Comprehensive Analysis of Motorcycle Crashes in Texas: A Multi-Year Snapshot

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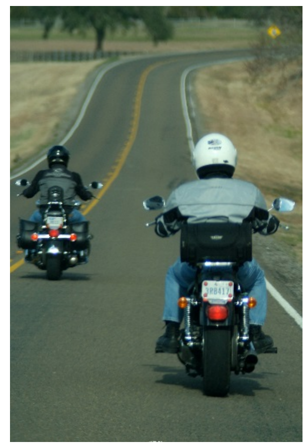


September 2016

Center for Transportation Safety
Texas A&M Transportation Institute

Comprehensive Analysis of Motorcycle Crashes in Texas: A Multi-Year Snapshot

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Disclaimer

This research was performed in cooperation with the Texas Department of Transportation (TxDOT). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of TxDOT. This report does not constitute a standard, specification, or regulation.

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1 Introduction

In 2014, over 400,000 motorcycles were registered in the Texas, which is approximately a two-fold increase over the number of registrations recorded in 2001.[1] Although motorcycles comprise a relatively small proportion (2 percent) of the total motor vehicles in operation,[2] motorcycle drivers and passengers account for a considerable proportion (12 percent in 2015) of all fatal crashes each year in Texas. In 2015, there were 455 motorcyclists who died on Texas roads.[3] In that same year, motorcyclists sustained 1,866 incapacitating injuries. Although Texas has experienced a decrease in motorcyclist fatalities each year since 2013, the occurrence of fatal and severe crashes remains high, as do the medical and other costs endured by motorists and society at large.[4]

Motorcyclists are at a considerably increased risk of sustaining a fatal or nonfatal injury due to a crash. At the national level, the rate of motorcyclist fatalities per vehicle mile traveled is

[1] Fiscal year REGISTRATION CLASS CODE COUNT Report prepared by the IT Division of the TxDMV and the Report of Rental Trailers prepared by Explore Inc.
[2] Ibid.
[3] Based on data from TxDOT CRIS.
[4] Derrick AJ, Faucher LD. 2009. Motorcycle helmets and rider safety: A legislative crisis. J Public Health Pol. 30(2):226-242.

26 times higher than the rate among passenger car occupants, with overall injury rates approximately five times higher among motorcyclists than passenger car occupants.[5] There are several reasons for the overrepresentation of motorcyclist crashes. Operating a motorcycle safely requires the ability to maintain balance even on smooth roadways, coordination of actions and sense, and acute awareness. Motorcycles usually are smaller than other vehicles and, as such, are less conspicuous to other motorists. Finally, unlike most other motor vehicles, which are enclosed, motorcyclists are exposed to their environment. They must contend with extreme weather conditions, particularly heat in Texas, which could impair their ability to operate the motorcycle safely. In the event of a crash, the motorcycle provides no protection from direct contact with the roadway, fixed objects, and other potential hazards.

Many of the injuries sustained by motorcyclists are associated with high medical treatment and other costs that may also result in long-term consequences. The medical costs combined with work loss costs for motorcyclist crash deaths in Texas were $665 million in 2013.[6] In addition, diagnoses such as a spinal cord injury can require a substantial amount of recovery time. The motorcyclist may never achieve the same quality of life he or she enjoyed prior to the crash. This change impacts not only the motorcyclist but also his or her family members and friends.

Given the frequency of motorcycle crashes and their potential for notable costs in terms of loss of life as well as economic costs, there is an urgent need to continue to work diligently toward driving the frequency of these crashes toward zero. To this end, the purpose of this project was to understand the complex nature of motorcycle crashes in Texas through construction of a motorcycle crash database and a multi-year analysis of these data with an emphasis on the prevention of fatal and incapacitating injury crashes. To aid in this effort, researchers used the most comprehensive analysis of motorcycle crash causation—a report led by H. H. Hurt titled *Motorcycle Accident Cause Factors and Identification of Countermeasures*—as a guide. The analysis is usually referred to simply as the Hurt Report after the name of its primary author. This report was released in 1981 and documents in-depth analyses of motorcycle crashes in the City of Los Angeles, California, from 1976–1977. Although it is over 35 years old, it remains among the most referenced pieces of motorcycle safety literature. Many of the research questions answered in this report for Texas were guided by key findings in the Hurt Report, which also allowed for making comparisons with this prior seminal work. The overarching goal of this project was to support the prevention of motorcycle crashes in Texas by producing up-to-date information that guides data-informed decision-making.

[5] NHTSA. 2015. Traffic Safety Facts 2013 Data: Motorcycles. DOT HS 812 148.
[6] CDC. Texas Motor Vehicle Crash Deaths: Costly but Preventable. Available at http://www.cdc.gov/motorvehiclesafety/pdf/statecosts/tx-2015costofcrashdeaths-a.pdf.

2 Methods

This project involved a variety of methods used to complete the two main project components: compilation of a motorcycle crash database and detailed analysis of motorcycle crash data. This section provides a description of the individual methods. The various data sources used for this project are also described. At the beginning of each section, the main research question or hypotheses being addressed are listed when applicable.

2.1 Motorcycle Crash Database Construction

The research team constructed the motorcycle crash record database using Microsoft Access.[7] The database includes several data tables that are linked by a common identifier such as the unique crash identifying number. It consists of the following tables from the Texas Department of Transportation (TxDOT) Crash Records Information System (CRIS): Crash, Unit, Person, Charges, Primary Person, CDL Endorsements, Driver License Restrictions, and Damages. Additional tables contain data representing driver training; distance from residence to crash; information extracted from narratives with respect to vehicle at fault; and motorcycle vehicle identification number (VIN), which is used to identify characteristics of a motorcycle involved in

[7] Microsoft Corporation, Redmond, WA.

a crash, including engine size. The database is designed so that additional CRIS records can be added over time and additional data from different sources can be updated or added over time. Given the relational nature of the database, queries can easily be created to extract only the necessary variables for a specific analysis.

The following criteria were used to filter crashes for inclusion in the database: (1) involvement of at least one motorcycle, motor scooter, or moped, including police motorcycles and all-terrain vehicles; (2) the entire state of Texas for a six-year time period from 2010–2015; and (3) all crash severities, defined as fatal (K), incapacitating (A), non-incapacitating (B), possible (C), and no injury, also described as property damage only (O). Once the database was constructed, various data management activities were undertaken. In line with the Texas Strategic Highway Safety Plan (SHSP), the research team created additional variables to represent standard crash type and location, system user, and user behavior categories. Examples include, but were not limited to, run off the road, head on, older driver, distracted driving, and driving under the influence (DUI). Inclusion of these additional variables facilitates more detailed analyses without having to define them every time a different analysis is desired. On an annual basis, crashes will be added to the database and various data management activities such as the one noted above will be completed.

2.2 Data Sources

2.2.1 CRIS

TxDOT collects, processes, records, and codes all crash data submitted by police officers through the Texas Peace Officer's Crash Report (Form CR-3) in CRIS. The CRIS database was the primary data source used for the analysis performed as part of this project.

The data reported herein include crashes and casualties coded in CRIS representing six years, from 2010–2015. For this report, motorcycle crashes are defined as those that involve at least one motorcycle, motor scooter, or moped, including police motorcycles and all-terrain vehicles. Frequency of crash and casualty were computed based on a combination of crash, unit, and driver classifications and specific variable coding, as defined by TxDOT in the 2014 Texas SHSP. Relevant variables used in this analysis are defined at the crash level in the SHSP as follows:

- Driving Under the Influence of Alcohol or Drugs Crash: A crash involving at least one driver under the influence of alcohol or another drug.
- Failure to Yield Right of Way (FTYROW): A crash in which the first harmful event occurred on an approach to or exit from an intersection and resulted from an activity, behavior, or control related to the movement of traffic units through the intersection and in which at least one vehicle failed to yield right of way.
- Head-on Crash: A crash involving two vehicles going straight that were traveling in opposite directions prior to impact.
- Older Driver Crash: A crash involving at least one driver age 65 or older.

- Run-off-the-Road Crash: A single-vehicle crash where the impact of the first harmful event occurred on the shoulder, beyond the shoulder, or in the median of the roadway.
- Speeding-Related Crash: A crash in which at least one driver was speeding above the limit or driving at an unsafe speed below the limit.

2.2.2 TABC ALCOHOL OUTLETS DATA

The Texas Alcoholic Beverage Commission (TABC) publishes information on licenses and permits readily available using its online Public Inquiry System, in downloadable standard comma-delimited formatted files, or through an open records request. Included in the data are county, class, and number of the license/permit; expiration date; name of establishment; name of owner; street address (city, zip); mailing address (city, zip); license/permit issue date; and phone number.[8]

2.2.3 GEOSERVICES TEXAS A&M UNIVERSITY (TAMU)

The Texas A&M University Department of Geography houses TAMU GeoServices, which provides geographic information processing services to students, faculty, and staff. TAMU GeoServices assists in geospatial research, data processing, analysis, and visualization. Services offered include assistance with geocoding, address processing, and open source geospatial mapping and visualization.[9]

2.2.4 POPULATION ESTIMATES

The population estimates for the state of Texas and individual counties are based on the online American Factfinder tool provided by the U.S. Census Bureau's Population Division.[10]

2.2.5 TRAINING DPS

Completion of the Basic Rider Course is required to obtain a motorcycle driver's license (Class M). The course covers motorcycle operation, protective clothing and gear, how to avoid dangerous situations, and how to get out of dangerous situations. The two-day course includes in-class and field instruction. In order to pass the course, attendees must pass a 25-question written exam with a score of 80 or higher and a skills exam with 20 or fewer errors. The curriculum for the motorcycle safety course is maintained by the Motorcycle Safety Foundation.[11,12]

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[8] TABC. TABC License/Permit Public Information. Available at https://www.tabc.state.tx.us/public_information/index.asp.
[9] Texas A&M GeoServices. About Our Services. Available at http://geoservices.tamu.edu/About/.
[10] United States Census Bureau. American FactFinder. Available at https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml.
[11] Texas Department of Public Safety. The Course for Motorcycle Riders. Available at http://www.txdps.state.tx.us/msb/thecourse.htm.
[12] Motorcycle Safety Foundation. Available at http://msf-usa.org/.

2.2.6 REGISTRATION DATA

All vehicles are required to be registered with the State of Texas each year. The Texas Department of Motor Vehicles (DMV) maintains data on the number of motor vehicle registrations in the state of Texas by vehicle type. These data are updated on an annual basis and can be accessed through the DMV website.[13]

2.2.7 RHINO—GEO-HINI

The Road–Highway Inventory Network (RHiNo) database contains data on road segments in terms of characteristics like roadway width, shoulder width, and traffic volumes. The Geometrics (GEO-HINI) database is a supplement to RHiNo and records geometric information related to curves in each segment using reference identifiers. The start and endpoints of each curve can be identified by using a starting marker and the length of the curve.

2.2.8 VIN DATA

The CRIS unit data file incudes a field for the VIN for every vehicle involved in a crash. VIN data can be used to look up attributes of vehicles including the motorcycle make, model, engine size, and other attributes. For this study, VINs for each fatal motorcycle crash from 2015 were selected along with a sample of 250 motorcycle crashes randomly chosen from the remaining nonfatal crash severity categories. Key attributes for each motorcycle were coded by entering each VIN into the Kelley Blue Book AutoCheck Vehicle History. This tool searches a vehicle's history based on its VIN or license plate number to provide information on previous accidents, title problems, odometer readings, and other use and events (e.g., flood damage, fire damage, or theft).[14]

2.3 Statistical Approaches

This study utilized three categories of statistical analytical approaches: (a) descriptive measures, (b) analytical statistics produced by statistical models, and (c) geospatial plotting and related measures. Below is a brief explanation of how descriptive measures and analytical statistics were used. Section 2.4 provides an explanation of how geospatial methods were used to address the research hypotheses and questions. Various software packages were used to complete the analyses discussed in this report, including Microsoft Excel and Access 2013,[15] SAS v. 9.0,[16] STATA v. 14,[17] and ArcGIS v. 10.4.[18]

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[13] Texas Department of Motor Vehicles. 2014. FY 2001–2014 Number of Passenger, Motorcycles & Pick-Up Trucks Registered Statewide. Available at http://www.txdmv.gov/reports-and-data/cat_view/13-publications/25-reports-data/65-vehicle-titles-registration/229-number-of-vehicles-registered.

