



The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

Papers downloaded from AgEcon Search may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

Modeling the Injury Severity of Young Drivers Using Highway Crash Data from Kansas

Niranga Amarasingha (Corresponding Author)

Graduate Research Assistant

Department of Civil Engineering,

Kansas State University,

2118 Fiedler Hall,

Manhattan, KS 66506.

Email: niranga@ksu.edu

phone: (785)-395-5516

Fax: (785)-532-7717

and

Sunanda Dissanayake, Ph.D., P.E.

Associate Professor

Department of Civil Engineering

Kansas State University,

2118 Fiedler Hall,

Manhattan, KS 66506.

Email: sunanda@ksu.edu

Tel: (785)-532-1540

Fax: (785)-532-7717

ABSTRACT

Young drivers have elevated motor vehicle crash rates compared to other drivers. The study investigates characteristics of young driver crashes that took place in Kansas from year 2006 to 2008 by comparing them with more experienced drivers. In order to calculate the population-based rates, number of licensed drivers in each group was taken into account, where the data were taken from the United States Department of Transportation (USDOT). Annual vehicle miles traveled were obtained from National Household Travel Survey data to calculate the exposure-based crash rates. Young drivers were divided into two groups: aged 15-19 (teen) and aged 20-24 (young-adult) for detailed investigation. Multinomial logit models were developed, and likelihood ratio (LR) estimates and odds ratios (ORs) were used to identify overly represented characteristics and contributory causes of young driver crashes. Teen drivers were more likely to involve in crashes due to failure to give time and attention, falling asleep, failure to yield right of way, and distractions. Alcohol involvement, driving without a valid license, having restrictions on driver's license, and involvement on off-roadway crashes were significant factors which increase the young driver injury severity. Driving with a valid license and wearing seat belt decrease the young driver injury severity. Based on the identified factors, crash mitigation strategies are presented.

INTRODUCTION

Teen and young-adult drivers have much greater motor vehicle crash rates than other drivers, both in Kansas and throughout the United States (US). The higher crash propensity among young or beginning drivers may result from lack of driving experience and their risk-taking behavior. Motor vehicle crashes are the leading cause of death among young drivers in the US (IIHS 2010). National statistics in 2008 showed that teenage drivers accounted for 12% of all drivers involved in fatal crashes and 14% of all drivers involved in all police-reported crashes. Also, beginning drivers were three times more likely to die in a motor vehicle crash than an average driver. In Kansas, young driver safety issue has been identified by Kansas Strategic Highway Safety Plan as one of the major concerns that leads to increased fatalities and serious injuries (KDOT 2010). Hence it is important to investigate the characteristics and contributory circumstances related to young driver crashes and associated severities while identifying over-represented factors. Such results can be used to recommend better crash mitigation strategies, thereby improving safety associated with young drivers.

Accordingly, the objectives of this study were to investigate the characteristics, the contributory causes, and the crash severity factors related to highway crashes involving teen and young-adult drivers by investigating the likelihood ratios by developing a multinomial logit model. The comparisons between teen drivers, young-adult drivers, and experienced drivers were also carried out in order to identify the young driver over representation in various crash characteristics and contributory factors of young driver involved crashes.

LITERATURE REVIEW

High crash rates by young drivers is well documented in literature whichever the exposure data (eg: number of licensed drivers, vehicle miles travel) used in calculating the rates. In Maryland, for example, the youngest drivers have been found to have the highest rate of motor vehicle crashes per licensed driver and per annual miles driven (Ballesteros and Dischinger 2002). In particular, young drivers have greater risk of crashes than their older counterparts. Numerous contributory factors have been related to crash risk of young drivers such as risk-taking behavior, nighttime driving, driving with young passengers, and being under the influence of alcohol (Fu and Wilmot 2008). Inattention and distraction were also identified as critical factors which increase injury severity of young drivers involved in motor vehicle crashes (Neyens and Boyle 2007). Many studies have focused on the young driver crash involvement and crash risk. Based on the study conducted by Fu and Wilmot, the young driver risk-taking behavior was much critical in male drivers with the presence of male peers than female to female driver-passenger combination (Fu and Wilmot 2008). The risk of being involved in a fatal crash was much higher for teenage drivers when passengers were present. Cooper, Atkins and Gillen (2005) studied the new passenger restrictions, which is new provisional license holders' restriction of transporting under 20 years old for the first six months, in California using fatal and crash data. The law has been effective in reducing the rate, and the reduction of passengers in crash-involved cars resulted in estimated saving of eight lives and 684 injuries over three years. Hanna et al. (2006) investigated the young unlicensed drivers' involvement in fatal crashes, using data from Fatality Analysis Reporting System (FARS).

The young unlicensed driving involvement and practices in fatal crashes were similar to young licensed drivers' involvement and practices in fatal crashes. However, the errors for experienced young driver were relatively few in number and small in magnitude, according to the study conducted by McKnight and McKnight (2003). The benefits of experience apply rather

generally across all aspect of driving, as behavioral short comings such as failure to employ routine safe operating practices, failure to recognize the danger and risk taking is high in beginning drivers. A logit model of teen driver injury crashes, which was developed by Vachal, Faculty and Tayler (2009) offered insight for creating a safer driving environment for teen drivers. The increased licensing age and seat belt emphasis might reduce teen traffic injuries. The risk attached to lower age, lack of seat belt use, and impaired driving is evident. Also, gender is a factor in teen driver injury severity, with females at higher risk. For several years, many efforts such as introduction of graduated license have been focused on reducing young driver crash involvement in the US. It has resulted in some progress nationally in reducing the fatal crashes, among 16 year-olds but young driver over involvement in crashes was still a big problem (Williams, Ferguson and Wells 2003). Gonzales et al. (2005) studied aged 16 year drivers involved in fatal motor crashes and compared them with fatal crash involved experienced drivers with respect to characteristics and driver behaviors. According to the study, new drivers must be given a top priority to improve traffic safety as they bear considerable responsibility for fatal crashes.

