Identifying Factors That Predict Teen Driver Crashes

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ABSTRACT

Reducing crashes, in particular those that result in injury or fatality, is an ongoing struggle for agencies tasked with making our roads safer. The ability to predict these crashes would allow the agencies to develop interventions to change drivers' behavior and ultimately reduce the number of these crashes. Teen drivers are ideally suited for this type of intervention for several reasons. They are disproportionately over-represented in crashes – teens account for only 4% of the driver population but account for 10% of crashes (Vachal and Malchose, 2009). Also, many teen crashes occur within the first year of being licensed and are the result of a lack of driving experience. Lastly, the learning curve is still steep at this point in teens' driving history which makes them more susceptible to interventions.

In an attempt to predict these crashes, North Dakota driver licensing data and crash data were used to develop a sample of 20,392 teen drivers age 14 to 17. Within the first year after being licensed, these drivers sustained 317 crashes that resulted in an injury or death. The resulting logistic regression model identifies gender, traffic convictions, rural/urban, geography, and involvement in previous property-damage-only (PDO) crashes as markers that are significant in predicting these injury and fatal crashes. According to the model, living in an urban area increases risk of being in an injury or fatal crash within the first year after attaining a license by 2.5 times compared to drivers who live in rural areas. Drivers involved in a previous PDO crash are 25 times more likely to be involved in an injury or fatal crash than those not involved in a previous PDO crash. These results can be used in a driver improvement program. One application may be an advisory or warning letter targeted to teen drivers suggesting additional training or guidance for those who exhibit the above markers. Hopefully, this letter will alter their behavior and reduce their likelihood of being involved in an injury or fatal crash.

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1. INTRODUCTION

In 2009, there were 140 fatalities and 4,462 injuries resulting from 17,673 traffic crashes in North Dakota (NDDOT 2009). Teen drivers are disproportionately represented in these numbers. The increased crash risk for teen drivers is well established. Williams (2003) shows that this increased risk is independent of whether crash risk is measured in terms of licensed drivers, population, or miles traveled. North Dakota teens are no exception to this increased risk. Teen drivers in North Dakota account for only 4% of the driver population, but account for 10% of crashes (Vachal and Malchose 2009).

Newly licensed drivers also exhibit additional crash risk. During the first month after licensure, crash rates among novice drivers are as high as 123 per 10,000. By the seventh month after licensure, this rate drops to 73 per 10,000, a 41% decrease. The decline becomes more gradual through the 24th month when it is 60% lower than the first month (Mayhew, Simpson, and Pak 2003). This increased crash risk among novice drivers is compounded when comparing novice teen drivers to older novice drivers. In fact, in the first month after licensure the crash rate among novice drivers, age 16 to 19, is twice the rate, 114 compared to 56, of older novice drivers, age 20 and older. These higher rates for young novice drivers persist in each of the first 24 months of licensure, including a 45% difference in the 24th month (Mayhew, Simpson, and Pak 2003).

Identifying high-risk drivers and crash risk factors, which can be used to predict future crashes, is a goal of licensing and traffic safety agencies. Having the capability to accurately predict future crashes would allow these agencies to develop interventions focused on removing or minimizing this additional risk and modifying driving behavior. In particular, reducing injury and fatal crashes are a high priority because of the high costs both human and economic associated with those crashes (Malchose and Vachal 2010).

Many studies have added to the discussion of identifying markers to aid in predicting crashes. Early on, Peck (1971) suggested that by the statistical nature of driver crash frequencies it is difficult to accurately predict who will and will not be involved in crashes. More recently advances in the field have led Lui and Marchbanks (1990) to suggest that involvement in a fatal crash is not a random event. This belief is held by others working in the area, including Chandraratna, Stamatiadis, and Stromberg (2006), Hauer (1991), and Chen (1995). These findings give hope that interventions can be found that will prevent crashes and reduce the number and severity of injuries.

These interventions might range from simple driver improvement letters, to changes in existing policy, to implementation of new policy. Driver improvement letters have been shown to be effective in preventing crashes although this effectiveness varies by type of letter, age and gender of the targeted driver (Jones, 1997, Kaestner, et. al. 1965, Masten and Peck 2004, McBride and Peck 1970) and are most likely less effective than more policy orientated interventions. Moving from a secondary seatbelt law to a primary seatbelt law and implementing a comprehensive graduated driver licensing program are just a couple of the policy interventions which have been used successfully in other states.

The goal of this research is to identify those crash risk factors exhibited by North Dakota teens, and identify when and to whom interventions should be applied to reduce crash injury and death. Having confirmed the high crash risk for North Dakota teens in the months following licensure, it makes sense to target interventions to drivers during this timeframe. The data shows that injury and fatal crash rates remain very high till the eighth month after licensure when the rate starts to drop and level off. Therefore, focusing on identifying factors that will predict injury and fatal crashes within the first year after licensure covers this high-risk time while also providing analytical convenience. The types of interventions to be applied are a matter for further investigation and will depend on funding and the state's ability to implement driver improvement programs through existing or new state policies.

2. METHODS

2.1 Data

North Dakota Drivers' License (NDDL) data from 2006 to 2009 was used in the analysis. This includes information on license status, road test results, citations, and crashes. All information is complete with the exception of the license status information. License status continually changes as drivers become licensed, deceased or suspended for various reasons. However, it is not currently feasible to track daily license status changes after the fact. So in place of a history of license's status, the current status of each license was captured in a single yearly file.

Using the NDDL data, all drivers holding only a class D, or both a class D and class M license, were identified along with the date they passed their class D road test. Drivers with any other class of license were excluded from the analysis to reduce the variation in miles traveled, type of vehicles driven, and driving situations encountered which all affect crash risk. Selecting only holders of a class D license ensures a more homogeneous sample of drivers and improves detection of risk factors by removing the confounding factors mention above. North Dakota driver's license classes are listed in Table 2.1.

