large increases in traffic crashes have transformed the travel environment in the oil region of western North Dakota. Roads once used only for local access and agricultural purposes are now being used at high volumes to serve expanding oil production. Oil companies, oil workers, commercial trucks, and industrial equipment associated with gas and oil development all use these roads to access oil drilling and production sites. This has led to an increase in traffic volume and a larger number of overweight and oversized vehicles on the road. A survey questionnaire was sent to drivers to better understand the perceptions and behaviors of road users in this region. County-level crash data were gathered for the state of North Dakota to understand changes in driving conditions during the latest oil boom – specifically between 2004 and 2013. This study addresses two key goals related to improving traffic safety in the region: first, to examine public perceptions of traffic safety issues and priorities; and, second, to address crash trends and possible intervention strategies with a focus on large truck/passenger vehicle interaction. Survey results indicate that drivers perceive the region to be dangerous and driving improvements can be made. Crash data reveal that most crash statistics are growing at near exponential rates.

1.2. Introduction

Road usage in western North Dakota has changed. Interstate, highway, and low-volume unpaved roads have been used with greater frequency because of a growing energy sector. This evolution is especially evident in a 17-county region where oil extraction methods have improved production economics (Figure 1.1.). Roads once used only for local access and agricultural purposes are now being used at high volumes to serve expanding oil production. This has led to greater traffic volume, overweight vehicles, and oversized trucks on the road. As a result, a number of roads are in poor condition and many others are deteriorating rapidly; it is estimated that an investment of over $4.13 billion is needed during the next 20 years for transporting oil and allowing travelers to have acceptable roadway use (UGPTI 2014). An increased public safety risk associated with increased traffic is evident in the number and severity of crashes in the region. Crash incidence trends in the core of the oil region show exponential growth, especially for more serious crashes. The rate of crashes resulting in fatalities, injuries, and property-damage-only (PDO) is considerably higher than the rest of the

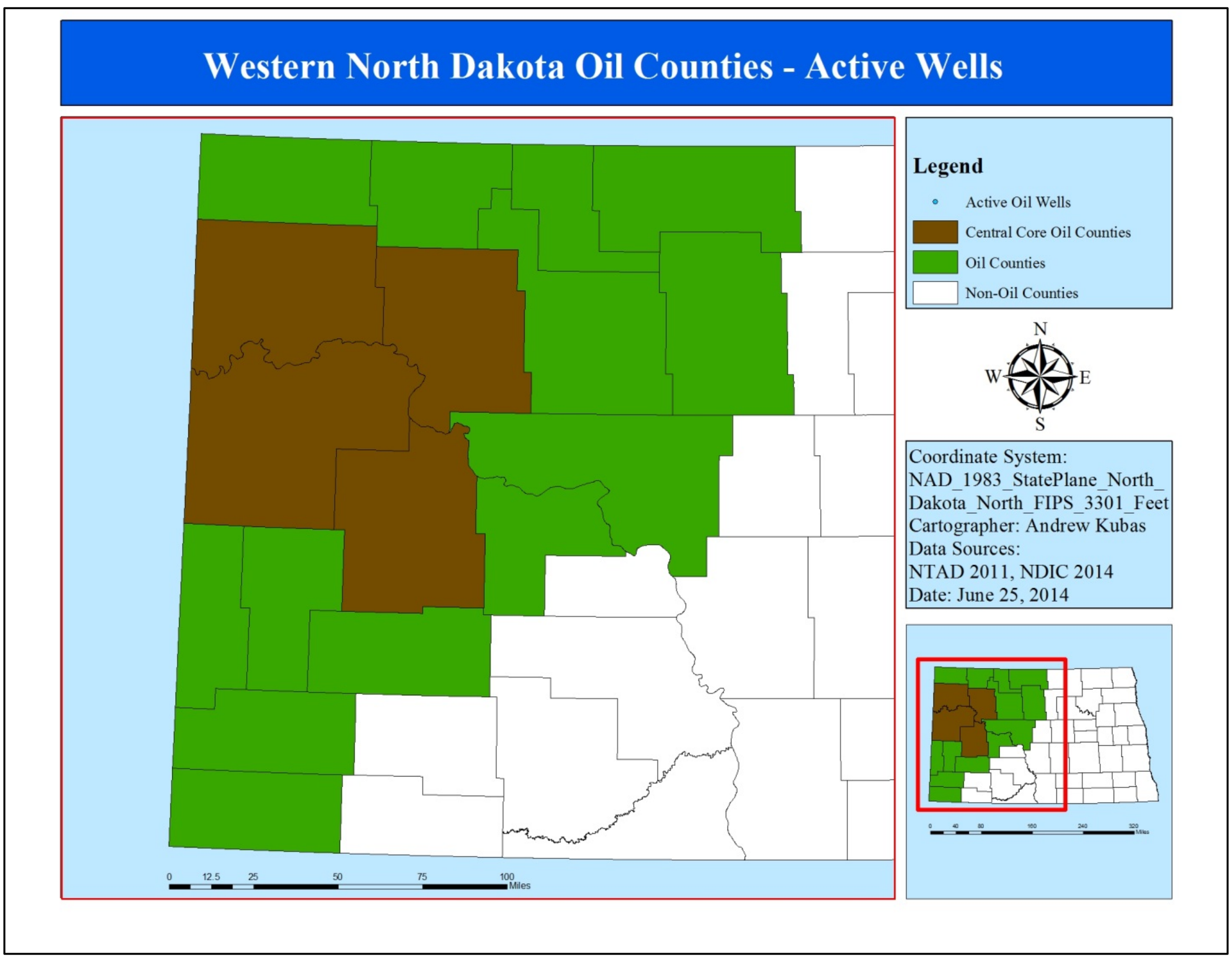

Figure 1.1. Western North Dakota Oil Counties

state. Moreover, large truck crashes in the central core grew 1,784% from 2004 to 2013, a rate that is far greater than the 319% increase in vehicle miles traveled (VMT). Driving factors such as these have prompted stakeholders in the region to take action to encourage safety on the roadway.

Early research regarding the impacts that oil extraction has on a region shows a similar situation to that currently being experienced in North Dakota. Oil extraction in the North Sea created noise, safety hazards, increased traffic volumes, altered landscape, construction camps, and localized changes to infrastructure – all of which are presently occurring in western North Dakota (Affolter 1976). Oil development has been predicted to threaten transportation modes such as road networks, ports, and airports (Laska et al. 2005). Factors outside of oil development – perceived safety, driver behavior, large truck/passenger vehicle interaction, and safety campaigns – also affect safety on roadways.

Drivers often perceive themselves as being safer than others (DeJoy 1989; Delhomme, Verlhiac, and Martha 2009). Out-of-state oil workers perpetuate the “self-versus-other” dynamic in western North Dakota. In addition to perceptions, driver behavior directly impacts safety. Operating a vehicle while impaired, speeding, and choosing not to wear a seat belt contribute to danger on the roadway. Drivers have different underlying mechanisms that determine whether one commits an emotional or reckless driving violation (Martinussen et al. 2013). Individuals behave differently after being in an accident (af Wahlberg 2012) and exhibit more stress, worry, and exhaustion (Lucas 2003). Nonetheless, motorists that have experienced a crash tend to have higher levels of risk-taking, perhaps due to socio-environmental factors (Lin et al. 2004).

National fatalities from large truck crashes decreased from 1975 to 1999, likely due to safety improvements to trucks and passenger cars (Lyman and Braver 2005). It has been estimated that further safety improvements such as side view assist, forward collision warning, lane departure warning, and vehicle stability control would be relevant to approximately one-fourth of all large truck crashes in the United States (Jermakian 2012). Other studies show that large trucks execute lane changes more smoothly on arterial roads and freeways than shorter vehicles (Aghabayk et al. 2011). These national large truck crash trends represent a deviation from present crash statistics in western North Dakota.

Safety campaigns have been waged attempting to promote safer driving habits and discourage dangerous driving activities. Safety tools such as "*What's the Hurry?*" (Whittam et al. 2006), the Hawaii Opportunity Probation with Enforcement (Hawken 2011), the South Dakota 24/7 Sobriety Project (Loudenburg, Drube, and Leonardson n.d.), the "*Checkpoint Strikeforce*" program (Lacey et al. 2008), the annual *Drunk Driving: Over the Limit, Under Arrest* Labor Day crackdown (Solomon et al. 2008), Target Zero Team Project (Cicchino 2012), Saving Lives program (Hingson et al. 1996), Strategic Evaluation States initiative (Syner et al. 2008), the "*Better Driver Campaign*" in Florida (Lee et al. 2010), and "*Click It Or Ticket*" (Kim and Yamashita 2003) are geared toward improving safety on the roadway and have been studied extensively. Many of these programs emphasize preventing impaired driving, and some do so specifically targeting young males (Murry, Stam, and Lastovicka 1993).

Although these topics have been studied widely by academics and transportation safety personnel, none have focused solely on North Dakota oil development. Moreover, none have given priority to rural road segments. The goal of this study is to measure driver behaviors, perceptions, and priorities given rapidly changing road networks in western North Dakota and worsening crash trends. Three objectives obtain this goal: (1) measuring public perceptions of traffic safety issues and priorities in the state's oil producing region; (2) determining the efficacy of public education, specifically *ProgressZone: Moving Forward Safety* and *Code for the Road* as safety intervention strategies; and, (3) querying rural crash data to parallel it with on-road driving experiences as reported by oil county drivers.

1.3. Methods

A mail survey was sent to drivers in the 17 western North Dakota oil counties. The first survey was sent in 2012, and a follow-up questionnaire was mailed in 2014. The state driver licensing division used the 17-county oil region driver population for the sampling. Of the 2,620 surveys successfully mailed in 2012, 779 were verified as valid North Dakota responses. In 2014, 2,666 surveys were mailed with 696 valid responses. Response rates were 29.7% and 26.1%, respectively. Younger respondents (age 18-44) are slightly underrepresented compared to their proportion of the driver population, but nonetheless there were enough respondents in each age cohort to extrapolate responses. Response rate was higher than expected due to parameters used in survey design and administration. These parameters include keeping the survey to one page, using university letterhead, and using university-branded envelopes. Given the timeliness of oil development, it was expected that an above-average response would be obtained. A proportionate stratified random sample was used to select drivers and was stratified by county boundaries. The most surveys were sent to Williams, Stark, and Ward counties, respectively, which are home to the three largest cities in the region.

Responses were entered into a database using SPSS and were queried for statistical analyses. Data are reported in aggregate when discussing frequencies and descriptive considerations. In the event that there are noticeable discrepancies and/or changes in driver responses between 2012 and 2014, the two years are separated for analysis. Aggregated and disaggregated data are distinguished throughout the analysis.

In addition to survey data, crash reports were collected from 2004 to 2013. These reports were obtained from the North Dakota Department of Transportation and the FARS database. Rural road data were queried to track the total number of crashes, large truck crash rates, and crash severity – including injuries, fatalities, or PDO crashes. Crashes were tracked per 100 million VMT and per 100,000 population. County-level statistics were obtained and oil counties were compared to the rest of the state.

1.4. Results

Survey responses offer important insight into driver perceptions, attitudes, and behaviors regarding traffic conditions. Simple frequency analysis of ordinal and dichotomous survey responses provides a baseline of driver views and behaviors. Five-point Likert scales and ranking/ordering were used to quantify responses. This allows for statistical testing of relationships, means, and significance. Quantitative analysis shows there are different exposure rates, safety behaviors, perceptions, and priorities in the oil region. Querying crash data resulted in a noticeable trend: nearly all crash statistics in the oil counties have increased considerably since 2004, with spikes in every major crash statistic occurring either in 2009 or 2011.

1.4.1. Survey Questionnaire: Quantitative Analysis Results

Responses show that a clear majority, 88.6% of drivers, do not feel safer driving now than they did five years ago based on those reporting that they either feel "less safe" or "much less safe," respectively. A smaller proportion, 73.0%, had to brake or swerve suddenly to avoid a crash at least once within the last three months. This likely contributes to perceptions of poor safety and explains the negatively correlated relationship between how one perceives safety compared to five years ago and having to suddenly brake or swerve to avoid a crash (Pearson Correlation=-0.475, $p<0.001$, $n=1,449$). This is a logical relationship: drivers who have had to brake or swerve suddenly to avoid a crash are likely to consider that an unsafe experience and thus have a higher tendency to view the roads as being less safe.

Roughly three-quarters (74.5%) of drivers in 2014 meet or pass a large truck daily, a slight decrease from 79.4% of drivers in 2012. A majority (53.7% in 2012; 51.1% in 2014) of drivers specified that they felt either “unsafe” or “very unsafe” when passing trucks and roughly two-thirds (65.7% in 2012, 66.7% in 2014) felt the same way when being passed by large trucks. As expected, the substantive relationship between these two variables is strong and positively correlated (Pearson Correlation=0.741, $p<0.001$, $n=1,427$). This indicates that as one feels unsafe passing large trucks, one is more likely to also feel unsafe being passed by large trucks. Drivers were subsequently asked about their willingness to drive for a longer amount of time during a typical 20 minute commute if it meant less interaction with large trucks or driving on roads with better driving conditions. Results were similar across the two situations in both years: roughly one-fifth of drivers would travel an extra five minutes, about two-fifths would increase travel time by ten minutes, and approximately one-fifth would double their travel time an extra twenty minutes to drive a route with fewer trucks or better driving conditions. This indicates that some drivers strongly desire to avoid danger on the roadway.

Understanding driver behavior provides insight into dangerous actions taken by residents living in the oil region. Questions concerning seat belt use and speeding were addressed. The proportion of drivers “always” or “nearly always” wearing a seat belt in 2012 (86.4%) remained stable in 2014 (86.9%). A slightly higher proportion wears a seat belt when traveling in a vehicle going over 30 miles per hour (93.0% in 2012, 95.0% in 2014). There was a strong, positive correlation between these two variables: drivers who more often use a seat belt while driving in town are also more likely to use a seat belt in a vehicle traveling more than 30 miles per hour

(Pearson Correlation=0.719, $p<0.001$, n=1,444). This is reasonable as high seat belt use is often associated with habitual use. Self-reported speeding tendencies were comparable: about three-quarters (75.8%) of drivers "rarely" or "never" driver faster than 70 miles per hour on a road with a speed limit of 65 miles per hour.

The survey highlighted familiarity with two safety campaigns. *ProgressZone: Moving Forward Safely* was designed specifically to meet local western North Dakota needs (NDPC 2013). The campaign promoted four safety themes: passing with caution, slowing down, buckling up, and sharing the road. These messages were displayed on billboards and advertisements in the 17 western North Dakota oil counties in 2012. *Code for the Road* was targeted at high-risk (18-34 year-old) males and emphasizes safety messages such as buckling up, driving sober, and slowing down. It is a statewide campaign, but given the demographic of generally young, male oil workers moving into the western part of the state for employment, it was believed that the campaign would improve road safety in the targeted area. These safety messages have been displayed on television and internet advertisements in 2014 (Heidle, Horton, and Lerman 2014). Drivers were asked whether they had read, seen, or heard the safety messages promoted by the two initiatives. Drivers were then subsequently asked if they changed their driving behavior after seeing such ads. The *ProgressZone: Moving Forward Safely* advertisements were recognized by 31.2% of respondents, 42.9% of which positively improved their driving behaviors. The *Code for the Road* messages were read, seen, or heard by 18.6% of drivers, of which 29.9% positively improved their driving. Thus, among all of the drivers within this sample, 11.1% improved their driving behaviors as a direct result of the two safety campaigns.

Drivers ranked their priorities for four issues in traffic safety: improved road signage, increased law enforcement presence, heightened driver awareness, and education for truck/passenger car interaction. Road signage is important in providing drivers information for navigation and vehicle control (Rasanen and Horberry 2006). Increased law enforcement presence has been proven to reduce crime, the fear of crime occurring, and provides the public with a greater sense of security (NHTSA 2001). Driver awareness is a critical element in traffic safety. Driver expectations, perceptions, and distractions can create a significant risk for both the driver and others. The size/mass relationship of large trucks and passenger vehicles, along with operational differences such as acceleration/deceleration times and turning radiuses, heighten the risk of a crash (Vachal 2012). Drivers ranked these four issues on a scale from one to four, with one being least important and four being most important.

