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by Niranga Amarasingha and Sunanda Dissanayake

Young drivers have higher motor vehicle crash rates compared to other drivers, and understanding the reasons for this would help to improve safety. This study, therefore, investigated characteristics and contributory causes of young-driver crashes and developed multinomial logit models to identify severity affecting factors. It was found that teen drivers were more likely to be involved in crashes due to failure to give time and attention and falling asleep. Among other factors, alcohol involvement, not wearing a seat belt, driving without a valid license, having restrictions on driver's license, and involvement in off-roadway crashes were factors that increased young-driver injury severity. Based on identified factors, countermeasure ideas for improving safety have also been suggested.

INTRODUCTION

Teen and young-adult drivers have much higher motor vehicle crash rates per licensed driver than other drivers, both in Kansas and throughout the United States (U.S.) (Ballesteros and Dischinger 2002). 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 U.S. (IIHS 2008). National statistics in 2008 showed teenage drivers accounted for 12% of all drivers involved in fatal crashes and 14% of all drivers involved in all police-reported crashes but they accounted for less than 5% of all drivers (IIHS 2008, USDOT 2008). Also, beginning drivers were three times more likely to die in a motor vehicle crash than an average driver (IIHS 2008). In Kansas, the young-driver safety issue has been identified by the 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 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 the safety of young drivers.

Accordingly, the objectives of this study were to investigate the characteristics, contributory causes by numbers and percentages, crash rates, and crash-severity factors related to highway crashes involving teen and young-adult drivers by investigating coefficient estimates through development of a multinomial logit model. Crash rates were calculated in terms of crashes per 1,000 drivers and Vehicle Miles of Travel (VMT). Comparisons between teen drivers, young-adult drivers, and experienced drivers were also carried out in order to identify young-driver over-representation in various crash characteristics and contributory causes of young-driver-involved crashes.

LITERATURE REVIEW

High crash rates by young drivers are well documented in the literature, whichever exposure data (e.g., number of licensed drivers, vehicle miles travel) are 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 that increase injury severity of young drivers involved in motor vehicle crashes (Neyens and Boyle 2007). Many studies have focused on young-driver crash involvement and crash risk. Based on the study conducted in Louisiana using crash data from 1999 to 2004, young driver risk-taking behavior was much more present in male drivers with the presence of male peers than the 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 et al. (2005), using fatality and crash data from 1991 to 1997, studied the new passenger restrictions in California, which are that new provisional license holders are restricted from transporting those under 20 years old for the first six months. The law has been effective in reducing these rates, and the reduction of passengers in crash-involved cars resulted in an estimated saving of eight lives and 684 injuries over three years. Hanna et al. (2006) investigated young unlicensed drivers' involvement in fatal crashes, using data from Fatality Analysis Reporting System (FARS).

Young unlicensed driver involvement in fatal crashes was similar to young licensed drivers' involvement in fatal crashes. However, the errors for experienced young drivers were relatively few in number and small in magnitude, according to the study conducted in California from 1996 to 2000 by McKnight and McKnight (2003). Benefits of experience apply rather generally across all aspects of driving, as behavioral shortcomings such as failure to employ routine safe operating practices, failure to recognize danger, and risk-taking are high in beginning drivers. A logit model of teen-driver injury crashes, which was developed by Vachal and Malchose (2009), using crash data from 2001 to 2007, offered insight for creating a safer driving environment for teen drivers. They found that 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 the introduction of graduated licenses have been focused on reducing young-driver crash involvement in the U.S. It has resulted in some progress nationally in reducing fatal crashes among 16 year olds but young drivers' over involvement in crashes was still a big problem (Williams, Ferguson, and Wells 2005). Gonzales et al. (2005) studied 16-year-old drivers involved in fatal vehicle crashes during 1995-2000 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 databases such as FARS and the General Estimate System (GES). Also, many research studies have focused on young-driver crash involvement and crash risk. Most of the preliminary 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 and multiple probit analyses were done to check the association between driver injury severity and related factors. For example, binary logistic regression models were developed to compare teen drivers and experienced drivers 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 model using the Florida traffic database. 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 contain both teenage drivers and their passengers, to develop an ordered logit model. The dependent variable, which was injury severity, was also defined under five categories. Results showed that teen drivers have an increased likelihood of more severe injuries if distracted by a cell phone or passengers than other sources of distraction. Using injury crash records, a multinomial logit model was developed to study driver, vehicle, and road-related factors for North Dakota teenage drivers (Vachal and Malchose 2009). The relative likelihood of severity, which is driver fatality or disabling injury, in a crash was the dependent variable.