Only drivers who first passed their road test between January 1, 2006, and December 31, 2008, and did not re-take the test during the same timeframe, were selected for the analysis. Eliminating drivers who had to re-test would ensure that they were a license holder for the entire time. This license is an unrestricted license and can be obtained when a person is at least 14 years and six months old. The class D drivers also had to have a matching license status record at the beginning of 2009 that indicated they had either a current or temporary license, including suspended licenses. Suspended license holders were included due to that fact that the reason they are suspended might be a crash involving driving under the influence, and that the crash could be predicted.

Table 2.1 North Dakota Drivers' License Classes

Class	Description
A	Any combination of vehicles with a gross combination weight rating of 26,001 pounds or more, provided the GVWR of the vehicle(s) being towed is in excess of 10,000 pounds. (Holders of a Class A license with applicable endorsements may operate Class B, C, and D vehicle groups, but not a Class M.)
B	Any single vehicle with gross vehicle weight rating of 26,001 pounds or more and any such vehicle towing a vehicle not in excess of 10,000 pounds. (Holders of a Class B license with applicable endorsements may operate Class C and D vehicle groups, but not Class M.)
C	Any single vehicle with a gross vehicle weight rating of 26,000 pounds or less, any such vehicle towing a vehicle with a gross weight rating not in excess of 10,000 pounds comprising :Vehicles designed to transport 16 or more passengers, including the driver; and Vehicles used in the transportation of hazardous materials under 49 CFR Part 172(placarded material) and 42 CFR part 73. Holders of a Class C license may operate a Class D vehicle, but not a Class M vehicle.
D	Any single vehicle less than 26,001 pounds GVWR; may tow vehicles not in excess of 10,000 pounds. Trucks towing trailers, semi-trailers, or farm trailers not over 16,000 pounds gross weight; not to exceed 26,000 Gross Combination Weight Rating (GCWR). Not valid for Class A,B,C, or M.
M	Any two or three wheeled motorcycle.

The sample was then limited to teen drivers, age 14 to 17, based on their age at the date of licensing (i.e., their road test date). Applying the above criteria left 20,392 drivers in the sample. These drivers were involved in a total of 317 crashes resulting in an injury or fatality during their first year of licensure.

2.2 North Dakota Teen Crashes

It is well documented that teen drivers are at increased risk of crashes (Shope 2006, Williams 2003, and Williams and Ferguson 2002). Researchers concur on many of the factors that elevate crash risk. These include age, gender, lack of driving experience, night time driving, alcohol use, risk-seeking behavior, and the presence of teen passengers in the vehicle. North Dakota teens are no exception to this increased crash risk (Vachal and Malchose 2009).

Using the NDDL data for 2006 to 2008, the population of currently licensed drivers was compared by age group to the crashes involving those drivers. Teen drivers are found to be disproportionately over-represented in the crashes. From Figure 2.1, we see that this over-representation exists in the 14 to 18 age group and the 19 to 24 age group. The two youngest groups of drivers represent fewer than 17% of all drivers, but more than 32% of all crashes. Drivers in the both the 25 to 34 and the 35 to 44 age groups are roughly equally represented in both populations, while drivers beyond the 25 to 34 age group become under-represented in the crash population.

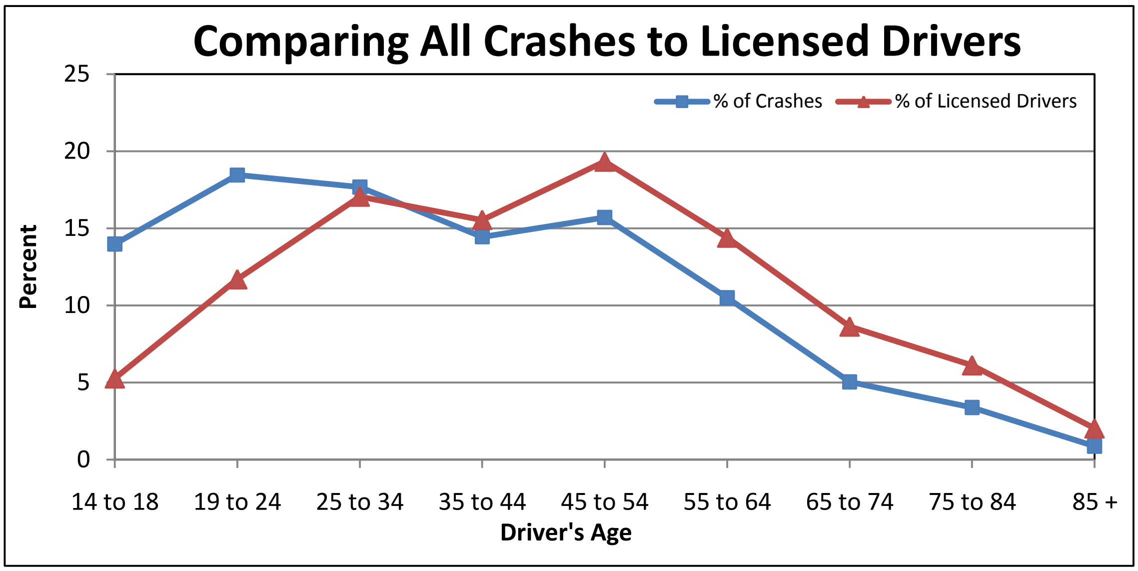

Figure 2.1 Comparison of All Crashes to Licensed Drivers, 2006 to 2008.

This over-representation persists when the data is limited to crashes that result in an injury or a fatality. Figure 2.2 shows that the two youngest groups are again over-represented in the crashes while the next two oldest age groups are roughly equally represented with the remaining age groups again under-represented in the crashes.