[14] Kelley Blue Book. Find a Vehicle's History. Available at http://www.kbb.com/vehicle-history-report/.

[15] Microsoft Corporation, Redmond, WA.

[16] SAS Institute Inc., Cary, NC.

[17] StataCorp LP, College Station, TX.

[18] Environmental Systems Research Institute (ESRI), Redlands, CA.

Descriptive measures comprise the majority of data presented in this report. Descriptive measures include counts and percentages or proportions, such as the number of K crashes in 2015 or the percent of K crashes where the driver was not wearing a helmet. Descriptive measures in this report were often stratified by year, injury severity, demographics, and other factors in order to make comparisons and to identify factors or variables that may be issues, particularly for K or A crashes involving motorcycles.

In this report, analytical statistics are presented in Section 9 to identify the factors or variables that were most strongly associated with fatal injury among motorcycle drivers. This information can be a useful tool for prioritizing interventions. For this study, statistical models were constructed using multiple logistic regression to quantify the degree to which key variables were associated with fatal injury among motorcycle drivers. This type of statistical approach produces odds ratios. An odds ratio that is markedly greater than 1 suggests that a factor or variable may increase the risk of fatality provided that a motorcycle driver is involved in a crash. This is particularly true if the measure of stability that is computed for each odds ratio, known as the 95 percent confidence interval, excludes 1. Very wide confidence intervals mean that the estimated odds ratio is not stable. Odds ratios equal to 1 or close to 1 are indicative that the variable is not associated with fatality. If the 95 percent confidence interval excludes 1, then the variable is considered statistically significant. Section 9 presents the results of this analysis and provides additional explanation of the findings.

2.4 Mapping Approaches

2.4.1 DISPLAYING CRASH LOCATIONS AS POINTS

To display the point locations of crashes and injuries, the geographic coordinates of latitude and longitude provided by TxDOT's CRIS were plotted in ESRI ArcMap, a geographic information system software, as shown in Figure 1. This software is able to read data files (e.g., .csv or .txt) with geographic coordinates and plot them using the "Display XY Data" tool and a geographic coordinate system, such as North American Datum 1983 (NAD83).[19]

[19] ESRI. Add x,y coordinate data as a layer. Available at http://pro.arcgis.com/en/pro-app/help/mapping/layer-properties/add-x-y-coordinate-data-as-a-layer.htm.

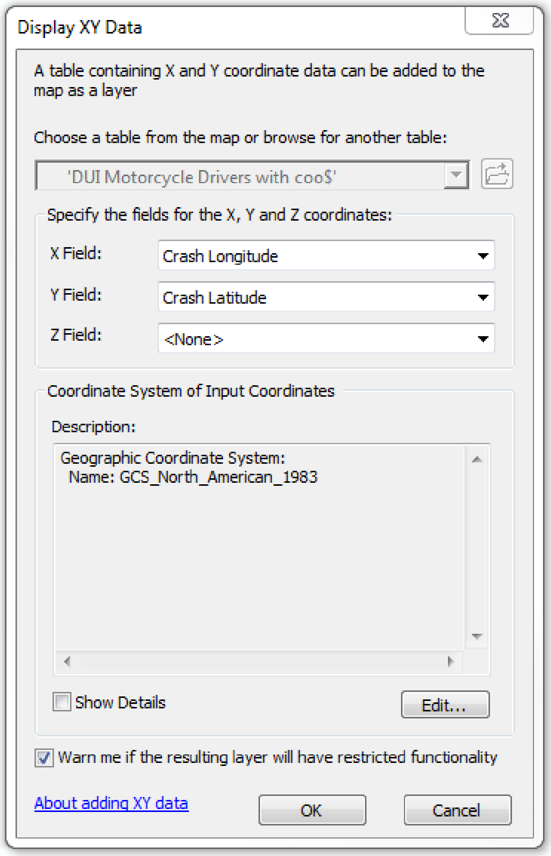

Figure 1: Screenshot of plotting crash data for latitude and longitude.

2.4.2 VISUALIZING STATEWIDE MOTORCYCLE K AND A INJURIES BY SEASONS, 2010–2015

All K and A motorcycle crash injuries with geographical coordinates in TxDOT's CRIS from years 2010 to 2015 were plotted. Dates of when the injuries occurred were provided and used to divide the injuries into seasons: spring (March, April, and May), summer (June, July, and August), fall (September, October, and November), and winter (December, January, and February). ESRI ArcMap was used to create a kernel density map, also known as a heat map, for each seasonal subset of injuries.[20] Kernel density calculates a magnitude-per-unit area from point or polyline features using a kernel function to fit a smoothly tapered surface to each point or polyline.[18] For this analysis, a 20-mile search area and a 0.25-mile raster pixel size were chosen to provide a smooth high resolution raster layer depicting generalized areas with a high frequency of motorcycle K and A injuries for the entire state of Texas. The heat map used the same equal interval classification and color scale so that comparisons could be made between the seasons. A simplified base map was chosen to provide geographical references while not distracting from the kernel density raster layer. Once plotted, the crashes or injuries are represented as points on a map and can be preserved as a shapefile for further spatial analysis.

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[20] ESRI. Kernel Density. Available at http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/kernel-density.htm.

2.4.3 PROXIMITY OF K AND A MOTORCYCLE CRASHES TO ON-PREMISE CONSUMPTION TABC LICENSED ESTABLISHMENTS, STATEWIDE 2010–2015

All K and A motorcycle crashes from years 2010 to 2015 with urban and rural area types included were plotted using the geographic coordinates provided by TxDOT's CRIS. In addition, all of the physical addresses for businesses licensed by TABC to sell alcohol and allow for on-premise consumption were geocoded and their locations plotted.[21] A 2-mile buffer was then drawn around each TABC licensed establishment and used to spatially join with the motorcycle K and A crashes that were located within their boundaries, as shown in Figure 2. This process provided the total number of crashes within each establishment's 2-mile buffer. This was done for all DUI-related motorcycle K and A crashes and all non-DUI-related motorcycle K and A crashes for both urban and rural area types. The results for each combination of crash and area type proximity analysis are presented in Section 5.

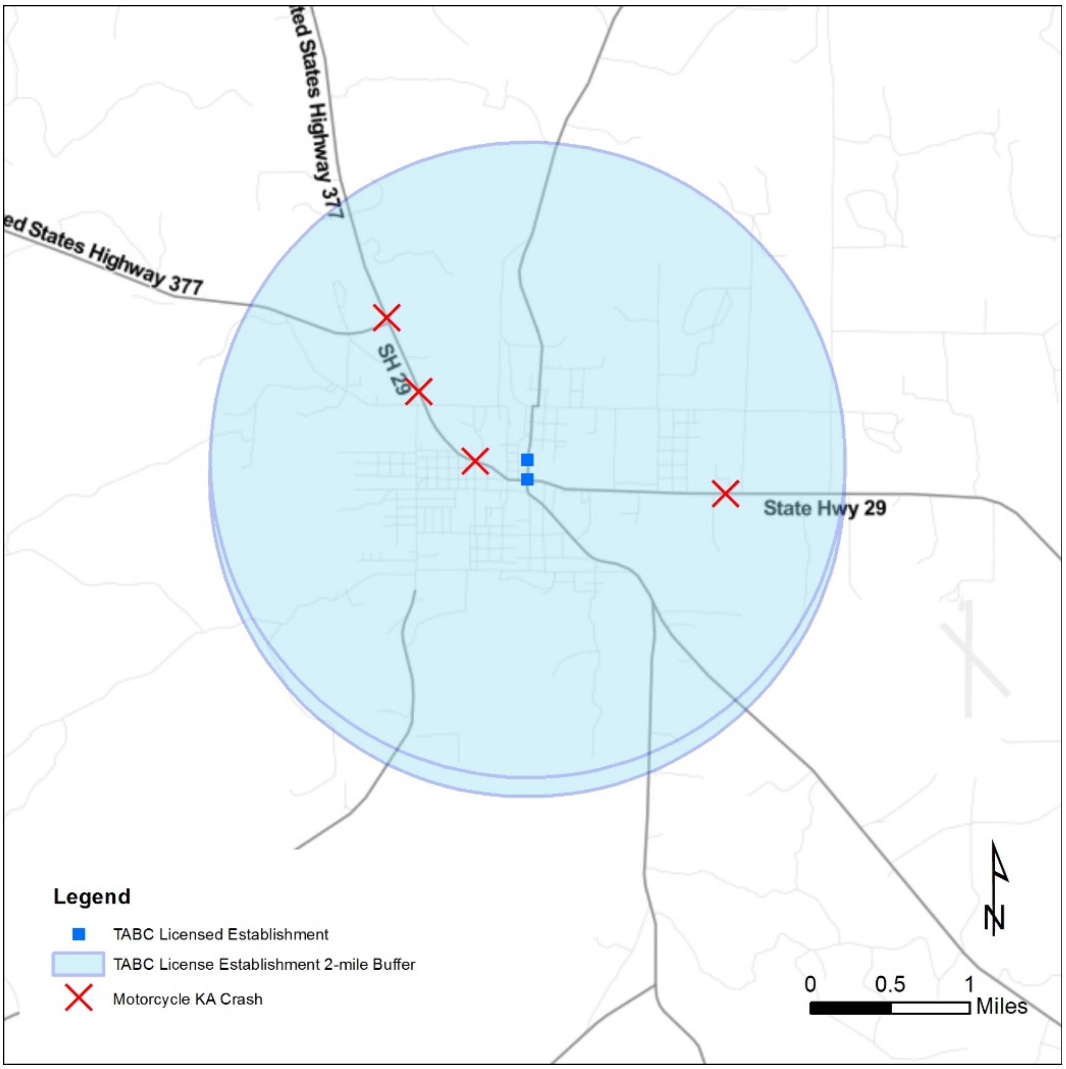


Figure 2: Example buffer for determining crashes occurring within a 2-mile radius.

[21] TABC. Public Information. Available at https://www.tabc.state.tx.us/public_information/layout.asp.

2.4.4 PROXIMITY OF K MOTORCYCLE CRASHES TO HOME ADDRESS, STATEWIDE 2010–2015

All K motorcycle crashes from years 2010 to 2015 with crash coordinates (latitude and longitude) and a home address in the state of Texas were selected. The physical home addresses were also extracted from CRIS and processed through Texas A&M GeoServices to obtain the coordinates (latitude and longitude). Crashes and home addresses were plotted using the "XY to Line" tool in ArcMap. Essentially, this tool constructs a straight line to connect the crash location to the home address. The distance in miles was calculated using the "Calculate Geometry" feature. The results of this analysis are presented and discussed in Section 8.

3 Overview: Motorcycle Crashes 2010–2015

This chapter presents an overview of the frequency of motorcycle crashes over time and their relationship to motorcycle vehicle registrations with the State of Texas. Much of this information has been presented elsewhere with updates on a regular basis.[22,23] It is included here as well to provide the reader with the available data with respect to the scope or magnitude of the problem and its historical context.