Mercier et al. (1997) assessed whether age and gender, or both, influenced injury severity in head-on automobile collisions on rural roads. Data were obtained from Iowa Department of Transportation's Accident File, beginning from 1986 through part of 1993. All the collisions could be divided into three groups; head-on, broadside, and angle approach. Since the head-on collisions were the most severe crashes, the study was limited to those crashes. Also, this study limited for crashes on paved surfaces, and front seat occupants. The principal components logistic regression and hierarchical logistic regression models were developed using injury severity as the dependent variable, which was measured as fatal, major, or minor. In the preliminary analysis, 14 independent variables were considered. Results showed that age remains as a very important factor for predicting injury severity. The deployed air bags seemed more beneficial for women than for men, whereas use of lap and shoulder restraints appeared to be more beneficial for men. This study recommended reexamining the design parameters for protective systems in automobiles.

Aldridge et al. (1999) investigated the effect of passengers on young driver accident propensity using crash data that were extracted from a Kentucky accident database between 1994 and 1996. In this study, young drivers were individuals between the ages of 16 and 20 years and peers to these young drivers were individuals between 12 and 24 years old. The analysis was done using the induced-exposure technique, which measures the Relative Accident Ratio (RAIR) by taking the ratio of the percentage of at-fault drivers in a specific subgroup to the percentage of not-at-fault drivers for the same subgroup. Seven possible interaction variables, driver gender, total occupant gender, time of the week, time of the day, vehicle age, and safety restraint usage were considered. Young drivers have a high propensity for causing single-vehicle crashes when traveling with peers, but they have lower propensity to cause either single-vehicle crashes or multi-vehicle crashes when traveling with adult/child passengers. These findings of this study supported for the Kentucky's graduated license program. Further, it suggested increased education and a training period for young drivers under adult supervision.

Despite these suggestions, young drivers still have higher crash rates compared with other drivers. Using a multinomial logit model, this study compared the young drivers' crash rates for each characteristic with experienced drivers' crash rate that may add new information to the young driver safety literature. Also, no research has been done to investigate young driver safety issues using Kansas crash data.

Kansas Law Related to Young Drivers

The Kansas law prior to 2010 covering licenses is summarized in this section (KDOT 2009). 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 allowed. Even then, the most direct and accessible route between the driver's home and school or work was to be used. However, a restricted license holder could drive anywhere, anytime with a licensed adult driver's supervision. Passenger restrictions included transportation of non-sibling minor passengers. At age 16, a full license was granted if a 50-hour affidavit, which is proof of completion of 50 hours of driving, had been turned in. The law changed in 2010 with the current law allowing fewer restricted licenses at age 16 instead of a full license, and after six months a full license is granted. Even though the law changed in 2010, it did not have any effect on this study because all data for this analysis were 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 the restricted license was 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 range of young drivers considered was from age 15 to 24. In order to investigate young-driver characteristics in detail, they were further divided into two groups: the teen-driver group from age 15 to 19 and the young-adult-driver group from age 20 to 24. 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 ages ranged from 25 to 64 (Ballesteros and Dischinger 2002; Gonzales et al. 2005). Those above age 65 were not considered to compare with young drivers because older-driver characteristics may be different from those of 25- to 64-year-old drivers, and older drivers have also been found to have unique highway safety challenges (Gonzales et al. 2005; Kostyniuk and Shope 2003).