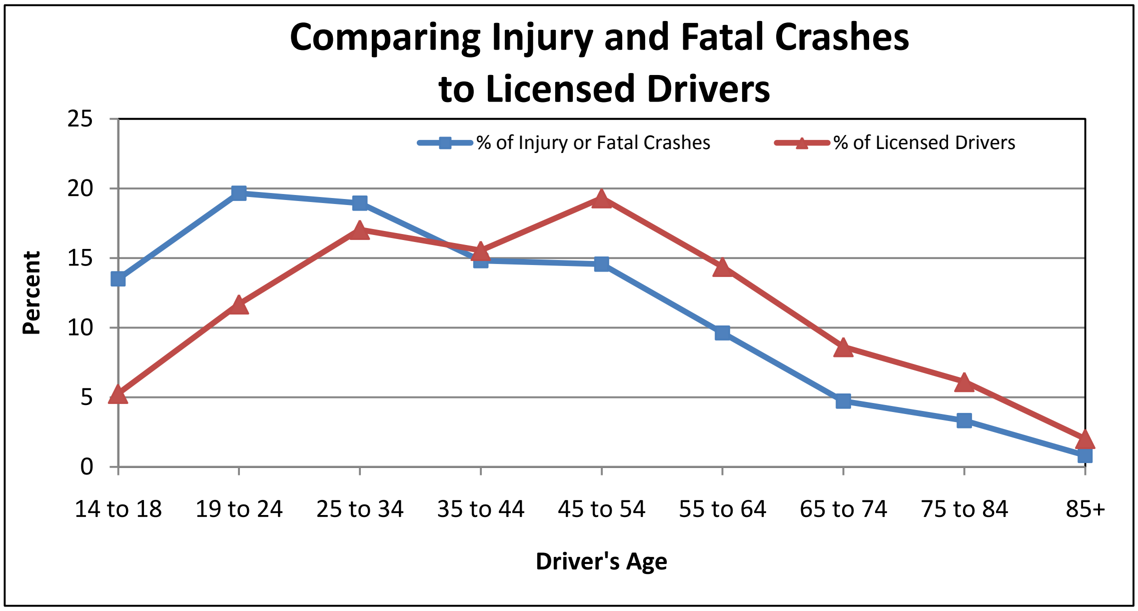

Figure 2.2 Comparison of Injury and Fatal Crashes to Licensed Drivers

Not only are North Dakota teens over-represented when comparing crashes to licensed drivers, but newly licensed teen drivers in North Dakota are also at increased risk of being in a crash. Analyzing crashes by months after licensure, shows that the crash rates for the first seven months range from fewer than 70 per 10,000 to a high of 107 per 10,000 and represent the riskiest months for novice teen drivers (Figure 3). This rate drops after the seventh month and remains under 60 for the rest of the 24 month period. From the first month until the last month, the rate drops by just over 75%.

Comparing the results from the first eight months with the results from middle eight months (months 9 to 16), shows the rate during the first eight months is statistically higher, ($Z=13.55$, $n=20,392$, $p<.001$). The rate for the first eight-month period is also significantly higher than the rate for the last eight-month period (months 17 through 24), ($Z=18.35$, $n=20,392$, $p<.001$). Comparing the second and third eight-month period reveals that the second eight-month period is significantly higher than the third eight-month period, ($Z=5.05$, $n=20,392$, $p<.001$).

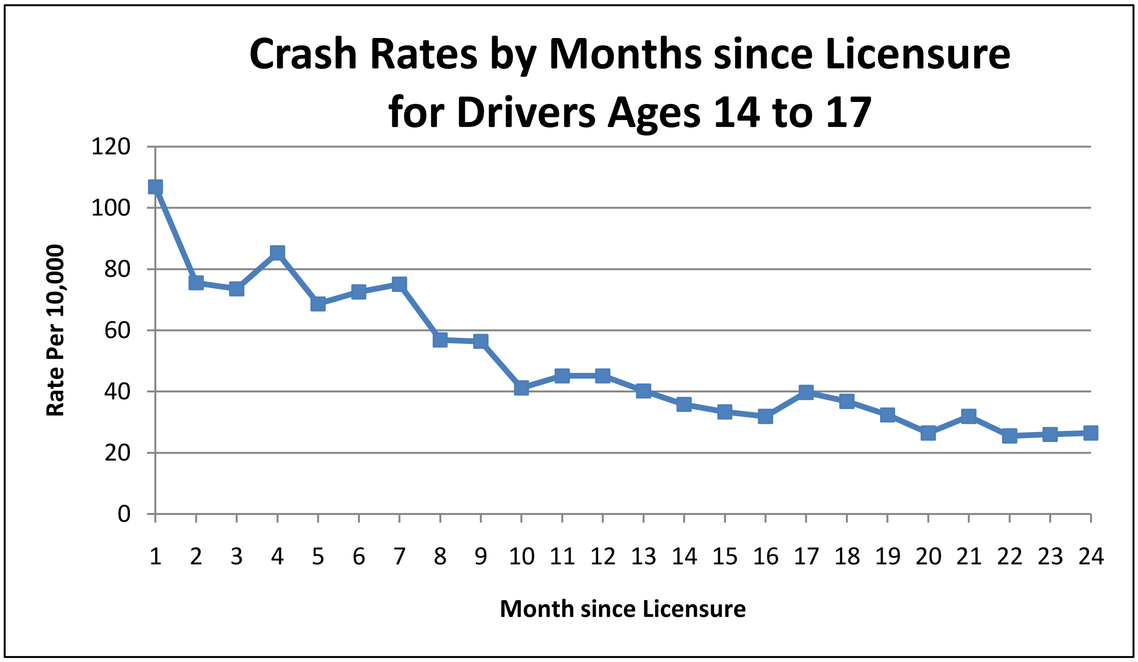

Figure 2.3 Crash Rates by Months since Licensure

Breaking the crash rates down in Figure 2.4 by type of crash yields similar-looking functions when compared to all crashes. Rates for both types of crashes drop considerably after the seventh month and remain low, again decreasing by just over 75% from the beginning until the end of the 24-month period after licensure. However, the injury and fatal crash rates are less varied compared to property-damage-only crashes. Property-damage -only (PDO) crashes range from a high of 85 per 10,000 to a low of 19, while the injury and fatal crash rate ranges from 21 per 10,000 to 5.

Comparing each of the three PDO crash time periods indicates successively lower rates as the time from licensure increases. The first period is statistically higher than both the second period ($Z=11.35$, $n=20,392$, $p<.001$) and the third period ($Z=15.85$, $n=20,392$, $p<.001$), while the rate for months 9 to 16 is statically higher than the rate for months 17 to 24, ($Z=4.70$, $n=20,392$, $p<.001$). For injury and fatal crashes, the initial eight-month period is significantly higher than both the second and third eight-month periods, ($Z=7.30$, $n=20,392$, $p<.001$) and ($Z=8.86$, $n=20,392$, $p<.001$), respectively. However, the difference between the last two periods approaches, but does not reach, statistical significance, ($Z=1.62$, $n=20,392$, $p=.0526$).