Driver awareness is the most important issue to drivers. Over half, 60.5%, ranked it as the most important of the four issues. Similarly, the lowest proportion, 5.9%, ranked driver awareness as least important. This congruity suggests that driver awareness is the most important issue facing North Dakota drivers in the oil region. A clear majority, 83.0%, believed that driver awareness was a top priority based on those who ranked the issue as a 3 or 4. A majority of drivers also perceived two other issues to be important: passenger vehicle/large truck interaction (63.9%) and greater law enforcement presence (62.9%). In contrast, 58.1% ranked signage related to traffic rules as either least important or second-least important. Over one-third (36.7%) believed that signage related to traffic rules was least important as a traffic safety priority; no other issue had more than 17.5% of drivers holding this viewpoint. A paired samples t-test demonstrates that the distribution of signage ratings is significantly different than the distribution for law enforcement presence ($t=-15.986$, $df=1,428$, $p<0.001$), driver awareness ($t=-30.754$, df=1,427, p<0.001), and large truck/passenger vehicle interaction (t=-14.051, df=1,420, p<0.001).

The potential to focus traffic safety efforts for more efficient resource use may be possible. For instance, some significant differences between males and females were found related to risk behaviors and tendencies. Responses were found to be significantly different between men and women for five questions in 2014 (Table 1.1.). Women felt less safe driving today compared to five years ago (F=12.763, df=1, p<0.001). Women also felt less safe than their male counterparts when passing large trucks (F=14.983, df=1, p<0.001) and when being passed by large trucks (F=7.576, df=1, p=0.006). Females tend to report safer driving practices than males. Women have a higher tendency to wear their seat belts in town (F=10.113, df=1, p=0.002) and in a vehicle going faster than 30 miles per hour (F=21.486, df=1, p<0.001). This parallels other North Dakota studies which have found that females exhibit safer driving behaviors than males and are less likely to engage in dangerous driving actions (*31*-*33*). This knowledge is crucial to traffic safety officials for targeting safety improvements and dangerous behavior reduction strategies towards a male audience. In North Dakota, this may be especially useful focusing on high-risk (18-34 year-old) males (Vachal, Benson, and Kubas 2011-2013).

Age is another factor for which traffic safety efforts can be focused. In this survey, extreme values tend to be associated with the youngest (18-34) and oldest (75+) age cohorts, respectively (Table 1.2.). Of the 13 variables studied longitudinally, 10 had statistically significant differences between reported mean values across all age groups in 2014. Of these, six were also statistically significant in 2012. Age appears to be a determinant of driver views and behaviors related to driving safety. For example, ratings of perceived safety compared to five years ago improves as one gets older; those over the age of 75 rate current road conditions the

Table 1.1. Differences in Mean Driver Views and Behaviors, by Gender

QUESTION	YEAR	SCALE[1]	ALL DRIVERS	MALE	FEMALE	SIG.
Safety vs. 5 yrs. Ago	2014	1-5	1.61	1.73	1.53	**
	2012	1-5	1.58	1.61	1.53	
Sudden brake/swerve	2014	0-1	0.72	0.72	0.72	
	2012	0-1	0.73	0.75	0.71	
LE visibility	2014	0-1	0.69	0.66	0.72	
	2012	0-1	0.71	0.73	0.70	
Meet/pass trucks	2014	1-5	4.62	4.64	4.61	
	2012	1-5	4.69	4.74	4.61	**
Safe passing trucks	2014	1-5	2.58	2.77	2.45	**
	2012	1-5	2.53	2.60	2.43	*
Safe being passed	2014	1-5	2.23	2.36	2.14	**
	2012	1-5	2.24	2.25	2.23	
SB use in town	2014	1-5	4.53	4.40	4.63	**
	2012	1-5	4.51	4.40	4.67	**
SB use over 30 MPH	2014	1-5	4.79	4.66	4.88	**
	2012	1-5	4.72	4.63	4.85	**
Drive > 70 in a 65 MPH zone	2014	1-5	1.99	2.01	1.98	
	2012	1-5	1.99	2.06	1.90	*
Signage to traffic rules	2014	1-4	2.37	2.40	2.34	
	2012	1-4	2.19	2.19	2.19	
LE presence	2014	1-4	2.89	2.95	2.85	
	2012	1-4	2.89	2.96	2.80	*
Driver awareness	2014	1-4	3.40	3.43	3.38	
	2012	1-4	3.35	3.34	3.37	
Truck/car interaction	2014	1-4	2.72	2.65	2.78	
	2012	1-4	2.89	2.87	2.92	
Drive longer to avoid oil trucks	2014	1-4	2.46	2.37	2.51	
	2012	1-4	2.50	2.55	2.43	
Drive longer for better roads	2014	1-4	2.51	2.42	2.57	
	2012	1-4	2.48	2.56	2.36	*

*Significant at the 5% level for 1-way ANOVA
**Significant at the 1% level for 1-way ANOVA
[1]Note nominal/ordinal scales require different tests of significance

highest (F=6.759, df=5, p<0.001). The same trend occurs when rating how safe one feels passing trucks (F=4.051, df=5, p=0.001) and being passed by large trucks (F=4.770, df=5, p<0.001). The opposite trend occurs for other issues. The likelihood of meeting or passing large trucks while driving decreases with age (F=15.857, df=5, p<0.001) as does the rate at which one chooses to drive faster than 70 miles per hour in a 65 mile per hour zone (F=8.209, df=5, p<0.001). Instances of braking or swerving suddenly to avoid a crash occurred more often for younger drivers than for older drivers (Chi-Sq.=53.367, df=5, p<0.001). This implies that more risk is

Table 1.2. Mean Values of Responses, by Age

QUESTION	YEAR	SCALE[1]	AGE GROUP AND CORRESPONDING MEAN VALUE					
			18-34[2]	35-44	45-54	55-64	65-74	75+
Safety vs. 5 yrs. Ago	2014	1-5	1.6**	1.5**	1.5**	1.5**	1.7**	2.0**
	2012	1-5	1.4**	1.3**	1.5**	1.6**	1.6**	1.9**
Sudden brake/swerve	2014	0-1	0.8##	0.9##	0.8##	0.8##	0.6##	0.5##
	2012	0-1	0.9##	0.9##	0.8##	0.7##	0.7##	0.5##
LE visibility	2014	0-1	0.5##	0.6##	0.7##	0.7##	0.8##	0.7##
	2012	0-1	0.6	0.7	0.7	0.7	0.8	0.8
Meet/pass trucks	2014	1-5	4.7**	4.7**	4.8**	4.7**	4.5**	4.0**
	2012	1-5	4.8**	4.9**	4.8**	4.7**	4.6**	4.3**
Safe passing trucks	2014	1-5	2.6**	2.7**	2.5**	2.5**	2.5**	3.1**
	2012	1-5	2.4	2.4	2.5	2.5	2.6	2.6
Safe being passed	2014	1-5	2.2**	2.2**	2.1**	2.1**	2.3**	2.8**
	2012	1-5	2.1	2.1	2.2	2.2	2.3	2.5
SB use in town	2014	1-5	4.6	4.7	4.5	4.5	4.5	4.5
	2012	1-5	4.4	4.5	4.5	4.5	4.5	4.7
SB use over 30 MPH	2014	1-5	4.8	4.8	4.8	4.8	4.8	4.8
	2012	1-5	4.7	4.7	4.7	4.7	4.7	4.8
Drive >70 in a 65	2014	1-5	2.5**	2.2**	2.1**	2.0**	1.7**	1.8**
	2012	1-5	2.4**	2.5**	2.1**	1.9**	1.8**	1.7**
Signage, traffic rules	2014	1-5	2.2**	2.2**	2.2**	2.2**	2.7**	3.0**
	2012	1-5	2.0**	1.9**	2.1**	2.1**	2.5**	2.5**
LE presence	2014	1-5	2.2**	2.8**	2.8**	2.9**	3.2**	3.3**
	2012	1-5	2.6**	2.8**	2.8**`	2.9**	3.2**	2.9**
Driver awareness	2014	1-5	3.4	3.4	3.3	3.3	3.5	3.5
	2012	1-5	3.4	3.3	3.3	3.4	3.4	3.4
Truck/car interaction	2014	1-5	2.5**	2.5**	2.6**	2.7**	3.1**	2.9**
	2012	1-5	2.7	2.8	2.9	2.9	3.0	2.8

**Significant at the 1% level for 1-way ANOVA

##Significant at the 1% level for Pearson Chi-Square

[1] Note nominal/ordinal scales require different tests of significance

[2] The 18-24 and 25-34 age cohorts were combined into one group due to small response size from 18-24 cohort

being taken by young drivers. Educating this group how to interact with large trucks is vital for creating safer driving conditions and eliminating risky decision-making on the roadway.

Knowing that the views and behaviors towards safety vary significantly across age groups is useful in targeting specific demographics with safety messages and intervention strategies. For example, results concerning the need to suddenly brake or swerve to avoid a crash reveal that more attention needs to be given to younger drivers with regard to defensive driving techniques. Younger drivers were also less likely to think that increased law enforcement visibility reduces crashes (Chi-Sq.=17.797, df=5, p=0.003). Clearly, law enforcement presence is less influential on younger drivers than on their older counterparts. Practitioners can use this knowledge to improve the efficacy of law enforcement personnel and enhance safety on North Dakota’s roadways.

1.4.2. Crash Data Results

Crash reports were collected for the 17 western North Dakota oil counties from 2004 to 2013. Results of the crash data are compelling: almost every crash statistic has increased noticeably since 2004, and major spikes occurred in 2009 and 2011. Fatalities rose 136.8% from 2004 to 2013 in the oil counties and the largest number (90) occurred in 2013 (Figure 1.2.). This outpaced the 115.7% growth in VMT in the same time period. Although there were instances from 2004-2005 and from 2009-2010 in which the number of fatalities decreased from the previous year, the overall trend in western North Dakota shows that traffic fatalities have risen with the increase in oil development. This may explain why many respondents in the survey indicated that they felt less safe driving presently compared to five years ago.

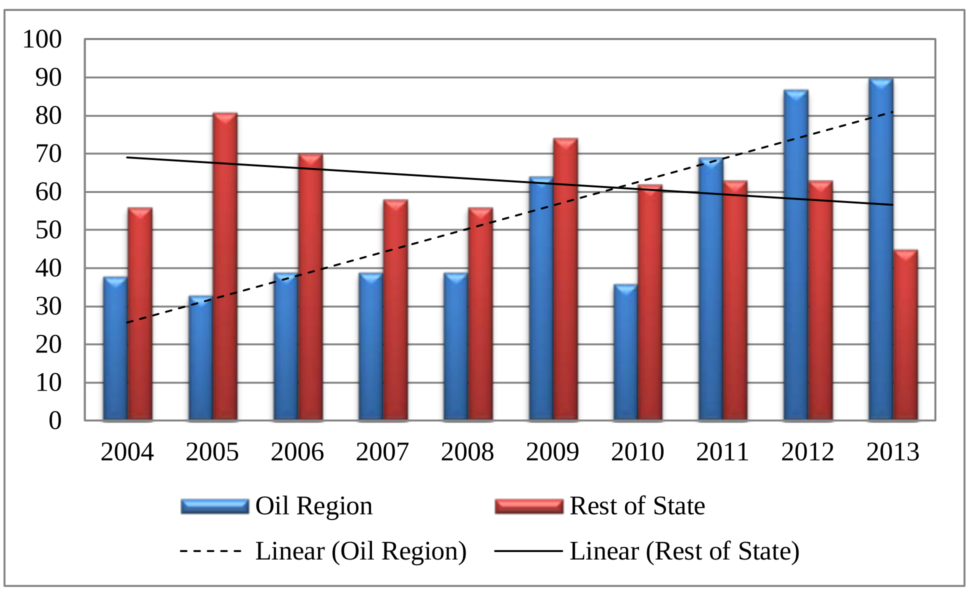

Figure 1.2. Total Number of Traffic Fatalities, 2004-2013

Traffic fatality trends in the oil region differ from other North Dakota counties: statistically-based linear trend lines are included to illustrate the contrast. Whereas traffic fatalities in the oil region more than doubled compared to 2004 and peaked in 2013 (R^2=0.7049), the number of traffic fatalities in the rest of the state remained relatively stable, peaking in 2005 (R^2=0.1702).

Starting in 2011, traffic fatalities in the oil region outpaced traffic fatalities in the rest of the state. This is especially alarming given the underlying population and the annual VMT attributed to the two groups. The oil counties have an estimated population of 193,316 which is roughly one-third the size of the rest of the state (530,077), yet in the oil region there were 46.6 fatalities per 100,000 individuals, a rate that is over five times higher than the 8.5 fatalities per 100,000 individuals in the rest of the state in 2013 (US Census Bureau 2014). Moreover, the 17 oil counties had a smaller share of North Dakota's annual rural VMT (3,488,790,000) compared to the rest of the state (4,106,952,000), yet the region experienced 2.58 fatalities per 100 million VMT in 2013, a rate that was over twice as high as the 1.10 fatalities per 100 million VMT in the rest of North Dakota. Both statistics reveal that driving was more dangerous in the oil counties than in the balance of the state. Note that fatalities, while increasing, are still largely episodic in nature and are difficult to use for assessing traffic safety issues and strategies.

Like fatalities, injuries that result from car crashes also increased significantly (R^2=0.8062) (Figure 1.3.). During the time frame studied, the total number of non-fatal injuries from traffic crashes in oil counties increased 407% from 237 to 1,202. Non-fatal injuries in the 17 western oil counties increased every year from 2007 to 2012 and may be a direct factor in why some drivers surveyed feel less safe and favor increased driver awareness or more law enforcement presence as strategies to reduce crashes. The number of non-fatal injuries in the rest of the state also rose noticeably (R^2=0.7856). Both the oil region and the rest of the state experienced spikes in the number of injuries resulting from crashes after 2008. Beginning in 2011, there were more injuries in the oil region than in the remainder of the state. There were 621.8 injury crashes per 100,000 individuals in oil counties in 2013. This rate was much higher than the 213.4 injury crashes per 100,000 population in the rest of the state. There were 34.5 traffic injuries per 100 million VMT in oil counties, a higher rate than in other parts of the state (27.5 injury crashes per 100 million VMT). These numbers again indicate that driving was more dangerous in 2013 in the oil region than it was in the rest of North Dakota; individuals living in this part of the state have a higher likelihood of being involved in a crash resulting in a serious injury.

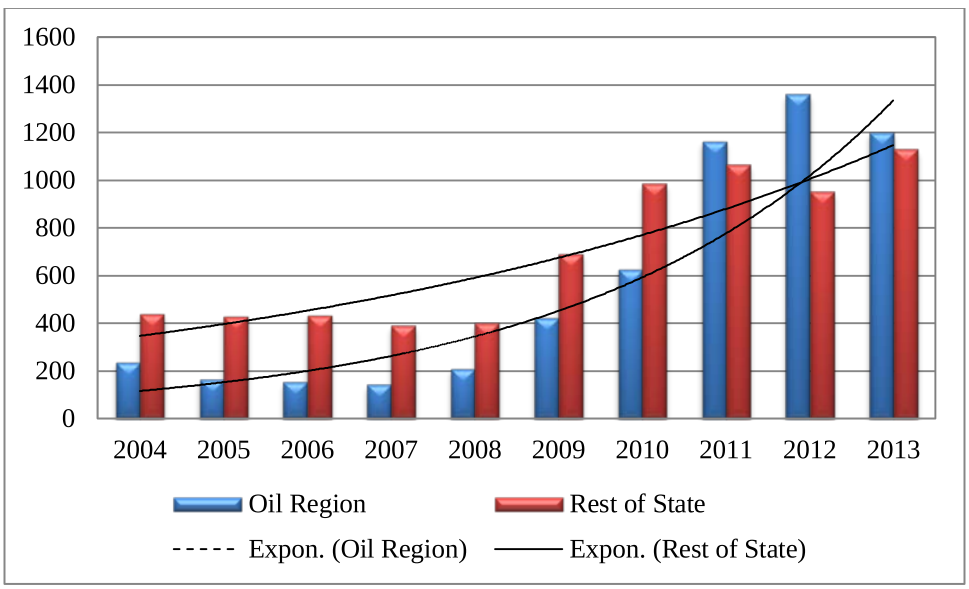

Figure 1.3. Total Number of Traffic Injuries, 2004-2013

With increases in oil development come growing numbers of large trucks and heavy machinery required to extract and transport natural resources. This has resulted in a higher propensity for trucks to become involved in traffic crashes: there were 516.8 crashes involving large trucks per 100,000 population in oil counties and just 90.7 per 100,000 population elsewhere in 2013. The representation in terms of exposure is not known since VMT is not reported by vehicle class for the oil counties. Large truck crash involvement in the oil region appears to be growing exponentially (R^2=0.9298) but has less variability in the rest of the state (R^2=0.5824) (Figure 1.4.). From 2004 to 2013 the total number of large trucks involved in crashes in oil counties increased over 623%. This may explain drivers' fears of passing and being passed by large trucks. Within the last five years alone there has been a 237.5% increase in the total number of trucks involved in a crash.