DATA AND METHODOLOGY

Data

Crash data from 2006 to 2008 were obtained from the Kansas Department of Transportation (KDOT). This data set, Kansas Accident Reporting System (KARS) database, comprises all police-reported crashes that have occurred in Kansas. Motor vehicle young-driver-involved crashes on 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) young-driver-involved crashes and 186,600 (58% of total crashes) experienced-driver-involved crashes. Driver contributory factors for 54,349 crashes were recorded for the 94,817 young-driver-involved crashes. There were up to 10 contributing factors recorded in the traffic crash database for some crashes, while contributory factors were not recorded at all in some other crashes. Environment-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 crash rates, driver’s license information for each year by age was obtained from the U.S. Department of Transportation (USDOT 2008; USDOT 2007; USDOT 2006). Table 1 provides the number of licensed drivers in Kansas during 2006 through 2008 by age group and gender. From 2006 to 2008, the number of licensed teen drivers increased from 159,655 to 166,663, and the number of licensed young-adult drivers increased from 177,407 to 181,616 in Kansas. However, the number of experienced drivers 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 2009). The Midwest region consists of Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, North Dakota, Nebraska, Ohio, South Dakota, and Wisconsin. Annualized travel day VMT by each age for the Midwest were extracted from the NHTS database (NHTS 2009). This gives the average VMT by the interviewed drivers in each age, and the VMTs were divided by the respective sample size to obtain VMT per driver. The VMT per driver were categorized for each age group. Then multiplying those values by the number of Kansas drivers in their respective age group, the total annual VMT by Kansas drivers in each age group was estimated. Estimated Kansas VMT for teen, young-adult, and experienced groups were 920, 1,724, and 17,750 million per year, respectively (NHTS 2009). Those values were then multiplied by three in order to obtain total VMT for three years. The crash rates per VMT were calculated for each age group by dividing the number of crashes of age group by VMT of respective age group.

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

A multinomial logit model was developed to identify variables expected to have an explanatory effect on injury severity of young drivers involved in crashes. Using the coefficient of the explanatory variables, risk factors that increase 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

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

where,

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

The logit model assumes a driver-injury severity function has a linear-in-parameters form as

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

where

β_i = a vector of estimable coefficients for injury severity i and x_i is a vector of variables for driver n; and
ε_i = a random component which has identically and independently distributed error terms.

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

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

The maximum likelihood method is then used to estimate the coefficients.

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 or more 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 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 it is not significant. The second problem is that confidence intervals on the model coefficients will be very wide. To help assess multicollinearity, the correlation matrix of the independent variables was 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. In such cases, only one of those two variables was used for development of the model.

RESULTS

Driver, Environment, and Road-Related Characteristics

Crash rates were higher for teen drivers than young-adult drivers, and rates for young-adult drivers were higher than for experienced drivers, as shown in Table 2.

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

Characteristic		Number of Crashes Involving Drivers						Crashes per 1000 Drivers			Crashes per Million VMT		
		Teen		Young adult		Experienced							
		Number	%	Number	%	Number	%	Teen	Young adult	Exp.	Teen	Young adult	Exp.
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's 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

Table 2: continued

Characteristic	Number of Crashes Involving Drivers						Crashes per 1000 Drivers			Crashes per Million VMT		
	Teen		Young adult		Experienced							
	Number	%	Number	%	Number	%	Teen	Young adult	Exp.	Teen	Young adult	Exp.
Total	49,165	100	44,802	100	184,079	100	100.3	82.9	45.3	17.8	8.7	3.5
Alcohol related	1,261	3	2,454	5	5,640	3	2.6	4.5	1.4	0.5	0.5	0.1
Light Conditions												
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 Conditions												
Good	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												
Weekdays	37,434	76	33,481	75	145,755	79	76.4	62.0	35.9	13.6	6.5	2.7
Weekend	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 Conditions												
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
Work zones	1,061	2	1,294	3	2,355	1	2.2	2.4	0.6	1.2	0.8	0.0
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

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

A majority of drivers involved in crashes had valid driver's licenses. 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 a slightly higher crash involvement (54%) at intersections than experienced drivers (52%). On weekends and in dark lighting conditions, teen-driver crash involvement was slightly higher than that of experienced drivers. Teen-driver crash rates per 1,000 licensed teen drivers, when they were traveling on rural local roads or in the nighttime, were two to three times that of experienced drivers. In other cases, crash-involvement percentages were similar among teen and young-adult drivers as well as experienced drivers.

