THREE ESSAYS ON THE GRADUATED DRIVER LICENSING PROGRAM IN NORTH DAKOTA

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Three Essays on the Graduated Driver Licensing Program in North Dakota

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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

Graduated Driver Licensing (GDL) is a stepwise driver licensing program for novice drivers. The objective of GDL programs is to improve novice drivers' driving experience and skills over time, under low risk conditions. In this study, the effectiveness of GDL program implemented in North Dakota is examined using a before-and-after-time study. The first time period is before the initiation of a three-phase GDL program in North Dakota, pre-GDL period from 2007 to 2011. The second time period is after the implementation of a three-phase GDL program in North Dakota, post-GDL period from 2012 to 2016. The goal of the research design is to examine if teen driver involvement rate and likelihood of crash outcomes, in fatal and injury crashes, has changed over time. In theory, this would be due to the implementation of the three-phase GDL program.

Results indicate that after the implementation of the three-phase GDL program, teen driver crash involvement rates in fatal and injury crashes in North Dakota has been reduced. However, starting from 2015, there is an increasing trend in the reduced crash rates at the state level. County level crash rate analysis indicates that crash rates have been reduced, specifically in counties including metropolitan and micropolitan statistical areas in North Dakota. In other counties, including most of the rural areas of the state, crash rates have not been changed. Change in the likelihood of crash outcomes for teen drivers involved in fatal and injury crashes found not statistically significant. However, change in the likelihood of crash outcomes for the control group (adult drivers) has found increasing and statistically significant. This indicates that in the post-GDL period the likelihood of crash outcomes for teen drivers maintained unchanged with the implementation of the GDL program.

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INTRODUCTION

In the United States, unintentional injuries are the leading cause of death for the age group 14-17, for 2009-2014, see Table 1.

Table 1. Leading Causes of Death, United States, 2009-2014.

	Age Groups			
Rank	14	15	16	17
1	Unintentional Injury	Unintentional Injury	Unintentional Injury	Unintentional Injury
2	Suicide	Suicide	Suicide	Suicide
3	Malignant Neoplasms	Homicide	Homicide	Homicide

Source: National Vital Statistics System, National Center of Health Statistics, CDC. (Center for Disease Control & Prevention 2018a)

Among all unintentional injuries, motor vehicle crashes are the top ranked cause of death for the same time period, see Table 2.

Table 2. Leading Causes of Unintentional Injury Death, United States, 2009-2014.

	Age Groups			
Rank	14	15	16	17
1	Motor Vehicle Traffic	Motor Vehicle Traffic	Motor Vehicle Traffic	Motor Vehicle Traffic
2	Drowning	Drowning	Poisoning	Poisoning
3	Poisoning	Poisoning	Drowning	Drowning

Source: National Vital Statistics System, National Center of Health Statistics, CDC. (Center for Disease Control & Prevention 2018b)

According to the United States Center of Disease Control and Prevention (CDC), for male teen drivers, newly licensed teen drivers, and teen drivers with teen passengers, the crash risk is higher than other teen drivers. For all teen drivers, the CDC highlights that, the leading causes of crashes are lack of driver experience, driving with teen passengers, night time driving,

no restraint use while driving, distracted driving, drowsy driving, reckless driving, and impaired driving.

In order to reduce teen driver crash risk and undesirable motor vehicle accident outcomes, the CDC (Center for Disease Control & Prevention 2018b) recommends that

- Teenagers should use seat belts,
- Teenagers should not drink and drive, and
- Graduated Driver Licensing (GDL) Programs should be implemented and participation of teen drivers and their parents to GDL programs should be encouraged.

Graduated Driver Licensing (GDL) Program

Graduated Driver Licensing (GDL) is a stepwise driver licensing program for novice drivers. The objective of GDL programs is to improve novice drivers' driving experience and skills over time, under low risk conditions. Typical GDL programs include age-based, time-based, and restriction-based requirements for driving and licensing for novice drivers until they obtain their full driving licenses.

In the United States, GDL programs have been implemented since the 1990s. Current GDL programs vary from state to state. Most programs include three stages; a learner stage, an intermediate stage, and a full license stage. In the learner stage, most states require drivers to complete a minimum amount of supervised training. Upon passing the road test, in the intermediate stage, unsupervised driving is allowed with some restrictions. Once drivers obtain a full license, they have unrestricted driving. (Governors Highway Safety Association 2017)

In 2011, Safe Teen and Novice Driver Uniform Protection Act of 2011 (STANDUP Act) was introduced in the 112th Congress. The objective of this bill was to describe national standards for GDL Programs in the United States. States that meet certain requirements for GDL laws would have been able to use driver safety grants. The bill was not enacted. (112th Congress, n.d.)

North Dakota Graduated Driver Licensing (GDL) Program

In North Dakota, a three-phase GDL program is in effect; learner stage, intermediate stage, and full license stage. (North Dakota Department of Transportation 2017)

Teenagers enter the learner stage by obtaining an instruction permit, after passing a written test. The minimum age to obtain the instruction permit is 14 years old. Teenagers holding an instruction permit can practice driving given that they are accompanied with a person with a valid license for the class of vehicle being driven. The supervising person must be at least 18 years of age and had at least three years of driving experience. The holding period for an instruction permit depends on age. If the teenager is less than 16 years old, a 12-month holding period is required. If the teenager is older than 16 years old, the instruction permit must be held for 6 months or until the teenager reaches 18 years old, whichever comes first. During this phase, teenagers younger than 16 years old are required to have at least 50 hours of supervised training. If the teenager is older than 16 years old, a minimum amount of supervised driving is not required.

After passing a road test, teenagers obtain an intermediate (restricted) license. The minimum age to obtain a restricted license is 15 years old, with parent's request. At this phase, the teenager is only allowed to drive a parent's or guardian's vehicle. If the teenager is younger

than 16 years old, night time restrictions apply from the later of sunset or 9 pm to 5 am. There are exceptions for driving to and from work, school, and religious activities.

Teenagers 16 years old and older can get an unrestricted driver's license in North Dakota. Although there are no restrictions on driving, there are still rules and policies for young drivers.

- The instructional permit or restricted license of an 18 year old or younger driver is cancelled, if the driver commits an alcohol-related offense while driving or, if the driver accumulates 6 or more penalty (demerit) points on their driving record (policy for other drivers; 12 or more points for drivers over 18 years old).
- For drivers 20 years old and younger, the blood alcohol concentration limit is 0.02 (policy for other drivers; 0.08 for over 21 years old and 0.04 for commercial vehicle drivers).
- Use of a cell phone while driving is illegal for all drivers 18 years old and younger, except in case of emergencies.

Need for the Study

North Dakota was one of the last states to implement GDL programs in the United States. Starting from January 1, 2012, a three-phase GDL program is in effect. This program includes minimum amount of supervised driving, vehicle ownership, and night time driving restrictions; however, still does not include any passenger restrictions. No study has been published evaluating the effectiveness of GDL program in North Dakota.

In this study, the effectiveness of the GDL Program that has been implemented in North Dakota is evaluated, using a before-and-after-time study approach. Teen driver involved motor vehicle crashes in North Dakota are investigated for pre-GDL (2007-2011) and post-GDL (2012-

2016) periods. The pre-GDL time period is before the initiation of the three-phase GDL program in North Dakota. The post-GDL time period is after the three-phase GDL program has begun. The goal of the research design is to examine if the involvement of teen drivers in fatal and injury crashes and the outcome of crashes between these two time periods has changed over time. Three specific research topics are addressed:

- Change in the fatal and injury crash rate at the state level
- Change in the fatal and injury crash rate at the county level
- Change in the likelihood of crash outcomes

In theory, reduced crash rates and reduced likelihood of fatal and injury crashes would be due to the implementation of the three-phase GDL program, which aims to improve North Dakota teen drivers' driving experience and skills over time.

LITERATURE REVIEW

Graduated Driver Licensing (GDL) Programs in Other Countries

Graduated driver licensing has been implemented in several countries including Australia, Canada, Israel, Netherlands, and New Zealand. Although GDL programs have common characteristics, driving restrictions and licensing policies vary among countries. Different states or territories in a given country may have different GDL programs implemented.

GDL in Australia

In Australia, different states and territories have different driver licensing policies. The earliest age to obtain a learner's license is 15 years and 9 months, in Australia Central Territory (ACT). In ACT, after the learner's license stage, drivers need to pass probationary license stages in order to obtain a full driver's license. A good driving record is required to pass from one stage to the other. Licensing stages have restrictions on keeping driving logbooks, using mobile phones, supervised driving, passengers, vehicle power, alcohol limit, and night time driving. (Government Of ACT 2017)

GDL in Canada

In Canada, different provinces and territories have different driver licensing policies. Graduated driver licensing is designed as a three-stage program; learner stage, intermediate stage, and full stage. The earliest age to obtain a learner's license is 14 years, in Alberta. In Alberta, the minimum time required to hold a learner's license is 12 months. After passing a road test, drivers obtain an intermediate license. Drivers must hold an intermediate license for at least 24 months. A learner's license has passenger and night time restrictions and an intermediate license has passenger restrictions. (Government of Alberta 2017)

In Manitoba, teenagers 15 years and 6 months old (if entered in a high school driver education program) can obtain a learner's license. The minimum time required to hold a learner's license is 9 months. After passing a road test, drivers obtain an intermediate license. Drivers must hold an intermediate license for at least 15 months. Both learner's and intermediate license holders have night time and passenger restrictions. Once drivers obtain a full license, they must maintain zero blood alcohol concentration for the first 36 months. (Manitoba Public Insurance 2018)

GDL in Israel

In Israel, 16 years and 9 months old teenagers can obtain driver's licenses after passing written and driving exams. After being licensed, new drivers must be accompanied for the next 6 months; during the first three months any time of the day and during the last three months only at night. (Toledo et al. 2014)

GDL in the Netherlands

In 2011, the Netherlands started a young driver licensing program (2toDrive), a six-year experimental program that will continue until November 2017. Program participants can start driving lessons at the age of 16.5 and can take the driving test at the age of 17. After passing the driving test, they obtain a driving license. However, until they reach 18 years old, they can only drive when they are accompanied by an experienced driver. (Dutch Ministry of Infrastructure and Environment 2017)

GDL in New Zealand

In New Zealand, the minimum age to obtain a learner's license is 16 years old. A learner's license allows drivers to drive supervised. After six months, drivers can obtain a restricted license by passing a 60-minute practical driving test. In this second stage, unsupervised driving, with passenger and night time driving restrictions, is allowed. If the driver is supervised, passengers and night time restrictions do not apply. Restricted license driving takes 12-18 months. Drivers can obtain their full license by passing a 30-minute practical driving test. (The New Zealand Transportation Agency 2017)

Categorization of Graduated Driver Licensing (GDL) Programs

GDL programs can be categorized in four main groups (Engstr et al. 2003), single-phase systems with no probationary license, single-phase systems with probationary license, two-phase systems, and graduated licensing systems.

- In single-phase systems with no probationary license, a driver is fully licensed after passing written and driving exams.
- In single-phase systems with probationary license, a driver is still required to pass written and driving exams but not fully licensed until completing a probationary period.
- In two-phase systems, a provisional license is given after passing written and driving exams. The driver is permitted to drive alone but further theory and practical training is required before obtaining the full license.
- Graduated licensing system is typically a three-stage program. In the first stage, the driver obtains a learner's permit and practices supervised driving. In the

second stage, driver can practice unsupervised driving, with restrictions on driving. And, in the third stage, the driver is fully licensed.

Categorization of Graduated Driver Licensing (GDL) Program Evaluation Studies

Graduated Driver Licensing (GDL) Program evaluation studies can be categorized in a number of different ways.

By Crash Data Used

National level studies include fatal crashes only. The main reason for that is the absence of injury and property damage crash data at the national level. In the United States, Fatality Analysis Reporting System (FARS) data is used to analyze fatal crashes. State level studies mostly include fatal and all other injury crashes.

By Performance Measures

The most common measures used in GDL program evaluations are change in the crash rates and change in the likelihood of crash outcomes. In crash rate calculations, crash counts and crash count normalization factors are used. Population, number of licensed drivers, and vehicle miles traveled are the most commonly used crash count normalization factors. In the absence of reliable data sources, crash counts of other driver groups are also used as the normalization factor (Ehsani, Raymond Bingham, and Shope 2013; Curry et al. 2013; O'Brien et al. 2013; Mitchell et al. 2015; McCartt and Teoh 2015). Crash rates from different studies can be compared, given that crash counts are calculated in a similar way and normalization factors are collected from reliable sources. Crash counts are also used in count-based models to assess the changes in the likelihood of crash outcomes. In several studies, fatality is defined as the most important crash outcome.

However, the set of variables used in the models vary, different models are describing different risk environments for drivers.

By Area of Interest

Although most of the studies evaluate overall effectiveness of GDL programs, there are also studies that evaluate the effectiveness of specific GDL program components, such as night time driving restrictions, supervised driving requirements, and passenger restrictions.

The following are the examples of studies discussed above.

Willams et al. (Williams, Tefft, and Grabowski 2012) reviewed GDL research literature, covering the period 2010 to 2012. As it highlighted, although GDL programs have existed in Australia, Canada, New Zealand, and the Unites States for many years, most of the GDL program research is primarily on United States crash data. The main reason for this is the availability and accessibility of the United States' national fatal crash data. The authors discussed the effect of GDL programs for different age groups. Based on program evaluations, results indicated that GDL programs have a positive effect on crash reduction rates for 16 years old and 17 years old drivers. Risk factors for provisional license holders are listed as late-night driving and passengers under 21 years old.

Mitchell et al. (Mitchell et al. 2015) compared novice and full-licensed driver crash types for New South Wales, Australia. In their study, the novice driver group is described as 17 to 25 years old drivers and the full-licensed driver group is described as 40 to 49 years old drivers. The authors discussed that the middle-age driver population group has the lowest crash risk. Therefore, in their comparative study, the 40 to 49 years old driver population was used as the control group. Crash data was collected from police crash reports and public and private

hospitals. Road infrastructure data was collected using Google Earth, based on the crash locations given in police crash reports. In the data analysis, passenger vehicle crashes involving novice drivers were identified from the crash data and compared to the same crash type involving full-license holders 40 to 49 years old. The variables used in the analysis were age, gender, collision type, injury type, injury severity, year, weather condition, and relation to intersection. The authors concluded that novice drivers and full-licensed driver crash characteristics have similarities, all drivers can benefit from preventive crash risk reduction strategies.

Carpenter and Pressley (Carpenter and Pressley 2013) analyzed Fatality Analysis Reporting System data to evaluate GDL nighttime compliance in the United States. Crashes involving at least one teen driver between the ages of 15 and 17 years old were included in the study, for the time period 2006-2009. The categorical variables used in the study were the time of the crash, driver age, gender, crash location (urban/rural, based on the population density in the surrounding area), road classification (interstate, non- interstate), weather, day of the week, alcohol involvement, seatbelt use, speeding, and number of passengers. In the statistical analysis, Chi-squared tests and Student-t tests were used to determine statistical significance of categorical variables. The results showed that teen drivers, between 15 and 17 years old, involved fatal crashes at night are more likely to be drinking, not using seatbelts, driving at the weekend, and killed.

Toledo et al. (Toledo et al. 2014) studied Israeli young male drivers' accompanied driving and solo driving patterns. In Israel, the GDL system requires that new drivers must be accompanied by an experienced driver for the first three months after obtaining a driver's license. Data was collected from in-vehicle data recording devices, installed on 217 vehicles

driven by young male drivers. Analysis of data indicated that there is a significant difference between accompanied and solo driving patterns. Young drivers spend more time, approximately double, in the solo driving period compared to the accompanied driving period. Results showed that most of the night-time driving is solo driving. In solo driving periods, drivers also chose to drive in more risky driving environments, such as arterial roads and collector roads.

Curry et al. (Curry et al. 2013) examined the effects of New Jersey's GDL system on citations issued for police-reported crashes involving teen drivers and citations issued for violation of GDL restrictions. The data used in the study was obtained from The New Jersey Motor Vehicle Commission's Licensing and Registration database and New Jersey crash record data, for the years 2008 to 2011. Outcome measures for 21 years old and younger drivers were compared to outcome measures for 35 to 54 years old drivers. Monthly crash rates were used for crash related outcomes. For citation related outcomes passenger, seatbelt use, nighttime driving, alcohol, and communication device usage related monthly violations rates were used. Multivariate modeling was used to estimate the effect of GDL on monthly rates. Variables used in initial regression models were period (before GDL, after GDL), gender (male, female), season (January-March, June- August, other), and license status (novice, experienced). Study results showed that after the GDL period, there were an increase in citation rates and a decrease in crash rates. The authors concluded that GDL has a positive effect on young drivers' safety.

Ehsani et al. (Ehsani, Raymond Bingham, and Shope 2013) studied effects of GDL on crashes involving 16 to 18 year old drivers in Maryland, Florida, and Michigan. For each state different time period data is used, for Maryland 1998 to 2009, for Florida 1990 to 2009, and for Michigan 1992 to 2009. The authors highlighted that, for the given time periods, GDL is applied

to all novice drivers in Maryland and only the new drivers younger than 18 years old in Florida and Michigan. The research data include all police- reported crashes and was obtained from the University of Michigan Transportation Research Institute. For each state monthly crash rates were calculated for different types of crashes, based on the population of 16-18 years old residents in each state. The covariates used in the study are adult driver crash rates (25-54 years old), gasoline prices, and GDL effective date. A linear regression model was used to estimate teen crash rates and covariates. Then, for each state, a time serious analyses were conducted to identify any seasonal trends and variation in the data. It this last step, state models were calibrated using the output obtained from time series analyses. The authors concluded that GDL has a positive effect on 16, 17, and 18 years old drivers. However, for novice drivers older than 18 years old, GDL was not found to be effective since there was an increase in crash rates.

Curry et al. (Curry et al. 2014) studied the effects of graduated driver licensing on intermediate license holder drivers 21 years old and younger. The study period covered 2006 to 2012 and research data was obtained from New Jersey Motor Vehicle Commission license database and Department of Transportation crash database. The crash rates for drivers 21 years old and younger and 21 to 24 years old were used in the analyses. The authors discussed that the 21-24 driver group was likely to be the most similar group to the 21 years old and younger drivers in terms of being affected by actors such as gas price, driving patterns, and economic conditions. Variables used in the study were crash types, crash time (day or night), number of teen passengers, and number of vehicles in the crash (single-vehicle, multi-vehicle). First, monthly citation and crash rates for each age group were estimated, per 10,000 licensed drivers in each age group. Crash and citation rates were adjusted for gender, seasonal, and overall trends.

Then, negative binomial modeling was used to compare pre-GDL and post-GDL periods. The study results suggest that GDL system has an impact on reducing crashes involving teen drivers, particularly 18- and 19-years old drivers.

In Nebraska, teenagers must either complete a driver education safety course or complete 50 hours of accompanied driving to obtain their intermediate stage operator permit. Shell et al. (Shell et al. 2015) studied the effect of driver education on teen crashes and traffic violations in Nebraska for the first two years of driving in a GDL system. Crash data and traffic violation data, 2003 to 2009, were obtained from multiple agencies. Hierarchal logistic regression was conducted to develop a predictive model using the variables for gender, ethnicity, residence area (rural, urban), income level, driver education (driver education safety course taken or not), and certification log (proof of 50 hours of accompanied driving). Results showed that teenagers a completing driver education safety course were less likely to be involved in crashes and to commit traffic violations comparing to teenagers completing 50 hours of accompanied driving. It was also highlighted that this conclusion is independent of gender, income level, residence classification, and age.

McCartt and Teoh (McCartt and Teoh 2015) analyzed fatal crashes involving teenage drivers in the United States. Data used in the study included all passenger vehicle crashes from 1996 to 2012. Authors noted that most of the states in the United States started to implement GDL systems starting in 1996. Crash data was obtained from two different resources, Fatality Analysis Reporting System (FARS) and National Automated Sampling System General Estimates System (HASS GES). The authors discussed that the ideal crash rates should be calculated using the number of licensed drivers. However, since a national licensure database is

not available, crash rates used in this study were calculated using population data obtained from U.S. Census and travel mileage data, obtained from National Household Travel Survey. Crash rates were calculated for two different driver populations, 16 to 19 years old and 30 to 59 years old drivers. The authors concluded that teenage drivers' crash risk has declined since the implementation of GDL programs. Authors also noted that graduated driver licensing programs do not address all crash related factors. Therefore, crash risk for teenagers is still high.

Chen et al. (Chen et al. 2014) analyzed spatial variations in the effectiveness of GDL program in the state of Michigan. Fatality Analysis Reporting System data for the time period 1990-2004, involving teenage drivers between 14 and 17 years old, is used in the analysis. Log adjusted county-level teenage driver fatality rates were calculated. Then, using spatial regression models, temporal trends in the log fatality rates were investigated. The authors concluded that Michigan's GDL system is effective at reducing the risk of fatal crashes for teen drivers. It was also noted that, in Michigan, teenagers in less urbanized counties were more likely to be involved in fatal crashes.

O'Brein et al. (O'Brien et al. 2013) used auto-regressive integrated moving average interrupted time series analysis to evaluate the effectiveness of 30-hours of supervised driving requirement in the GDL program in Minnesota. Crash data was obtained from the state data system and included all crashes from 1994-2002. However, in the analyses only fatal and serious injury crash counts were used. Two driver populations were considered, 16- and 17-years old drivers. Another young driver group, 25 to 39 years old, was included in the study as a covariate to control factors that affect all drivers (such as weather, enforcement programs, and economic conditions). Another covariate included in the study was gasoline price. The authors noted that

16- and 17-years old drivers are more sensitive than other young drivers and adults to gasoline prices. It was concluded that the authors found no evidence of the effectiveness of supervised driving on crash involvement of 16- and 17-years old drivers.

CHANGE IN THE CRASH RATES AT THE STATE LEVEL

Crash rate analysis includes defining crash categories, calculating crash counts, defining a crash normalization factor, normalizing crash counts, and analyzing normalized crash counts. This chapter first presents an overview of crash count normalization factors. In the later sections, methodology used in this study and results are presented.

Crash Count Normalization Factors

The major challenge in crash rate analysis is to identify a suitable crash normalization factor to normalize crash counts, to identify a suitable measure of exposure. Thus, identifying potential crash normalization factors and data availability are two important factors effecting the results of crash rate analysis.

Potential normalization factors that can be used in this study and data availability are summarized as follows:

Vehicle Miles Traveled

Vehicle miles traveled (VMT) is a measure used in transportation planning for a variety of purposes. It measures the amount of travel for all vehicles in a geographic region over a given period of time, typically a one-year period. For this study, VMT data can be obtained from Federal Highway Administration (FHWA), yearly and monthly vehicle miles traveled statistics, available by state, by urban/rural road classification, and by vehicle configuration type. However, this data is not stratified by age groups. (The United States Federal Highway Administration 2016b).

Data can be also obtained from North Dakota Statewide Traffic Safety Surveys conducted by Upper Great Plains Transportation Institute. (Vachal, Benson, and Kubas 2016)

This data includes average miles driven per year per age group data. The youngest age group that the survey results are reported for is 18 to 24 years old drivers.

Data Availability: All drivers, including 18 to 24 years old drivers, for the time period 2007-2016.

Data Source: North Dakota Department of Transportation, Crash Summary Reports.

Number of Licensed Drivers

Data can be collected from the North Dakota Driver's License Records data set. However, it should be noted that, reliable licensing counts are difficult to obtain since licensing status of drivers may change over time in a given time period. Number of licensed driver counts is also provided by the United States Federal Highway Administration (FHWA), published in annual reports as number of drivers by age and by state. (The United States Federal Highway Administration 2016a)

Data Availability: 14 to 17 years old North Dakota drivers, for the time period 2007-2016.

Data Source: North Dakota Department of Transportation, Crash Summary Reports.

Population Data

United States Census Bureau's population data can be used. A full census is performed every ten years and for other years population estimates are given. (The United States Census Bureau 2016)

Data Availability: 14-17 years old North Dakota teens, for the time period 2007-2016.

Data Source: United States Census Bureau.

Crash Data

As was discussed in the literature, crash data can be used in normalizing the crash counts. The first step in this approach is to describe an adult driver age group in the crash data. Then, for this adult driver group, crash counts are calculated. At this step, it is assumed that the adult driver group is not subject to any GDL requirements. However, it is also assumed that, adult drivers are subject to the same or similar driving environment changes over time compared to teen drivers. Therefore, adult driver crash counts, can be used as a normalization factor for teen driver counts. The limitation of this approach is to determine the adult driver age group in the crash data. In the literature, there is no consensus regarding how to determine the appropriate adult driver age group.

Data Availability: All crashes in North Dakota, for the time period 2007-2016.

Data Source: North Dakota Department of Transportation, Crash Database.

In this study, crash data is used to normalize teen driver involved crash counts.

- Vehicle miles traveled (VMT) data is not used since this data cannot be stratified by age group of interest, 14 to 17 years old drivers.
- Driver license count (the number of licensed drivers) data is not used since this data does not indicate any evidence of driving activity for the given, 14 to17 years old, driver group.
- Population data is not used since this data does not indicate any evidence of driving activity for the given, 14 to 17 years old, driver group.

Methodology

The methodology used in this study includes the following steps:

Describe Study Period

Teen driver involved motor vehicle crashes in North Dakota will be investigated for 5-year-before-and-after time periods: pre-GDL (2007-2011) and post-GDL (2012-2016).

It should be noted that the robustness of the study findings can be assessed using different pre-GDL and post-GDL time periods. Based on preliminary data analysis, 5-year-before-and-after time period is chosen for further analysis in this study.

Other study periods considered in the preliminary analysis are as follows:

- 4-year-before-and-after time period: pre-GDL (2008-2011) and post-GDL (2012-2015).
- Adjusted 4-year-before-and-after time period: pre-GDL (2007-2010) and post-GDL (2013-2016).

Prepare Crash Data

North Dakota Motor Vehicle Crash Data is used in this study. The crash data needed for this study, for years 2007 to 2016, was provided by the North Dakota Department of Transportation, from state's Crash Reporting System (CRS). Each year's data is given separately, and data sets include all reported fatal, injury, and at least $1,000 property damage crashes for that given year.

Data storage, usage, analysis, and reporting are performed in such a way that the assurance of confidentiality is granted, and limited usage protocols are followed.

Crash data set cleaning is done to remove any duplicated records from the data set.

Prepare Teen Crash Data

In this study, crash rates are represented by the number of drivers involved in the crash. This approach can be considered as first calculating crash counts, and then calculating weighted crash counts using the drivers involved in the crash. The main advantage of this approach is to address driver involvement in the crash rather than the crash event. In this way, data analysis is more sensitive to changes in the driver involvement in the crash events.

The following filters are used when calculating teen driver counts:

- Driver is 14 to 17 years old
- Driver's gender is either male or female, information is not missing
- Vehicle involved in the crash, driven by teen driver, is either passenger car or pick up/van/utility
- Crash location is known, has coordinate system data available in the crash data set, and crash location is within the state of North Dakota
- Crash severity is either fatal or injury, not property damage only

The filters given above are used to present the scope of the study and to satisfy the assumptions of statistical analysis techniques to be used in the study. Specifically,

- Non-serious injury crashes are included in the study because there are not enough number of fatal and serious injury crashes in the state of North Dakota involving 14 to 17 years old drivers for meaningful statistical analysis.
- Vehicle configuration is used instead of drivers' license class because in this way control group (adult driver group) can be filtered in a similar way and similar driving patterns can be compared.

- Gender filter is used to eliminate data with missing gender field information. However, it should be noted that this filter also removes hit-and-run drivers.

Prepare Normalization Crash Data

Figure 1 presents that the highest percentage of injury crashes occurred in the 25 to 34 years old age demographic and more than half of the injury crashes occurred in the 25 to 54 years old age demographic. In this study, crashes involving 25 to 54 years old drivers are used to calculate the normalization factor.

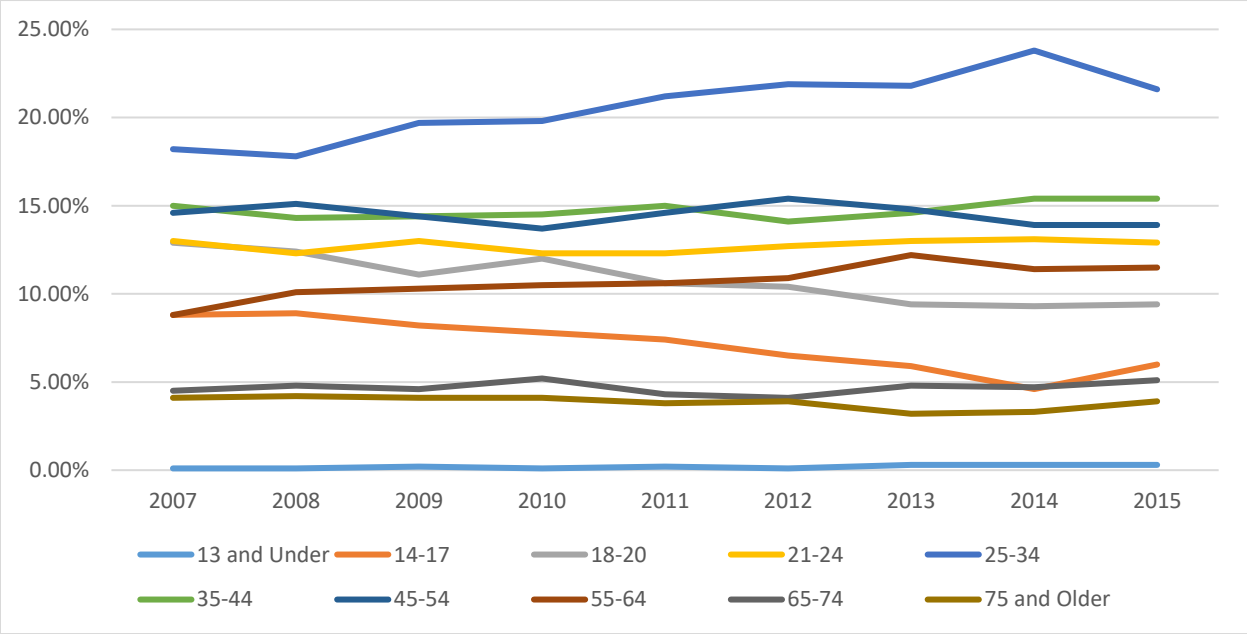

Figure 1. Percentage of Driver Crash Involvement in Injury Crashes by Age

The following filters are used when calculating adult driver counts:

- Driver is 25 to 54 years old
- Driver's gender is either male or female, information is not missing
- Vehicle involved in the crash, driven by adult driver, is either passenger car or pick up/van/utility

- Crash location is known, has coordinate system data available in the crash data set, and crash location is within the state of North Dakota
- Crash severity is either fatal or injury, not property damage only

It is also assumed that adult drivers are subject to the same or similar driving environment changes over time compared to teen drivers. These changes include, but not limited to, road network coverage, road infrastructure, economic conditions, demographics, traffic volume, vehicle safety technology, and enforcement of traffic safety compliance on roads and highways.

Define Crash Categories

The following table summarize crash categories used in this study.

Table 3. Crash Categories

Driver related	All Male Female	14 Years Old 15 Years Old 16 Years Old 17 Years Old
Number of vehicles related	Single Vehicle Crash Multi Vehicle Crash	
Location related	Urban Rural	State Local
Contributing factor related	Restraint Use: Improper Speeding	Impaired Distracted
Passenger profile related	Adult Passenger: At least one No Passenger: Driving Alone Teen Passenger: Only or More	One Teen Passenger Many Teen Passengers
Driver injury condition related	Driver has Fatal or Serious Injury Driver has Non-Serious Injury Driver has No Injury	

Counts and Rates

Teen driver and adult driver crashes identified for each crash category. Driver counts and rates (number of teen drivers/number of adult drivers) are calculated respectively, Tables 4-29 and Figures 2-26.

Figure 2 shows that teen driver crash involvement rate in fatal or injury crashes is lower in the post-GDL period than the pre-GDL period. Within the post-GDL period, there is a U-shaped distribution, rates steadily fall until 2014 and then steadily rise. Similar trend is seen for male and female teen drivers, in Figure 3 and Figure 4 respectively.

14 years old teen driver crash involvement rates are impacted from the GDL program at most. Staring from 2013, rates are reduced more than half, Figure 5. For other age groups, 15 to 17 years old, trends are similar to the U-shaped distribution, rates steadily fall until 2014 and then steadily rise, Figure 6 to Figure 8.

Teen driver crash involvement rates in urban and rural roads have been reduced since the implementation of the GDL program, Figure 9 and Figure 10. However, immediate and after effects of the changes in crash rates are different for crashes in urban and rural roads. In rural roads, immediate effects are stronger than the urban roads. In rural roads, after effects are stronger than the immediate effects.

Teen driver crash involvement rates in state and urban roads have been reduced since the implementation of the GDL program, Figure 11 and Figure 12. However, staring from 2015, rates have been in increasing.

The contribution of impaired driving has been reduced in teen driver crashes since the implementation of the GDL program, Figure 13. It should be noted that changes in impaired

driving related crash rates started in 2009. And, it looks like, GDL program has helped maintaining reduced crash rates at lower levels.

Distracted teen driver involved crash rates have been reduced significantly since the implementation of the GDL program, Figure 15. It should be noted that, in 2016, only 9 teen drivers and 16 adult drivers are listed in Table 17. These numbers are incorrect. The reason for this problem is that NDDOT CRS data field for "distracted" variables was revised in 2016. And, the data set for 2016 was not reflecting these revisions appropriately. Therefore, numbers for distracted teen drivers and distracted adult drivers involved in fatal or injury crashes are not captured correctly for year 2016.

Rates of teen drivers not using proper restraint and involved in fatal and injury crashes have been reduced by half since the implementation of the GDL program, Figure 14.

Figure 16 shows that rate of teen drivers speeding and involved in fatal or injury crashes is lower in the post-GDL period than the pre-GDL period. Within the post-GDL period, there is a U-shaped distribution, rates steadily fall until 2014 and then steadily rise.

The rate of teen drivers involved in fatal or injury crashes, by passenger profile, is given in Figure 17 to Figure 19. It should be noted that rates of teen drivers with passengers, either only teen passengers or at least one adult passenger, are lower in the post-GDL period than the pre-GDL period. However, starting from 2016, rates for post-GDL period are increased and as high as the pre-GDL period. Rates for teen drivers with no passengers are lower in the post-GDL period than the pre-GDL period. No passenger rates do not change from 2015 to 2016 significantly. Given above information and given that North Dakota GDL Program still does not

include any passenger restrictions, rates of teen drivers involved in fatal or injury crashes, by passenger profile, should be monitored closely in the future studies.

Figure 20 and Figure 21 present crash rate changes for teen only passenger categories. Trend in only one teen passenger rates are similar to at least one adult passenger rates. However, rates for many teen passengers are significantly reduced in the post-GLD period. As it can be seen in Table 23, number of adult drivers involved in fatal or injury crashes and had many teen passengers in their vehicle are only a few number compared to the teen drivers' related numbers. This indicates that, although crash rates are reduced for teen drivers, risk of involving in fatal and injury crashes is high for teen drivers than adult drivers when there are many teen passengers in the vehicle.

Figure 22 to Figure 24 present crash rate changes by driver's injury category. Rates for fatal or serious injury have been reduced since 2010 and reduced rates have been maintained at during the post-GDL period. Non-serious injury and no injury rates have been slightly reduced in the post-GDL period.

The rate of teen drivers involved in fatal or injury crashes, by number of vehicles involved in the crash, is presented in Figure 25 and Figure 25. Rates for both single vehicle and multi vehicle crash categories have been reduced since the implementation of the GDL program. However, both rates are slightly increased in 2015 and 2016.

