sustainability

MDPI

Article

How Gender Affects Motor Vehicle Crashes: A Case Study from San Antonio, Texas

Khondoker Billah [1], Hatim O. Sharif [2,*] and Samer Dessouky [2]

[1] School of Civil and Environmental Engineering and Construction Management, University of Texas at San Antonio, San Antonio, TX 78249, USA; khondoker.billah@utsa.edu
[2] Department of Civil and Environmental Engineering, University of Texas at San Antonio, San Antonio, TX 78249, USA; samer.dessouky@utsa.edu
* Correspondence: hatim.sharif@utsa.edu; Tel.: +1-210-458-6478

Abstract: Traffic crashes are among the leading causes of injuries and fatalities worldwide. The main assumption of this study is that traffic crash rates, injury severity, and driving behaviors differ by the driver's gender. Utilizing ten years (2011–2020) of data from the Texas Crash Record and Information System database, this study investigates how some of the most prominent driving behaviors leading to crashes and severe injuries (distracted driving, speeding, lane departure, and driving under influence) vary by gender in San Antonio, Texas. The spatial distribution of crashes associated with these driving behaviors by gender is also investigated, as well as the influence of some environmental and temporal variables on crash frequency and injury severity. This study adopted bivariate analysis and logistic regression modeling to identify the effect of different variables on crash occurrence and severity by gender. Male drivers were more likely to be involved in a speeding/DUI/lane departure-related crash and subsequent severe injuries. However, female drivers were slightly more associated with distracted-driving crashes and subsequent injuries. Nighttime, interstate/highway roads, the weekend period, and divider/marked lanes as the primary traffic control significantly increased the crash and injury risk of male drivers. Driving behavior-related crashes were mostly concentrated on some interstate road segments, major intersections, and interchanges. The results from this study can be used by authorities and policy-makers to prioritize the use of limited resources, and to run more effective education campaigns to a targeted audience.

Keywords: motor vehicle crashes; distracted driving; speeding; logistic regression; bivariate analysis

Citation: Billah, K.; Sharif, H.O.; Dessouky, S. How Gender Affects Motor Vehicle Crashes: A Case Study from San Antonio, Texas. *Sustainability* **2022**, *14*, 7023. https://doi.org/10.3390/su14127023

Academic Editor: David Logan

Received: 8 May 2022
Accepted: 6 June 2022
Published: 8 June 2022

1. Introduction

Road traffic crashes are the leading causes of injuries (about 50 million injuries worldwide), and the eighth leading cause of reported fatalities (about 1.35 million fatalities worldwide) every year worldwide; for children and young adults (aged between 5 and 29), they are the leading cause of death [1]. In 2020, a total of 205,498 people were injured in motor vehicle crashes in Texas, including one fatality every two hours and 15 min [2]. The ratio of male to female passengers who died in these crashes (354 male vs. 302 female fatalities) was much smaller compared to the ratio of male and female drivers in fatal crash incidents (1437 male vs. 510 female driver fatalities) [2]. Differences by gender in driving behavior and crash involvement have long been demonstrated in several studies [3–7]. Some studies suggest that males are more likely to be involved in fatal crashes whereas females are more likely to be involved in non-fatal crashes [3,8]. However, the fatality risk of female drivers in crashes with similar physical impacts is greater than that of male drivers [9]. The crash risk is slightly higher for male drivers due to impatience and lack of attention [6]. One study used multiple regression analysis with driver age, macho personality, and the power of the car as predictors, and concluded that young men placed greater emphasis on the speed and sportiness of cars, and were significantly more likely to exhibit aggressive driving behavior [10]. Moreover, the attitude towards traffic safety issues is significantly

correlated with driving behavior. A study found that persons involved crashes started to take more risks while driving within just one year from their involvement in crashes [11]. One study used five years of data from Sweden, and concluded that fatal and serious injury crash risk significantly increased during the nighttime for young drivers; the risk was about twice as much for male drivers compared to female drivers during late night hours [12]. Other studies corroborated that male drivers tend to perceive risky driving behaviors to be less serious and less likely to result in accidents, and thus they are more likely to engage in risk-taking behaviors [13–15]. Although older females were 22% more likely to pass an on-road test, older male and female drivers did not show differences in their specific or total number of driving errors on the comprehensive driving evaluation [16]. While distracted driving, driving under the influence (DUI), speeding, and lane departure are some of the crash types emphasized in the Texas Strategic Highway Safety Plan [17], the effect of driver gender of on some of these crash types has not been extensively studied.

DUI could be defined as the offense of driving/operating a vehicle while being impaired by the influence of alcohol/drugs to a pre-defined level, which is known to result in the incapability of the driver to safely drive/maneuver a motor vehicle [18]. DUI has been demonstrated to be significantly associated with severe vehicle crashes [19]. In the United States, about 30% of all motor vehicle fatalities involve drivers with alcohol consumption over the legal limit while driving [20]. In 2020, about 25% of all fatalities from crashes in Texas were associated with driving under the influence of alcohol [2]. The gender gap in DUI convictions has been narrowing over the years, as suggested by a study that used data for the 1992–2008 period from the Mississippi Alcohol Safety Education Program [21]. Another study reported a similar gap-narrowing trend for DUI arrest rates in the United Sates over the 1982–2004 period using data from the Federal Bureau of Investigation, the Centers for Disease Control and Prevention, and the National Highway and Transportation Safety Administration (NHTSA) [22]. Although the gender gap in DUI continues to narrow, female DUI rates remain much lower than male rates, as concluded by a study that used data from 1985–2015 over the United States [23]. An increasing proportion of female DUI clients was observed in another study that used de-identified data (n = 19,619) from a large DUI program in Southern California for the 2009–2014 period [24]. However, the blood alcohol content (BAC) at arrest did not significantly vary by gender [24]. The vehicle control of young female drivers is more likely to be affected at a lower BAC level compared to male drivers, as concluded by a study that used simulated driving data of forty young drivers at four different BAC levels [25]. Except for the common recidivism risk factors for both genders (prior DUI arrest, driving behaviors, and the health consequences of alcohol/drug use), the recidivism risk factors (within 12 months) of driving under the influence (DUI) of alcohol/drugs for male drivers were criminal history and heavy alcohol consumption, while substance use disorder was a unique factor for female drivers [26]. Another study in Pennsylvania concluded that first-time DUI offenders processed through an accelerated rehabilitative disposition program were significantly less likely to be rearrested within the next four years [27]. Male drivers, especially young male drivers, were more likely to be involved in DUI crashes and fatalities [28–32]. Another study concluded that young male drivers (aged 16–20) had the highest relative risk of a fatal single-vehicle injury crash [33].

According to NHTSA, distracted driving includes all activities that might divert the attention of the driver from driving, and includes (but is not limited to) talking/texting on a cellphone or talking to people in a vehicle, eating/drinking, and operating the vehicle's stereo or navigation system [34]. Studies have identified driver inattention as one of the key causes of motor vehicle crashes [35,36]. The driver's gender does not affect distracted driving, as reported by a study that found no statistically significant difference in driving experience among drivers (measured as months since full licensure) [37]. Another study also concluded that gender was not statistically associated with distracted driving behavior, but text messaging while driving was statistically significantly associated with males [38]. Males are more likely to send text messages, use a navigation system, and use a cellphone compared to females, who are more likely to interact with children on the back seat or

perform personal grooming while driving [39]. Moreover, male drivers were found to post more distracted driving-related contents of their driving on social media than females [40]. Some studies suggest that the perception of male and female drivers towards distracted driving legislation might differ. One study on 510 college-age adolescents concluded that female drivers are more likely to consider "texting while driving" an illegal action compared to their counterparts [41]. Females are more likely to comply with distracted driving rules, and the presence of hand-held cellphone use ban laws while driving was found to reduce hand-held cellphone use in female drivers [42]. Another study found that the odds of female adolescents supporting a law against texting while driving was almost twice that of male adolescents, and suggested that public health campaigns targeted at female adolescents might be more successful [43].

Speeding over the permissible limit of the road by the drivers is one of the key determinants of the likelihood of a traffic crash and injury severity [44,45]. Male drivers are more likely to speed for sensation seeking, and are more likely to be involved in speeding crashes compared to female drivers [46–49]. However, one study found a contradictory result, in which female drivers reported more frequent speeding intentions [50]. Some studies did not find any significant effect of gender on speeding [51]. The association of driver anger with relatively more frequent speeding behavior has been also reported [52]. One study compared the ticketing patterns of automated cameras and on-duty police using data from Lafayette, Louisiana, and concluded that females are significantly more likely to be given speeding tickets by police officers compared to their male counterparts [53]. Speeding crashes during rainy weather resulted in significantly different severe injuries for male and female drivers, and the pattern of injury severity of male and female drivers varied over time [54]. Another study concluded that young male drivers travelled at a higher average speed and accelerated faster when compared to female drivers [55].

A lane/roadway departure crash is a crash that occurs when a vehicle crosses the edge line/center line or leaves the traveled way [56]. One study analyzed 400 serious injury crashes in Victoria, Australia from 2014 to 2016, and concluded that male drivers were more likely to be injured in lane departure crashes compared to female drivers [57]. Although there is limited research on the effect of gender on lane departure crashes, the effect of lane departure warning systems in vehicles on the driving behavior (by gender) has been well studied. A study found that the use of lane departure warning systems in vehicles reduced the lane departure incidents of male drivers but increased such incidents for female drivers [58]. Male drivers were more likely to turn on a lane departure warning/prevention system while driving, and experienced comparatively more warnings compared to female drivers [59]. A third study concluded that male drivers received fewer lane departure warnings [60]. The use of an integrated crash warning system in a vehicle resulted in a significant reduction in lane-change near crashes for male drivers and road-departure near crashes for female drivers [61]. Novice male drivers were associated with statistically greater variability in lane keeping and maximum departure distance compared to their female counterparts [62]. One study in Louisiana used data of 122,978 crashes over 13 years, and concluded that male drivers are more likely to be involved in lane departure crashes [63]. However, another study in Louisiana found a monotonic decreasing trend for male drivers and an increasing trend for female drivers involved in lane departure crashes [64].

The main objective of this study is to understand how crash rates, injury severity, and driving behaviors differ by the driver's gender in the City of San Antonio, Texas, with focus on the crash types emphasized in the Texas Strategic Highway Safety Plan. The spatial distribution of crashes associated with the driving behaviors leading to these crashes by gender is also investigated. The identification of high-risk crash locations for different crash types is expected to contribute to safer roadways. Very few studies were focused on the effect of gender on certain types of crashes, and the evaluation of the effect of the gender of the drivers on different crash types is expected to contribute to the existing literature. The City of San Antonio, Texas Department of Transportation, and

other stakeholders should benefit from this study when making decisions about resource allocation and design modification/selection. Understanding the effect of driver gender on different crash types should assist the authority/stakeholders in running specialized campaigns to a targeted audience.