Vehicle and Crash-Related Characteristics

Teen drivers had higher crash involvement (68%) than that of experienced drivers (46%), 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 in crashes driving those vehicles. This may be due to teens driving older vehicles more often.

A higher percentage of vehicles were destroyed due to crashes involving teen drivers (8%) compared with experienced drivers (5%). Teen drivers also had a higher crash-involvement percentage in collisions with a fixed object (15%) than experienced drivers (10%). However, teen-driver, crash-involvement percentages for many other vehicle and crash-related characteristics were similar to young-adult drivers as well as experienced drivers. Crash rates of vehicle and crash-related characteristics had a similar pattern as driver, environment, and vehicle-related crash rates when comparing teen, young-adult, and experienced drivers.

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

Characteristic		Number of Crashes Involving Drivers						Crashes per 1000 Drivers			Crashes per Million VMT		
		Teen		Young adult		Experienced							
		Number	%	Number	%	Number	%	Teen	Young adult	Exp.	Teen	Young adult	Exp.
Vehicle Damage													
	No 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 and 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

Table 3: continued

Characteristic		Number of Crashes Involving Drivers						Crashes per 1000 Drivers			Crashes per Million VMT		
		Teen		Young adult		Experienced							
		Number	%	Number	%	Number	%	Teen	Young adult	Exp.	Teen	Young adult	Exp.
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

For example, teen crash rates per 1,000 drivers were higher than that of experienced drivers in most of vehicle- and crash-related characteristics as observed in driver, environmental and vehicle-related crash rates. However, teen-driver crash rates per 1,000 drivers when operating an automobile, or making a turn, were about three times that of experienced drivers. Also, teen-driver crash rates per 1,000 drivers when the vehicle was destroyed, non-colliding/overturning, or colliding with other vehicles were much higher than that of experienced drivers. Teen-driver crash rates per million VMT in operating automobile, or turning, non-colliding and overturning, avoiding maneuver, or colliding with a fixed object were about six to nine times that of experienced drivers.

Contributory Causes

Contributory causes for young-driver crashes were also investigated using Kansas crash data. Many factors might have combined to produce circumstances that led to a traffic crash; there was rarely a single cause of such an event. Mainly these contributory causes could be divided into four categories: driver, roadway, environment, and vehicle-related factors. Driver-related contributory causes involve actions taken by or the condition of the driver of the motor vehicle. Contributory causes for teen, young-adult, and experienced drivers are provided in Table 4. Failure to give time and attention was the top-ranked driver contributory cause in teen-driver crashes, followed by speeding, failure to yield right of way, and disregarding traffic signs/signals. Those driver-related contributory causes were also the most critical factors among young-adult drivers and experienced drivers.

Crash rates for teen driver-related contributory causes per 1,000 licensed drivers were much higher than that of experienced drivers. Corresponding young-adult-driver-contributed crash rates were also higher than that of experienced drivers. Teen-driver-involved crashes per million VMT due to failure to give enough time and attention, failure to yield right of way, and speeding exceeded eight to nine times that of experienced drivers and twice that of young-adult drivers. The most frequent environment-related contributory causes for teen-driver-involved crashes were identified as animals in the road, followed by raining and snowing. The most common vehicle-related contributory causes for teen-driver crashes were identified as failure of brakes, followed by failure of tires.