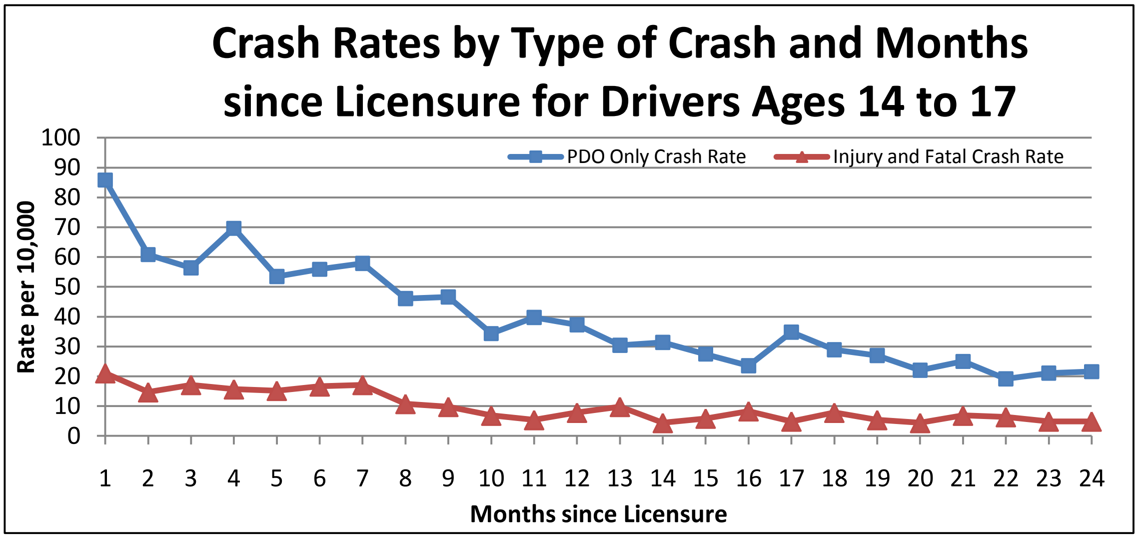

Figure 2.4 Crash Rates by Type of Crash and Months since Licensure

Figure 2.5 indicates that crash rates are elevated for the older ages during the first few months. Testing indicates a statistical difference among rates over the first eight months for the different age groups, (χ^2=7.97, df=3, n=20,392, p=.0466). This may be because older drivers wait longer to get their licenses because of a lack of interest, because they are apprehensive about driving or because drivers ages 16 and 17 do not have to meet the behind-the-wheel requirements to get a license in North Dakota. They older drivers may wait longer merely because they are not exposed to driving. Others have noticed similar trends. Mayhew, Simpson, and Pak (2003), concluded that regardless of age, novice drivers are at increased crash risk, which decreases with experience. However, they also state these decreases are more pronounced in the younger novice drivers (ages 16-19) and hypothesize that this may be caused by younger drivers being "initially more likely to drive in a manner that places them at risk of a collision" or that younger drivers have a steeper learning curve.

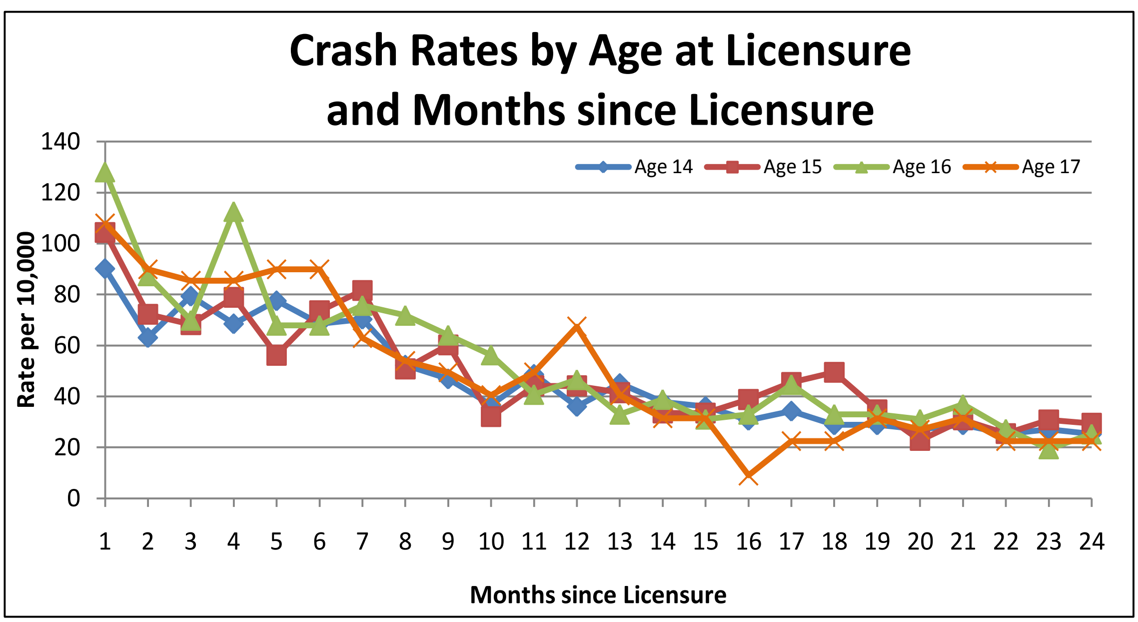

Figure 2.5 Crash Rates by Age at Licensure and Months since Licensure

3. ANALYSIS

3.1 Predictor Variables

The NDDL data includes demographic variables, citation convictions, and crash history information. Potential predictors were identified based on the findings from previous research in the area and cross referencing that with the available data. This data was analyzed using contingency tables analysis and significance testing to determine if a univariate relationship exists between the variable of interest and crashes resulting in an injury or fatality.