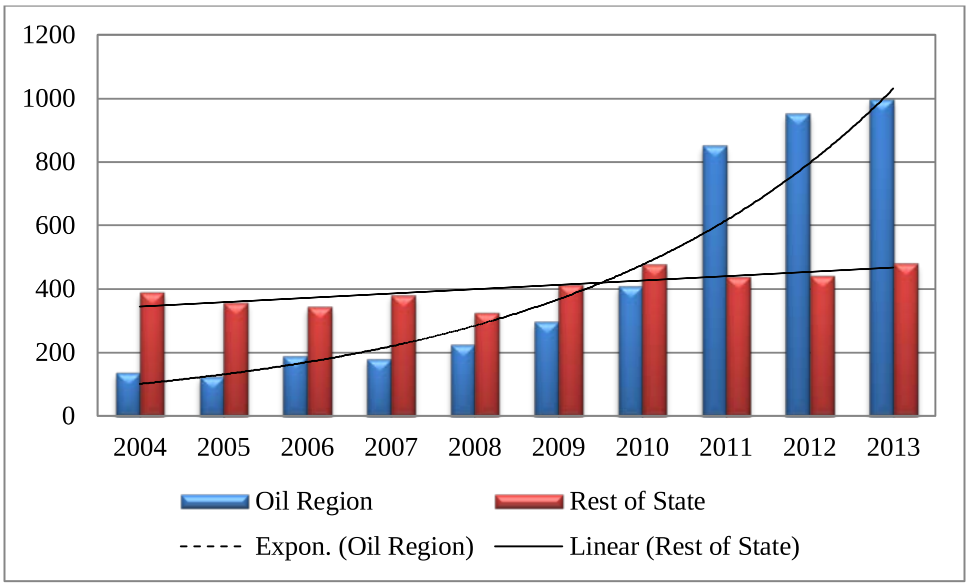

Figure 1.4. Large Truck Crash Trends, 2004-2013

1.5. Discussion

The driving environment in the 17 western North Dakota oil counties is noticeably different than in other parts of the state. Whereas other areas experienced traffic growth related to many different factors, this particular region has seen extensive growth surrounding one specific issue: the development of the oil industry. This development has coincided with drastic increases in population, job opportunities, and economic prosperity. As individuals flock to this area, increased traffic – more personal vehicles, large trucks, oil trucks, and heavy machinery – is becoming commonplace.

Survey responses show that local residents perceive driving conditions to be unsafe. Most drivers believed that law enforcement presence needs to increase to improve safety on oil roads. Some behaviors, such as seat belt use and speeding, can be improved via greater compliance. It is undeniable that *ProgressZone: Moving Forward Safely* and *Code for the Road* have had some positive influence. The core messages were widely recognized by drivers – perhaps in conjunction with other safety efforts. Drivers positively changed behaviors after exposure to these messages.

An examination of crash data revealed that the total number of crashes, injuries, fatalities, and the number of large trucks involved in crashes has increased substantially since 2004. Some crash patterns appear to be increasing exponentially. Every major crash statistic spiked, with some occurring in 2009 and others in 2011. This likely impacts driver views, attitudes, behaviors, and perceptions, and may go hand-in-hand with why many drivers view roads as unsafe. All 17 counties within the region had either a spike in crash rates or little-to-no improvement between 2010 and 2011, suggesting that driving conditions during this annual interval were particularly dangerous. Some counties improved crash trends between 2012 and 2013, but forecasts for continued oil drilling and extraction mean that a higher-density, industrial driving environment is expected to continue well into the future. Therefore, public safety efforts focused on traffic safety are necessary to slow and reverse current trends in crashes, injuries, and economic loss.

Future research may benefit from integrating non-North Dakota residents into this survey through creel techniques or private company participation. The oil industry boom has attracted temporary workers and businesses from Canada, Montana, South Dakota, eastern North Dakota, Minnesota, and other areas. Including non-western North Dakotans provides an outside voice to better understand if perceptions of poor driving conditions are accurate across all residents or if they are simply a product of locals experiencing changing conditions firsthand. Future research will be further improved if the State of North Dakota tracks VMT by vehicle class to include large truck data. This will allow researchers to accurately assess if crash rates parallel changes in VMT.

New insights may be gained with future driver contact, and it seems prudent to expand or discuss alternative strategies for increasing travel safety in the region. Work with private companies in educating their workers about safe practices for maneuvering in traffic with increasing truck density may be beneficial. School and community events may also be strong venues for reaching drivers with messages specific to oil region traffic safety issues such as interacting with trucks.

Deterrence methods may be considered based on successful experiences elsewhere. Traffic surcharges may be useful in discouraging risky driving behavior such as driving too fast, following too closely, and improper passing. Some jurisdictions successfully instituted surcharges on existing traffic fees for moving violations. The surcharges collected are generally dedicated to an associated cause such as emergency medical services or traumatic brain injury funds. An example is Douglas County, Colorado where a Victim Assistance and Law Enforcement (VICE) surcharge is assessed on each traffic violation (Douglas County Sheriff's Department 2012). If a driver is cited for three traffic violations on a citation, the assessment totals $30 with surcharges of $10 applied for each violation. All surcharges collected are dispersed to local programs providing services to crime victims. If one of the violations is speeding, an additional surcharge applies. The State of Colorado collects a $12 surcharge for each speeding citation. These funds are dedicated to the Colorado Traumatic Brain Injury fund (U.S. Department of Health and Human Services 2012). In Texas, the Driver Responsibility Program is governed by Texas Transportation Code, Chapter 708. An annual surcharge of $100 is assessed for three years following offenses such as impaired driving, driving under an invalid license, and driving without insurance. The Trauma Center and Texas General Revenue Funds receive 99% of the funds collected; 1% is provided to the Transportation Department for program administration (Texas Department of Public Safety 2012). Another example is found in New York where anyone convicted of an alcohol or drug related traffic offense must pay $250 for three years beyond the standard fees (New York Department of Motor Vehicles 2012).

Operational solutions may also be discussed. Given that roughly three-quarters of drivers were willing to increase the distance driven to avoid trucks, passenger- or truck-only routes or one-way traffic may be useful in certain situations or during selected time intervals. Public education and awareness regarding this change would be crucial. Increased use of roadway safety enhancements such as clear zone, intersection lighting, edge lines, and rumble strips could also be considered. The ability of counties to pool needs in contracting as a group or joining into a state services contract may accelerate these investments.

Finally, the ability of counties to share best practices and supplement efforts to manage heavy trucks in order to maintain roads in good condition may contribute to longer-term road safety. Road degradation, both paved and gravel, is widespread. Although enforcement efforts are led by the state, several counties have begun their own efforts. Sharing best practices and standards related to these efforts may be useful for those already engaged and for counties or locales considering similar strategies.

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CHAPTER 2. CRASH PATTERNS AND PROXIMITY TO OIL EXTRACTION ACTIVITY: A CASE STUDY OF WESTERN NORTH DAKOTA

2.1. Abstract

Road conditions in western North Dakota have changed considerably with the growth of the oil industry. Traffic crashes in western North Dakota rose substantially between 2004 and 2013, the timeframe in which oil production began to grow exponentially. Some crash types are more prominent closer to oil wells, but statistical analyses of crash patterns revealed that oil activity alone may not explain danger on the roadway. A cluster analysis was performed in GIS to track where severe crashes most often occur. Three variables – proximity to oil wells, city limits, and roadway type – appear to be strong determinants of crash severity. When analyzed broadly, there are statistically significant differences in crash severity factoring for the three variables. When analyzed narrowly, crashes near oil development, outside of city limits, on any road type result, on average, in at least a minor injury.

2.2. Introduction

During the last 10 years western North Dakota has experienced unprecedented economic prosperity due largely to the success of a growing energy sector. The region's latest oil boom began in 2004, and parallels the advent of hydraulic fracturing as a viable oil extraction technique. Since this boom began, North Dakota has become the second-leading oil producer in the United States, passing Oklahoma, California, and Alaska in annual crude oil production (U.S. Energy Information Administration 2014). Monthly oil production now exceeds one million barrels per day and is expected to continue to rise in the future (Helms 2014).

Geographic determinism limits where oil extraction takes place. In North Dakota, 17 counties produce oil due to their proximity to conventional sources such as the Bakken and

Three Forks formations (Figure 2.1.) and unconventional oil sources such as the Elm Coulee, Central Basin, Nesson Little Knife, Eastern Transitional, and Northwest Transitional formations in which future drilling is anticipated (Gaswirth et al. 2013). Oil production in these counties is growing at exponential rates; there were just 3,339 active wells in 2004, a number that grew to 10,219 in 2013 (R^2=0.921) (North Dakota Department of Mineral Resources 2014). Recent estimates suggest that as many as 60,000 new wells may be on-line over the next 20 years (Upper Great Plains Transportation Institute 2014).

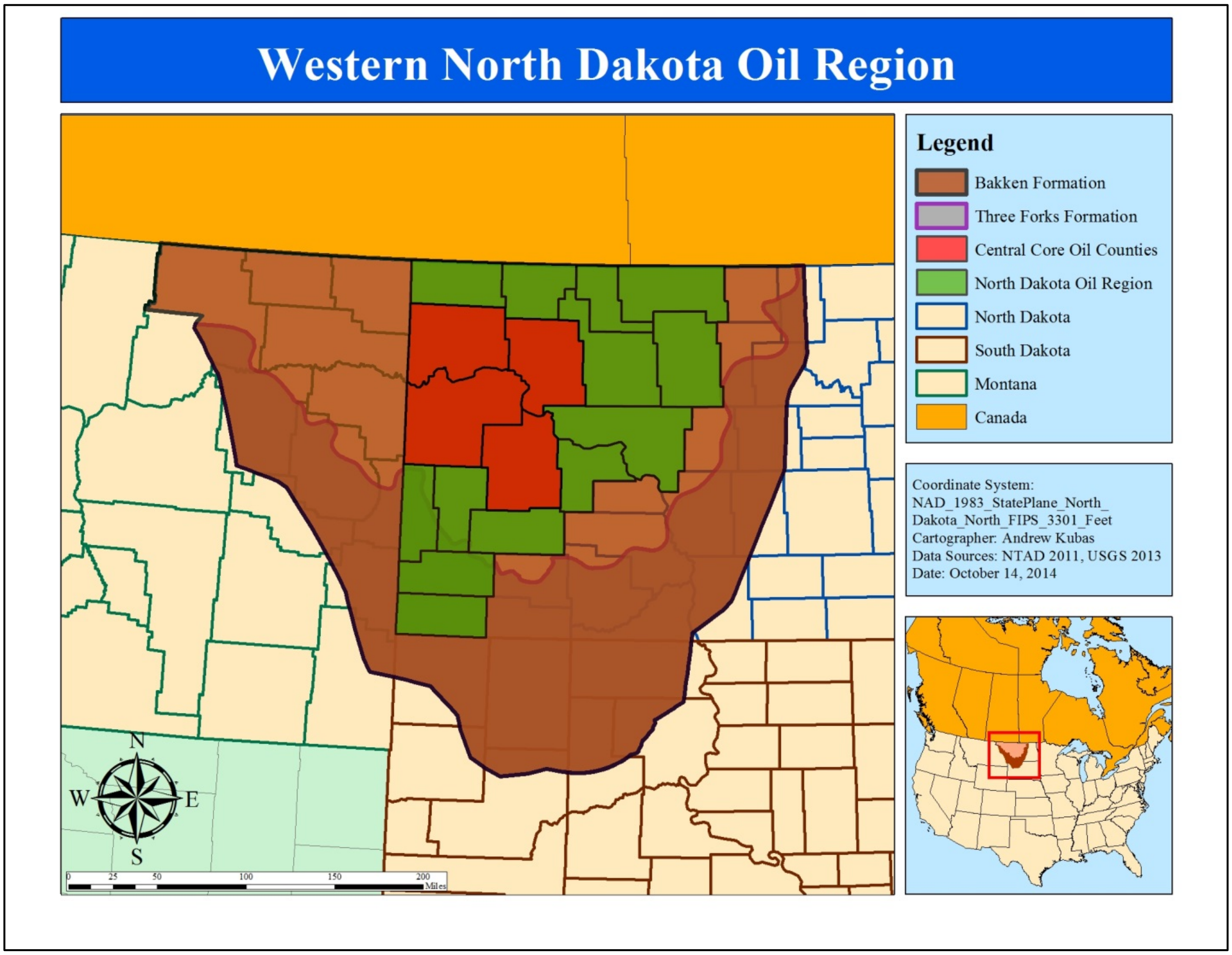

Figure 2.1. Western North Dakota Oil Region

Oil wells represent potential hazards for drivers: as oil development amplifies, road usage changes. Roads once used for local access and agricultural purposes are not utilized at high volumes to serve expanding oil production. This has resulted in a higher volume of traffic, overweight vehicles, and oversized trucks on the road – it is estimated that for each horizontal well drilled, anywhere from 600 to 1,000 truck loads are required during the construction, erection, and production phases (NDDOT 2008). As such, many roads are in poor condition and others are deteriorating rapidly; an estimated investment of $4.13 billion is needed during the next 20 years for transporting oil and allowing travelers to have acceptable roadway use (Upper Great Plains Transportation Institute 2014). An increased public safety risk associated with additional traffic is evident in the number and severity of regional crashes. Some crash incidence trends show exponential growth, especially for serious crashes.

Prior research about changes oil extraction brings to a community shows a similar situation to that which is developing in North Dakota. Oil extraction in the North Sea created noise, safety hazards, increased traffic volumes, altered landscape, construction camps, and localized changes to infrastructure – all of which are present in western North Dakota (Affolter 1976). Laska et al. (2005) showed that oil development could threaten transportation modes such as road networks, ports, and airports. Additionally, perceived safety, driver behavior, large truck/passenger vehicle interaction, and safety campaigns are all factors influencing traffic safety.

Certain driver characteristics can be determinants of risk. One determinant is that of being a high-risk (18-34 year-old) driver. These operators are less experienced than their counterparts on the road, are more likely to engage in risky behaviors, and exhibit traits at-odds with traffic safety. Novice drivers underestimate risk (Davey et al. 2008) and have as much as a 50% increased risk of a crash (Ivers et al. 2009). This risk is amplified with alcohol consumption (Phelps 1987). Donmez, Boyle, and Lee (2010) argue that high-risk young male drivers are not homogeneous and there is a hierarchy of danger within this already dangerous driver group. In North Dakota, 18-34 year-old drivers are less likely to wear a seat belt, more likely to speed, and more likely to operate a vehicle after consuming alcohol (Vachal, Benson, and Kubas 2014).

Vehicle class is another source of danger. The sheer size of large trucks causes infrastructural damage to the roadway faster than damage caused by passenger vehicles. Damages to both gravel and paved roads pose safety threats to drivers. To mitigate road surface deterioration on unpaved roads, recommendations include reducing semi-truck tire pressure (Shalaby and Reggin 2002), increasing the aggregate base thickness and corresponding asphalt concrete layer (Skorseth 2011), and having an average daily traffic (ADT) count of less than 300 (Massachusetts Department of Transportation 2010; Hough, Smadi, and Schulz 1996; Jahren et al. 2005). On paved roads, truck weight regulation is vital: oversized trucks can increase pavement costs by more than 100% (Pais, Amorim, and Minhoto 2013). In North Dakota many oil trucks are over the road weight limits and require special permits for operation (NDDOT 2008). Given the economic incentive of extracting oil, many unpaved and paved roads have an ADT over 300.