Icy or slushy conditions and wet road surfaces were the most frequent road-related contributory causes for all age groups. Teen drivers' crash percentage due to animals in the road was less than that of young-adult drivers and experienced drivers. Conversely, the crash percentage of teen drivers due to rain was higher than that of young-adult drivers and experienced drivers. Teen drivers' crash percentage due to failure of brakes was higher than that of young-adult drivers and experienced drivers. Also, the crash percentage for teen drivers involved in crashes due to wet road surfaces was higher than that of young-adult drivers and experienced drivers.

Table 4: Crash Frequencies, Percentages, and Crash Rates for Contributory Causes

Characteristic	Number of Crashes Involving Drivers						Crashes per 1000 Drivers			Crashes per Million VMT		
	Teen		Young adult		Experienced							
	Number	%	Number	%	Number	%	Teen	Young adult	Exp.	Teen	Young adult	Exp.
Driver Related												
Failure to give time and attention	13,842	36	10,339	34	31,606	35	28.2	19.1	7.8	5.01	2.00	0.59
Speeding	5,699	15	4,608	15	11,518	13	11.6	8.5	2.8	2.06	0.89	0.22
Failure to yield right of way	5,193	14	3,649	12	11,575	13	10.6	6.8	2.9	1.88	0.71	0.22
Disregarding traffic sign/signal	4,942	13	4,108	13	12,231	13	10.1	7.6	3.0	1.79	0.79	0.23
Improper action	2,320	6	1,838	6	7,410	8	4.7	3.4	1.8	0.84	0.36	0.14
Turning or lane changing	1,361	4	1,040	3	3,577	4	2.8	1.9	0.9	0.49	0.20	0.07
Aggressive driving	1,335	3	1,122	4	2,000	2	2.7	2.1	0.5	0.48	0.22	0.04
Other driver factors	1,254	3	994	3	3,833	4	2.6	1.8	0.9	0.45	0.19	0.07
Alcohol impaired	1,190	3	2,208	7	5,345	6	2.4	4.1	1.3	0.43	0.43	0.10
Distraction	1,155	3	730	2	1,786	2	2.4	1.4	0.4	0.42	0.14	0.03
Environment Related												
Animal on road	1,742	50	2,290	54	15,226	68	3.6	4.2	3.8	0.63	0.44	0.29
Rain	681	20	716	17	2,372	11	1.4	1.3	0.6	0.25	0.14	0.04
Falling snow	257	7	420	10	1,514	7	0.5	0.8	0.4	0.09	0.08	0.03
Vision obstruction glare	249	7	143	3	607	3	0.5	0.3	0.1	0.09	0.03	0.01
Vehicle Related												
Brakes	218	34	133	25	369	20	0.4	0.2	0.1	0.08	0.03	0.01
Tires	157	25	151	29	486	26	0.3	0.3	0.1	0.06	0.03	0.01
Road Related												
Icy or slushy	998	44	1,222	50	4,076	50	2.0	2.3	1.0	0.36	0.24	0.08
Wet	757	34	640	26	1,967	24	1.5	1.2	0.5	0.27	0.12	0.04
Snow packed	208	9	304	13	1,053	13	0.4	0.6	0.3	0.08	0.06	0.02

Odds Ratios

To measure the association between teen drivers' and experienced drivers' contributory causes 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 ($y = 1/x_1, x_2, ..., x_p$) divided by the probability of the event not occurring (Long 1997).

$$(4)\quad Odds = \frac{P\left(y = 1/x_1, x_2, ..., x_p\right)}{P\left(y = 0/x_1, x_2, ..., x_p\right)}$$

The ratio of odds of one variable ($odds_1$) and odds of other variable ($odds_0$),

$$\text{(5)} \quad odds\ ratio = \frac{odds_1}{odds_0}$$

is called Odds Ratio (OR). It gives the relative amount by which the odds a variable ($odds_1$) increases (OR > 1.0) or decreases (OR < 1.0) when the value of one of the predictor variables ($odds_0$) is increased by 1.0 unit. In this study, OR is used to access the injury risk of a particular age group, if a certain factor is present. Results of ORs and CIs of driver-contributory causes 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 drivers, whose ages range between 15 and 24, as shown in Table 5.