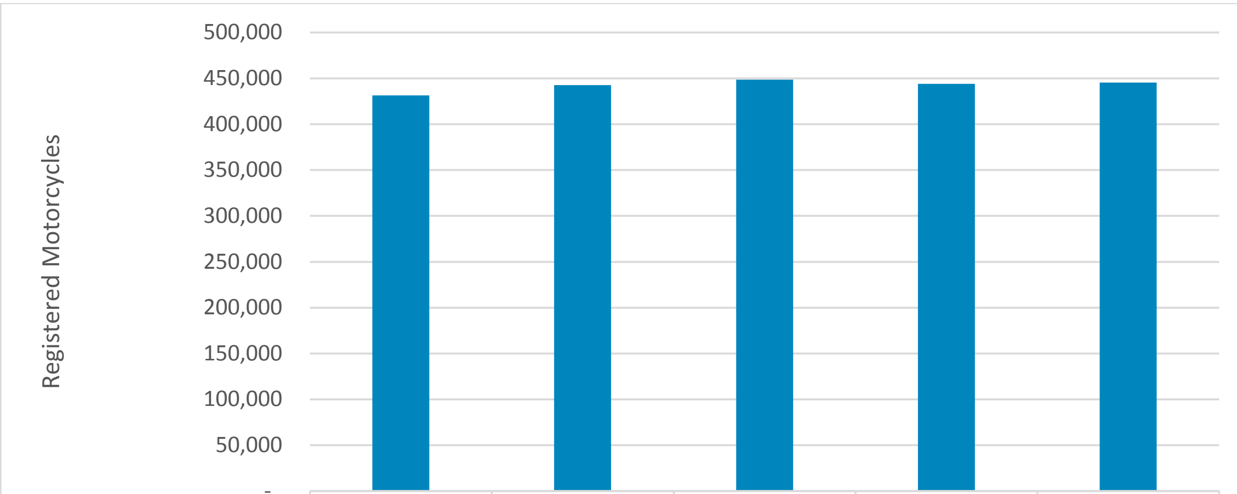
KEY POINTS

- The number of registered motorcycles doubled from 2000 to 2014.
- The counties with the most motorcycle registrations were Bexar, Collin, Dallas, Denton, El Paso, Harris, Montgomery, Tarrant, and Travis, which correspond to the most populated areas of Texas.
- The majority of crashes were non-incapacitating (37 percent) in 2015.
- The rate of fatal and incapacitating injuries for motorcyclists was eight per 100,000 population.

[22] 2016 Texas Strategic Highway Safety Plan: A Report of Progress. Texas Department of Transportation. Spring 2017.
[23] 2016–2021 Texas Strategic Action Plan for Motorcycles. Texas Department of Transportation.

3.1 Frequency of Motorcycle Registrations

Based on data from the Texas Department of Motor Vehicles, the number of registered motorcycles has more than doubled in the last 15 years, from approximately 179,329 in 2000 to 445,395 in 2014.[24] The increase in passenger vehicles during this same time period was approximately one-third. This indicates that motorcycle use may be increasing as a hobby or daily mode of transportation in Texas. Figure 3 displays the changes in motorcycle registrations by year for the most recent five years. Since 2011, the overall number exceeds 440,000. With respect to the age of registered motorcycles in the midyear of 2014, approximately 14 percent were a model year older than 2000.



	2010	2011	2012	2013	2014
Registered Motorcycles	431,505	442,483	448,399	443,856	445,395

Figure 3: Number of motorcycle registrations by year in Texas, 2010–2014.

Figure 4 displays the variation in number of motorcycle registrations by county in Texas in 2014. The top counties for motorcycle registrations include Bexar, Collin, Dallas, Denton, El Paso, Harris, Montgomery, Tarrant, and Travis. Each of these counties include over 10,250 registrations and no more than 51,353 registrations. As expected, these counties correspond to the most populated areas of Texas.

[24] Texas A&M Transportation Institute. 2001, 2014. Extract from the Texas Department of Motor Vehicles registration database provided to the Texas A&M Transportation Institute for conformity.

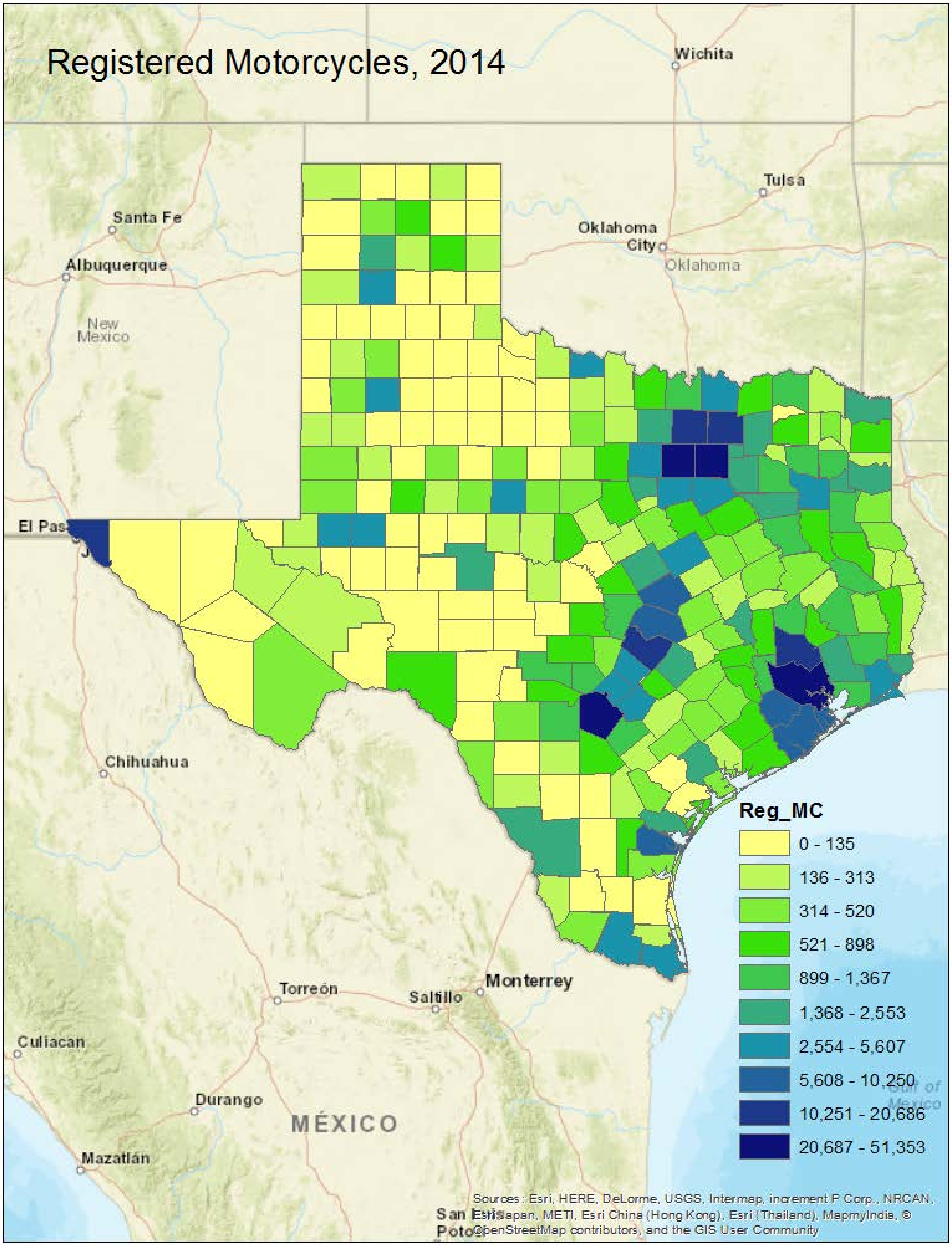


Figure 4: Density of motorcycle registrations by county in Texas, 2014.

3.2 Counts of Crashes by Year

This section presents the overall frequency of crashes and their severity by year and rural status. The data presented in this section include all crashes involving at least one motorcycle, motor scooter, or moped—including police motorcycles and all-terrain vehicles (excluding off-road crashes). A single crash event could involve multiple vehicles and people, resulting in multiple deaths or injuries per crash event.

To provide context for the overall magnitude of crashes involving motorcycles, Figure 5 presents the frequency of crashes by person and vehicle type over the prior three years. The total number of crashes in 2013, 2014, and 2015 was 445,885, 477,308, and 506,729, respectively. The increase in the raw number of crashes over time is likely correlated with the increase in population observed in Texas in recent years and the resulting increases in vehicle miles traveled (VMT) that typically track alongside increases in population. The largest share of crashes involves passenger vehicles, sport utility vehicles, pickups, and large trucks. Overall, motorcycles, pedal cyclists, and pedestrians are involved in a small proportion of crashes each year. As an example, in 2015, crashes involved over 460,000 passenger vehicles but just over 8,000 motorcycles. Of note, while the number of passenger vehicles involved in crashes increased by approximately 60,000 vehicles from 2013 to 2015, the number of motorcycles involved in crashes decreased across those same years by approximately 800. Although the number of crashes is lower for motorcycles, crashes involving motorcycles tend to be of much greater severity. Data supporting this observation are presented in Section 5 of this report.

Figure 6 displays the frequency of motorcycle crashes by their severity. Since 2010, the distribution of crash severity has been fairly consistent. In 2015, the majority (37 percent) of crashes were B, followed by A (22 percent), C (21 percent), O (14 percent), K (6 percent), and unknown (<1 percent).

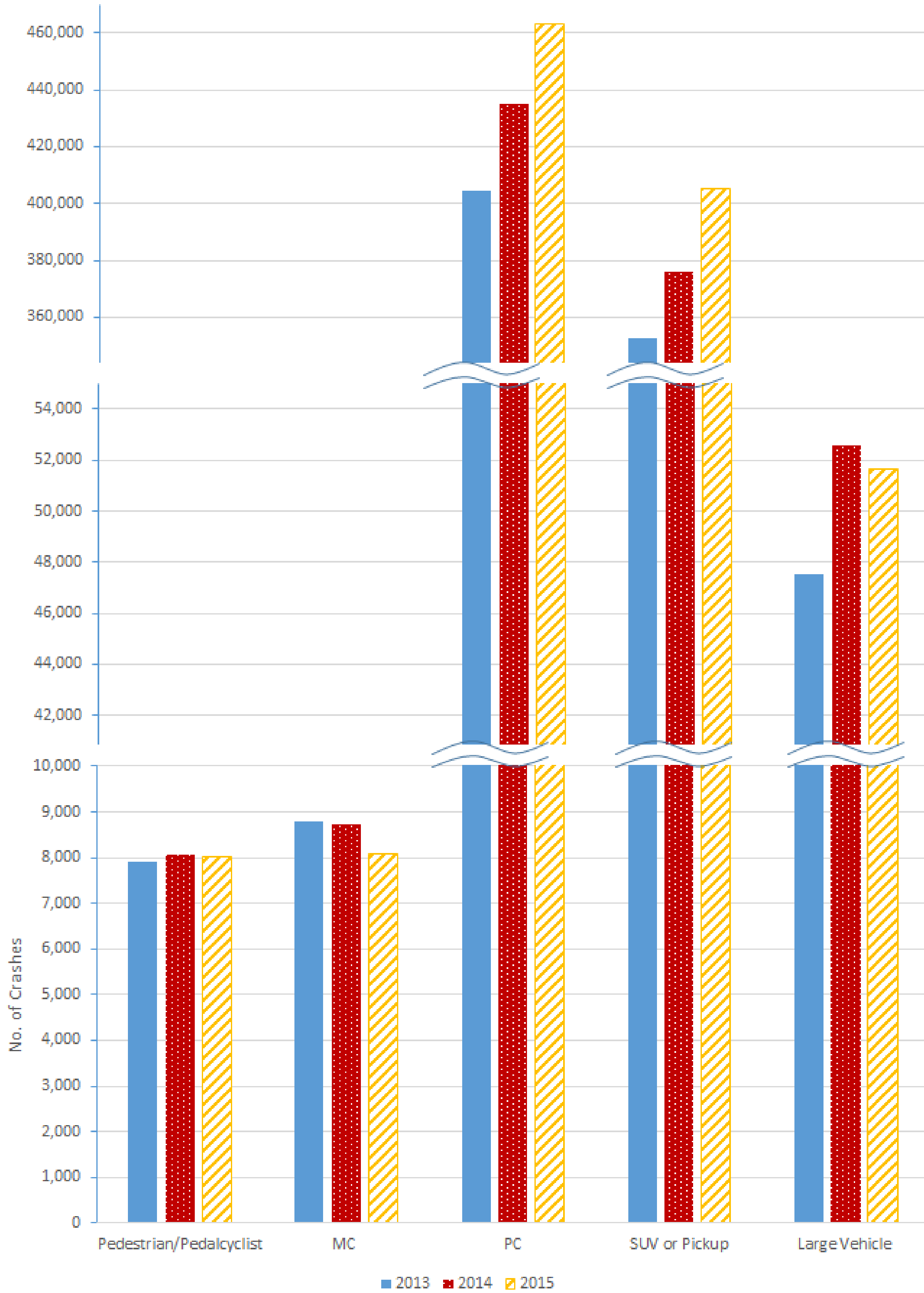
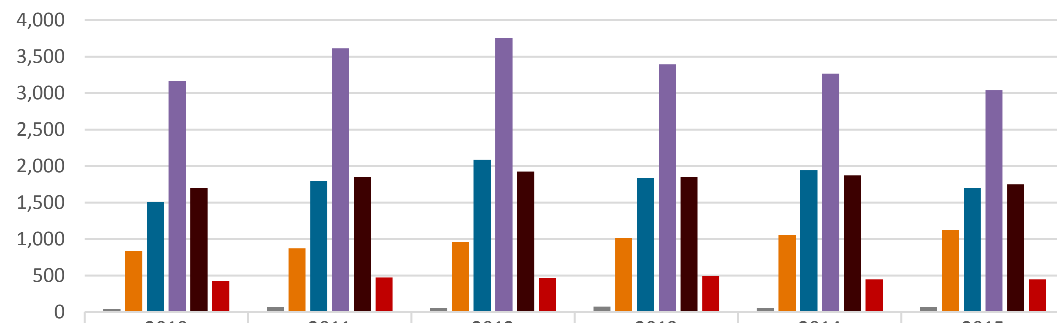