Numbers of young driver related studies have used state level databases or national level data bases such as the FARS and General Estimate System (GES). Also many research studies have focused on the young driver crash involvement and crash risk. Most of the preliminarily analyses were done using the absolute number of crashes at each age, frequencies, percentages, and Pearson Chi-Square tests (Hanna et al. 2006; McKnight and McKnight 2003; Williams, Ferguson and Wells 2003). Second, more comprehensive analyses such as multiple logistic regression, multiple probit analyses were done to check the association between driver injury severity and related associations. For example, binary logistics regression models were developed to compare teen drivers and experience in Colorado using FARS data (Gonzales et al. 2005). In order to investigate the crash severity of young driver crashes, Dissanayake and Lu (2002) developed a sequential binary logistic regression models Using Florida Traffic Database. The crash severity was defined under five categories; no-injury, possible injury, non-incapacitating injury, incapacitating injury and fatal injury. Neyens and Boyle (2007) used GES data which contains both teenage drivers and their passengers to develop an ordered logit model. The dependent variable here, which was injury severity, was also defined under five categories. The results showed that teen drivers have an increased likelihood of more severe injuries if distracted by a cell phone or passengers than other source of distraction. Using injury crash records a multinomial logit model was developed to study driver-, vehicle- and road-related factors for North Dakota teens drivers (Vachal, Faculty and Tayler 2009). The relative likelihood of severity, which is the driver fatality or disabling injury, in a crash was the dependent variable.

Kansas Law Related to Young Drivers

Prior to 2010, the minimum age to obtain an instruction permit in Kansas was 14 years with the requirement of adult supervision at all times. Restricted licenses were issued at 15 years with only driving to, from, or in connection with any job or employment related work or school is allowed. Even then, the most direct and accessible route between the driver's home and school or work should be used. However, restriction license holder can drive anywhere, any time with licensed adult driver supervision. Passenger restrictions included transportation of non-sibling minor passengers. At the age of 16 years, a full license was granted, if 50 hour affidavit had been turned in. The law changed in 2010 with current law allowing lesser restriction licenses at age 16 years instead of full license and after 6 months a full license is granted. Even through the law

changed in 2010, it would not have any effect in this study because all data for this analysis was from the period before the law changed.

In Kansas, the minimum age to have a restricted license was 15 years. Most of the past studies which focused on young drivers commonly investigated the age limit from the time restricted license is granted to 25 years (Ballesteros and Dischinger 2002; McKnight and McKnight 2003). This age range shows similar driving behavior and crash risk (KDOT 2010). Hence, in this study the age range of young drivers considered was from 15 years to 24 years. In order to investigate the young driver characteristics in detail, they were further divided into two groups; the teen driver group aged from 15 to 19 years and young-adult driver group aged from 20 to 24 years. In order to compare young driver characteristics with other driver characteristics all middle age drivers in Kansas were taken into account. Those middle age drivers were defined as “experienced drivers” whose age ranging from 25 years to 64 years (Ballesteros and Dischinger 2002; Gonzales et al. 2005). Age above 65 years was not considered to compare with young drivers because those older driver characteristics may be different from the 25 years to 64 year olds and older drivers have also found to have unique highway safety challenges (Gonzales et al. 2005; Kostyniuk and Shope 2003).

DATA AND METHODOLOGY

Data

The crash data from year 2006 to 2008 were obtained from the Kansas Department of Transportation (KDOT). This data set, Kansas Accident Reporting System (KARS) database, comprises of all police-reported crashes that occurred in Kansas. Motor vehicle young driver involved crashes in highways were taken into account excluding motorcycle, and motor scooter crashes. The KARS database from 2006 to 2008 contained 94,817 (30% of total crashes) of young driver involved crashes and 186,600 (58% of total crashes) experienced driver involved crashes. The driver contributory factors for 54,349 crashes were recorded for the 94,817 young driver involved crashes. There were up to ten contributing factors recorded in the traffic crash database for some crashes while contributory factors were not recorded at all in some other crashes. Environmental-related contributory causes were recorded for 636 crashes involving teen drivers, 527 crashes involving young-adult drivers and 1,867 crashes involving experienced drivers.

Crash Rates

In order to calculate the crash rates, driver license information for each year by age were obtained from the U.S. Department of Transportation (USDOT 2008; USDOT 2007; USDOT 2006). Table 1 provides number of licensed drivers in Kansas during 2006 and 2008 by age group and gender. From year 2006 to 2008, number of licensed teen drivers has increased from 159,655 to 166,663 and number of licensed young-adult drivers has increased from 177,407 to 181,172 in Kansas. However, number of experienced drivers has dropped from 1,361,297 to 1,343,497. Vehicle Miles Traveled (VMT) was calculated using from National Household Travel Survey (NHTS) data for the Midwest region because the sample size for Kansas was too small (NHTS, 2007). Midwest region consists of Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, North Dakota, Nebraska, Ohio, South Dakota and Wisconsin. The estimated Kansas VMT for teen, young-adult, and experienced groups were; 920, 1,724 and 17,750 million per year respectively. Those values were then multiplied by three in order to obtain total VMT from

2006 to 2008, and crashes per VMT were calculated for each age group by dividing total number of crashes by VMT.

Table 1 Number of Licensed Drivers in Kansas

Driver Category		2006	2007	2008
Teen (15-19)	Male	81,815	83,689	85,138
	Female	77,840	80,033	81,525
	Total	159,655	163,722	166,663
Young-adult (20-24)	Male	89,475	91,088	91,788
	Female	87,932	90,084	89,828
	Total	177,407	181,172	181,616
Experienced (25-64)	Male	681,280	679,586	698,566
	Female	680,017	675,804	1,397,132
	Total	1,361,297	1,355,390	1,343,497

Source: USDOT 2008; USDOT 2007; USDOT 2006

Multinomial Logit Model

Multinomial logit model was developed to identify the variables that can be expected to be explanatory effect on injury severity of young drivers involved in crashes. Using the coefficient of the explanatory variables the risk factors which increases the young driver injury severity could be determined. The dependent variable, injury severity has several discrete categories. The dichotomous nature of the dependent variable facilitates the application of logit analysis, for which the probability of fatal injury against other injury severity categories is estimated by the maximum likelihood method (Long 1997). The probability of driver n being injured with severity outcome i is;

$$\Pi(x)_{ni} = P(U_{ni} \geq U_{ni'}), \quad \forall' \in I, \quad i' \neq i, \quad (1)$$

Where,

- $\Pi(x)$ = the probability of x injury category.
- n = a driver
- i = injury severity of n driver (eg: fatal injury, incapacitating injury, minor injury, no injury)
- U_{ni} = function determining injury severity outcome i of the n driver.
- $U_{ni'}$ = function determining injury severity outcome i' of the n driver.
- I = a set of I possible, mutually exclusive severity categories.

Logit model assumes that a driver injury severity function has a linear-in-parameters form as,

$$U_{ni} = \beta_i x_n + \varepsilon_{ni} \quad (2)$$

Where,

- β_i = vector of estimable coefficient for injury severity i and x_i is a vector of variables for driver n .