2. Study Data and Method

This study used data from the Crash Records Information System (CRIS) maintained by the Texas Department of Transportation (TxDOT) from January 2011 to December 2020. The CRIS database started to collect crash data in 2003, and includes all law enforcement officer-reported crashes that occurred within the State of Texas. Any crash that involves an injury or fatality of an involved person must be reported by the law enforcement officer to TxDOT within 10 days of the crash occurrence. Property damage-only crashes (of $1000 or more) are required to be reported to TxDOT as well, after investigation. Each recorded crash has a unique identifier, along with spatial, environmental, temporal, person-related, vehicle-related, and other relevant information. TxDOT provides yearly crash data in several files (crash, unit, person, primary person, charge, restriction, damage, and endorsement), and different files could be merged using the unique crash identifiers for analysis.

The primary crash contributing factor reported for each crash was used in the selection of alcohol, distraction, lane departure, and speeding crashes. Crashes with "had been drinking" or "under influence of drug/alcohol" as the primary contributing factor were classified as DUI crashes; crashes with "changed lane when unsafe" or "failed to drive in single lane" as the primary contributing factor were classified as lane departure crashes; crashes with "distraction in vehicle", "driver inattention", "fatigued or asleep", or "cell-phone use" as the primary contributing factor were classified as distraction-related crashes; and crashes with "failed to control speed", "unsafe speed", or "speeding" as the primary contributing factor were classified as speeding-related crashes. The injury severity of the involved persons was divided into two categories: KA (fatal or serious) injury and KAB (fatal, serious, or non- serious) injury.

In order to evaluate the density distribution of alcohol, distraction, lane departure, and speeding crashes by driver gender, heat maps were prepared using ArcGIS Pro (version 2.6) by incorporating a smoothly varying color scheme [65]. The representation of the crash data as a continuous surface and the crash count of locations as density estimations were accomplished using the kernel density method. The value of the density estimation is highest at the center (at the location of the crash occurrence) and gradually decreases away from center [66].

The following quartic kernel function is used in the KDE tool:

$$K_2(p) = \begin{cases} 3\pi^{-1}\left(1 - p^T p\right)^2 & if\ p^T p < 1 \\ 0 & otherwise \end{cases} \quad (1)$$

where $K_2(p)$ represents the kernel function (usually radially symmetric unimodal) for 2-dimensional p, T indicates the transpose of the matrix [67], and

$$p = \frac{the\ distance\ from\ the\ center\ of\ the\ kernel}{bandwidth} \quad (2)$$

The following formula predicts the density at any (x, y) location:

$$Density = \frac{1}{(radius)^2} \sum_{j=1}^{n} \left[\frac{3}{\pi} \cdot pop_j \left(1 - \left(\frac{distance_j}{radius} \right)^2 \right)^2 \right], (For\ distance_j < radius) \quad (3)$$

where the values of $j = 1, \ldots, n$ represent the input point crashes; pop_j represents the population field value of point j; and $distance_j$ represents the distance between point j and the (x, y) location.

Although heat maps reveal overall crash density distribution, hot spot analysis is required in order to identify locations which are prone to severe injury crashes. This study used the Getis-Ord Gi* statistic in the hot spot analysis to identify hot spots and cold spots (statistically significant spatial clusters of high and low values) of alcohol, distraction, lane departure, and speeding crashes by gender. In this process, for each individual input feature, an output feature is produced with a z-score, *p*-value, and a confidence level bin with the underlying null hypothesis of complete spatial randomness of features. The presence of statistically significant clustered/dispersed features (based on the z-score, which represents the standard deviation, and the *p*-value, which represents the probability of randomness in clustering) would reject the null hypothesis. A very small *p*-value along with very high/low standard deviation suggests the miniscule probability of cluster production from random distribution. An overly smooth pattern is obtained with an excessively large search bandwidth, which makes the differentiation of local hot spots harder. Conversely, a spiky density pattern that shows individual hot spots is obtained from a narrow search bandwidth. Several studies adopted the "trial and error" method to resolve the problem [68,69].

This study explores the significance of the gender in different types of crashes using bivariate analysis and logistic regression analysis. Bivariate analysis is used as an exploratory tool in hypothesis testing in order to determine how the gender of involved persons affects each crash type. The chi-squared test was incorporated in the bivariate analysis to determine if there is any statistically significant difference by driver gender in different types of crash. While the chi-squared test is effective in determining how two variables are related to each other, it cannot take into account the possible confounding factors, and does not ensure a causal relationship. The benefits of logistic regression over bivariate analysis are that logistic regression enables the analysis of how gender affects one type of crash while controlling for other parameters, and that it evaluates the hierarchy of the effect of gender on different crash types. This study used RStudio for logistic regression analysis. The performance of the models was evaluated from the obtained parameters (e.g., null deviance, which represents how well the response could be predicted by the model with only the intercept; residual deviance, which expresses the effectiveness of the response prediction in presence of other predictors, and the respective degrees of freedom). The effectiveness of the regression model (with predictor variables included) in reducing the deviance is evaluated from the difference between the null and residual deviance. The odds ratio (the ratio of the odds of occurrence of an event in the presence and in the absence of the independent variable) was used in the determination of the strength of association. This paper incorporated the logit with the natural logarithm of the odds, as shown by Equation (4):

$$\text{Logit}\,(Y) = \text{In}\,(Y/1 - Y) = \beta_0 + \beta_1 \times Z_1 + \ldots + \beta_i \times Z_i \quad (4)$$

where Y represents the probability of the gender of involved person, Z_i represents the independent variable, and β_i represents the model coefficient.

3. Results and Discussion

3.1. Spatial Analysis

A total of 9873 crashes caused by driving under influence of alcohol/drugs occurred in San Antonio during the study period. These crashes involved 14,479 drivers: 9881 males and 4598 females. Crash coordinates were available for 8525 crashes (5881 male and 2644 female drivers). The crashes resulted in of 757 severe injuries (from 439 crashes), which included 542 male drivers (112 fatalities, 430 serious injuries) and 215 female drivers (43 fatalities, 172 serious injuries).

The DUI crash concentration was highest in the northern part just outside the city center for both male and female drivers. Major intersections in the downtown area have a higher concentration of DUI crashes (Figures 1 and 2). Major intersections on the northern part of the city's inner highway loop also have a relatively higher concentration of DUI

crashes. Male-driver DUI crashes were more frequent along major roads just outside of city center. A substantially high proportion of DUI severe crashes for male drivers was observed at the city center. The number of severe crashes was substantially lower at the city center for female drivers. The pattern of female-driver DUI severe crashes in the downtown area is slightly different.

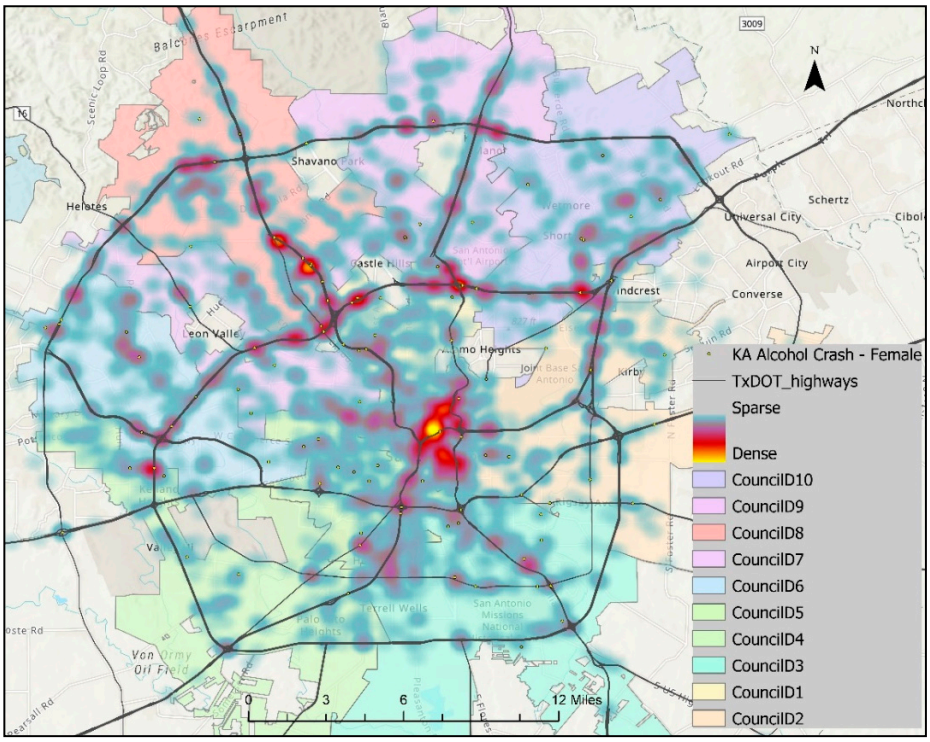

Figure 1. Heat map of all DUI crashes in San Antonio involving female drivers (2011–2020).

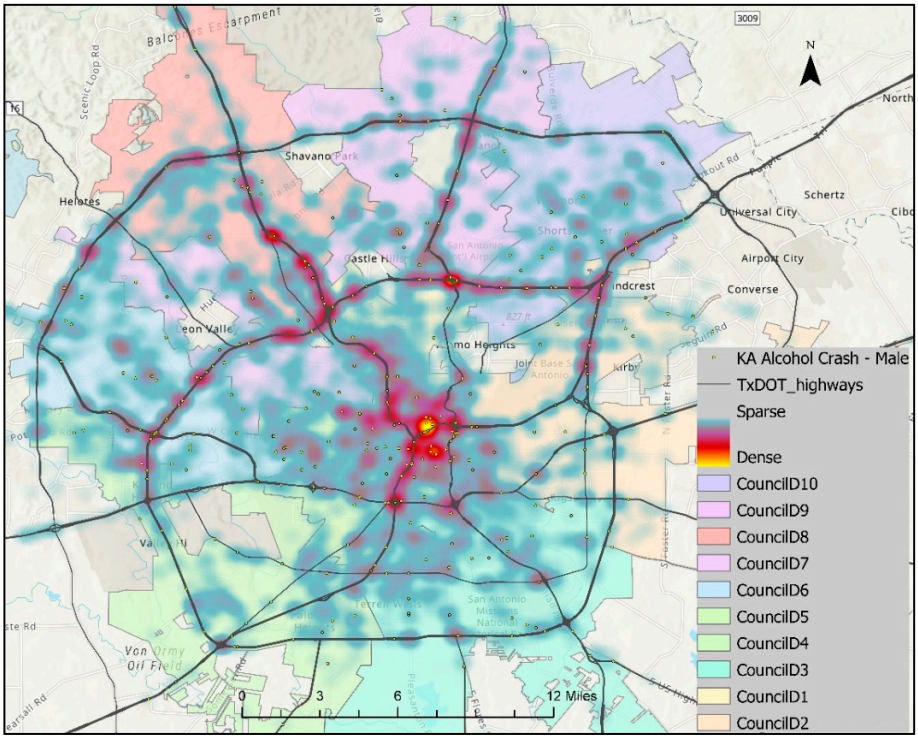

Figure 2. Heat map of all DUI crashes in San Antonio involving male drivers (2011–2020).