Of the 20,392 drivers in the dataset, 51.2% (n=10,444) were male; however, females, not males, had a higher crash rate during the first year after licensure. The percentage of females that had a crash was 1.85% compared to 1.27% for males, which represents a statistically significant difference (χ^2=11.05, df=1, n=20,392, p=0.0009). Age as noted earlier also plays a role in determining crash risk. The rate of crashes within one year increases each year from a low of 1.44% for drivers age 14 at the time of licensing to a high of 2.02% for 17 year olds. Statistical testing shows that there is no significant relationship between age at time of licensing and one-year crash rates (χ^2=4.21, df=3, n=20,392, p=0.2400).

Traffic citations in one form or another have been used in predicting crashes in many instances (Elliott, et. al. 2001, Chandraratna, et. al. 2006, and Reason, et. al. 1990). The breakdown used here was based on input from the ND Highway Patrol and contingency tables results for North Dakota teen convictions. This breakdown divides convictions into “Risk” and “No Risk” categories. The “Risk” convictions include speeding, reckless driving, driving under the influence, and convictions that are more procedural, but still pose significant risk such as failure to yield and improper U-turn. All other convictions are labeled as “Low-Risk.” For a complete list of convictions in each category see Appendix A.

Only actual convictions and conviction dates were used in this analysis. Elliott et. al. (2001) suggest that using convictions alone may introduce a potential bias due to drivers who plead to a lesser charge. Their strategy involved using offenses that actually resulted in a conviction, but used the original violation offense instead of the conviction offense. Unfortunately, the original violation information, although kept by the North Department of Transportation, was not available for the analysis so the actual conviction information was used. This change could be investigated in any future analysis.

For each driver only convictions that occurred before a driver’s first injury or fatal crash, or within the first year after licensure if a driver was not involved in an injury or fatal crash during the first year, were included in the analysis. The number of “Risk” convictions ranged from 0 to 7. However, because of small numbers at the higher end of the range, drivers with more than 1 speeding convictions were all collapsed into one or more. The percentage of drivers with zero and those with one or more “Risk” convictions are 1.57% and 1.48%, respectively (χ^2=0.15, df=1, n=20,392, p=0.7032). A variable counting the raw number of convictions for each driver was included. The total number of convictions ranged from 0 to 10. Re-coding the variable to values of 0 and 1 or more shows that 1.59% and 1.01% of drivers had crashes, respectively. Testing reveals that there is no significant difference (χ^2=2.84, df=1, n=20,392, p=0.0919).

North Dakota drivers encounter a variety of functional road classes and traffic density, including everything from gravel roads with very little traffic to rural and urban interstates with high traffic counts. This exposure affects a driver’s chance of being in a crash. As a proxy for exposure, a variable based on the driver’s city of residence was included. A driver was labeled as urban if they live in one of the four metropolitan areas in the state, Fargo (including West Fargo), Grand Forks, Bismarck, and Minot.

Because the majority of a driver's annual vehicle miles traveled occur close to their residence, the bulk of their driving, and therefore crash risk, would be on functional road classes and traffic densities in and around their city of residence. The location of the resulting crashes suggests that this is indeed the case.

Of the 20,392 drivers in the cohort, 60% (n=12,240) live in a rural area according to our definition with the remaining 40% (n=8,152) living in the urban areas. The percentage of drivers involved in an injury or fatal crash in the first year after licensure is more than double in the urban areas compared to rural areas, 2.36% compared to 1.02%, respectively. This difference is statistically significant, (χ^2=56.90, df=1, n=20,392, p<0.0001).

Previous crashes have also been identified as predictive of future crashes (Chandraratna, et. al 2006, and Chen, et. al. 1995). The number of PDO crashes, prior to a driver's first injury or fatal crash or within the first year after licensure if a driver was not involved in an injury or fatal crash during the first year, was also analyzed. The number of previous PDO crashes ranged from 0 to 3 (one driver), but were reduced to values of 0 and 1 or more. The relationship between the presence of a previous PDO and an ensuing injury or fatal crash was found to be highly significant. Among those drivers who did not have a prior PDO crash, the percentage having an injury or fatality crash was 1.49%, while 24.59% of drivers who had at least one prior PDO crash had an injury or fatality crash (χ^2=212.15, df=1, n=20,392, p<.0001). Table 3.1 shows the breakdown of drivers who were in a crash involving an injury or fatality within the first year after licensure by whether they had previous property damage only crash.

Table 3.1 Breakdown of Previous PDO Crashes vs. Injury or Fatal Crashes

Previous Property Damage Only Crash	Injury or Fatal Crash within One Year After Licensure		Totals
	No	Yes	
No	20,029 (98.51%)	302 (1.49%)	20,331 (99.70%)
Yes	46 (75.41%)	15 (24.59%)	61 (0.30%)
Totals	20,075 (98.45%)	317 (1.55%)	20,392 (100.0%)

Whether or not a driver has been at-fault in previous crashes has been shown to be a predictor of future crashes (Chandraratna, et. al. 2006, and Elliott, et. al. 2001). Because this model predicts a driver's first crash involving injury or fatality, the at-fault is attached to previous property-damage-only crashes. Of the 61 previous property-damage-only crashes that are included in the driver cohort history, 17 (27.87%) are designated as having an at-fault driver with two (11.76%) of those having a subsequent crash involving injury and/or fatality. The remaining 44 (72.13%) previous property damage only crashes involved drivers who were not identified as being at-fault with 13 (29.56%) having a subsequent crash involving injury and/or fatality. The differences between at-fault and not at-fault drivers in previous PDO crashes is not significant (χ^2=2.09, df=1, n=61, p=.1480) with regards to having a subsequent crash involving injury and/or fatality.

Table 3.2 lists all variables considered in the model along with the levels of the variable and the percentage of drivers with crashes for each of those levels.