Heavy-duty trucks are more likely to be involved in serious crashes (Braver et al. 1992), especially when speeding (Neeley and Richardson 2009; Islam and Hernandez 2013; Vadlamani et al. 2011). The area's dependence on tanker trucks, gravel trucks, flatbeds, dump trucks, and service trucks stems largely from a lack of pipeline infrastructure (Dobb 2013) and has degraded the quality of life (Gibson 2013). The quality of life diminishes because injuries and fatalities increase with the growth of the oil industry, often due directly or indirectly to the prevalence of large trucks. The growth in serious crashes is taking place despite the fact that, nationally, large truck crash involvement has improved. Studies show large trucks execute lane changes more smoothly on arterial roads and freeways than shorter vehicles (Aghabayk et al. 2011). Modern safety improvements such as side view assist, forward collision warning, lane departure warning, and vehicle stability control could be relevant to roughly one-quarter of all heavy-duty truck crashes in the United States (Jermakian 2012), enhancements that would benefit the oil region. Safety improvements made to truck and passenger cars in the 20^{th} century were likely linked to a significant drop in national fatalities caused by large trucks (Lyman and Braver 2005). These national large truck crash trends deviate from present crash patterns in western North Dakota.

Highway vehicle crashes are the leading cause of oil and gas extraction worker fatalities (OSHA; Urbina 2012). In Qatar, an oil-rich nation, legislation mandating seat belt use was linked to a reduction in hospital admissions (Bener et al. 2007). Given that North Dakota does not have a primary seat belt law, such legislation could be a viable tool to save lives in the oil-rich portion of North Dakota and beyond. Previous studies have investigated crash incidence trends in the oil region as compared to the rest of North Dakota and found that driving conditions are generally more dangerous in oil counties (Kubas and Vachal 2014a; Kubas and Vachal 2014b). The rate of crashes resulting in injuries, fatalities, and those involving heavy-duty trucks in the oil region is considerably higher than in the rest of the state and outpaces the growth in vehicle miles traveled (VMT) during the same time period (Kubas and Vachal 2014a). The goal of this project, however, is to investigate if crash patterns are segmented within the oil region itself. Is proximity to an oil well linked to danger? Do crashes cluster in certain areas of the region? Answers to these questions are at the heart of the study to determine what, if anything, inside of the oil region determines dangerous conditions.

2.3. Methods

Crash reports were collected from 2004 to 2013. These reports were obtained from the North Dakota Department of Transportation. Each report contains variables indicating latitude and longitude coordinates along with dozens of variables describing conditions at the time of the crash. The reports were utilized in two ways.

First, taken collectively, crash reports were given unique identification numbers and uploaded into SPSS as an entire database. From this database, reports were exported into an Excel file, and the latitude and longitude coordinates were displayed in GIS to track crash locations via temporal and spatial relationships. Based on the review of the literature, rural road data were queried to track five crash types: high-risk (18-34 year-old) drivers, male drivers, large truck crashes, injury crashes, and fatal crashes. These crash types were treated as dependent variables. Then, a GIS shapefile was downloaded from the North Dakota Department of Mineral Resources' Oil and Gas Division's ArcIMS viewer map server. The shapefile consisted of active oil wells in North Dakota, each of which fell within one of the 17-county region's boundaries. To determine if crash patterns are segmented within the oil patch, arbitrary buffer zones of one-half mile, one mile, and two miles were placed around each individual oil well. Using the "dissolve" geoprocessing function in GIS, crashes falling within each buffer zone were transformed into dummy variables. These dummy variables were added to the original crash files and were uploaded to SPSS for further querying. Buffer zones were treated as independent variables. Statistical analyses were performed to identify any differences in crash patterns occurring in a buffer zone and crashes that occur elsewhere in the region. It was hypothesized that these five crash types would occur more often inside the buffers.

Second, an injury severity scale was developed based on a variable within the crash reports. Using GIS, this eight-point ordinal scale was subjected to cluster analysis to determine where the most dangerous crashes occur. This cluster analysis revealed that other interacting variables – proximity to city limits and major roadways – may also be determinants of danger. Therefore, a "city limits" and "roadway" polygon shapefile were created in GIS to track crashes in these zones in addition to the arbitrary buffer areas. These dichotomous variables were combined, and a nominal eight-point location classification scale was developed to examine differences in crash trends in all permutations of 1) proximity to oil, 2) city limits, and, 3) roadway type.

2.4. Theory

The primary basis for this study is decision theory. In decision theory individuals choose the optimal choice (in this case, arriving from Point A to Point B safely) from a number of options. Unlike other theoretical lenses, in decision theory "there are no players in the game other than the decision maker; the game is played against nature" (Ormerod 2010: 1761). This natural environment consists of factors outside of the decider's control; in transportation, these include hazardous weather, vehicle mechanical failure, animals in the roadway, inexperienced drivers, distracted drivers, and impaired drivers, among others. Humans may have an idea of the probability of an event, but it may be difficult – or impossible – to quantify precisely. Decision theory assumes a value-standard based on morals is at hand and that deciders try to obtain the best outcome possible (Hansson 1994). Thus, given the rationality of human beings, one will choose to act in a way to get the best result: it is not logical for one to willingly choose an option resulting in a loss or negative consequence.

Important intervening variables in decision theory are certainty, risk, and uncertainty. Thus, it is the known outcomes of a choice, one's perceived risk when partaking in a choice, and one's comfort level with not knowing the outcome of a choice that determine whether or not one chooses to drive believing that he/she will arrive from Point A to Point B safely.

In decision theory, choosing is straightforward: alternative actions are compared by considering what the outcome might be in a specific scenario (Ormerod 2010). The preferred action is chosen because consequences from each option in different scenarios are compared with one another (Ormerod 2010). Thus, decision theory predicts "option consequences" and often takes "the form of a decision tree" (Brown 2012: 209).

Because it is certainty, risk, and uncertainty that influence one's decision to drive, studies have found that increasing the certainty of driver's decisions (de Moraes Ramos et al. 2011), being risk averse (Liu and Polak 2007), and maximizing utility when conditions are uncertain (Galdames, Tudela, and Carrasco 2011) can be manipulated to guide one's choice. This study focuses on decision-making under uncertain conditions. The uncertainty of oil development in western North Dakota has been incorporated into the lives of local residents. The typical western North Dakota driver does not know where a new well will be constructed, how much oil it will produce, how many trucks will be encountered on a typical commute, and how traffic safety will vary daily. Despite this uncertainty, drivers are traveling at record numbers: the annual VMT in the region was the highest ever in recorded history in 2013 (NDDOT 2014). This paper will describe risks associated with crash patterns near oil development, and will address some uncertainty surrounding crash incidence trends near oil extraction.

2.5. Results

Between 2004 and 2013, crashes in the oil region grew steadily. Whereas there were just 3,353 crashes in 2004, there were 6,389 crashes in the region in 2013. Between 2010 and 2011, there was a noticeable spike in the number of crashes taking place both inside and outside of the buffer areas (Figure 2.2.). Since 2011, crashes inside of the buffers have grown consistently, but crashes outside of the buffer zones have tapered off slightly. Although total crashes is an important metric in understanding traffic safety patterns, five crash types – 18-34 year-old drivers, male drivers, trucks, injuries, and fatalities – will be highlighted in this study. Each of these dependent variables were derived from the original SPSS crash database and were transformed into dummy variables. As a result, mean values for these variables represent the proportion of each crash type. The three buffer zones – also coded as dummy variables – are the independent variables.

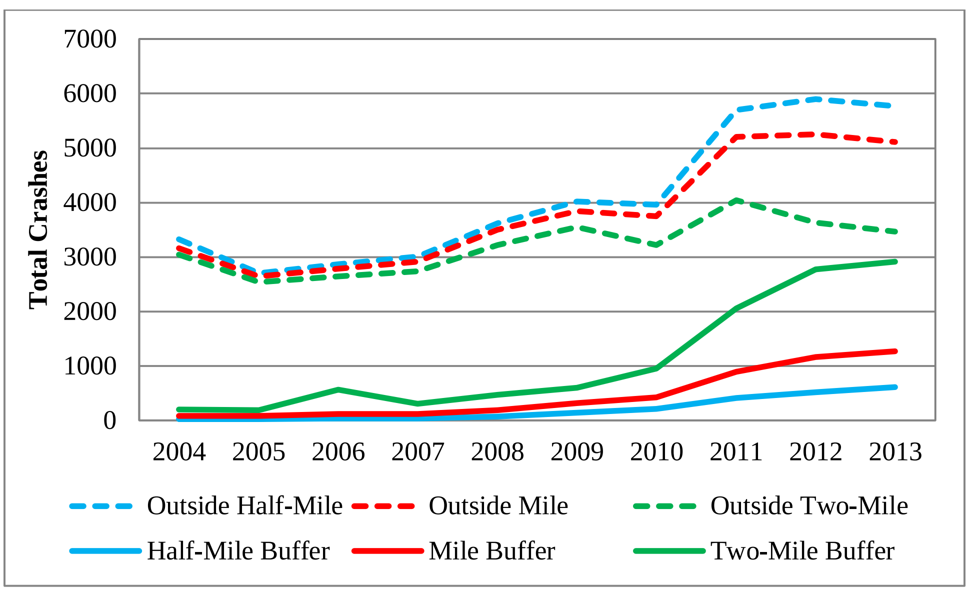

Figure 2.2. Total Crashes Inside and Outside of Buffer Zones

Unfortunately, it is impossible to normalize crash rates inside and outside of the buffer zones. North Dakota does not track VMT by vehicle class; therefore it is impossible to compare large truck crash rates per 100 million VMT to passenger vehicle crash rates. Moreover, some rural North Dakota roads have not been subjected to traffic count studies and no information about VMT exists. Some buffer zones intersect multiple road segments, making a weighted estimation of VMT difficult. When discussing region-wide trends, it is possible to track crash statistics by VMT because county-level VMT statistics are provided by the NDDOT. Furthermore, the oil well buffers do not follow any municipal boundary. This makes estimating population inside and outside of buffer zones nearly impossible and tracking crash patterns per 100,000 population becomes implausible.

To mitigate these shortcomings, one metric was created to normalize data and identify differences in crash trends. This metric examines crash type per square mile, which explains crash concentrations both in the areas nearest oil development and in areas farther from extraction activity.

2.5.1. Key Drivers

High-risk young drivers and male drivers impact overall traffic safety. In this study, high-risk young drivers are classified as 18-34 year-olds. Studies have found that this group of drivers is more likely to engage in dangerous behaviors behind-the-wheel and is less likely to partake in safe driving practices. This is true in North Dakota where both 18-34 year-old males and females have traffic knowledge, attitudes, behaviors, and beliefs that differ from older (35+ year-old) drivers (Vachal, Benson, and Kubas 2010 – 2014).

In the entire 17-county focus area, high-risk young driver crashes between 2004 and 2013 mirrored changes in VMT: during the study period, high-risk drivers involved in crashes increased 126% and VMT increased 115%. However, there is a noticeable disparity between high-risk young driver crash trends inside and outside of the buffer zones. High-risk young driver crashes have remained mostly constant outside of the buffer zones. In contrast, these drivers are being involved in a larger number of crashes inside of the buffers. High-risk young drivers are represented in a greater proportion of crashes inside the half-mile buffer zone (Chi-Sq.=9.623, df=1, p=0.002), the mile buffer (Chi-Sq.=10.936, df=1, p=0.001), and the two-mile buffer area (Chi-Sq.=19.812, df=1, p<0.001). Crash trends involving high-risk young drivers differ based on proximity to oil development.

The number of male drivers involved in crashes more than doubled from 2,042 in 2004 to 4,810 in 2013, and grew rapidly starting in 2009. The increase in male driver crashes mirrors exponential growth (R^2=0.8925). During the study period, crashes involving male drivers outpaced VMT growth, an indication that the representation of these drivers in traffic crashes is due to factors beyond additional vehicles on the roadway.

In all three areas outside of the buffer zones the number of male drivers involved in crashes grew, but at rates that were much lower than inside of the buffer zones. For example, there was a 111.9% increase in male drivers involved in crashes outside of the half-mile buffer between 2004 and 2013 – the largest growth rate outside of the buffers. In contrast, the smallest growth rate inside of the buffered areas occurred within the one-mile buffer zone, where male drivers involved in crashes grew by 1,823.2%.

A higher proportion of males crashed inside of all three buffer zones. In the half-mile buffer, 80.9% of crashes involved male drivers, a higher rate than the 67.7% outside of the buffer. This difference was statistically significant at the 1% level (Chi-Sq.=162.620, df=1, p<0.001). The same trend emerged in the one-mile buffer area: male driver crash involvement outpaced the area outside of the buffer zone by 80.0% to 66.9%, respectively (Chi-Sq.=332.334, df=1, p<0.001). In the two-mile buffer zone roughly four-fifths (79.7%) of drivers involved in crashes were males compared to about two-thirds (64.5%) outside of the buffer (Chi-Sq.=858.587, df=1, p<0.001). Studies discussed in the literature have indicated that men are more likely to be involved in traffic collisions than women. In western North Dakota, when men are compared to other men, there is a significant difference between crash involvement inside and outside of the buffer zones. Male drivers are more likely to be involved in a crash nearer to an oil well than farther away from it.

2.5.2. Vehicle Class

Crashes involving large trucks inside of the half-mile buffer zone (R^2=0.9179), the mile buffer zone (R^2=0.9409), and the two-mile buffer zone (R^2=0.9426) appear to be growing exponentially. The same trend emerges outside of the buffer zones: large truck crashes outside of the half-mile buffer (R^2=0.9359), the mile buffer (R^2=0.9312), and the two-mile buffer (R^2=0.9096) have grown exponentially. As a whole, large truck crash involvement grew during the study period by 679%, clearly outpacing VMT growth during the same timeframe. Nonetheless, large truck crash involvement grew at a faster rate inside of the buffer zones.

This is noticeable when comparing large truck crash rates per square mile. In the half-mile buffer zone in 2013, there were 0.119 large truck crashes per square mile compared to just 0.032 large truck crashes per square mile outside of the buffer. Over the entire 10-year period studied, 22.6% of crashes inside of the half-mile buffer involved large trucks. Just 9.4% of crashes outside of the buffer zone involved large trucks. This difference was statistically significant at the 1% level (Chi-Sq.=385.482, df=1, p<0.001). The same pattern took place in the other buffer zones: large truck crashes were more likely in the one-mile buffer zone (Chi-Sq.=709.458, df=1, p<0.001) and in the two-mile buffer (Chi-Sq.=1,480.124, df=1, p<0.001). Proximity to oil wells is linked to one's propensity of being involved in a large truck crash.

2.5.3. Crash Severity

Non-fatal injuries also appear to have grown at exponential rates, though the total number of injuries decreased slightly between 2012 and 2013 (R^2=0.7684). Injury crashes increased substantially in the buffer zones but remained stagnant outside of arbitrary buffer areas. By volume, a higher number of injury crashes occur outside of buffer zones. However, injuries tend to be concentrated more densely inside of the buffer areas. When addressed per square mile, injuries inside of the one-half mile buffer zone exceeded the non-buffer area in 2007, and every year from 2009 to 2013. Drivers traveling inside of the one-half mile buffer zone (Chi-Sq.=24.314, df=1, p<0.001), the one-mile buffer (Chi-Sq.=67.344, df=1, p<0.001), and the two-mile buffer (Chi-Sq.=159.993, df=1, p<0.001) have a statistically higher likelihood of being involved in an injury crash. Once again, drivers have a greater likelihood of being involved in an injury crash nearer to oil wells.

Fatalities in the oil region varied between 2004 and 2013, though the general trend follows exponential growth (R^2=0.7907). The variability may be explained because fatalities are largely episodic in nature and are sometimes difficult to use when assessing traffic safety issues. In 2004 there were just 28 fatalities in the 17-county region. By 2013 there were 88 – the highest in the study period. Fatalities in the buffer zones have grown at a faster rate than fatalities farther from oil development.

By volume, the number of fatal crashes outside of the buffers generally outpaces the number of fatal crashes inside of the buffer areas. Unlike the other metrics, when fatal crashes are normalized by square mile, the rate at which fatalities occur are comparable in the one-half mile and one-mile buffers. There were no statistically significant differences factoring for fatalities in the half-mile (Chi-Sq.=0.264, df=1, p=0.607) and the mile buffer zone (Chi-Sq.=2.516, df=1, p=0.113).