Table 4. Number of Drivers: All

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	427	2,157
2008	Before	431	2,115
2009	Before	399	2,234
2010	Before	426	2,421
2011	Before	426	2,604
2012	After	395	2,738
2013	After	364	2,939
2014	After	279	3,048
2015	After	351	2,802
2016	After	365	2,626
	Total	3,863	25,684

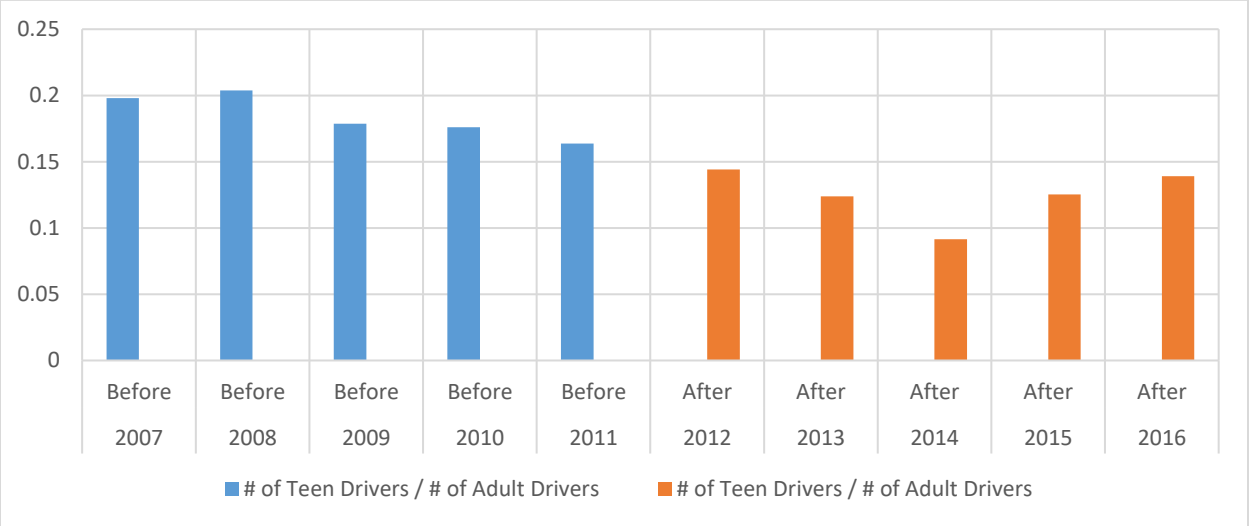

Figure 2. Ratio of Drivers: All

Table 5. Number of Drivers: Male

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	185	1,093
2008	Before	195	1,112
2009	Before	192	1,181
2010	Before	208	1,291
2011	Before	192	1,508
2012	After	189	1,592
2013	After	166	1,719
2014	After	133	1,802
2015	After	170	1,619
2016	After	185	1,431
	Total	1,815	14,348

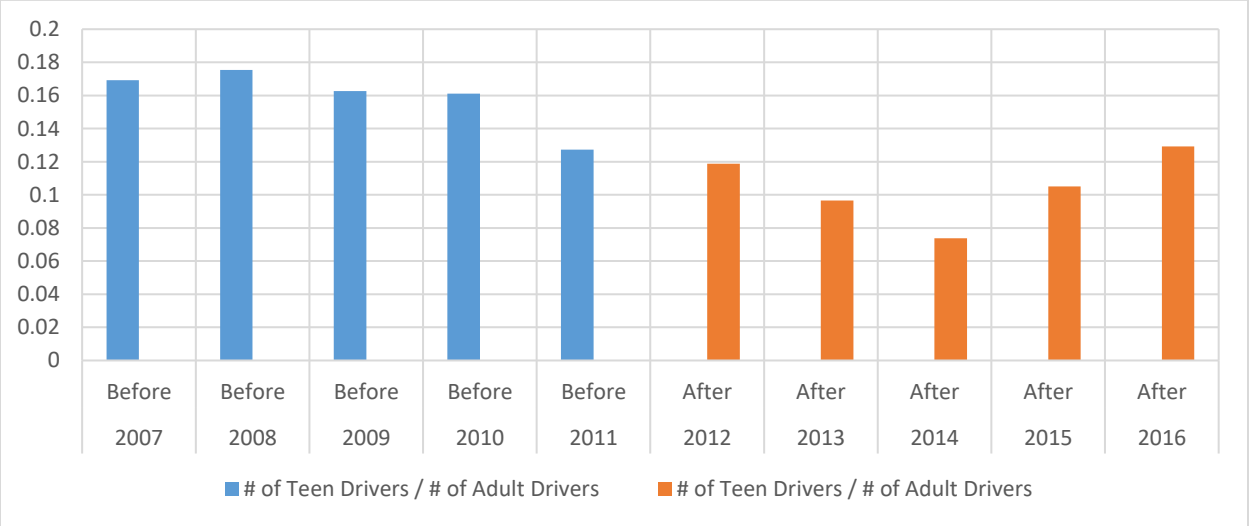

Figure 3. Ratio of Drivers: Male

Table 6. Number of Drivers: Female

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	242	1,064
2008	Before	236	1,003
2009	Before	207	1,053
2010	Before	218	1,130
2011	Before	234	1,096
2012	After	206	1,146
2013	After	198	1,220
2014	After	146	1,246
2015	After	181	1,183
2016	After	180	1,195
	Total	2,048	11,336

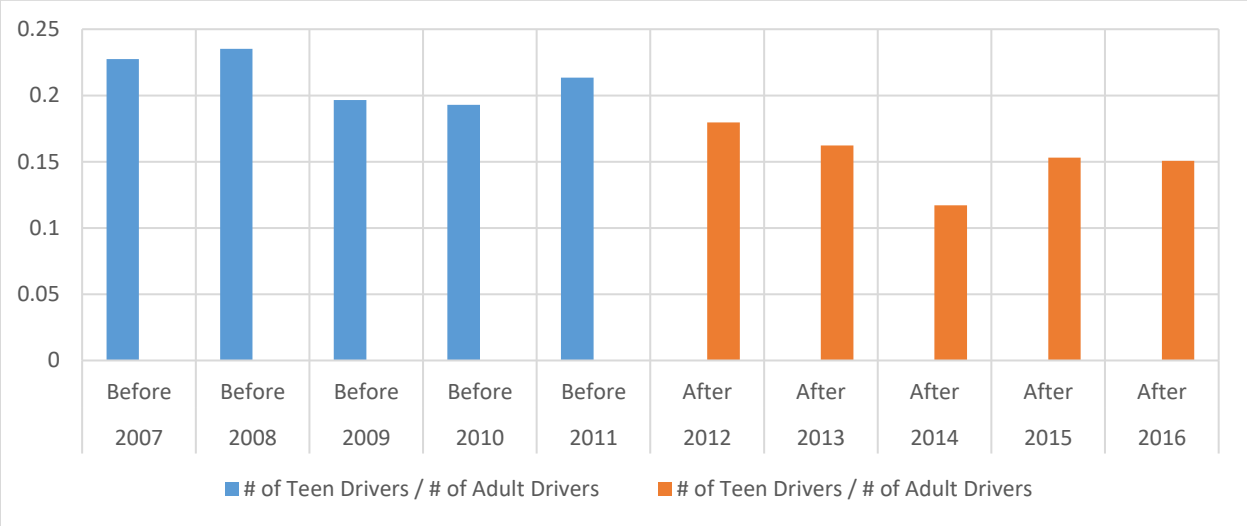

Figure 4. Ratio of Drivers: Female

Table 7. Number of Drivers: 14 Years Old Teen Drivers

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	15	2,157
2008	Before	13	2,115
2009	Before	21	2,234
2010	Before	19	2,421
2011	Before	20	2,604
2012	After	27	2,738
2013	After	7	2,939
2014	After	10	3,048
2015	After	10	2,802
2016	After	4	2,626
	Total	146	25,684

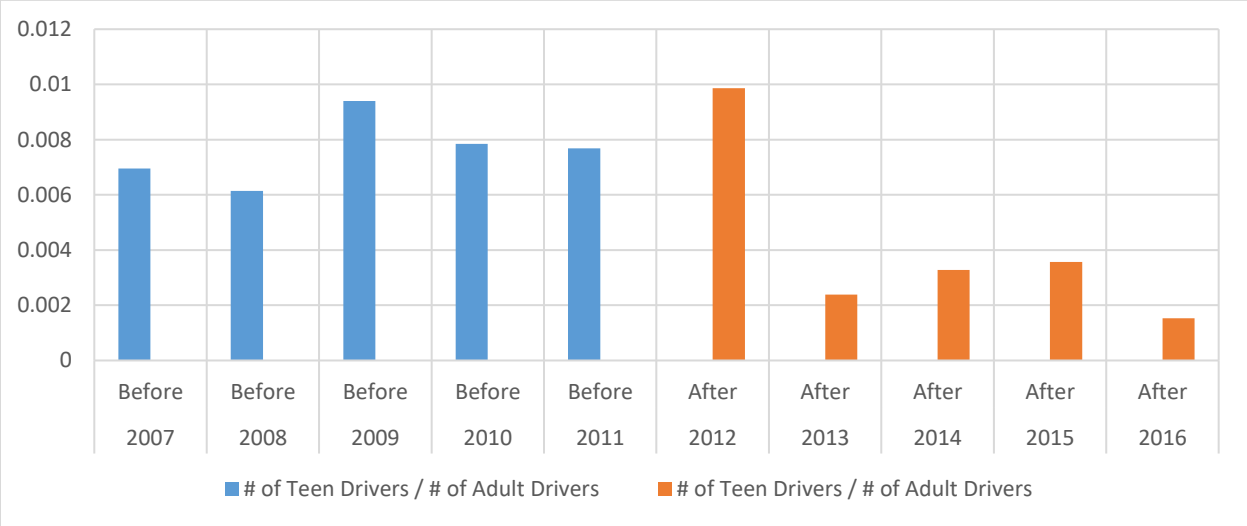

Figure 5. Ratio of Drivers: 14 Years Old Teen Drivers

Table 8. Number of Drivers: 15 Years Old Teen Drivers

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	90	2,157
2008	Before	92	2,115
2009	Before	90	2,234
2010	Before	94	2,421
2011	Before	87	2,604
2012	After	73	2,738
2013	After	65	2,939
2014	After	56	3,048
2015	After	80	2,802
2016	After	72	2,626
	Total	799	25,684

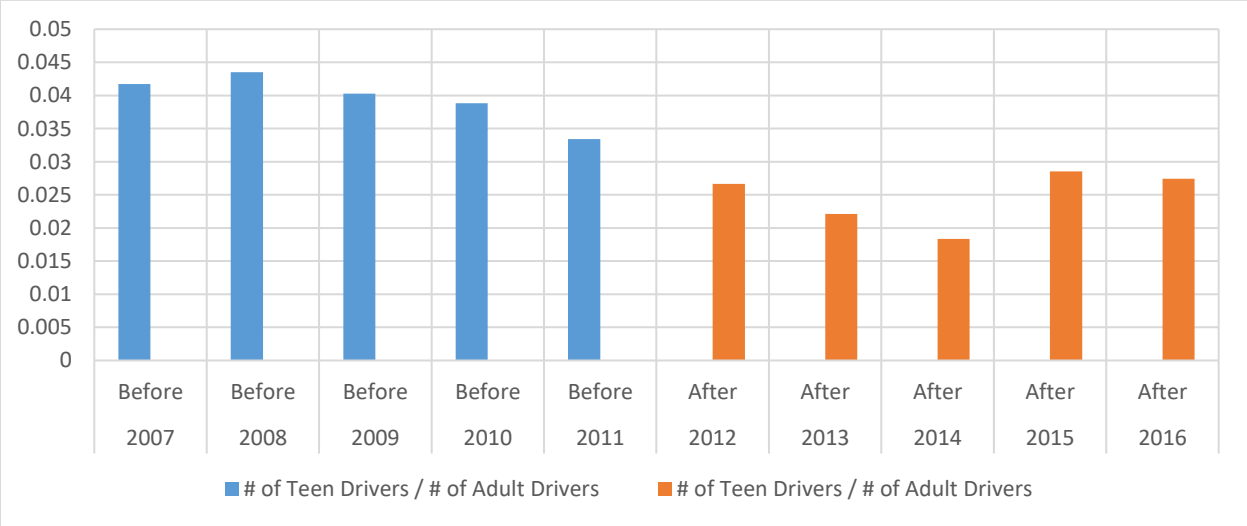

Figure 6. Ratio of Drivers: 15 Years Old Teen Drivers

Table 9. Number of Drivers: 16 Years Old Teen Drivers

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	149	2,157
2008	Before	156	2,115
2009	Before	126	2,234
2010	Before	144	2,421
2011	Before	161	2,604
2012	After	135	2,738
2013	After	133	2,939
2014	After	102	3,048
2015	After	131	2,802
2016	After	139	2,626
	Total	1,376	25,684

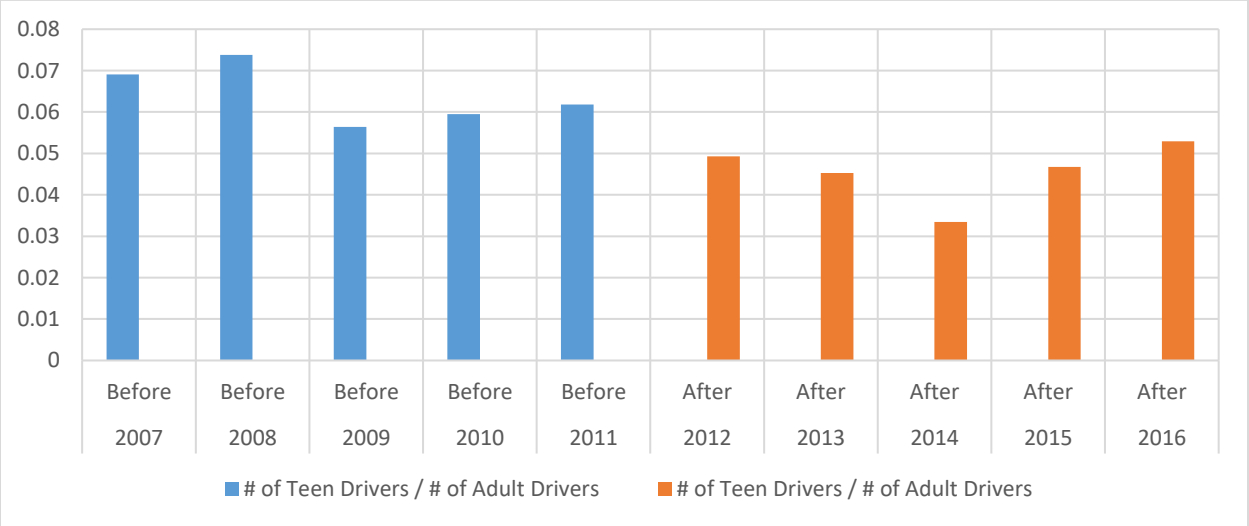

Figure 7. Ratio of Drivers: 16 Years Old Teen Drivers

Table 10. Number of Drivers: 17 Years Old Teen Drivers

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	173	2,157
2008	Before	170	2,115
2009	Before	162	2,234
2010	Before	169	2,421
2011	Before	158	2,604
2012	After	160	2,738
2013	After	159	2,939
2014	After	111	3,048
2015	After	130	2,802
2016	After	150	2,626
	Total	1,542	25,684

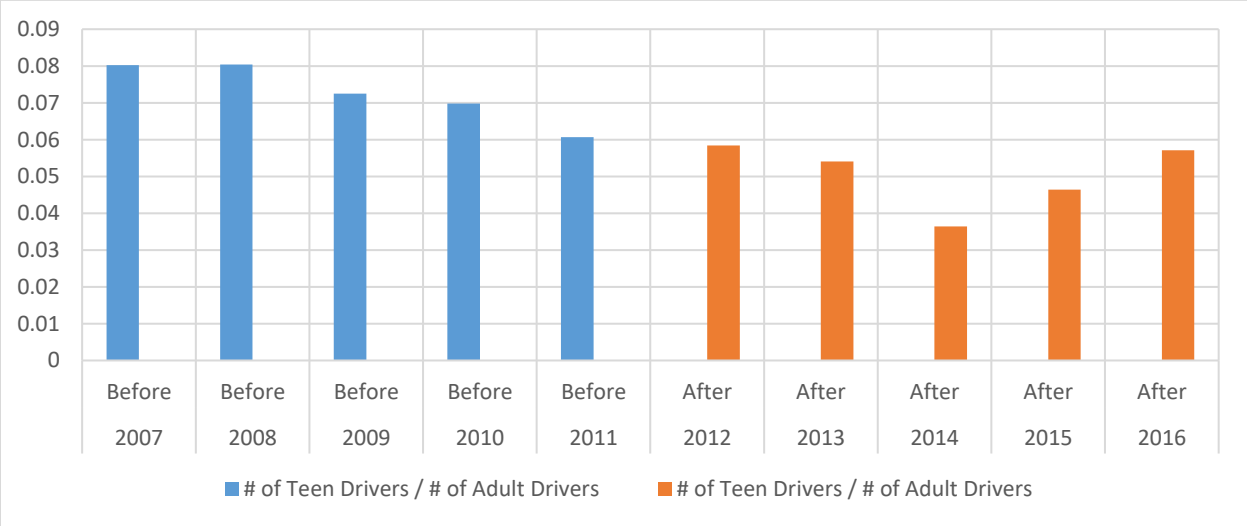

Figure 8. Ratio of Drivers: 17 Years Old Teen Drivers

Table 11. Number of Drivers: Crash in Urban Roads

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	292	1,640
2008	Before	308	1,563
2009	Before	263	1,624
2010	Before	298	1,769
2011	Before	303	1,719
2012	After	292	1,896
2013	After	271	2,019
2014	After	194	2,080
2015	After	254	2,079
2016	After	257	2,015
	Total	2,732	18,404

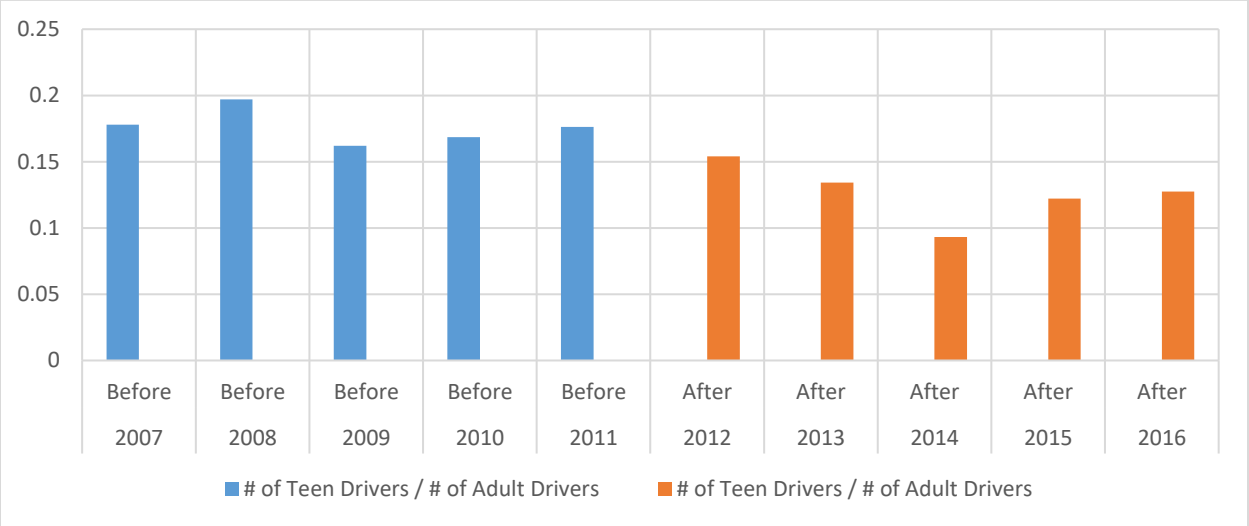

Figure 9. Ratio of Drivers: Crash in Urban Roads

Table 12. Number of Drivers: Crash in Rural Roads

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	135	517
2008	Before	123	552
2009	Before	136	610
2010	Before	128	652
2011	Before	123	885
2012	After	103	842
2013	After	93	920
2014	After	85	968
2015	After	97	723
2016	After	108	611
	Total	1,131	7,280

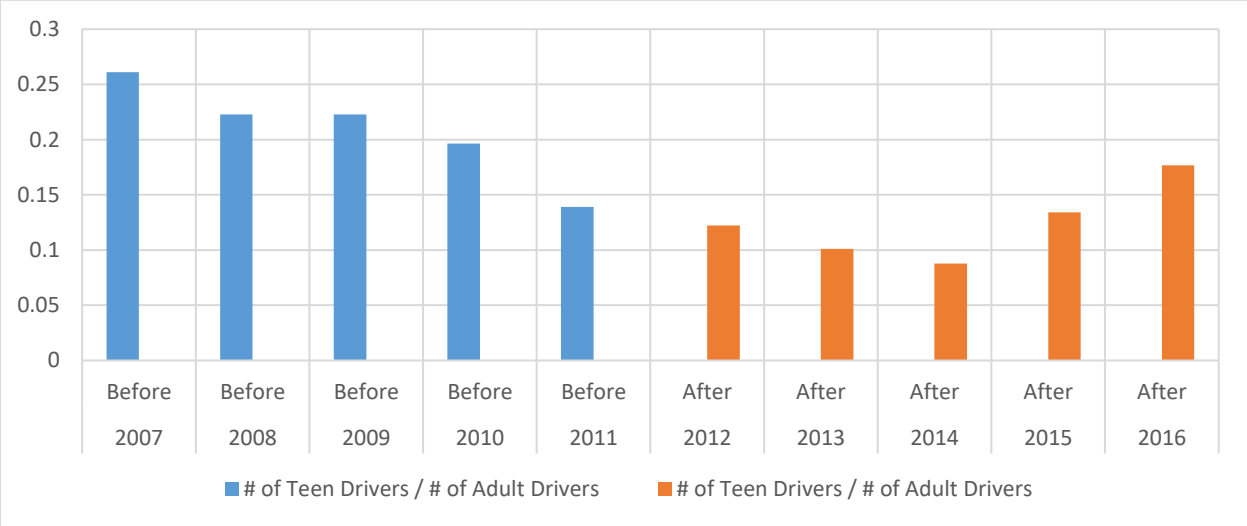

Figure 10. Ratio of Drivers: Crash in Rural Roads

Table 13. Number of Drivers: Crash in State Roads

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	48	357
2008	Before	46	384
2009	Before	53	400
2010	Before	56	495
2011	Before	58	711
2012	After	37	535
2013	After	63	877
2014	After	69	1,180
2015	After	82	973
2016	After	94	972
	Total	606	6,884

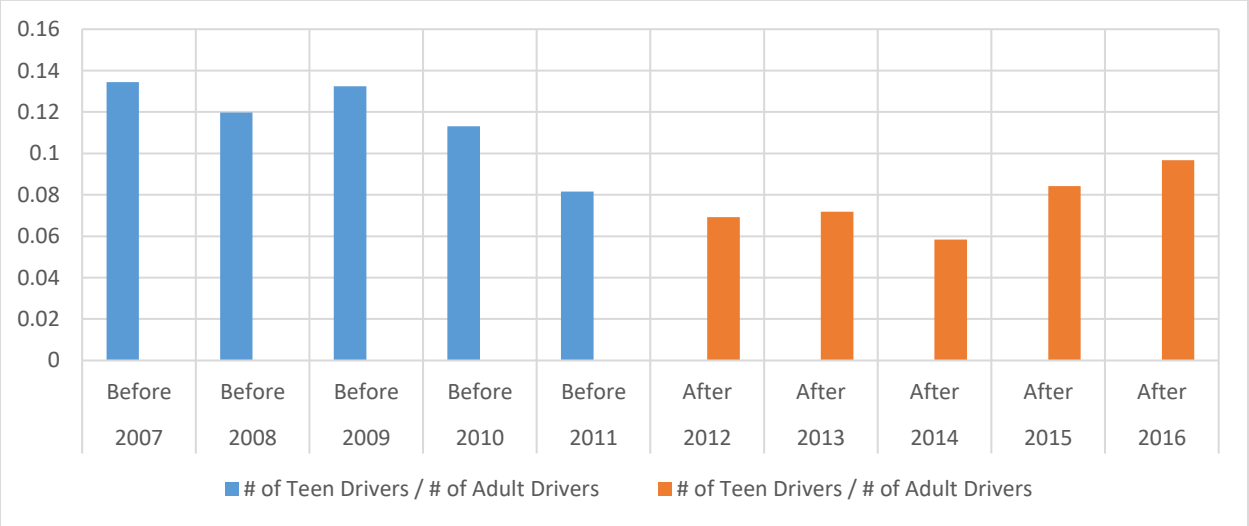

Figure 11. Ratio of Drivers: Crash in State Roads

Table 14. Number of Drivers: Crash in Local Roads

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	379	1,800
2008	Before	385	1,731
2009	Before	346	1,834
2010	Before	370	1,926
2011	Before	368	1,893
2012	After	358	2,203
2013	After	301	2,062
2014	After	210	1,868
2015	After	269	1,829
2016	After	271	1,654
	Total	3,257	18,800

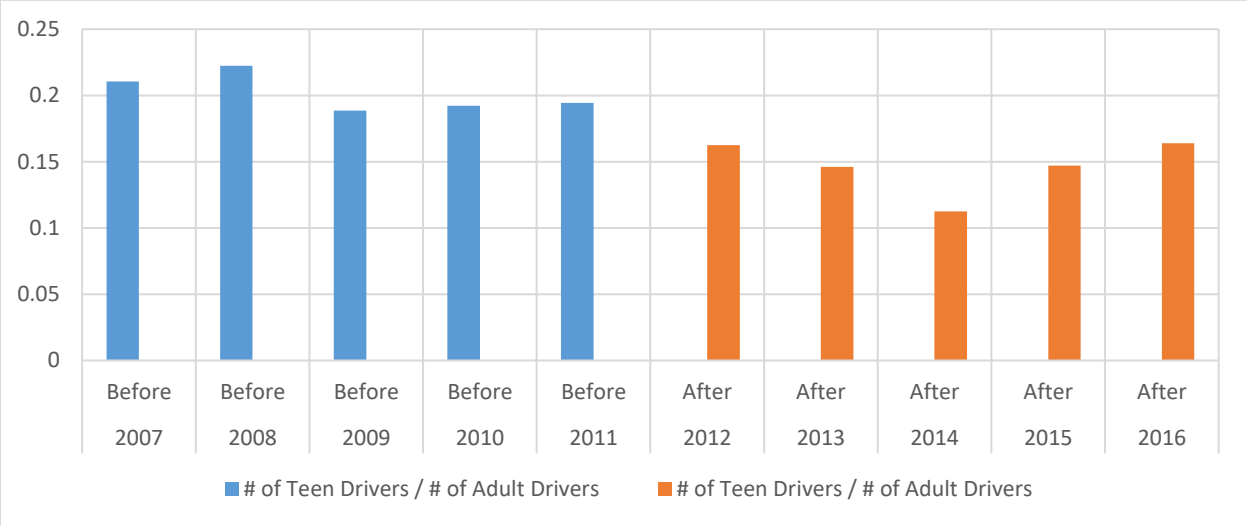

Figure 12. Ratio of Drivers: Crash in Local Roads

Table 15. Number of Drivers: Impaired

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	21	188
2008	Before	20	198
2009	Before	9	219
2010	Before	16	199
2011	Before	10	263
2012	After	10	297
2013	After	12	267
2014	After	6	271
2015	After	6	257
2016	After	10	222
	Total	120	2,381

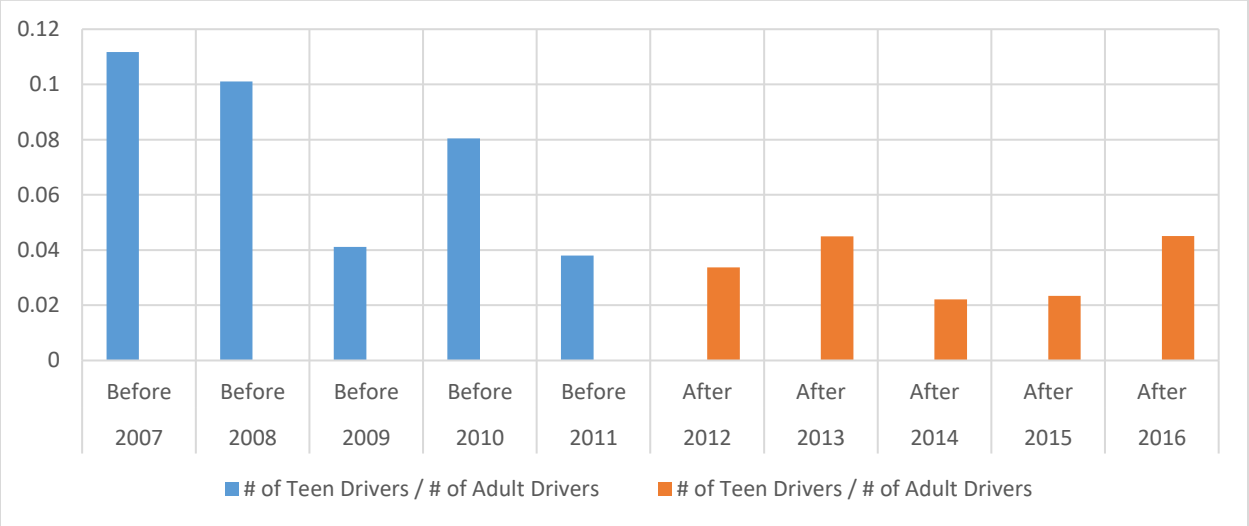

Figure 13. Ratio of Drivers: Impaired

Table 16. Number of Drivers: Improper Restraint Use

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	46	483
2008	Before	49	497
2009	Before	48	519
2010	Before	41	613
2011	Before	39	601
2012	After	31	687
2013	After	30	673
2014	After	17	659
2015	After	30	592
2016	After	22	635
	Total	353	5,959

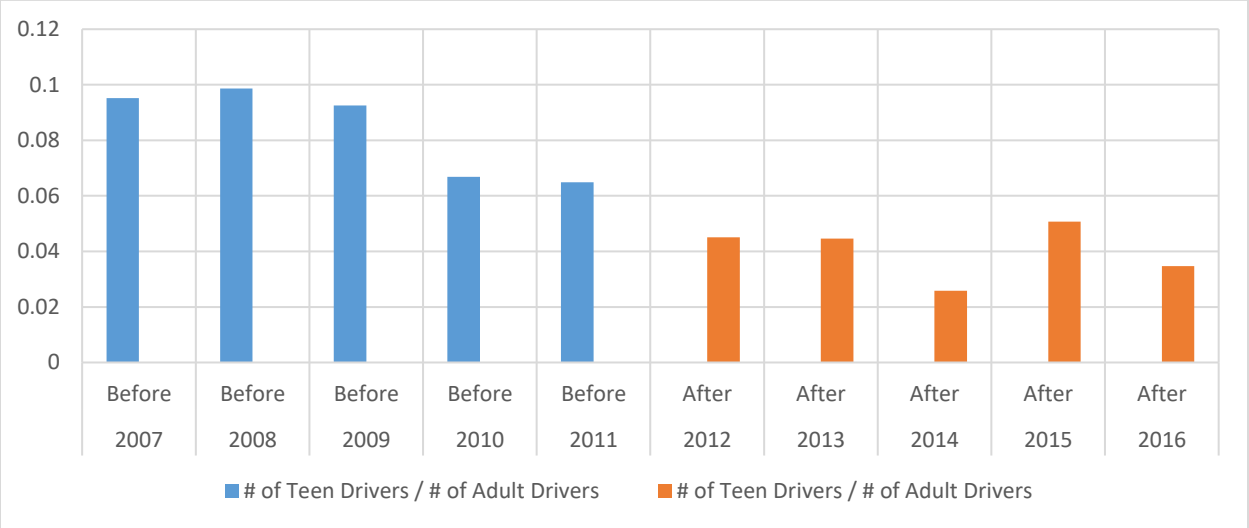

Figure 14. Ratio of Drivers: Improper Restraint Use

Table 17. Number of Drivers: Distracted

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	67	170
2008	Before	63	193
2009	Before	42	144
2010	Before	50	146
2011	Before	47	153
2012	After	29	157
2013	After	31	166
2014	After	25	163
2015	After	22	146
2016	After	9	16
	Total	385	1,454

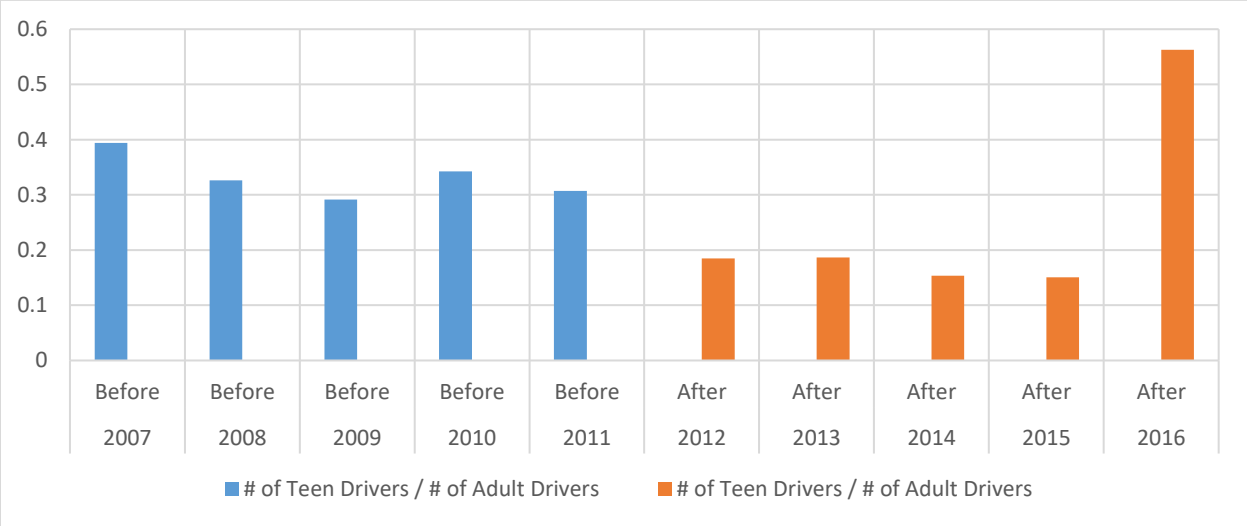

Figure 15. Ratio of Drivers: Distracted

Table 18. Number of Drivers: Speeding

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	123	313
2008	Before	118	334
2009	Before	118	364
2010	Before	146	447
2011	Before	152	544
2012	After	125	515
2013	After	107	630
2014	After	95	600
2015	After	117	549
2016	After	115	447
	Total	1,216	4,743

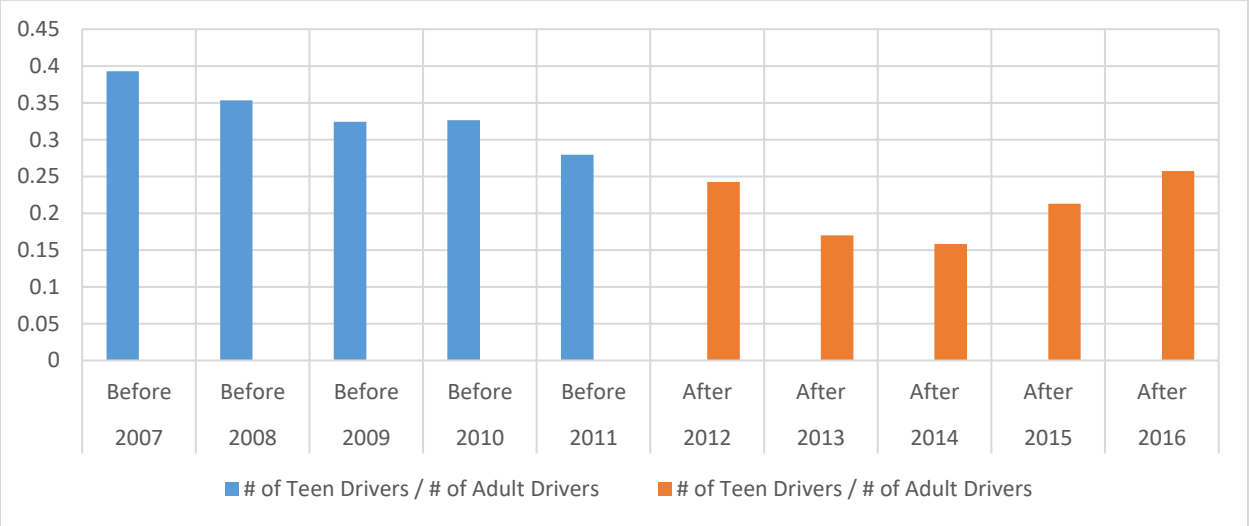

Figure 16. Ratio of Drivers: Speeding

Table 19. Number of Drivers: At Least One Adult Passenger in the Vehicle

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	45	448
2008	Before	49	474
2009	Before	51	457
2010	Before	56	528
2011	Before	44	603
2012	After	64	611
2013	After	50	634
2014	After	33	689
2015	After	26	512
2016	After	50	495
	Total	468	5,451

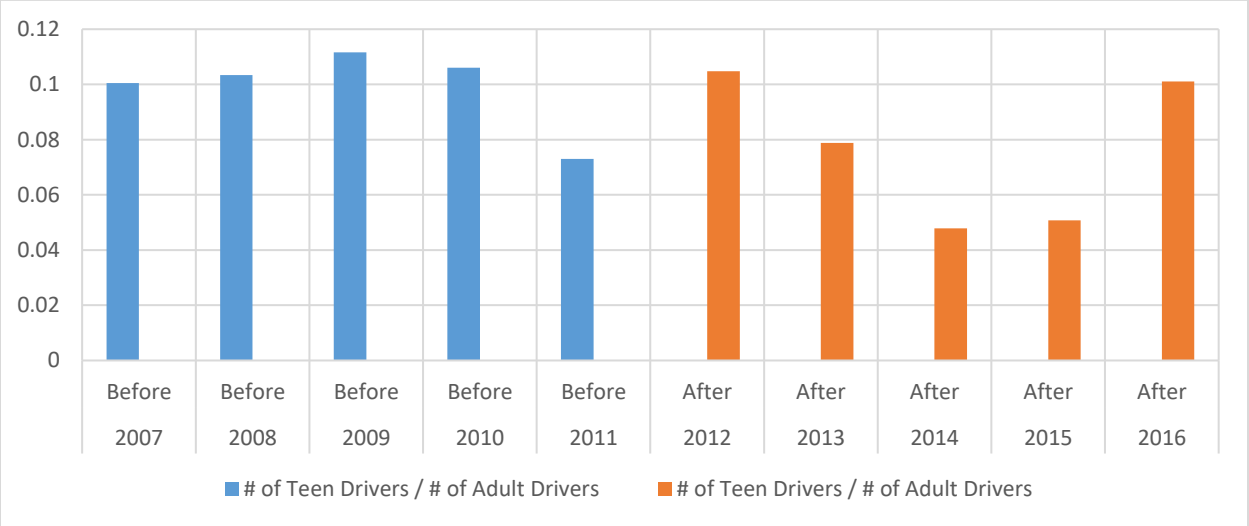

Figure 17. Ratio of Drivers: At Least One Adult Passenger in the Vehicle

Table 20. Number of Drivers: No Passenger in the Vehicle

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	248	1,406
2008	Before	242	1,436
2009	Before	222	1,541
2010	Before	220	1,627
2011	Before	240	1,757
2012	After	197	1,847
2013	After	226	2,053
2014	After	170	2,123
2015	After	240	2,072
2016	After	213	1,894
	Total	2,218	17,756

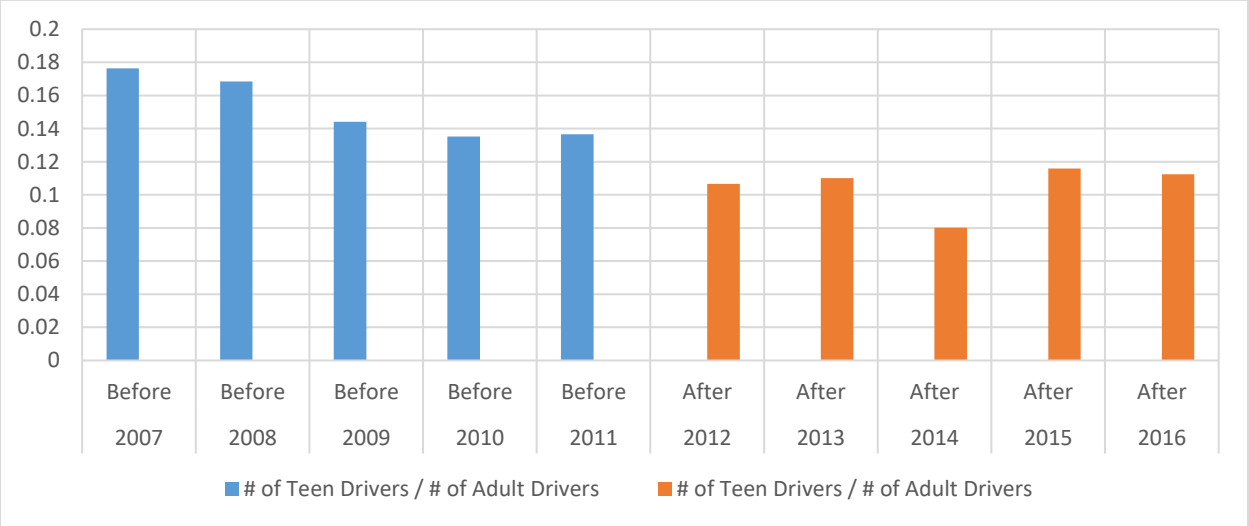

Figure 18. Ratio of Drivers: No Passenger in the Vehicle

Table 21. Number of Drivers: Only Teen Passengers in the Vehicle

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	101	37
2008	Before	114	30
2009	Before	105	31
2010	Before	126	35
2011	Before	118	37
2012	After	106	37
2013	After	74	42
2014	After	64	34
2015	After	69	36
2016	After	88	25
	Total	965	344

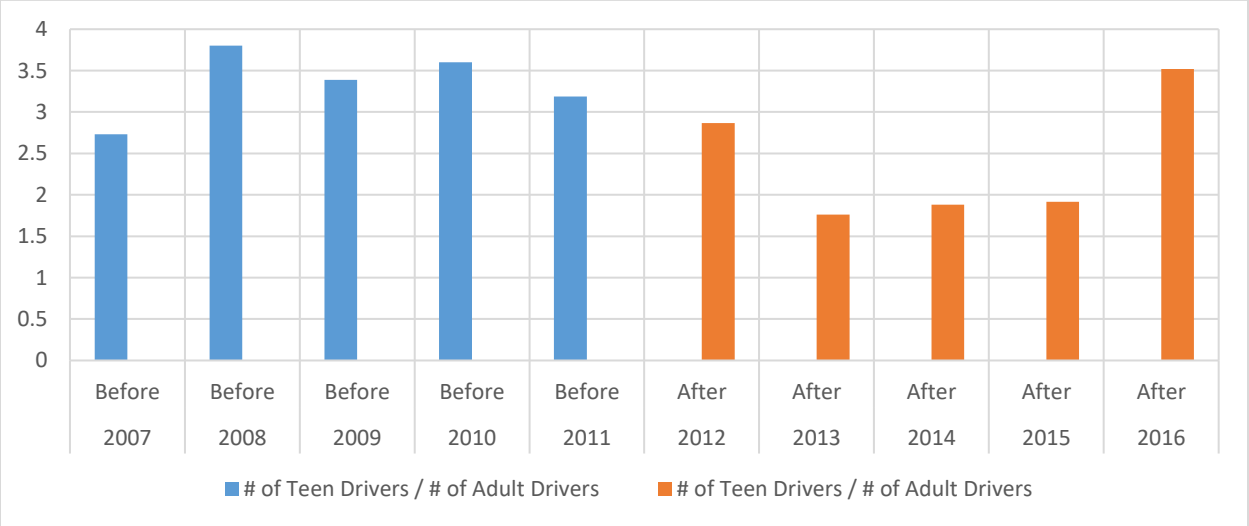

Figure 19. Ratio of Drivers: Only Teen Passengers in the Vehicle

Table 22. Number of Drivers: Only One Teen Passenger in the Vehicle

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	67	33
2008	Before	68	27
2009	Before	83	29
2010	Before	91	32
2011	Before	92	34
2012	After	70	34
2013	After	50	35
2014	After	49	30
2015	After	54	32
2016	After	67	21
	Total	691	307