ε_{ni} = random component which is identically and independently distributed error terms.

Then the multinomial logit model defined as follows (Long 1997);

$$\Pi(x)_{ni} = \frac{e^{\beta_i x_n}}{\sum_{\forall i' \in I} e^{\beta_i' x_n}} \quad (3)$$

The maximum likelihood method is then employed to measure the associations by constructing the likelihood function as follows.

$$l(\beta) = \prod_{i=1}^n \pi(x_i)^{y_i} (1 - \pi(x_i))^{1-y_i} \quad (4)$$

Where,

$l(\beta)$ = the likelihood function.

$\pi(x_i)$ = the probability of the dependent variable.

y_i = the i th observed outcome, with the value of either 0 or 1 only.

i = 1, 2, 3, ..., n , where n is the number of observations.

The log likelihood expression is considered to maximize the likelihood function in order to obtain the coefficient estimates.

$$LL(\beta) = \ln(l(\beta)) = \sum_{i=1}^n \{ y_i \ln(\pi(x_i)) + (1 - y_i) \ln(1 - \pi(x_i)) \} \quad (5)$$

Where,

$LL(\beta)$ = the log likelihood function.

Maximization typically requires an iterative numerical method, which means that it involves successive approximations. The best estimate of β could be obtained accordingly using statistical software.

Goodness-of-fit Measure - The goodness-of-fit of the predictive model could be assessed for significance and predictive power. To evaluate the significance and predictive power of the logistic regression model, the change in deviance can be determined by comparing the log likelihood functions between the unrestricted model and the restricted model, under the null hypothesis that coefficients for the predictive model are equal to zero, with the following expression (Allison 2001):

$$G = -2(LL(c) - LL(\theta)) \quad (6)$$

Where,

- $LL(c)$ = log likelihood function of the restricted model.
- $LL(\theta)$ = log likelihood function of the unrestricted model.
- G = goodness-of-fit value.

If G is significant at the 5% level, then the null hypothesis would be rejected, and one could conclude that the proposed model generally fit well with the observed outcome.

The likelihood ratio (LR) test is the Chi-Square test where at least one of the predictors' regression coefficients is not equal to zero in the model. The LR Chi-Square statistic can be calculated by;

$$LR = -2 \text{ Log } L(\text{null model}) - 2 \text{ Log } L(\text{fitted model}) \quad (7)$$

Where,

- $L(\text{null model})$ = intercept-only model.
- $L(\text{fitted model})$ = intercept and covariates model.

In some cases, logistic regression results may seem paradoxical, which means the model fits the data well, even though none of the independent variables has a statistically significant impact on predicting the dependent variable. This has happened due to the correlation of two independent variables. Neither variable may contribute significantly to the model after the other one is included. However, model fit will be worse if both variables were removed from the model. This is because the independent variables are collinear and the results show multicollinearity. In traffic safety analysis, the goal is to understand how the various independent variables impact the dependent variable; hence, multicollinearity is a considerable problem (Motulsky, 2011). One problem is that even though the variable is important, model results show that it is not significant. The second problem is that the confidence intervals on the model coefficients will be very wide. To help to assess multicollinearity, the correlation matrix of the independent variables can be investigated. If the element of correlation matrix has high value, model fit is affected by multicollinearity of the independent variable correspondent to that element. Also, each independent variable can be predicted from other independent variables. The model-fit statistic such as individual R^2 value and a variance inflation factor (VIF) are high for any of the independent variables, and model fit is affected by multicollinearity.

To measure the association between teen drivers and experienced drivers contributory factors for crashes, Odds-Ratios (ORs) and 95% Confidence Intervals (CIs) were calculated using binary logit analysis (Long 1997). The OR is a widely used statistic in traffic safety studies for comparing whether the probability of a certain event is the same for two groups. The "odds" of an event (y) is defined as the probability of the outcome event occurring ($y = 1/x_1, x_2, \dots, x_p$) divided by the probability of the event (Long 1997).

$$Odds = \frac{P(y = 1/x_1, x_2, \dots, x_p)}{P(y = 0/x_1, x_2, \dots, x_p)} \quad (8)$$

The odds ratio for a predictor is defined as the relative amount by which the odds ($odds_1$) of the outcome increase (OR > 1.0) or decrease (OR < 1.0) when the value of the one of predictor variables ($odds_0$) is increased by 1.0 unit.

$$odds\ ratio = \frac{odds_1}{odds_0} \quad (9)$$

RESULTS

Driver-, Environmental-, and Road-Related Characteristics

The crash rates were higher for teen drivers than young-adult drivers and rates for young-adult drivers were higher than experienced drivers as shown in Table 2. Teen driver crashes per 1,000 drivers was 100.3 while young-adult driver crash rate was 82.9 and experienced driver crash rate was 45.3. Teen driver crashes per Million VMT was 17.80 while rates were 8.66 and 3.46 for young-adult and experienced drivers respectively. Both teenage driver and young-adult driver involved crashes per 1,000 licensed drivers were twice that of experienced drivers. Teenage driver crashes per million VMT were approximately four times that of experienced drivers, while young driver crashes per million VMT were two times that of experienced drivers. This indicated that teenage drivers have much more critical highway safety concerns on per mile driven basis. Male driver crash involvement (53%) was higher than that of female drivers (47%). Male drivers had higher crash rates than female drivers as shown in Table 2. Female driver involvement in crashes per 1,000 drivers was 96.3, while male driver involvement in crashes per 1,000 drivers was 104.1. Female young-adult driver crash rate per 1,000 teen female licensed drivers was almost two times that of experienced drivers. The trend was similar for the male drivers. Both teen male and female driver crashes per million VMT were approximately four times that of experienced drivers while young-adult driver crashes per million VMT was two times that of experienced drivers.

Overall, teen driver crash rate per 1,000 licensed teen drivers were twice that of experienced driver crash rates for driver-, environmental-, road-, vehicle-, and crash-related characteristics. Young driver crash rates per 1,000 licensed young drivers were slightly less than crash rates per 1,000 licensed teen drivers for those characteristics. The teen driver crashes per VMT were approximately four times more than experienced driver involved crashes per VMT and two times more than young-adult driver involved crashes per VMT. The overall trend was similar for driver-, environmental-, road-, vehicle-, and crash-related characteristics of Kansas drivers. Majority of drivers involved in crashes had a valid driver license. More than 6% of teen drivers were not wearing seat belts while 3% of teen drivers were under the influence of alcohol at the time of the crash. Teen drivers had high crash involvement (54%) at intersections than experienced drivers. In weekends and dark lighting conditions, teen driver crash involvement was higher than that of experienced drivers. In other cases crash involvement percentages were approximately similar among teen and young-adult drivers as well as experienced drivers.