The proportion of male drivers in driving under the influence of alcohol or drug crashes was statistically significantly higher compared to female drivers in reference to all crashes as well as severe injury-causing crashes. About 2.3% of all male drivers and about 1.4% of all female drivers involved in crashes were driving under the influence of alcohol/drugs. Alcohol/drug-related crashes were responsible for about 5.4% of all severe male-driver crashes and about 3.7% of all female-driver crashes. Female drivers were 40% less likely to be involved in a DUI crash and about 32% less likely to be involved in severe injury-causing DUI crash. Riskier driving behavior while intoxicated and the relatively higher BAC of male drivers might contribute to the higher probability of crashes and severe injury of male drivers in DUI crashes. The proportion of male drivers was substantially higher in all age groups for driving under influence of alcohol or drugs crashes. The proportion of female drivers was relatively higher in the young (age 20–29) and middle-aged (age 30–49) age groups (Figure 3). For drivers aged 65 and older, the proportion of male drivers involved in driving under the influence of alcohol or drug crashes was the highest (about 77%).

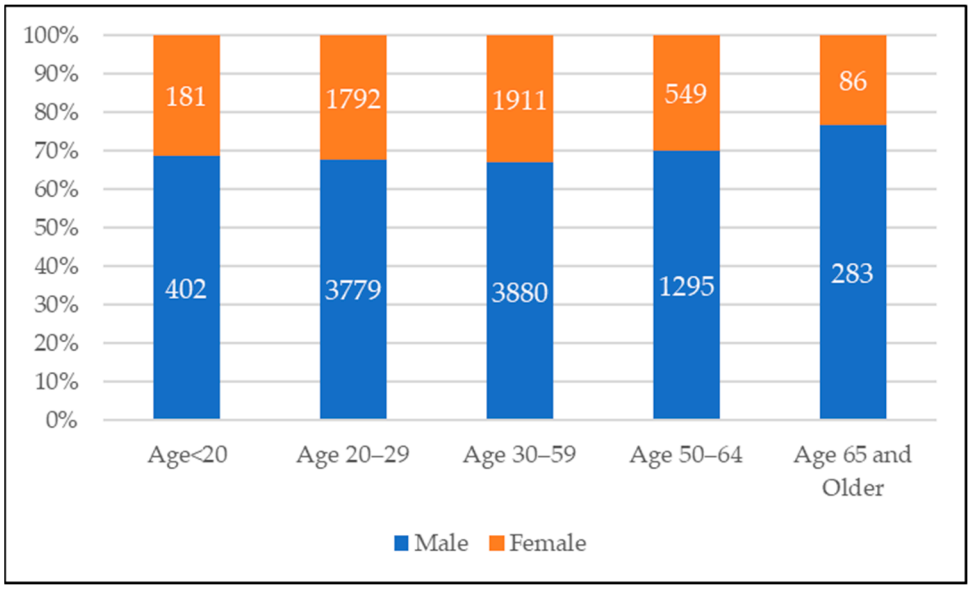

Figure 3. DUI crash count and crash proportion by the age and gender of the driver.

A total of 148,787 crashes attributed to distracted driving involving a total of 264,045 drivers occurred during the study period. These crashes include 147,033 male and 117,013 female drivers, and resulted in 3903 severe injuries from 2025 crashes. The resulting injuries involved 2335 male drivers (387 fatalities, 2048 serious injuries) and 1568 female drivers (114 fatalities, 1454 serious injuries). Male drivers were significantly more likely to be involved in a fatal crash attributed to distracted driving compared to female drivers.

Distracted-driving crashes, especially those involving male drivers, have a high concentration at the city center. The difference in the spatial pattern of distracted-driving crashes based on gender is negligible. Distracted-driving crashes are concentrated at intersections near the city center and the intersections of highways and major roads (Figures 4 and 5). Severe distracted-driving crashes were primarily concentrated in the downtown area at the city center and on the northwest and southeast parts of the city center. Segments of highways and major roads around the city's outer loop also have high concentrations of severe crashes attributed to distracted driving. Severe crashes involving male drivers were more concentrated at major interchanges.

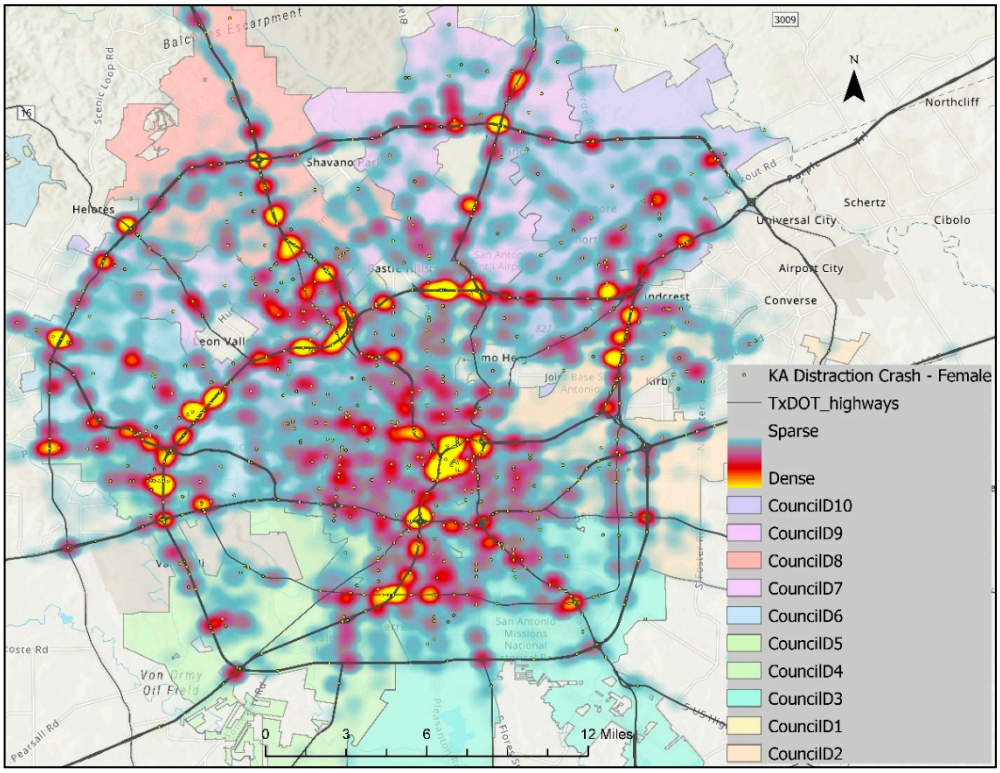

Figure 4. Heat map of all distracted-driving crashes in San Antonio involving female drivers (2011–2020).

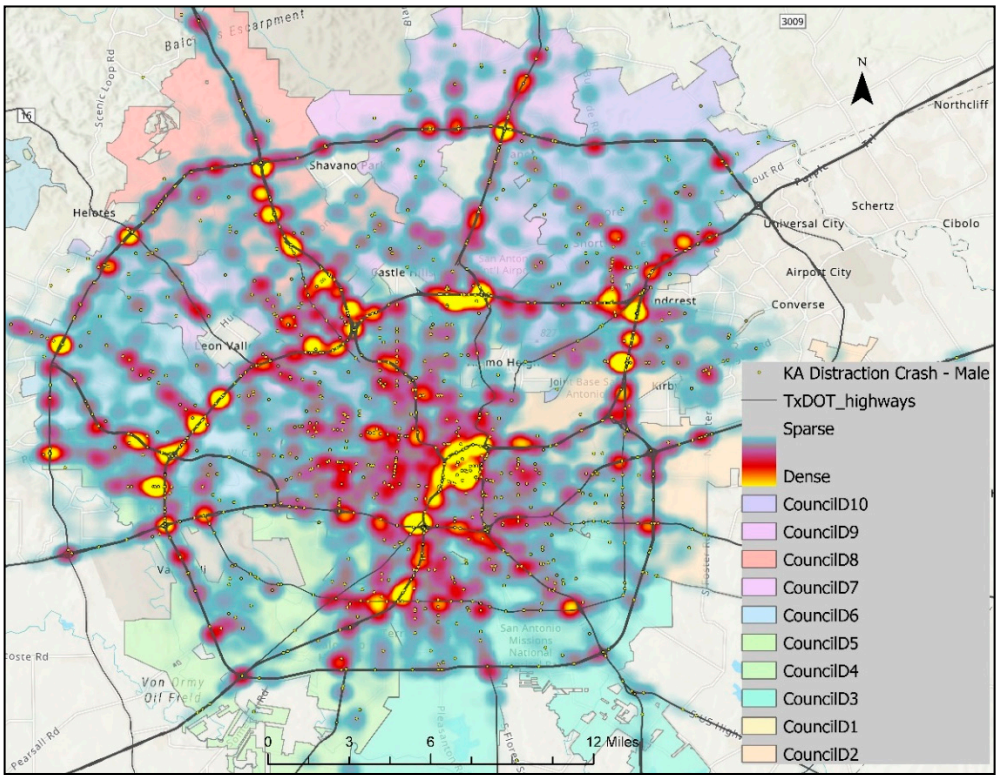

Figure 5. Heat map of all distracted-driving crashes in San Antonio involving male drivers (2011–2020).

Female drivers were significantly more likely to be involved in distracted-driving crashes compared to their male counterparts when this crash type is expressed as a proportion of the total crashes for each gender. The proportion of severely injured female drivers associated with distracted driving was also substantially higher compared to male drivers. Female drivers were 6% more likely to be involved in distracted-driving crashes, and were 22% more likely to be involved in severe injury-causing distracted-driving crashes. Talking over a cellphone or talking with another person in the vehicle and the use of a cellphone are some of the identified reasons behind the increased risk of female drivers in distracted-driving crashes. The teen (age < 20 years) and older-age groups (age 50–64 years and age 65 years or older) had comparatively higher proportions of male drivers involved in distracted driving (Figure 6). For the young and middle-aged groups, female drivers were relatively more involved in distracted-driving crashes.