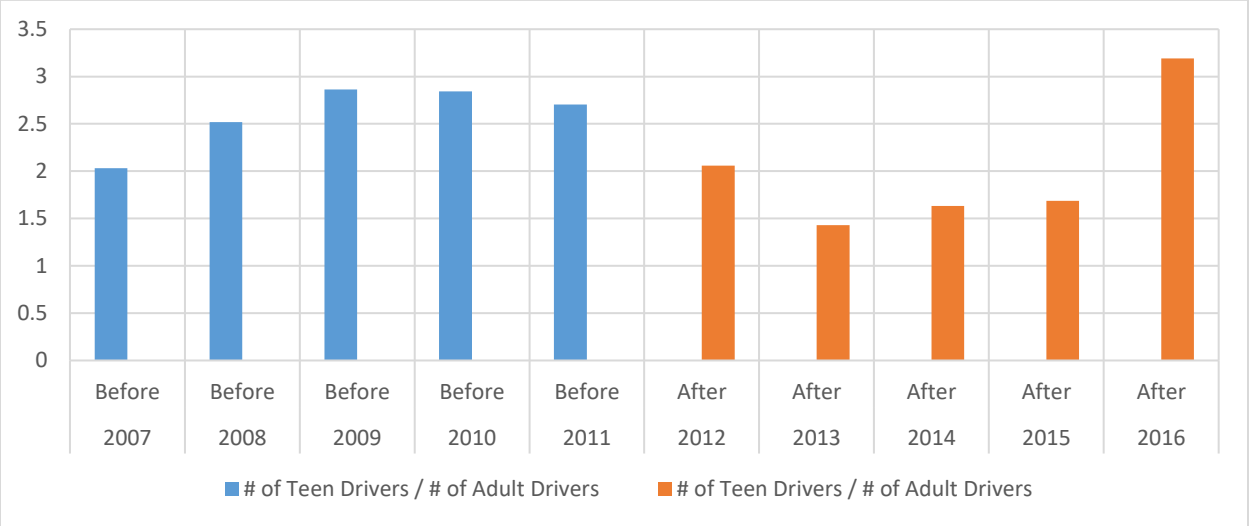

Figure 20. Ratio of Drivers: One Teen Passenger in the Vehicle

Table 23. Number of Drivers: Only Many Teen Passengers in the Vehicle

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	34	4
2008	Before	46	3
2009	Before	22	2
2010	Before	35	3
2011	Before	26	3
2012	After	36	3
2013	After	24	7
2014	After	15	4
2015	After	15	4
2016	After	21	4
	Total	274	37

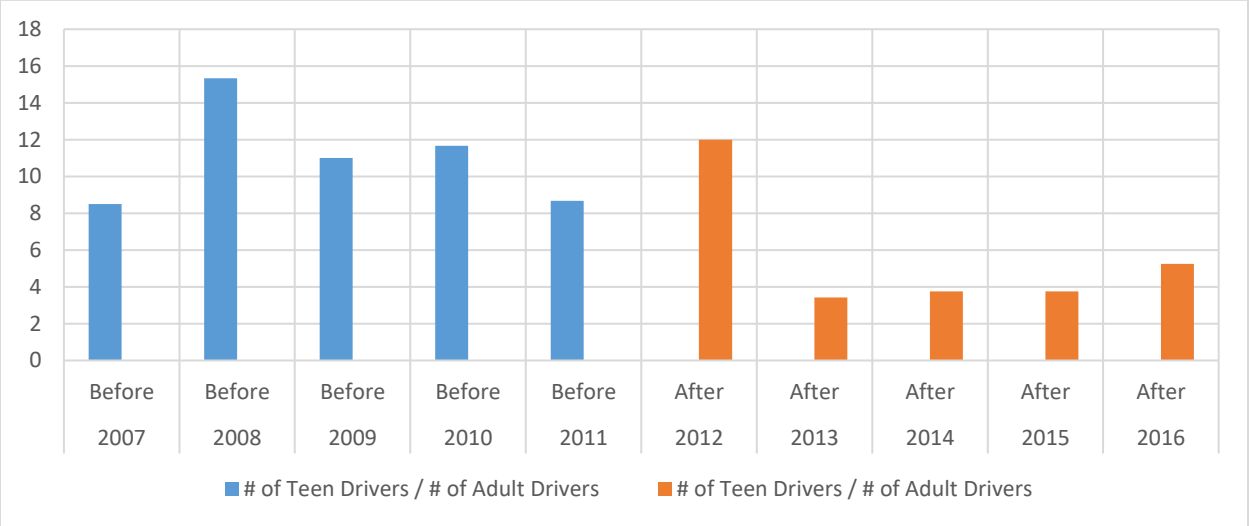

Figure 21. Ratio of Drivers: Only Many Teen Passengers in the Vehicle

Table 24. Number of Drivers: Vehicle Driver has Fatal or Serious Injury

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	25	115
2008	Before	16	96
2009	Before	19	97
2010	Before	11	126
2011	Before	14	155
2012	After	20	207
2013	After	12	214
2014	After	10	196
2015	After	20	180
2016	After	11	152
	Total	158	1,538

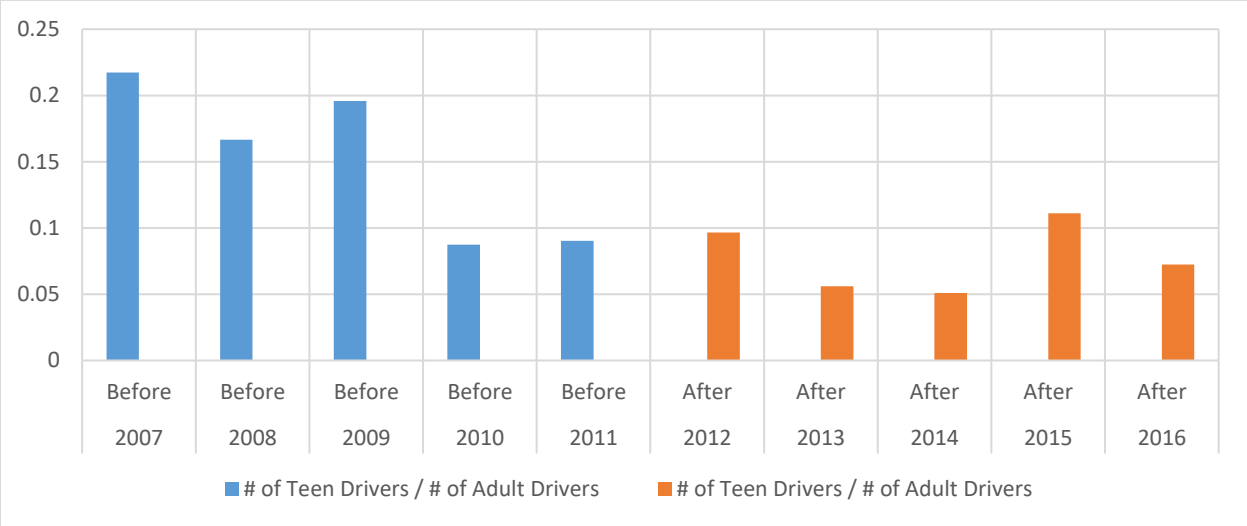

Figure 22. Ratio of Drivers: Vehicle Driver has Fatal or Serious Injury

Table 25. Number of Drivers: Vehicle Driver has Non-Serious Injury

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	193	1,117
2008	Before	226	1,151
2009	Before	205	1,222
2010	Before	221	1,288
2011	Before	221	1,367
2012	After	177	1,412
2013	After	190	1,494
2014	After	148	1,627
2015	After	173	1,467
2016	After	203	1,369
	Total	1,957	13,514

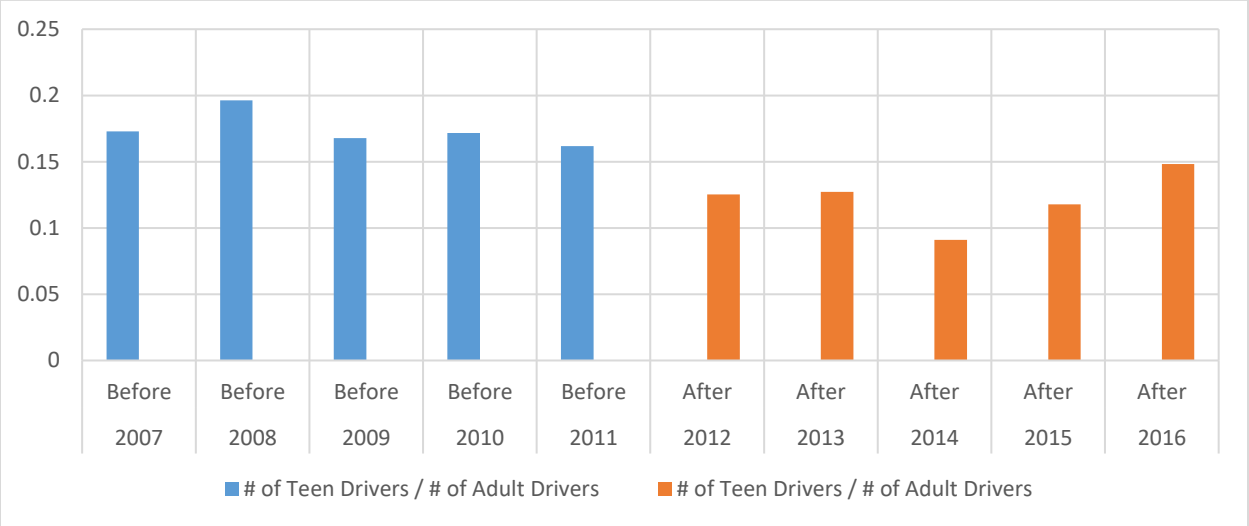

Figure 23. Ratio of Drivers: Vehicle Driver has Non-Serious Injury

Table 26. Number of Drivers: Vehicle Driver has No Injury

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	209	925
2008	Before	189	868
2009	Before	175	915
2010	Before	194	1,007
2011	Before	191	1,082
2012	After	198	1,119
2013	After	162	1,231
2014	After	121	1,225
2015	After	158	1,155
2016	After	151	1,105
	Total	1,748	10,632

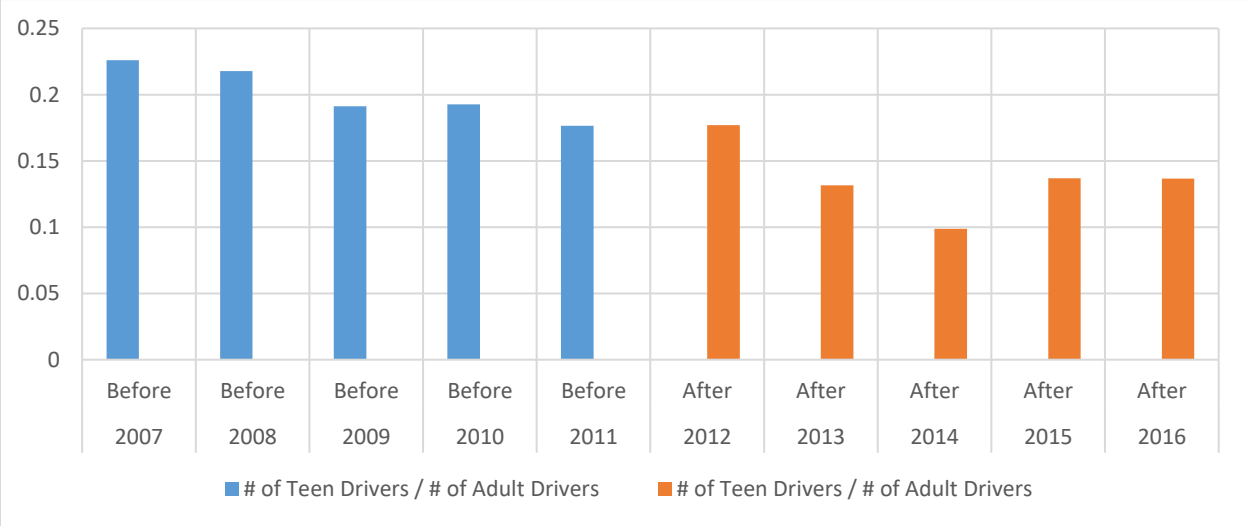

Figure 24. Ratio of Drivers: Vehicle Driver has No Injury

Table 27. Number of Drivers: Single Vehicle Crash

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	107	382
2008	Before	106	384
2009	Before	99	394
2010	Before	109	405
2011	Before	114	518
2012	After	79	499
2013	After	88	494
2014	After	78	487
2015	After	84	450
2016	After	95	413
	Total	959	4,426

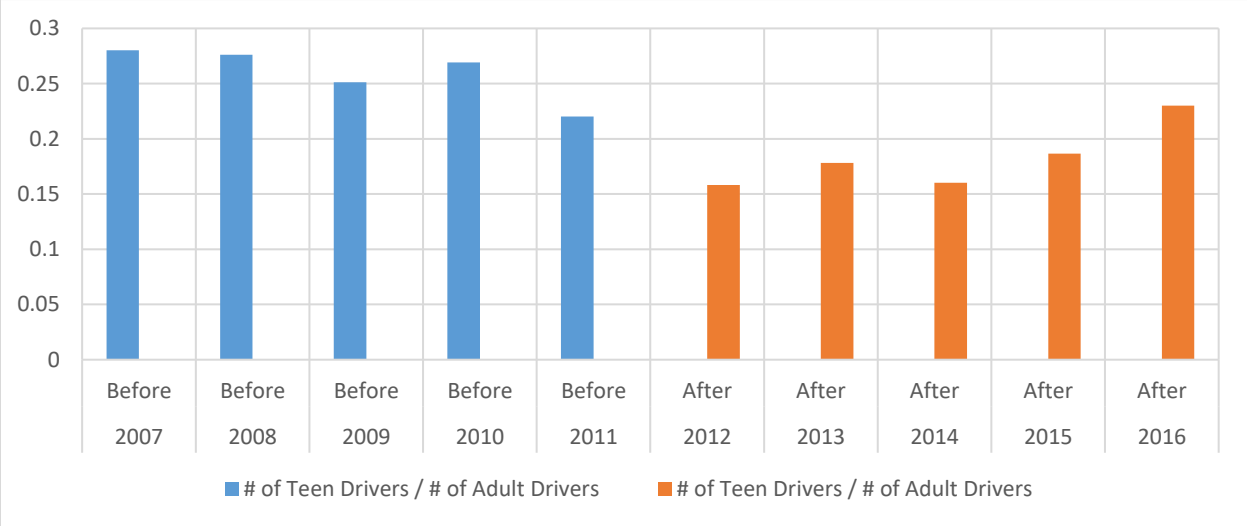

Figure 25. Ratio of Drivers: Single Vehicle Crash

Table 28. Number of Drivers: Multi Vehicle Crash

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	320	1,775
2008	Before	325	1,731
2009	Before	300	1,840
2010	Before	317	2,016
2011	Before	312	2,086
2012	After	316	2,239
2013	After	276	2,445
2014	After	201	2,561
2015	After	267	2,352
2016	After	270	2,213
	Total	2,904	21,258

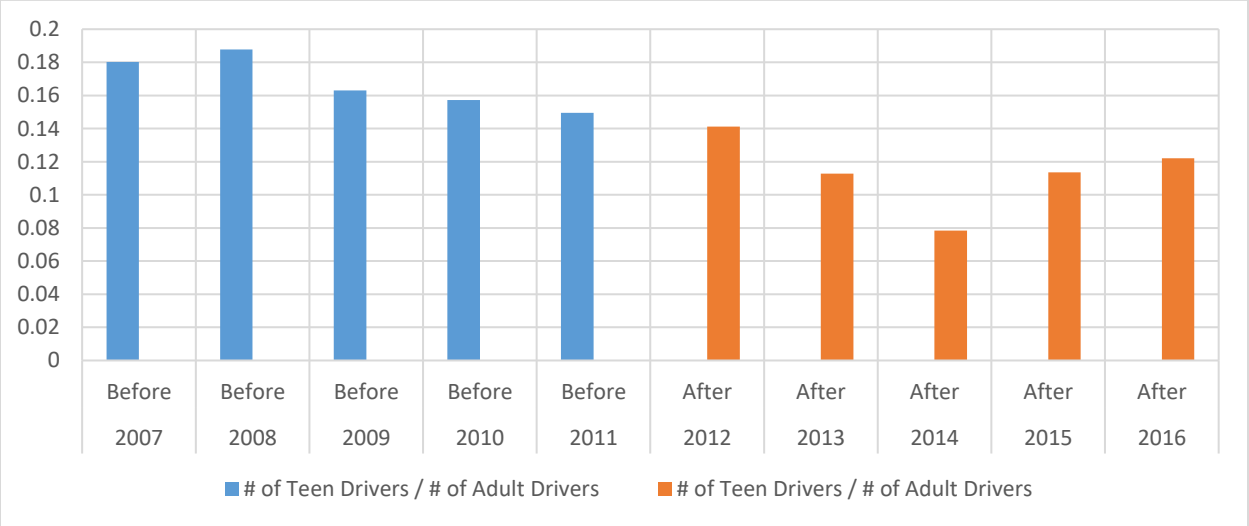

Figure 26. Ratio of Drivers: Multi Vehicle Crash

Table 29. Total Number of Teen and Adult Drivers by Period

Years	Period	# of Teen Drivers	# of Adult Drivers
2007 - 2011	Before	2,109	11,531
2008 - 2016	After	1,754	14,153

Statistical Analysis

For each crash category, the Chi-Square test is used to examine the association between period (pre-GLD and post-GD) and driver counts (teen and adult). Specifically, the following question is examined for each crash category:

- Is there a statistically significant association between period (pre-GLD and post-GD) and driver counts (teen and adult)?

All analyses are performed in Statistical Analysis System (SAS) software and the p-value for Chi-Square statistic is used to answer above question. Chi-Square test compares the observed frequencies with the expected frequencies collectively and involves the difference between the two considering the degree of freedom for each of the variable. If the p-value is small enough, then it can be concluded there is an association between observed and expected frequencies.

For each crash category, the odds ratio and odds ratio confidence intervals at alpha = 0.05 are calculated to examine the direction of the association. Specifically, the following question is examined for each crash category:

- In which period the odds of teen driver involvement in crash is relatively higher?

All analyses are performed in Statistical Analysis System (SAS) software and odd ratio statistics is used to answer above question. Odds ratio is the estimates of relative risk and is a good measure of association and the direction of the association for a variety of study designs. Odds ratio is equal to 1 if variables are independent from each other, and values greater than 1 indicates association between variables within the given confidence level.

Results

Table 30 and Table 31 summarize output statistics for the statistical analysis. Results in Table 30 indicate that there is an association between driver counts (teen and adult) and period (pre-GDL and post-GDL), for all crash categories considered in this study, at alpha = 0.05.

The nature of these associations can be interpreted using Tables 4-28 and Figures 2-26. Results presented in Table 31 present a statistical foundation to these interpretations by providing a statistically significant measure of association and the direction of the association for each crash category.

The following examples demonstrate, how odd ratio statistics given in Table 31 should be interpreted:

- For "All" category, the Odds Ratio Estimate of Relative Risk statistics is 1.476. This means that the odds of involving in fatal or injury crashes are roughly 1.5 times higher for teen drivers during the pre-GDL period than for teen drivers during the post-GDL period. And, since the 95% confidence interval for this value is [1.379, 1.580], which does not include 1, the p-value for the odds ratio is strictly less than 0.05.
- For "Impaired" category, the Odds Ratio Estimate of Relative Risk statistics is 2.127. This means that the odds of involving in fatal or injury crashes are roughly 2 times higher for impaired teen drivers during the pre-GDL period than for impaired teen drivers during the post-GDL period. And, since the 95% confidence interval for this value is [1.455, 3.110], which does not include 1, the p-value for the odds ratio is strictly less than 0.05.

Table 30. P-value for Chi-Square, statistically significant at alpha = 0.05

	Number of Subjects in the Stratum	P-value for Chi-Square	Exact P-value for Chi-Square	P-value < a=0.05?
All	29,547	0.000	0.000	✓
Male	16,163	0.000	0.000	✓
Female	13,384	0.000	0.000	✓
14 Years Old Teen Drivers	25,830	0.000	0.000	✓
15 Years Old Teen Drivers	26,483	0.000	0.000	✓
16 Years Old Teen Drivers	27,060	0.000	0.000	✓
17 Years Old Teen Drivers	27,226	0.000	0.000	✓
Urban	21,136	0.000	0.000	✓
Rural	8,411	0.000	0.000	✓
State	7,490	0.000	0.000	✓
Local	22,057	0.000	0.000	✓
Impaired	2,501	0.000	0.000	✓
Restraint Use: Improper	6,312	0.000	0.000	✓
Distracted [1]	1,814	0.000	0.000	✓
Speeding	5,959	0.000	0.000	✓
Adult Passenger: At least one	5,919	0.009	0.009	✓
No Passenger: Driving Alone	19,974	0.000	0.000	✓
Teen Passenger: One or Many	1,309	0.004	0.004	✓
One Teen Passenger	998	0.027	0.027	✓
Many Teen Passengers	311	0.029	0.034	✓
Driver has Fatal or Serious Injury	1,696	0.000	0.000	✓
Driver has Non-Serious Injury	15,471	0.000	0.000	✓
Driver has No Injury	12,380	0.000	0.000	✓
Single Vehicle Crash	5,385	0.000	0.000	✓
Multi Vehicle Crash	24,162	0.000	0.000	✓

[1] 2016 data is excluded in the analysis

Table 31. Odds Ratio Estimate, Pre-GDL vs. Post-GDL, at alpha = 0.05

	Odds Ratio Estimate of Relative Risk	Lower CL, Odds Ratio	Upper CL, Odds Ratio	Higher Odds Period for Teen Drivers
All	1.476	1.379	1.580	Pre-GDL
Male	1.522	1.380	1.678	Pre-GDL
Female	1.398	1.272	1.537	Pre-GDL
14 Years Old Teen Drivers	1.862	1.336	2.597	Pre-GDL
15 Years Old Teen Drivers	1.607	1.394	1.852	Pre-GDL
16 Years Old Teen Drivers	1.411	1.266	1.574	Pre-GDL
17 Years Old Teen Drivers	1.438	1.297	1.595	Pre-GDL
Urban	1.401	1.292	1.518	Pre-GDL
Rural	1.677	1.478	1.903	Pre-GDL
State	1.462	1.236	1.731	Pre-GDL
Local	1.373	1.274	1.480	Pre-GDL
Impaired	2.127	1.455	3.110	Pre-GDL
Restraint Use: Improper	2.052	1.643	2.563	Pre-GDL
Distracted [1]	1.971	1.539	2.523	Pre-GDL
Speeding	1.609	1.418	1.826	Pre-GDL
Adult Passenger: At least one	1.287	1.066	1.555	Pre-GDL
No Passenger: Driving Alone	1.441	1.319	1.574	Pre-GDL
Teen Passenger: One or Many	1.440	1.124	1.843	Pre-GDL
One Teen Passenger	1.356	1.035	1.776	Pre-GDL
Many Teen Passengers	2.154	1.070	4.334	Pre-GDL
Driver has Fatal or Serious Injury	1.876	1.350	2.608	Pre-GDL
Driver has Non-Serious Injury	1.435	1.304	1.578	Pre-GDL
Driver has No Injury	1.475	1.333	1.633	Pre-GDL
Single Vehicle Crash	1.419	1.233	1.633	Pre-GDL
Multi Vehicle Crash	1.479	1.369	1.599	Pre-GDL

[1]2016 data is excluded in the analysis

Based on the result, the following conclusion can be drawn from the study:

There exist an association between driver counts (teen and adult) and period (pre-GDL and post-GDL), for all crash categories considered in this study, at alpha = 0.05.

The average rate for teen driver involvement in fatal and injury crashes has been reduced since the implementation of the GDL program, for all crash categories considered in this study, at alpha = 0.05.

In some categories, there has been an increase in crash rates starting from years 2015 or 2016, in the post-GDL period. Because of this reason, the reductions in average rates cannot be directly tied to the implementation of the GDL Program in North Dakota. The following categories can be considered in this group:

- All
- Male
- 15 Years Old
- 16 Years Old
- 17 Years Old
- Rural
- State
- Local
- Speeding
- Adult Passenger: At least one
- Teen Passengers: One or Many
- Driver has non-serious injury

- Single Vehicle Crash
- Multi Vehicle Crash

In some categories, results indicate that, the implementation of the GDL Program has direct impact on the reduced crash rates, either in changing the crash rate or maintaining the crash rate. Therefore, the reductions in average rates can be tied to the implementation of the GDL Program in North Dakota. The following categories can be considered in this group:

- Female
- 14 Years Old Drivers
- Urban
- Impaired
- Restraint Use: Improper
- Distracted
- No Passenger: Driving Alone
- Many Teen Passengers
- Driver has Fatal or Serious Injury
- Driver has No Injury

In this study, change in the crash rates at the state level is examined. In the next study, change in the crash rates at the county level will be examined.

CHANGE IN THE CRASH RATES AT THE COUNTY LEVEL

In this study, teen driver involvement in fatal and injury crashes in North Dakota is studied at the county level to compare pre-GDL and post-GDL time periods. The following questions are addressed:

- Is there a statistically significant association between period (pre-GLD and post-GD) and driver counts (teen and adult) by county?
- And, if for some counties the association between period (pre-GLD and post-GD) and driver counts (teen and adult) is significant and for others the association is not significant, how this variation can be explained?

Crash Count Normalization Factors

In order to compare the results of this study and the previous study, same count normalization factor is used. Therefore, in this study, crash data is used to normalize teen driver involved crash counts.

Methodology and Results

Study period, crash data preparation, teen crash data preparation, and normalization crash data preparation steps of this study are identical to the previous study.

Define Crash Categories

The crash category used in this study is identical to the "All" crash category used in the first study. No other crash categories are considered in this study given the scope of the research questions to be answered. However, this study can be repeated for other crash categories discussed in state level study, given that sample size related assumptions for statistical analysis techniques used are satisfied.

Counts and Rates

Teen driver and adult driver crashes identified and driver counts and rates (number of teen drivers/number of adult drivers) are calculated respectively, Appendix C.

Statistical Analysis

For each county, the Chi-Square test is used to examine the association between period (pre-GLD and post-GD) and driver counts (teen and adult). Specifically, the following question is examined for each crash category:

- Is there a statistically significant association between period (pre-GLD and post-GD) and driver counts (teen and adult)?

All analyses are performed in Statistical Analysis System (SAS) software and the p-value for Chi-Square and Fisher's Exact Test statistic are used to answer above question. Chi-Square test compares the observed frequencies with the expected frequencies collectively and involves the difference between the two considering the degree of freedom for each of the variable. Fisher's Exact Test is another statistical significance test used in the analysis of contingency tables and it is the only practical way to assess contingency tables that have small or zero counts. In both tests, if the p-value is small enough, then it can be concluded there is an association between observed and expected frequencies.

For each county, the odds ratio and odds ratio confidence intervals at alpha = 0.05 are calculated to examine the direction of the association. Specifically, the following question is examined for each crash category:

- In which period the odds of teen driver involvement in crash is relatively higher?

All analyses are performed in Statistical Analysis System (SAS) software and odd ratio statistics is used to answer above question. Odds ratio is the estimates of relative risk and is a good measure of association and the direction of the association for a variety of study designs. Odds ratio is equal to 1 if variables are independent from each other, and values greater than 1 indicates association between variables within the given confidence level.

For 9 counties in North Dakota, statistical analysis output indicates that there is an association between driver counts (teen and adult) and period (pre-GDL and post-GDL), at alpha = 0.05. These counties and related statistical analysis outputs are summarized in Table 32, Table 33, and Figure 27. For other counties in North Dakota, summarized in Appendix E, there exist no statistically significant associations between driver counts (teen and adult) and period (pre-GDL and post-GDL), at alpha = 0.05.

Table 32. P-value for Chi-Square, statistically significant at alpha = 0.05

	Number of Subjects in the Stratum	P-value for Chi-Square	Exact P-value for Chi-Square	P-value < a=0.05?
Burleigh	5,268	0.000	0.000	✓
Cass	8,163	0.000	0.000	✓
Dickey	122	0.019	0.023	✓
Emmons	96	0.027	0.033	✓
Morton	950	0.004	0.004	✓
Pembina	114	0.022	0.027	✓
Stark	854	0.000	0.000	✓
Ward	2,669	0.001	0.001	✓
Williams	1,698	0.000	0.000	✓

Table 33. Odds Ratio Estimate, Pre-GDL vs. Post-GDL, at alpha = 0.05

	Odds Ratio Estimate of Relative Risk	Lower CL, Odds Ratio	Upper CL, Odds Ratio	Higher Odds Period for Teen Drivers
Burleigh	1.309	1.133	1.512	Pre-GDL
Cass	1.317	1.138	1.523	Pre-GDL
Dickey	2.793	1.165	6.698	Pre-GDL
Emmons	3.689	1.106	12.305	Pre-GDL
Morton	1.730	1.193	2.508	Pre-GDL
Pembina	3.131	1.141	8.591	Pre-GDL
Stark	2.215	1.480	3.314	Pre-GDL
Ward	1.443	1.151	1.808	Pre-GDL
Williams	2.491	1.793	3.460	Pre-GDL

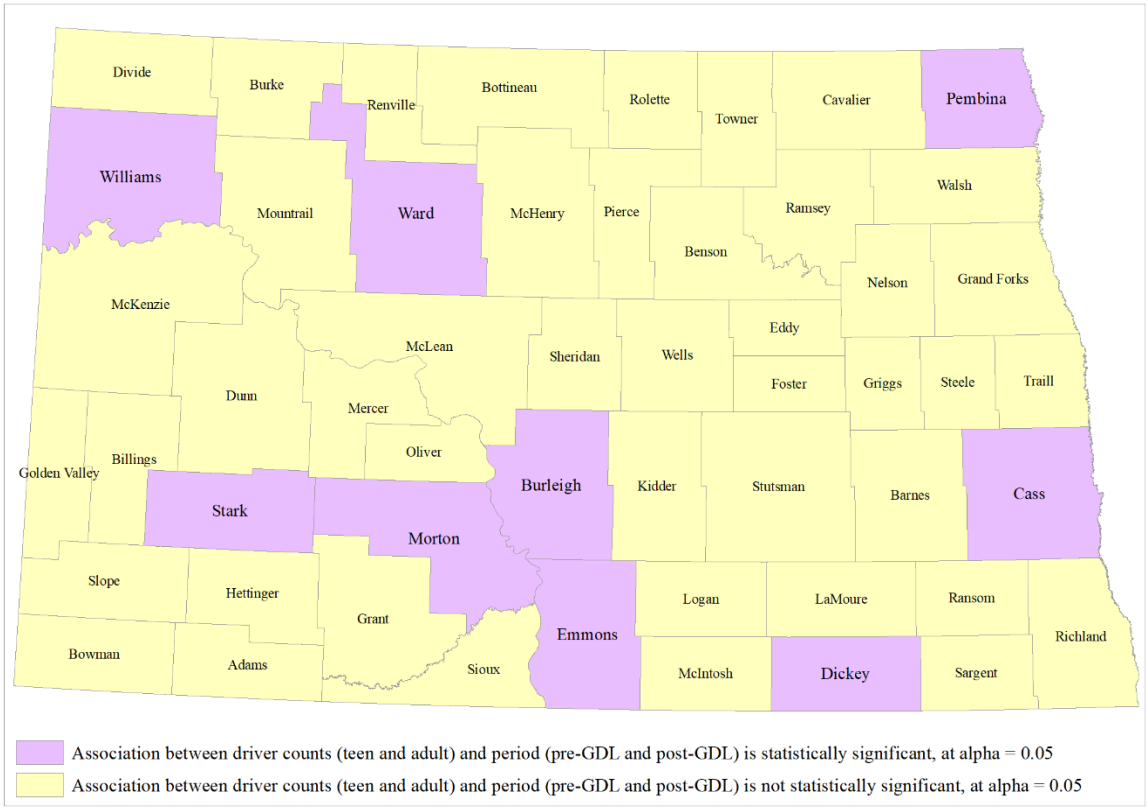

Figure 27. Association between Driver Counts and Period by County

Dickey, Emmons, and Pembina

Although results indicate that there exists a statistically significant association between driver counts (teen and adult) and period (pre-GDL and post-GDL), at alpha = 0.05, for these counties, the following should be noted when interpreting the effectiveness of GLD Program in these counties:

During the study period, 2007-2016, only few numbers of teen and adult drivers are involved in fatal and injury crashes in these counties.

- Dickey, 32 teen and 90 adult drivers
- Emmons, 17 teen and 79 adult drivers
- Pembina, 20 teen and 94 adult drivers

Odds ratio statistics for these counties also do have wide confidence intervals.

- Dickey, Odds Ratio CI: [1.165, 6.698]
- Emmons, Odds Ratio CI: [1.106, 12.305]
- Pembina, Odds Ratio CI: [1.141, 8.591]

Therefore, results obtained for these counties may have no practical use at all.

Burleigh, Cass, Morton, Stark, Ward, and Williams

Results obtained for these counties are more reliable regarding the number of teen and adult drivers used in the analysis. Therefore, results obtained for these counties may have practical use when interpreting the effectiveness of GDL Program implemented in North Dakota. However, using further information, different conclusions can also be made.

Figure 28 presents metropolitan and micropolitan statistical areas in North Dakota and in neighbor states.

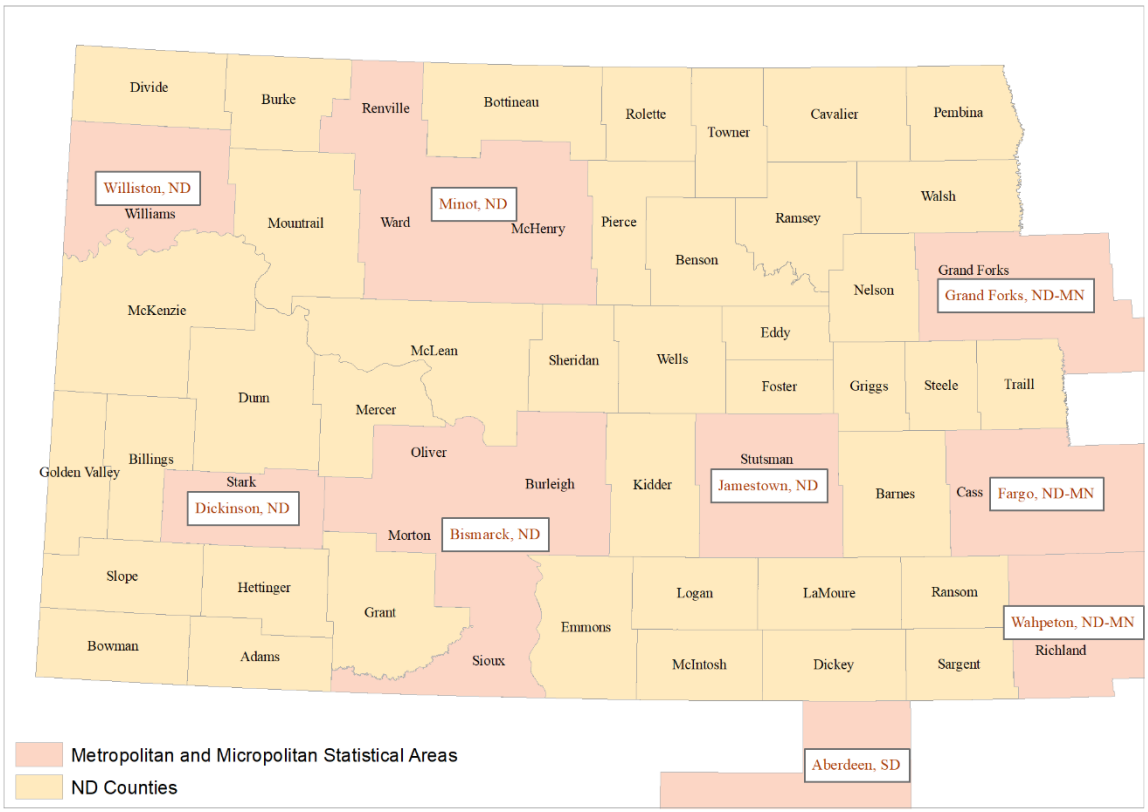

Figure 28. Metropolitan and Micropolitan Statistical Areas

Using this additional information, for all 9 counties, a common characteristic is identified.

- Burleigh, related to Bismarck, ND Metropolitan Statistical Area
- Cass, related to Fargo, ND-MN Metropolitan Statistical Area
- Morton, related to Bismarck, ND Metropolitan Statistical Area
- Stark, related to Dickinson, ND Micropolitan Statistical Area
- Ward, related to Minot, ND Micropolitan Statistical Area
- Williams, related to Williston, ND Micropolitan Statistical Area
- Dickey, related to Aberdeen, SD Micropolitan Statistical Area

- Emmons, related to Bismarck, ND Metropolitan Statistical Area
- Pembina, not directly related to any Metropolitan or Micropolitan Area. However, it is between Grand Forks, ND Metropolitan Area and Winnipeg, Manitoba, Canada Metropolitan Area, approximately 75 miles from each and connected to them via I-29 and MB-75, respectively.

Given above information, the following are concluded:

- GDL Program in North Dakota is found effective in nine counties. The common characteristics of these counties is consisting of a core city with a large population or close to one or more core cities with large population, with significant social and economic activity.
- On the other hand, GDL Program in North Dakota is not found effective in all counties consisting of a core city with a large population or close to one or more core cities with large population. For example, in Grand Forks, Stutsman, and Richland, there exists no statistically significant association between driver counts (teen and adult) and period (pre-GDL and post-GDL), at alpha = 0.05.

In the next step of the study, for both teen driver and adult driver groups, a number of spatial autocorrelation tests are performed. Spatial autocorrelation tests measure spatial autocorrelation based on feature locations and values. Given a set of features, such as counties, and given a set of attributes, such as number of drivers, spatial autocorrelation evaluates if the set of features are random, clustered, or dispersed.

In the first part of this study, core city and large population areas are found as GDL Program effective. Therefore, in the second part of the study, for both teen drivers and adult

drivers, urban, rural, local, and state crash categories are tested for spatial autocorrelation. The objective of this testing procedure is to identify if urban/rural or state/local attributes have any impact on results obtained in the first part. In other words, if the reductions in rates are tied to urban/rural or state/local characteristics of crashes, then the effectiveness of GDL Program found for these counties may not be valid.

All tests are performed in ESRI ArcGIS using Spatial Autocorrelation (Global Moran's Index) Tool. This tool calculates z-score and corresponding p-value, and null hypothesis states that features used in the analysis are randomly distributed over the study area. Table 34 and Appendix F present test results and results show that only one cluster is detected in the study area, adult drivers, crashes in rural road segments, and in the post-GDL period.

Table 34. Global Moran's Index Summary, at alpha= 0.05

	Moran's Index	z-score	P-value	Pattern
Teen, Pre-GDL, Urban	-0.083885	-0.646439	0.517995	Random
Teen, Pre-GDL, Rural	-0.055566	-0.305991	0.759611	Random
Teen, Pre-GDL, State	-0.044047	-0.212019	0.832092	Random
Teen, Pre-GDL, Local	-0.081124	-0.615687	0.538101	Random
Teen, Post-GDL, Urban	-0.081384	-0.627929	0.530051	Random
Teen, Post-GDL, Rural	0.080922	0.879343	0.379215	Random
Teen, Post-GDL, State	-0.130672	-1.005777	0.314523	Random
Teen, Post-GDL, Local	-0.065236	-0.461127	0.644707	Random
Adult, Pre-GDL, Urban	-0.069725	-0.555671	0.578436	Random
Adult, Pre-GDL, Rural	0.162270	1.527727	0.126580	Random
Adult, Pre-GDL, State	0.152838	1.484856	0.137582	Random
Adult, Pre-GDL, Local	-0.066244	-0.508104	0.611380	Random
Adult, Post-GDL, Urban	-0.073617	-0.598680	0.549387	Random
Adult, Post-GDL, Rural	0.511421	4.964702	0.000001	Clustered
Adult, Post-GDL, State	0.039754	0.525507	0.599231	Random
Adult, Post-GDL, Local	-0.066440	-0.512691	0.608167	Random

Further analysis performed to examine the detected cluster. The cluster test is performed in ESRI ArcGIS using Cluster and Outlier Analysis Tool. Figure 29 presents the location of the cluster in North Dakota, Williams and McKenzie counties. This is a high-high cluster which means that cluster is highly statistically significant, and it consists high values of the attribute.