Vehicle- and Crash- Related Characteristics

Teen drivers had higher crash involvement when they were in automobiles (68%) than that of experienced drivers as shown in Table 3. Almost 29% of teens were involved in crashes when they were driving vehicles made in 1994 or earlier, while only 16 % of experienced drivers were involved crashes driving those vehicles.

Table 2 Crash Frequencies, Percentages, and Crash Rates by Driver Group: Driver-, Environmental- and Road-Related Characteristics

Characteristic	Number of Crashes						Crashes per 1000 Drivers			Crashes per Million VMT		
	Teen		Young-adult		Experienced		Teen	Youn g adult	Exp.	Teen	Youn g adult	Exp.
	No.	%	No.	%	No.	%						
Total	49,165	100	44,802	100	184,079	100	100.3	82.9	45.3	17.8	8.7	3.5
Gender												
Female	23,061	47	19,918	44	79,816	43	96.3	74.4	39.4	8.3	3.9	1.5
Male	26,098	53	24,878	56	104,222	57	104.1	91.3	51.2	9.4	4.8	2.0
License Compliance												
Valid licensed	46,137	94	40,565	91	173,343	94	94.1	75.1	42.7	16.7	7.8	3.3
Not licensed	2,532	5	3,772	8	9,055	5	5.2	7.0	2.2	0.9	0.7	0.2
Restriction Compliance												
No restrictions on driver license	31,447	64	28,721	64	108,060	59	64.2	53.2	26.6	11.4	5.6	2.0
Restricted license	14,874	30	13,118	29	67,997	37	30.4	24.3	16.7	5.4	2.5	1.3
Safety belt not used	2,993	6	2,641	6	6,261	3	6.1	4.9	1.5	1.1	0.5	0.1
Alcohol related	1,261	3	2,454	5	5,640	3	2.6	4.5	1.4	0.5	0.5	0.1
Light Condition												
Daylight	33,862	69	29,250	65	129,084	70	69.1	54.1	31.8	12.3	5.7	2.4
Night or dark	15,195	31	15,449	34	54,634	30	31.0	28.6	13.5	5.5	3.0	1.0
Weather Condition												
Normal conditions	41,262	84	36,601	82	152,284	83	84.2	67.8	37.5	14.9	7.1	2.9
Rain	4,780	10	4,522	10	16,873	9	9.8	8.4	4.2	1.7	0.9	0.3
Adverse conditions	2,937	6	3,527	8	14,371	8	6.0	6.5	3.5	1.1	0.7	0.3
Time of Crash												
5.00 - 9.00	6,242	13	5,653	13	32,260	18	12.7	10.5	7.9	2.3	1.1	0.6
9.00 - 13.00	6,986	14	7,592	17	34,857	19	14.3	14.1	8.6	2.5	1.5	0.7
13.00 - 17.00	15,586	32	12,058	27	51,123	28	31.8	22.3	12.6	5.6	2.3	1.0
17.00 - 21.00	12,067	25	10,791	24	44,091	24	24.6	20.0	10.9	4.4	2.1	0.8
21.00 - 5.00	8,263	17	8,684	19	21,661	12	16.9	16.1	5.3	3.0	1.7	0.4
Day of Week												
Week days	37,434	76	33,481	75	145,755	79	76.4	62.0	35.9	13.6	6.5	2.7
Week end	11,727	24	11,311	25	38,295	21	23.9	20.9	9.4	4.2	2.2	0.7
Functional Class												
Rural roads	9,380	19	5,291	12	22,988	12	19.1	9.8	5.7	3.4	1.0	0.4
Urban interstate	113	0	163	0	799	0	0.2	0.3	0.2	0.0	0.0	0.0
Urban arterial	16,519	34	14,983	33	57,881	31	33.7	27.7	14.3	6.0	2.9	1.1
Urban collector	3,741	8	2,801	6	10,606	6	7.6	5.2	2.6	1.4	0.5	0.2
Urban local street	6,840	14	5,749	13	19,734	11	14.0	10.6	4.9	2.5	1.1	0.4
Crash Location												
On roadway	18,347	37	17,670	39	78,379	43	37.4	32.7	19.3	6.6	3.4	1.5
Intersection	26,619	54	23,500	52	95,470	52	54.3	43.5	23.5	9.6	4.5	1.8
Off roadway	4,188	9	3,615	8	10,194	6	8.5	6.7	2.5	1.5	0.7	0.2
Road Surface Condition												
Dry	38,565	78	34,010	76	143,223	78	78.7	63.0	35.3	14.0	6.6	2.7
Wet	6,404	13	6,070	14	22,949	12	13.1	11.2	5.7	2.3	1.2	0.4
Debris	3,965	8	4,515	10	17,191	9	8.1	8.4	4.2	1.4	0.9	0.3
Road Surface Character												
Straight and level	36,164	74	32,778	73	134,254	73	73.8	60.7	33.1	13.1	6.3	2.5
Straight not level	9,176	19	8,350	19	35,888	19	18.7	15.5	8.8	3.3	1.6	0.7
Curved	3,479	7	3,389	8	12,833	7	7.1	6.3	3.2	1.3	0.7	0.2

Table 3 Crash Frequencies, Percentages and Crash Rates by Diver Group: Vehicle- and Crash-Related Characteristics