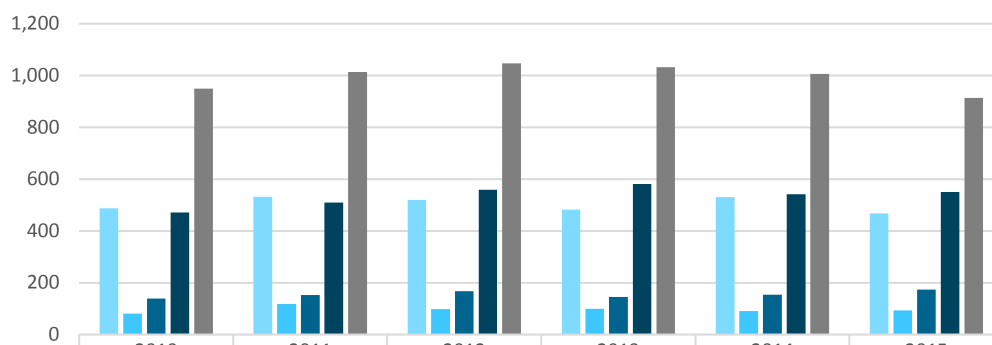
Figure 5: Frequency of crashes by vehicle or person type.



	2010	2011	2012	2013	2014	2015
Unknown	42	65	56	74	60	66
Non-injury	836	872	959	1,012	1,051	1,124
Possible	1,511	1,800	2,086	1,837	1,943	1,700
Non-incapacitating (B)	3,167	3,613	3,759	3,392	3,267	3,040
Incapacitating (A)	1,700	1,852	1,926	1,849	1,875	1,750
Fatal (K)	427	473	465	491	449	447

Figure 6: Frequency of motorcycle crashes by crash severity and year.

The frequency of motorcycle crashes varies by area population. Each year, the distribution of fatal and incapacitating injuries is similar by population size category, as shown in Figure 7. In 2015, the largest number of crashes occurred in urbanized areas followed by rural areas. However, a large number of crashes did not have the rural status categorized each year.



	2010	2011	2012	2013	2014	2015
Rural (<5000)	487	532	520	483	531	467
Small Urban (5000-49,999)	81	118	98	99	91	93
Large Urban (50,000-199,999)	139	152	167	145	154	173
Urbanized (200,000+)	471	510	559	581	542	550
Not Recorded	949	1,013	1,047	1,032	1,006	914

Figure 7: Frequency of K and A motorcycle crashes by area population and year.

3.3 Rates of Fatalities and Injuries by Year Based on Registrations and Population

Because the frequency of crashes is influenced greatly by exposure to traffic and the roadway, comparisons between geographies and demographic groups is often done by computing rates or the number of crashes divided by the number of people in the population, the number of registered vehicles, or the number of VMT. In this section, rates per population and per motorcycle registration are presented. A summary of rates per vehicle miles traveled for motorcycles in Texas requires more complex computations and is presented separately in Section 4. Overall, in Texas, the rate of fatal and incapacitating injuries was eight per 100,000 population in 2015. Table 1 presents these values for the 10 counties with the highest rates. The county with the highest rate is Real, located near San Antonio, Texas, with a rate of 544 fatal and incapacitating motorcycle injuries per 100,000 population. This is much greater than the state rate (eight per 100,000 population). The Appendix presents rates for each county in Texas.

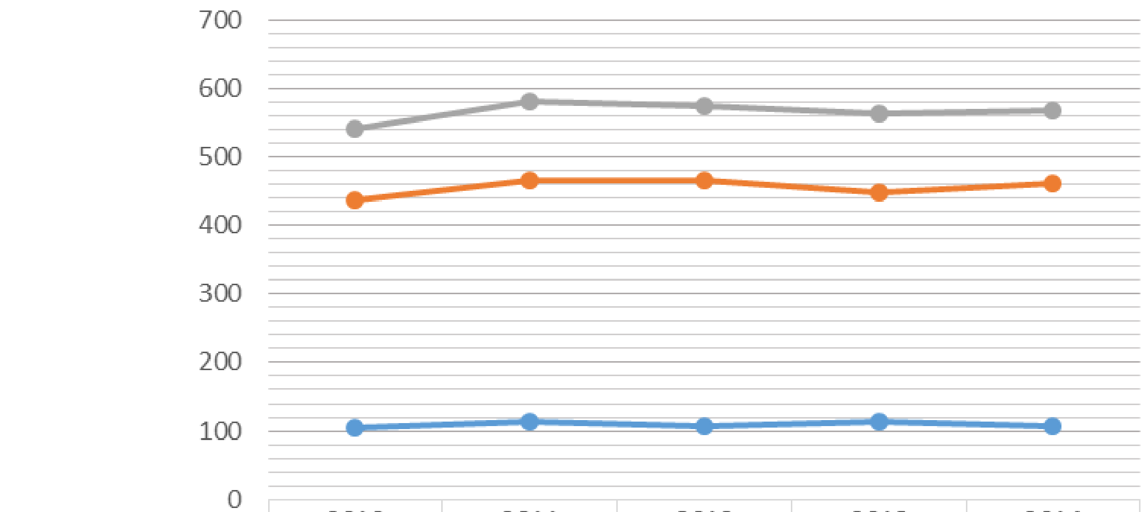
Table 1: Rates of K and A severity for the 10 counties with the highest motorcycle injury rates per population, 2015.

Counties	Population[1]	K	A	K and A	K and A rates per 100,000 population
Real	3,307	2	16	18	544.3
Bandera	21,269	1	14	15	70.5
Bosque	17,891	1	6	7	39.1
Gillespie	25,963	0	9	9	34.7
Colorado	20,870	2	5	7	33.5
San Jacinto	27,413	2	7	9	32.8
Burnet	45,463	1	13	14	30.8
Harrison	66,746	7	13	20	30.0
Fayette	25,110	2	5	7	27.9
Wood	43,356	2	10	12	27.7
STATE TOTAL	**27,469,114**	**452**	**1,864**	**2,316**	**8.43**

[1] Population estimates based on Census Factfinder (2016).[25]

[25] United States Census Bureau. Census Factfinder. Available at http://factfinder.census.gov.

Figure 8 presents the rates of K and A injuries over time from 2010–2014 based on the number of registered motorcycles (registration data for 2015 not yet available). Overall rates are fairly stable, with the rate for 2014 at 568 per 100,000 registrations. Table 2 presents the rates for the top 10 counties with the highest rates. Again, Real County was the highest, with a rate of 25,883 per 100,000 registrations. The state average was much lower at 565 per 100,000 vehicle registrations. To compare, the total rate of K and A injuries for Texas in 2014 was 87 per 100,000 vehicle registrations (all vehicle types combined). The rate for motorcycles is about seven times the rate for all vehicles.



	2010	2011	2012	2013	2014
K Injury Rates	104.12	114.07	107.28	113.68	106.41
A Injury Rates	437.67	466.75	466.71	448.79	461.47
KA Injury Rates	541.79	580.83	573.99	562.47	567.87

Figure 8: Rates of K and A injuries based on motorcycle vehicle registrations by year.

Table 2: Rates of K and A injury severity for the 10 counties with the highest rates per motorcycle vehicle registrations, 2014.

Counties	Vehicle Registrations	K	A	K and A	K and A Rates per 100,000 Registrations
Real	85	0	22	22	25,882.4
Edwards	41	0	6	6	14,634.2
La Salle	98	0	8	8	8,163.3
Hamilton	210	0	11	11	5,238.1
Blanco	339	5	7	12	3,539.8
Bandera	823	4	14	18	2,187.1
Gillespie	609	1	11	12	1,970.4
Burleson	457	1	7	8	1,750.6
Kerr	1,367	1	21	22	1,609.4
Callahan	373	1	5	6	1,608.6
STATE TOTAL	**440,492**	**466**	**2,021**	**2,487**	**564.6**

4 Vehicle Miles Traveled and Household Survey Data

In order to more fully understand motorcycle safety, it is important to investigate the characteristics of travel by motorcycle. Information about drivers and the way they travel using a motorcycle can help put perspective on the injury and fatality statistics and help identify what segments of the motorcycling community should be targeted for safety programs.

VMT is used in traffic safety research as a measure of exposure or the time at risk of being involved in a motor vehicle crash. As discussed in Section 3, VMT is often used to compute standardized rates so that the frequency of crashes can be compared over time. Other denominators can be used, such as number of motorcycle vehicle registrations or population size, but these denominators usually are not as precise as VMT in terms of quantifying the actual exposure time spent on the roadway or how much vehicles are actually driven. Prior to this report, VMT estimates for motorcycles driven in the state of Texas have not been available. The available TxDOT travel survey data for the state of Texas along with other types of data support the estimations of VMT for motorcycles at this time. This section details the methodology implemented to compute VMT estimates while also presenting crash rates based on this measure of exposure or time at risk.

KEY POINTS

- The rate of fatal crashes for motorcycles was 24.2 per 100 million VMT for motorcycles compared to 1.3 per 100 million VMT for all vehicles in 2014. The rate for motorcycle crashes is 18.6 times higher.
- 75–80 percent of all daily motorcycle mileage is 50 miles or less per motorcyclist.
- Despite representing a small portion (0.5–1 percent) of total vehicle miles traveled, motorcycle driver fatalities account for 13–14 percent of all traffic fatalities.
- A majority of motorcycle trips are made by those 35 to 64 years of age.

4.1 Methodology for Estimation of Motorcycle Travel Data and Characteristics

4.1.1 DATA SOURCES

The total vehicle miles traveled by motorcycles was calculated using travel survey data collected by TxDOT in its Travel Survey Program (TSP) for 25 metropolitan transportation organizations and from the National Household Travel Survey (NHTS). Although there are many differences between the NHTS and the TxDOT surveys, they both capture intra-urban travel data within planning regions.[26]

Both the NHTS and TxDOT TSP surveys represent a sample of household demographic and travel characteristics for Monday through Friday weekdays during the school year. The NHTS also includes travel data of weekend trips, while the TxDOT TSP does not. Both surveys include (but are not limited to) the following data:

- **Household Data:** Income, size; number of persons employed; geographic attributes.
- **Person Data:** Age; ethnicity; employment status; gender; work location; occupation.
- **Vehicle Data:** Type (car, truck, motorcycle, etc.); make, model, and make year; odometer reading.
- **Trip Data:** Trip begin and end; trip mode (vehicle, bus, etc.); household vehicle used; trip begin and end location and land use type; reason for trip (trip purpose); geographic attributes.

The data for this study were inclusive of 15 household travel surveys conducted by TxDOT between 2002 and 2013. The study also utilized surveys of Texas households from the 2009 NHTS.

[26] Schiffer, RG. 2012. Long-Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models. In *NCHRP Report 735*: National Cooperative Highway Research Program.

Table 3: Summary of travel survey data.