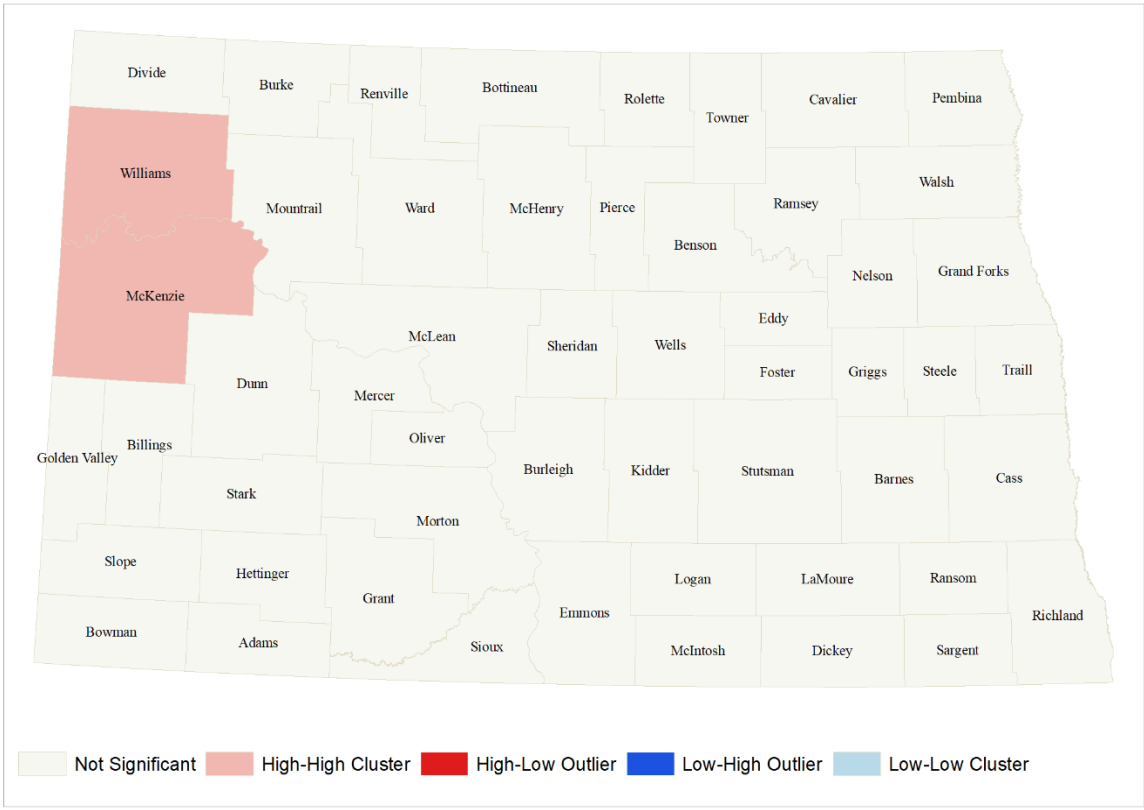

Figure 29. Cluster on Adult Drivers involved in Rural Crashes in the Post-GDL Period

Based on the spatial autocorrelation results, following can be concluded:

- In the first part of the study, GDL program is found effective in nine counties including Williams County. However, in this part of the study, it is found that there is a high value cluster of adult drivers in Williams County in the post-GDL period. Since, number of teen drivers is normalized using number of adult drivers,

this high cluster value may be the reason to reduce the rate of teen driver involvement in fatal and injury crashes in the post-GDL period.

- For other eight counties, there is no teen or adult driver clusters are detected. This means that GDL effectiveness related results found for these counties may not be tied to urban/rural or state/local attributes in the data.

CHANGE IN THE LIKELIHOOD OF CRASH OUTCOMES

In the first two studies, change in the teen driver involvement rates in fatal and injury crashes is studied, at state and county levels. In this study change in the likelihood of crash outcomes is studied for fatal and injury crashes. First, an overview of crash outcome and predictor variables used in the study are presented. In the later sections, methodology used in this study and results are presented.

Crash Outcome and Predictor Variables

In this study, two crash outcomes are considered, fatal or serious injury outcome and non-serious injury or no injury. These two outcomes are mutually exclusive events. Outcome is fatal or serious injury if the driver involved in the crash is killed or seriously injured (disabling injury). Outcome is non-serious injury or no injury if the driver involved in the crash is non-seriously injured (non-disabling injury) or has no injury.

The predictor variables are designed according to crash categories considered in the first two studies. Table 35 and Table 36 summarizes list of variables and descriptions used in the study.

Table 35. List of Dependent and Independent Variables

Driver Condition (Dependent Variable)	1	Driver is killed or seriously injured (disabling injury) in the crash
	0	Otherwise, driver is non-seriously (non-disabling) injured or had no injury
Period	0	Crash date is in pre-GDL period, 2007 to 2011
	1	Crash date is in post-GDL period, 2012-2016
Age	14, …, 17	Age of teen driver
	25, …, 54	Age of adult driver

Table 35. List of Dependent and Independent Variables (continued)

Gender	1	Driver is male
	0	Driver is female
Impaired	1	Driver is alcohol, drug, or alcohol and drug impaired
	0	Otherwise, driver is not impaired
Distracted	1	Distraction is one of the contributing factors in the crash for this driver
	0	Otherwise, distraction is not one of the contributing factors in the crash for this driver
Speeding	1	Speeding is one of the contributing factors in the crash for this driver
	0	Otherwise, speeding is not one of the contributing factors in the crash for this driver
Seatbelt	1	Restraint is used properly
	0	Otherwise, no restraint is installed, or restraint is not used properly
Urban	1	Crash is on urban road
	0	Crash is on rural road
State	1	Crash is on state road
	0	Crash is on local road
MSA	1	Crash location is in one of the following Metropolitan and Micropolitan Statistical Area Counties: Burleigh, Cass, Grand Forks, McHenry, Morton, Oliver, Renville, Richland, Stark, Stutsman, Ward, Williams
	0	Otherwise, crash location is not in one of the Metropolitan and Micropolitan Statistical Area Counties
Single Vehicle	1	Only one motor vehicle (driver) is involved in the crash
	0	Otherwise, more than one motor vehicles (drivers) are involved in the crash
Passenger Vehicle	1	Driver is operating a passenger car
	0	Driver is operating a pick up/utility/van
Only Teen Passenger	1	There is only teen passengers in the vehicle, one or more
	0	Otherwise, driver is alone or there is at least one non-teen (adult or under 13) passenger is in the vehicle

Methodology

In order to explore the change in the likelihood of crash outcomes, logistic regression modeling is used. Logistic regression is a form of statistical modeling and it describes relationships between a categorical variable and a set of predictor variables.

Two models are developed, one for teen drivers and one for adult drivers. In both models, driver condition variable, described in Table 35, is used as the dependent variable. Driver condition variable is a dichotomous, which can take only two possible values, 0 or 1. Independent variables used in the model are also categorical variables. Age variable, described in Table 35, is a polytomous variable and it can take integer values ranging from 14 to 54. Other independent variables used in the model are dichotomous variables and take values of 0 or 1. Thus, logistic regressions models developed in this study are binary logit models.

Once the models are developed, two traditional goodness-of-fit tests are used to assess how well models fit the data, the Person chi-square and the Likelihood Ratio chi-square. Main effects model is interpreted using Wald Test statistics to assess the significance of the variables in the model. In order to interpret main effect model parameter estimates appropriately, correlation among predictor variables are examined by using Variation Inflation Factor (VIF) and Tolerance (TOL).

All analysis are performed in SAS using PROC LOGISTICS procedure.

Results

Adult Driver Model

Table 36 summarizes the goodness-of-fit statistics for the model. Both Likelihood Ratio and Pearson statistics suggests that the model fits the data adequately.

Table 36. Goodness-of-Fit Statistics: Adult Driver Model

Criterion	Chi-Square	DF	Pr > ChiSq	Significant at alpha = 0.05?
Likelihood Ratio	2533.9039	41	<.0001	✓
Person	3100.8761	41	<.0001	✓

Figure 30 presents the Receiver Operating Characteristics (ROC) curve for the adult driver model. The ROC curve goes close to top left corner of the plot, area under the curve is 0.8344. This indicates that the model has a high discrimination ability between possible model outcomes, levels of the dependent variable, using predictors.

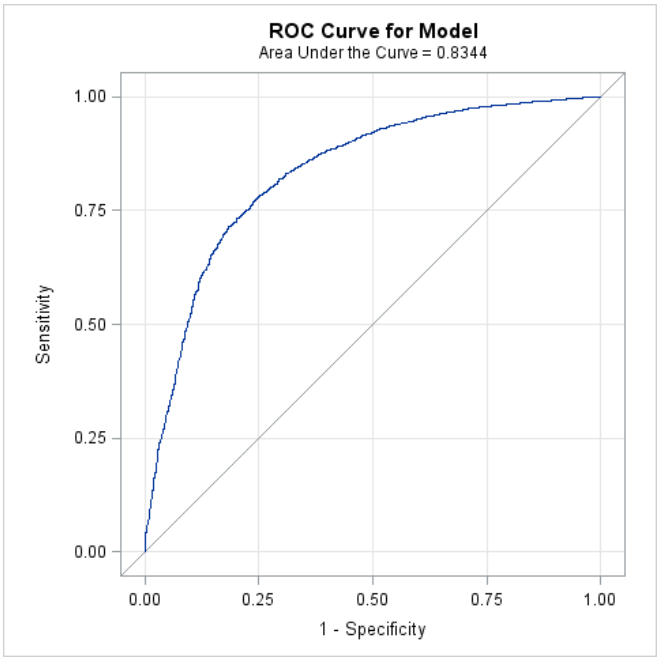

Figure 30. Receiver Operating Characteristics Curve: Adult Driver Model

Table 37 and Appendix G summarize the main effect model statistics. Period, impaired, distracted, seatbelt, single vehicle, passenger vehicle, state, and MSA variables are found significant, at alpha = 0.05. Thus, the predictors in the final model are Period, impaired, distracted, seatbelt, single vehicle, passenger vehicle, state, and MSA.

Table 37. Main Effects Model Statistics: Adult Driver Model

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Significant at alpha = 0.05?
Intercept		3.0877	0.4215	53.6713	<.0001	✓
Period	1	0.3457	0.0593	33.9976	<.0001	✓
Gender	1	0.0024	0.0636	0.0015	0.9695	✗
Impaired	1	0.8791	0.0705	155.3578	<.0001	✓
Distracted	1	-0.3658	0.1329	7.5726	0.0059	✓
Speeding	1	0.1004	0.0661	2.3096	0.1286	✗
Seatbelt	1	-1.2298	0.0613	402.5430	<.0001	✓
Only Teen Passenger	1	-0.3543	0.3346	1.1212	0.2897	✗
Single Vehicle	1	0.1801	0.0693	6.7532	0.0094	✓
Passenger Vehicle	1	0.1411	0.0609	5.3738	0.0204	✓
Urban	1	-1.5946	0.0833	366.7614	<.0001	✓
State	1	0.4020	0.0641	39.2967	<.0001	✓
MSA	1	-0.2128	0.0663	10.2890	0.0013	✓

Table 38 presents Variation Inflation Factor and Tolerance for the predictor variables. Tolerance value smaller than 0.1 indicates potential multi-collinearity issues for the given variable. Variation Inflation Factor is the reciprocal of TOL. Thus, Variation Inflation Factor greater than 10 indicates potential multi-collinearity issues for the given variable. No multi-collinearity issues are found for model predictor variables.

Table 38. Variation inflation Factor and Tolerance: Adult Driver Model

Parameter	Tolerance	Tolerance < 0.1?	Variance Inflation	Variance Inflation > 10?
Intercept	.	N/A	0.000	✗
Period	0.976	✗	1.024	✗
Gender	0.919	✗	1.088	✗
Age	0.975	✗	1.026	✗
Impaired	0.800	✗	1.249	✗
Distracted	0.993	✗	1.007	✗
Speeding	0.871	✗	1.148	✗
Seatbelt	0.870	✗	1.150	✗
Only Teen Passenger	0.997	✗	1.003	✗
Single Vehicle	0.702	✗	1.425	✗
Passenger Vehicle	0.937	✗	1.068	✗
Urban	0.566	✗	1.767	✗
State	0.794	✗	1.259	✗
MSA	0.762	✗	1.313	✗

Table 39 and Appendix G present odds ratio estimates with 95% confidence interval.

In conclusion, it is found that period variable is a statistically significant predictor of crash outcome in adult driver model. Thus, in adult driver involved fatal and injury crashes, time period change (from pre-GDL to post-GDL), has impact on the likelihood of the crash outcome in terms of driver condition, “fatal or serious injury” vs. “non-serious injury or no injury”.

In other word, the parameter estimates of period variable, 0.3457 is increment to log odds for post-GDL time period, given the other variables are held constant in the model. This means that adult drivers involved in fatal or injury crashes in post-GDL time period have approximately

1.4 times higher odds for crash outcomes than the adult drivers involved in fatal or injury crashes in the pre-GDL period.

Table 39. Odds Ratio Estimates with 95% CI: Adult Driver Model

Effect	Estimate	95% Confidence Limits	
Period 0 vs 1	1.413	1.258	1.588
Gender 0 vs 1	1.002	0.885	1.136
Impaired 0 vs 1	2.409	2.097	2.765
Distracted 0 vs 1	0.694	0.53	0.894
Speeding 0 vs 1	1.106	0.971	1.258
Seatbelt 0 vs 1	0.292	0.259	0.33
Only Teen Passenger 0 vs 1	0.702	0.341	1.284
Single Vehicle 0 vs 1	1.197	1.045	1.371
Passenger Vehicle 0 vs 1	1.152	1.022	1.297
Urban 0 vs 1	0.203	0.172	0.239
State 0 vs 1	1.495	1.318	1.695
MSA 0 vs 1	0.808	0.71	0.921

Teen Driver Model

Table 40 summarizes the goodness-of-fit statistics for the model. Both Likelihood Ratio and Pearson statistics suggests that the model fits the data adequately.

Table 40. Goodness-of-Fit Statistics: Teen Driver Model

Criterion	Chi-Square	DF	Pr > ChiSq	Significant at alpha = 0.05?
Likelihood Ratio	260.6494	15	<.0001	✓
Person	356.7761	15	<.0001	✓

Figure 31 presents the Receiver Operating Characteristics (ROC) curve for the teen driver model. The ROC curve goes close to top left corner of the plot, area under the curve is 0.8407. This indicates that the model has a high discrimination ability between possible model outcomes, levels of the dependent variable, using predictors.

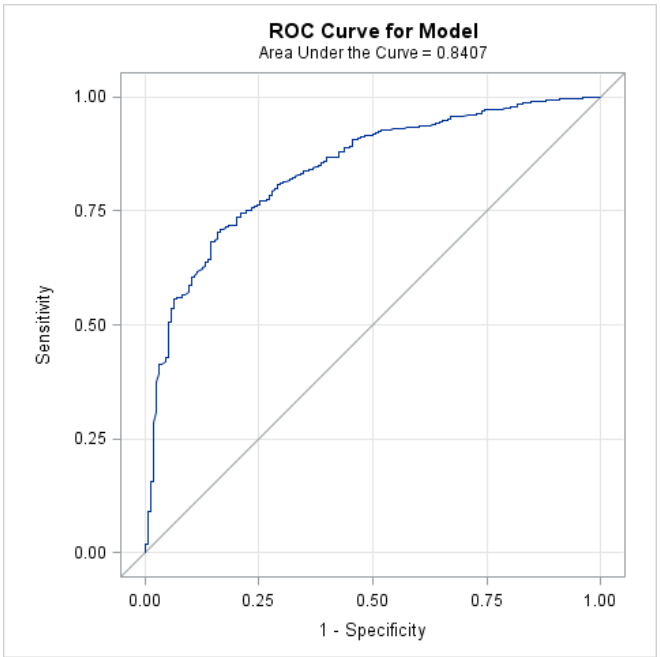

Figure 31. Receiver Operating Characteristics Curve: Teen Driver Model

Table 41 summarizes the main effect model statistics. Age, impaired, seatbelt, and urban variables are found significant, at alpha = 0.05. Thus, the predictors in the final model are age, impaired, seatbelt, and urban.

Table 41. Main Effects Model Statistics: Teen Driver Model

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Significant at alpha = 0.05?
Intercept		2.8233	0.5787	23.806	<.0001	✓
Period	0	0.1822	0.1778	1.0501	0.3055	✗
Gender	0	-0.0436	0.1790	0.0594	0.8075	✗
Age	14	0.00801	0.4719	0.0003	0.9865	✗
Age	15	-0.4522	0.2289	3.9033	0.0482	✓
Age	16	-0.0999	0.2096	0.227	0.6338	✗
Impaired	0	1.4898	0.2611	32.5564	<.0001	✓
Distracted	0	-0.4713	0.3662	1.6569	0.1980	✗
Speeding	0	-0.0542	0.1912	0.0804	0.7768	✗
Seatbelt	0	-1.1664	0.1834	40.4502	<.0001	✓
Only Teen Passenger	0	0.1045	0.1964	0.2832	0.5946	✗
Single Vehicle	0	0.2629	0.2203	1.424	0.2327	✗
Passenger Vehicle	0	-0.0508	0.1827	0.0772	0.7811	✗
Urban	0	-1.6841	0.2531	44.2559	<.0001	✓
State	0	0.6790	0.1997	11.5585	0.0007	✗
MSA	0	0.2283	0.1997	1.3069	0.2530	✗

Table 42 presents Variation Inflation Factor and Tolerance for the predictor variables. Tolerance value smaller than 0.1 indicates potential multi-collinearity issues for the given variable. Variation Inflation Factor, is the reciprocal of TOL. Thus, Variation Inflation Factor

greater than 10 indicates potential multi-collinearity issues for the given variable. No multi-collinearity issues are found for model predictor variables.

Table 42. Variation inflation Factor and Tolerance: Teen Driver Model

Parameter	Tolerance	Tolerance < 0.1?	Variance Inflation	Variance Inflation > 10?
Intercept	.	N/A	0.000	✗
Period	0.951	✗	1.052	✗
Gender	0.932	✗	1.073	✗
Age	0.930	✗	1.076	✗
Impaired	0.862	✗	1.160	✗
Distracted	0.980	✗	1.020	✗
Speeding	0.827	✗	1.209	✗
Seatbelt	0.890	✗	1.123	✗
Only Teen Passenger	0.978	✗	1.023	✗
Single Vehicle	0.623	✗	1.606	✗
Passenger Vehicle	0.912	✗	1.096	✗
Urban	0.593	✗	1.686	✗
State	0.856	✗	1.169	✗
MSA	0.775	✗	1.291	✗

Table 43 and Figure 32 present odds ratio estimates with 95% confidence interval.

In conclusion, it is found that period variable is not a statistically significant predictor of crash outcome. Thus, in teen driver involved fatal and injury crashes, time period has no impact on the likelihood of the crash outcome in terms of driver condition, “fatal or serious injury” vs. “non-serious injury or no injury”.

Table 43. Odds Ratio Estimates with 95% CI: Teen Driver Model

Effect	Estimate	95% Confidence Limits	
Period 0 vs 1	1.200	0.846	1.700
Gender 0 vs 1	0.957	0.673	1.359
Age 14 vs 17	1.008	0.428	2.801
Age 15 vs 17	0.636	0.407	1.001
Age 16 vs 17	0.905	0.600	1.367
Impaired 0 vs 1	4.436	2.639	7.362
Distracted 0 vs 1	0.624	0.285	1.214
Speeding 0 vs 1	0.947	0.649	1.375
Seatbelt 0 vs 1	0.311	0.217	0.446
Only Teen Passenger 0 vs 1	1.110	0.749	1.620
Single Vehicle 0 vs 1	1.301	0.846	2.007
Passenger Vehicle 0 vs 1	0.950	0.665	1.363
Urban 0 vs 1	0.186	0.112	0.304
State 0 vs 1	1.972	1.327	2.908
MSA 0 vs 1	1.256	0.850	1.862

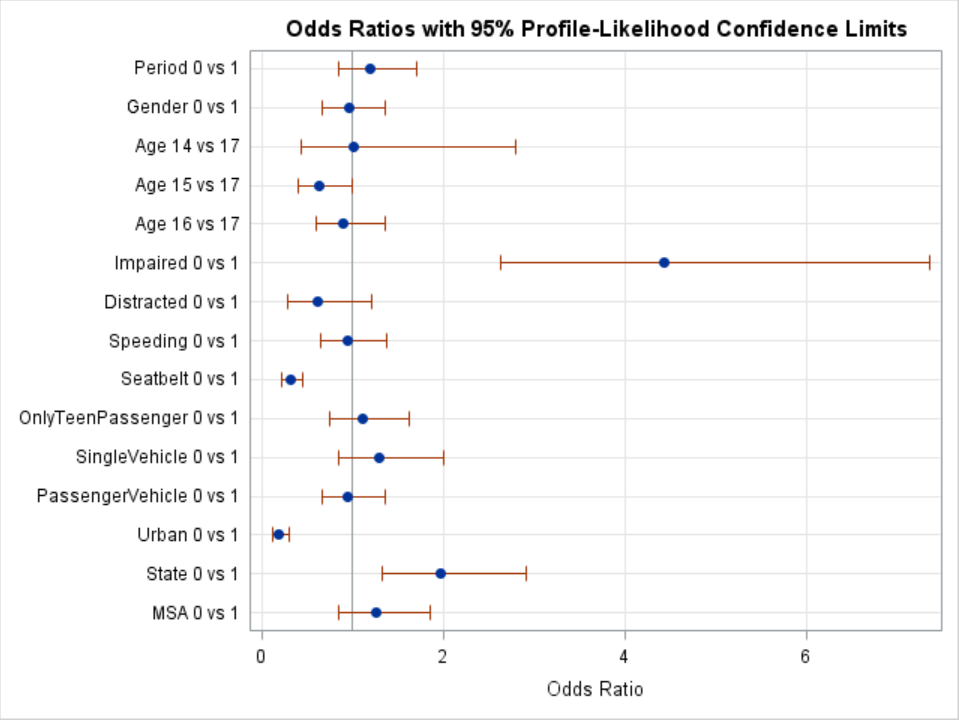

Figure 32. Odds Ratio Estimates with 95% CI: Teen Driver Model

CONCLUSION AND FUTURE WORK

In this study, 14 to17 years old teen driver involved fatal and injury crashes are analyzed for pre-GDL (2007-2011) and post-GDL (2012-2016) time periods. An adult driver group, between 25 and 54 years old, is used as a control group. The goal of the research design is to examine if the involvement of teen drivers in fatal and injury crashes and the outcome of crashes between these two time periods has changed over time. Three specific research topics are addressed:

- Change in the fatal and injury crash rate at the state level
- Change in the fatal and injury crash rate at the county level
- Change in the likelihood of crash outcomes

In theory, reduced crash rates and reduced likelihood of fatal and injury crashes would be due to the implementation of the three-phase GDL program, which aims to improve North Dakota teen drivers' driving experience and skills over time. Research findings and future research questions are summarized in the following sections of this chapter.

State Level

There is a statistically significant association between period (pre-GLD and post-GD) and driver counts (teen and adult). In the post-GDL period, the odds of teen driver involvement in crash is relatively higher than the pre-GDL period, 1.48 times.

For a number of crash categories, rates are analyzed, and a number of different crash involvement rate trends are identified:

- In some crash categories, the average crash involvement rates are significantly reduced from pre-GDL period to post-GDL period. However, these crash

categories findings cannot be directly tied to the effectiveness on GDL program in reducing the crash involvement rates. The reason is that, in these crash categories, there is also a declining trend in the crash involvement rates, in many cases starting from the early- or mid-pre-GDL period.

- In some crash categories, the average crash involvement rates are reduced. However, crash involvement rates in post-GDL period follows a U-shaped distribution, rates steadily fall until 2014 and then steadily rise.

County Level

Not for all counties in North Dakota, the association between period (pre-GLD and post-GD) and driver counts (teen and adult) is significant.

Results indicate that teen driver crash involvement rates are reduced in counties consisting of a core city with a large population or close to one or more core cities with large population, with significant social and economic activity.

Likelihood of Crash Outcomes

It is found that the likelihood of crash outcomes is not changed for teen drivers. However, in the control group, likelihood of crash outcomes has changed, higher in the post-GDL period. This result indicates that teen drivers performed better than adult drivers during the pre-GDL period.

Future Research Questions

At state level, for many crash categories, why crash involvement rates are following a U-shaped distribution? Why year 2014 has the lowest crash involvement rates?

There are counties in North Dakota consisting of a core city with a large population or close to one or more core cities with large population, with significant social and economic activity. Why crash involvement rates are decreased in only some of these counties in the post-GDL period? Why crash involvement rates are not changed in counties not consisting of a core city with a large population?

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APPENDIX A. LIST OF VARIABLES IN NORTH DAKOTA CRASH DATA FILES

Table A1. Master File Variable List.

010 | CRASH DATE	210 | FIRST HARMFUL EVENT
020 | CRASH NUMBER	220 | ENTRY DATE(YYMMDDDD)
030 | CRASH TIME	230 | COUNTY
040 | REPORT TYPE	240 | CITY NUMBER
050 | CRASH TYPE	250 | HIGHWAY NUMBER
060 | CRASH SEVERITY	260 | MILE POINT
070 | HIT AND RUN	270 | MILES FROM
080 | AGENCY TYPE	280 | TOWNSHIP
090 | INTER TYPE	290 | RANGE
100 | RELATION TO ROAD	300 | FEET FROM
110 | RELATION TO JUNCTION	310 | NODE
120 | ROAD GEOM	320 | NEXT NODE
130 | ACCESS CONTROL	330 | FUNCTION CLASS
140 | ROAD COND	340 | URBAN RURAL
150 | SURFACE TYPE	350 | NATIONAL HIGHWAY SYSTEM
160 | SURFACE COND	360 | LATITUDE
170 | WEATHER	370 | LONGITUDE
180 | LIGHT	380 | WZR LOCATION
190 | ENG CONCERNS –	390 | WZR TYPE OF ZONE
200 | MANNER OF COLLISION	400 | WORKERS PRESENT

Table A2. Operator File Variable List.

010 | CRASH DATE
020 | CRASH NUMBER
030 | OPERATOR UNIT NUMBER
040 | OPERATOR AGE
050 | OPERATOR SEX
060 | OPERATOR DRUG/ALCOHOL
070 | OPERATOR ALCOHOL TEST
080 | OPERATOR DRUG TEST
090 | OPERATOR SAFETY
100 | OPERATOR AIR BAG
110 | OPERATOR INJURY
120 | OPERATOR

Table A3. Occupant File Variable List.

010 | CRASH DATE
020 | CRASH NUMBER
030 | OCCUPANT UNIT NUMBER
040 | OCCUPANT SEAT POSITION
050 | OCCUPANT AGE
060 | OCCUPANT SEX
070 | OCCUPANT DRUG/ALCOHOL
080 | OCCUPANT ALCOHOL TEST
090 | OCCUPANT DRUG TEST
100 | OCCUPANT SAFETY
110 | OCCUPANT AIR BAG
120 | OCCUPANT INJURY
130 | OCCUPANT

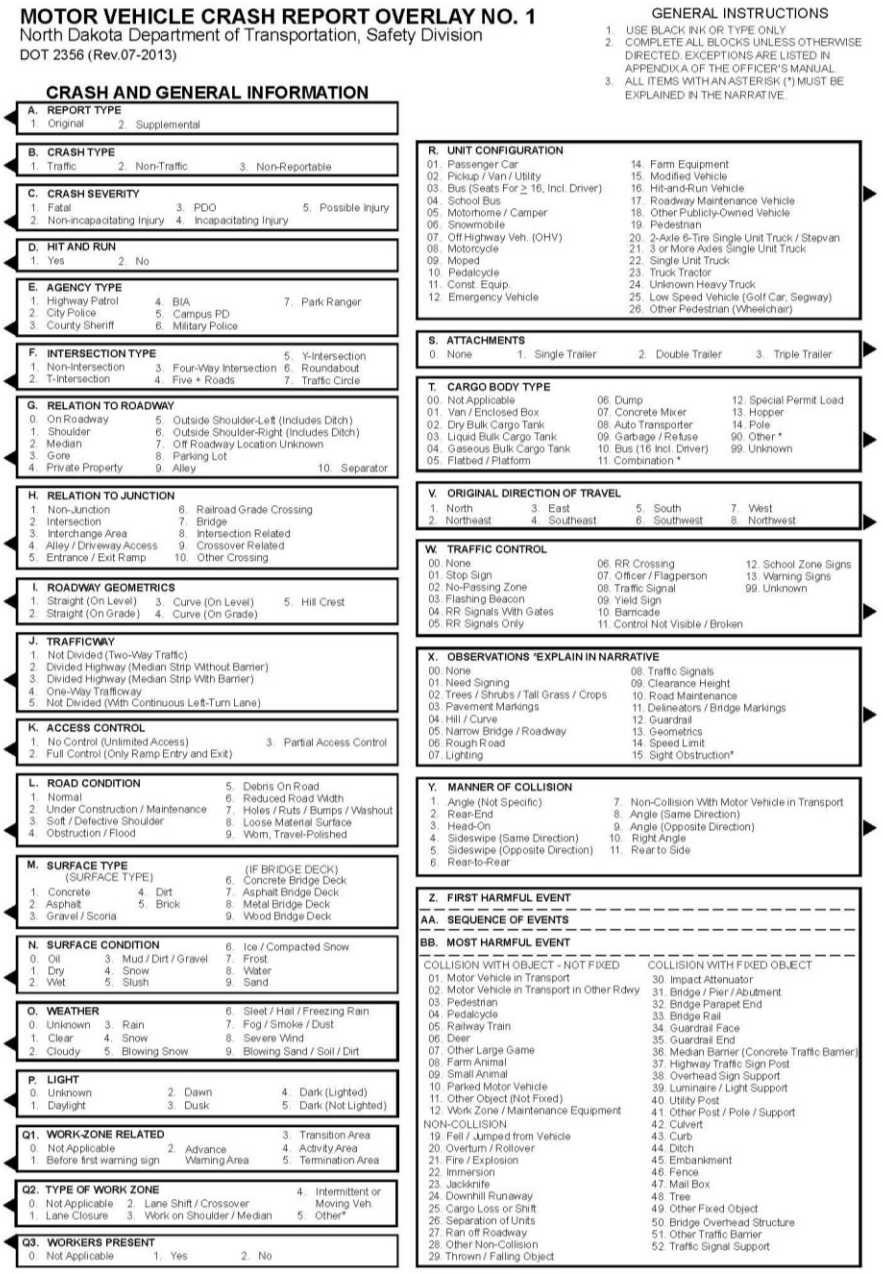
Table A4. Pedestrian File Variable List.

010 | CRASH DATE
020 | CRASH NUMBER
030 | PEDESTRIAN UNIT NUMBER
040 | PEDESTRIAN AGE
050 | PEDESTRIAN SEX
060 | PEDESTRIAN DRUG/ALCOHOL
070 | PEDESTRIAN ALCOHOL TEST
080 | PEDESTRIAN DRUG TEST
090 | PEDESTRIAN INJURY

Table A5. Unit File Variable List.

010 | CRASH DATE
020 | CRASH NUMBER
030 | UNIT NUMBER
040 | TRAFFICWAY
050 | VISUAL OBSTRUCTION
060 | UNIT CONFIGURATION
070 | ATTACHMENTS
080 | TRUCK BODY TYPE
090 | ANTI LOCK BRAKE
100 | DIRECTION OF TRAVEL
110 | TRAFFIC CONTROL
120 | SEQUENCE OF EVENTS 1
130 | SEQUENCE OF EVENTS 2
140 | SEQUENCE OF EVENTS 3
150 | MOST HARMFUL EVENT
160 | TOWED
170 | EXTENT DEFORMITY
180 | DAMAGED AREAS
190 | DRIVER CONDITION
200 | EVASIVE ACTION
210 | CITATION
220 | CONTRIBUTING FACTOR 1
230 | CONTRIBUTING FACTOR 2
240 | CONTRIBUTING FACTOR 3
250 | VEHICLE MOVEMENT
260 | VEHICLE MAKE
270 | VEHICLE YEAR
280 | VEHICLE VIN

APPENDIX B. NORTH DAKOTA MOTOR VEHICLE CRASH REPORT OVERLAY



MOTOR VEHICLE CRASH REPORT OVERLAY NO. 1
North Dakota Department of Transportation, Safety Division
DOT 2356 (Rev.07-2013)

GENERAL INSTRUCTIONS
1. USE BLACK INK OR TYPE ONLY
2. COMPLETE ALL BLOCKS UNLESS OTHERWISE DIRECTED. EXCEPTIONS ARE LISTED IN APPENDIX A OF THE OFFICER'S MANUAL.
3. ALL ITEMS WITH AN ASTERISK (*) MUST BE EXPLAINED IN THE NARRATIVE.

CRASH AND GENERAL INFORMATION

A. REPORT TYPE
1. Original 2. Supplemental

B. CRASH TYPE
1. Traffic 2. Non-Traffic 3. Non-Reportable

C. CRASH SEVERITY
1. Fatal 3. PDO 5. Possible Injury
2. Non-incapacitating Injury 4. Incapacitating Injury

D. HIT AND RUN
1. Yes 2. No

E. AGENCY TYPE
1. Highway Patrol 4. BIA 7. Park Ranger
2. City Police 5. Campus PD
3. County Sheriff 6. Military Police

F. INTERSECTION TYPE
1. Non-Intersection 3. Four-Way Intersection 5. Y-Intersection 6. Roundabout
2. T-Intersection 4. Five + Roads 7. Traffic Circle

G. RELATION TO ROADWAY
0. On Roadway 5. Outside Shoulder-Left (Includes Ditch)
1. Shoulder 6. Outside Shoulder-Right (Includes Ditch)
2. Median 7. Off Roadway Location Unknown
3. Gore 8. Parking Lot
4. Private Property 9. Alley 10. Separator

H. RELATION TO JUNCTION
1. Non-Junction 6. Railroad Grade Crossing
2. Intersection 7. Bridge
3. Interchange Area 8. Intersection Related
4. Alley / Driveway Access 9. Crossover Related
5. Entrance / Exit Ramp 10. Other Crossing

I. ROADWAY GEOMETRICS
1. Straight (On Level) 3. Curve (On Level) 5. Hill Crest
2. Straight (On Grade) 4. Curve (On Grade)

J. TRAFFICWAY
1. Not Divided (Two-Way Traffic)
2. Divided Highway (Median Strip Without Barrier)
3. Divided Highway (Median Strip With Barrier)
4. One-Way Trafficway
5. Not Divided (With Continuous Left-Turn Lane)

K. ACCESS CONTROL
1. No Control (Unlimited Access) 3. Partial Access Control
2. Full Control (Only Ramp Entry and Exit)

L. ROAD CONDITION
1. Normal 5. Debris On Road
2. Under Construction / Maintenance 6. Reduced Road Width
3. Soft / Defective Shoulder 7. Holes / Ruts / Bumps / Washout
4. Obstruction / Flood 8. Loose Material Surface
9. Worn, Travel-Polished

M. SURFACE TYPE
(SURFACE TYPE) (IF BRIDGE DECK)
1. Concrete 4. Dirt 6. Concrete Bridge Deck
2. Asphalt 5. Brick 7. Asphalt Bridge Deck
3. Gravel / Scoria 8. Metal Bridge Deck
9. Wood Bridge Deck

N. SURFACE CONDITION
0. Oil 3. Mud / Dirt / Gravel 6. Ice / Compacted Snow 7. Frost
1. Dry 4. Snow 8. Water
2. Wet 5. Slush 9. Sand

O. WEATHER
0. Unknown 3. Rain 6. Sleet / Hail / Freezing Rain 7. Fog / Smoke / Dust
1. Clear 4. Snow 8. Severe Wind
2. Cloudy 5. Blowing Snow 9. Blowing Sand / Soil / Dirt

P. LIGHT
0. Unknown 2. Dawn 4. Dark (Lighted)
1. Daylight 3. Dusk 5. Dark (Not Lighted)

Q1. WORK-ZONE RELATED
0. Not Applicable 2. Advance Warning Area 3. Transition Area 4. Activity Area
1. Before first warning sign 5. Termination Area

Q2. TYPE OF WORK ZONE
0. Not Applicable 2. Lane Shift / Crossover 4. Intermittent or Moving Veh.
1. Lane Closure 3. Work on Shoulder / Median 5. Other*

Q3. WORKERS PRESENT
0. Not Applicable 1. Yes 2. No

R. UNIT CONFIGURATION
01. Passenger Car
02. Pickup / Van / Utility
03. Bus (Seats For ≥ 16, Incl. Driver)
04. School Bus
05. Motorhome / Camper
06. Snowmobile
07. Off Highway Veh. (OHV)
08. Motorcycle
09. Moped
10. Pedalcycle
11. Const. Equip.
12. Emergency Vehicle
14. Farm Equipment
15. Modified Vehicle
16. Hit-and-Run Vehicle
17. Roadway Maintenance Vehicle
18. Other Publicly-Owned Vehicle
19. Pedestrian
20. 2-Axle 6-Tire Single Unit Truck / Stepvan
21. 3 or More Axles Single Unit Truck
22. Single Unit Truck
23. Truck Tractor
24. Unknown Heavy Truck
25. Low Speed Vehicle (Golf Car, Segway)
26. Other Pedestrian (Wheelchair)

S. ATTACHMENTS
0. None 1. Single Trailer 2. Double Trailer 3. Triple Trailer

T. CARGO BODY TYPE
00. Not Applicable
01. Van / Enclosed Box
02. Dry Bulk Cargo Tank
03. Liquid Bulk Cargo Tank
04. Gaseous Bulk Cargo Tank
05. Flatbed / Platform
06. Dump
07. Concrete Mixer
08. Auto Transporter
09. Garbage / Refuse
10. Bus (16 Incl. Driver)
11. Combination *
12. Special Permit Load
13. Hopper
14. Pole
90. Other *
99. Unknown

V. ORIGINAL DIRECTION OF TRAVEL
1. North 3. East 5. South 7. West
2. Northeast 4. Southeast 6. Southwest 8. Northwest

W. TRAFFIC CONTROL
00. None
01. Stop Sign
02. No-Passing Zone
03. Flashing Beacon
04. RR Signals With Gates
05. RR Signals Only
06. RR Crossing
07. Officer / Flagperson
08. Traffic Signal
09. Yield Sign
10. Barricade
11. Control Not Visible / Broken
12. School Zone Signs
13. Warning Signs
99. Unknown

X. OBSERVATIONS *EXPLAIN IN NARRATIVE
00. None
01. Need Signing
02. Trees / Shrubs / Tall Grass / Crops
03. Pavement Markings
04. Hill / Curve
05. Narrow Bridge / Roadway
06. Rough Road
07. Lighting
08. Traffic Signals
09. Clearance Height
10. Road Maintenance
11. Delineators / Bridge Markings
12. Guardrail
13. Geometrics
14. Speed Limit
15. Sight Obstruction*

Y. MANNER OF COLLISION
1. Angle (Not Specific)
2. Rear-End
3. Head-On
4. Sideswipe (Same Direction)
5. Sideswipe (Opposite Direction)
6. Rear-to-Rear
7. Non-Collision With Motor Vehicle in Transport
8. Angle (Same Direction)
9. Angle (Opposite Direction)
10. Right Angle
11. Rear to Side

Z. FIRST HARMFUL EVENT

AA. SEQUENCE OF EVENTS

BB. MOST HARMFUL EVENT

COLLISION WITH OBJECT - NOT FIXED
01. Motor Vehicle in Transport
02. Motor Vehicle in Transport in Other Rdwy
03. Pedestrian
04. Pedalcycle
05. Railway Train
06. Deer
07. Other Large Game
08. Farm Animal
09. Small Animal
10. Parked Motor Vehicle
11. Other Object (Not Fixed)
12. Work Zone / Maintenance Equipment

NON-COLLISION
19. Fell / Jumped from Vehicle
20. Overturn / Rollover
21. Fire / Explosion
22. Immersion
23. Jackknife
24. Downhill Runaway
25. Cargo Loss or Shift
26. Separation of Units
27. Ran off Roadway
28. Other Non-Collision
29. Thrown / Falling Object

COLLISION WITH FIXED OBJECT
30. Impact Attenuator
31. Bridge / Pier / Abutment
32. Bridge Parapet End
33. Bridge Rail
34. Guardrail Face
35. Guardrail End
36. Median Barrier (Concrete Traffic Barrier)
37. Highway Traffic Sign Post
38. Overhead Sign Support
39. Luminaire / Light Support
40. Utility Post
41. Other Post / Pole / Support
42. Culvert
43. Curb
44. Ditch
45. Embankment
46. Fence
47. Mail Box
48. Tree
49. Other Fixed Object
50. Bridge Overhead Structure
51. Other Traffic Barrier
52. Traffic Signal Support

Figure B1. Motor Vehicle Crash Report Overlay No. 1.