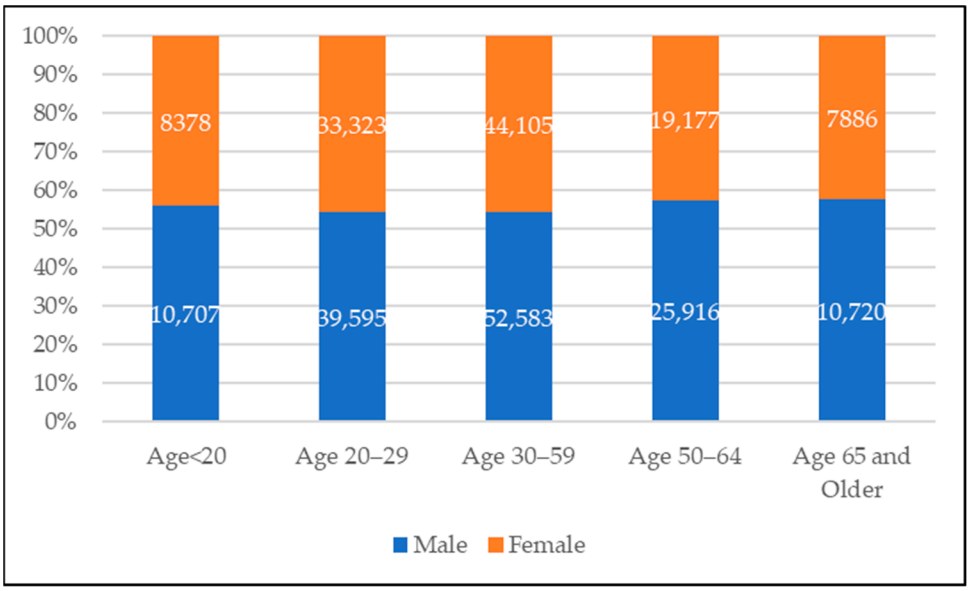

Figure 6. Distracted-driving crash count and crash proportion by the age and gender of the driver.

A total of 32,371 crashes (involving 55,153 drivers) caused by lane departure occurred in San Antonio during the study period. These crashes include 32,275 male drivers and 22,878 female drivers. Crash coordinates were available for 30,964 crashes. The crashes were responsible for 804 severe injuries (resulting from 444 crashes), including 530 male drivers (112 fatalities, 418 serious injuries) and 274 female drivers (34 fatalities, 240 serious injuries).

Segments of the inner highway loop and Interstate-10 on the northwest part of the city and the outer highway loop on the north part of the city have very high concentrations of lane departure crashes for both male and female drivers (Figures 7 and 8). Segments of Interstate-35, just north of the downtown area, and part of Interstate-10 to the west of downtown area also experience very high concentrations of lane departure crashes. Some minor roads in the city center have very high lane departure crash densities. However, the severe injury crashes were mainly concentrated on the interstate roads (Interstate-10, Interstate-35, and Interstate-37) around the city center. Male and female lane departure crash heatmaps look almost identical, with relatively more severe lane departure crashes at the major interchanges for male drivers. Female drivers have a relatively higher proportion of severe lane departure crashes on the northeast part of the city center. The outer highway loop has relatively more female-driver severe lane departure crashes.

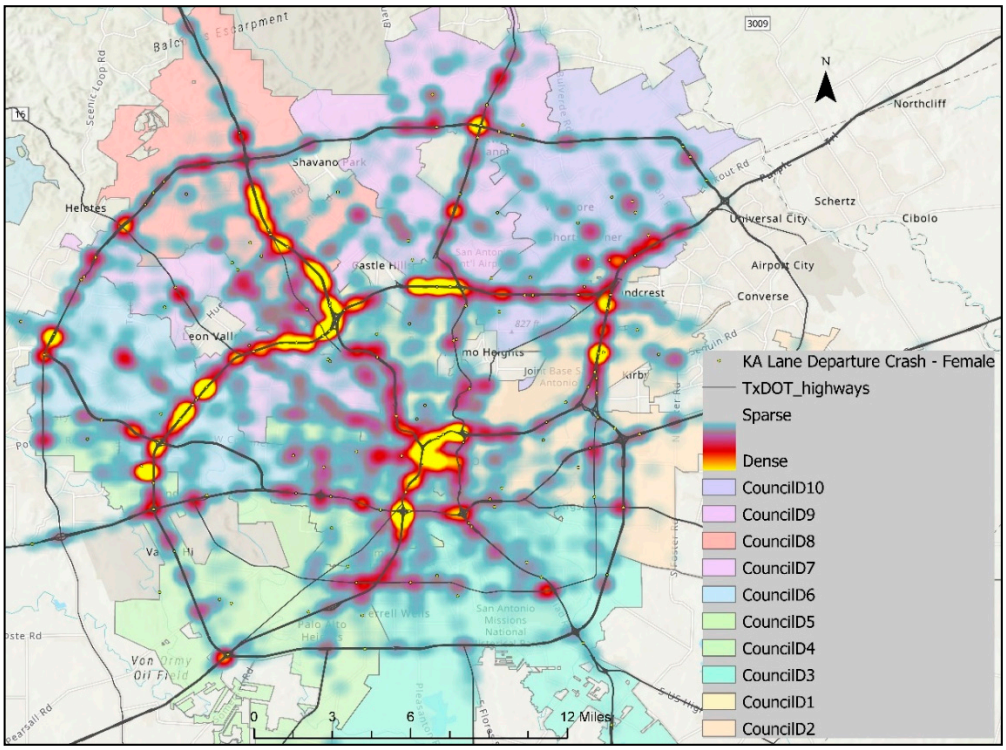

Figure 7. Heat map of all lane departure crashes in San Antonio involving female drivers (2011–2020).

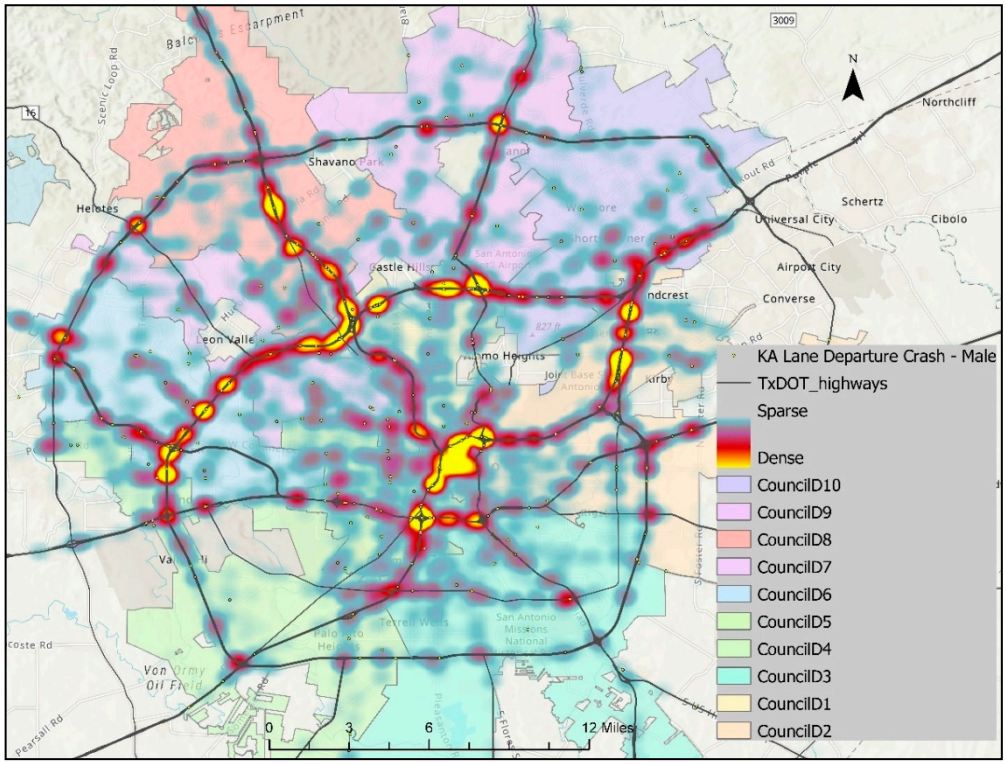

Figure 8. Heat map of all lane departure crashes in San Antonio involving male drivers (2011–2020).

When all lane departure crashes are considered, male drivers are significantly more likely to be involved in a crash compared to their female counterparts. When only severe injury-causing lane departure crashes are considered, the higher likelihood of male driver involvement in crashes is statistically not significant. The likelihoods of a female driver

being involved in any lane departure crash and in a lane departure crash resulting in a severe injury were about 8% and 30% lower compared to male drivers. About 58% of all lane departure crashes involved male drivers. For teen drivers (age < 20), the male to female driver ratio related to lane departure crashes was the closest to 1 among all age groups (Figure 9). The proportion of male drivers increases with age, and was the highest in the 50–64 years age group (about 62%).

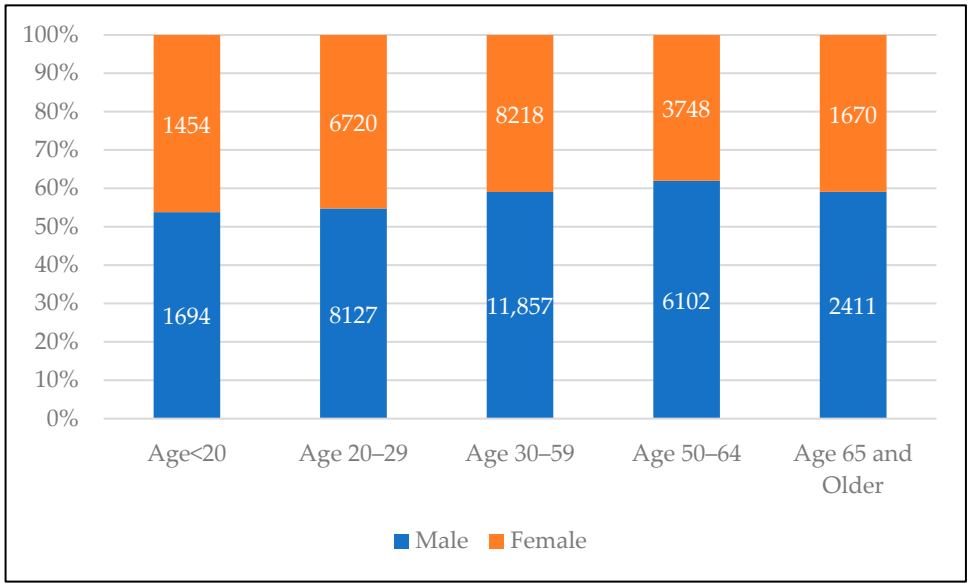

Figure 9. Lane departure crash count and the crash proportion by the age and gender of the driver.

A total of 33,140 crashes (involving 56,604 drivers) were caused by the speeding of vehicles over the permissible limit occurred during the study period. These crashes include 34,368 male drivers and 22,236 female drivers. Crash coordinates were available for 30,717 crashes. These crashes were responsible for 1888 severe injuries (involving 1141 crashes) including 1364 male drivers (377 fatalities, 987 serious injuries) and 524 female drivers (79 fatalities, 445 serious injuries).

Speeding crashes were primarily concentrated on major roads with relatively higher speed limits. Segments of the inner loop and Interstate-10 and the segment on Interstate-10 in between the inner and outer loops on the northwest part of the city have substantially high concentrations of speeding crashes. Male and female driver crashes exhibit similar patterns *n* in the overall crash heatmap (Figures 10 and 11). The interstate roads around the city center (Interstate-10 on the west and south side, Interstate-35 on the north side, and Interstate-37 on the east side of the city center) have relatively higher proportion of male-driver speeding crashes. Female-driver crashes were more frequent at the interchanges. Interstate roads are relatively less congested and are of better quality, and drivers might tend to overspeed on these roads more frequently compared to roads with a lower speed limit. Female-driver severe crashes were also more concentrated at the interchanges. Severe crashes involving male drivers were more frequent along some routes (on the inner loop between Interstate-10 and Interstate-35 on the east part of the city, on Interstate-10 in the northwest part, and on the Interstate road segments outside the city center.