Table 3.2 Predictor Variable Definitions and Percentage Each Population Involved in Injury or Fatal Crash

Variable	Level	Model Name	Model Value	N	Crash %
Gender*	Female	Gender	0	9,948	1.85%
	Male		1	10,444	1.27%
Age 14 at Licensure	No	age14	0	14,848	1.60%
	Yes		1	5,544	1.44%
Age 15 at Licensure	No	age15	0	12,918	1.61%
	Yes		1	7,474	1.46%
Age 16 at Licensure	No	age16	0	15,242	1.54%
	Yes		1	5,150	1.61%
Age 17 at Licensure**	No			18,168	1.50%
	Yes			2,224	2.02%
Convictions**	0	conv	0	19,010	1.59%
	1+		1	1,382	1.01%
Risk Convictions	0	riskconv	0	16,818	1.57%
	1+		1	3,574	1.48%
Rural/Urban*	Rural	rur_urb	0	12,240	1.02%
	Urban		1	8,152	2.36%
Previous PDO Crash*	0	pdo	0	20,331	1.49%
	1+		1	61	24.59%
Previous At-Fault PDO Crash*	No	atfault	0	20,375	1.55%
	Yes		1	17	11.76%

* Significant at p<0.05, ** Significant at p<0.10

3.2 Logistic Regression

The variables listed in Table 3.1 were used to build a logistic regression model to predict the likelihood a driver will be involved in a crash resulting in an injury or fatality within the first year after licensure. Here the outcome is dichotomous; either a driver is involved in an injury or fatal crash during the first year after licensure, the event, or they are not involved in an injury or fatal crash during the first year after licensure, the non-event.

In situations where the outcome or dependent variable is dichotomous, logistic regression allows for simultaneously studying the effects of multiple variables on the dependent variable. Therefore the probability that a driver is involved in an injury or fatal crash during the first year after licensure is:

$$P_s = \frac{1}{1+ e^{g(x)}}, \tag{1}$$

and

$$P_n = 1 - P_s = \frac{e^{g(x)}}{1+e^{g(x)}}, \tag{2}$$

where

P_n = probability of not having an injury or fatal crash within the first year of licensure, and

P_s = probability of having an injury or fatal crash within the first year of licensure, and

where $g(x)$ includes the set of independent variables in Table 1 related to driver demographics and driving history, in

$$g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n \quad (3)$$

The maximum-likelihood technique is used to determine the coefficients that make the observed set of outcomes, P_n and P_s most likely.

4. RESULTS

Since there were four age groups under consideration, only three categorical variables were used in the model. Only variables for ages 14, 15, and 16 were included in the model. Age 17 is the reference age of the drivers and is represented when all of the age variables are equal to zero. None of the age variables were found to be statistically significant (Table 4.1). These findings seem contrary to much of the current literature, including Vachal and Malchose (2009). However, these differences can most likely be explained by the differences in the cohorts. For example, Vachal and Malchose (2009), like much of the research, limit the cohort to drivers age 14-17 regardless of time of licensure. In these cases, the drivers age 14 are newly licensed, because the minimum age of licensure is 14 years and six months, and they fall into the first year after licensure, while a large majority of 16 and 17 year old drivers are in their second or third year of licensure and have gained the driving experience necessary to mitigate some of the driving risk. Looking at the first year after licensure seems to reinforce the well-known driving axiom that driver experience plays a large role in teen driver crashes.

Four variables were found to be statistically significant. They are gender, previous convictions, rural/urban residence, and previous PDO crashes. The independent variables resulted in 60.4% concordance of predicted and observed dependent values. The area under the receiver operating curve was 0.656. The area under the receiver operating curve measures the ability of the model to correctly classify those with and without the measure of interest. In our case it measures the model's ability to correctly identify a driver who will have a crash involving an injury or fatality within one year of licensure. A value of 0.5 is a useless model, while a value of 1.0 is a perfect model. Model with values above 0.7 are considered to be good. The variables in the model were also checked for multicollinearity. All variables have tolerances of more than 0.43 and variance inflation factors of less than 2.3.

The negative sign in front of all of the variables except rural/urban residence and previous property-damage-only crash indicates that an injury or fatal crash is less likely to occur than when the variable is not present. For example, since gender is coded male=1 and female=0, results show that when the driver is male there is less risk they will be involved in an injury or fatal crash in the first year after licensure. From the odds ratio, we can see that males are almost 30% less likely to be involved in this type of crash, contrary to other crash research which suggests that males are more at risk of being in a crash than females (Shope and Bingham 2008, Waller, et. al. 2001, and Espino, et. al. 2006).

Having previous convictions decreases a driver's odds of being in an injury or fatal crash by almost 50%. This seems counter intuitive since most people associate tickets/convictions with risk-taking behavior when the discussion involves teen drivers. However, because our variable includes all tickets/convictions, including low risk convictions like driving without liability insurance and failure to wear a seatbelt, drivers, being convicted of a lower risk violation and possibly a portion of those convicted of high risk violations, may heed the corrective undertones associated with receiving a ticket and adjust their driving behavior. Parents of the teen driver may also take steps to adjust their teen's driving behavior when alerted by the ticket. Even though having a previous citation was significant, having a previous citation associated with "high" risk driving was not. This may point to the need to use the actual citations in the model instead of convictions. It may be that pleading down some of the riskier citations to lesser charges is confounding the previous citation and previous risk citation variables.

Teen drivers living in an urban area are almost 2.5 times more likely to be involved in an injury or fatal crash within the first year after licensure than those living in a rural area. During the first year after licensure, the complex driving situations and traffic density encountered in the urban areas appear to be a greater risk than the lack of seatbelt use and gravel roads in rural areas. Vachal and Malchose (2009) suggest that travel on the rural roadways increases a teen driver's risk of being in a severe or fatal driver injury in crash. A possible explanation maybe that as teen drivers gain more experience, those in the urban setting may become more adept at handling their driving situations than those in the rural setting, but in the short term, urban drivers are at much higher risk of being in an injury and fatal crash. Additionally, this difference may be explained by differences in the driving exposure. As mentioned earlier crash rates are often times report in terms of crashes per mile driven, and obviously on average the more a person drives the more likely they are to be in a crash. It could be the case for our data that the teen drivers in urban settings drive more than teens in the rural setting. Unfortunately, the individual driving exposures were not available in the records. Future research might employ some type of surrogate for miles driven to help correct this limitation.