Table 5: Odds Ratios (ORs) and Confidence Intervals (CIs) for Driver Contributory Factors

Contributory Causes	Teen versus Experienced			Teen versus Young Adult			Young versus Experienced		
	OR's	95% CI		OR's	95% CI		OR's	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper
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

When interpreting results, ORs greater than one showed greater contribution from the particular factor for a considered driver-age group than the other driver-age group. For example, in teen versus experienced driver comparison, an OR value of 1.08 for failed to give and time and attention or fell asleep means teen drivers were 1.08 times more likely to be involved in crashes as experienced drivers due to failure to give enough time and attention or falling asleep. Similarly, teen drivers were more likely to be involved in crashes due to failure to yield right of way; driving too fast for conditions; following too closely; distractive, restless, careless, and aggressive driving; and exceeding posted speed limit compared with experienced drivers. Also, teen drivers were significantly more likely to have crashes due to failure to give time and attention or falling asleep, failure to yield right of way, distractive driving, making improper turns, or exceeding the posted speed limit when compared with

20- to 24-year-old drivers. The findings for young versus experienced drivers are identical to those of teen versus experienced drivers.

Multinomial Logit Model

A multinomial logit model was developed to investigate the injury severity of crashes involving young drivers, age 15 to 24. The dataset included 93,964 crashes from 2004 to 2008. The dependent variable had four categories: fatally/severely injured, injured, possible injured, or not injured. All the characteristics in Tables 2 and 3 were considered in developing the model. Most of these independent variables were treated as categorical variables. Thus, the numbers in Table 2 and 3 are summary statistics for variables in the estimations. Results of the young-driver injury-severity model are presented in Table 6. The model diagnostics showed a Likelihood Ratio Chi Square statistic of 35,102 whose p-value is < 0.001. In addition to the overall p-value, the logit model also reports the individual p-value for each independent variable. A low p-value means 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. Some of significant variables had limited observations, but the results were not affected when those variables were removed or combined. The estimated model intercepts represent the mean impact of all variables that influence each injury severity level that were not included in the model. Negative coefficient estimates of the developed model show the reduced probability of potential injury severity, while positive coefficient estimates show the increased probability of potential injury severity. The significant variables in the model were age, gender, seatbelt use, air bag deployed, alcohol involvement, light condition, good weather, crash type, vehicle damage, vehicle maneuver, driver ejection, vehicle manufacturing year, and posted speed limit. The effects of each of these variables are explained in the following paragraphs.

According to the coefficients of the estimated logit model, teen drivers showed higher injury severity when involved in crashes. This could be expected because young drivers' inexperience may limit them to make necessary judgments and it may increase the severity when they are involved in crashes. The negative coefficient of the variable gender indicates that being a young male involved in a crash tends to decrease the probability of having a more severe injury. Seat belt-restrained young drivers were less likely to suffer severe injuries when involved in crashes. The effectiveness of seat belt restraint in reducing crash injuries is well known. The positive coefficient of the airbag deployed variable indicates that young drivers were more likely to suffer severe injuries when they were involved in crashes. This is not an expected result because generally air bags are used to reduce the injury severities when involved in crashes. Alcohol involvement was a significant factor that increased young-driver injury severity. Alcohol increases the probability of severe injuries among young drivers.

Decreased injury severities could be expected when streets are lighted and increased injury severities could be expected when streets are dark. According to the developed model, young drivers were less likely to suffer severe crashes whether streets are lighted or dark. Young drivers were more likely to suffer severe injuries when they involved in crashes during good weather. This may be because they may drive without proper precautions during good weather conditions. The estimated coefficient for off roadway crashes had a positive sign as expected. This means that young drivers' injury severity was higher when they were involved in run-off-the-road crashes. Collisions with fixed objects, other vehicles, pedestrians/animals increased young-driver injury severity. Also, involvement of non-collision and overturn crashes showed a higher injury severity for young drivers. Vehicle damage was a significant factor that increased young-driver injury severity, whether it was minor damage, functional, disabling, or destroyed at the time of crash. Young drivers were more likely to suffer severe injuries in crashes occurring when they were attempting a lane change or backing up. Conditions of ejection at the time of crash increased injury severity while non-ejection