Survey Region	Households (HH)	Persons	Trips	Vehicles	Motor-cycles	HH with Motorcycle	Motor-cycle Trips
Abilene	1,917	3,673	15,905	4,460	69	57	4
Amarillo	1,431	2,779	12,405	3,248	47	38	0
Austin	1,460	2,743	10,998	2,846	38	34	–
Beaumont	1,498	2,870	11,014	3,703	50	41	15
Corpus Christi	1,731	3,470	14,456	3,829	48	39	4
El Paso	2,884	5,898	21,691	6,288	56	45	6
Houston	5,370	11,228	47,220	12,894	176	143	60
Killeen-Temple	1,294	1,946	8,729	3,157	60	54	27
Laredo	1,829	3,321	12,004	3,244	212	160	–
Lubbock	1,418	2,809	13,212	3,216	38	35	13
San Antonio	1,905	3,613	14,865	3,844	38	33	–
Sherman Dennison	1,873	3,706	15,228	4,444	76	62	18
Victoria	1,649	3,139	13,895	3,807	41	36	7
Waco	1,323	1,998	9,069	3,259	51	42	2
Wichita Falls	1,777	3,435	14,677	4,153	78	66	11
Texas Total	29,359	56,628	235,368	66,392	1,078	885	167
2009 NHTS	20,120	39,152	154,392	45,122	1,308	1,062	458

Note: Persons and trips are only for survey respondents >=16 years of age.

Table 3 reveals that sample sizes for motorcycles are not large, so caution should be used in interpreting the results. Nonetheless, very little is known about motorcycle characteristics, and these data can provide insight into how motorcycles are used for travel.

Regional travel survey data are a good source of regional travel characteristics. However, an acknowledged weakness of the survey data is the lack of long-distance travel.[27] These trips are typically infrequent and represent such activities as tourism, family visitations between cities, and business travel, among others. An additional weakness of these surveys is their inability to

[27] Schiffer, RG. 2012. Long-Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models. In *NCHRP Report 735*: National Cooperative Highway Research Program.

capture travel that is not generated in a region. This is travel that occurs within a region but does stop or travel that begins/ends outside of the region.[28]

Traffic count data are an unreliable source of motorcycle data. Most traffic counts in the state do not differentiate between vehicle types such as truck and auto. Those that do differentiate have limitations with regards to capturing motorcycles. There is active research to identify and develop ways to better estimate motorcycle usage on roadways, but to date, there is no gold standard method.[29,30] This study involved using travel survey data to derive a reasonable estimation of motorcycle travel and demand.

4.1.2 VEHICLE MILES OF TRAVEL

Overall, travel using motorcycles was estimated using the reported odometer readings from the travel surveys. The odometer reading methodology is an analysis of annual mileage for each reported motorcycle in the TxDOT and NHTS surveys. Both surveys report the total estimated mileage of motorcycles. However, this mileage is self-reported by respondents, which can lead to varying and inaccurate results. In the TxDOT surveys, only the total mileage is reported, so the analysis incorporated an annual calculation based on the survey year and the vehicle make year. The NHTS reports an annual mileage. The statistical averages of the annual mileages were used to compute a statewide motorcycle VMT based on multiplying the reported average number of miles per motorcycle by the number of registered motorcycles in Texas. The results of this analysis are presented in Table 4.

Table 4: 2014 Texas statewide VMT (millions).

Motorcycle Mileage Data Source	Average Annual Motorcycle Mileage	Annual Motorcycle VMT (millions)
TxDOT TSP	5,665	2,495.5
TxDOT TSP and NHTS Combined	4,224	1,860.7
NHTS	3,373	1,485.8
2014 Based on MOBILE6 Data	2,558	1,126.8
2014 Federal Highway Administration (FHWA) Highway Statistics	2,372	1,044.8

[28] Hard, E, Byron C, Songchitruksa, P, Farnsworth, S, Borchardt, D, Green, L. 2016. Synopsis of New/Emerging Methods and Technologies to Collect Origin-Destination (O-D) Data. Edited by Federal Highway Administration TMIP: Texas A&M Transportation Institute.
[29] Middleton, D; Turner, P; Scopatz, R. Methodologies for Estimating Motorcycle VMT. Available at https://www.msf-usa.org/downloads/imsc2013/Oct16_Session1-Middleton_Turner-Methodologies_for_Estimating_Motorcycle_VMT_PAPER.pdf.
[30] Middleton, D, Turner, P, Charara, H, Srinivasa, S, Geedipally, S, Scopatz, R. Improving the Quality of Motorcycle Travel Data Collection. Available at http://www.trb.org/Publications/Blurbs/170151.aspx.

The estimated cumulative miles of travel by motorcycles thus ranges from about 1.045 billion miles to about 2.495 billion miles. This represents a range of about 0.5 percent to 1 percent of total vehicle miles traveled in Texas. In 2014, motorcycle travel as reported in highway statistics was 0.7 percent of total VMT. The motorcycle VMT based on the TxDOT TSP and NHTS combined data is 0.8 percent of total Texas VMT. Because the FHWA information is based on counts and count estimates,[31] the researchers recommend using 1.861 billion miles in the calculation of crash rates.

4.2 Fatality and Injury Rates for Motorcycles

Motorcycle operator fatalities account for about 13 to 14 percent of all traffic fatalities in Texas. This number is in stark contrast to the very low proportion (0.5 to 1 percent) of travel by all vehicles in Texas. Overall, the crash rates for motorcycles are substantially higher than for all vehicles in Texas, as shown in Table 5. For K and A crashes, the rates are approximately 18 times higher for both severities. Even if the largest estimate of VMT was used for motorcycles, the rates would be lower than those shown in Table 5, but still considerably larger than the rate for all vehicles. The fatality crash rate of 25 fatalities per 100 million VMT is in line with rates reported for the National Highway Traffic Safety Administration (NHTSA) at the national level.[32]

Table 5: Crash and injury rates based on VMT for motorcycles versus all vehicles for Texas, 2014.

	K Crash Rate	A Crash Rate	K and A Crash Rate	Total Crash Rate
Motorcycles	24.2	100.1	124.3	464.8
All vehicles	1.3	5.6	6.9	196.5
	K Injury Rate	**A Injury Rate**	**K and A Injury Rate**	**All Injury Rate**
Motorcycles	25.1	108.6	133.7	439.5
All vehicles	1.5	7.1	8.5	99.4

Note: Rates per 100 million VMT (motorcycles: 18.607; all vehicles: 2,429,890).

4.3 Motorcycle Operator and Trip Characteristics

The travel survey data were also used to explore the number of motorcycle trips made by age, gender, and income levels. In each case, the trip making of motorcycle operators was compared to that of automobile drivers.

[31] Jackson, TR. 2001. Fleet Characterization Data for MOBILE6: Development and use of age distributions, average annual mileage accumulation rates, and projected vehicle counts for use in MOBILE6. EPA420-R-01-047, M6.FLT.007 Environmental Protection Agency.

[32] National Center for Statistics and Analysis. 2016 June. Motorcycles: 2014 Data (Traffic Safety Facts. Report No. DOT HS 812 292). Washington, DC: National Highway Traffic Safety Administration.

Figure 9 provides the results of the analysis of trip making by age categories. Data from the two studies are also compared to the percent of total driver's licenses or percent of motorcycle training certificates for each age category. The graph reveals that although most of the motorcycle training certificates are held by operators in the 16- to 24-year-old and 25- to 34-year-old groups, these groups do not comprise the bulk of motorcycle trips. The bulk of motorcycle trips are made by operators between 35 and 64 years of age, with the 45- to 54-year-olds making the most trips of any one group. Young people make up a much larger percent of automobile trips, roughly in proportion to the percent of licenses they hold.

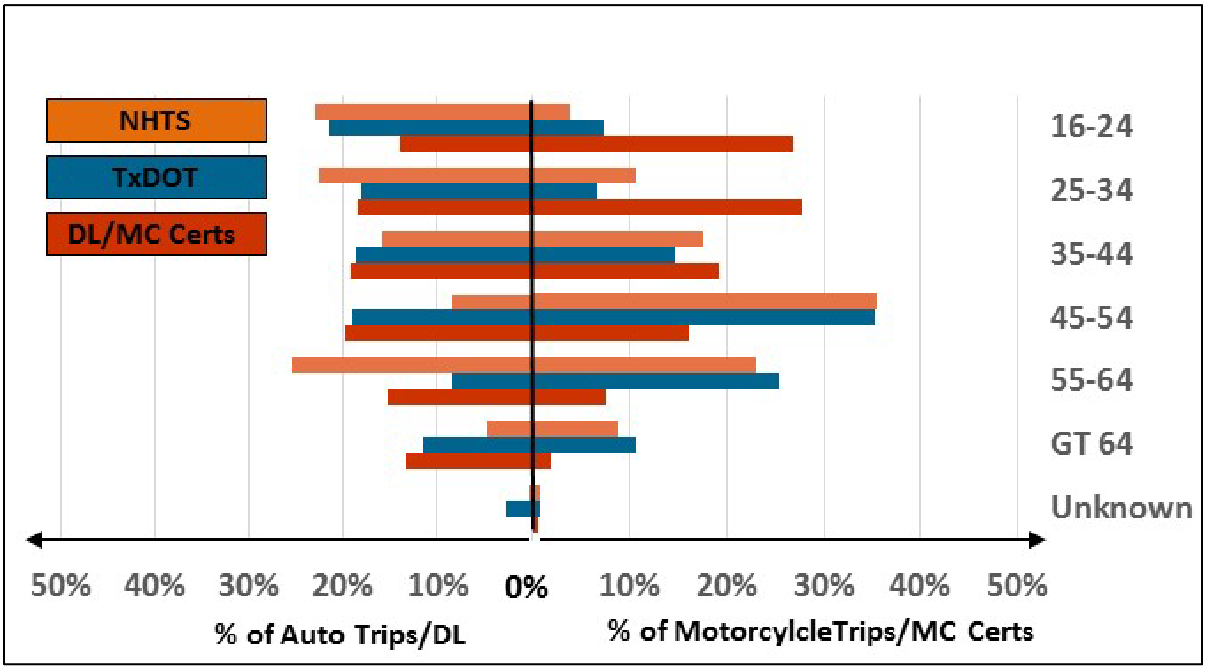


Figure 9: Motorcycle (MC) trips/certifications and auto/driver licenses as percent of age group.

Selected results from the travel survey analysis are presented in Figure 9 through Figure 11. Each chart compares a demographic category's percent of trips and percent of motorcycle trips, and, except for Figure 11, driver's licenses to motorcycle certifications. In Figure 9, the percent of auto trips versus percent of driver's licenses are somewhat comparable. However, while motorcycle certifications are skewed toward younger groups, the percent of motorcycle trips is skewed toward older groups. In Figure 10, while certifications and licenses show some correlation with trips, and females and males contribute equal auto trips, males contribute significantly more to motorcycle trips than females. Strikingly, Figure 11 shows that while lower incomes constitute over half of auto trips, they contribute very little to motorcycle trips, which are heavily weighted to the highest income group.

Figure 10 presents a comparison of female and male operators and drivers. Motorcycle trips are overwhelmingly made by male operators.

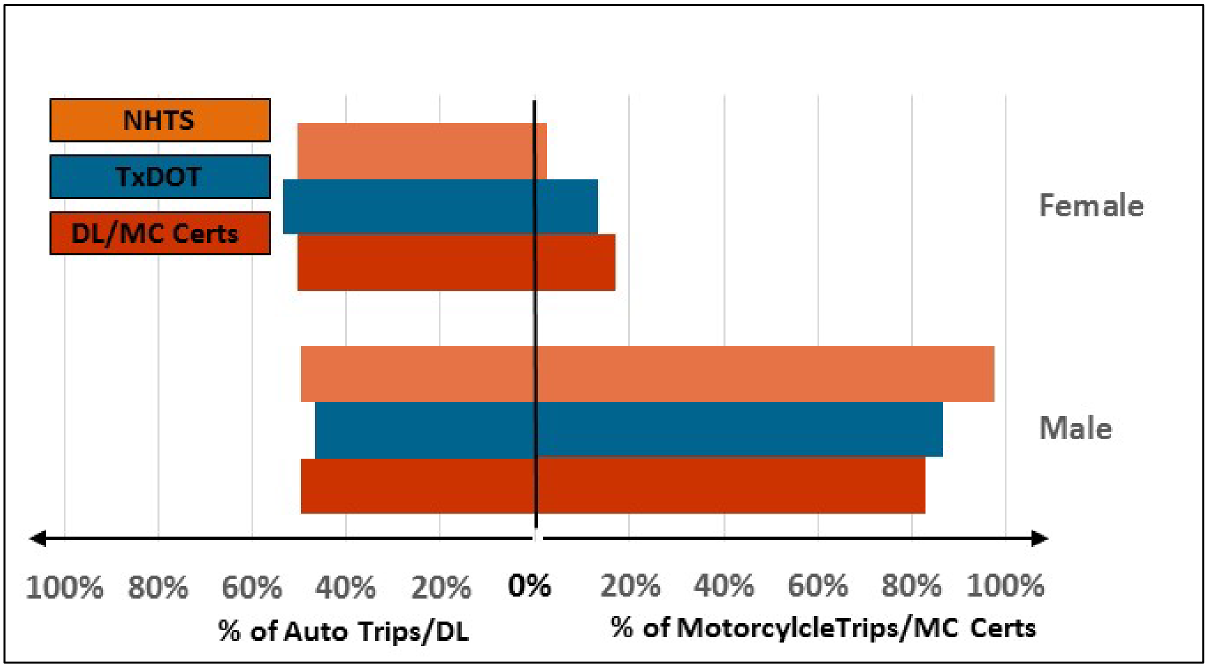


Figure 10: Motorcycle trips/certifications and auto/driver licenses as percent of gender.