In 2013, there were more fatalities in the two-mile buffer zone (47) than there were outside of it (41). This was the only year in which fatalities in the buffer zone outpaced fatalities elsewhere in the region. With regard to fatalities per square mile, rates were generally higher inside of the two-mile buffer zone. There was a statistically higher likelihood of being involved in a fatality inside of the two-mile buffer zone than being involved in a fatality elsewhere in the study area (Chi-Sq.=9.989, df=1, p=0.002). This is a surprising finding: if drivers are more likely to be involved in a crash that results in a fatality in the two-mile buffer instead of the one-half or one-mile buffers, this implies that proximity to oil wells is not the sole cause of fatal danger in the region. Therefore, with regard to fatalities, other interacting variables must be determinants of danger on the roadway.

2.5.4. Cluster Analysis

What are these variables? An Anselin Local Morans I test was performed using ArcGIS to map crash clusters based on crash severity (Figure 2.3.). The 2013 two-mile buffer zone was chosen for the cluster analysis based on the statistically significant difference in fatality rates and the fact that – by volume – fatalities in the buffer outpaced fatalities in the non-buffer area. This cluster analysis was performed to better understand where the most severe crashes take place. An eight-point crash severity scale was used based on definitions in the crash database. A score of seven represented a fatality, a score of zero represented a property-damage-only crash, and scores from one through six represented a hierarchy of injuries ranging from possible (one) to disabling (six). When the cluster analysis was performed, three important findings emerged. First, areas with a high probability of a high crash severity score (in other words, the most severe

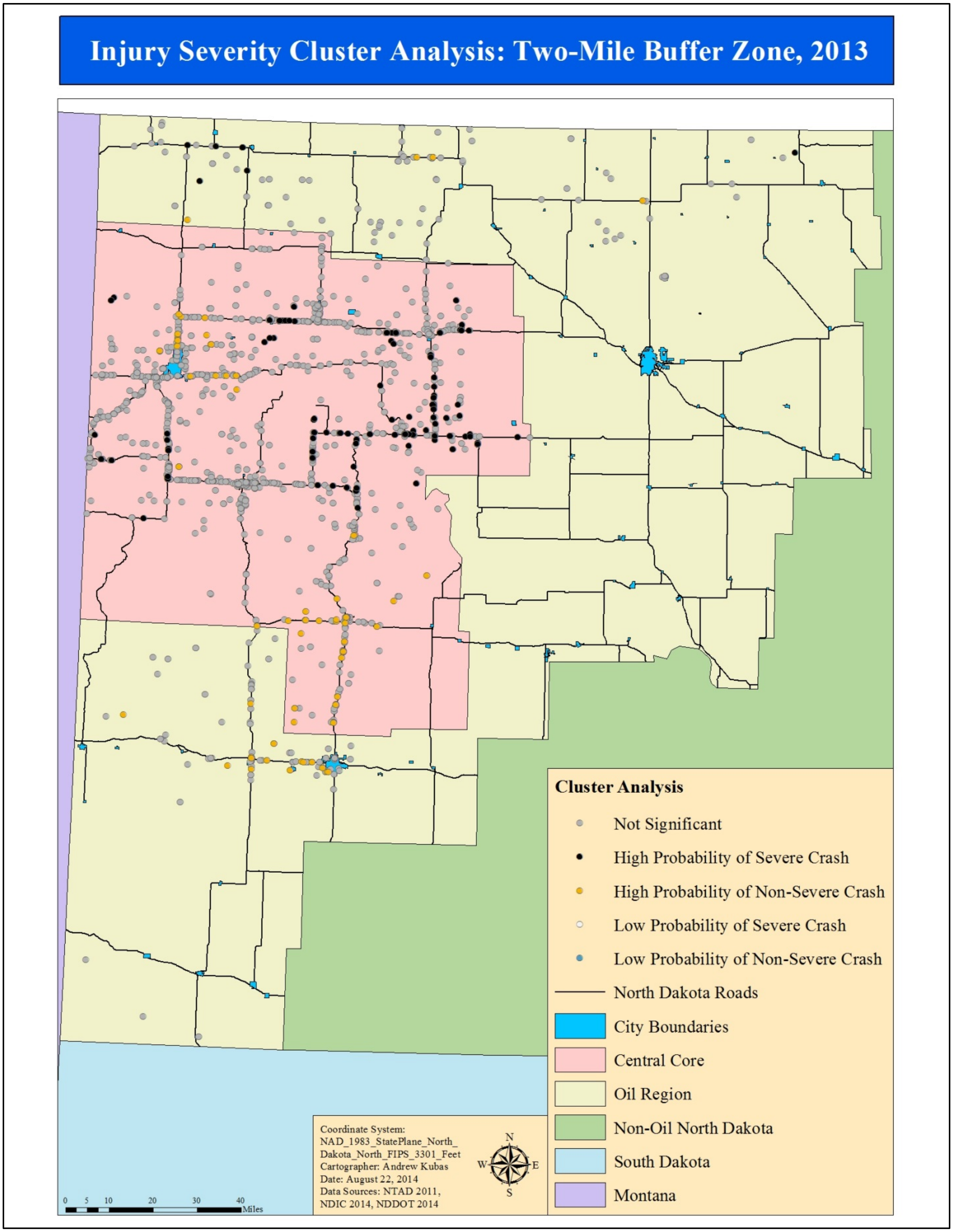

Figure 2.3. Cluster Analysis of Crash Severity in Two-Mile Buffer Zone, 2013

crashes) are concentrated in the central core of the oil region. The central core consists of the four highest producing oil counties as defined by the North Dakota Industrial Commission: McKenzie, Mountrail, Dunn, and Williams (Department of Mineral Resources 2014). These counties have higher VMT than other oil counties in North Dakota, thereby increasing the risk of a crash occurring. Second, more severe crashes tend to cluster outside the city limits of major towns in the central core. Third, the most severe crashes cluster near major state and county roads; many take place directly on them. Compared to other roads in the region, these roadways tend to be highly traveled, paved, have higher posted speed limits, and lead directly to the largest cities and towns in the region. These three findings imply that proximity to an oil well may determine some danger on the roadway, but this danger is augmented by traffic volume, a notion that is accepted in transportation theory (Yan et al. 2012; Jovanis and Chang 1986; Ewing and Kim 2012).

In western North Dakota – like most areas nationwide – traffic volume is greater on major roads and in larger cities. Therefore, in addition to the buffer zones placed around active oil wells, two other polygon shapefiles were created in GIS for analysis. First, a 50-foot buffer zone was created from the centerline of major North Dakota roadways. Second, a boundary area was placed around the city limits of all cities and towns in the region. Crashes occurring inside of these two new polygon shapefiles were coded for statistical analysis and re-uploaded into the SPSS database. A general linear model indicates that interactions between some of the three spatial features – oil well proximity, city limits, and major roads – are predictors of crash metrics (Table 2.1.). The interaction between city limits and oil well proximity is most prevalent and strongest in the two-mile buffer. The interaction between major roads and proximity to oil wells is insignificant. The effect of city limits on injury crashes and fatal crashes evident. This

Table 2.1. General Linear Model: Predictors of Crash Metrics by Buffer Zone

	High-Risk Drivers					
	Half-Mile Buffer		One-Mile Buffer		Two-Mile Buffer	
Source	F	Sig.	F	Sig.	F	Sig.
In City Limits	0.331	0.565	0.886	0.347	9.090	**0.003**
On Major ND Road	1.521	0.217	4.995	**0.025**	3.104	0.078
In Buffer	2.162	0.141	2.648	0.104	5.270	**0.022**
In City Limits * On Major ND Road	0.054	0.816	0.087	0.768	1.081	0.298
In City Limits * In Buffer	0.064	0.801	0.167	0.683	1.343	0.247
On Major ND Road * In Buffer	0.167	0.683	0.983	0.321	1.341	0.247
In City Limits * On Major ND Road * In Buffer	0.491	0.483	1.242	0.265	0.217	0.641
	Male Drivers					
	Half-Mile Buffer		One-Mile Buffer		Two-Mile Buffer	
Source	F	Sig.	F	Sig.	F	Sig.
In City Limits	14.254	**0.000**	13.045	**0.000**	24.702	**0.000**
On Major ND Road	0.002	0.969	1.822	0.177	7.668	**0.006**
In Buffer	3.782	0.052	32.387	**0.000**	195.106	**0.000**
In City Limits * On Major ND Road	1.196	0.274	4.894	**0.027**	16.250	**0.000**
In City Limits * In Buffer	6.492	**0.011**	3.506	0.061	4.915	**0.027**
On Major ND Road * In Buffer	2.353	0.125	1.344	0.246	3.487	0.062
In City Limits * On Major ND Road * In Buffer	0.561	0.454	0.522	0.470	2.445	0.118
	Large Truck Crashes					
	Half-Mile Buffer		One-Mile Buffer		Two-Mile Buffer	
Source	F	Sig.	F	Sig.	F	Sig.
In City Limits	5.621	**0.018**	17.086	**0.000**	25.151	**0.000**
On Major ND Road	2.986	0.084	15.199	**0.000**	28.351	**0.000**
In Buffer	33.190	**0.000**	68.537	**0.000**	313.648	**0.000**
In City Limits * On Major ND Road	2.970	0.085	12.667	**0.000**	23.046	**0.000**
In City Limits * In Buffer	2.275	0.131	10.814	**0.001**	16.256	**0.000**
On Major ND Road * In Buffer	0.089	0.765	0.393	0.531	0.023	0.879
In City Limits * On Major ND Road * In Buffer	0.076	0.782	1.951	0.162	2.595	0.107
	Injury Crashes					
	Half-Mile Buffer		One-Mile Buffer		Two-Mile Buffer	
Source	F	Sig.	F	Sig.	F	Sig.
In City Limits	15.991	**0.000**	26.546	**0.000**	59.944	**0.000**
On Major ND Road	0.415	0.519	0.102	0.749	2.613	0.106
In Buffer	0.005	0.946	1.634	0.201	9.740	**0.002**
In City Limits * On Major ND Road	0.043	0.835	0.276	0.599	1.042	0.307
In City Limits * In Buffer	5.792	**0.016**	8.333	**0.004**	33.642	**0.000**
On Major ND Road * In Buffer	0.059	0.808	1.434	0.231	2.788	0.095
In City Limits * On Major ND Road * In Buffer	2.103	0.147	7.520	**0.006**	18.590	**0.000**
	Fatal Crashes					
	Half-Mile Buffer		One-Mile Buffer		Two-Mile Buffer	
Source	F	Sig.	F	Sig.	F	Sig.
In City Limits	2.292	0.130	4.186	**0.041**	22.356	**0.000**
On Major ND Road	0.016	0.899	0.678	0.410	0.413	0.521
In Buffer	0.623	0.430	0.073	0.786	0.373	0.541
In City Limits * On Major ND Road	0.060	0.806	0.631	0.427	0.163	0.686
In City Limits * In Buffer	0.000	0.998	0.135	0.713	1.309	0.253
On Major ND Road * In Buffer	0.254	0.614	2.398	0.121	0.221	0.638
In City Limits * On Major ND Road * In Buffer	0.149	0.699	0.397	0.529	0.071	0.789
	Injury Severity					
	Half-Mile Buffer		One-Mile Buffer		Two-Mile Buffer	
Source	F	Sig.	F	Sig.	F	Sig.
In City Limits	25.509	**0.000**	38.157	**0.000**	95.845	**0.000**
On Major ND Road	0.424	0.515	0.008	0.929	3.026	0.082
In Buffer	0.627	0.429	10.392	**0.001**	48.871	**0.000**
In City Limits * On Major ND Road	0.251	0.616	1.214	0.271	0.061	0.805
In City Limits * In Buffer	7.261	**0.007**	7.180	**0.007**	29.068	**0.000**
On Major ND Road * In Buffer	0.082	0.774	2.404	0.121	2.159	0.142
In City Limits * On Major ND Road * In Buffer	1.878	0.171	7.038	**0.008**	12.893	**0.000**

demonstrates that the probability of being involved in crashes is not uniform. There are significant differences in one's likelihood of being involved in a more serious crash when addressed broadly by proximity to these three geospatial features.

Can these three geospatial features be analyzed narrowly in a meaningful way to provide more certainty to drivers? The codification process used here allows each crash to be identified by three dichotomous dummy variables: buffer zone (1=occurred in buffer; 0=occurred outside buffer), city limits (1=occurred in town; 0=occurred outside of town), and roadway (1=occurred on a county, state, or federal road; 0=occurred on a local road). From these three dummy variables, an eight-point location classification scale was created using the compute function in SPSS. The location classification scale had eight possible permutations, ranging from {0,0,0} (outside buffer, outside of town, on local road) to {1,1,1} (in buffer, in town, on major road).

When crash patterns are factored by the new location classification, results are compelling. In all three buffer zones, crashes most commonly occur outside of the buffer, outside of city limits, off of major North Dakota roads (Table 2.2.). However, these crashes do not have the highest score in any of the five crash metrics. In fact, the injury severity score is below 1.00, implying that, on average, the crashes result in property damage only. In contrast, crashes taking place inside of the buffer, outside of city limits, on either road type have an injury severity score greater than 1.00 which implies that, on average, crashes in these locations result in at least a minor injury. In all three buffers, the injury severity score is highest inside of the buffer, outside of city limits, on major roads. Compared to the other seven locations, crashes taking place here had statistically significant differences for severity score in the one-half mile buffer ($F=36.078$, $df=7$, $p<0.001$), the one-mile buffer ($F=48.438$, $df=7$, $p<0.001$), and the two-mile buffer scheme ($F=83.609$, $df=7$, $p<0.001$).

Table 2.2. Least Significant Difference Mean Separation Test for Crash Metrics and Injury Severity Scale

Location Classification	N	High-Risk	Males	Truck	Injury	Fatal	Injury Severity
Half-Mile Buffer Zone Mean Values							
In Buffer, In City, In Road Buffer	37	0.41ab	0.62ab	0.19bc	0.0811a	0.0000a	0.32a
In Buffer, In City, Out Road Buffer	46	0.48b	0.65abc	0.13ab	0.1087ab	0.0000a	0.48a
In Buffer, Out City, In Road Buffer	542	0.44b	0.78c	0.22c	0.2583c	0.0055bc	1.31c
In Buffer, Out City, Out Road Buffer	1,488	0.46b	0.83d	0.23c	0.2130b	0.0134cd	1.08b
Out Buffer, In City, In Road Buffer	1,054	0.39a	0.70bc	0.12ab	0.1727ab	0.0057bc	0.69a
Out Buffer, In City, Out Road Buffer	5,458	0.40a	0.61a	0.06a	0.1259ab	0.0042b	0.50a
Out Buffer, Out City, In Road Buffer	8,483	0.40a	0.68bc	0.11ab	0.1804ab	0.0160d	0.84a
Out Buffer, Out City, Out Road Buffer	25,790	0.43b	0.69bc	0.10ab	0.1882ab	0.0128c	0.83a
One-Mile Buffer Zone Mean Values							
Location Classification	N	High-Risk	Males	Truck	Injury	Fatal	Injury Severity
In Buffer, In City, In Road Buffer	80	0.39ab	0.73bc	0.19c	0.1000a	0.0000a	0.46a
In Buffer, In City, Out Road Buffer	205	0.47b	0.70b	0.09ab	0.1561ab	0.0146cd	0.79a
In Buffer, Out City, In Road Buffer	1,087	0.42ab	0.79c	0.21c	0.2530d	0.0120cd	1.25c
In Buffer, Out City, Out Road Buffer	3,331	0.45b	0.81c	0.22c	0.2207c	0.0156d	1.11b
Out Buffer, In City, In Road Buffer	1,011	0.39a	0.69b	0.11b	0.1751ab	0.0059bc	0.69a
Out Buffer, In City, Out Road Buffer	5,299	0.40ab	0.60a	0.06a	0.1246a	0.0038b	0.49a
Out Buffer, Out City, In Road Buffer	7,938	0.40ab	0.67b	0.10b	0.1757ab	0.0159d	0.81a
Out Buffer, Out City, Out Road Buffer	23,947	0.43b	0.68b	0.09b	0.1852b	0.0124cd	0.81a
Two-Mile Buffer Zone Mean Values							
Location Classification	N	High-Risk	Males	Truck	Injury	Fatal	Injury Severity
In Buffer, In City, In Road Buffer	291	0.40ab	0.75cd	0.19e	0.1203a	0.0034a	0.58ab
In Buffer, In City, Out Road Buffer	1,101	0.40ab	0.72c	0.12d	0.1462a	0.0045a	0.69b
In Buffer, Out City, In Road Buffer	2,399	0.44b	0.80de	0.20e	0.2509d	0.0179b	1.25d
In Buffer, Out City, Out Road Buffer	6,975	0.45b	0.81e	0.21e	0.2258c	0.0161ab	1.12c
Out Buffer, In City, In Road Buffer	800	0.38a	0.68b	0.10cd	0.1875b	0.0063a	0.71b
Out Buffer, In City, Out Road Buffer	4,403	0.40ab	0.58a	0.04a	0.1206a	0.0041a	0.46a
Out Buffer, Out City, In Road Buffer	6,626	0.39a	0.65b	0.08c	0.1612ab	0.0145ab	0.73b
Out Buffer, Out City, Out Road Buffer	20,303	0.43b	0.66b	0.07b	0.1771b	0.0117a	0.75b

If displayed values do not share a letter in common, then the difference in mean value is statistically significant at the 5% level

With regard to decision theory, these findings are useful in two ways. First, it provides information about where crashes in general are most commonly occurring in the oil region even if they are relatively safe crashes. Second, when factoring for the five crash metrics studied in this project and the injury severity scale, it indicates where specific crash types and the most severe crashes are taking place. In general, the five crash metrics and the injury severity scale are most visible in the buffer zones, outside of town, on either roadway type, information that is valuable for the decision-making processes of drivers.