Characteristic	Number of Crashes involved drivers						Crashes per 1000 Drivers			Crashes per Million VMT		
	Teen		Young-adult		Experienced		Teen	Young-adult	Exp.	Teen	Young-adult	Exp.
	No.	%	No.	%	No.	%						
Vehicle Damage												
Not damage	949	2	1,016	2	6,161	3	1.9	1.9	1.5	0.3	0.2	0.1
Minor damage	11,262	23	10,465	23	52,083	28	23.0	19.4	12.8	4.1	2.0	1.0
Functional	16836	34	16,007	36	67,953	37	34.4	29.6	16.7	6.1	3.1	1.3
Disabling	16,012	33	14,110	31	48,165	26	32.7	26.1	11.9	5.8	2.7	0.9
Destroyed	3,826	8	2,962	7	8,625	5	7.8	5.5	2.1	1.4	0.6	0.2
Vehicle Body type												
Automobile	33,432	68	29,195	65	83,981	46	68.2	54.0	20.7	12.1	5.6	1.6
Van	1,410	3	1,469	3	17,867	10	2.9	2.7	4.4	0.5	0.3	0.3
Pickup-truck	8,075	16	7,342	16	38,396	21	16.5	13.6	9.5	2.9	1.4	0.7
Sport utility vehicle	6,062	12	5,930	13	32,730	18	12.4	11.0	8.1	2.2	1.1	0.6
Other	176	0	861	2	11,051	6	0.4	1.6	2.7	0.1	0.2	0.2
Vehicle year												
<1990	4,184	9	2,551	6	9,954	5	8.5	4.7	2.5	1.5	0.5	0.2
1990 - 1994	9,805	20	6,285	14	20,589	11	20.0	11.6	5.1	3.5	1.2	0.4
1995 - 1999	18,251	37	14,579	33	48,875	27	37.2	27.0	12.0	6.6	2.8	0.9
2000 - 2004	13,109	27	15,203	34	66,857	36	26.8	28.1	16.5	4.7	2.9	1.3
>2005	3,497	7	5,912	13	36,316	20	7.1	10.9	8.9	1.3	1.1	0.7
Vehicle Maneuver												
Straight-following road	29,820	61	27,417	61	109,217	59	60.9	50.8	26.9	10.8	5.3	2.1
Turn or changing lanes	9,474	19	7,400	17	26,650	14	19.3	13.7	6.6	3.4	1.4	0.5
Avoiding maneuver	1,724	4	1,591	4	5,287	3	3.5	2.9	1.3	0.6	0.3	0.1
Stopped, parking or backing	7,499	15	7,769	17	40,935	22	15.3	14.4	10.1	2.7	1.5	0.8
Other	431	1	413	1	1,352	1	0.9	0.8	0.3	0.2	0.1	0.0
Accident Class												
Other non-collision & overturned	2,055	4	1,622	4	5,023	3	4.2	3.0	1.2	0.7	0.3	0.1
Collision with vehicle	37,231	76	33,269	74	137,315	75	76.0	61.6	33.8	13.5	6.4	2.6
Collision with pedestrian or animal	2,325	5	3,268	7	23,161	13	4.7	6.0	5.7	0.8	0.6	0.4
Collision with object	7,544	15	6,631	15	18,542	10	15.4	12.3	4.6	2.7	1.3	0.3
Injury Severity												
Fatal injury	83	0	117	0	436	0	0.2	0.2	0.1	0.0	0.0	0.0
Disabled injury	486	1	431	1	1,786	1	1.0	0.8	0.4	0.2	0.1	0.0
Injury	3,522	7	3,033	7	10,190	6	7.2	5.6	2.5	1.3	0.6	0.2
Possible injury	3,436	7	3,186	7	12,843	7	7.0	5.9	3.2	1.2	0.6	0.2
Not injured	39,390	80	36,127	81	150,954	82	80.4	66.9	37.2	14.3	7.0	2.8
Ejection												
Ejected	278	1	234	1	613	0	0.6	0.4	0.2	0.1	0.0	0.0
Not ejected	46,216	94	42,342	95	173,972	95	94.3	78.4	42.8	16.7	8.2	3.3
Trapped	287	1	239	1	1,144	1	0.6	0.4	0.3	0.1	0.0	0.0

This may be due to teen might more often use older vehicles. Higher percentage of vehicles was destroyed due to crashes involving teen drivers compared to experienced drivers. Teen drivers also had higher crash involvement percentage in collision with a fixed object than experienced drivers. However, teen-driver crash involvement percentages for many other vehicle- and crash-related characteristics were similar to the young-adult drivers as well as experienced drivers. Crash rates of vehicle- and crash-related characteristics showed the same pattern as driver-, environmental-, and vehicle-related crash rates when comparing teen, young-adult and experienced drivers. However, teen driver crash rate per 1,000 drivers when operating an automobile, or taking a turn were three times that of experienced drivers. Also teen driver crash rates when vehicle destroying, non-colliding/overturning, or colliding with other vehicle were three times that of experienced drivers. Teen driver crashes per Million VMT in operating automobile, vehicle destroying, or tuning, non-colliding and overturning, avoiding maneuver, colliding with fixed object were eight times that of experienced drivers. Teen driver crash rates per 1,000 licensed teen drivers, when they are traveling at rural local road or in the night time were three times that of experienced drivers.

Contributory Factors

The contributory causes for young driver crashes were also investigated using Kansas crash data. Many factors might have combined to produce circumstances that lead to a traffic crash; there was rarely a single cause of such an event. Mainly these contributory causes could be divided into four categories of factors that contribute to crashes driver-, roadway-, environment-, and vehicle-related contributory factors. The driver-related contributory factors involve the actions taken by or the condition of the driver of the motor vehicle. The contributory factors for teen, young-adult and experienced drivers are provided in Table 4. Those contributory factors were recorded for 74% of the young-adult and teen drivers involved in crashes. Failure to give time and attention was the top ranked driver contributory cause in the teen driver crashes followed by speeding, failure to yield right of way and disregarding traffic signs/signals. Those driver-related contributory factors were also the most critical factors among young-adult drivers and experienced drivers. The crash rates for teen driver-related contributory causes per 1,000 licensed drivers were slightly more than three times that of experienced drivers. Corresponding young-adult driver contributed crash rates were two times that of experienced drivers. Teen driver involved crashes per VMT due to failure to give time and attention, failure to yield right of way, speeding, and disregarding traffic signs and signals were eight times that of experienced drivers and twice that of young-adult drivers.

The most frequent environmental-related contributory factors for teen driver involved crashes were identified animals in the road, followed by raining/snowing. The most common vehicle-related contributory factor for teen driver crashes were identified as failure of brakes, followed by failure of tires. The most frequent vehicle-related contributory factors for young-adult drivers were identified as failure of tires and brakes respectively. Icy or slushy conditions and wet road surfaces were the most frequent road-related contributory factors for all age groups.

The teen drivers' crash percentage due to animals in the road was less than that of young-adult drivers and experienced drivers. Conversely, crash percentage of teen drivers due to rain was higher than that of young-adult drivers and experienced drivers. The teen drivers' crash percentage due to failure of brakes was higher than that of young-adult drivers and experienced drivers. Also, crash percentage for teen driver involved in crashes due to wet road surfaces was higher than that of young-adult drivers and experienced drivers. Crash rates due to

environmental-, vehicle- and road-related contributory factors for teen drivers were higher than that of young-adult drivers and experienced drivers.