Finally, Figure 11 provides an analysis of trip making by income. Very low income operators make very few motorcycle trips, but they make the most auto trips. The most motorcycle trips are made by operators in the highest income categories. Overall, male motorcycle drivers between 36 to 64 years of age with higher incomes are responsible for the majority of the trip making.

Although the trip-making characteristics vary between the TxDOT TSP and NHTS data, these trip characteristics provide insight into the groups that are riding motorcycles and those who might be targeted by safety campaigns. For example, the age distribution displayed in Figure 11 is mirrored by the distribution of crashes to some extent. With respect to age, drivers in the 36 to 64 age group are overrepresented in motorcycle crashes as compared to drivers involved in passenger vehicle crashes (see Section 6).

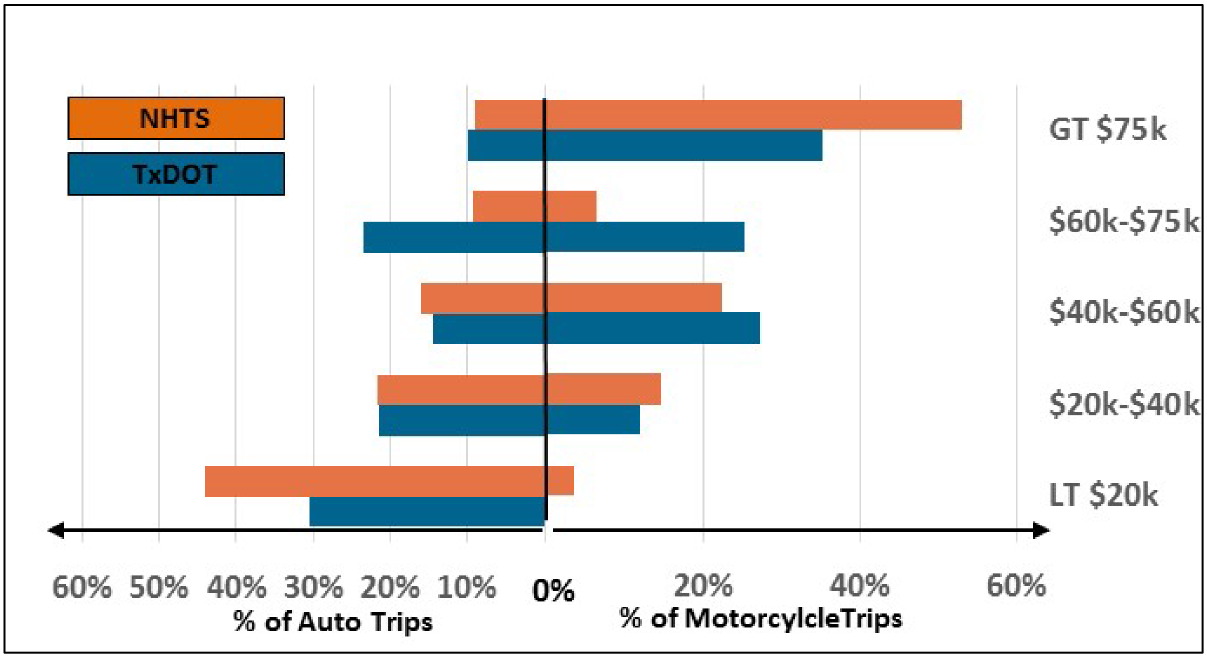


Figure 11: Motorcycle trips and auto trips as percent of income group.

4.3.1 DAILY CUMULATIVE MOTORCYCLE USE AND TRAVEL

Trip frequency and trip length were explored using the TxDOT TSP and NHTS data for households that owned motorcycles. The analysis found that of all households that owned motorcycles, only 8 percent made a weekday trip and only 3 percent made a weekend trip (see Figure 12). The tour length is the combination of all motorcycle trips made by an individual motorcycle on the survey day. Seventy-five to 80 percent of all daily motorcycle mileage is 50 miles or less based on data from the NHTS and TxDOT survey.

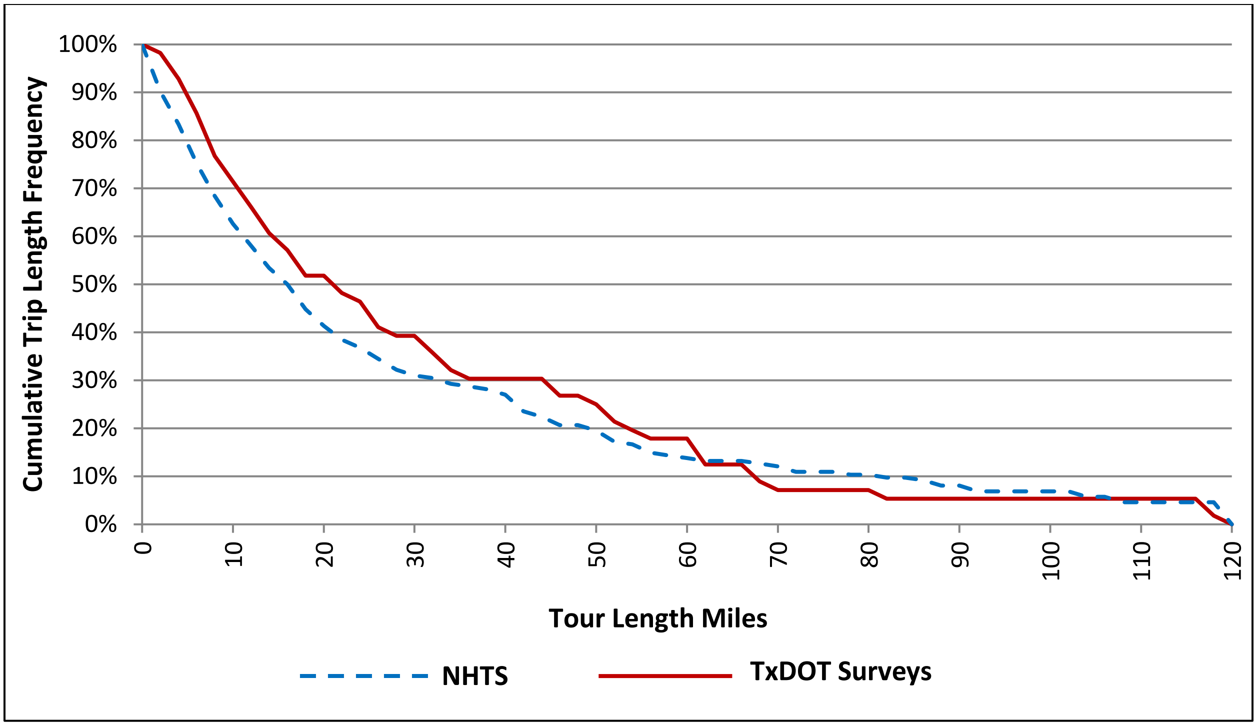


Figure 12: Tour length frequency distribution.

5 Crash Factors

Crash factors include factors impacting all vehicles involved in the crash, such as manner of collision and contributing factors, and how these factors impact the overall crash severity. This section focuses on describing how motorcycle collisions occur, both as single-vehicle collisions and collisions with other vehicles. It also addresses DUI and speed as they relate to crash severity. Crash severity is equal to the injury severity of the person who sustained the most severe injury. As an example, if four people were involved in a crash and one died, two sustained an incapacitating injury, and one was uninjured, then the crash severity would be rated as fatal (K).

KEY POINTS

- 28 percent of motorcycle crashes were K or A crash severity compared to 4 percent for non-motorcycle crashes.
- 44 percent of fatal crashes were associated with DUI.
- Injury severity was associated with posted speed limits, and areas with higher speed limits were associated with more severe injuries.
- 49 percent of motorcycle crashes were single-vehicle crashes.
- For multi-vehicle crashes at intersections, the most frequent contributing factor was failure to yield right of way while turning left.

5.1 Crash Severity

Research hypotheses:

- *Crash severity will increase with speed and whether DUI is a factor.*
- *Almost half of all fatal accidents will involve drug or alcohol impairment.*
- *DUI crashes involving motorcycles will be in closer proximity to alcohol outlets such as bars than non-DUI crashes.*
- *The average BAC, lighting conditions, time of day, and day of week will differ comparing DUI motorcycle crashes to DUI passenger car crashes.*

To better understand the severity of crashes involving motorcycles, researchers computed the frequency and percent of crashes for motorcycle crashes compared to non-motorcycle crashes (see Tables 6 and 7). The contributions of driving under the influence and speed were also examined with respect to crash severity.

Overall, motorcycle crashes include a higher proportion of more severe crashes compared to non-motorcycle crashes. Across 2010–2015, 26 percent of motorcycle crashes were K or A crash severity compared to only 4 percent of non-motorcycle crashes. Similarly, only 11 percent of motorcycle crashes involved property damage only compared to 61 percent of non-motorcycle crashes.

Table 6: Frequency and percent of motorcycle crashes by crash severity and year.

Year	K	A	B	C	O	Total[1]
2010	427 (6%)	1,700 (22%)	3,167 (41%)	1,511 (20%)	836 (11%)	7,683 (100%)
2011	473 (5%)	1,852 (21%)	3,613 (42%)	1,800 (21%)	872 (10%)	8,675 (100%)
2012	465 (5%)	1,926 (21%)	3,759 (41%)	2,086 (23%)	959 (10%)	9,251 (100%)
2013	491 (6%)	1,849 (21%)	3,392 (39%)	1,837 (21%)	1,012 (12%)	8,655 (100%)
2014	449 (5%)	1,875 (22%)	3,267 (38%)	1,943 (22%)	1,051 (12%)	8,645 (100%)
2015	447 (6%)	1,750 (22%)	3,040 (37%)	1,700 (21%)	1,124 (14%)	8,127 (100%)
Total	2,752 (5%)	10,952 (21%)	20,238 (40%)	10,877 (21%)	5,854 (11%)	51,036 (100%)

[1] Includes unknown severity crashes.

Table 7: Frequency and percent of non-motorcycle crashes by crash severity and year.

Year	K	A	B	C	O	Total[1]
2010	2,781 (1%)	11,781 (3%)	48,390 (12%)	81,653 (21%)	234,083 (60%)	392,002 (100%)
2011	2,803 (1%)	11,729 (3%)	46,571 (12%)	81,312 (21%)	228,536 (59%)	384,433 (100%)
2012	3,037 (1%)	12,847 (3%)	50,836 (12%)	88,588 (21%)	247,729 (59%)	417,728 (100%)
2013	3,064 (1%)	13,418 (3%)	52,218 (12%)	88,805 (20%)	272,683 (61%)	445,894 (100%)
2014	3,190 (1%)	13,663 (3%)	53,077 (11%)	92,184 (19%)	298,306 (62%)	477,372 (100%)
2015	3,179 (1%)	13,654 (3%)	54,650 (11%)	96,461 (19%)	332,053 (64%)	520,050 (100%)
Total	18,054 (1%)	77,092 (3%)	305,742 (12%)	529,003 (20%)	1,613,390 (61%)	2,637,479 (100%)

[1] Includes unknown severity crashes.