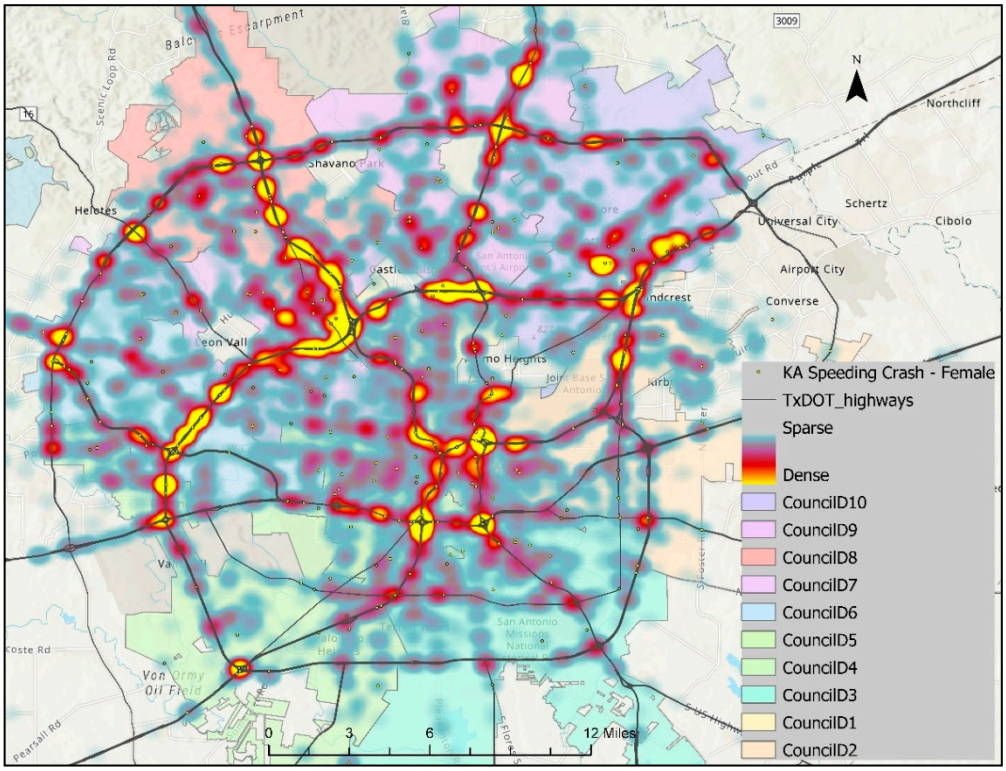

Figure 10. Heat map of all speeding crashes in San Antonio involving female drivers (2011–2020).

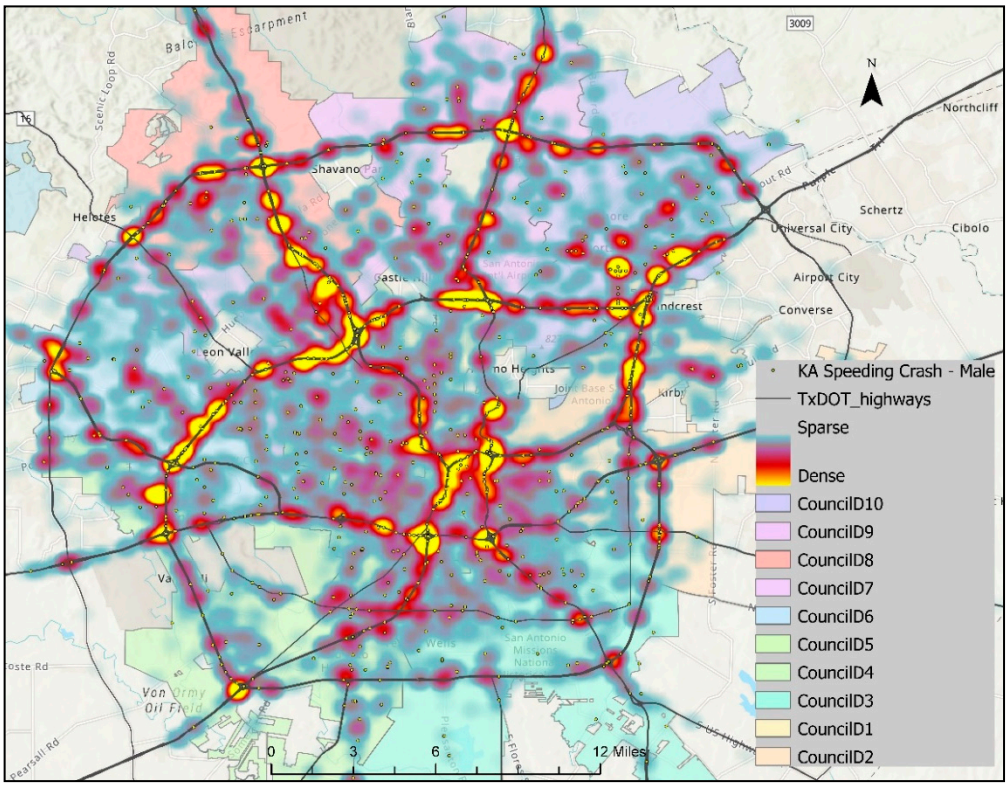

Figure 11. Heat map of all speeding crashes in San Antonio involving male drivers (2011–2020).

3.2. Bivariate Analysis

A total of 484,014 crashes occurred on San Antonio roadways during the study period, involving 787,191 primary persons. Information regarding gender was available for

763,528 persons (432,530 male and 330,998 female). These crashes resulted in a total of 15,599 severe injuries (2618 fatalities, 12,981 severe injuries). Male drivers were among 9878 fatalities/severe injuries (7966 severe injuries, 1912 fatalities), while female drivers were among 5721 fatalities/severe injuries (5015 severe injuries, 706 fatalities).

The results from bivariate analysis (chi-squared test) are represented in Table 1. The results suggest that male drivers are significantly more likely to be involved in a crash under dark lighting conditions, whereas female drivers have a higher probability of being involved in a crash in daylight lighting conditions. A similar proportion is observed for dark and daylight lighting conditions when only fatal and serious injury crashes are considered. In the presence of full or partial daylight (daylight/dawn/dusk lighting conditions), female drivers were 24–35% more likely to be involved in a crash, and were about 28–60% more likely to be involved in a severe-injury crash compared to male drivers.

Table 1. Bivariate analysis results for all crashes and severe crashes.

			All Crash			KA Crash		
Variable	**Reference**	**df**	***p*-Value**	**Chi-Squared**	**OR**	***p*-Value**	**Chi-Squared**	**OR**
Lane Departure_Yes	Lane Departure_No	1	2.20×10^{-16}	84.6	0.92	9.51×10^{-2}	2.8	0.70
Alcohol_Yes	Alcohol_No	1	2.20×10^{-16}	807.5	0.60	5.00×10^{-6}	20.8	0.68
Distraction_Yes	Distraction_No	1	2.20×10^{-16}	152.8	1.06	5.00×10^{-6}	26.1	1.22
Speeding_Yes	Speeding_No	1	2.20×10^{-16}	411.7	0.83	2.20×10^{-16}	69.9	0.63
Weekend	Weekday	1	2.20×10^{-16}	775.9	0.86	9.38×10^{-10}	37.5	0.80
8 p.m.–6 a.m.	6 a.m.–8 p.m.	1	2.20×10^{-16}	3487.2	0.70	2.20×10^{-16}	190.0	0.60
Intersection_Yes	Intersection_No	1	2.20×10^{-16}	420.8	1.11	4.03×10^{-10}	39.1	1.24
Speed Limit > 45 mph	Speed Limit $\leq$ 45 mph	1	2.20×10^{-16}	1168.1	0.83	2.28×10^{-8}	31.2	0.80
Road Class: Other	Interstate/US & State Highway	1	2.20×10^{-16}	605.3	1.12	8.10×10^{-4}	11.2	1.12
Road Alignment: level	Grade/Hillcrest	1	2.20×10^{-16}	69.1	1.06	0.13	2.4	1.07
Lighting Condition: Daylight	Dark	1	2.20×10^{-16}	3099.6	1.35	2.20×10^{-16}	136.1	1.61
Weather Condition: Inclement	Clear	1	2.20×10^{-16}	128.8	0.91	0.77	0.1	1.02
Surface Condition: Wet/Inclement	Dry	1	2.20×10^{-16}	124.6	0.92	0.50	0.5	1.04
Traffic Control: stop/yield/signal/crosswalk	Divider / marked lane	1	2.20×10^{-16}	662.3	1.16	2.20×10^{-16}	89.3	1.45

Consistent with previous studies, male drivers were more likely to be involved in speeding crashes, and suffer more severe injuries from speeding crashes compared to female drivers. Speeding crashes associated with male and female drivers were about 8.0% and 6.7% of all male and female crashes, respectively. Speeding crashes were responsible for 14.1% and 9.4% of all severe injuries involving male and female drivers, respectively. The likelihood of involvement in a speeding crash was 17% lower for female drivers. When only severe injury-causing crashes are considered, the likelihood of involvement of female drivers in a speeding crash was about 37% lower.

The teenage group has the highest proportion of male drivers (65%) among all age groups, followed by the 65 years and older group (Figure 12). Overall, about 60% of all speeding crashes involved male drivers.

Female drivers are significantly more likely to be involved in a crash on roads with straight-level alignment. The likelihood of involvement in a crash on straight-level roadways was about 18% greater for female drivers. For all other road alignment types, the likelihood of a crash was greater for male drivers. Statistically significant differences in the crash frequency and injury severity of male and female drivers was observed for different roadway speed limits. When the roadway speed limit was greater than 45 mph, the observed crash frequency involving male drivers was significantly lower than expected.

However, the rate of severe injuries suffered by male drivers on roadways with greater than a 45 mph speed limit was significantly higher than expected. This suggests that female drivers are more likely to be involved in crashes on roads with a higher speed limit, but those crashes tend to be significantly less severe compared to male driver crashes on those roads. Female drivers were about 17% less likely to be involved in a crash on roadways with a speed limit greater than 45 mph, and about 20% less likely to sustain a severe injury on those roadways compared to male drivers. Male drivers are associated with relatively more reckless driving and speeding, which might be the reason behind there being more severe crashes involving male drivers on roads with a higher speed limit.