2.6. Discussion

Roadway safety is a dynamic topic and is affected by multiple interacting variables. It is impossible to account for all of the interaction simultaneously as some factors (mechanical failure, weather) are difficult to estimate and others (distraction, impairment) are challenging to control. In western North Dakota, five crash metrics and an injury severity score differ based on the interaction between proximity to oil development, city limits, and roadway type – three variables that were easily manipulated by the researcher. Although the initial hypotheses were shown to be correct – there are noticeable differences in crash characteristics depending on whether or not the crash occurs near oil extraction – the results of fatal crash likelihood in the two-mile buffer zone proved that crash severity is not determined solely by proximity to oil development. A cluster analysis of crashes taking place inside of the two-mile buffer zone revealed that city limits and roadway type may plausibly be additional determinants of crash severity.

The location classification schemes presented in this study suggest that the risk of being involved in a more severe crash increases as one is nearer to oil development, outside of city limits, and on major North Dakota roadways, though it should be noted that the roadway has less influence on crash severity than the other geospatial variables. These are logical findings: traffic associated with oil development has larger size/mass than passenger vehicles which puts non-oil traffic at a heightened chance of a severe outcome during a crash. Areas outside of city boundaries do not have traffic regulated via stop signs, stop lights, and lower posted speed limits as occurs inside city limits. This subsequently increases the chances of severe crashes occurring outside of town. Major roads typically have higher posted speed limits and greater traffic volume, creating more opportunities for more dangerous crashes.

Not coincidentally, the location classification schemes with the highest average injury severity scores also have the greatest prevalence of high-risk young drivers, male drivers, and large truck crash involvement. This suggests that these are valid sources of danger and contribute directly to crash severity which explains why, over the study period, crashes in these location classification schemes resulted *on average* in at least a minor injury. Education, policy, and enforcement efforts should target these drivers in these location classifications as crashes here typically end in at least a minor injury.

With regard to decision theory, drivers still encounter uncertain situations when driving, but the location classification schemes presented in this study provide some certainty in terms of route choices for western North Dakota drivers as related to average scores both for the five crash metrics and the injury severity scale. Considering that roughly three-quarters of western North Dakota drivers are willing to drive out-of-the-way to drive on roads with fewer oil trucks or better surface conditions (Kubas and Vachal 2014a), it may be prudent to take extra time to travel through cities and away from oil development – if permitted by geographic determinism.

Future research can be improved by reporting VMT by vehicle class in North Dakota. This would allow researchers to better understand shifts in travel patterns. Moreover, researchers could benefit from this information by comparing truck travel inside of buffer zones, non-buffer oil county areas, and in the non-oil counties of North Dakota. This study would also benefit from accurate normalization of crash patterns per 100,000 population. Without a viable way of estimating the population inside and outside of the arbitrary buffer zones, it is difficult to assess if some crashes can be attributed to denser populations. It should be reiterated that there are some inherent flaws with using crashes per square mile as a barometer of overall traffic safety. Although western North Dakota is generally considered rural, the presence of some small cities and towns presents a minor obstacle in understanding how to interpret crashes per square mile. Nonetheless, this method was useful for quantifying crashes inside of the buffer zones to compare the density of different crash types despite there being a greater volume of crashes outside of the three buffers. This data normalization technique helped explain some of the statistically significant differences in crash pattern inside and outside of the buffers.

Finally, it should be stressed that some of the five crash metrics studied in this project are directly related to the oil extraction industry, and statistically significant differences in crash patterns should be interpreted with some caution. The literature clearly categorizes young drivers, male drivers, and large semi-trucks as being linked to danger on the roadway. When analyzed individually in controlled environments, it may be true that these variables pose greater threats to safety on the roadway. However, when analyzed collectively as part of resource extraction tactics, it is logical that the increased prevalence of 18-34 year-old drivers, male drivers, and large trucks in traffic crashes may simply be a product of the oil industry. It is known that large trucks are necessary for oil extraction, and given the heightened publicity of "man camps" in western North Dakota (Yesalavich 2014), a larger representation of males involved in crashes – especially those under the age of 34 – is not surprising for this line of work. In western North Dakota danger on the roadway may partially be due to these groups, but may also stem from the increased volume and concentration of drivers from the booming oil industry.

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CHAPTER 3. DRIVER PERCEPTIONS OF WESTERN NORTH DAKOTA OIL ROADS: A MIXED METHODS APPROACH

3.1. Abstract

A 17-county region in western North Dakota has experienced unprecedented change as a result of an expanding oil and gas industry. One public health concern indirectly related to energy extraction is that of traffic crashes. The recent oil boom has been paralleled with noticeable growth in traffic crashes, both in terms of volume and severity. A mail survey was sent to residents in this region to highlight traffic safety concerns. Included on the survey questionnaire was an open-ended comment section designed to elicit information about additional concerns from local residents. Emergent theme content analysis was performed for these responses, and themes were coded, organized, and queried based on geospatial information. During this data collection and analysis phase, crash reports were obtained for a 10-year (2004-2013) study period. The qualitative responses and crash data were linked with one another via zip code boundaries; concerns raised by respondents were normalized by population and compared to cluster analyses of crash patterns in order to determine if qualitative perceptions from residents match the reality of actual crash trends. Results show that – with regard to three major themes – respondents accurately perceive danger associated with crash severity, but perceptions of truck danger and law enforcement presence were mixed across the region.

3.2. Introduction

Communities centered upon resource extraction are typically subjected to “boom” and “bust” cycles. Western North Dakota is presently “booming” due to a growing energy sector. Although the success of the oil industry is generally synonymous with benefits such as economic prosperity, it is undeniable that some negative consequences stem from this growth. One public health concern– traffic crashes – has been a growing source of danger since the latest oil boom began in 2004. This danger has amplified via two sources. First, the influx of job seekers results in more vehicles on the roadway and more vehicle miles traveled. This subsequently heightens the likelihood of a crash (Ewing and Kim 2012; Jovanis and Chang 1986; Yan et al. 2012). Second, traffic associated with oil development – heavy-duty machinery, semi-trucks, overloaded vehicles, spuds, tankers, bobtails, and other vehicle classes – cause more serious injuries during a crash (Braver et al. 1992), especially when speeding (Islam and Hernandez 2013; Neeley and Richardson 2009; Vadlamani et a. 2011).

Studies show that community members generally resist sudden, unexpected change – especially when outsiders engage in resource extraction (Evans, Goodman, and Lansbury 2002). When community members become repeatedly exposed to danger, responses to the danger progress from appropriate to inadequate and sometimes threaten residents (Comstock and Mallonee 2005). Not In My Back Yard ("NIMBY") movements have occurred for decades and have focused on social, cultural, and environmental issues such as resisting the deinstitutionalization of group home residents (Piat 2000), opposing developments for homeless people (Young 2012), and objecting to policies with harmful environmental consequences (Kang and Jang 2013). A major gap in the literature surrounds how oil extraction alters perceptions of traffic safety. Undoubtedly, local residents must have concerns regarding changing traffic conditions and overall traffic safety, especially when considering the rise in total crashes and crash severity stemming from the advent of oil extraction (Kubas and Vachal 2014). The goal of this study is to qualitatively measure traffic safety priorities to better understand firsthand experiences of drivers in western North Dakota. Then, these priorities will be compared to recent regional crash patterns to identify if perceptions highlighted by residents match the reality of driving conditions.

3.3. Methods

A mixed methods approach was used to collect and analyze data. Academics define mixed methods approaches in many ways, though most definitions connect quantitative and qualitative elements. Creswell (2003) argues that mixed methods approaches employ “strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand research problems” (18). The collected data include “at least one quantitative method (designed to collect numbers) and one qualitative method (designed to collect words)” (Caracelli and Greene 1993: 195). These separate forms of data are collected, analyzed, and combined within the context of a single study (Johnson and Onwuegbuzie 2004) or entire research program (Angell and Townsend 2011). Generally, these data are mixed and the researcher prioritizes one or both forms of data as framed by philosophical worldviews or theoretical lenses (Creswell and Plano Clark 2010). The decision of which data to prioritize “is determined by the researchers” (Creswell, Fetters, and Ivankova 2004: 4).

There are four main purposes for combining methods. First, mixed methods research provides complementarity, or the ability “to address different aspects of the same question” (O’Cathain, Murphy, and Nicholl 2007: 8) and “to compensate for the weaknesses of the other” (Small 2011: 64). Second, this approach provides expansion, which is the opportunity “to address different questions” (O’Cathain, Murphy, and Nicholl 2007: 8). Third, this approach promotes development because one method can be “used to inform the development of another” (O’Cathain, Murphy, and Nicholl 2007: 8). Fourth, mixed methods provide confirmation to researchers “to verify the findings derived from one data with those derived from another”

(Small 2011: 63). These studies contend that neither quantitative nor qualitative approaches can achieve these purposes individually.

Mixed methods research rose to prominence in the twentieth century. Creswell (2003) credited mixing different methods to “when Campbell and Fiske used multiple methods to study validity of psychological traits” in 1959 (15). Johnson, Onwuegbuzie, and Turner (2007) recognized Denzin as the first to define triangulation as “the combination of methodologies in the study of the same phenomenon” in 1978 (114). Triangulation has since become a focal point of mixed methods approaches. More recently, Small (2011) discussed how this form of research has become especially important over the last decade via “the growth of an interdisciplinary community of scholars devoted to cataloguing, developing, and promoting mixed methods research” (60). This research design has become a viable tool to analyze data, particularly in the social sciences.

Researchers tend to agree on when is best to use a mixed methods approach. Angell and Townsend (2011) contend that mixed methods research questions should explore the meaning of a construct or phenomenon from multiple perspectives. Creswell et al. (n.d.) suggest that mixed methods should be used when “the quantitative approach or the qualitative approach, by itself, is inadequate to develop multiple perspectives and a complete understanding about a research problem or question” (6). Such a design provides “multi-level perspectives” to research questions and creates “real-life contextual understandings” for principal investigators (Creswell et al. n.d.: 4).

This approach has been used extensively across disciplines, especially in the social sciences. Research topics utilizing mixed methods include patient satisfaction (Andrew et al. 2007), bullying (Guerra, Williams, and Sadek 2011), and pediatric health access (Parry and

Willis 2013). Additionally, mixed methods have been employed regularly in traffic safety studies (see Classen et al. 2007; Hindle and Franco 2009; Joslin et al. 2011; Shane, Strong, and Mathes 2012; and Sucha 2014).

This project collected and analyzed data via mixed methods. A survey questionnaire was sent to drivers in western North Dakota to obtain information about perceived driving conditions. The questionnaire consisted of 17 questions with nominal, ordinal, and interval levels of measurement for response choices. Moreover, participants were invited to write comments on the back of the survey discussing concerns with traffic safety. The survey was mailed to 2,666 drivers living in the 17-county "oil region" as defined by the North Dakota Industrial Commission. Mailing was stratified by county boundary. In sum, 696 valid responses were returned for a response rate of 26.1%. Of these, 231 included written responses. Responses were manually entered into SPSS where a database was created for querying. With the exception of zip code demographic information, for the purposes of this study, only qualitative data from the written responses were considered. (For results from the quantitative element of the survey, see Kubas and Vachal 2014 and Kubas 2014). Written responses were subjected to emergent theme content analysis. These responses were coded and organized by theme following Curry, Nembhard, and Bradley's (2009) constant comparative method in qualitative research. In this technique, "data are reviewed line by line in detail" and "as a concept becomes apparent, a code is assigned to that segment of the document" (Curry, Nembhard, and Bradley 2009: 1446). The corresponding codes for each theme were attached to individual responses in the original SPSS database for further querying.

In addition, rural road crash reports for the 17-county region were acquired for a 2004-2013 study period. The crash records include dozens of variables tracking specific crash metrics, such as vehicle classification, crash type, crash severity, road conditions, and impairment, among others. Included in the crash records were longitude and latitude coordinates for each crash. These coordinates were uploaded to ArcGIS and crash patterns were tracked across spatial and temporal dimensions.

One key variable included in both the survey and crash records is zip code. Themes presented in the written component of the survey were tracked by zip code to see if concerns from drivers are more prevalent in specific areas. Similarly, a zip code shapefile in ArcGIS was merged with crash records to identify if some zip codes are more susceptible to specific crash types – whether by volume, vehicle class, or severity. Information from these two sources of data was used for triangulation and explaining if this combination of methodological approaches accurately measures the same phenomenon: traffic safety in specific western North Dakota zip codes.

This approach follows concurrent procedures in mixed methods research provided by both Lopez-Fernandez and Molina-Azorin (2011) and Creswell (2003). In this design, the researcher gathers both forms of data "at the same time" during the project (Lopez-Fernandez and Molina-Azorin 2011: 3) and then "integrates the information in the interpretation of the overall results" (Creswell 2003: 16). Furthermore, the decision to attach qualitative codes to the original SPSS database for descriptive statistical considerations follows Caracelli and Greene's (1993) definition of data merging in which "qualitative and quantitative data are jointly reviewed and consolidated into numerical codes or narrative for purposes of further analysis" (197). The ultimate goal is to determine if the two forms of data can be used to arrive at similar conclusions, resulting in findings with strong validity and reliability. This will be useful to traffic safety experts and practitioners as a multifaceted approach to understanding traffic safety concerns is preferable to studying only one form of data.

3.4. Results

3.4.1 Qualitative Analysis

Upon completion of the emergent theme content coding process, 15 themes were identified (Table 3.1.). Overall, 11 of these themes were interpreted as being directly related to the survey questionnaire and traffic safety in the region. The other four themes were related to firsthand experiences, ideas, and anecdotes, yet these were still tangentially related to traffic safety. The following analysis highlights the six most common themes – the majority of issues identified by respondents – as they outnumber all other themes.

Table 3.1. Emergent Theme Content Analysis Codes

Theme	Instances Mentioned	Percent
Trucks as a Source of Danger	44	19.9%
Safety Improvement Recommendations	*38*	*17.2%*
Hope to Avoid a Crash	32	14.4%
Out-of-State Drivers as Problem/“Us-vs.-Them” Mentality	31	14.0%
Importance of Law Enforcement Presence	20	9.0%
Perceived Danger on Roadway	16	7.2%
Stiffer Penalties Advocated	10	4.5%
No Other Travel Choice Options	10	4.5%
Use Oil Revenue for Local Infrastructure	*7*	*3.2%*
Potholes	6	2.7%
Firsthand Experiences/Personal Story	*3*	*1.4%*
Dust as Safety Issue	*2*	*1.0%*
Infrastructure Improvement	1	0.5%
Passenger Vehicle-Large Truck Interaction	1	0.5%
TOTAL	**221**	**100.0%**

Italics: Themes indirectly related to oil traffic safety

3.4.1.1. Trucks as a source of danger

Most commonly, respondents discussed negative impacts of large trucks and related this vehicle type to danger in the region. Roughly one-fifth (19.9%) of responses in the qualitative analysis focused on this theme. Responses varied from being concise to in-depth. A common complaint from respondents was that semi-truck drivers had blatant disregard for stop signs. One respondent noted that “trucks never stop at STOP signs” (ID 555). This was reaffirmed by respondent 276 who wrote that it was a “shame you can’t get semi’s [sic] and most oil vehicles to obey traffic laws, such as STOP signs.” Others mentioned that “trucks run stop signs and pull out into traffic” (ID 549) and still others questioned “why stop signs do not apply to trucks, esp[ecially] semi-oil tankers” (ID 294). The idea that semi trucks should obey traffic laws is an important issue to drivers in western North Dakota.