5.1.1 DRIVING UNDER THE INFLUENCE

To examine the contribution of DUI to crash severity, motorcycle crash severity was stratified by DUI status. As the categories of severity increase, so does the percentage of crashes in that category that were coded with DUI as a contributing factor. The percentage increases from 3 percent for property damage only crashes to 44 percent for fatal crashes (see Table 8).

Table 8: Percentage of crash severity by DUI as contributing factor, 2010–2015.

DUI status	Non-injury	Possible injury	Non-incapacitating injury	Incapacitating injury	Fatal
No	97%	96%	94%	88%	56%
Yes	3%	4%	6%	12%	44%

Note: Crashes with unknown crash severity are excluded.

As expected, many DUI crashes occurred from 6 PM to 3 AM. The K and A crashes during this time period accounted for 77 percent for motorcycles and 65 percent for all vehicles (see Figures 13 and 14). Rather than all vehicles, motorcycle DUI crashes with K and A injuries uniformly distributed between 6 PM and 3 AM. All vehicle DUI K and A crashes peaked between 2 AM to 3 AM.

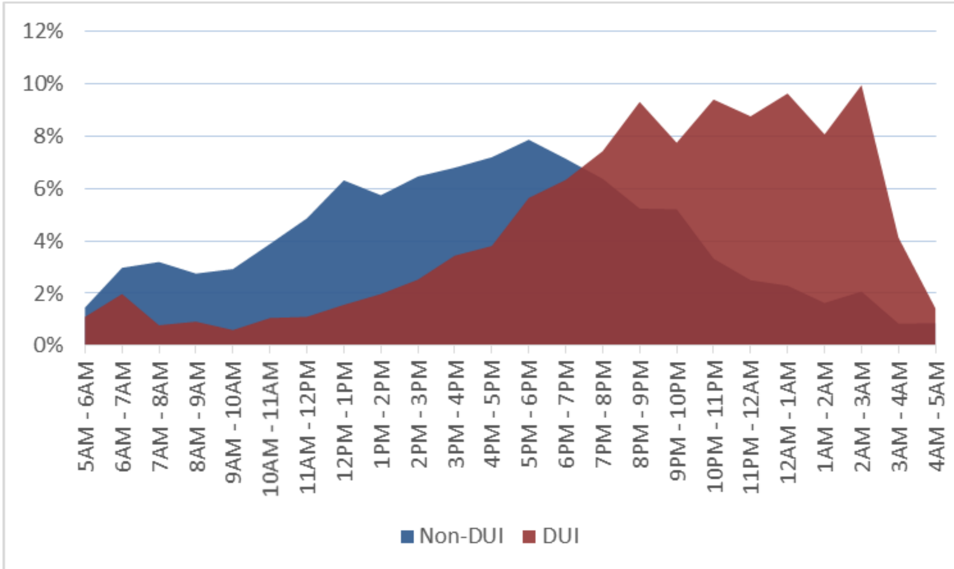


Figure 13: Motorcycle DUI and non-DUI K and A only crashes by time of day.

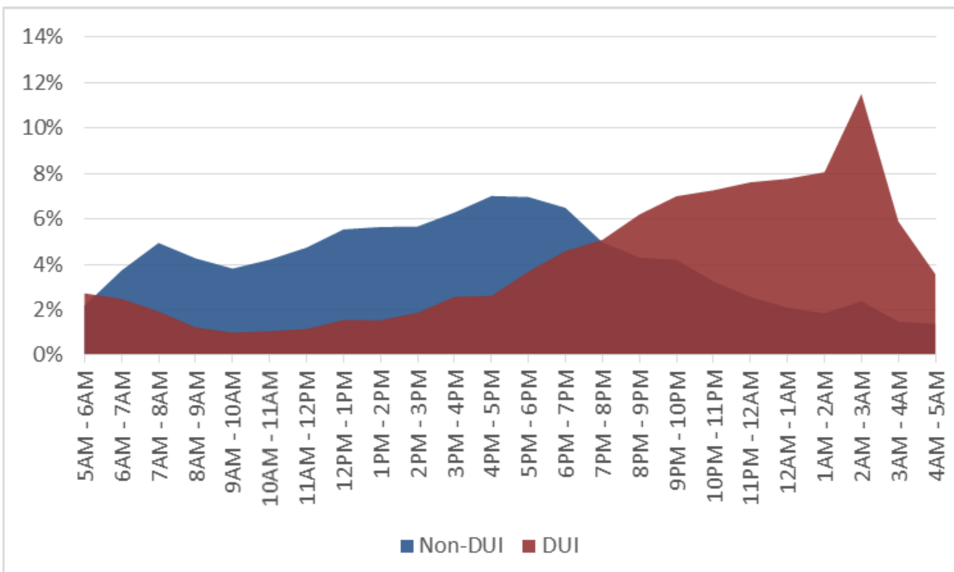


Figure 14: All vehicle DUI and non-DUI K and A only crashes by time of day.

The frequency of K and A crashes varies widely by the day of the week and the time of day, especially for crashes involving DUI vs. non-DUI. Figures 15 and 16 and Tables 9 and 10 display this variation. As expected, the percentages are highest during evening hours and on Friday through Monday, or roughly days associated with the weekend. The peaks start to occur after 7 PM, with the last peak occurring at 2 AM, or the time usually associated with alcohol establishment closures. This distribution is very different when compared with non-DUI K and A crashes, as shown in Figure 16 and Table 10. For non-DUI crashes, the peak is around 4 PM to 7 PM, especially on weekdays during typical rush hour times. Increases also can be seen around the times riders may be traveling in the morning to work and during the lunch hour. For weekend days, the peaks occur earlier in the afternoon, with no increases in the morning hours.

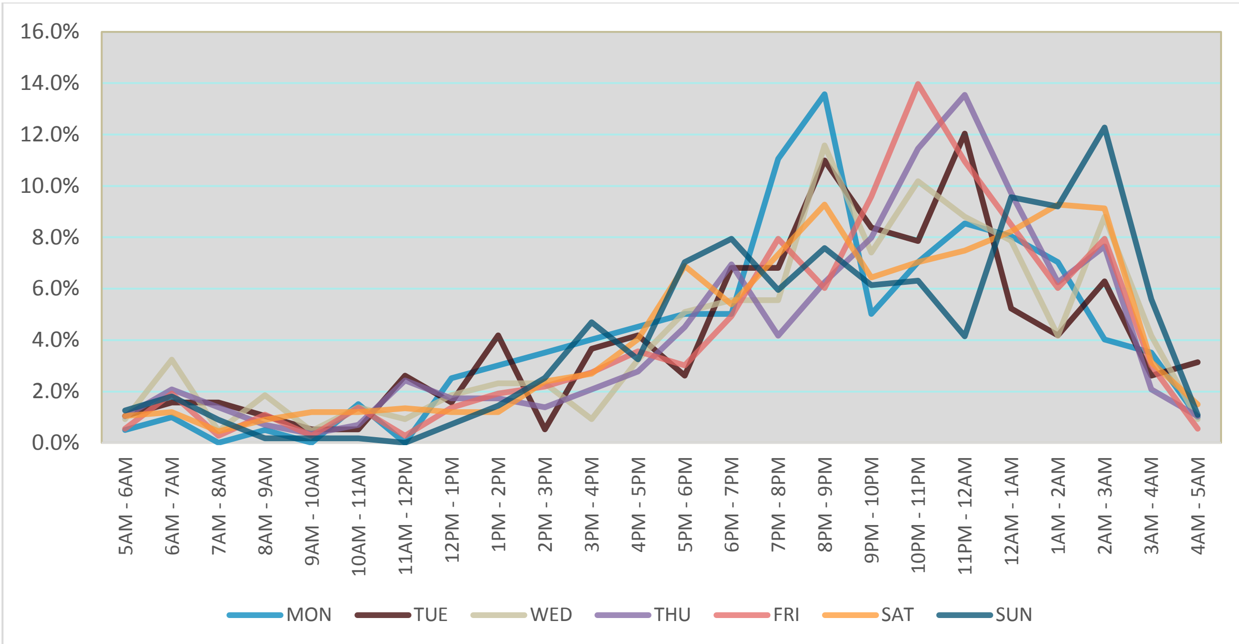


Figure 15: Percentage of DUI K and A motorcycle crashes by day of week and time of day, 2010–2015.

Table 9: Frequency of DUI motorcycle crashes by day of week and time of day, 2010–2015.

	MON	TUE	WED	THU	FRI	SAT	SUN
5 AM–6 AM	1	2	2	3	2	7	7
6 AM–7 AM	2	3	7	6	7	8	10
7 AM–8 AM	0	3	1	4	1	3	5
8 AM–9 AM	1	2	4	2	4	6	1
9 AM–10 AM	0	1	1	1	1	8	1
10 AM–11 AM	3	1	3	2	5	8	1
11 AM–12 PM	0	5	2	7	1	9	0
12 PM–1 PM	5	3	4	5	5	8	4
1 PM–2 PM	6	8	5	5	7	8	8
2 PM–3 PM	7	1	5	4	8	16	14
3 PM–4 PM	8	7	2	6	10	18	26
4 PM–5 PM	9	8	7	8	13	27	18
5 PM–6 PM	10	5	11	13	11	46	39
6 PM–7 PM	10	13	12	20	18	36	44
7 PM–8 PM	22	13	12	12	29	49	33
8 PM–9 PM	27	21	25	18	22	62	42
9 PM–10 PM	10	16	16	23	35	43	34
10 PM–11 PM	14	15	22	33	51	47	35
11 PM–12 AM	17	23	19	39	40	50	23
12 AM–1 AM	16	10	17	28	31	55	53
1 AM–2 AM	14	8	9	18	22	62	51
2 AM–3 AM	8	12	19	22	29	61	68
3 AM–4 AM	7	5	9	6	11	21	31
4 AM–5 AM	2	6	2	3	2	10	6
	199	191	216	288	365	668	554

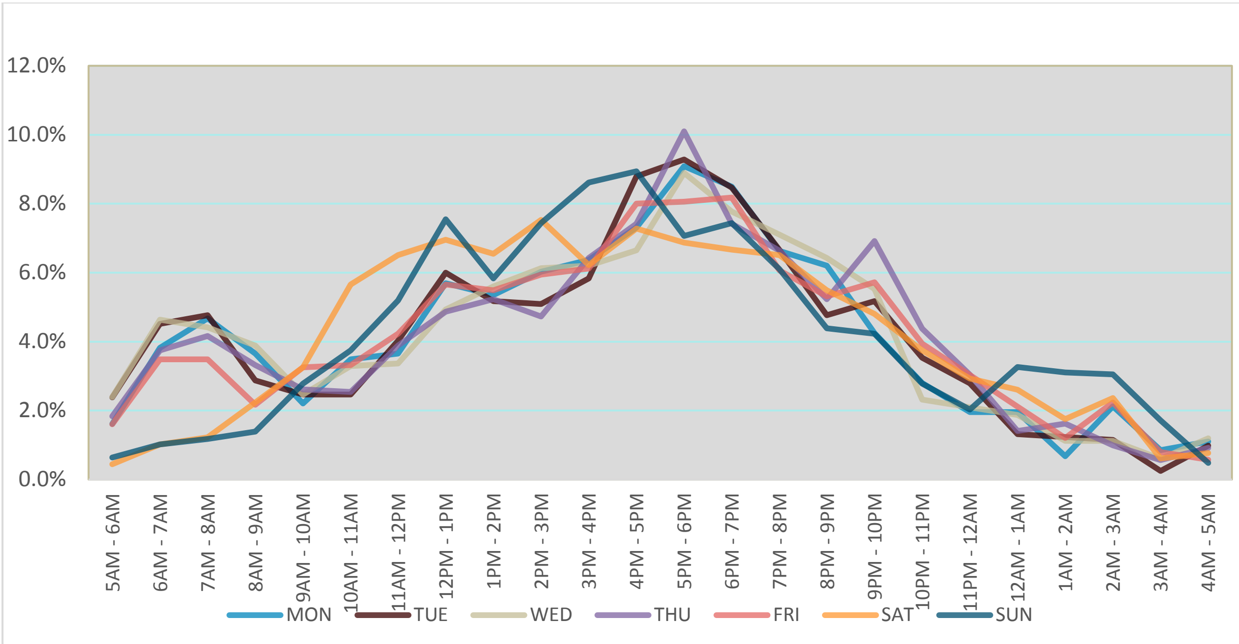


Figure 16: Percentage of Non-DUI K and A motorcycle crashes by day of week and time of day, 2010–2015.