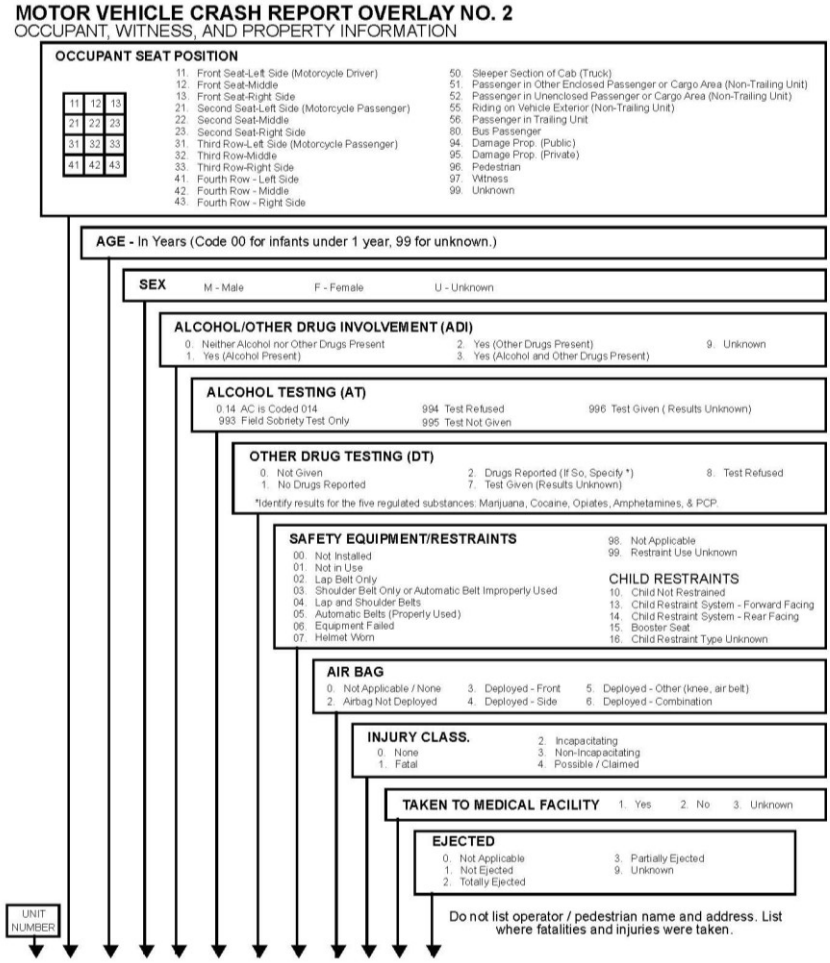


Figure B2. Motor Vehicle Crash Report Overlay No. 2.

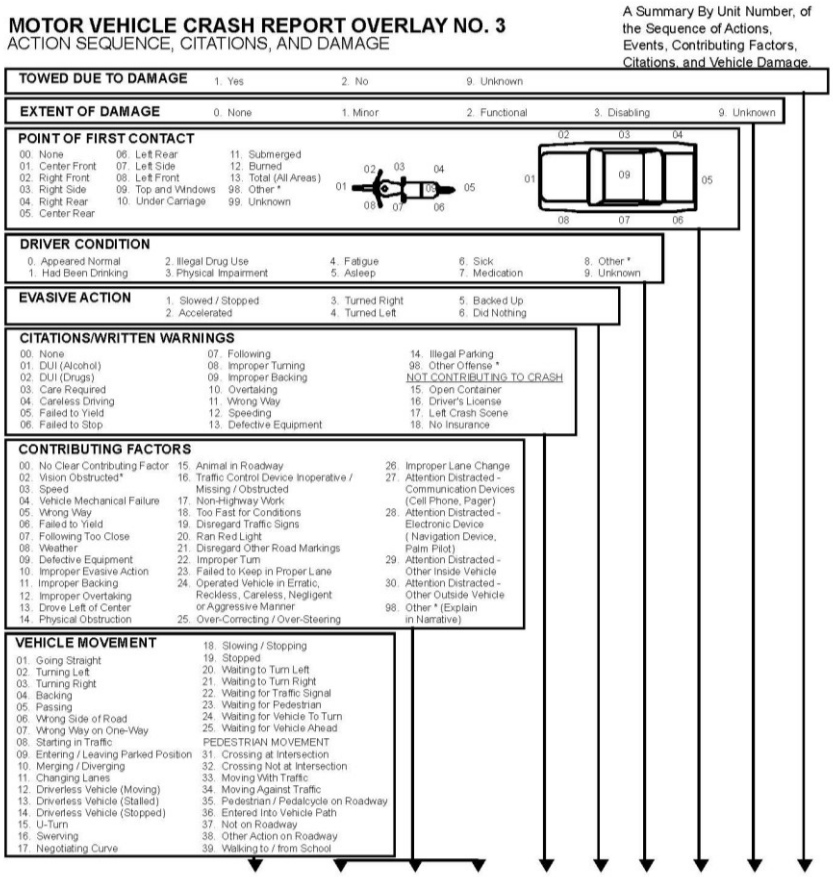


Figure B3. Motor Vehicle Crash Report Overlay No. 3.

APPENDIX C. NUMBER OF DRIVERS AND RATES BY COUNTY

Table C1. Number of Drivers: Adams County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	0
2008	Before	1	1
2009	Before	1	1
2010	Before	0	4
2011	Before	0	1
2012	After	0	6
2013	After	1	4
2014	After	0	2
2015	After	0	1
2016	After	0	4
	Total	5	24

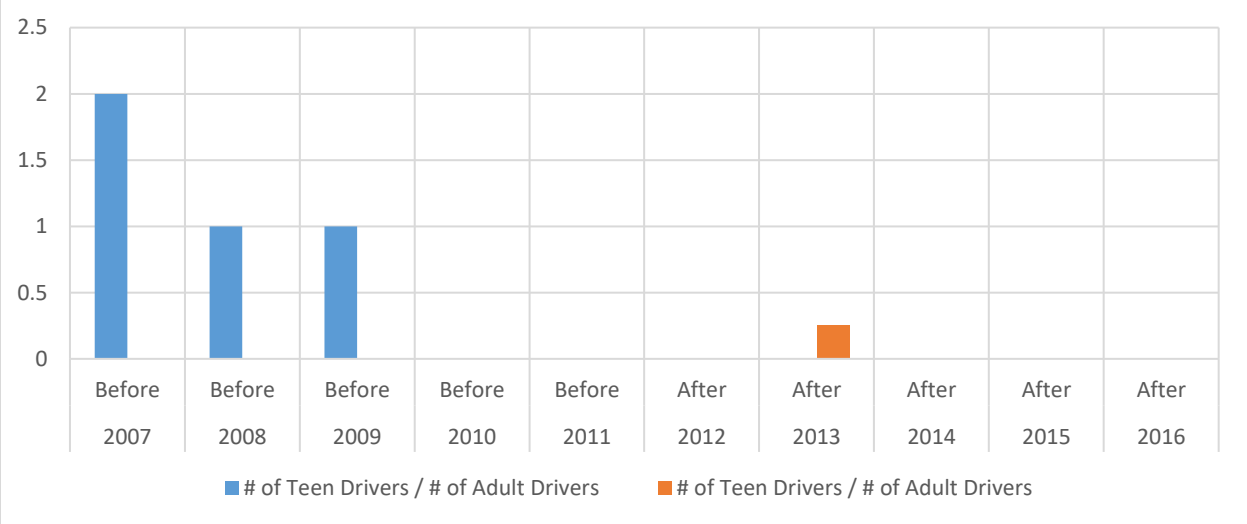


Figure C1. Ratio of Drivers: Adams County

Table C2. Number of Drivers: Barnes County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	4	13
2008	Before	2	19
2009	Before	3	35
2010	Before	6	21
2011	Before	10	26
2012	After	9	27
2013	After	3	45
2014	After	1	21
2015	After	3	28
2016	After	2	26
	Total	43	261

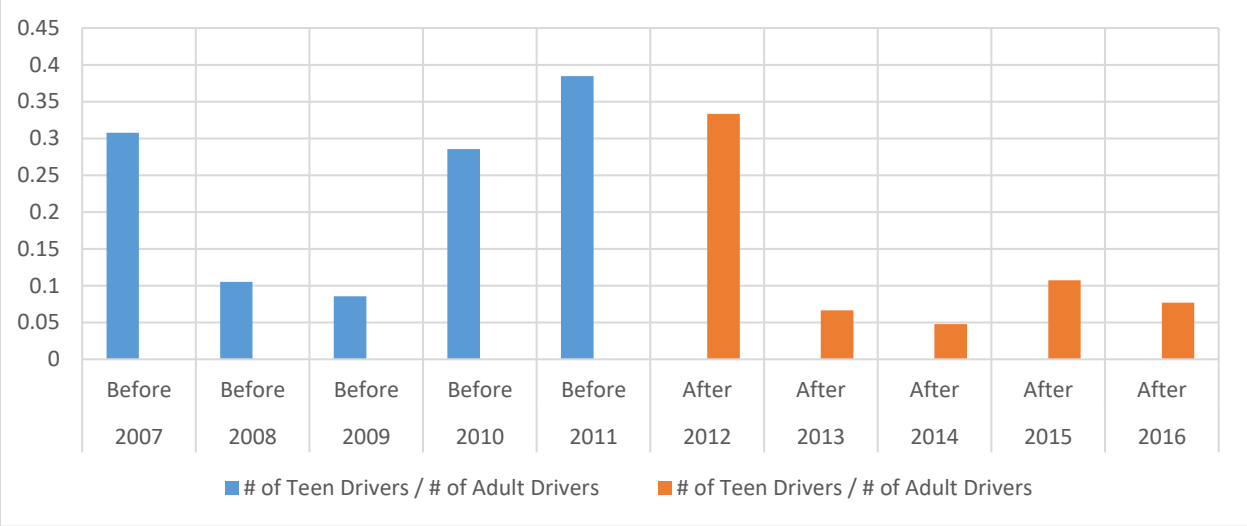


Figure C2. Ratio of Drivers: Barnes County

Table C3. Number of Drivers: Benson County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	1	11
2008	Before	1	9
2009	Before	1	13
2010	Before	2	6
2011	Before	0	15
2012	After	2	13
2013	After	4	3
2014	After	1	15
2015	After	1	7
2016	After	1	3
	Total	14	95

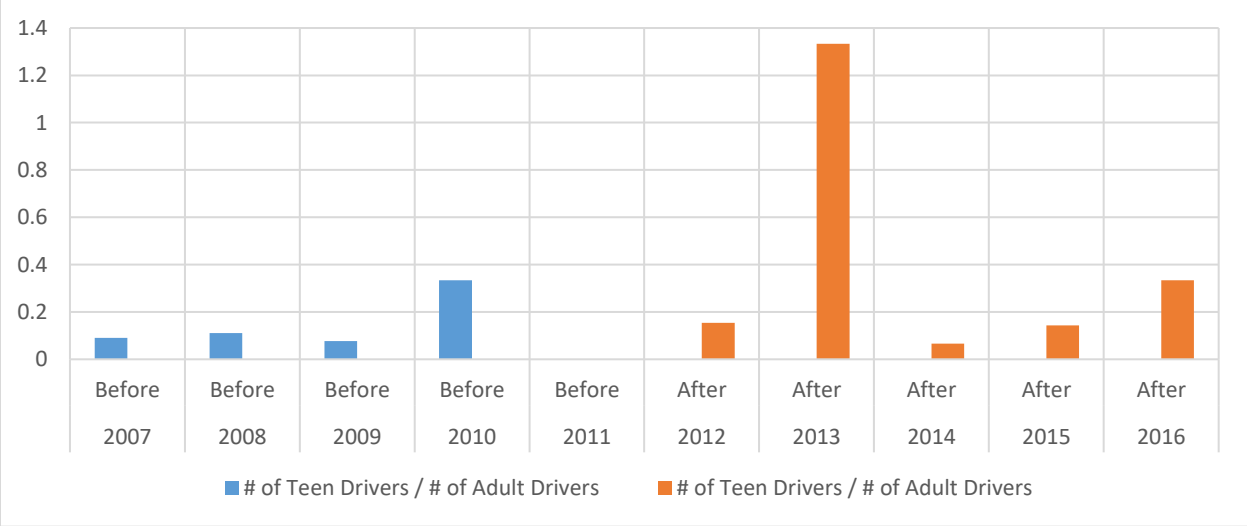


Figure C3. Ratio of Drivers: Benson County

Table C4. Number of Drivers: Billings County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	0	1
2008	Before	0	1
2009	Before	0	1
2010	Before	0	1
2011	Before	2	3
2012	After	0	9
2013	After	0	10
2014	After	1	3
2015	After	0	7
2016	After	0	2
	Total	3	38

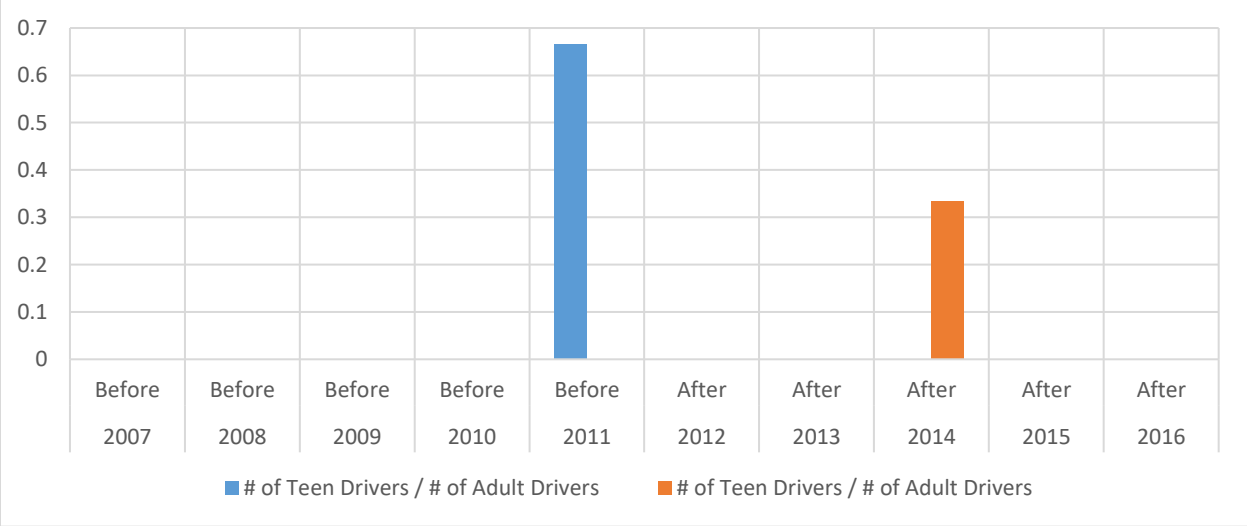


Figure C4. Ratio of Drivers: Billings County

Table C5. Number of Drivers: Bottineau County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	0	4
2008	Before	1	9
2009	Before	8	8
2010	Before	4	6
2011	Before	2	13
2012	After	2	11
2013	After	3	12
2014	After	1	13
2015	After	2	9
2016	After	2	11
	Total	25	96

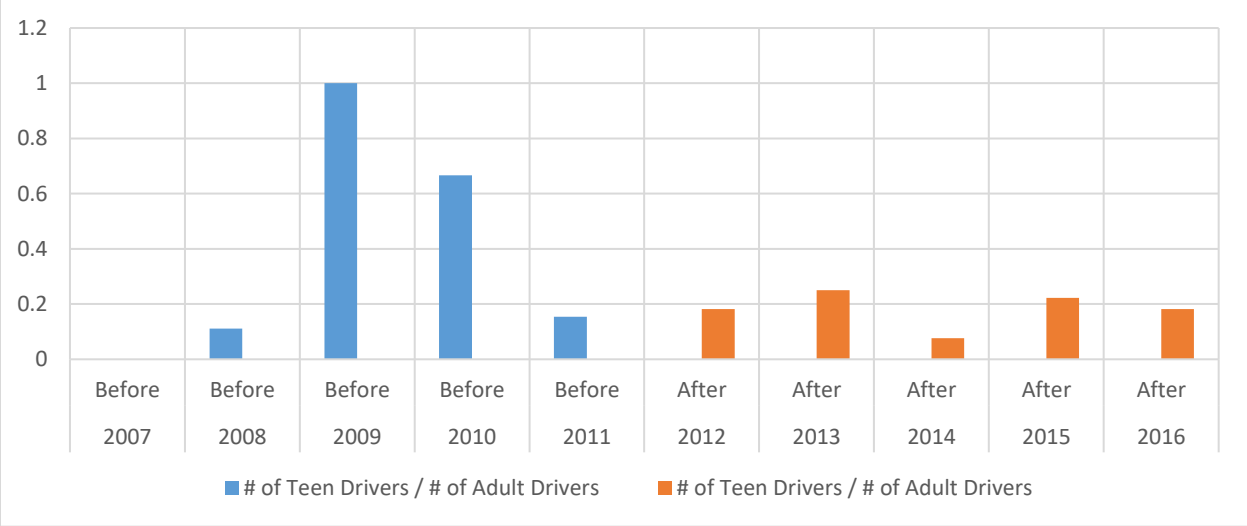


Figure C5. Ratio of Drivers: Bottineau County

Table C6. Number of Drivers: Bowman County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	3
2008	Before	2	3
2009	Before	1	5
2010	Before	1	6
2011	Before	4	3
2012	After	1	1
2013	After	2	3
2014	After	0	6
2015	After	1	2
2016	After	0	0
	Total	14	32

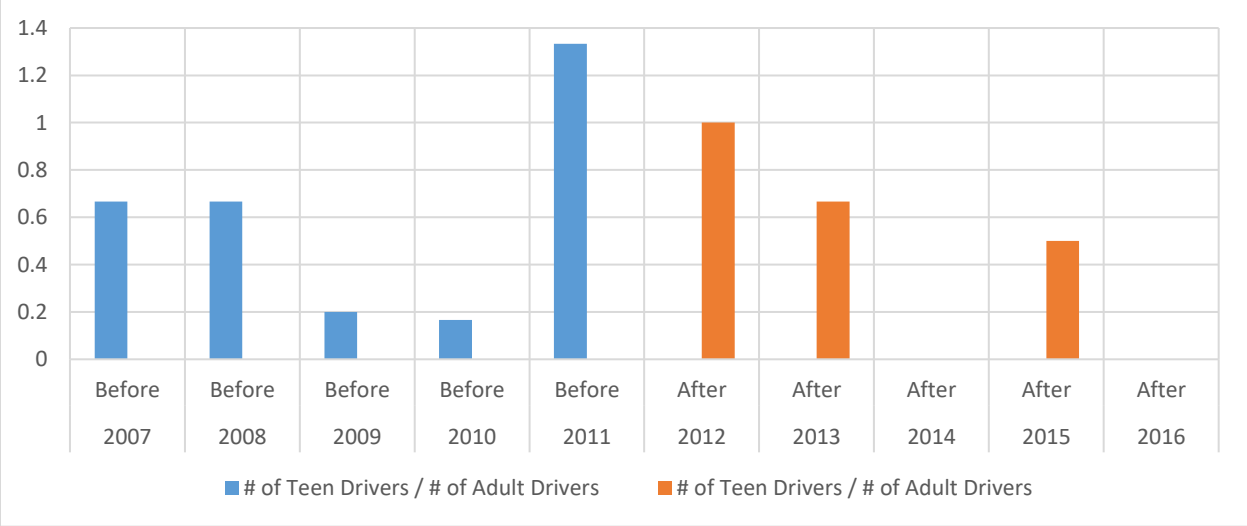


Figure C6. Ratio of Drivers: Bowman County

Table C7. Number of Drivers: Burke County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	1	6
2008	Before	2	6
2009	Before	2	8
2010	Before	0	5
2011	Before	0	3
2012	After	1	7
2013	After	0	7
2014	After	0	2
2015	After	1	10
2016	After	1	6
	Total	8	60

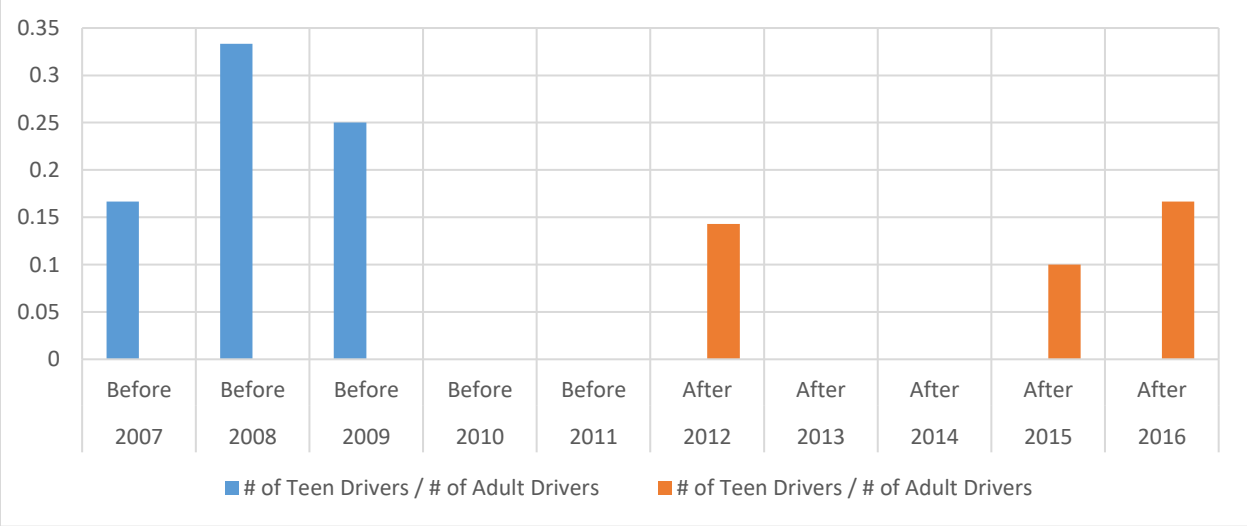


Figure C7. Ratio of Drivers: Burke County

Table C8. Number of Drivers: Burleigh County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	93	415
2008	Before	113	397
2009	Before	84	400
2010	Before	86	416
2011	Before	94	390
2012	After	99	429
2013	After	95	489
2014	After	66	444
2015	After	76	489
2016	After	84	509
	Total	890	4,378

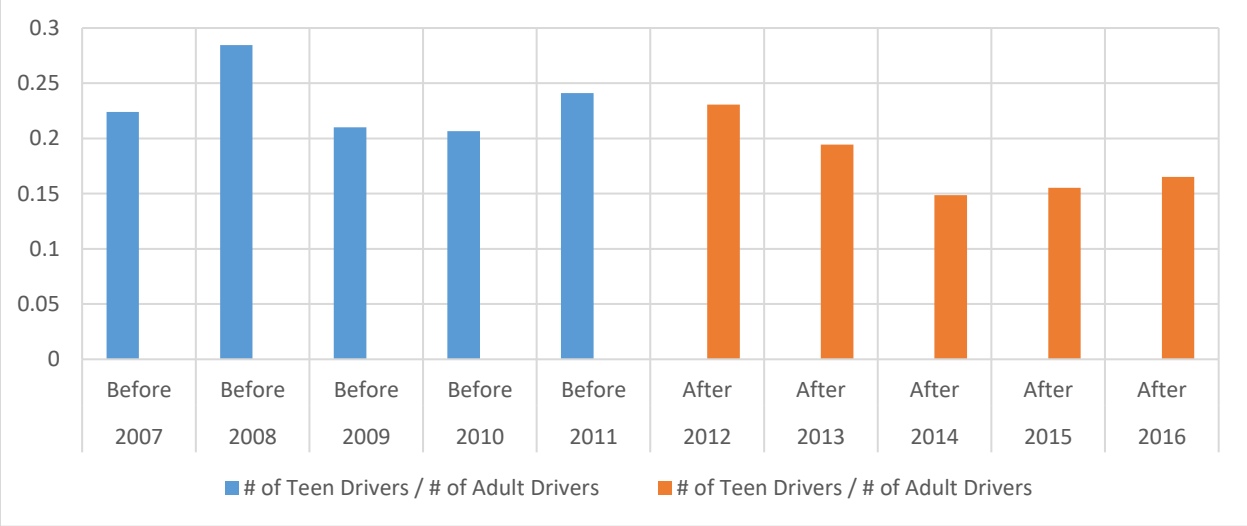


Figure C8. Ratio of Drivers: Burleigh County

Table C9. Number of Drivers: Cass County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	97	670
2008	Before	82	678
2009	Before	89	690
2010	Before	85	733
2011	Before	76	629
2012	After	83	630
2013	After	88	795
2014	After	64	886
2015	After	72	785
2016	After	72	859
	Total	808	7,355

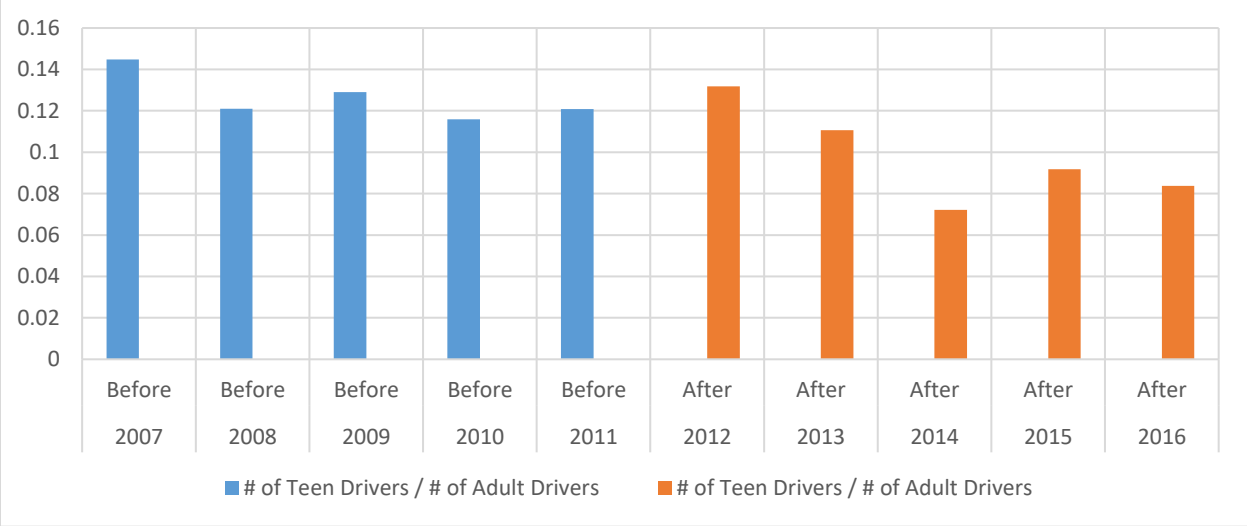


Figure C9. Ratio of Drivers: Cass County

Table C10. Number of Drivers: Cavalier County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	3	6
2008	Before	0	5
2009	Before	0	4
2010	Before	3	5
2011	Before	2	10
2012	After	0	3
2013	After	0	3
2014	After	1	6
2015	After	1	4
2016	After	0	5
	Total	10	51

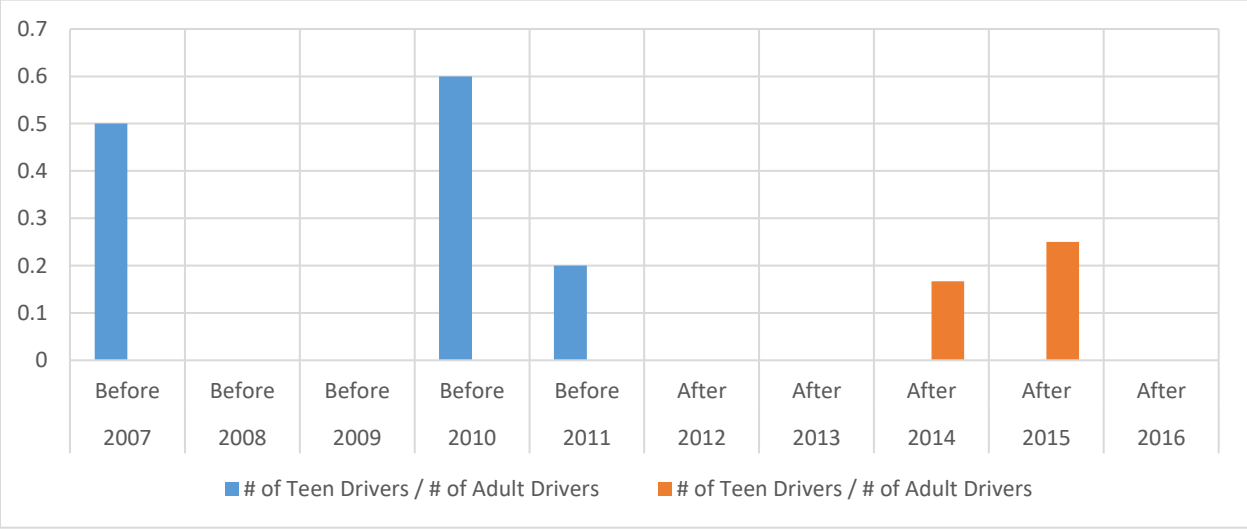


Figure C10. Ratio of Drivers: Cavalier County

Table C11. Number of Drivers: Dickey County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	6	13
2008	Before	2	8
2009	Before	8	7
2010	Before	4	5
2011	Before	3	10
2012	After	3	11
2013	After	2	12
2014	After	0	11
2015	After	1	6
2016	After	3	7
	Total	32	90

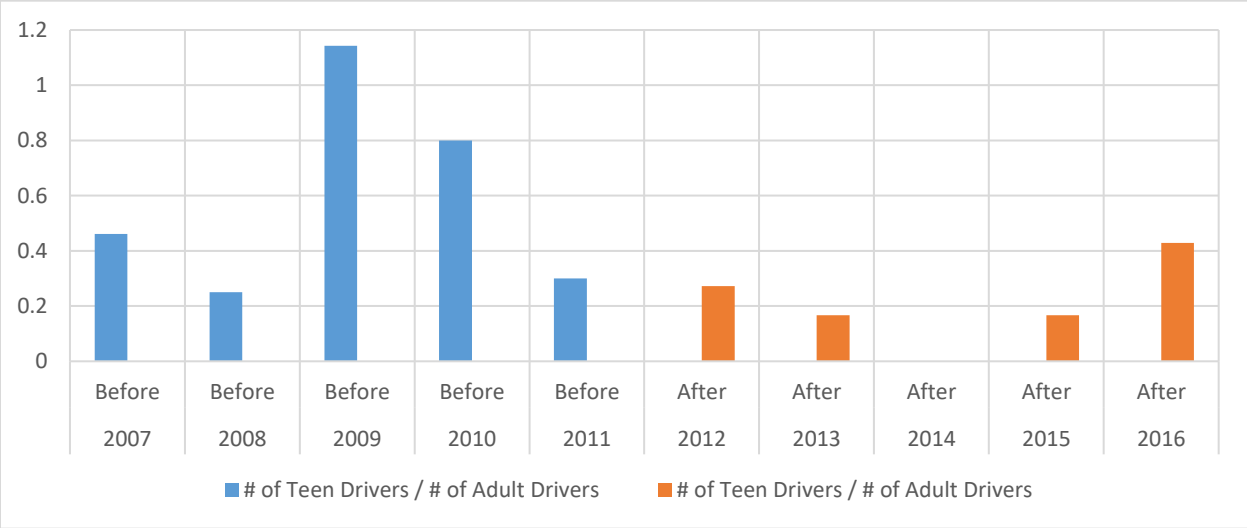


Figure C11. Ratio of Drivers: Dickey County

Table C12. Number of Drivers: Divide County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	3	4
2008	Before	0	6
2009	Before	1	6
2010	Before	0	7
2011	Before	0	2
2012	After	0	8
2013	After	0	18
2014	After	1	13
2015	After	1	7
2016	After	2	5
	Total	8	76

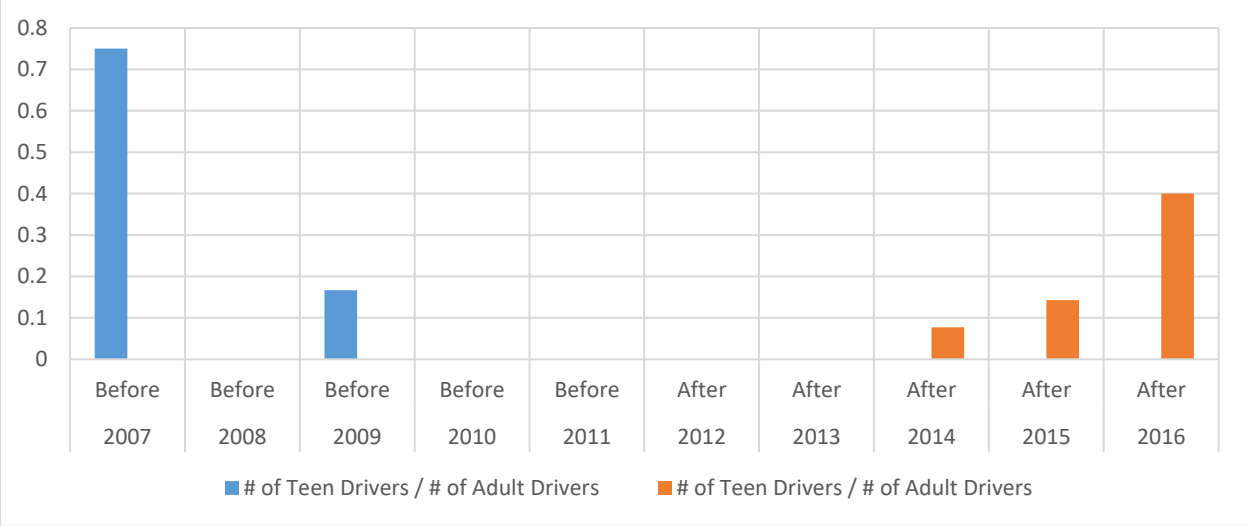


Figure C12. Ratio of Drivers: Divide County

Table C13. Number of Drivers: Dunn County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	0	9
2008	Before	1	13
2009	Before	0	9
2010	Before	2	15
2011	Before	3	31
2012	After	0	25
2013	After	2	21
2014	After	0	25
2015	After	0	21
2016	After	2	18
	Total	10	187

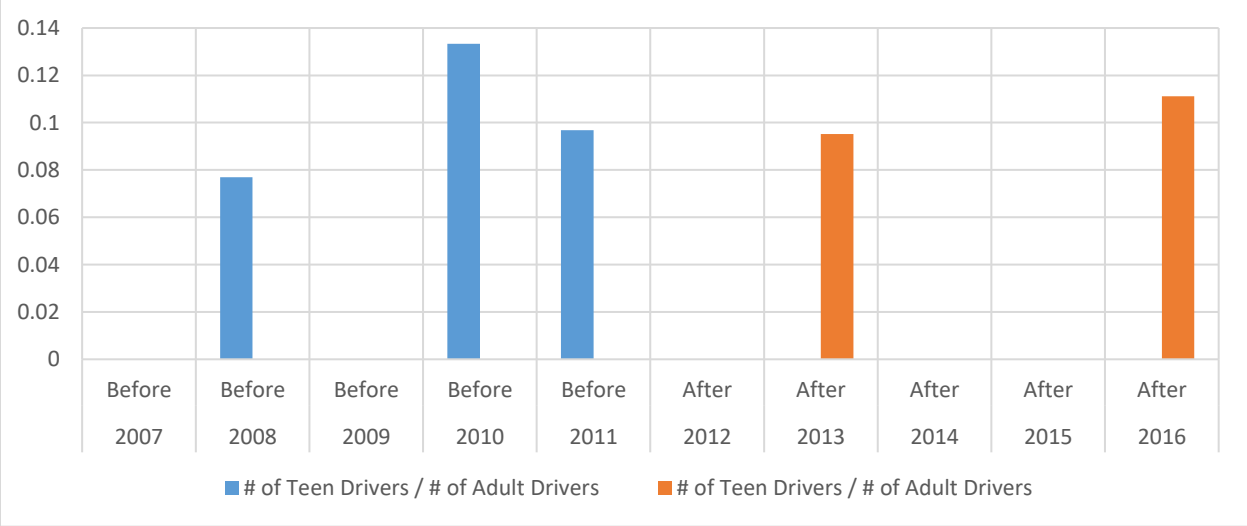


Figure C13. Ratio of Drivers: Dunn County

Table C14. Number of Drivers: Eddy County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	3
2008	Before	0	4
2009	Before	0	4
2010	Before	1	7
2011	Before	0	7
2012	After	1	8
2013	After	1	1
2014	After	0	3
2015	After	0	4
2016	After	0	2
	Total	5	43

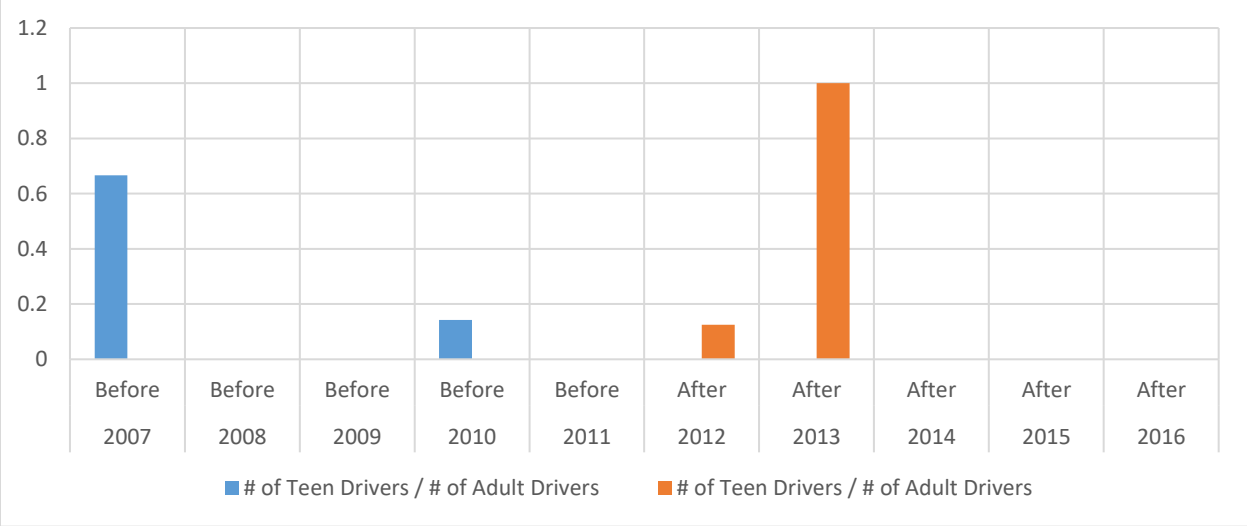


Figure C14. Ratio of Drivers: Eddy County

Table C15. Number of Drivers: Emmons County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	11
2008	Before	4	6
2009	Before	0	8
2010	Before	2	4
2011	Before	5	8
2012	After	0	8
2013	After	1	4
2014	After	2	14
2015	After	1	9
2016	After	0	7
	Total	17	79