The most influential predictor of an injury or fatal crash is a previous PDO crash. Drivers who have at least one PDO crash are more than 25 times more likely to be involved in an injury or fatal crash in the first year after licensure than drivers not involved in a previous PDO crash. This could be the result of inexperienced drivers continuing to drive while still lacking the necessary driving experience to overcome the deficits that resulted in the first crash. Gerbers (1999) suggests less skilled drivers are more likely to be involved in a crash, regardless of whether they at-fault or not. Chandraratna, et. al. 2006, suggest, “There is a portion of drivers who seem to be involved more frequently in crashes than others.” It could also be the result of risk seeking behavior where the behavior persists after the PDO resulting in the future injury or fatal crash.

Table 4.1 Logistic Model Results

Parameter	Estimate	S.E.	P-value	Significance	Log Odds	95% CI
Intercept	-4.2069	0.1802	<0.0001	**		
Gender	-0.3109	0.1160	0.0073	**	0.733	0.584-0.920
Age 14 at Licensure	-0.1587	0.1919	0.4081		0.853	0.586-1.243
Age 15 at Licensure	-0.2822	0.1815	0.1200		0.754	0.528-1.076
Age 16 at Licensure	-0.2319	0.1892	0.2205		0.793	0.547-1.149
Convictions	-0.6285	0.3145	0.0457	*	0.533	0.288-0.988
Risk Convictions	-0.1373	0.1762	0.4357		0.872	0.617-1.231
Rural/Urban	0.8383	0.1194	<0.0001	**	2.312	1.830-2.922
Previous PDO Crash	3.2362	0.3512	<0.0001	**	25.436	12.778-50.630
Previous At-Fault PDO Crash	-1.1832	0.8344	0.1562		0.306	0.060-1.572

N=20,392, *p<0.05, **p<0.01

5. CONCLUSION

This research focuses on teen drivers and, identifies several markers, from gender to previous crash involvement that indicate increased risk for driver involvement, in a future severe or fatal crash. Novice drivers including those in North Dakota show a marked increase increases during the first year after licensure. Finding risk markers for these teen drivers would help those agencies tasked with reducing crashes develop strategies targeted at this high-risk group of drivers.

Using North Dakota drivers' license data, several variables were found to be significant in predicting teen driver is involvement a future crash. The top predictor is being in a previous property-damage-only crash. A driver is 25 times more likely to be in an injury or fatal crash within the first year after licensure if they were in a previous property-damage-only crash. Gender, prior citations, and population density variables were also found to be significant in predicting crash risk. Having prior convictions reduces the risk of future injury or fatal crashes by almost 50%, while living in an urban area increases your risk by 230%. Although these indicators have some limitations, they provide a basis for future research and the development of strategies to target these drivers and attempt to modify their behavior or driving experience.

Developing a graduated driver's license program, which provides re-training or places additional restrictions on teen drivers involved in property-damage-only crashes within the first year, could give the teen driver time to gain the additional experience necessary to avoid more severe accidents in the future. These license restrictions could be implemented for a brief time period and be as simple as requiring additional parental supervision when driving or restricting passengers to family members only. Other interventions could be as simple as some type of reinforcement or reminder letter after a teen driver receives a moving violation. This alert to parents may produce substantial benefits in reducing crash risk for very novice teen drivers. These are ideal points in time to change a driver's behavior simply because they are easily identifiable markers and are shown here to predict more severe crashes down the road.

This ability to predict crashes could one day lead to measures which save lives, prevent injuries, and reduce the severity of injuries. This model provides a first step toward this ability by predicting crashes in teen drivers. Intervention strategies can be developed to coincide with the markers identified in the model as being predictors of future crashes. These interventions could be as easy as a targeted warning letters or as complex as additional requirements as part of the driver licensing program. Further research is needed to identify potential strategies and prove these interventions generalizable to the driving population as well as investigate longer intervention timeframes.

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APPENDIX A

Risk	Citation	Description
High	105	Reckless Driving 39-08-03
High	106	Violated Eye Restriction 39-06-17
High	107	Violated Restrictions other than 106
High	109	Aggravated Reckless Driving 39-08-03
High	119	Fleeing Law Enforcement Officer in M/V 39-10-71
High	131	Operating an Unsafe Motor Vehicle 39-21-46(2)
High	150	Administrative Action 0/S 39-20 -
High	151	Administrative Action 39-20 :
High	152	Driving Under the-Influence 39-08-01
High	153	Actual Physical Control 39-08-01
High	211	Negligent Homicide with a M/V 39-06-31
High	215	Manslaughter with a M/V 39-06-31
High	216	Felony Involving. A Motor Vehicle
High	309	Causing Accident with Emergency Vehicle
High	310	Careless Driving, Basic Rule 39-09-01
High	311	Failure to Yield/Stop Sign 39-10-44
High	323	Drag Racing or Racing
High	327	Exhibition Driving 39-08-03.1
High	329	Disregarding Traffic Control Device 39-10-04
High	330	Permitting Unauthorized Minor/Person to Drive 3
High	331	Driving on Wrong Side of Highway 39-10-08, 39-1
High	336	Disregarding the Commands of a Police Officer
High	337	Overtaking Where Prohibited or in an Unsafe Man
High	339	Illegal Passing of School Bus 39-1046 (Driver)
High	353	11-15 MPH Over 70/75 Speed Limit (8-1-03)
High	354	16-20 MPH Over 70/75 Speed Limit (8-1-03)
High	355	21-25 MPH Over 70/75 Speed Limit (8-1-03)
High	356	26-30 MPH Over 70/75 speed Limit (8-1-03)
High	357	31-35 MPH Over 70/75 Speed Limit (8-1-03)
High	358	36+ MPH Over 70/75 Speed Limit (8-1-03)
High	363	Open Container 39-08-18
High	370	lmproper MC Operation
High	375	Operate MV W/O License 39-06-01
High	376	Operate a CMV without a license 39-06-01, 39-06
High	377	Care Required 39-09.01.1
High	391	11-15 MPH Over Speed Limit (Effective 7-1-01)
High	392	16-20 MPH Over Speed Limit (Effective 7-1-01)
High	393	24-25 MPH Over Speed Limit (Effective 7-1-01-)
High	394	26-35 MPH Over Speed Limit (Effective 7-1-01)
High	395	36-45 MPH Over Speed Limit (Effective 7-1-01)
High	396	46+ MPH Over Speed Limit (Effective 7-1-01)
High	402	Unsafe Speed (No Zone or MPH listed)
High	410	Minor in Possession/Consumption of Alcohol
High	412	Fail to Stop for Emergency Vehicle 39-10-25
High	413	Fail to Yield to Pedestrian 39-10-28
High	417	Fail to Have MV Under Control 39-10-30
High	422	Obstructed View 39-10-54
High	423	Following Emergency Vehicle 39-10-26
High	428	Overload/Overweight 39-12-05
High	431	Light Equipment Not Lighted 39-21-01
High	440	Illegal Passing of School Bus 30-10-46.1 (OWNER