Table 4 Crash Frequencies, Percentages, and Crash Rates for Contributory Factors

Contributory Factor	Number of Crashes						Crashes per 1000 drivers			Crashes per Billion VMT		
	Teen		Young		Experienced		Teen	Young-adult	Experienced	Teen	Young-adult	Experienced
	No.	%	No.	%	No.	%						
Driver Related												
Failure to give time and attention	13,842	36	10,339	34	31,606	35	28.2	19.1	7.8	15.5	6.2	0.2
Speeding	5,699	15	4,608	15	11,518	13	11.6	8.5	2.8	6.4	2.8	0.1
Failure to yield right of way	5,193	14	3,649	12	11,575	13	10.6	6.8	2.9	5.8	2.2	0.1
Disregarding traffic sign/signal	4,942	13	4,108	13	12,231	13	10.1	7.6	3.0	5.5	2.5	0.1
Improper action	2,320	6	1,838	6	7,410	8	4.7	3.4	1.8	2.6	1.1	0.1
Turning or lane changing	1,361	4	1,040	3	3,577	4	2.8	1.9	0.9	1.5	0.6	0.0
Aggressive driving	1,335	3	1,122	4	2,000	2	2.7	2.1	0.5	1.5	0.7	0.0
Other driver factors	1,254	3	994	3	3,833	4	2.6	1.8	0.9	1.4	0.6	0.0
Alcohol impaired	1,190	3	2,208	7	5,345	6	2.4	4.1	1.3	1.3	1.3	0.0
Distraction	1,155	3	730	2	1,786	2	2.4	1.4	0.4	1.3	0.4	0.0
Environmental Related												
Animal at road	1,742	50	2,290	54	15,226	68	3.6	4.2	3.8	1.9	1.4	0.1
Rain	681	20	716	17	2,372	11	1.4	1.3	0.6	0.8	0.4	0.0
Falling snow	257	7	420	10	1,514	7	0.5	0.8	0.4	0.3	0.3	0.0
Vision obstruct-glare	249	7	143	3	607	3	0.5	0.3	0.1	0.3	0.1	0.0
Vehicle Related												
Brakes	218	34	133	25	369	20	0.4	0.2	0.1	0.2	0.1	0.0
Tires	157	25	151	29	486	26	0.3	0.3	0.1	0.2	0.1	0.0
Road Related												
Icy or slushy	998	44	1,222	50	4,076	50	2.0	2.3	1.0	1.1	0.7	0.0
Wet	757	34	640	26	1,967	24	1.5	1.2	0.5	0.8	0.4	0.0
Snow packed	208	9	304	13	1,053	13	0.4	0.6	0.3	0.2	0.2	0.0

Odds Ratios

The results of ORs and CI of driver contributory factors were examined among the three driver age groups. Comparisons were made between teen versus experienced groups, between teen versus young-adult groups, and between experienced versus young groups as shown in Tables 5. When interpreting results, OR's greater than one show greater contribution from the

particular factor for considered driver-age group than the other driver-age group. The teen drivers were more likely to have crashes due to failure to give time and attention, falling asleep, failure to yield right of way, distraction, making improper turn or exceeding the posted speed limit compared to 20 to 24 year old drivers. Also teen drivers were more likely to involve in crashes due to driving too fast for conditions, following too closely, restless, careless, and aggressive driving compared to experienced drivers.

Table 5 Odds Ratios (OR's) and Confidence Intervals (CI) for Driver Contributory Factors

Factors	Teen versus Experienced			Teen versus Young-adult			Young versus Experienced		
	OR's	95% CI		OR's	95% CI		OR's	95% CI	
		L	U		L	U		L	U
Failed to give time and attention or fell asleep	1.08	1.04	1.11	1.11	1.08	1.15	1.01	0.98	1.04
Failed to yield right of way	1.06	1.04	1.09	1.16	1.11	1.21	1.01	0.99	1.04
Too fast for conditions	1.12	1.08	1.16	0.97	0.92	1.01	1.13	1.10	1.17
Followed too closely	1.06	1.02	1.11	1.01	0.96	1.06	1.06	1.02	1.09
Distraction	1.80	1.59	2.03	1.20	1.03	1.38	1.67	1.50	1.85
Disregard traffic signs, signal or improper or no signal	0.81	0.77	0.86	0.88	0.82	0.95	0.86	0.82	0.90
Improper lane change, backing or passing	0.64	0.60	0.67	0.93	0.87	1.00	0.66	0.63	0.69
Restless/careless/aggressive/ antagonistic driving	1.61	1.50	1.72	0.95	0.88	1.03	1.64	1.55	1.75
Under influence of alcohol or drugs	0.51	0.48	0.55	0.41	0.38	0.44	0.83	0.79	0.87
Avoidance or evasive action	0.93	0.87	0.99	1.06	0.97	1.16	0.90	0.85	0.96
Made improper turn	0.95	0.88	1.02	1.16	1.06	1.28	0.89	0.84	0.95
Exceeded posted speed limit	2.03	1.85	2.23	1.14	1.02	1.27	1.92	1.77	2.09
Wrong side or wrong way, impeding traffic, too slow, improper Parking	0.72	0.64	0.80	0.81	0.70	0.93	0.79	0.72	0.87
Ill medical condition	0.23	0.18	0.29	0.60	0.45	0.80	0.30	0.26	0.35

Multinomial Logit Model

The results of the young driver injury severity model which included four injury severity levels are presented in Table 6. The model diagnostics showed a Likelihood Ratio Chi Square statistic of 35,102 whose p-value is < 0.0001. In addition to the overall p-value, logit model also report the individual p-value for each independent variable. A low p-value means that this particular independent variable significantly improves the fit of the multinomial logit model, showing that the variable has a significant impact on the model. Those significant variables are directly associated with injury severity of young driver crashes.

According to the coefficients of the estimated logit model, teen drivers showed higher injury severity when involved in crashes. Alcohol involvement and restrictions on driver license were significant factors which increase the young driver injury severity. Seat belt restrained drivers were less likely to suffer severe injuries when involved in crashes. Also, ejection or trapped at the time of crash increase the injury severity while non-ejection decreases the injury severity of young driver. Valid license hold driver were less likely to suffer injuries.