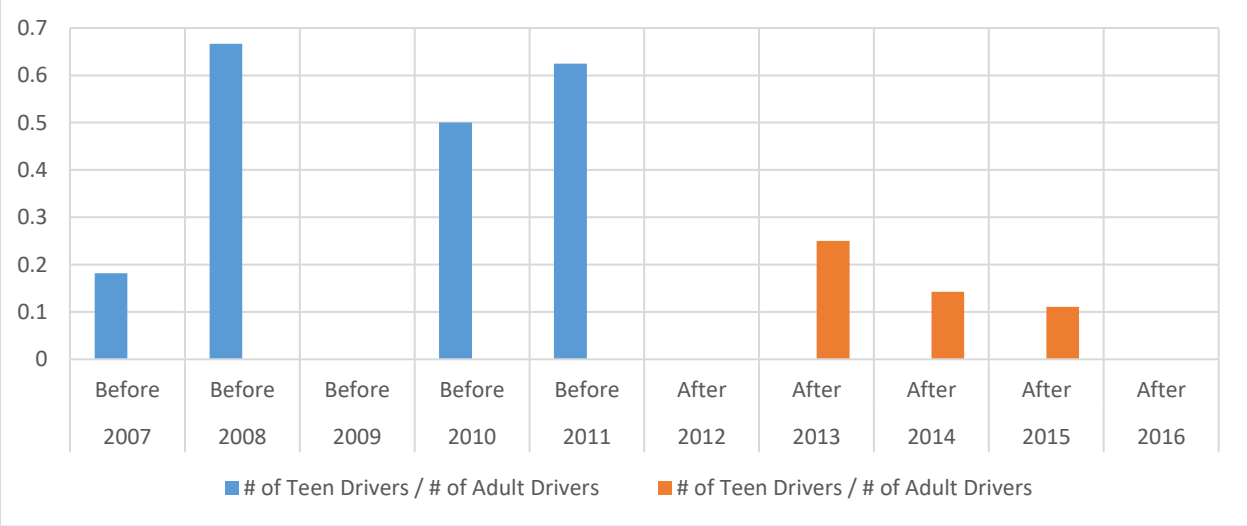


Figure C15. Ratio of Drivers: Emmons County

Table C16. Number of Drivers: Foster County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	4
2008	Before	1	7
2009	Before	1	2
2010	Before	2	9
2011	Before	0	5
2012	After	1	6
2013	After	1	5
2014	After	0	4
2015	After	0	9
2016	After	0	2
	Total	8	53

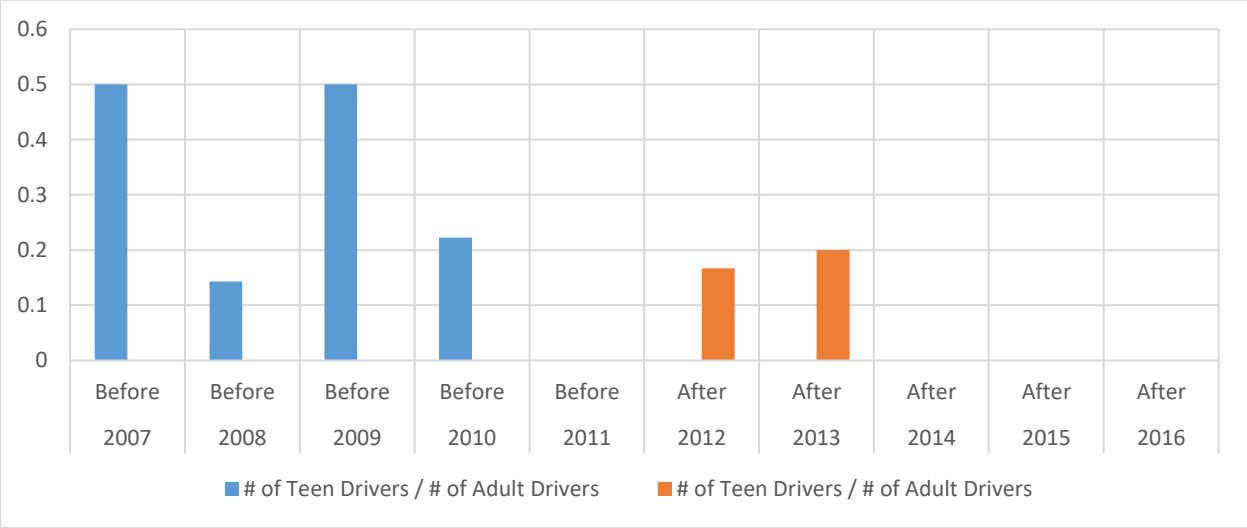


Figure C16. Ratio of Drivers: Foster County

Table C17. Number of Drivers: Golden Valley County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	0	2
2008	Before	1	1
2009	Before	1	4
2010	Before	0	5
2011	Before	0	8
2012	After	2	1
2013	After	0	3
2014	After	0	3
2015	After	1	3
2016	After	1	3
	Total	6	33

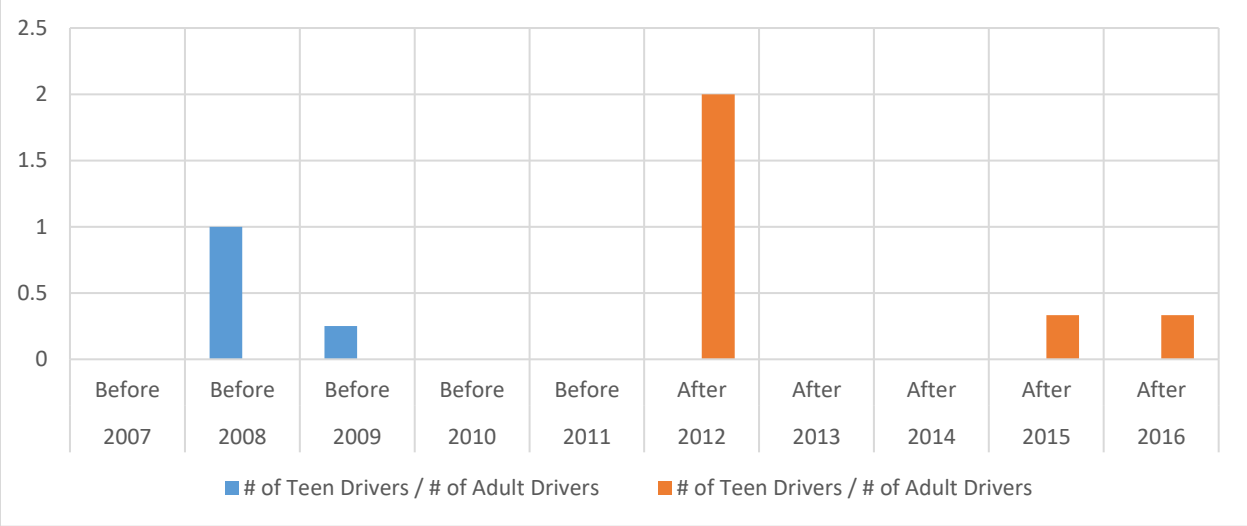


Figure C17. Ratio of Drivers: Golden Valley County

Table C18. Number of Drivers: Grand Forks County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	31	254
2008	Before	41	234
2009	Before	33	254
2010	Before	37	285
2011	Before	41	279
2012	After	42	311
2013	After	33	274
2014	After	23	307
2015	After	40	287
2016	After	42	258
	Total	363	2,743

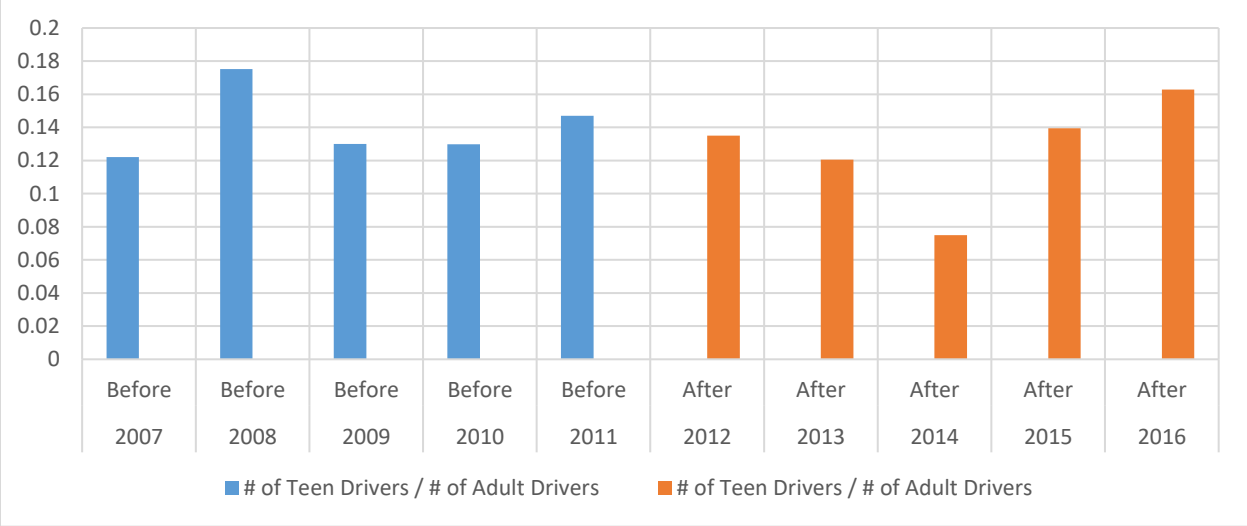


Figure C18. Ratio of Drivers: Grand Forks County

Table C19. Number of Drivers: Grant County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	1	1
2008	Before	0	1
2009	Before	0	3
2010	Before	2	5
2011	Before	2	5
2012	After	0	6
2013	After	3	8
2014	After	2	3
2015	After	2	1
2016	After	0	4
	Total	12	37

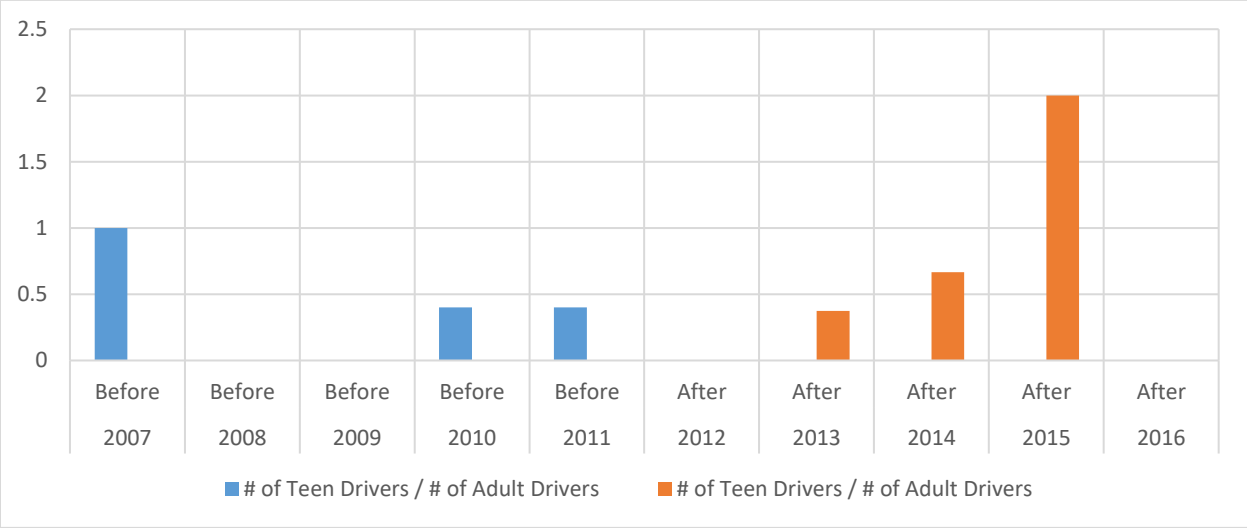


Figure C19. Ratio of Drivers: Grant County

Table C20. Number of Drivers: Griggs County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	2
2008	Before	1	0
2009	Before	0	1
2010	Before	0	0
2011	Before	0	0
2012	After	2	3
2013	After	0	2
2014	After	0	2
2015	After	0	0
2016	After	0	5
	Total	5	15

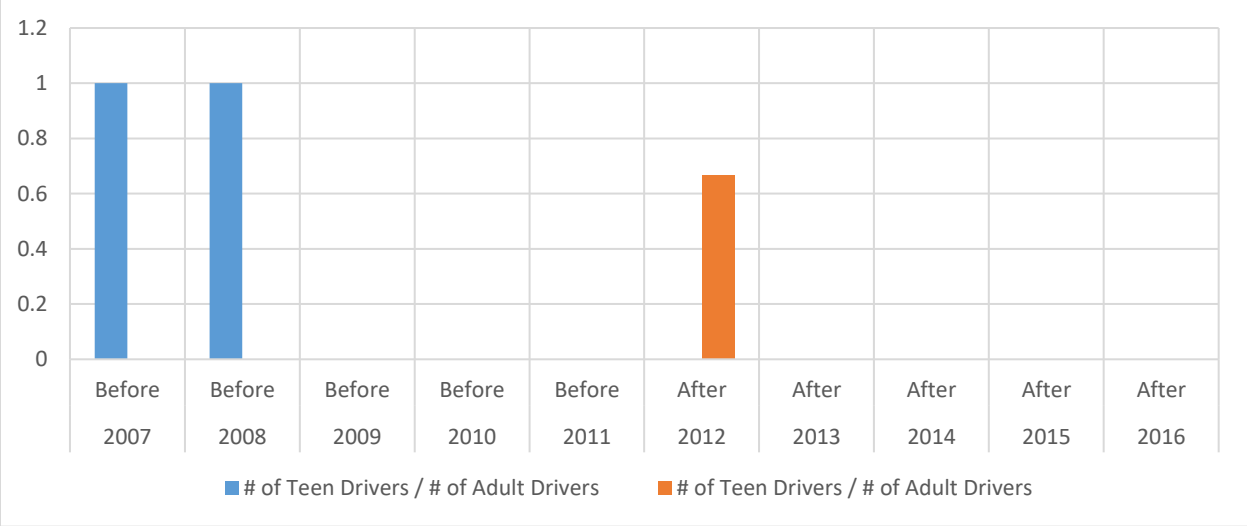


Figure C20. Ratio of Drivers: Griggs County

Table C21. Number of Drivers: Hettinger County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	1	1
2008	Before	0	7
2009	Before	2	1
2010	Before	3	8
2011	Before	1	6
2012	After	1	4
2013	After	1	4
2014	After	1	4
2015	After	0	1
2016	After	1	4
	Total	11	40

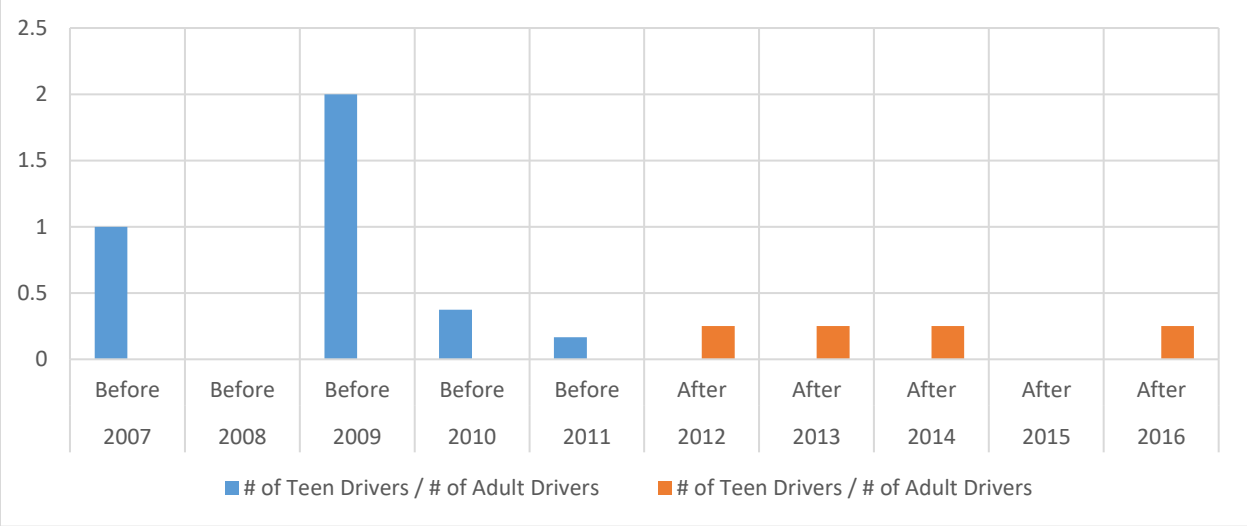


Figure C21. Ratio of Drivers: Hettinger County

Table C22. Number of Drivers: Kidder County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	1	4
2008	Before	2	4
2009	Before	2	11
2010	Before	0	7
2011	Before	1	6
2012	After	0	9
2013	After	1	10
2014	After	1	11
2015	After	0	4
2016	After	1	11
	Total	9	77

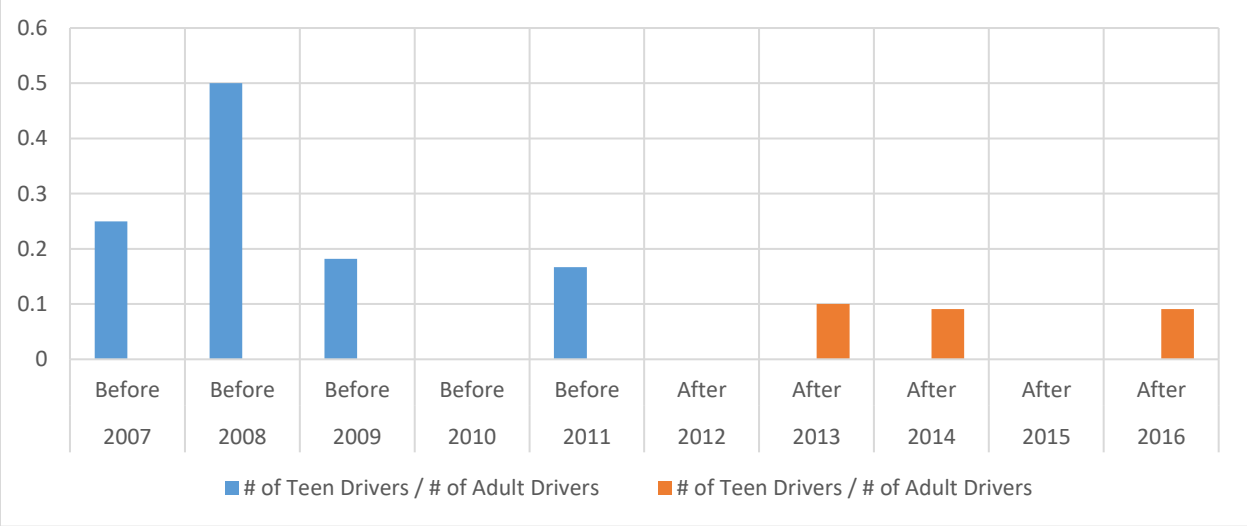


Figure C22. Ratio of Drivers: Kidder County

Table C23. Number of Drivers: LaMoure County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	8
2008	Before	2	8
2009	Before	2	4
2010	Before	1	2
2011	Before	1	2
2012	After	1	3
2013	After	1	2
2014	After	3	3
2015	After	2	6
2016	After	3	4
	Total	18	42

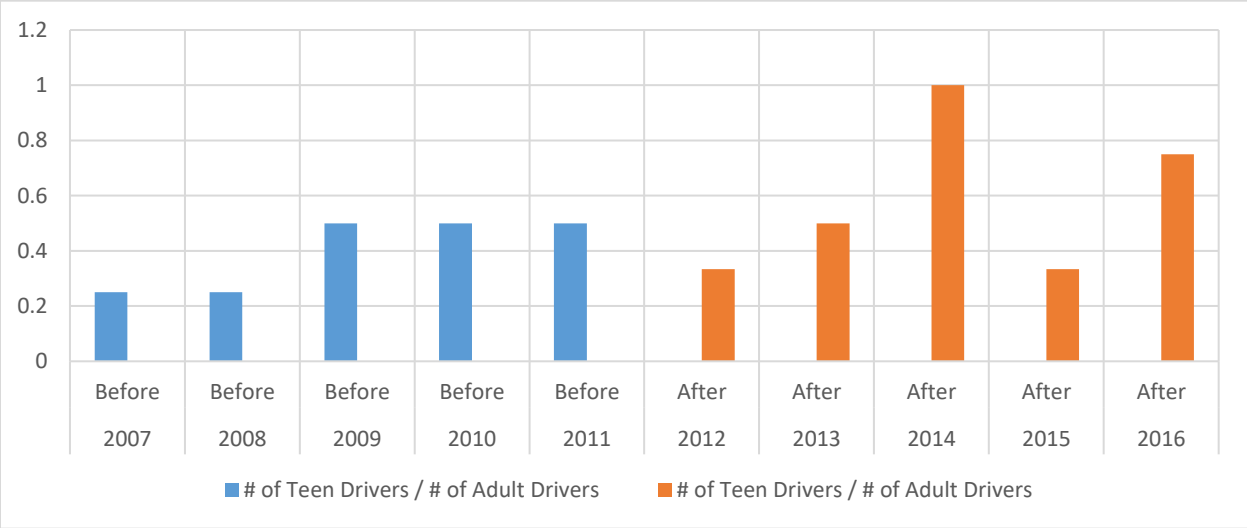


Figure C23. Ratio of Drivers: LaMoure County

Table C24. Number of Drivers: Logan County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	0	4
2008	Before	0	3
2009	Before	2	2
2010	Before	0	2
2011	Before	0	3
2012	After	1	2
2013	After	1	1
2014	After	2	1
2015	After	0	2
2016	After	1	2
	Total	7	22

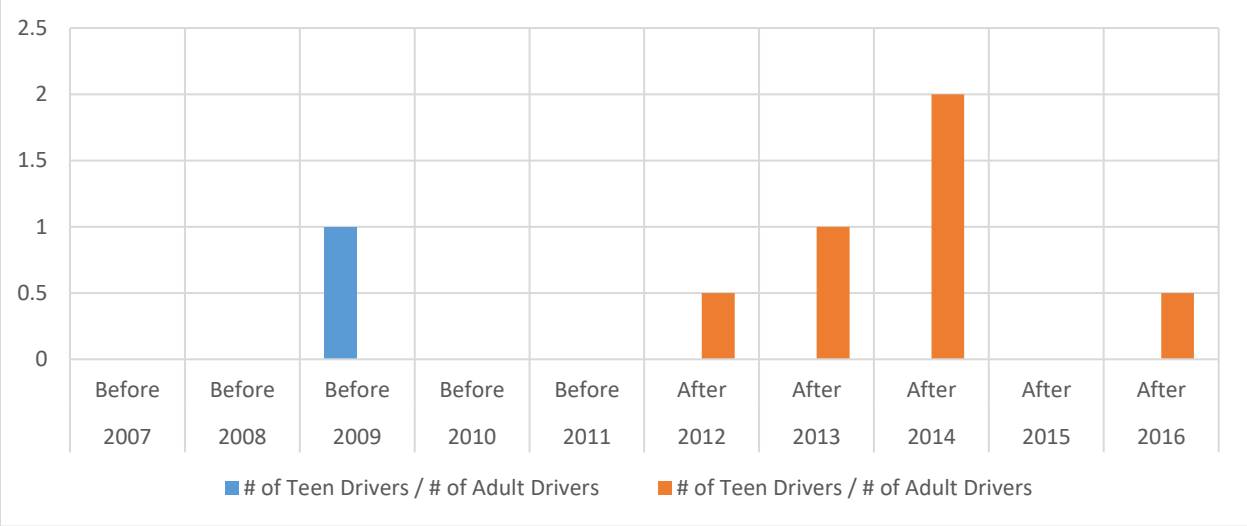


Figure C24. Ratio of Drivers: Logan County

Table C25. Number of Drivers: McHenry County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	0	9
2008	Before	5	11
2009	Before	4	14
2010	Before	5	13
2011	Before	3	14
2012	After	2	13
2013	After	4	16
2014	After	3	14
2015	After	2	13
2016	After	1	14
	Total	29	131

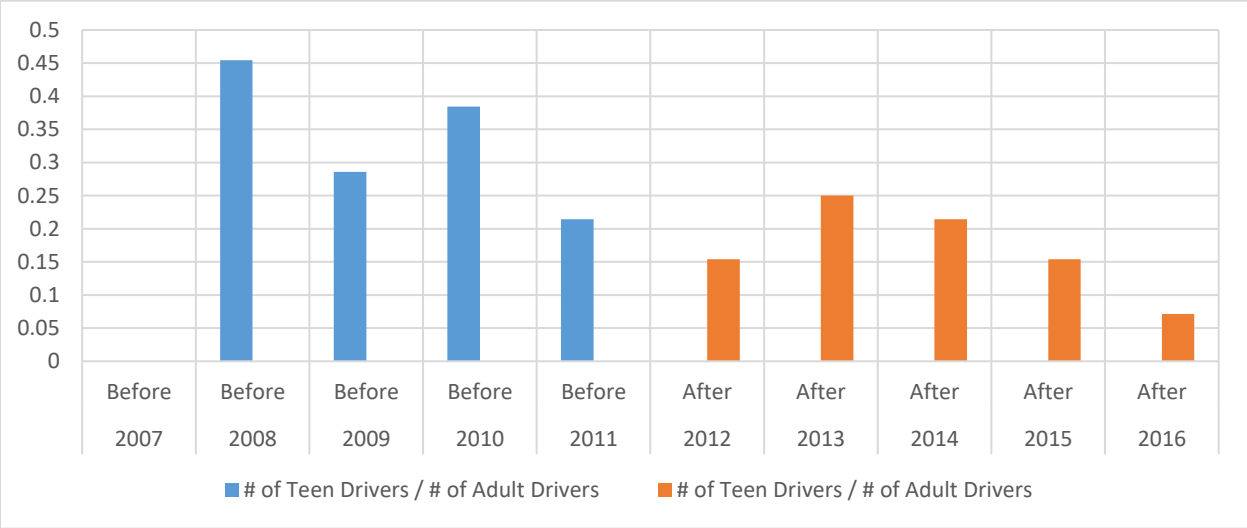


Figure C25. Ratio of Drivers: McHenry County

Table C26. Number of Drivers: McIntosh County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	1	4
2008	Before	2	1
2009	Before	1	2
2010	Before	1	2
2011	Before	2	3
2012	After	1	7
2013	After	3	4
2014	After	0	3
2015	After	0	2
2016	After	1	0
	Total	12	28

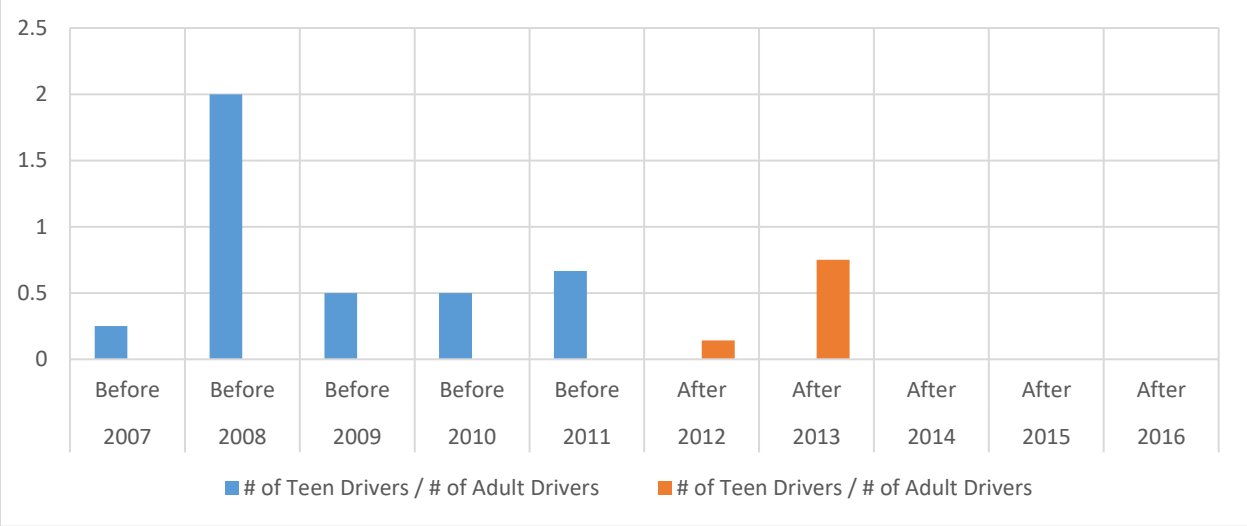


Figure C26. Ratio of Drivers: McIntosh County

Table C27. Number of Drivers: McKenzie County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	15
2008	Before	5	11
2009	Before	2	22
2010	Before	2	31
2011	Before	0	96
2012	After	6	125
2013	After	3	157
2014	After	8	216
2015	After	3	117
2016	After	1	57
	Total	32	847

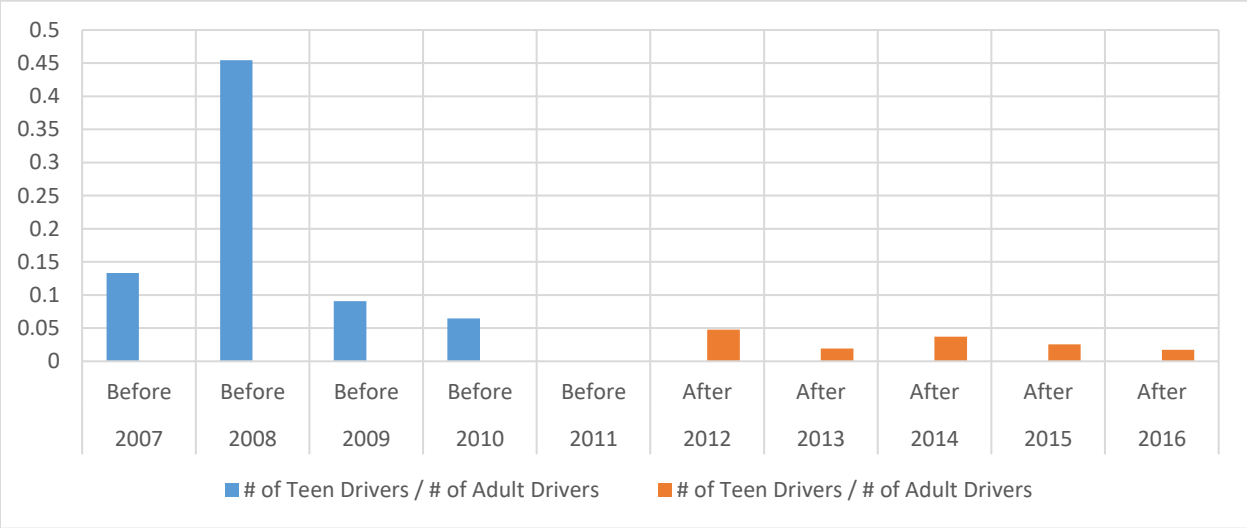


Figure C27. Ratio of Drivers: McKenzie County

Table C28. Number of Drivers: McLean County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	8	22
2008	Before	4	23
2009	Before	4	23
2010	Before	1	14
2011	Before	6	22
2012	After	4	16
2013	After	4	29
2014	After	7	22
2015	After	9	27
2016	After	5	18
	Total	52	216

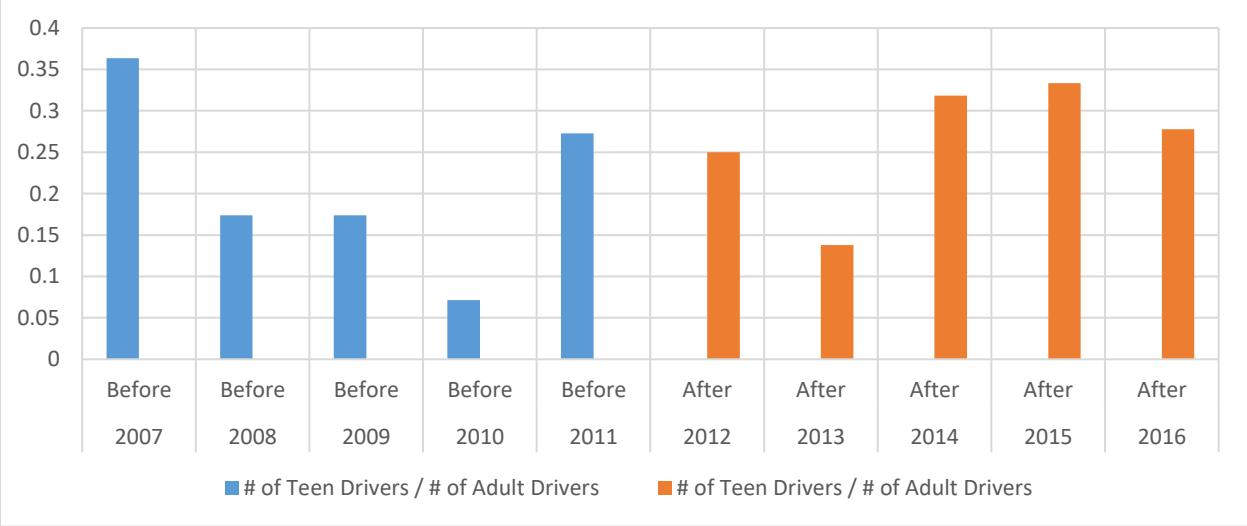


Figure C28. Ratio of Drivers: McLean County

Table C29. Number of Drivers: Mercer County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	7	17
2008	Before	1	10
2009	Before	7	20
2010	Before	7	13
2011	Before	4	20
2012	After	2	11
2013	After	3	14
2014	After	1	8
2015	After	4	9
2016	After	5	12
	Total	41	134

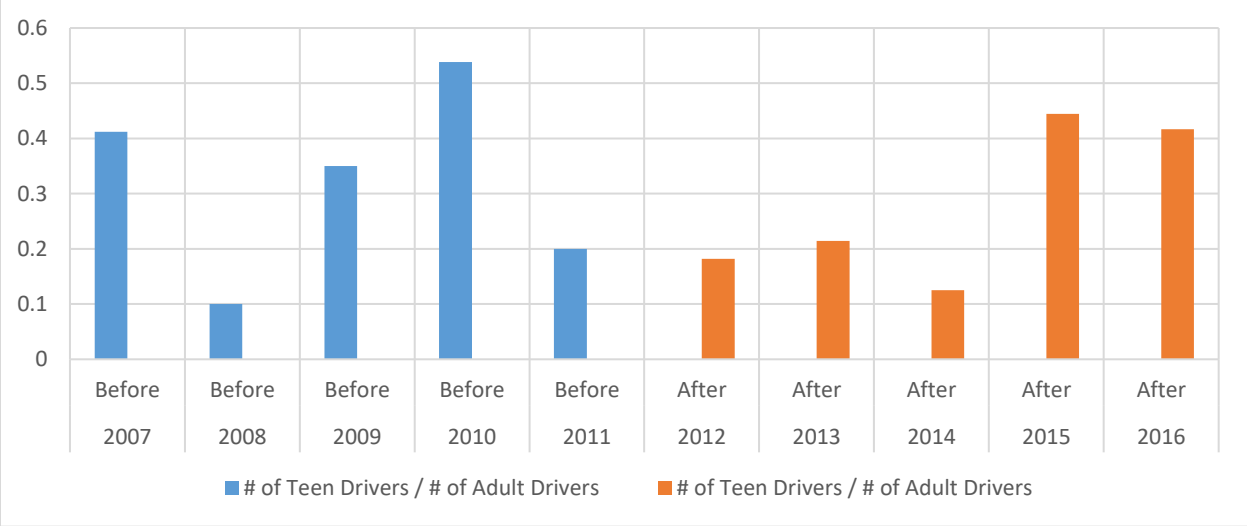


Figure C29. Ratio of Drivers: Mercer County

Table C30. Number of Drivers: Morton County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	18	77
2008	Before	13	53
2009	Before	15	66
2010	Before	14	101
2011	Before	28	108
2012	After	8	66
2013	After	9	74
2014	After	5	58
2015	After	17	110
2016	After	12	98
	Total	139	811

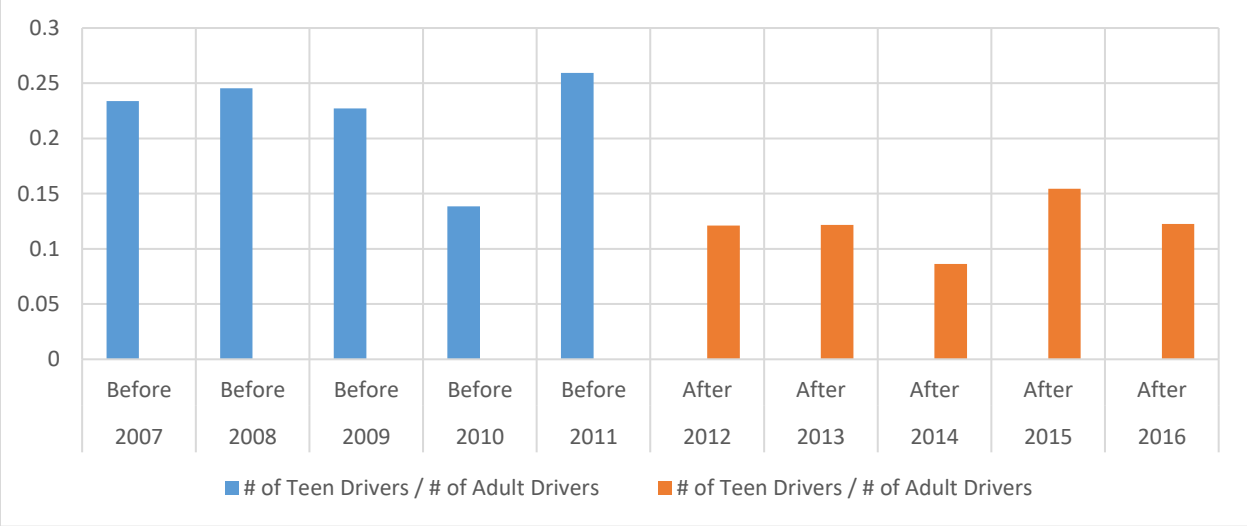


Figure C30. Ratio of Drivers: Morton County

Table C31. Number of Drivers: Mountrail County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	4	21
2008	Before	4	24
2009	Before	3	26
2010	Before	4	41
2011	Before	3	72
2012	After	3	49
2013	After	2	62
2014	After	0	56
2015	After	2	37
2016	After	4	19
	Total	29	407

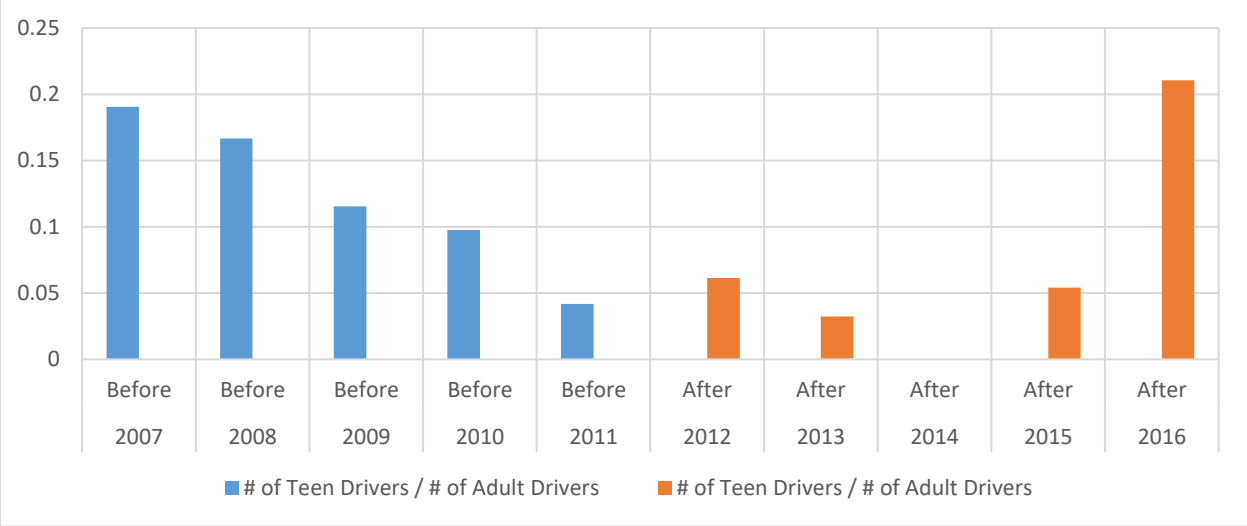


Figure C31. Ratio of Drivers: Mountrail County

Table C32. Number of Drivers: Nelson County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	3	5
2008	Before	0	1
2009	Before	0	8
2010	Before	0	4
2011	Before	3	2
2012	After	1	6
2013	After	1	8
2014	After	0	3
2015	After	0	4
2016	After	1	4
	Total	9	45