Table 6: Driver Injury-Severity Model Results

Label	Parameters	Coef.	Std. Err.	p-value
intercept	Fatal and severe injury	-3.345	0.235	<0.001
	Injury	0.941	0.015	<0.001
	Possible injury	0.384	0.058	<0.001
	Not injured	-	-	-
AGE	Age 15-19	0.115	0.028	<0.001
	Age 20-24	0.000	-	-
GENDER	Driver male	-0.579	0.028	<0.001
	Driver female	0.000	-	-
VALID	Valid license	-0.076	0.050	0.130
	Not licensed	0.000	-	-
RESTRC	Restricted driver license	0.018	0.029	0.542
	Not restricted driver license	0.000	-	-
SEATB	Seat belt used	-0.546	0.057	<0.001
	Airbag deployed	0.875	0.043	<0.001
	Constraint system not used	0.000	-	-
ALCO	Alcohol involved	0.414	0.060	<0.001
	No alcohol	0.000	-	-
LIGHT	Dark	-0.132	0.053	0.012
	Streetlight on	-0.121	0.056	0.032
	Daylight	0.000	-	-
WEATHER	Sunny	0.257	0.066	<0.001
	Rain	0.047	0.047	0.3148
	Adverse weather conditions	0.000	-	-
WEEK	Weekday	0.033	0.032	0.297
	Weekends	0.000	-	-
RURAL	Rural roads	0.043	0.045	0.332
	Urban roads	0.000	-	-

Label	Parameters	Coef.	Std. Err.	p-value
LOCATION	Off roadway	0.096	0.051	0.016
	Intersection on roadway	-0.086	0.056	0.125
	Non-intersection on roadway	0.000	-	-
TYPE	Overturned	1.526	0.201	<0.001
	Collision with vehicle	0.282	0.063	<0.001
	Collision with pedestrian or animal	1.797	0.142	<0.001
	Collision with object	0.539	0.070	<0.001
	Other non-collision and others	0.000	-	-
DAMAGE	Destroyed	3.033	0.175	<0.001
	Disabling	2.956	1.629	<0.001
	Functional	2.552	0.052	<0.001
	Minor damage	1.092	0.041	<0.001
	No damage	0.000	-	-
PANUM	Driver alone	0.052	0.029	0.211
	With passengers	0.000	-	-
AUTO	Automobile	0.139	0.139	0.073
	Other vehicle	0.000	-	-
MANU	Back up	0.468	0.168	<0.001
	Turn or changing lanes	0.612	0.612	<0.001
	Straight-following	0.000	-	-
EJECT	Not Ejected	-0.517	0.183	0.005
	Ejected	2.582	0.140	<0.001
	Trapped	0.000	-	-
NEW	Vehicle manufacturing year > 2000	-0.177	0.030	<0.001
	Vehicle manufacturing year <=2000	0.000	-	-
WZONE	Work zone	-0.197	0.125	0.115
	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

decreased injury severity of young drivers. Youth driving in newer vehicles were less likely to suffer severe injuries as expected. Driving on higher-posted speed limit roadways was also a significant factor that increased young drivers' injury severity.

The identified relationships for variables age, gender, seat belt use, airbag deployed, alcohol involvement, ejection, and speed were also identified in previous other young-driver-related research (Dissanayake and Lu 2002, Vachal and Malchose 2009). Variables such as valid licenses, restrictions on driver's licenses, rainy weather conditions, driving through intersections on roadways, driving alone, and driving through work zones were not significant at 95% confidence interval.