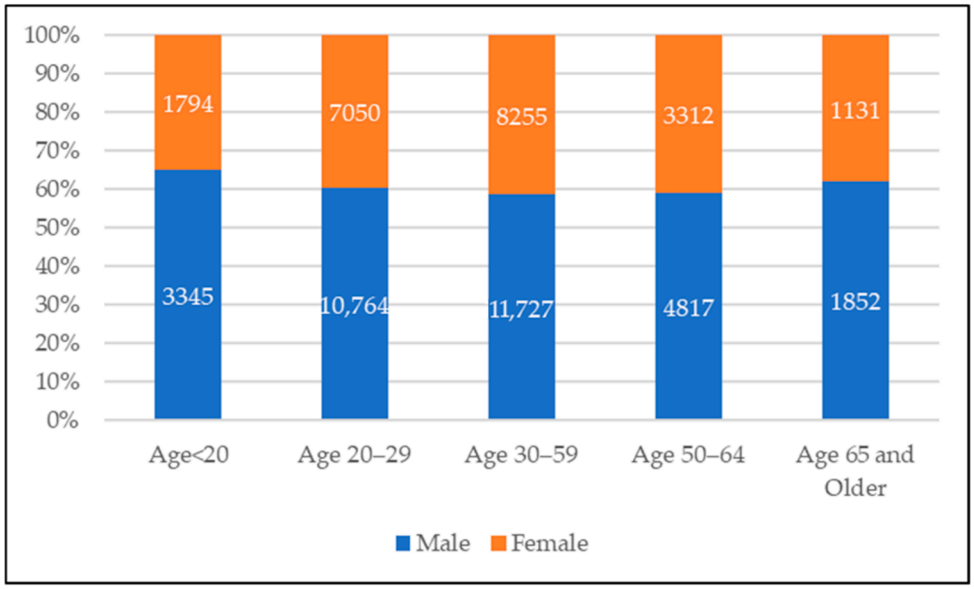

Figure 12. Speeding crash count and crash proportion by the age and gender of the driver.

Crash frequency and crash severity varied significantly by gender for different road classes. Male drivers were more likely to be involved in crashes on interstate and US/State Highways, but the crash severity of male drivers was only significantly higher on interstate highways. The likelihood of severe crashes for female drivers was highest on the city streets and Farm-to-Market roads. This observation is consistent with the association of the roadway speed limit and gender of driver. Interstates have the highest speed limit, and crashes tend to be more severe compared to those on city streets [70]. Female drivers were about 14% less likely to be involved in any crash type on interstates compared to male drivers. The maneuvering tasks on interstates are relatively easier due to one-way traffic and lesser variation in the traffic environment. This might imply that female drivers feel more comfortable in uniform traffic conditions while male drivers are comparatively more adept at handling road environment variations.

Male drivers were relatively less frequently involved in crashes during the daytime, and the difference between the expected and observed crashes was statistically significant. The risk of severe injury of male drivers was significantly higher during the nighttime period. Female drivers, on the other hand, were more susceptible to severe injury during a daytime crash, and they were statistically more frequently involved in daytime crashes than expected. Female drivers were about 30% less likely to suffer from a crash, and about 40% less likely to sustain a severe injury from a nighttime crash compared to their male counterparts. The increased risk of severe injury of male drivers during the nighttime might be attributed to certain driving behaviors of male drivers (e.g., reckless driving, risk taking, driving under influence of alcohol or drugs, and speeding).

Female drivers experienced significantly more crashes and severe injuries than expected during the weekdays. About 20.7% of all crashes involving female drivers occurred in the weekend period, which resulted in about 26.0% of all severe injuries suffered by

female drivers. On the other hand, about 23.3% of all crashes involving male drivers occurred during the weekend period, which resulted in about 30.6% of all severe injuries suffered by male drivers. Female drivers were 14% less likely to suffer from a crash, and were 20% less likely to sustain a severe injury during the weekend period compared to male drivers. The higher proportion of DUI and speeding crashes during the weekend period (which involves a relatively higher proportion of male drivers) might be the reason behind the increased crash frequency and crash severity risk for male drivers.

The primary traffic control of the roadway was a significant factor that affected the crash frequency and injury severity of male and female drivers. When the traffic was primarily controlled by stop/yield signs, crosswalks, or signal lights, female drivers were at significantly greater risk of being involved in or being severely injured by a crash. On the other hand, when the traffic was primarily controlled by dividers or marked lanes, the male drivers were more susceptible to a crash and any subsequent severe injury resulting from the crash. This might emphasize the difference in driving skill by gender. Male drivers might be more adept in handling the vehicle when the traffic is primarily controlled by stop or yield signs, signal lights, and crosswalks, while female drivers might maneuver the vehicle in a safer way when the traffic is primarily controlled by dividers or marked lanes. Compared to male drivers, female drivers were 16% more likely to be involved in a crash when traffic was controlled by stop/yield signs, signal lights, or crosswalks, and the likelihood of a severe injury increased by 45%.

The roadway surface condition is another factor that significantly affected crash frequency by gender. When the road surface condition was ice/snow/standing water/wet, male drivers were significantly more likely to be subjected to a crash. Female drivers were subjected to fewer crashes than expected under such adverse conditions. This suggests that female drivers are more cautious while driving in adverse surface conditions, and that they can handle such adverse conditions better than male drivers in terms of avoiding a crash. The likelihood of female drivers being involved in a crash in adverse surface conditions was about 8% lower than male drivers. The risk of severe injury crashes on adverse road surfaces was slightly increased for female drivers. However, the increase was not statistically significant.

Weather conditions significantly affect the crash frequency by gender of the driver. Similarly to adverse surface conditions, female drivers were more adept in terms of avoiding a crash under inclement weather conditions, and the observed crash count involving female drivers under adverse weather conditions was significantly lower than the expected crash count. Female drivers were about 9% less likely to be involved in a crash compared to male drivers under inclement weather conditions, but their severe injury risk was slightly greater than that of male drivers.

3.3. Logistic Regression Analysis

The logistic regression model was developed using environment, temporal, road, and drive-related variables. While bivariate analysis discretely identifies the most important predictors, the logistic regression model takes all variables into consideration at the same time in order to identify the most important predictors. Two logit models were constructed: one for all crashes, and the other for severe-injury crashes. The coefficient estimates are represented in log-odds terms along with respective reference categories, standard error, significance, and odds ratio (Table 2). The effect of the gender of the driver on each categorical variable could be inferred from the sign and value of the respective estimated coefficient. A negative estimated coefficient is indicative of a decrease in the odds of a female-driver crash or an increase in the odds of a male-driver crash. Conversely, a positive coefficient of the coefficient indicates an increase of the female-driver crash odds or a decrease in the male driver crash odds. For example, when all crashes are considered, the weekend period is associated with a negative coefficient (-0.12) and the weekday period is the reference category. This implies that a change from the weekday period to weekend period decreases the log-odds of a female driver crash or increases the log-odds

of a male driver crash by 0.12. Similarly, when only severe injury crashes are considered, the coefficient associated with the weekend period (−0.148) implies that a change from the weekend to weekday period would increase the log-odds of a male driver crash by 0.148. The significance of any variable is expressed with asterisk signs, and (***), (**), and (*) respectively indicate that the *p*-value is less than 0.001, 0.01, and 0.05 (i.e., the variable significantly affects the crash frequency/severity by gender). The quantification of the strength of association is expressed with an odds ratio. For example, the significance level associated with the weekend period (***) implies a statistically significant association with crash frequency by gender, and the value of the odds ratio (0.89) implies that female drivers are less likely to be involved in a crash during the weekend period (Table 2). When only severe crashes are considered, the likelihood of a female driver sustaining a severe injury is about 0.86 times than that of a male driver.

Table 2. Logistic regression results for all crashes and severe crashes.

Variable	Reference	All Crashes			Severe Crashes		
		Estimates	Std Error	OR	Estimates	Std Error	OR
intercept		−0.598 ***	0.031		−0.788 ***	0.181	
Daylight	Dark	0.097 ***	0.011	1.10	0.190 **	0.067	1.21
Speeding	No_Speeding	−0.125 ***	0.012	0.88	−0.341 ***	0.069	0.71
Other Roads	Highway/Interstate	0.038 ***	0.007	1.04	−0.019	0.050	0.98
Weekend	Weekday	−0.120 ***	0.007	0.89	−0.148 **	0.046	0.86
Speed Limit > 45	Speed Limit ≤ 45	−0.131 ***	0.009	0.88	−0.158 *	0.062	0.85
Not_distracted	dstracted	−0.041 ***	0.006	0.96	−0.111 *	0.049	0.90
8 p.m.–6 a.m.	6 a.m.–8 p.m.	−0.211 ***	0.012	0.81	−0.274 ***	0.072	0.76
Level Road Alignment	Hillcrest/Grade Road Alignment	0.002	0.008	1.00	−0.039	0.052	0.96
Inclement weather	Clear weather	−0.024	0.017	0.98	0.080	0.129	1.08
Adverse surface condition	Dry surface condition	−0.019	0.014	0.98	0.113	0.107	1.12
Intersection_Yes	Intersection_No	−0.002	0.007	1.00	−0.015	0.054	0.96
Not_DUI	DUI	0.269 ***	0.024	1.31	0.113	0.107	1.12
No_lane_departure	Lane Departure	0.067 ***	0.012	1.07	0.186	0.100	1.20
Signal light/stop/yield/crosswalk	Divider/marked lane	0.079 ***	0.007	1.08	0.251 ***	0.055	1.29

Note: Significance code: *** means $p < 0.001$; ** means $p < 0.01$; * means $p < 0.05$.

The logistic regression analysis results are generally consistent with the bivariate analysis findings. However, the strength of association and statistical significance were different for several variables. Nonetheless, the directions of the effects of different variables on crash frequency/severity by gender were similar in both models. Unlike the bivariate analysis (for which all of the selected variables significantly affected crash severity by gender), road alignment, weather conditions, surface conditions, and intersection status did not significantly affect the crash severity by gender. While bivariate analysis determines the effect of a variable on crash frequency/severity as a stand-alone variable, logistic regression determines the effect of one variable in the presence of the other variables, and the difference in the results between the two models reflects this phenomenon. The difference in results between the two models is evident for severe crashes as well. All of the variables considered were found to significantly affect the crash frequency by gender as standalone variables in the bivariate analysis when all crashes are considered. However, logistic regression did not determine the weather conditions, surface conditions, road alignment, and the presence/absence of an intersection to significantly affect crash frequency when all crashes were considered. Except for road alignment, surface conditions, lane departure, and weather conditions, all other variables significantly affected crash severity by gender in the bivariate analysis. In addition to these variables, road class, driving under the influence of alcohol/drugs, and the presence/absence of an intersection were also deemed to be not significantly associated with crash severity by gender in the logistic regression model. The crash occurrence time, speeding, traffic control, and ethnicity of driver were the most significant predictors in the prediction of severe crashes by gender.

The magnitude of the effect of several variables on crash frequency/severity by gender was also substantially different in the two models. While the ORs of a female driver being involved in any crash or in a severe crash under daylight lighting conditions were 1.35 and 1.61, respectively, compared to dark lighting conditions in the bivariate analysis, the magnitudes were considerably modest in the logistic regression model (1.10 and 1.21, respectively, for all crashes and severe crashes). In general, the magnitude of the odds ratio of any variable (for all crashes or for severe crashes only) was considerably lower in the logistic regression model when the effect of the variable is evaluated in the presence of other variables compared to its effect as a standalone variable.