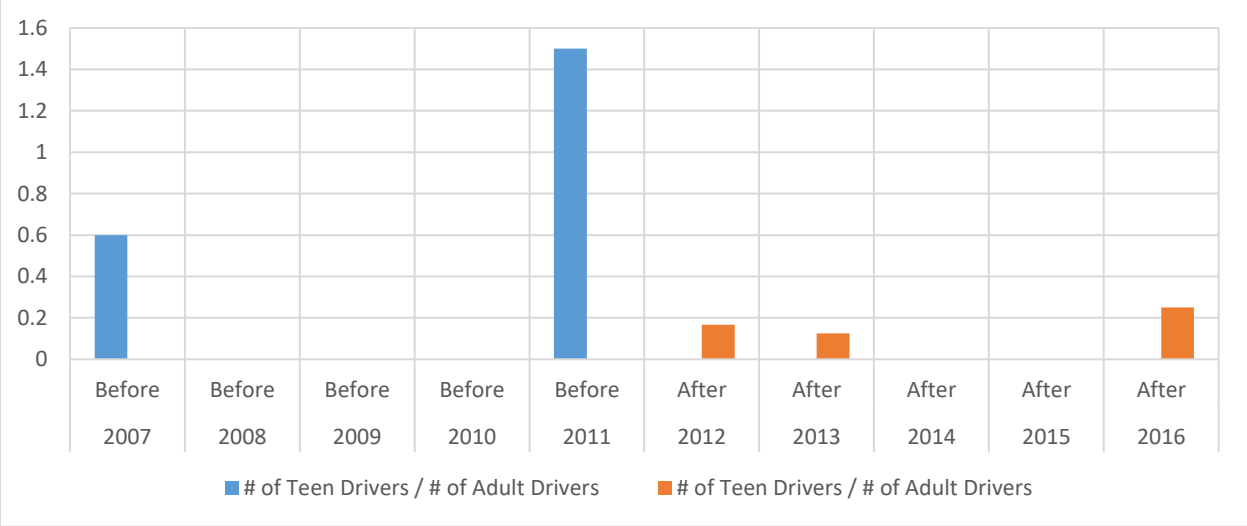


Figure C32. Ratio of Drivers: Nelson County

Table C33. Number of Drivers: Oliver County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	1	2
2008	Before	0	3
2009	Before	1	6
2010	Before	0	6
2011	Before	0	2
2012	After	0	1
2013	After	1	6
2014	After	1	3
2015	After	1	2
2016	After	0	3
	Total	5	34

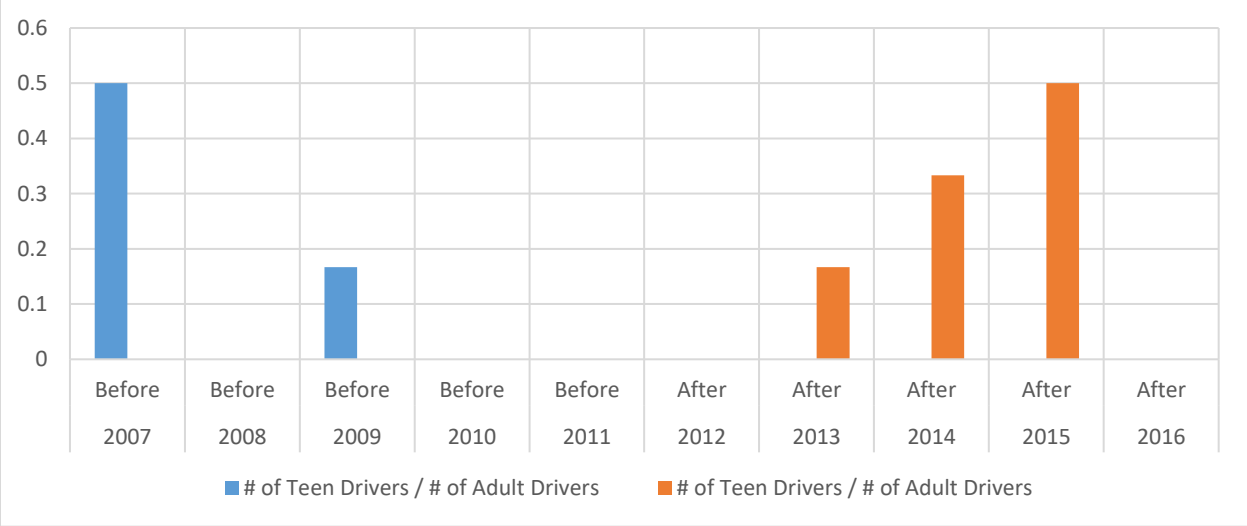


Figure C33. Ratio of Drivers: Oliver County

Table C34. Number of Drivers: Pembina County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	3	3
2008	Before	1	5
2009	Before	1	11
2010	Before	4	10
2011	Before	4	6
2012	After	0	10
2013	After	1	20
2014	After	1	10
2015	After	2	10
2016	After	3	9
	Total	20	94

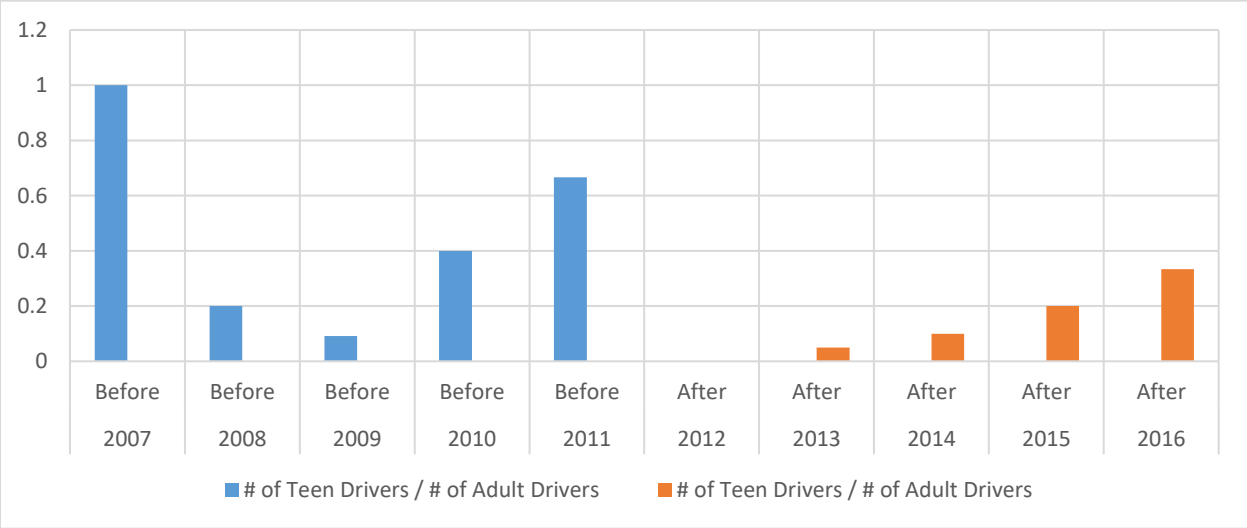


Figure C34. Ratio of Drivers: Pembina County

Table C35. Number of Drivers: Pierce County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	1	5
2008	Before	6	5
2009	Before	0	5
2010	Before	1	9
2011	Before	1	5
2012	After	0	6
2013	After	0	10
2014	After	0	7
2015	After	0	6
2016	After	3	5
	Total	12	63

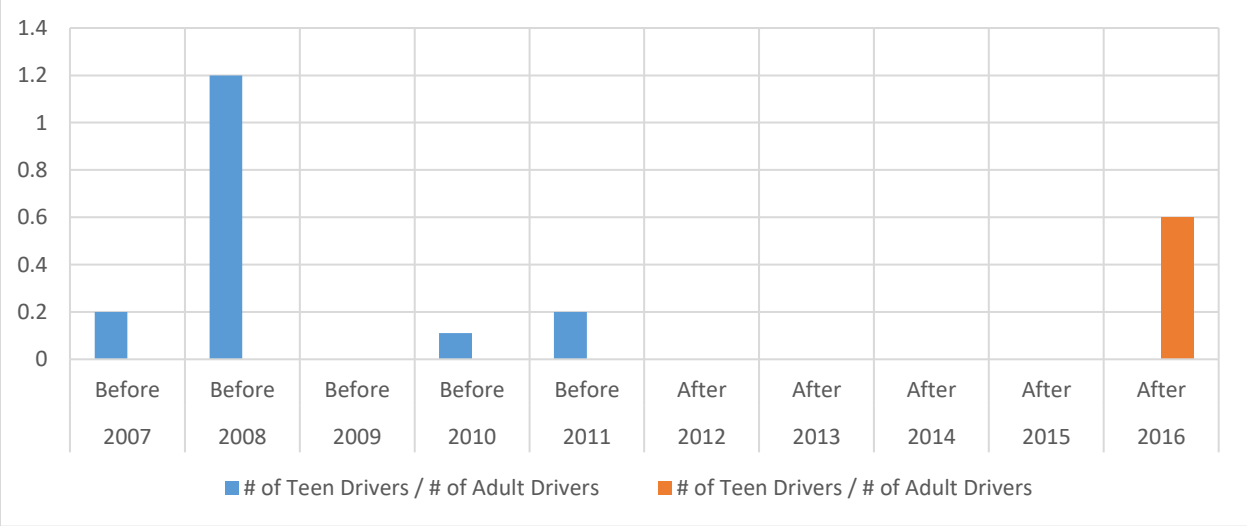


Figure C35. Ratio of Drivers: Pierce County

Table C36. Number of Drivers: Ramsey County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	8	28
2008	Before	10	23
2009	Before	7	19
2010	Before	3	20
2011	Before	5	26
2012	After	9	38
2013	After	7	30
2014	After	5	14
2015	After	4	23
2016	After	6	38
	Total	64	259

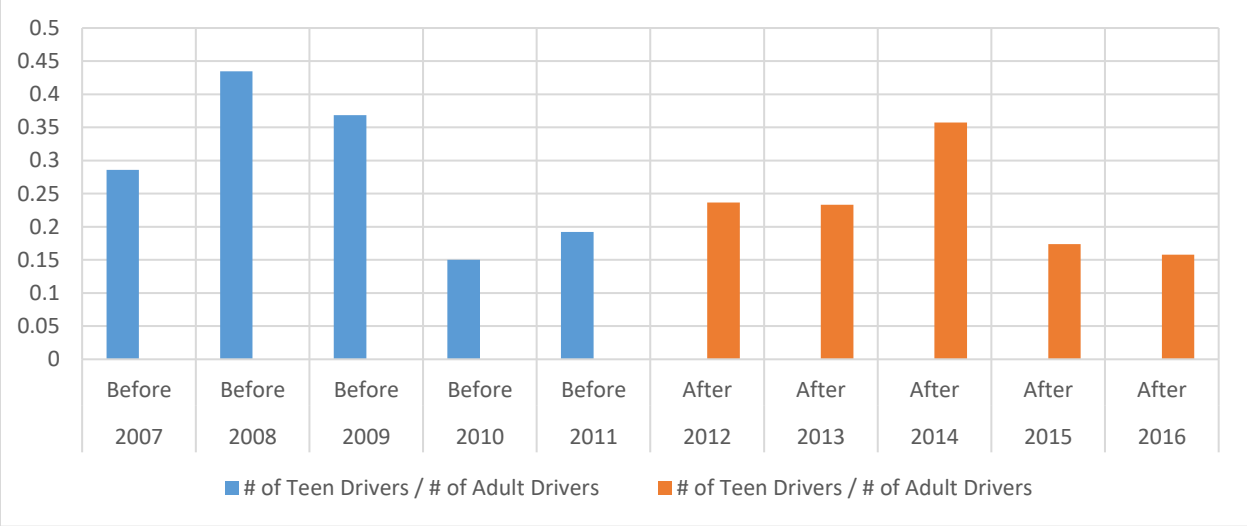


Figure C36. Ratio of Drivers: Ramsey County

Table C37. Number of Drivers: Ransom County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	7
2008	Before	2	6
2009	Before	4	7
2010	Before	1	6
2011	Before	5	10
2012	After	6	2
2013	After	4	6
2014	After	4	6
2015	After	3	3
2016	After	2	5
	Total	33	58

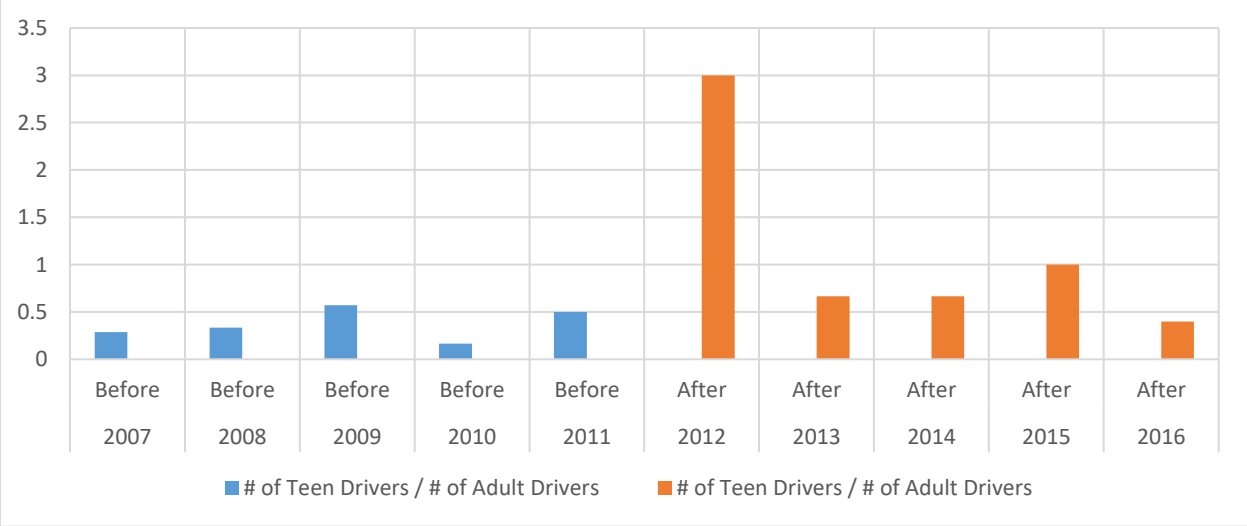


Figure C37. Ratio of Drivers: Ransom County

Table C38. Number of Drivers: Renville County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	3
2008	Before	4	2
2009	Before	1	6
2010	Before	1	1
2011	Before	1	10
2012	After	1	5
2013	After	0	7
2014	After	1	2
2015	After	2	4
2016	After	3	7
	Total	16	47

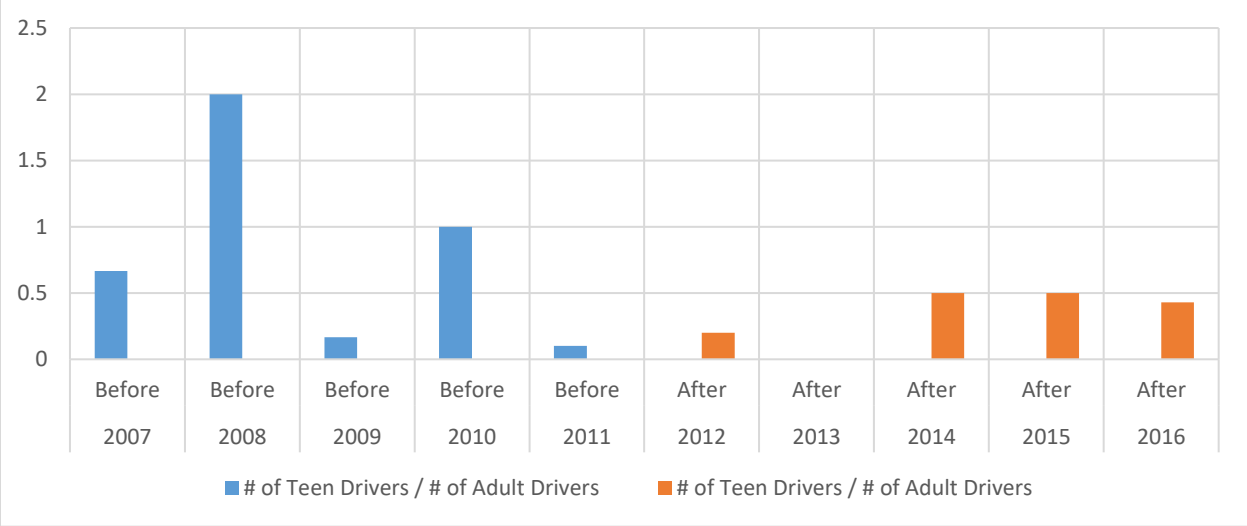


Figure C38. Ratio of Drivers: Renville County

Table C39. Number of Drivers: Richland County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	8	26
2008	Before	10	48
2009	Before	10	37
2010	Before	9	34
2011	Before	9	34
2012	After	7	32
2013	After	12	47
2014	After	3	40
2015	After	6	38
2016	After	7	37
	Total	81	373

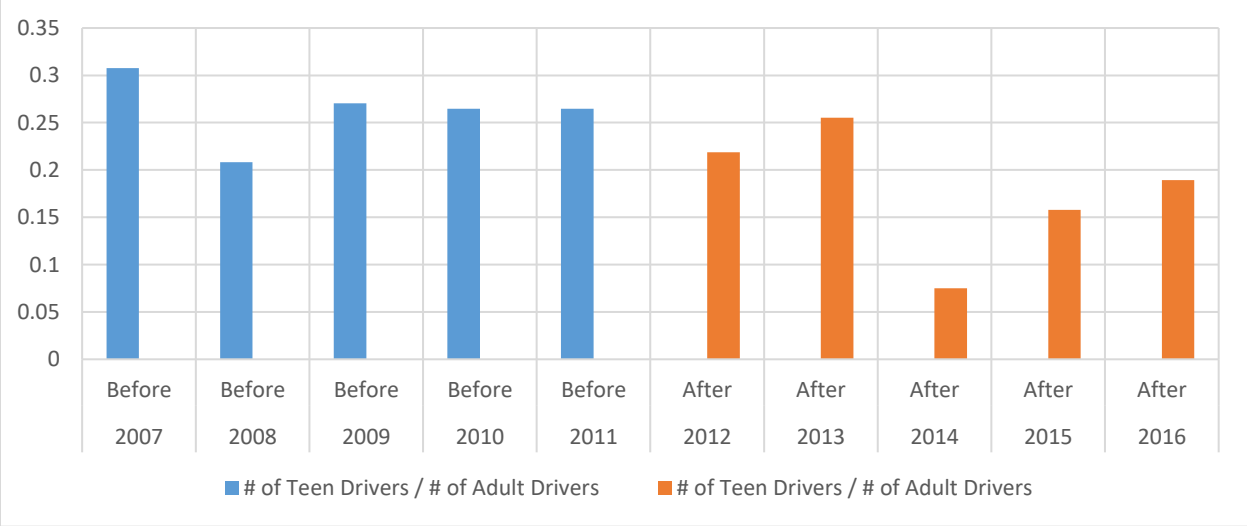


Figure C39. Ratio of Drivers: Richland County

Table C40. Number of Drivers: Rolette County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	7	32
2008	Before	1	28
2009	Before	3	25
2010	Before	7	16
2011	Before	4	27
2012	After	1	11
2013	After	1	11
2014	After	1	11
2015	After	0	5
2016	After	1	10
	Total	26	176

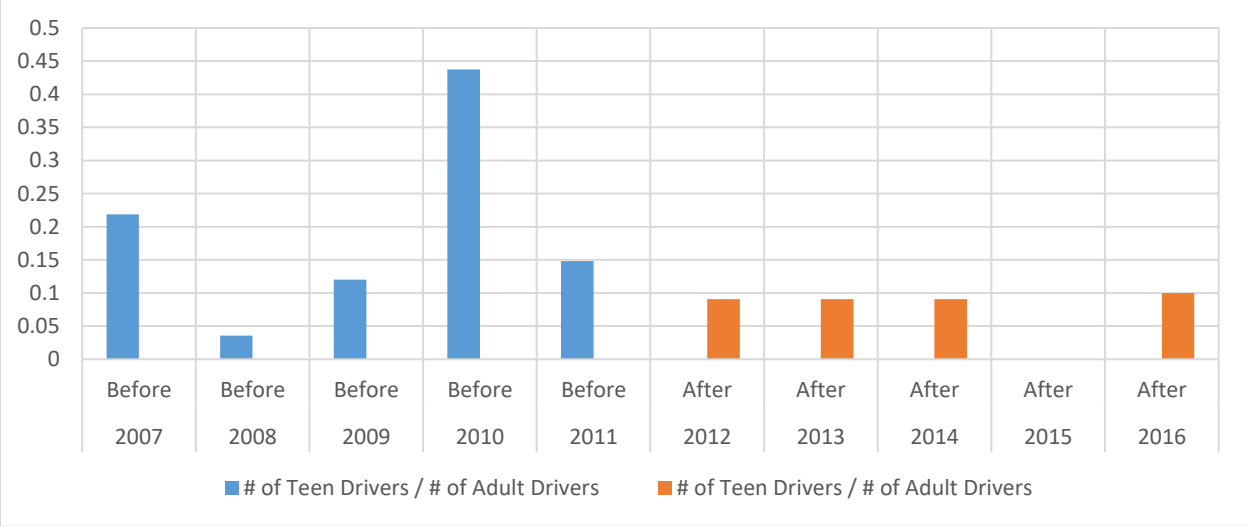


Figure C40. Ratio of Drivers: Rolette County

Table C41. Number of Drivers: Sargent County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	12
2008	Before	2	6
2009	Before	1	0
2010	Before	0	3
2011	Before	0	1
2012	After	1	2
2013	After	0	1
2014	After	1	4
2015	After	2	5
2016	After	1	6
	Total	10	40

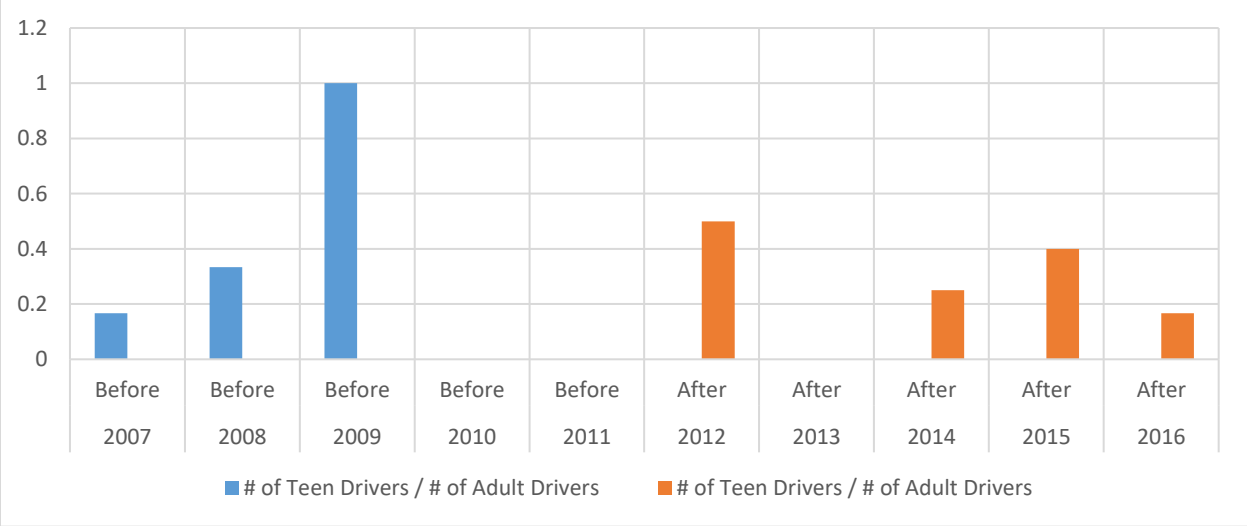


Figure C41. Ratio of Drivers: Sargent County

Table C42. Number of Drivers: Sheridan County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	4
2008	Before	0	4
2009	Before	2	2
2010	Before	1	2
2011	Before	1	5
2012	After	0	3
2013	After	2	0
2014	After	0	2
2015	After	0	3
2016	After	0	1
	Total	8	26

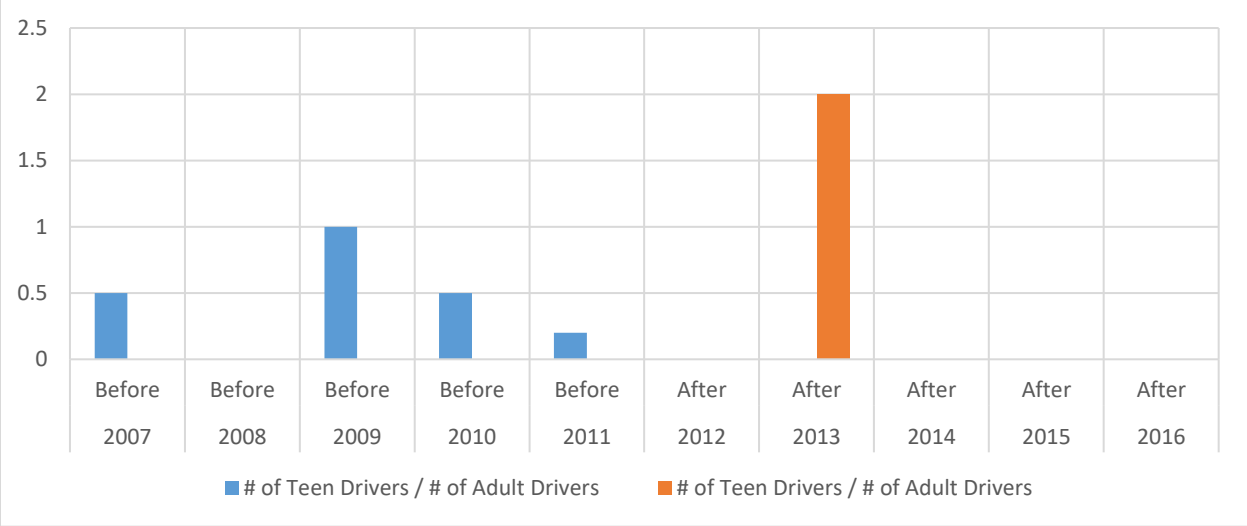


Figure C42. Ratio of Drivers: Sheridan County

Table C43. Number of Drivers: Sioux County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	1	6
2008	Before	0	5
2009	Before	0	3
2010	Before	0	0
2011	Before	0	4
2012	After	0	2
2013	After	0	4
2014	After	0	1
2015	After	0	2
2016	After	3	11
	Total	4	38

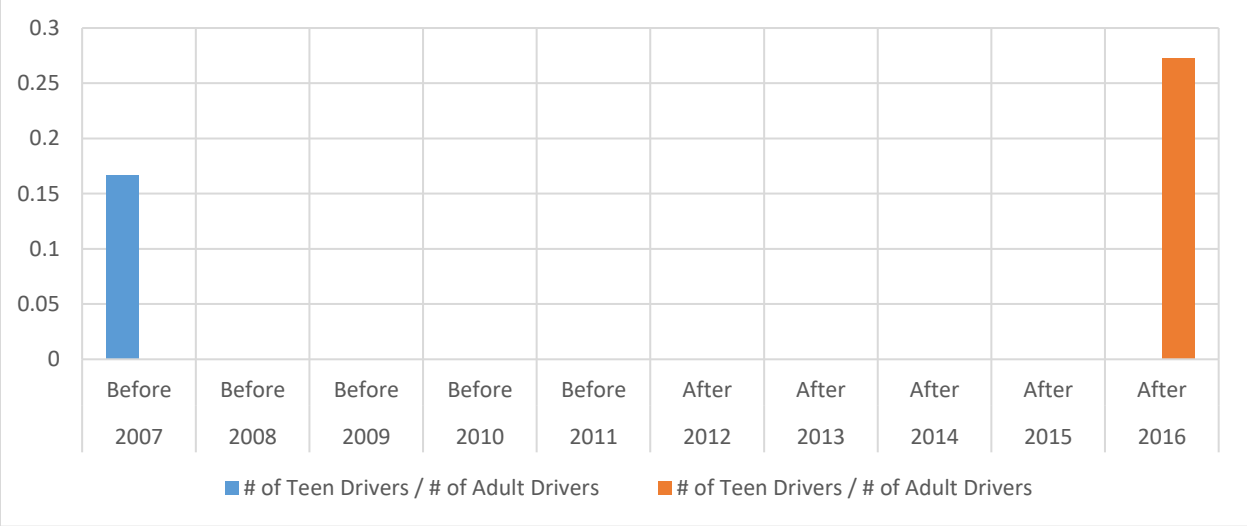


Figure C43. Ratio of Drivers: Sioux County

Table C44. Number of Drivers: Slope County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	0	0
2008	Before	0	2
2009	Before	0	0
2010	Before	1	4
2011	Before	0	0
2012	After	0	1
2013	After	0	3
2014	After	0	2
2015	After	0	4
2016	After	0	1
	Total	1	17

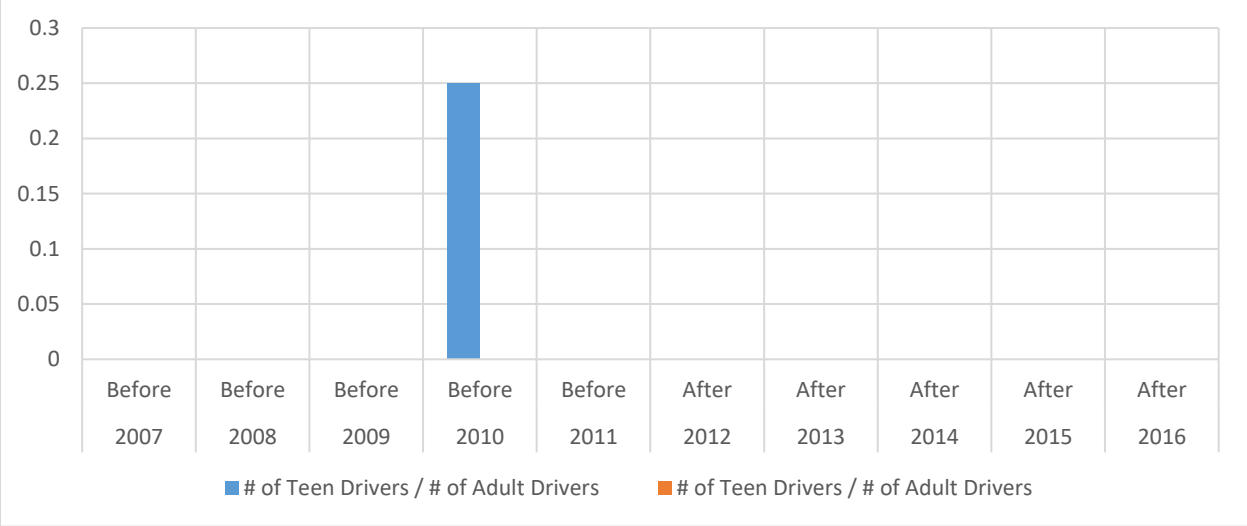


Figure C44. Ratio of Drivers: Slope County

Table C45. Number of Drivers: Stark County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	17	54
2008	Before	9	57
2009	Before	4	39
2010	Before	15	77
2011	Before	22	67
2012	After	7	101
2013	After	6	84
2014	After	8	105
2015	After	13	89
2016	After	12	68
	Total	113	741

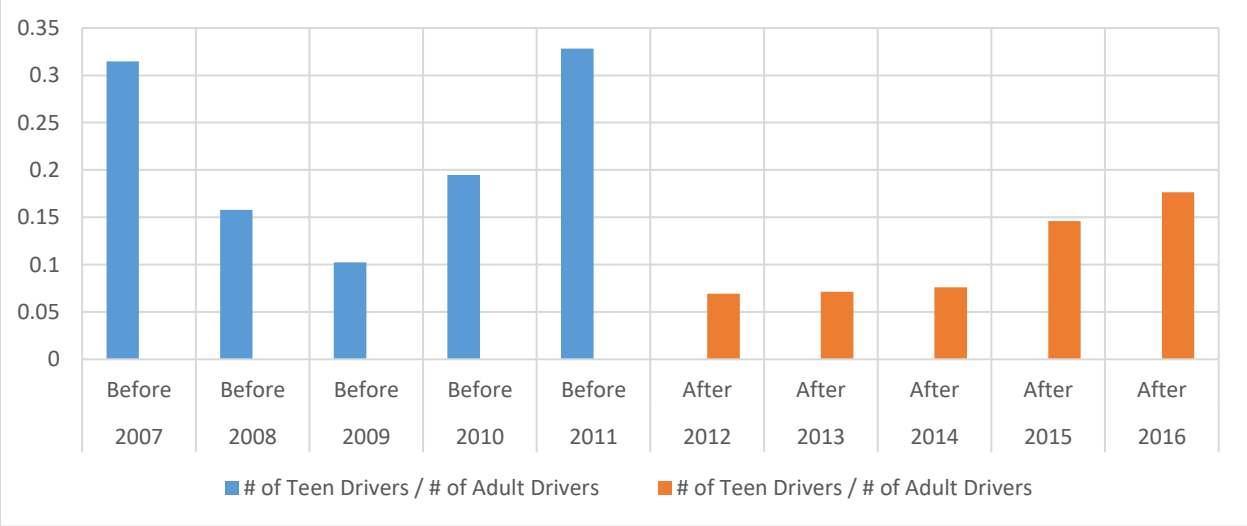


Figure C45. Ratio of Drivers: Stark County

Table C46. Number of Drivers: Steele County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	1
2008	Before	0	3
2009	Before	1	0
2010	Before	1	3
2011	Before	3	1
2012	After	2	2
2013	After	0	1
2014	After	1	1
2015	After	0	2
2016	After	0	0
	Total	10	14

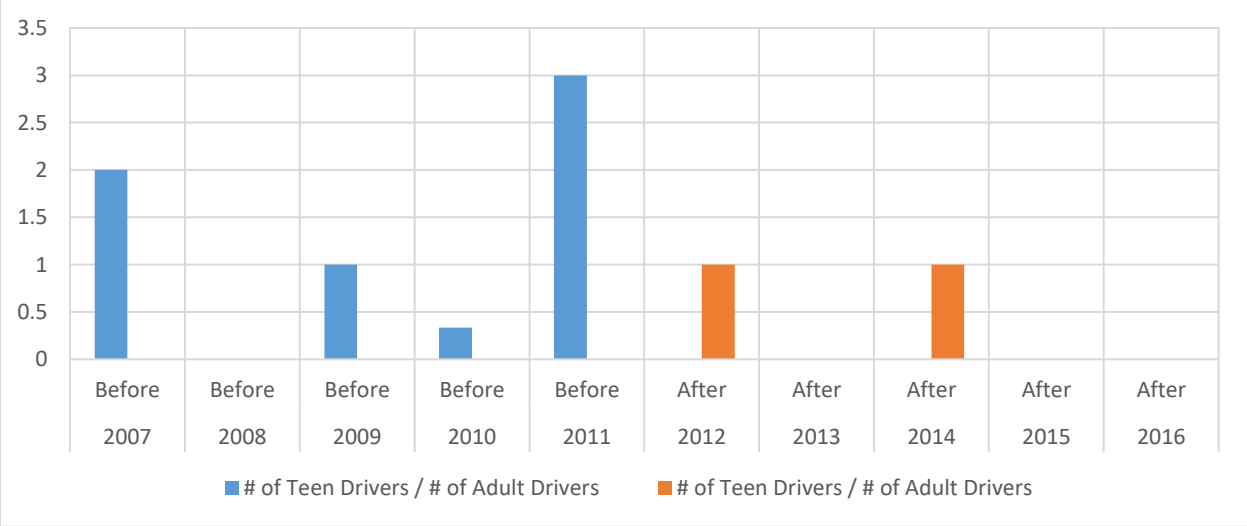


Figure C46. Ratio of Drivers: Steele County

Table C47. Number of Drivers: Stutsman County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	12	67
2008	Before	24	75
2009	Before	21	87
2010	Before	18	73
2011	Before	21	97
2012	After	11	84
2013	After	17	73
2014	After	14	78
2015	After	16	92
2016	After	15	72
	Total	169	798

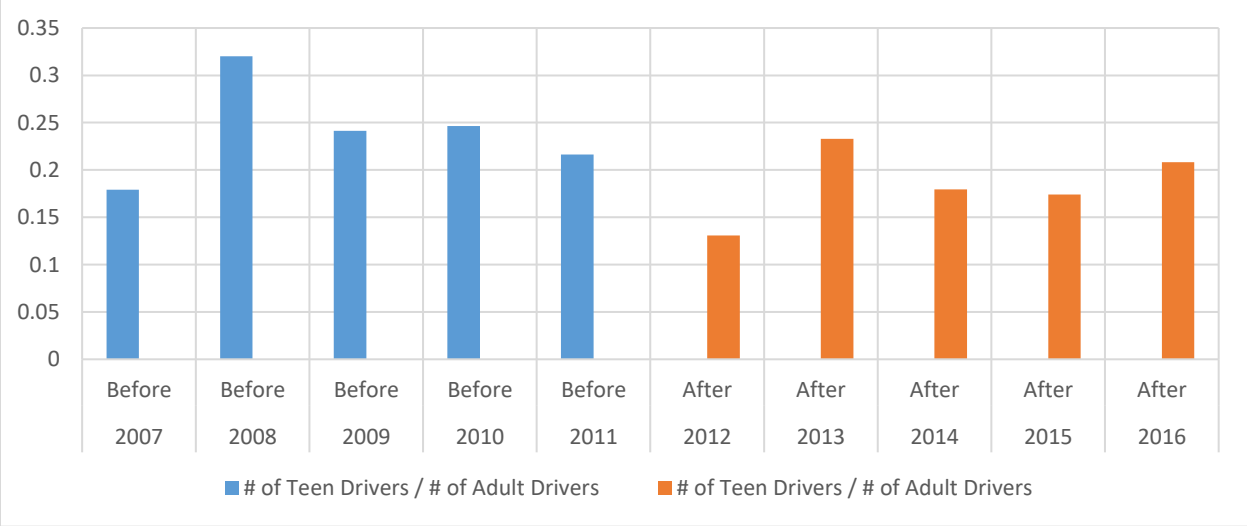


Figure C47. Ratio of Drivers: Stutsman County

Table C48. Number of Drivers: Towner County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	0	6
2008	Before	0	2
2009	Before	2	4
2010	Before	0	3
2011	Before	0	3
2012	After	0	1
2013	After	0	0
2014	After	1	0
2015	After	0	4
2016	After	0	0
	Total	3	23

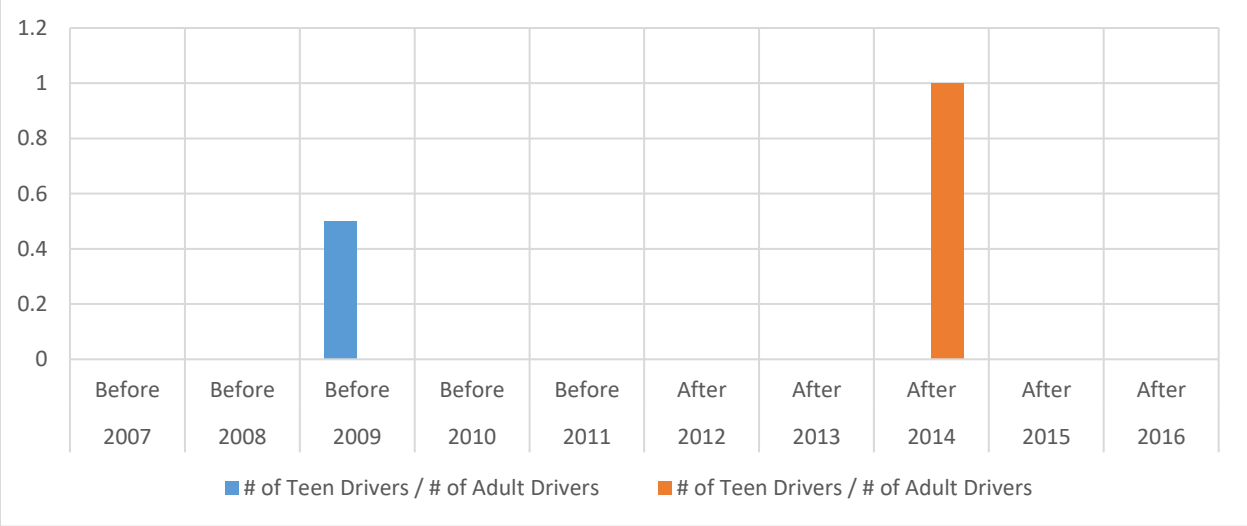


Figure C48. Ratio of Drivers: Towner County

Table C49. Number of Drivers: Traill County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	3	14
2008	Before	6	24
2009	Before	2	7
2010	Before	4	16
2011	Before	4	15
2012	After	6	15
2013	After	0	12
2014	After	3	30
2015	After	2	3
2016	After	4	12
	Total	34	148