DISCUSSION AND COUNTERMEASURE IDEAS

Engineering-Related Countermeasure Ideas

Young drivers' crash rates are higher than that of experienced drivers', and therefore protective devices, crashworthy cars, and safer road infrastructures will particularly reduce young drivers' risk. While driving, a young driver's behavior is influenced by his or her general frame of mind, which among other things, reflects the situation just behind or approaching. As shown in the logit model results developed in this study, high speeds was one of the risk factors, as young drivers lack experience. Hence, predictable traffic situations and low complexity resulting from an improved road infrastructure are beneficial for young drivers. 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 warnings. Also, road infrastructures should be improved to avoid hitting animals. This is a main road-related contributory factor for crashes in Kansas.

Policy-Related Countermeasure Ideas

In particular, the Graduated Licensing System is designed to address 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 who are safe, increasing awareness of their own limitations and of the risks inherent to drivers.

Education-Related Countermeasure Ideas

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 in education programs in order to increase awareness. These 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 ages than the legal driving age (OECD 2006). Training programs could be focused more on backing up, turning, and changing lanes because young drivers show high injury severity for those maneuvers when they are involved in crashes. Another factor is preventing teen drivers from adopting bad habits and informal rules in traffic such as speeding, drinking while driving, etc. (OECD 2006). According to the model developed, teen drivers are at high risk for injuries. Also, crash rates show teen drivers' involvement in crashes are higher than young-adult drivers. Hence, parental management practices may be important influences on teen-driver practices and safety.

Enforcement-Related Countermeasure Ideas

Enforcement will have a proportionately higher impact on young drivers, as they more frequently violate traffic rules such as driving without a valid driving license and not obeying driver's license restrictions (Hanna et al. 2006). The results show that 5% of young drivers were not licensed and 37% of young drivers have restrictions on their licenses. Special attention should be paid to unlicensed driving because the more regulated and demanding the driving process becomes, the more tempted teens will be to drop out of the licensing process and drive without a license. However, it is difficult for police to specifically identify young drivers on the road, making the young-driver-specific countermeasures difficult to enforce.

According to the developed model, one of the significant variables for reducing injury risk is increasing seat belt usage. In 2010, Kansas turned to a primary seat belt-restraint law from a secondary law for teen drivers 15 to 17 years old. A primary seat belt law allows a law enforcement officer to stop a vehicle and issue a citation for not wearing a seat belt. A secondary seat belt-restraint law only allows for a citation to be issued if the vehicle is stopped for another primary violation. Also, avoiding alcohol-involved driving is an important factor in reducing injury risk. It is also a factor in reducing crash involvement. Age 21 is the legal drinking age in Kansas, so young drivers are restricted from alcohol use, but alcohol-involved crashes are a significant factor for increased crash injuries. Hence, enforcement is needed especially in locations where high alcohol use is expected. Distraction is a main contributory cause of teen-driver crashes. Many drivers use audio entertainment systems and mobile phones, but very few use on-vehicle visual displays such as a DVD (OECD 2006). Implementation of laws, such as prohibiting mobile phone use while driving and banning visual displays would be beneficial, particularly for young drivers.

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. 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-driver-involved crashes and contributory factors in Kansas, and compared those with experienced drivers. Crash data were obtained from KDOT, driver's license data were obtained from the US Department of Transportation, and annual vehicle miles driven were obtained from the National Household Travel Survey 2010. Young drivers were further divided into two groups: teen and young adults. A detailed frequency analysis and crash-rate analysis were carried out for both groups. Furthermore, a detailed frequency analysis was carried out for experienced drivers and comparisons were made among each driver group. The number of teen-driver-involved crashes per 1,000 licensed teen drivers was higher than that of young and experienced drivers. Teen drivers in Kansas were at considerable risk of motor vehicle crashes compared with experienced drivers. Factors that increase young drivers' injury severity, such as alcohol involvement and high speed, can be used for teen crash-prevention efforts. Many complex factors influence and contribute to teen-driving behavior. 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 compared with experienced drivers.

Based on 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 about these critical factors that are helpful to increase training, prevent crashes, and minimize driving risk.

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