Some respondents perceived a hierarchy of roadway power and categorized semi-truck drivers as believing that “they own the road” (ID 609). Given the mass/size relationship of large semi trucks to passenger vehicles, it may explain why some responses identified large truck drivers as “insane!” (ID 486, original emphasis) and others believed them to be “complete idiots!” (ID 108, original emphasis). Since semi-truck drivers are perceived to take ownership of the roadway, passenger vehicle drivers discussed instances in which they were marginalized by semi-truck driver behavior. According to one respondent, “trucks push you to travel fast then you want to because they tail[gate] you. Trucks pass you going 70-75 [miles per hour] no matter what the speed limit is” (ID 698). Respondent 515 reiterated this sentiment by declaring that it is common to be “passed by many big trucks while driving the 70 mph speed limit.” Respondent 421 attributed this behavior to truckers having “one thing on their mind, getting from point A to B as fast as they can. They have no concern for safety on the roadway!” (original emphasis). This is likely why another respondent advocated that “truck speed should be reduced” on major roadways (ID 125).

Issues with truck traffic are perhaps best summarized by the following respondent, who detailed a personal encounter with a dangerous truck driver:

> "On a recent trip home from [town] – I was traveling 65 mph. The speed limit. I observed a semi (oil rig) trying to pass a car behind me – He [sic] pulled over – but never went fast enough to go around – as I watch an approaching car – I saw the truck cut back in front of the car behind me – cutting off that car. Well then he did the same thing to me – twice – always pulling back behind me because he wasn't going fast enough to pass me before meeting an oncoming car – finally – up a hill – he tries again – and has to move over because of an oncoming car – and cuts me off. It was unbelievable – and I wanted to call 911 and say 'get this idiot off the road, please.' This is typical – either they pass you anywhere – up a hill – on a blind curve – going way over the speed limit – or the opposite – going so slow that they can't get around you – very dangerous – and irritating. No concern for others" (ID 318).

Truck traffic – specifically trucker behavior – is a critically important issue to western North Dakotans in this survey. It is evident that some drivers have not had safe experiences sharing the road with heavy-duty trucks. Improving large truck/passenger vehicle interaction will promote safer roadways and better driving environments for western North Dakotans.

3.4.1.2. Safety improvement recommendations

A smaller proportion, 17.2% of coded themes, addressed safety improvement recommendations respondents believed would be useful. Most of these recommendations pertained to general driving improvements in the respondent's area. A common suggestion highlighted improving roads in western North Dakota by transforming them into "4-lane [roads] with passing lanes [and] wider shoulders" (ID 48). Multiple respondents (ID 438; ID 229; ID 387; ID 353) advocated that major roads in their communities be widened to four lanes in order to "cut down on accidents" (ID 353). Similarly, one respondent recommended that a "truck lane" be built "on every highway in oil country" (ID 47) though this would be economically implausible. Local residents clearly perceive the widening of major roadways to be a viable safety improvement.

Some respondents suggested that expanding stoplight usage would be a worthwhile traffic safety endeavor. Some argued that stoplights are useful at junctions (ID 116), intersections (ID 10; ID 424), and on major roads (ID 12). Using stoplights was not the only form of traffic regulation identified by residents; lowering speed limits was also a common suggestion. The ability to "slow down all the traffic" (ID 569) was praised by drivers who simply recommended that the region "lower speed limits" (ID 492). More specifically, some desired that speed limits be "lowered from 65 to 45" in key areas (ID 31).

One particular driver detailed the benefits that lowered speed limits would have for his/her daily commute. This driver wanted "to see the speed limit on 2-lane roads set to 55 mph" (ID 216). The justification behind this change was as follows:

> "To pull into my house on [major road] I have to make a left hand turn. I've seen many trucks skid with smoke coming from their tires even when I turn my blinker on hundreds of yards before I turn and if theres [sic] traffic coming from the other direction I sit even longer, wait to make the left hand turn, talk about scary when you look in your rearview mirror and theres [sic] a big truck coming up on you and your [sic] not sure if its [sic] slowing down. Now my wife and I drive passed [sic] our home till we can make a right hand turn and turn around so we can make a right hand turn into our driveway" (ID 216).

The perceived benefits of implementing safety improvements – whether widening roadways, utilizing additional stoplights, or lowering speed limits – are numerous. Many of these benefits relate directly to personal gains in areas thought of as being highest priority: those traveled most frequently by a respondent. Although specific safety recommendations were not explicitly addressed in the survey questionnaire, it is evident that western North Dakotans have many ideas and solutions pertinent to improving travel safety in areas nearest to oil extraction activity.

3.4.1.3. Hope in avoiding future crashes

There were 32 instances in which comments contained an element of hope with regard to not being involved in a future accident. All 32 comments were written in direct response to Question 10 on the survey, which asked how many times respondents expected to be injured in a car crash in the future. On 21 occasions, respondents only wrote some derivation of "I hope never" (ID 529) or "hopefully never" (ID 242). Others went into more detail about the uncertainty surrounding future injury crashes. One driver noted that it was necessary to first "pray" and then "drive defensively and leave plenty of room" to avoid an injury crash (ID 674). Another driver discussed a lifestyle change in which most driving now occurs "closer to home" and traveling more than "30 miles or so from home" is only done "with reluctance" (ID 565). Another survey participant echoed this idea when sharing that "we haven't even visited [family] in the last few years since all the warnings of others of how bad the traffic is and the accidents are" (ID 658). Weaved throughout these comments is a common message that not only is traffic unpredictable, but in some instances radical driving behavior changes are required to guarantee that driving in the region does not result in an injury crash.

3.4.1.4. Out-of-state drivers and “us-vs.-them” mentality

There is a dichotomy between native western North Dakotans and non-native western North Dakotans as related to safe driving practices. Non-native western North Dakotans are stereotyped as being “the biggest hazards” (ID 518), “the most significant problem” (ID 310), and unable to “understand winter driving” (ID 407). Some respondents targeted drivers from specific areas as being the most dangerous: drivers from Canada (ID 555; ID 451), Wyoming (ID 392), Texas (ID 586) Idaho, Washington, and Minnesota (ID 388) were singled out as the least responsible when driving. One driver estimated that “more than half of the driving acts that I have witnessed are from drivers with out-of-state plates on their vehicles” (ID 162).

This sense of otherness has created an “us-versus-them” mentality. Multiple drivers insinuated that out-of-state drivers either “need to go home” (ID 259), or “should go back to their state” (ID 519). If staying here for the extended future, one participant desired that these drivers “be more cautious and curtious [sic]” when sharing the road (ID 555). Another driver went as far as to describe out-of-state workers as being here “solely to earn a paycheck” (ID 671). This individual further contended that these temporary residents “have no sense of community here in northwestern North Dakota” and are deteriorating community well-being (ID 671). These are claims being made on firsthand interactions with “others” instead of factual evidence. Nonetheless, there is a distinct bifurcation between how respondents perceived the driving behavior of local residents and out-of-state drivers.

3.4.1.5. Importance of law enforcement

Arguably the most unifying topic in the written response section of the questionnaire stressed the importance of law enforcement presence as a means of influencing drivers to operate vehicles safely. Nine percent of written comments pertained to this theme. Drivers in the region thought law enforcement was underrepresented in the area. Within this theme, there were two overarching perspectives. First, some respondents wanted greater law enforcement visibility to impact the behaviors of drivers. Second, participants believed that law enforcement personnel were too lenient and not upholding the law consistently.

One sentiment was that "there is a lack of police officers/law enforcement on the roads in our area" (ID 480). Some respondents noted that they "very seldom see patrolmen" (ID 111), they "don't see many police cars on the highway" (ID 625), or they "never see a patrol car!" (ID 431, original emphasis). One individual estimated that law enforcement presence may not be seen "for days or even weeks in my area" (ID 388). Another estimated that "in the past five years I have seen law enforcement approximately five times" (ID 708). These self-reported numbers are subject to inconsistencies, but they nevertheless paint a picture of residents who desire proactive law enforcement and greater visibility.

This belief has prompted some residents to conclude that "extra law enforcement couldn't hurt" (ID 458) and that "it would be nice if there were more highway patrol men on the roads" (ID 154). Some have gone as far as to wish that police "be at major intersections 24/7" no matter how impractical a request (ID 360). The reality is that residents "see very few if any highway patrol" (ID 515) and genuinely believe that law enforcement plays "a crucial part" in keeping roads safe (ID 14).

Another viewpoint is that law enforcement personnel do not uphold the law consistently. Although the comments do not provide evidence-based justifications for this claim, the perceived lack of trust is important as it likely has a direct effect on driver attitudes and behaviors. One respondent articulated that "law enforcement presence does no good if they don't enforce the law" (ID 455). This opinion was corroborated by another response which posited that local law enforcement “should take a more active part” in regulating “safe driving habits” in order “to help keep us safe” (ID 464). Participant 325 perhaps best described the role of law enforcement when detailing that their presence does “slow everyone down and we all drive more carefully. We know right away when the Highway Patrol or County Sheriff’s Office is in the vicinity.” Enforcement goes beyond having a presence; based on responses in this survey, it is just as vital to uphold the law.

3.4.1.6. Perceived danger on the roadway

There were 16 instances in which a response alluded to danger on the roadway. These references to danger reveal legitimate fear from drivers. For example, one driver felt as though “it is a matter of time before I’m killed on these roads” (ID 653). Others intentionally “avoid travel in western North Dakota” (ID 213), categorize each trip as “stressful” (ID 458) or “a nightmare” (ID 450), and choose to drive less frequently because current conditions “scare me” (ID 88). One respondent likened western North Dakota roadways to “taking your life in your own hands” on account of the uncertainty facing drivers (ID 555). Others label the increased traffic as “scary” (ID 281) or “very dangerous” (ID 165) and attribute these driving conditions mostly to the prevalence of large trucks (ID 541).

One driver summarized the daily fear by writing “I cannot possibly express how disturbed I am on a daily basis due to unsafe travel conditions for myself and those I love” (ID 121). It is evident that drivers in this study legitimately fear regional travel and have a tangible grasp of the danger they face daily. Responses from the open-ended comment section show drivers fear for themselves, family members, and complete strangers – evidence that perceived danger on the roadway is a valid concern for western North Dakotans.

3.4.2. Quantitative Data Merging and Triangulation

Following the model by Caracelli and Greene (1993), the aforementioned 15 qualitative themes were assigned numerical codes for further analysis. These codes play a vital role in establishing complementarity and in understanding different aspects of the same research item: traffic safety priorities in western North Dakota.

A zip code shapefile was manipulated in ArcGIS and frequencies for each of the 15 themes were tracked within respective zip code boundaries and normalized per 100,000 population. This technique identifies which comment themes were most common in zip code boundaries but does not represent actual crash patterns. Thus, crash data for metrics related to the 15 themes were queried and cluster analyses were performed to reveal where each metric was most likely to occur within respective zip code boundaries. The justification for this process is to provide triangulation by combining different methodological approaches to examining traffic safety priorities.

It should be emphasized that not every theme had a quantitative element in the crash records capable of being queried or manipulated. For example, one theme was that out-of-state drivers were mostly to blame for crashes; this resulted in an "us-versus-them" mentality among some respondents. Due to data privacy laws ensuring the anonymity of drivers, there was no variable in the crash file identifying state of origin for drivers involved in crashes. Thus, despite this theme emerging in the qualitative analysis, there was no way to provide complementary quantitative analysis to affirm that these drivers are more prominent in crashes in western North Dakota. Of the 15 themes highlighted in the qualitative analysis, three had matching variables in the crash file capable of being studied quantitatively.

3.4.2.1. Trucks as a source of danger

As discussed previously, the most common theme was that trucks are a major source of danger. In the crash file, a unit configuration variable classified vehicles as belonging to 26 different vehicle types. Five of these vehicle types were heavy-duty trucks, of which most in western North Dakota are related to oil extraction. A dummy variable was created based on this unit configuration scheme, and was subjected to an Anselin Local Morans I cluster analysis (Figure 3.1.). This cluster analysis identified zip code boundaries with high and low probabilities of large truck crash involvement. Presumably, zip codes of respondents who identified this issue as being important should align with zip code boundaries where trucks have a higher probability of crashing.

In general, crash patterns followed this assumption near the central core: heavy-duty trucks were more likely to be involved in a crash within zip code boundaries nearest the heart of oil extraction. However, there were some cities with less oil extraction activity – Minot, Velva, Garrison, Underwood, Bottineau, Bowman, Scranton, and Hazen – in which respondents reported large truck crashes as a concern, yet based on the cluster analysis large truck crashes were not prevalent in these areas. This reveals that although many of the concerns from qualitative responses are legitimate, there are a few instances where respondents perceive large truck crashes to be a concern, yet these fears should not be statistically warranted based on cluster analysis. Thus, there is a slight disconnect between resident perceptions of large truck crash patterns and the reality of large truck crash likelihood, though overall perceptions generally parallel crash patterns.

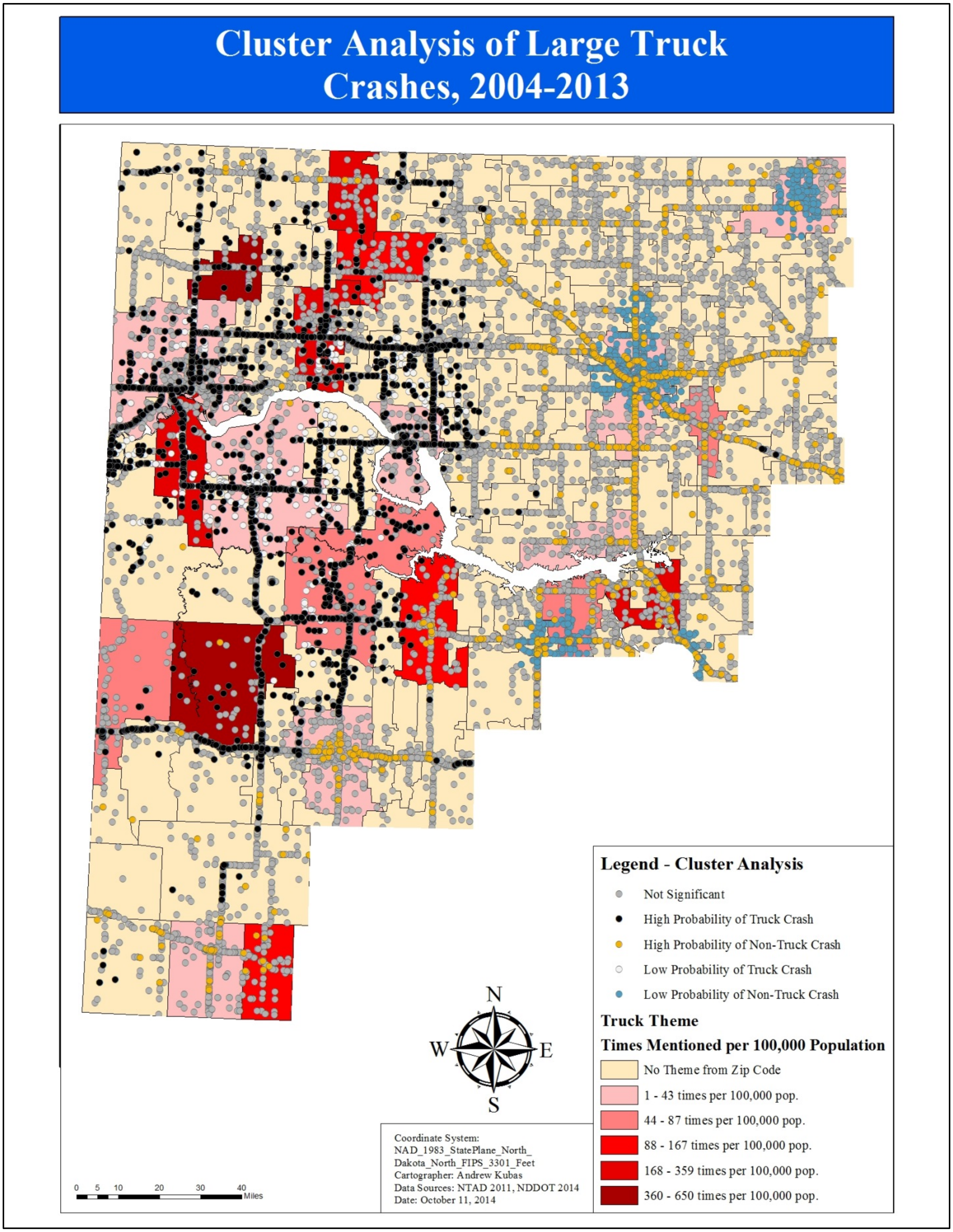

Figure 3.1. Large Truck Cluster Analysis Factoring for Qualitative Theme Responses

3.4.2.2 Safety recommendations and perceptions of danger

For the purposes of quantitative analysis, two qualitative themes were merged into one theme outlining perceptions of fear whilst driving in western North Dakota. About one-quarter of qualitative responses focused on either offering safety recommendations or discussing the inherent danger of traveling on western North Dakota roads daily. The crash records had no single variable directly relating to safety recommendations and/or danger. However, there was one variable – an injury severity classification scale – which indirectly related to both themes. For each crash, the involved individuals are given an injury severity score based on an eight-point ordinal scale. The scale ranges from zero (property damage only) to seven (fatality) with scores of one through six representing different levels of injuries. This injury severity scale was subjected to a cluster analysis to identify where the most severe crashes are most likely to occur (Figure 3.2.). Based on geographic areas defined by zip code boundaries, it was expected that the zip codes with a high likelihood of severe crashes would subsequently have the most respondents commenting about safety recommendations and/or general perceived danger when traveling on the roadway.