Table 6 Driver Injury Severity Model Results

Label	Parameters	Coef.	Std. Err.	p-value	Label	Parameters	Coef.	Std. Err.	p-value
intercept	Fatal and severe injury	-3.345	0.235	<0.001	LOCATION	Off roadway	0.096	0.051	0.016
	Injury	0.941	0.015	<0.001		Intersection on roadway	-0.086	0.056	0.125
	Possible injury	0.384	0.058	<0.001		Non intersection on roadway	0.000	-	-
	Not injured	-	-	-	CLASS	Overturned	1.526	0.201	<0.001
AGE	Age 15-19	0.115	0.028	<0.001		Collision with vehicle	0.282	0.063	<0.001
	Age 20-24	0.000	-	-		Collision with pedestrian or animal	1.797	0.142	<0.001
DRMALE	Driver male	-0.579	0.028	<0.001		Collision with object	0.539	0.070	<0.001
	Driver female	0.000	-	-		Other non-collision & others	0.000	-	-
VALID	Valid license	-0.076	0.050	0.130	DAMAGE	Destroyed	3.033	0.175	<0.001
	Not licensed	0.000	-	-		Disabling	2.956	1.629	<0.001
RESTRC	Restricted driver license	0.018	0.029	0.542		Functional	2.552	0.052	<0.001
	Not restricted driver license	0.000	-	-		Minor damage	1.092	0.041	<0.001
SEATB	Seat belt used	-0.546	0.057	<0.001		No damage	0.000	-	-
	Airbag deployed	0.875	0.043	<0.001	PANUM	Driver alone	0.052	0.029	0.211
	Constraint system not used	0.000	-	-		With passengers	0.000	-	-
ALCO	Alcohol involved	0.414	0.060	<0.001	AUTO	Automobile	0.139	0.139	0.073
	No alcohol	0.000	-	-		Other vehicle	0.000	-	-
LIGHT	Dark	-0.132	0.053	0.012	MANU	Back up	0.468	0.168	<0.001
	Street light on	-0.121	0.056	0.032		Turn or changing lanes	0.612	0.612	<0.001
	Day light	0.000	-	-		Straight-following	0.000	-	-
WEATHER	Sunny	0.257	0.066	<0.001	EJECT	Eject	-0.517	0.183	0.005
	Rain	0.047	0.047	0.3148		Not eject	2.582	0.140	<0.001
	Adverse weather condition	0.000	-	-		Trapped	0.000	-	-
WEEK	Weekday	0.033	0.032	0.297	NEW	Vehicle made > 2000	-0.177	0.030	<0.001
	Weekends	0.000	-	-		Vehicle male <=2000	0.000	-	-
RURAL	Rural roads	0.043	0.045	0.332	WZONE	Work zone	-0.197	0.125	0.115
	Urban roads	0.000	-	-		Not a work zone	0.000	-	-
					SPEED	Posted speed limit	0.016	0.002	<0.001
Goodness of Fit Tests									
Pearson Chi-Square		86,108	<0.001						
L.R. Chi Square		35,102	<0.001						

Young driver's injury severity was higher when they were involved in run-off-road crashes. Collision with fixed-objects, other vehicles, or pedestrian/animal increased the young driver injury severity. Also, involvement of non-collision and overturn crashes showed a higher injury severity for young drivers. The vehicle damage was a significant factor which increases the young driver injury severity whether it was minor damage, functional, disabling or destroyed at the time crash. Young drivers were more likely to suffer severe injuries in crashes occurred when they were attempting the lane change or backing up. Youth driving in newer vehicles were less likely to involve severe injuries. Driving on higher posted speed limit roadways were also significant factor which increase the young drivers' injury severity.

DISCUSSION AND COUNTERMEASURE IDEAS

Young drivers' crash rates are higher than that of experienced drivers', and therefore protective devices, crashworthy cars, safer road infrastructures will particularly reduce young drivers' risk. While driving, young driver's behavior is influenced by his or her general frame of mind, which among other things, reflect the situation just behind or approaching. As shown in logit model results developed in this study, high speeds were one of the risk factors, as young drivers lack experience. Hence, predictable traffic situations, law complexity resulting from an improved road infrastructure are beneficial for young drivers. In particular, Graduated Licensing System is designed to address the teen and inexperienced young drivers' crash risk by letting them acquire driving experience under low risk conditions (Williams, Ferguson and Wells 2003). The goal of the licensing process, including training, should be to create drivers that are safe, increasing awareness of their own limitations and of the inherent to drivers. Failure to give time and attention, failure to yield right of way, driving too fast for conditions and following too closely were the main contributory causes that could be included to education programs in order to increase the awareness which are also effective countermeasures for decreasing young driver risk. A driver's safety related characteristics are formed well before the age at which he or she legally begins driving; hence education programs and communication programs in schools can be focused on children at much younger age than legal driving age. Training programs could be focused more on backing up, turning and changing lanes because young drivers shows high injury severity for those maneuvers when they were involved in crashes. Another fact is preventing teen drivers from adopting bad habits and informal rules in traffic such as fast driving, drinking while driving etc. (OECD 2006). According to the model developed, teen drivers are at high risk for injuries, also crash rate shows teen drivers' involvements in crashes are higher than young-adult drivers. Hence, parental management practices may be important influences on teen driver practices and safety when imposed. For instance, enforcement will have a proportionately higher impact on young drivers, as they more frequently violate traffic rules such as driving with valid driving license, and driver license restriction on it (Hanna et al. 2006). Special attention should be paid to unlicensed driving because more regulated and demanding driving process becomes, the more tempted teens will drop out of licensing process and drive without license. However, it is difficult for police to specially identify young drivers on the road, this makes the young driver specific countermeasures difficult. Measures focusing on improving the safety of all road users under all conditions will also be beneficial for young drivers, who frequently exhibit dangerous behaviors. In particular, rural road and off- roadway crash involvement and high injury risk could be reduced by safer road infrastructures such as rumble strips and lane departure warning. Also road infrastructures should be improved to avoid the

hitting the animals on vehicles that are a main road-related contributory factor for crashes in Kansas.

One of the primary countermeasures for reducing injury risk is increasing the seat belt usage. In 2010, Kansas has turned to primary seat belt restraint law from secondary law for teen drivers aged 15 to 17 years olds. According to the developed model, avoiding alcohol involved driving is an important factor on reducing injury risk. It is also a factor in reducing crash involvement. Age 21 as the legal drinking age, young drivers are restricted to alcohol use, but alcohol involved crashes are significant factor for increased crash injuries. Hence, enforcement is needed specially locations where high alcohol use is expected. Distraction is a main contributory cause for teen drivers. Many drivers use audio entertainment systems, mobile phones, but very few use on-vehicle visual displays such as DVD. Implementation of laws, such as prohibiting mobile phone use while driving, stopping visual displays would be beneficial, particularly for young drivers. Not all effective countermeasures can be implemented simultaneously. However, some countermeasures are less effective when introduced in isolation (OECD 2006).