4. Conclusions

This study examined speeding, alcohol, lane departure, and distracted-driving crashes, and their dependence on the driver's gender in the city of San Antonio, Texas; it also analyzed the effect of environmental, temporal, human, and crash-related variables on crash frequency and crash severity using 10-year crash data. Bivariate analysis and logistic regression were used to evaluate the effect of selected variables individually and in presence of other variables on crash risk and severity. The analysis revealed that the most prominent predictors of male-driver crashes and severe injuries were speeding, DUI, lane departure, dark lighting conditions, the weekend period, nighttime, and interstate/highway roads. For any of the selected variables, the magnitude at which a variable affected crash frequency or crash severity by gender was substantially less pronounced in the logistic regression model compared to bivariate analysis. The consideration of the effects of other variables while evaluating the effect on any specific variable might be the reason behind the relatively low OR values in the logistic regression model.

Female drivers were less likely to be involved in a crash during adverse road surface and weather conditions, possibly due to their more careful driving approach in those conditions. However, both bivariate analysis and logistic regression suggest that they were more likely to sustain a severe injury from those crashes compared to male drivers. Female drivers might be less adept at following traffic signals and maneuvering on stop/yield signs, as they were more likely to suffer from a crash when the traffic was primarily controlled by signals/signs. However, they performed better than male drivers in terms of avoiding crashes when traffic was controlled by a divider or marked lanes. Female drivers were also less likely to be involved in a crash on interstate roads/highways, and were more likely to suffer from a crash on city streets. These might be indicative of the better performance of female drivers in conditions with less variation or which require less maneuvering.

Previous studies found that male drivers are more likely to engage in activities leading to the distraction of the drivers, and female drivers are more likely to comply with rules that discourage distracted driving [38,42]. However, the results from our study suggest that female drivers were significantly more likely to suffer from a distraction crash and severe injury compared to male drivers. Male drivers are more likely to speed and be involved in speeding crashes and subsequent severe injuries. This observation is consistent with the relationships with other variables such as the road speed limit and road class, where roads with speed limit greater than 45 mph and interstate/highway roads increased the likelihood of a male-driver crash/severe injury.

Nighttime (8 pm to 6 am) and dark lighting conditions are known to be associated with more severe crashes [36]. The proportion of crash-associated male drivers was significantly greater than their female counterparts during nighttime and under dark lighting conditions, which might explain the increased crash severity risk of male drivers under those conditions. Additionally, male drivers are overrepresented in DUI crashes. DUI crashes are relatively severe, and a substantial proportion of DUI crashes occur in late night hours under dark lighting conditions [71], thus increasing the injury severity of male drivers. The likelihood of a lane departure crash and subsequent injury was greater for male drivers, which is consistent with previous research [57]. Compared to other age groups, the proportion of young (<20 years) male and female drivers was substantially higher for speeding and

lane departure-related crashes, respectively. Older male drivers (aged 65 or older) were involved in a higher proportion of DUI and distraction-related crashes. These observations could be helpful in designing age group-specific safety campaigns.

The difference in the spatial distribution of distracted driving, speeding, lane departure, and DUI crashes by gender was negligible. However, severe crashes related to these driving behaviors exhibited some differences by gender. In the case of lane departure and distracted-driving severe crashes, male drivers were more common victims of severe injuries at the interchanges, whereas female drivers were more likely to suffer from a speeding severe injury at interchanges. Overall, the interstate road segments near the city center, and the segments on city inner and outer highway loops were associated with the highest concentration of driving behavior-related crashes.

The authors acknowledge a few limitations of this study. The reported injury severities were not cross-checked with hospital data or other external sources, and were dependent on the judgement of the reporting law enforcement officers, which can be subject to error. Crash data analyses could be prone to sample selection bias (the people involved in crashes might not accurately represent the general road user population), and the data used for this study are no exception. Coordinates for some crashes were missing in the data, and the heatmaps were prepared with the available crash coordinates only (93% of all crashes). In the case of hit and run, fled scene, and other incidents for which the crash severity could not be determined, the crash severity was reported as unknown for those persons. Another limitation is that traffic volume data were not available for the spatial analysis. Finally, the authors are aware that driving patterns certainly differ by gender, e.g., females tend to drive less during late-night hours, which might explain some of the results

Author Contributions: H.O.S. and S.D. guided this research, and contributed significantly to the preparation of the manuscript for publication and the development of the research methodology. K.B. processed the data, developed the scripts used in the analysis, and performed the analysis. K.B. prepared the first draft. H.O.S. and S.D. performed the final overall proofreading of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: The financial support of the Transportation Consortium of South-Central States (Tran-SET) is greatly appreciated (Tran-SET Project 17ITSTSA01 and Grant Number 69A3551747106). This research was partially funded by a professional service agreement between the University of Texas at San Antonio and the City of San Antonio.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Publicly available datasets were analyzed in this study. The data can be found here: https://cris.txdot.gov/ (accessed on 18 October 2021).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. World Health Organization. *Global Status Report on Road Safety 2018: Summary*; World Health Organization: Geneva, Switzerland, 2018. Available online: https://www-who-int.libweb.lib.utsa.edu/publications/i/item/global-status-report-on-road-safety-2018 (accessed on 6 February 2022).
2. Texas Department of Transportation. Texas Motor Vehicle Traffic Crash Facts Calendar Year 2020. Available online: https://ftp.txdot.gov/pub/txdot-info/trf/crash_statistics/2020/01.pdf (accessed on 21 April 2021).
3. Massie, D.L.; Campbell, K.L.; Williams, A.F. Traffic Accident involvement rates by driver age and gender. *Accid. Anal. Prev.* **1995**, *27*, 73–87. [CrossRef]
4. Mouloua, M.; Brill, J.C.; Shirkey, E. Gender Differences and Aggressive Driving Behavior: A Factor Analytic Study. *Proc. Hum. Factors Ergon. Soc. Annu. Meet.* **2007**, *51*, 1283–1286. [CrossRef]
5. Magaña, V.C.; Pañeda, X.G.; Garcia, R.; Paiva, S.; Pozueco, L. Beside and Behind the Wheel: Factors that Influence Driving Stress and Driving Behavior. *Sustainability* **2021**, *13*, 4775. [CrossRef]
6. Al-Balbissi, A.H. Role of Gender in Road Accidents. *Traffic Inj. Prev.* **2003**, *4*, 64–73. [CrossRef]
7. Bener, A.; Crundall, D. Role of gender and driver behaviour in road traffic crashes. *Int. J. Crashworthiness* **2008**, *13*, 331–336. [CrossRef]

8. Turner, C.; McClure, R. Age and gender differences in risk-taking behavior as an explanation for high incidence of motor vehicle crashes as a driver in young males. *Inj. Control Saf. Promot.* **2003**, *10*, 123–130. [CrossRef]
9. Evans, L. Female Compared with Male Fatality Risk from Similar Physical Impacts. *J. Trauma Acute Care Surg.* **2001**, *50*, 281–288. [CrossRef]
10. Krahé, B.; Fenske, I. Predicting aggressive driving behavior: The role of macho personality, age, and power of car. *Aggress. Behav.* **2002**, *28*, 21–29. [CrossRef]
11. Iversen, H. Risk-taking attitudes and risky driving behaviour. *Transp. Res. Part F Traffic Psychol. Behav.* **2004**, *7*, 135–150. [CrossRef]
12. Åkerstedt, T.; Kecklund, G. Age, gender and early morning highway accidents. *J. Sleep Res.* **2001**, *10*, 105–110. [CrossRef]
13. DeJoy, D.M. An examination of gender differences in traffic accident risk perception. *Accid. Anal. Prev.* **1992**, *24*, 237–246. [CrossRef]
14. Leary, M.R.; Tchividijian, L.R.; Kraxberger, B.E. Self-presentation can be hazardous to your health: Impression management and health risk. *Health Psychol.* **1994**, *13*, 461. [CrossRef] [PubMed]
15. Rhodes, N.; Pivik, K. Age and gender differences in risky driving: The roles of positive affect and risk perception. *Accid. Anal. Prev.* **2011**, *43*, 923–931. [CrossRef]
16. Classen, S.; Wang, Y.; Crizzle, A.M.; Winter, S.M.; Lanford, D.N. Gender differences among older drivers in a comprehensive driving evaluation. *Accid. Anal. Prev.* **2013**, *61*, 146–152. [CrossRef] [PubMed]
17. Billah, K.A. Pedestrian Crash Analysis for San Antonio. Ph.D. Thesis, The University of Texas at San Antonio, San Antonio, TX, USA, 2018.
18. Michael, W.J.; Gier, J.; Christopherson, A.S.; Verstraete, A.G. Drugs and Driving. *Traffic Inj. Prev.* **2010**, *5*, 241–253. [CrossRef]
19. Mia, M.F.; Dessouky, S.; Weissmann, J.; Sharif, H.O.; Billah, K. Geo-Locating and Identifying Wrong-Way Driving Entrance Points in Bexar County Highways by Implementing Mathematical Modeling and Land-Use Impact Assessment. *Sustainability* **2022**, *14*, 33. [CrossRef]
20. International Transport Forum. *Road Safety Annual Report 2017*; OECD Publishing: Paris, France, 2017.
21. Robertson, A.A.; Liew, H.; Gardner, S. An evaluation of the narrowing gender gap in DUI arrests. *Accid. Anal. Prev.* **2011**, *43*, 1414–1420. [CrossRef]
22. Schwartz, J. Gender differences in drunk driving prevalence rates and trends: A 20-year assessment using multiple sources of evidence. *Addict. Behav.* **2008**, *33*, 1217–1222. [CrossRef]
23. Schwartz, J.; Beltz, L. Trends in female and male drunken driving prevalence over thirty years: Triangulating diverse sources of evidence (1985–2015). *Addict. Behav.* **2018**, *84*, 7–12. [CrossRef]
24. Reilly, K.; Woodruff, S.I.; Hohman, M.; Barker, M. Gender differences in driving under the influence (DUI) program client characteristics: Implications for treatment delivery. *Women Health* **2019**, *59*, 132–144. [CrossRef]
25. Yadav, A.K.; Khanuja, R.K.; Velaga, N.R. Gender differences in driving control of young alcohol-impaired drivers. *Drug Alcohol Depend.* **2020**, *213*, 108075. [CrossRef] [PubMed]
26. Robertson, A.A.; Zhou, Q.M.; Tatch, A.; Walsh, M. Gender-Specific Predictors of Recidivism Among DUI Offenders. *J. Stud. Alcohol Drugs* **2019**, *80*, 641–650. [CrossRef] [PubMed]
27. Knoth, L.K.; Ruback, R.B. Conviction or Diversion and the Labeling of First-Time DUI Offenders: An Analysis of Sentencing and Recidivism in Pennsylvania. *Justice Q.* **2021**, *38*, 72–100. [CrossRef]
28. Abdel-Aty, M.A.; Abdelwahab, H.T. Exploring the relationship between alcohol and the driver characteristics in motor vehicle accidents. *Accid. Anal. Prev.* **2000**, *32*, 473–482. [CrossRef]
29. Caetano, R.; McGrath, C. Driving under the influence (DUI) among U.S. ethnic groups. *Accid. Anal. Prev.* **2005**, *37*, 217–224. [CrossRef]
30. Traffic Injury Research Foundation. *Alcohol-Crash Problem in Canada: 2010*; Canadian Council of Motor Transport Administrators: Ottawa, ON, Canada, 2013.
31. Beasley, E.E.; Beirness, D.J.; Porath-Waller, A.J. *A Comparison of Drug- and Alcohol-Involved Motor Vehicle Driver Fatalities*; Canadian Centre on Substance Abuse: Ottawa, ON, Canada, 2011.
32. Beirness, D.J.; Beasley, E.E. *Alcohol Drug Use among Drivers British Columbia Roadside Survey 2010*; Canadian Centre on Substance Abuse: Ottawa, ON, Canada, 2011.
33. Zador, P.L.; Krawchuk, S.A.; Voas, R.B. Alcohol-related relative risk of driver fatalities and driver involvement in fatal crashes in relation to driver age and gender: An update using 1996 data. *J. Stud. Alcohol* **2000**, *61*, 387–395. [CrossRef]
34. NHTSA. Distracted Driving. Available online: https://www.nhtsa.gov/risky-driving/distracted-driving (accessed on 20 February 2022).
35. Regan, M.A.; Hallett, C.; Gordon, C.P. Driver distraction and driver inattention: Definition, relationship and taxonomy. *Accid. Anal. Prev.* **2011**, *43*, 1771–1781. [CrossRef]
36. Billah, K.; Sharif, H.O.; Dessouky, S. Analysis of Bicycle-Motor Vehicle Crashes in San Antonio, Texas. *Int. J. Environ. Res. Public Health* **2021**, *18*, 9220. [CrossRef]
37. Pope, C.N.; Bell, T.R.; Stavrinos, D. Mechanisms behind distracted driving behavior: The role of age and executive function in the engagement of distracted driving. *Accid. Anal. Prev.* **2017**, *98*, 123–129. [CrossRef]
38. Hoff, J.; Grell, J.; Lohrman, N.; Stehly, C.; Stoltzfus, J.; Wainwright, G.; Hoff, W.S. Distracted Driving and Implications for Injury Prevention in Adults. *J. Trauma Nurs.* **2013**, *20*, 31–34. [CrossRef]