High	441	Causing Serious Bodily Injury
High	445	Disregard Flashing Light 39-10-07
High	448	Wrong Way on One Way 39-10-16
High	449	Following too Close 39-10-18
High	451	Improper Turn/U-Turn 39-10-35
High	462	Obstructed Windows 39-21-39
High	466	Impeding Traffic 39-09-09
High	691	Refused Alcohol Test
Low/None	121	Leaving the Scene of an Accident Involving Prop
Low/None	125	Leaving the Scene of an Accident Involving Injury
Low/None	126	Leaving the Scene of an Accident Involving Death
Low/None	130	Failure to Display Placard While Transporting Hazardous Materials
Low/None	160	Driving W/O Liability Insurance 39-08-20 (NO AC
Low/None	161	Driving W/O Liability Insurance 39-08-20 (WITH
Low/None	162	Driving W/O Liability Insurance 39-08-20 (2nd O
Low/None	203	Driving Under Suspension 39-06-42
Low/None	204	Driving while Out-of-Service (CDL) Admin. Rule
Low/None	205	Driving while Out-of-Service with Hazmat of pas
Low/None	207	Driving Under Revocation 39-06-42
Low/None	308	Child not in Restraining Device (After 8-1-99)
Low/None	312	Failure to Obey TCD at RR Crossing 39-06.2-10
Low/None	313	Failure to Slow Down at RR Crossing 39-06.2-10
Low/None	314	Failure to Stop Before,Tracks When, Tracks Not
Low/None	315	Failure to Stop at RR Crossing 39-06.2-10
Low/None	316	Failure to Obey RR Crossing Space 390-6.2-10
Low/None	317	Failure to Obey RR Crossing Clearance 39-06.2-10
Low/None	320	Improper Modified MV 39-21-45.1
Low/None	325	Failure to Yield to Funeral. Procession 39-10-7
Low/None	326	Fail to Display Plates/Tabs 39-04-37
Low/None	332	Failure to Dim Headlights 39-21-21
Low/None	334	Unlawful Stepping on Highway 39-10-47
Low/None	335	Improper Brakes 39-21-32, 39-21-33
Low/None	338	Unlawful Parking in a Prohibited Place Obstruct
Low/None	340	Not Valid
Low/None	342	Leaving MV Unattended 39-10-51
Low/None	343	Fail to Stop at RR Crossing 39-10-41
Low/None	346	Opening Doors When Unsafe 39-10-54.1
Low/None	349	Improper Equipment 39-21-46
Low/None	350	Operating W/0 Required Equipment 39-10.46
Low/None	351	1-5 MPH Over 70/75 Speed Limit (8-1-03)
Low/None	352	6-10 MPH Over 70/75 Speed Limit (8-1-03)
Low/None	364	Fail to Give Immediate Notice 39-08-09
Low/None	371	Improper MC Laned Traffic 39-10-2-03
Low/None	372	Clinging While Riding MC 39-10.2-04
Low/None	373	Carry Passenger W/0 Footrest 39-10.2-05
Low/None	374	Operate MC W/O Headgear 39-10.2-06
Low/None	390	1-10 MPH Over Speed Limit (Effective 7-1-01)
Low/None	401	Speeding 55 – 70 in a 55 Zone
Low/None	404	Improper/No Current Registration 39-04-37
Low/None	405	No Child Restraint 39-21-41.2 (Prior to 8-1-99)
Low/None	406	No Driver License in Possession 39-06-16
Low/None	407	Unlawful Use of Driver License 39-06-40
Low/None	408	Use of Safety Belts Required 39-21-41.4
Low/None	414	Failure to Use Turn Signal
Low/None	418	Altered Driver License in Possession 39-06-40

Low/None	419	Reproducing Driver License 39-06-40.1
Low/None	420	Not Valid
Low/None	421	Commercial Speeding 70/55
Low/None	424	Crossing Fire Hose 39-10-58
Low/None	425	Deposit Garbage on Highway 39-10-59
Low/None	427	Driving on Flood Works 39-10-65
Low/None	429	Oversize/Over Width Motor Vehicle 39-12-04
Low/None	430	Improper Lighting Equipment
Low/None	432	Improper Horn 39-21-36
Low/None	433	Improper Mirrors 39-21-38
Low/None	434	Improper Tires 39-21-40
Low/None	435	No Warning Flares 39-21-42
Low/None	436	Sifting/Leaking Load 39-21-44.1
Low/None	439	No Slow Moving Emblem 39-21-50
Low/None	442	Log Book Violation Log Book
Low/None	443	No Medical Card
Low/None	444	Violation of Duty Status
Low/None	446	Improper Lane Usage 39-10-17
Low/None	450	Driving in Restricted Area of Right of Way 39-1
Low/None	452	Improper Start from Parked Position 39-10-37
Low/None	453	Improper Signals or Signal Not Working 39-21-06
Low/None	455	Improper Backing 39-10-52
Low/None	457	Coasting Downgrade 39-10-56
Low/None	459	No Flag/Light on Projected Load
Low/None	461	Improper Muffler 39-21-37
Low/None	463	Improper Wipers 39-21-39
Low/None	464	Improper Tow Bar/Chains 39-21-44.2
Low/None	465	Overtime/Double/Standing Abreast Parking 39-10-