SUMMARY AND CONCLUSIONS

This study explored the detailed characteristics of young drivers involved crashes and contributory factors in Kansas and compared those with experienced drivers. Crash data were obtained from KDOT, driver license data were obtained from US Department of Transportation and annual vehicle miles driven were obtained from National Household Travel Survey 2010. Young drivers were further divided into two groups; Teen and Young-adults. Detailed frequency analysis and crash rate analysis were carried out for both of groups. Furthermore detailed frequency analysis was carried out for experienced drivers and comparisons were made among each driver groups. Number of teen driver involved crashes per 1000 licensed teen drivers was higher than that of young and experienced drivers. Number of teen driver involved crashes per million annual vehicle miles travel was twice that of young-adult drivers. Teen drivers in Kansas were at considerable risk of motor vehicle crashes compared with experienced drivers. The factors which increase young drivers' injury severity such as alcohol involvement, high speed can be used for teen crash prevention efforts. Many complex factors influence and contribute to teen driving behavior. The increased crash frequency and risk for this age group has been attributed to failure to give time and attention, falling asleep, failure to yield right of way, driving too fast for conditions, following too closely or distraction lead to increase the crash risk compared to experienced drivers.

Based on the identified critical factors countermeasure ideas were suggested to improve the safety of young drivers. Understanding these contributory factors could lead to better crash mitigation strategies. It is important for teen drivers to gain better education of these critical factors that is helpful to increase the training on those, prevent crashes and minimize the driving risk.

ACKNOWLEDGEMENT

This study is a part of an on-going project funded by Kansas Department of Transportation. The authors would like to thank KDOT for their support in providing the data.

REFERENCES

Allison, Paul D. 2001. "Logistic Regression Examples Using the SAS: Theory and Application." North Carolina:SAS Institute Inc.

Ballesteros, Michael. F., and Patricia. C. Dischinger. 2002. "Characteristics of Traffic Crashes in Maryland (1996- 1998): Differences among the Youngest Drivers." *Accident Analysis and Prevention* 34:279-284.

Cooper, Douglas, Frank Atkins, and David Gillen. 2005. "Measuring the Impact of Passenger Restrictions on New Teenage Drivers." *Accident Analysis and Prevention* 37:19-23.

Dissanayake, Sunanda, and John Lu. 2002. "Severity of Young Driver Crashes Using Sequential Binary Logistic Regression Modeling." CD-ROM Transportation Research Board of the National Academies, Washington D.C., Paper No: 00983.

Fu, Haoqiang, and Chester. G. Wilmot. 2008. "The Effect of Passenger Age and Gender on Young Driver Crash Risks." CD-ROM Transportation Research Board of the National Academies, Washington D.C., Paper No: 08-0617.

Gonzales, Michael M., L. Miriam Dickinson, Carolyn DiGuiseppi, and StevenR. Lowenstein. 2005. "Student Drivers: A study of Fatal Motor Vehicle Crashes Involving 16-Year Old Drivers." *Injury Prevention* 45: 140-146.

Hanna, Christian L., Dexter M. Taylor, Monique A. Sheppard, and Lucie Laflamme. 2006. "Fatal Crashes Involving Young Unlicensed Drivers in the U.S." *Journal of Safety Research* 37:385-393.

Insurance Institute Highway Loss for Highway Safety Data Institute. "Fatality Facts 2008 Teenagers." Accessed May 3, 2010.
http://www.iihs.org/research/fatality_facts_2008/teenagers.html

Kansas Department of Transportation. "Kansas Strategic Highway Safety Plan." Accessed May 3, 2010. http://www.atsa.com/galleries/default-file/Kansas_SHSP.pdf

Long, J. Scott. 1997. "Regression Models for Categorical and Limited Dependent Variables." California: SAGE.

Kostyniuk, Linda P., and Jean T. Shope. 2003. "Driving and alternatives: Older drivers in Michigan." *Journal of Safety Research* 34: 407-414.

McKnight, A. James, and A. Scott McKnight. 2003. "Young Novice Drivers: Careless or Clueless?" *Accident Analysis and Prevention* 35: 921-925.

Motulsky, Harvey. GraphPad Software. "Multicollinearity in Multiple Regressions." Accessed May 23, 2011. <http://www.graphpad.com/articles/Multicollinearity.htm>

Neyens, David M., and Linda N. Boyle. 2007. "The Effect of Distractions on the Crash Types of Teenage Drivers." *Accident Analysis and Prevention* 39: 206-212.

NHTS Data Center. "National Household Travel Survey (NHTS) 2009." Accessed May 3, 2010.
<http://nhts.ornl.gov/download.shtml#2009>

Organization for Economic Co-Operation and Development, Transportation Research Center. 2006. "Young Drivers: The Road to Safety." France: OECD Publishing.

Preusser, F. David, Susan A. Ferguson, and Allan F. Williams. 1998. "The Effect of Teenage Passengers on the Fatal Risk of Teenage Drivers." *Accident Analysis and Prevention* 30: 217-222.

U.S. Department of Transportation, Federal Highway Administration. "Highway Statistics 2008." Last Modified January 2010. Accessed March 5, 2010.
<http://www.fhwa.dot.gov/policyinformation/statistics/2008/dl22.cfm>

U.S. Department of Transportation, Federal Highway Administration. "Highway Statistics 2007." Last Modified December 2008. Accessed March 5, 2010.
<http://www.fhwa.dot.gov/policyinformation/statistics/2007/dl22.cfm>

U.S. Department of Transportation, Federal Highway Administration. "Highway Statistics 2006." Last Modified October 2007. Accessed March 5, 2010.

Vachal, Kimberly, Research Faculty, and Donal Malchose. 2009. "What Can We Learn About North Dakota's Youngest Drivers from Their Crashes?" *Accident Analysis and Prevention* 41:617-623.

Williams, Allan F., Susan A. Ferguson, and Joann K. Wells. 2005. "Sixteen-Year-Old Drivers in Fatal Crashes, United States, 2003" *Traffic Injury and Prevention* 6:202-206.

<http://www.fhwa.dot.gov/policy/ohim/hs06/htm/dl22.htm>.