The cluster analysis showed that the most severe crashes more commonly cluster in zip codes where residents commented about needed safety recommendations and/or danger faced by drivers. However, one misleading result could be interpreted as an outlier. The zip code encompassing Stanley, North Dakota did not recommend safety strategies or discuss perceptions of danger. Although these issues were not qualitatively highlighted by respondents, the cluster analysis demonstrated that some of the most severe crashes were most likely to take place inside of the zip code boundary. This may be interpreted as showing discontinuity between perceptions and reality. In actuality, not one valid comment came from a resident living in Stanley.

Therefore, it is unknown if residents from this town have safety recommendations to offer or regularly have fears of danger when driving. It should be reiterated that the general pattern of perceptions followed the reality of crashes in the study area based on the cluster analysis.

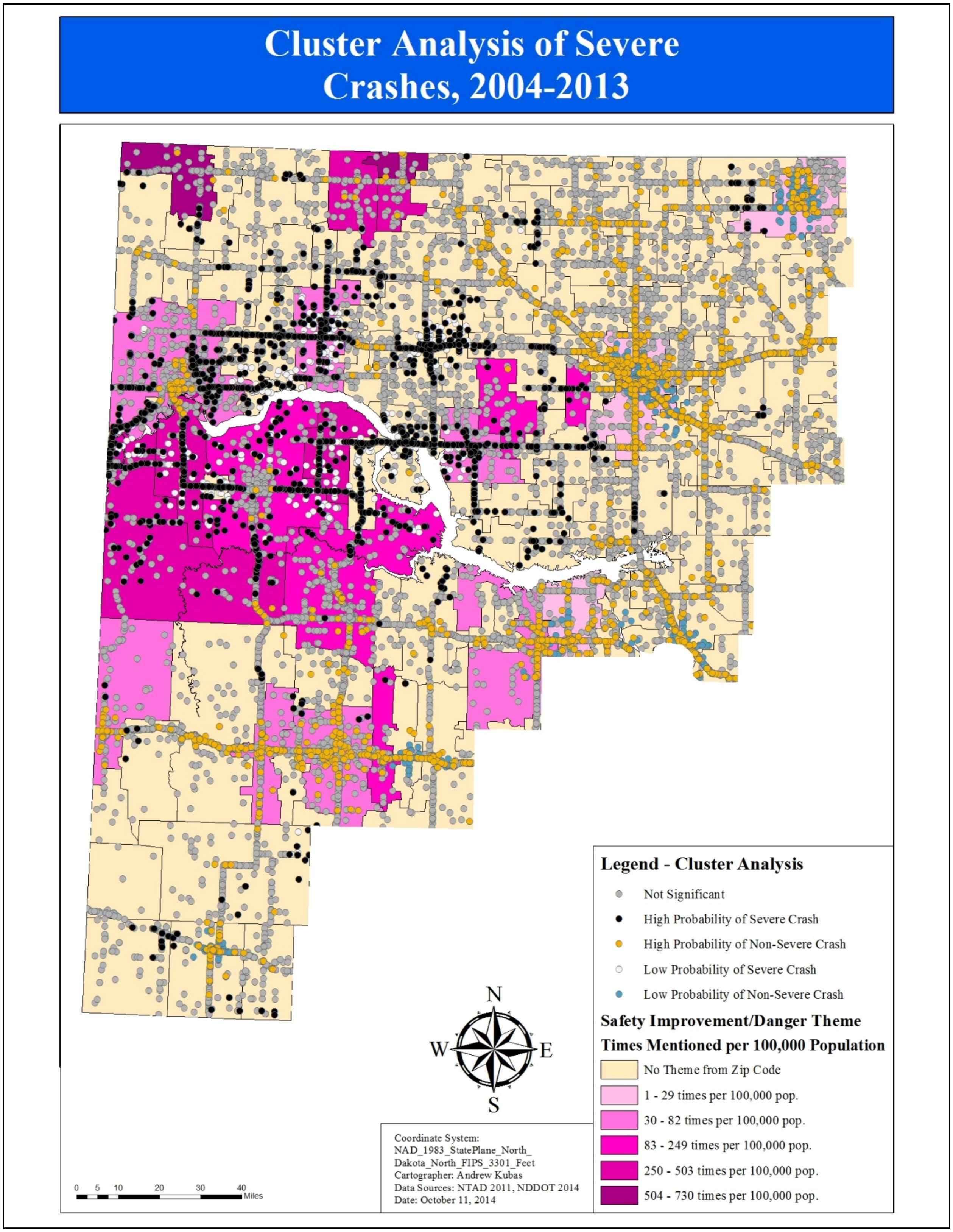

Figure 3.2. Crash Severity Cluster Analysis Factoring for Qualitative Theme Responses

3.4.2.3. Law enforcement presence

Qualitative analysis showed that respondents desired greater police presence on the roadway to promote safe travel behavior. Nearly all comments regarding this theme touched on the idea that – presently – law enforcement personnel are underrepresented and greater police visibility is needed to alter the negative behaviors of dangerous drivers.

One variable in the crash records examined police behaviors during a crash. This variable outlined whether or not a citation was issued to a driver involved in the crash. Issuing a citation for a crash is an added step for law enforcement when filing a crash report. Therefore, it is probable that a greater number of drivers will be exposed to a crash if it results in a citation: since additional paperwork is required, there is an additional amount of time in which other drivers can witness the aftermath of a crash. Thus, when the dichotomous citation variable in the crash record is subjected to cluster analysis, an inverse relationship is expected: one would logically anticipate that drivers who want greater law enforcement presence are less likely to have driven by a crash in which an officer issued a citation. Conversely, one would expect that some drivers may not wish for additional police presence because they have driven by a crash with police present and may have subsequently witnessed a citation being issued to an at-fault driver.

Results from this cluster analysis are mixed (Figure 3.3.). On one hand, respondents in many zip code boundaries identified additional law enforcement presence as vital to improving safety. These very communities, however, are among those which have the highest probability of law enforcement issuing citations to at-fault drivers during a crash. Respondents from communities such as Williston, Tioga, Watford City, New Town, and Dickinson most commonly identify a need for extra law enforcement in their towns, yet police within these cities are among the most likely to issue citations during crashes. This does not follow the anticipated inverse relationship.

In contrast, there are just as many communities in which residents did not identify a need for extra law enforcement, yet these communities are also among those with the highest likelihood of citations issued during a crash. In cities such as Bottineau, Max, Minot, Lignite, and Killdeer, extra law enforcement was not a priority yet citations were being issued at a higher rate than in other parts of the region. In these instances local residents may not want greater law enforcement presence because they are already satisfied with the performance of officers. Similarly, communities like Drake, Crosby, Golva, and Westhope had residents comment for a desire to see additional law enforcement. The cluster analysis validated that these communities have a lower likelihood of law enforcement personnel issuing a citation during a crash, revealing that these residents may have legitimate reasons for believing that law enforcement is underrepresented in their communities. These examples follow a plausible inverse relationship.

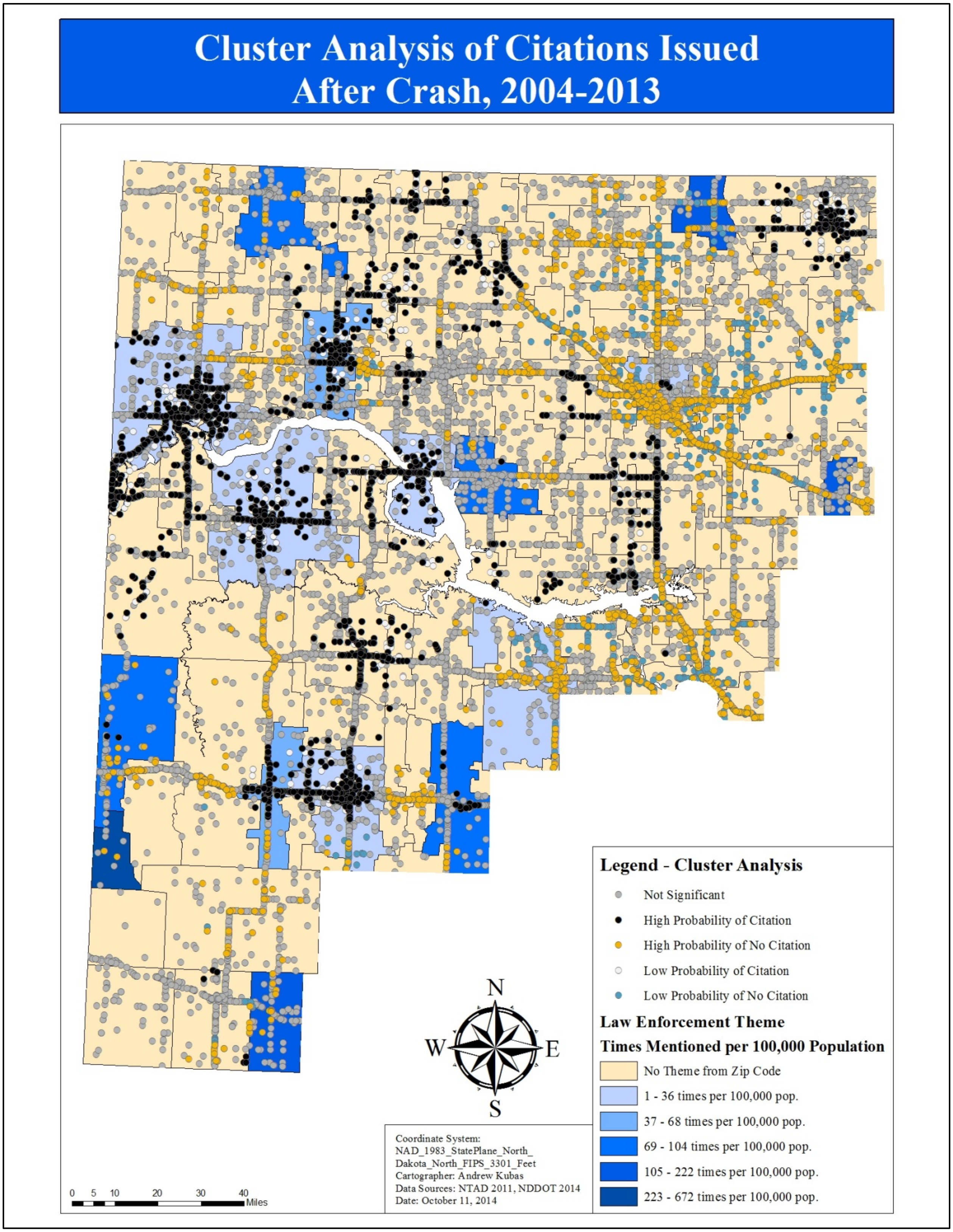

Figure 3.3. Citation Cluster Analysis Factoring for Qualitative Theme Responses

3.4. Conclusions

Numerous traffic safety priorities were identified by drivers living in western North Dakota. Based on open-ended responses to a survey questionnaire item, 15 themes were recognized as crucial to regional traffic safety. Some of these issues were explored in-depth, particularly as related to crash metrics available in statewide crash reports.

Three themes were directly related to crash statistics compiled by the NDDOT. Using ArcGIS, these three metrics were subjected to cluster analyses to determine where these crash types were most likely to occur. Using geographic zip code boundaries as a common identifier, responses from survey participants living in specific zip codes were spatially linked to recent (2004-2013) crash trends inside of the same zip code perimeters. This process was used first to provide complementarity and then to triangulate data around the social construct of traffic safety. In this mixed methods approach, different aspects of traffic safety were addressed simultaneously in order to better understand how local residents perceive driving conditions.

Results from the qualitative and quantitative analyses validate the idea that regional traffic safety can be improved. This is especially true with regard to perceptions of fear and danger: more severe crashes tend to cluster near areas where residents either wanted safety improvements or where they expressed high levels of fear and danger when traveling by passenger vehicle.

Results were less straightforward when factoring for truck safety and for one's desire to have greater law enforcement presence. In terms of truck safety, residents near the central core of the oil region generally blame large oil trucks for driving erratically and place much of the fault for unsafe conditions on these trucks. A cluster analysis showed that large trucks were more likely to be involved in crashes in the central core. Away from this high-production activity, fears of trucks were prevalent, but not necessarily warranted. A similar situation arose for one's desire to have greater law enforcement presence. A cluster analysis showed mixed results: some residents who wanted extra police presence were already living in zip code boundaries where citations had a high chance of being issued. Other communities had a high likelihood of issuing citations, and residents did not express a desire for additional law enforcement, which is to be expected if there is an association between these two variables.

This knowledge is useful to practitioners and traffic safety experts in that it validates that some perceived concerns from residents match regional crash patterns. Having this knowledge provides a bridge between perceptions and reality. This mixed methods approach reaffirms that these issues should no longer be thought of in abstract or uncertain terms. Instead, topic experts must embrace that these crash metrics are not just perceived problems in the region; spatial statistics prove that these metrics are actually more prevalent in certain parts of the study area.

Therefore, appropriate measures must be taken to mitigate danger on the roadway and improve traffic safety. One measure is adopting safety campaigns which target driver behavior. One particular campaign, *ProgressZone: Moving Forward Safely*, was widely recognized by drivers in the region and improved travel behavior (Kubas and Vachal 2012). Other campaigns could be targeted for truck traffic, safety improvements, or to promote law enforcement presence. Another strategy centers upon private truck company education. This is critically important for drivers moving to the area who have never lived in cold-climate environments as studies show that oil and gas extraction workers are most likely to suffer a fatal accident commuting to and from work than at the actual worksite itself (OSHA n.d.). Another recommendation is to sponsor school and community events related to sharing the road with oil and gas vehicles. Education is one of the pillars of traffic safety (Hedlund et al. 2008) and working with local residents can create grassroots movements promoting positive change. Hiring additional law enforcement is another proven technique to deter drivers from making poor decisions. This has been found true as most drivers are deterred from driving recklessly by the fear of receiving a ticket rather than the ticket itself (Vingilis and Salutin 1980). Considering that one theme from the survey requested extra law enforcement despite the fact that the State of North Dakota recently hired more police officers specifically to patrol the oil region (Smith 2014), it is reasonable to assume that even more police officers in western North Dakota would further curtail dangerous driving behaviors. Taken collectively, these recommendations can serve as a multifaceted approach to rethinking traffic safety as they stem from both driver-reported priorities and data-driven analyses.

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