39. Tison, J.; Chaudhary, N.; Cosgrove, L. *National Phone Survey on Distracted Driving Attitudes and Behaviors*; Report No. D. OT HS 811 555; National Highway Traffic Safety Administration: Washington, DC, USA, 2011.
40. Lamba, H.; Srikanth, S.; Pailla, D. *Driving the Last Mile: Characterizing and Understanding Distracted Driving Posts on Social Networks*; Association for the Advancement of Artificial Intelligence: Palo Alto, CA, USA, 2019.
41. Struckman-Johnson, C.; Gaster, S.; Struckman-Johnson, D.; Johnson, M.; May-Shinagle, G. Gender differences in psychosocial predictors of texting while driving. *Accid. Anal. Prev.* **2015**, *74*, 218–228. [CrossRef] [PubMed]
42. Rudisill, T.; Zhu, M. Hand-held cell phone use while driving legislation and observed driver behavior among population sub-groups in the United States. *BMC Public Health* **2017**, *17*, 437. [CrossRef]
43. Pope, C.N.; Mirman, J.H.; Stavrinos, D. Adolescents' perspectives on distracted driving legislation. *J. Saf. Res.* **2019**, *68*, 173–179. [CrossRef] [PubMed]
44. Billah, K.; Sharif, H.O.; Dessouky, S. Analysis of Pedestrian–Motor Vehicle Crashes in San Antonio, Texas. *Sustainability* **2021**, *13*, 6610. [CrossRef]
45. Qiong, W.; Zhang, G.; Ci, Y.; Wu, L.; Tarefder, R.A.; Alcántara, A.D. Exploratory Multinomial Logit Model–Based Driver Injury Severity Analyses for Teenage and Adult Drivers in Intersection-Related Crashes. *Traffic Inj. Prev.* **2016**, *17*, 413–422. [CrossRef]
46. Cestac, J.; Paran, F.; Delhomme, P. Young drivers' sensation seeking, subjective norms, and perceived behavioral control and their roles in predicting speeding intention: How risk-taking motivations evolve with gender and driving experience. *Saf. Sci.* **2011**, *49*, 424–432. [CrossRef]
47. Delhomme, P.; Chaurand, N.; Paran, F. Personality predictors of speeding in young drivers: Anger vs. sensation seeking. *Transp. Res. Part F Traffic Psychol. Behav.* **2012**, *15*, 654–666. [CrossRef]
48. Morgan, A.; Mannering, F. The effects of road-surface conditions, age, and gender on driver-injury severities. *Accid. Anal. Prev.* **2011**, *43*, 1852–1863. [CrossRef]
49. Staff, T.; Eken, T.; Wik, L.; Røislien, J.; Søvik, S. Physiologic, demographic and mechanistic factors predicting New Injury Severity Score (NISS) in motor vehicle accident victims. *Injury* **2011**, *45*, 9–15. [CrossRef]
50. Fernandes, R.; Hatfield, J.; Soames Job, R.F. A systematic investigation of the differential predictors for speeding, drink-driving, driving while fatigued, and not wearing a seat belt, among young drivers. *Transp. Res. Part F Traffic Psychol. Behav.* **2010**, *13*, 179–196. [CrossRef]
51. Husted, D.S.; Gold, M.S.; Frost-Pineda, K.; Ferguson, M.A.; Yang, M.C.K.; Shapira, N.A. Is Speeding a Form of Gambling in Adolescents? *J. Gambl. Stud.* **2006**, *22*, 209–219. [CrossRef] [PubMed]
52. Deffenbacher, J.L.; Deffenbacher, D.M.; Lynch, R.S.; Richards, T.L. Anger, aggression, and risky behavior: A comparison of high and low anger drivers. *Behav. Res. Ther.* **2003**, *41*, 701–718. [CrossRef]
53. Quintanar, S.M. Man Vs. Machine: An Investigation of Speeding Ticket Disparities Based on Gender and Race. *J. Appl. Econ.* **2017**, *20*, 1–28. [CrossRef]
54. Islam, M.; Mannering, F. The role of gender and temporal instability in driver-injury severities in crashes caused by speeds too fast for conditions. *Accid. Anal. Prev.* **2021**, *153*, 106039. [CrossRef] [PubMed]
55. Teo, S.H.; Gan, L.M. Speeding driving behaviour: Age and gender experimental analysis. *MATEC Web Conf.* **2016**, *74*, 00030. [CrossRef]
56. Federal Highway Administration. Roadway Departure Safety—Safety. Available online: https://safety.fhwa.dot.gov/roadway_dept (accessed on 20 February 2022).
57. Fitzharris, M.; Lenné, M.G.; Corben, B.; Arundell, T.P.; Peiris, S.; Liu, S.; Stephens, A.; Fitzgerald, M.; Judson, R.; Bowman, D.; et al. *Enhanced Crash Investigation Study (ECIS)*; Monash University: Melbourne, VC, Canada, 2020; p. 232.
58. Son, J.; Park, M.; Park, B.B. The effect of age, gender and roadway environment on the acceptance and effectiveness of Advanced Driver Assistance Systems. *Transp. Res. Part F Traffic Psychol. Behav.* **2015**, *31*, 12–24. [CrossRef]
59. Eichelberger, A.H.; McCartt, A.T. Toyota drivers' experiences with Dynamic Radar Cruise Control, Pre-Collision System, and Lane-Keeping Assist. *J. Saf. Res.* **2016**, *56*, 67–73. [CrossRef]
60. Li, G.; Li, S.E.; Cheng, B. Field operational test of advanced driver assistance systems in typical Chinese road conditions: The influence of driver gender, age and aggression. *Int. J. Automot. Technol.* **2015**, *16*, 739–750. [CrossRef]
61. Nodine, E.E.; Lam, A.H.; Najm, W.G.; Ference, J.J. Safety Impact of an Integrated Crash Warning System Based on Field Test Data (No. 11–0158). Article 11–0158. In Proceedings of the 22nd International Technical Conference on the Enhanced Safety of Vehicles (ESV) National Highway Traffic Safety Administration, Washinton, DC, USA, 13–16 June 2011; Available online: https://trid.trb.org/view/1360844 (accessed on 26 January 2022).
62. Hollopeter, N.; Brown, T.; Thomas, G. (Eds.) Differences in novice and experienced driver response to lane departure warnings that provide active intervention. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting, Baltimore, ML, USA, 12–14 March 2012; Sage Publications: Los Angeles, CA, USA, 2012.
63. Rahman, M.A.; Sun, X.; Das, S.; Khanal, S. Exploring the influential factors of roadway departure crashes on rural two-lane highways with logit model and association rules mining. *Int. J. Transp. Sci. Technol.* **2021**, *10*, 167–183. [CrossRef]
64. Hossain, A.; Sun, X. Trend Analysis of Lane Departure Crashes in Louisiana State, USA. In Proceedings of the 2020 Louisiana Transportation Conference, Baton Rouge, LA, USA, 1–4 March 2020.
65. Environmental Systems Research Institute (ESRI). ArcGIS Pro Tool Reference. Density Toolset Concept. 2014. Available online: https://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/how-kernel-density-works (accessed on 29 January 2022).

66. Silverman, B.W. *Density Estimation for Statistics and Data Analysis, 26*; CRC Press: Boca Raton, FL, USA, 1986.
67. Bailey, T.C.; Gatrell, A.C. *Interactive Spatial Data Analysis*; Longman Scientific Technical; John Wiley and Sons: Hoboken, NJ, USA, 1995.
68. Young, J.; Park, P.Y. Hotzone identification with GIS-based post-network screening analysis. *J. Transp. Geogr.* **2014**, *34*, 106–120. [CrossRef]
69. Plug, C.; Xia, J.C.; Caulfield, C. Spatial and temporal visualisation techniques for crash analysis. *Accid. Anal. Prev.* **2011**, *43*, 1937–1946. [CrossRef] [PubMed]
70. Renski, H.; Khattak, A.J.; Council, F.M. Effect of Speed Limit Increases on Crash Injury Severity: Analysis of Single-Vehicle Crashes on North Carolina Interstate Highways. *Transp. Res. Rec.* **1999**, *1665*, 100–108. [CrossRef]
71. Liu, J.; Li, X.; Khattak, A.J. An integrated spatio-temporal approach to examine the consequences of driving under the influence (DUI) in crashes. *Accid. Anal. Prev.* **2020**, *146*, 105742. [CrossRef] [PubMed]