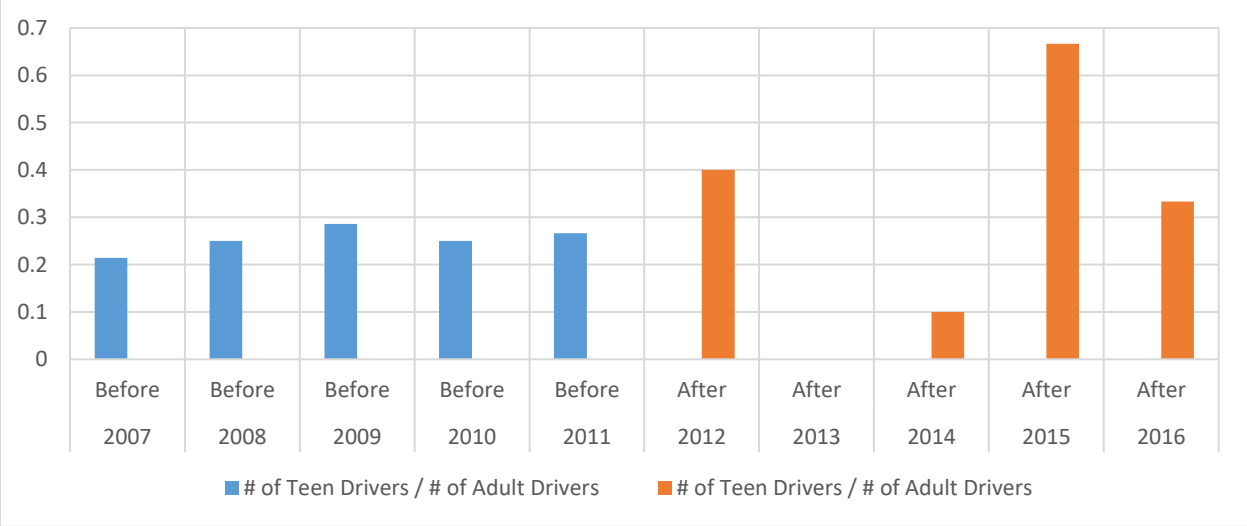


Figure C49. Ratio of Drivers: Traill County

Table C50. Number of Drivers: Walsh County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	9	29
2008	Before	5	26
2009	Before	7	37
2010	Before	6	18
2011	Before	8	29
2012	After	5	22
2013	After	5	33
2014	After	4	22
2015	After	1	23
2016	After	4	16
	Total	54	255

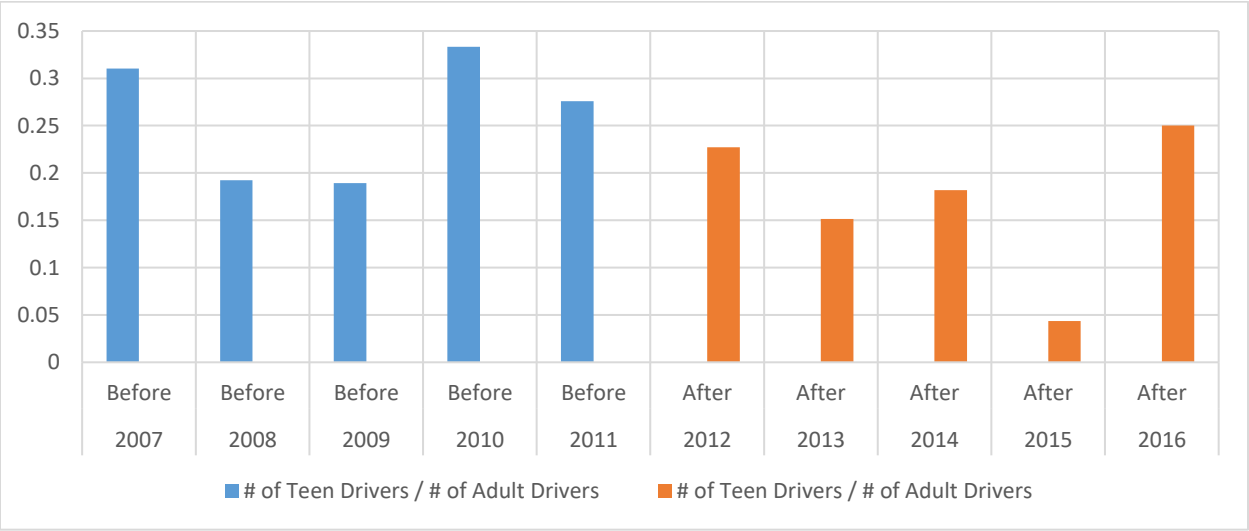


Figure C50. Ratio of Drivers: Walsh County

Table C51. Number of Drivers: Ward County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	34	186
2008	Before	37	159
2009	Before	38	194
2010	Before	50	227
2011	Before	26	256
2012	After	45	294
2013	After	21	257
2014	After	24	248
2015	After	38	265
2016	After	35	235
	Total	348	2,321

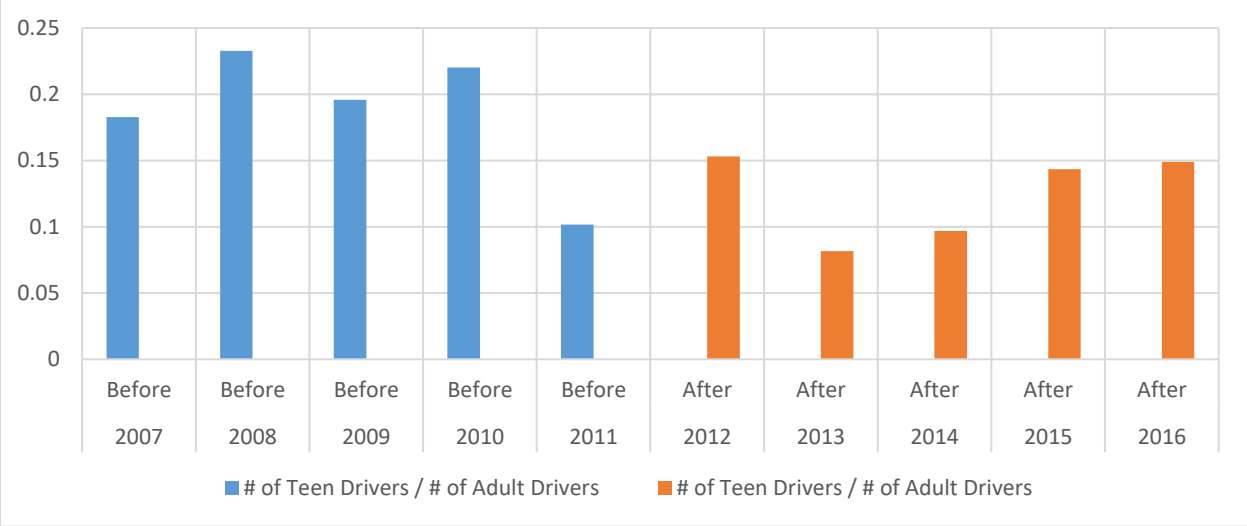


Figure C51. Ratio of Drivers: Ward County

Table C52. Number of Drivers: Wells County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	2	3
2008	Before	3	7
2009	Before	3	5
2010	Before	3	11
2011	Before	1	11
2012	After	0	12
2013	After	1	9
2014	After	1	7
2015	After	2	9
2016	After	2	1
	Total	18	75

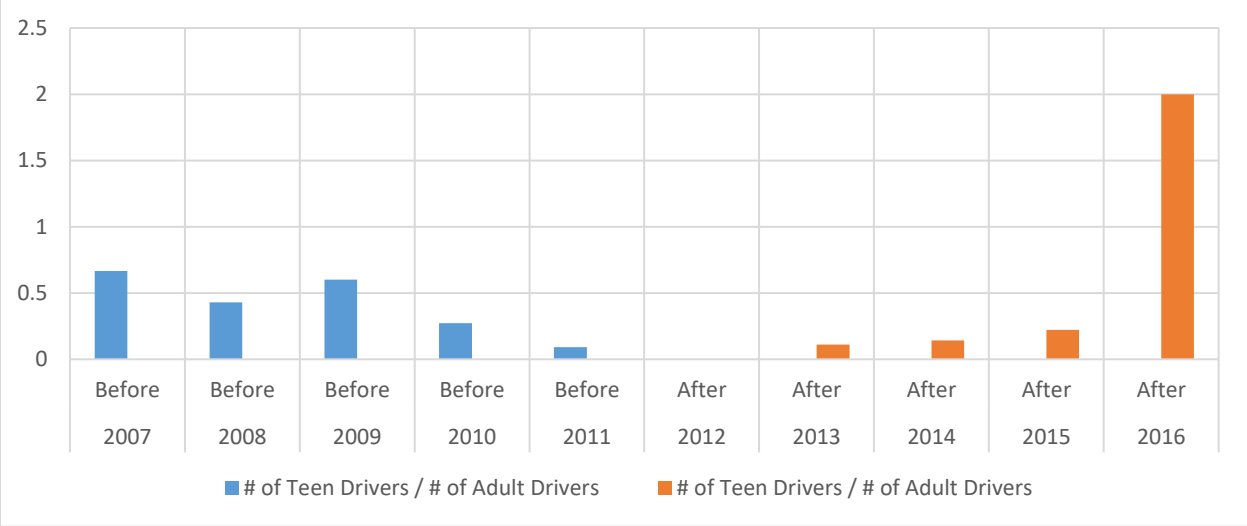


Figure C52. Ratio of Drivers: Wells County

Table C53. Number of Drivers: Williams County

Year	Period	# of Teen Drivers	# of Adult Drivers
2007	Before	12	50
2008	Before	18	61
2009	Before	14	78
2010	Before	26	99
2011	Before	15	193
2012	After	16	260
2013	After	14	225
2014	After	12	273
2015	After	17	189
2016	After	16	110
	Total	160	1,538

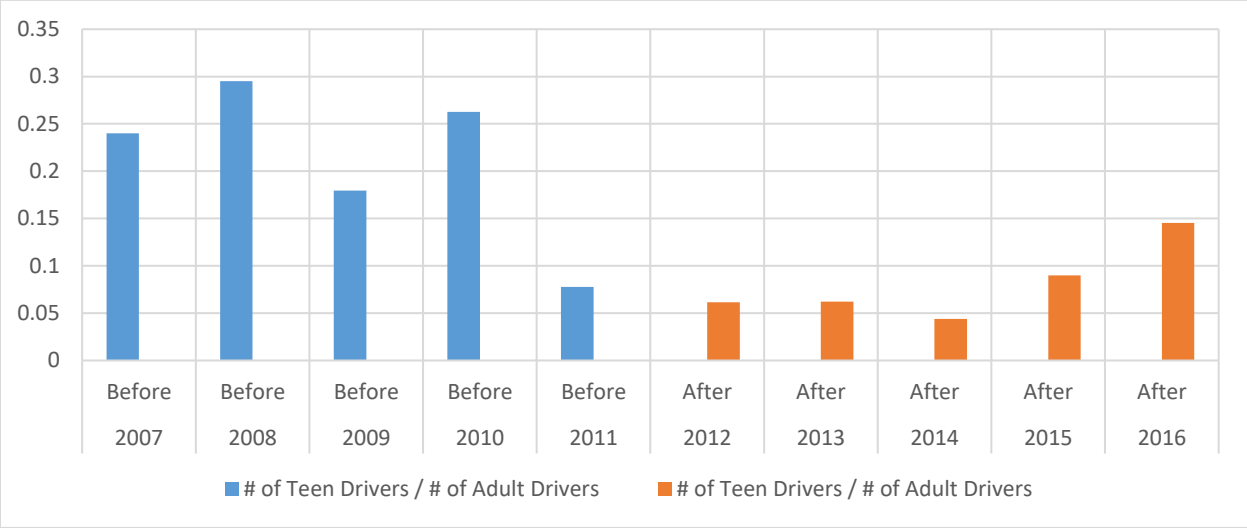


Figure C53. Ratio of Drivers: Williams County

APPENDIX D. LOGISTIC REGRESSION MODEL VARIABLES

Table D1. List of Class, Value, and Design Variables

Class	Value	Design variable		
Period	After	1		
	Before	-1		
Age	14	1	0	0
	15	0	1	0
	16	0	0	1
	17	-1	-1	-1
Gender	F	1		
	M	-1		
Urban/Rural	Rural	1		
	Urban	-1		
State/Local	Local	1		
	State	-1		
Impaired	0	1		
	1	-1		
Restraint	0	1		
	1	-1		
Distracted	0	1		
	1	-1		
Speeding	0	1		
	1	-1		
Passenger	AtLeastOneAdultPassenger	1	0	0
	NoPassenger	0	1	0
	OnlyTeenPassenger	0	0	1
	Other	-1	-1	-1
Teen Passenger	MANYTeen Passenger	1	0	
	ONETeen Passenger	0	1	
	Other	-1	-1	
Single/Multi	Multi Vehicle	1		
	Single Vehicle	-1		
Speed Limit	10-35	1	0	
	45-55	0	1	
	60-75	-1	-1	

APPENDIX E. COUNTY LEVEL PART A

Table E1. P-value for Chi-Square, statistically significant at alpha = 0.05

	Number of Subjects in the Stratum	P-value for Chi-Square	Exact P-value for Chi-Square	P-value < a=0.05?
Adams	29	0.033	0.054	X
Barnes	304	0.078	0.098	X
Benson	109	0.139	0.161	X
Billings	41	0.052	0.116	X
Bottineau	121	0.101	0.118	X
Bowman	46	0.559	0.739	X
Burke	68	0.400	0.471	X
Cavalier	61	0.206	0.294	X
Divide	84	0.333	0.438	X
Dunn	197	0.240	0.327	X
Eddy	48	0.936	1.000	X
Foster	61	0.203	0.269	X
Golden Valley	39	0.215	0.374	X
Grand Forks	3,106	0.315	0.342	X
Grant	49	0.945	1.000	X
Griggs	20	0.091	0.260	X
Hettinger	51	0.714	0.746	X
Kidder	86	0.151	0.175	X
LaMoure	60	0.366	0.409	X
Logan	29	0.104	0.192	X
McHenry	160	0.240	0.305	X
McIntosh	40	0.369	0.494	X

Table E1. P-value for Chi-Square, statistically significant at alpha = 0.05 (continued)

	Number of Subjects in the Stratum	P-value for Chi-Square	Exact P-value for Chi-Square	P-value < a=0.05?
McKenzie	879	0.062	0.076	X
McLean	268	0.612	0.645	X
Mercer	175	0.670	0.718	X
Mountrail	436	0.079	0.086	X
Nelson	54	0.223	0.286	X
Oliver	39	0.506	0.647	X
Pierce	75	0.066	0.113	X
Ramsey	323	0.330	0.401	X
Ransom	91	0.070	0.083	X
Renville	63	0.514	0.572	X
Richland	454	0.151	0.178	X
Rolette	202	0.196	0.237	X
Sargent	50	0.777	1.000	X
Sheridan	34	0.611	0.694	X
Sioux	42	0.393	0.613	X
Slope	18	0.197	0.389	X
Steele	24	0.521	0.678	X
Stutsman	967	0.108	0.127	X
Towner	26	0.654	1.000	X
Traill	182	0.633	0.705	X
Walsh	309	0.165	0.177	X
Wells	93	0.186	0.203	X

APPENDIX F. COUNTY LEVEL PART B

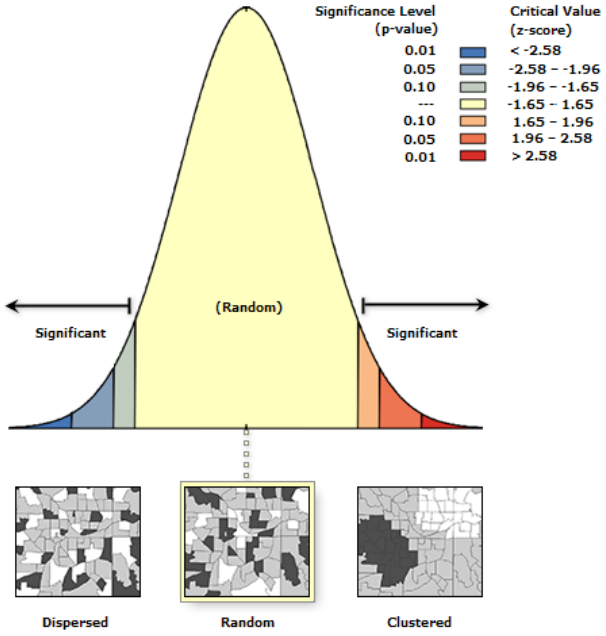


Figure F1. Global Moran's Index Summary, Teen Driver, Pre-GDL, Urban

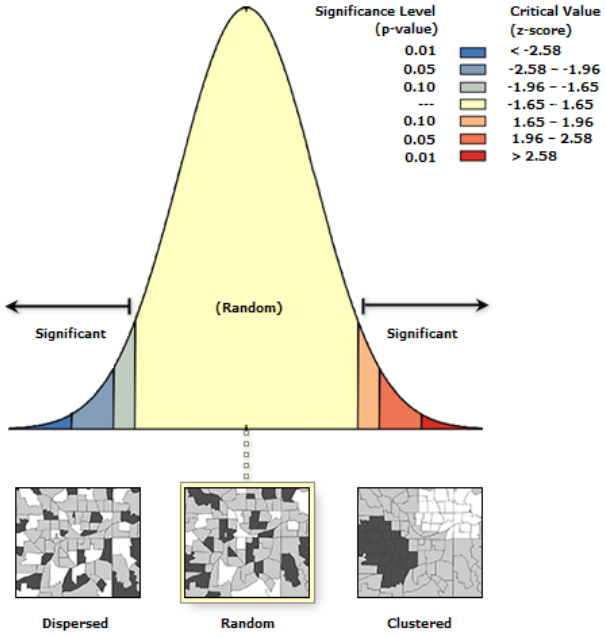


Figure F2. Global Moran's Index Summary, Teen Driver, Pre-GDL, Rural

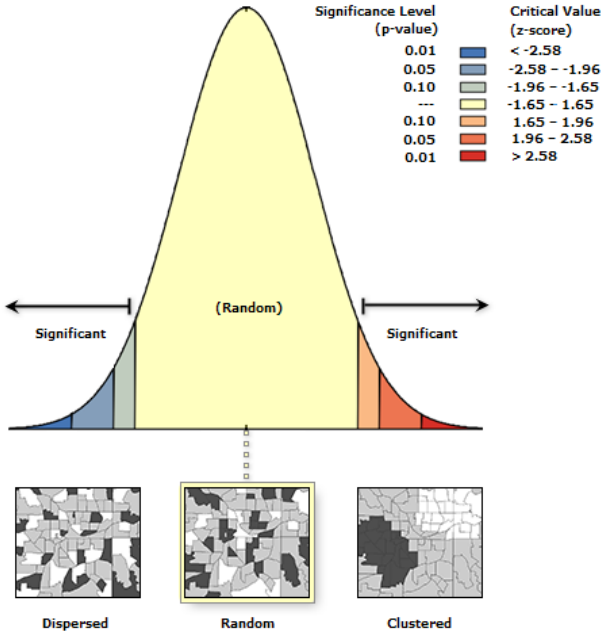


Figure F3. Global Moran's Index Summary, Teen Driver, Pre-GDL, State

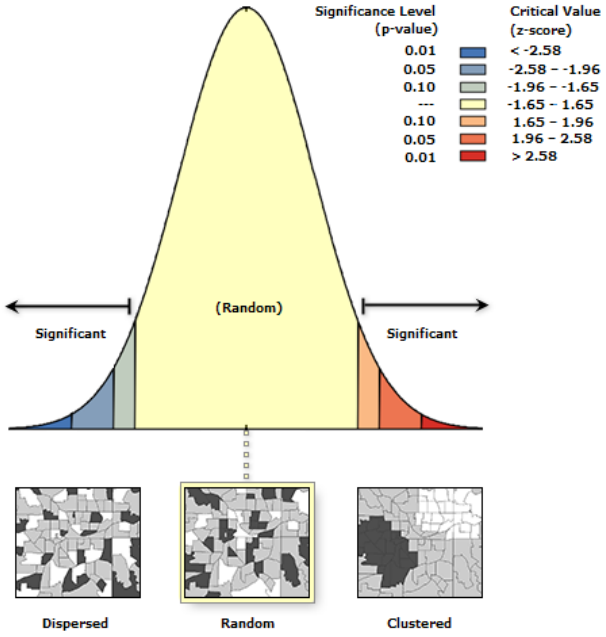


Figure F4. Global Moran's Index Summary, Teen Driver, Pre-GDL, Local

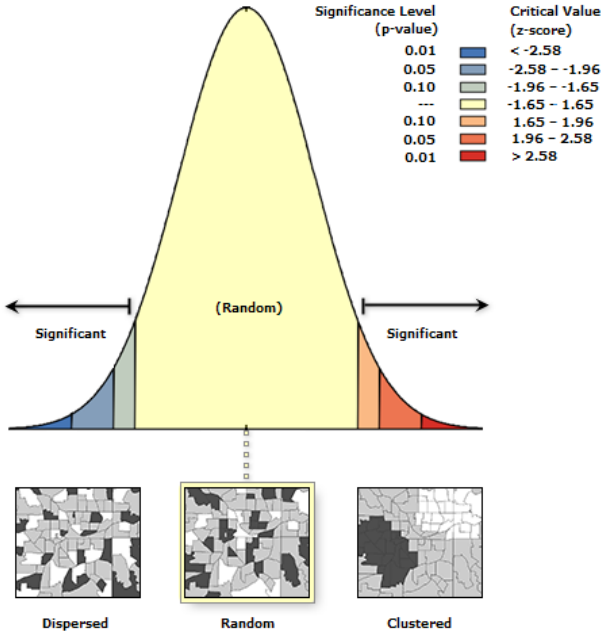


Figure F5. Global Moran's Index Summary, Teen Driver, Post-GDL, Urban

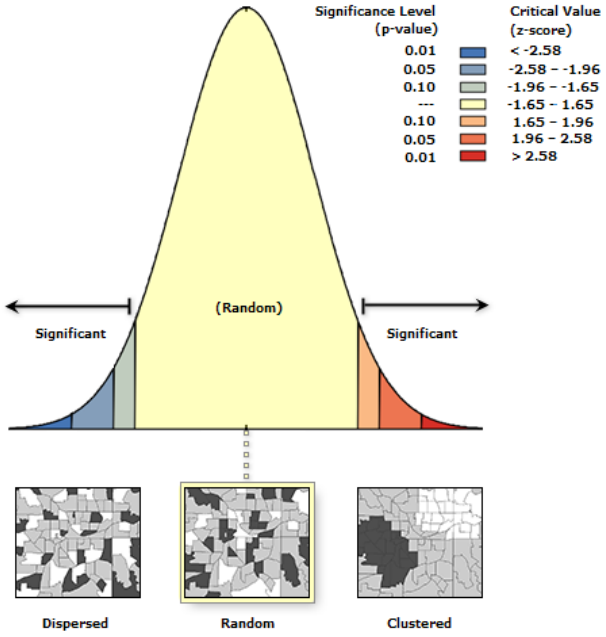


Figure F6. Global Moran's Index Summary, Teen Driver, Post-GDL, Rural

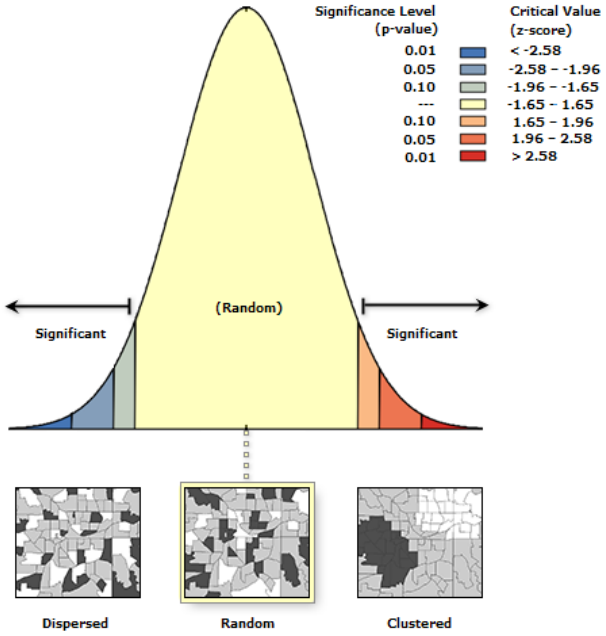


Figure F7. Global Moran's Index Summary, Teen Driver, Post-GDL, State

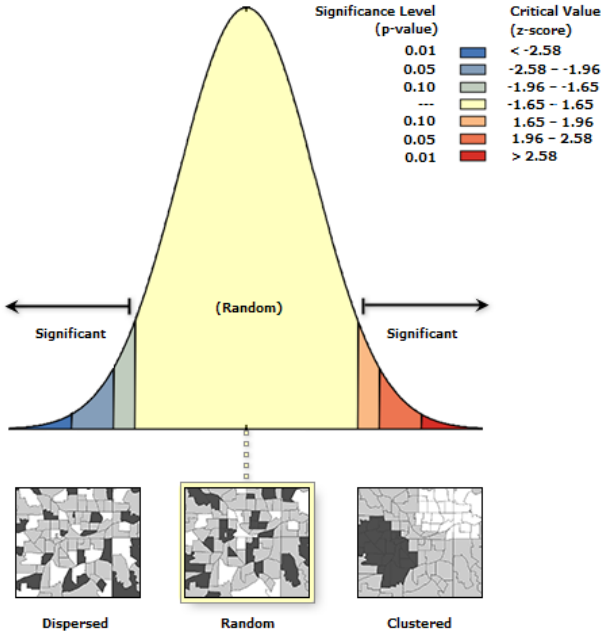


Figure F8. Global Moran's Index Summary, Teen Driver, Post-GDL, Local

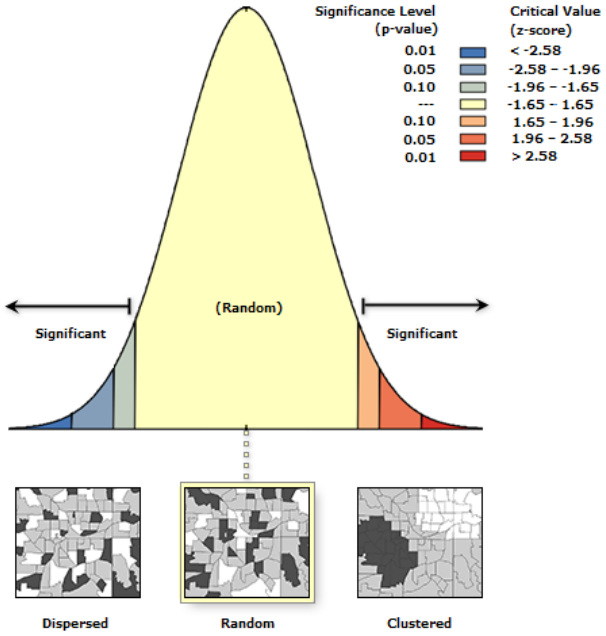


Figure F9. Global Moran's Index Summary, Adult Driver, Pre-GDL, Urban

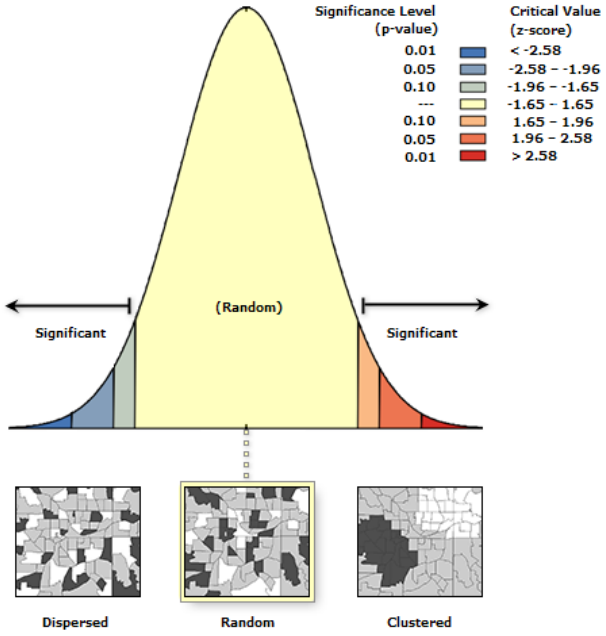


Figure F10. Global Moran's Index Summary, Adult Driver, Pre-GDL, Urban

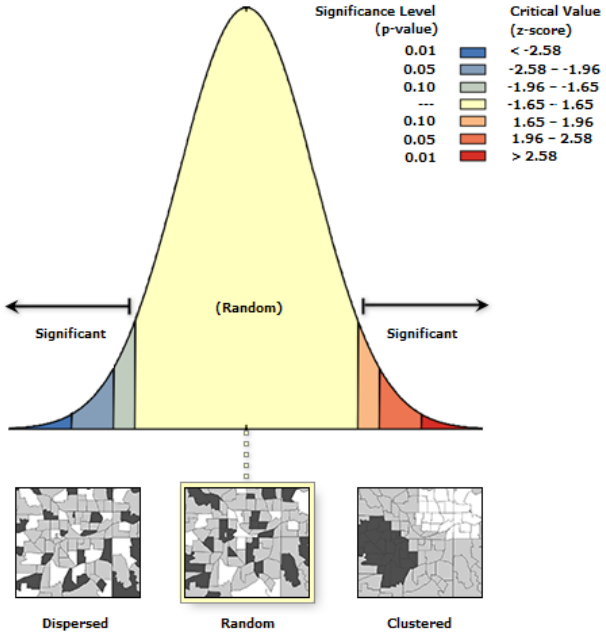


Figure F11. Global Moran's Index Summary, Adult Driver, Pre-GDL, Rural

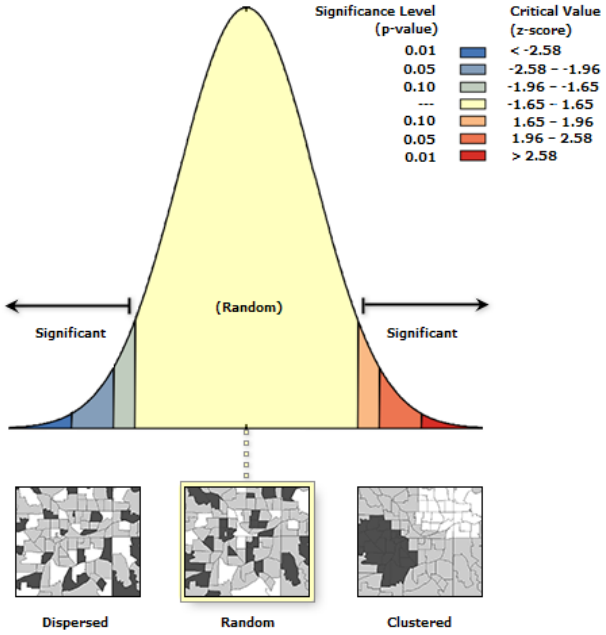


Figure F12. Global Moran's Index Summary, Adult Driver, Pre-GDL, State

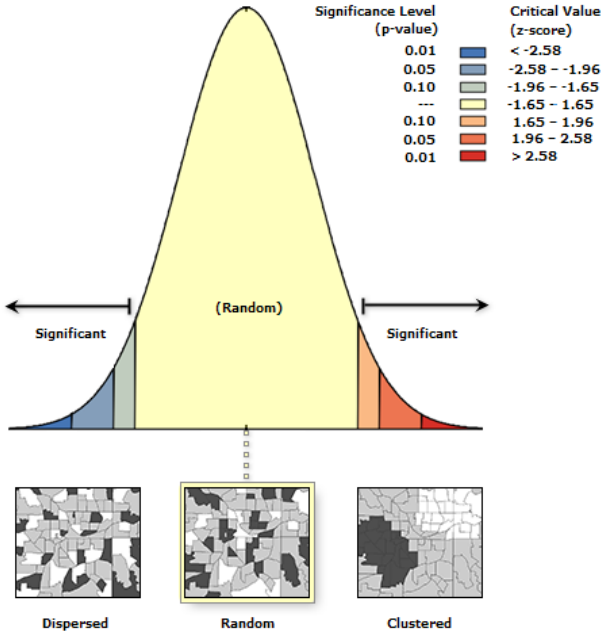


Figure F13. Global Moran's Index Summary, Adult Driver, Pre-GDL, Local

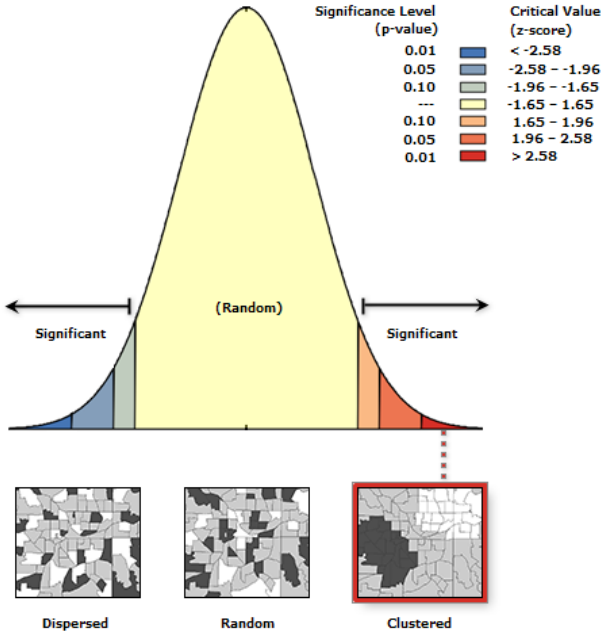


Figure F14. Global Moran's Index Summary, Adult Driver, Post-GDL, Rural

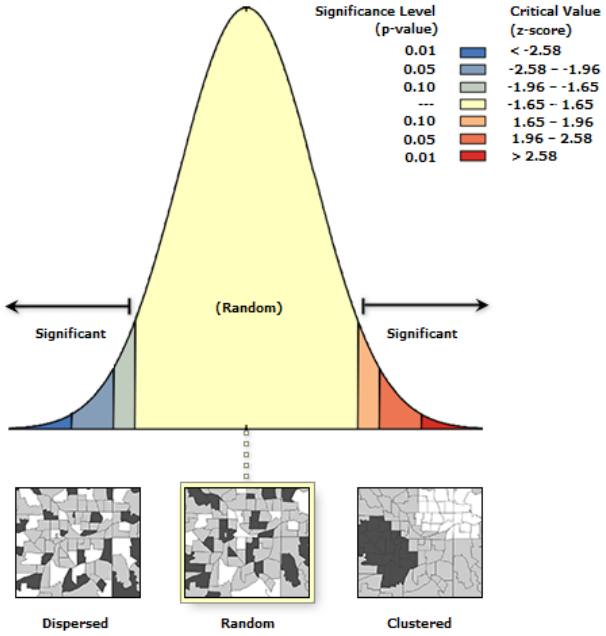


Figure F15. Global Moran's Index Summary, Adult Driver, Post-GDL, State

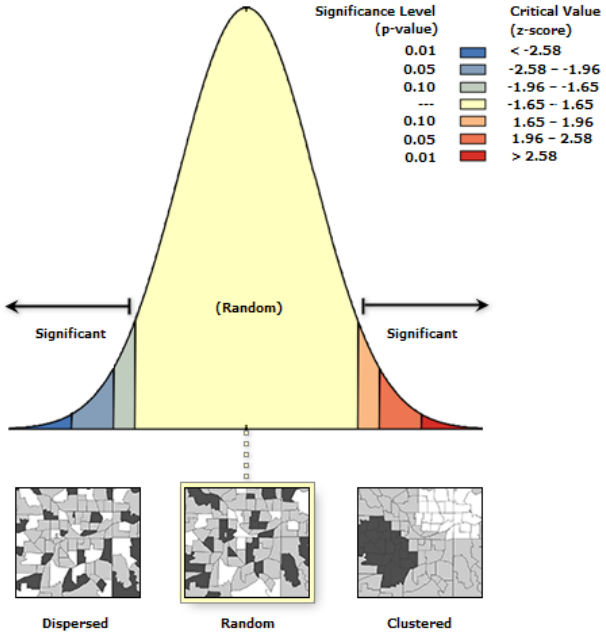


Figure F16. Global Moran's Index Summary, Adult Driver, Post-GDL, Local

APPENDIX G. MAIN EFFECT MODEL STATISTICS

Table G1. Main Effects Model Statistics: Adult Drivers, Age Variable

Parameter	Value	Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Significant at alpha = 0.05?
Age	25	0.5523	0.2133	6.7018	0.0096	✓
Age	26	0.3078	0.2097	2.1552	0.1421	✗
Age	27	0.4793	0.2162	4.9144	0.0266	✓
Age	28	0.3635	0.2123	2.9313	0.0869	✗
Age	29	0.2929	0.2132	1.8874	0.1695	✗
Age	30	0.2156	0.2143	1.0122	0.3144	✗
Age	31	0.3709	0.2301	2.5990	0.1069	✗
Age	32	0.7593	0.2379	10.1909	0.0014	✓
Age	33	0.4895	0.2330	4.4149	0.0356	✓
Age	34	0.0616	0.2213	0.0776	0.7806	✗
Age	35	0.6319	0.2522	6.2779	0.0122	✓
Age	36	-0.0316	0.2170	0.0212	0.8842	✗
Age	37	0.3051	0.2356	1.6763	0.1954	✗
Age	38	0.2691	0.2363	1.2968	0.2548	✗
Age	39	0.4907	0.2526	3.7741	0.0521	✗
Age	40	0.0871	0.2314	0.1418	0.7065	✗
Age	41	0.2840	0.2394	1.4072	0.2355	✗
Age	42	0.1026	0.2317	0.1962	0.6578	✗
Age	43	0.1129	0.2305	0.2401	0.6241	✗
Age	44	0.1758	0.2385	0.5437	0.4609	✗
Age	45	0.0310	0.2319	0.0179	0.8935	✗
Age	46	0.2345	0.2431	0.9301	0.3348	✗
Age	47	0.2649	0.2451	1.1680	0.2798	✗
Age	48	0.2977	0.2416	1.5173	0.2180	✗
Age	49	0.4843	0.2512	3.7179	0.0538	✗
Age	50	0.3715	0.2442	2.3155	0.1281	✗
Age	51	0.4934	0.2539	3.7753	0.0520	✗
Age	52	0.4333	0.2512	2.9752	0.0846	✗
Age	53	0.1760	0.2419	0.5294	0.4669	✗

Table G2. Odds Ratio Estimates with 95% CI: Teen Driver Model, Age Variable

Effect	Estimate	95% Confidence Limits	
Age 25 vs 54	1.737	1.137	2.629
Age 26 vs 54	1.360	0.896	2.042
Age 27 vs 54	1.615	1.052	2.459
Age 28 vs 54	1.438	0.943	2.172
Age 29 vs 54	1.340	0.878	2.028
Age 30 vs 54	1.241	0.811	1.881
Age 31 vs 54	1.449	0.921	2.274
Age 32 vs 54	2.137	1.340	3.411
Age 33 vs 54	1.631	1.032	2.576
Age 34 vs 54	1.064	0.686	1.637
Age 35 vs 54	1.881	1.150	3.098
Age 36 vs 54	0.969	0.630	1.477
Age 37 vs 54	1.357	0.854	2.155
Age 38 vs 54	1.309	0.822	2.081
Age 39 vs 54	1.633	0.998	2.694
Age 40 vs 54	1.091	0.692	1.716
Age 41 vs 54	1.328	0.830	2.127
Age 42 vs 54	1.108	0.702	1.744
Age 43 vs 54	1.120	0.711	1.758
Age 44 vs 54	1.192	0.746	1.905
Age 45 vs 54	1.032	0.653	1.624
Age 46 vs 54	1.264	0.785	2.041
Age 47 vs 54	1.303	0.807	2.114
Age 48 vs 54	1.347	0.839	2.167
Age 49 vs 54	1.623	0.994	2.668
Age 50 vs 54	1.450	0.899	2.346
Age 51 vs 54	1.638	0.998	2.708
Age 52 vs 54	1.542	0.945	2.536
Age 53 vs 54	1.192	0.742	1.920