Table 10: Frequency of non-DUI motorcycle crashes by day of week and time of day, 2010–2015.

	MON	TUE	WED	THU	FRI	SAT	SUN
5 AM–6 AM	19	29	32	26	28	11	12
6 AM–7 AM	45	55	62	53	61	25	19
7 AM–8 AM	55	58	59	59	61	30	22
8 AM–9 AM	43	35	52	47	38	55	26
9 AM–10 AM	26	30	33	37	57	80	52
10 AM–11 AM	41	30	44	36	58	139	70
11 AM–12 PM	43	49	45	55	74	160	97
12 PM–1 PM	67	73	66	69	99	171	141
1 PM–2 PM	63	63	75	74	96	161	109
2 PM–3 PM	71	62	82	67	104	185	139
3 PM–4 PM	75	71	83	91	107	153	161
4 PM–5 PM	86	107	89	105	140	179	167
5 PM–6 PM	107	113	119	143	141	169	132
6 PM–7 PM	100	103	104	105	143	164	139
7 PM–8 PM	78	81	95	94	106	160	114
8 PM–9 PM	73	58	86	74	93	135	82
9 PM–10 PM	50	63	74	98	100	118	79
10 PM–11 PM	33	43	31	62	69	92	52
11 PM–12 AM	23	34	28	43	53	72	38
12 AM–1 AM	23	16	25	20	37	64	61
1 AM–2 AM	8	15	15	23	21	43	58
2 AM–3 AM	25	14	15	14	39	58	57
3 AM–4 AM	10	3	8	8	14	15	32
4 AM–5 AM	13	12	16	13	10	19	9
	1,177	1,217	1,338	1,416	1,749	2,458	1,868

In addition to time of day, lighting conditions were examined and results are shown in Table 11. Seventy percent of all motorcycle DUI crashes occurred under dark lighting conditions. Seventy-five percent of all vehicle DUI crashes occurred under dark lighting conditions. These results are expected because most individuals consume alcohol being during evening, nighttime, and early morning hours. There was little to no difference when comparing motorcycle crashes to all vehicle crashes with respect to lighting conditions and DUI status.

Table 11: Lighting conditions for motorcycle crashes by DUI status.

	Motorcycle Crashes		All Vehicle Crashes	
Lighting condition	***Non-DUI***	***DUI***	***Non-DUI***	***DUI***
Dark	27%	70%	27%	75%
Daylight	70%	27%	71%	23%
Dawn/Dusk	3%	3%	2%	2%

5.1.1.1 Distance from Crash to Alcohol Outlets

It was hypothesized that DUI crashes involving motorcycles would occur in closer proximity to alcohol outlets such as bars and restaurants than non-DUI crashes involving motorcycles. To examine this issue, the research team plotted the location of alcohol outlets with on-site alcohol consumption using GIS methods. Next, the crash locations were plotted in order to determine the proportion of crashes occurring within a 2-mile buffer zone for each alcohol outlet. Since urban areas are dense with alcohol outlets, this analysis was stratified by rural status.

Among all crashes, 72 percent occurred within 2 miles of an alcohol outlet for DUI crashes. Meanwhile, 69 percent occurred beyond a 2-mile area for non-DUI crashes. The similar percentages indicate that there is not a relationship between proximity to an alcohol outlet and the crash location. When the data were examined for rural and urban crashes separately, the percentages were still similar for DUI versus non-DUI crashes. Again, this finding indicates that crashes are not more likely to occur in close proximity to an alcohol outlet regardless of whether they are in an urban or a rural area. If a relationship potentially existed, then the percentage of DUI crashes occurring within 2 miles would be much higher than the percentage of non-DUI crashes occurring within a 2-mile radius. These data are displayed in Table 12.

Table 12: Proximity to TABC alcohol outlets and DUI crashes involving motorcycles by rural status, 2015.

	All			**Urban**			**Rural**		
	Total	**Not within 2 miles**	**Within 2 miles**	**Total**	**Not within 2 miles**	**Within 2 miles**	**Total**	**Not within 2 miles**	**Within 2 miles**
DUI	1239	346	893	790	52	738	449	294	155
	100%	28%	72%	100%	7%	93%	100%	65%	35%
Non-DUI	6278	1925	4353	3797	206	3591	2481	1719	762
	100%	31%	69%	100%	5%	95%	100%	69%	31%

5.1.2 SPEED

To examine the impact of speed on crash severity, researchers computed the distribution of the posted speed limit in miles per hour for each category of severity. Figure 17 displays these distributions using vertical box plots. The horizontal line in the box is the median. The top of the box or upper hinge is the 75th percentile, while the bottom of the box or lower hinge represents the 25th percentile. The upper horizontal line or top whisker is the largest non-outlying value, while the bottom horizontal line or bottom whisker is the small non-outlying value. The individual dots are outlying values. As displayed in Figure 17, the median posted speed limit is slightly higher for more severe crash categories among motorcycle crashes. This finding implies that speed may play a small role in increasing the severity of a crash. While the median posted speed limit for more severe crashes is slightly higher, all median values fall between 40 mph and 50 mph. Interpretation of these data needs to include the fact that vehicles involved in a crash may have been traveling at a faster or slower speed at the time of collision.

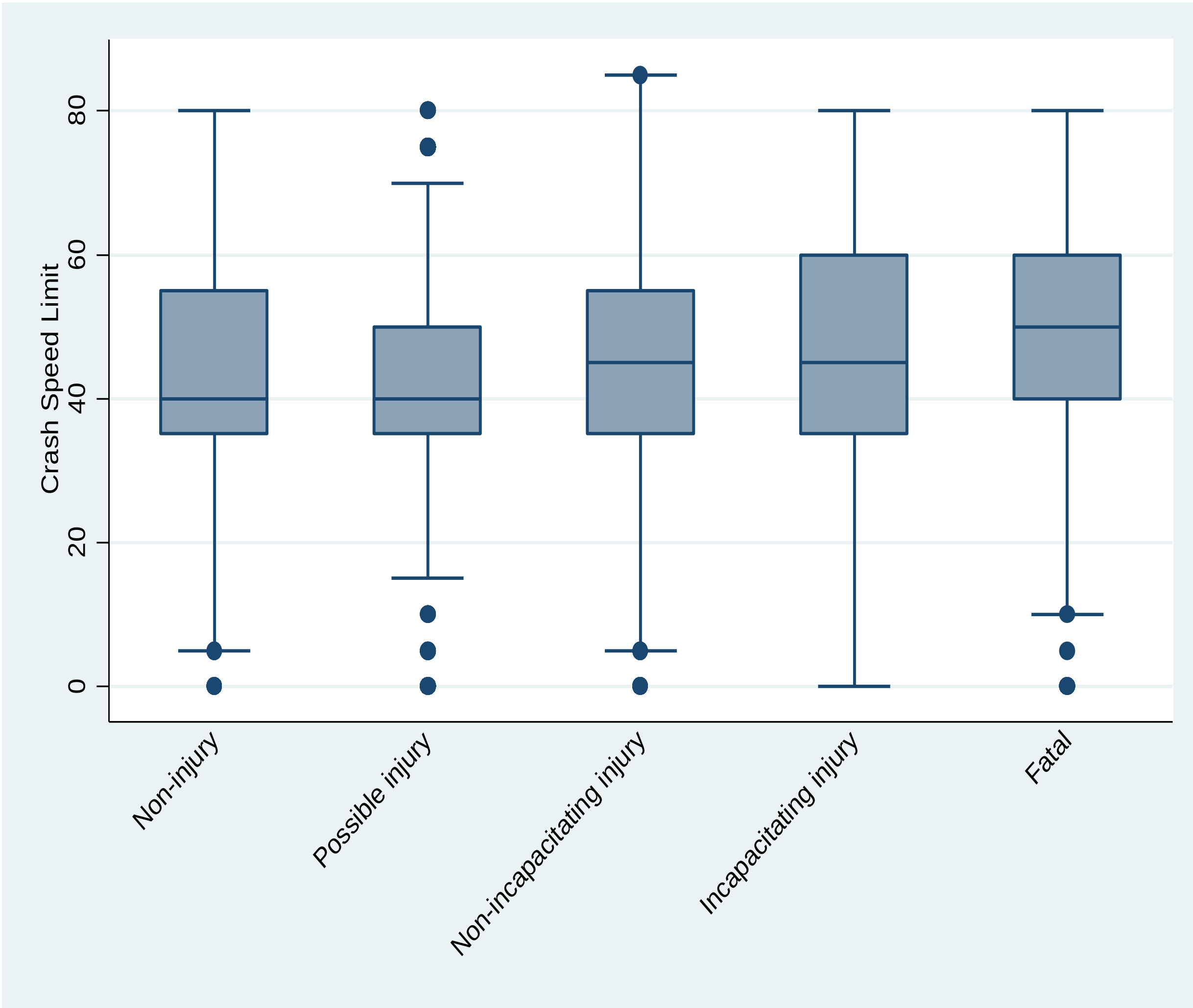


Figure 17: Distribution of crash speed limit by crash severity, 2010–2015.

When crash severity was tabulated against crash speed limit and percentages were computed, a similar pattern was observed, with a slightly increasing trend in crash severity for crash speed limit categories of 45–65 and 65+ mph. This result can be seen in Table 13.

Table 13: Percentage of crash severity by speed limit, 2010–2015.

Speed limit	Non-injury	Possible injury	Non-incapacitating injury	Incapacitating injury	Fatal
0–15	3%	3%	3%	3%	1%
15–25	1%	1%	1%	1%	1%
25–45	48%	51%	46%	39%	31%
45–65	39%	38%	40%	44%	48%
Over 65	9%	7%	10%	14%	19%

Another way to examine speed and its contribution to crash severity is to stratify crash severity by whether speed was indicated on the crash report as a contributing factor. As the categories of crash severity increase, the percentage of crashes with speeding cited as a contributing factor increases from 7 percent for property damage only crashes to 30 percent for fatal crashes (see Table 14).

Table 14: Percentage of crash severity by speed as a contributing factor, 2010–2015.

Speeding	Non-injury	Possible injury	Non-incapacitating injury	Incapacitating injury	Fatal
No	93%	92%	87%	81%	70%
Yes	7%	8%	13%	19%	30%

Note: Crashes with unknown crash severity are excluded.

5.2 Motorcycle Collisions with Other Vehicles

Research hypotheses:

- *Approximately half of motorcycle crashes will involve a collision with another vehicle, which is most often a passenger automobile.*
- *Among crashes with other vehicles, intersection crashes will be overrepresented.*
- *Among intersection crashes, left turns and failure to yield right of way will be prominent factors.*

There was a total of 51,036 motorcycle involved crashes, approximately 51 percent involved another motor vehicle. The other vehicle involved in the crash was a passenger vehicle in 90 percent of the cases, as shown in Table 15. The same holds true for K and A only multiple-vehicle motorcycle crashes.

Table 15: Frequency of type of vehicles involved in collisions with motorcycles, 2010–2015.

	All Severity		K and A	
Type of Vehicles Involved in Crash*	**Number of Crashes**	**Percent**	**Number of Crashes**	**Percent**
Another Motorcycle	814	3%	292	4%
Ambulance	14	<1%	4	<1%
Bus	65	<1%	18	<1%
Farm Equipment	10	<1%	7	<1%
Fire Truck	9	<1%	2	<1%
Not Reported	1	<1%	0	0%
Other (Explain in Narrative)	281	1%	78	1%
Passenger Car, 2-Door	1,828	7%	398	6%
Passenger Car, 4-Door	11,094	40%	2,506	36%
Pickup	5,267	19%	1,585	23%
Police Car/Truck	67	<1%	11	0%
Sport Utility Vehicle	5,156	19%	1,249	18%
Truck	610	2%	145	2%
Truck Tractor	426	2%	185	3%
Unknown	672	2%	120	2%
Van	1,195	4%	318	5%
Yellow School Bus	34	<1%	11	<1%
Total	27,543	100%	6,929	100%

Note: Types of vehicles are unique to the crash (i.e., multiple instances of the same vehicle type in a single crash are omitted).

To address the research hypotheses, motorcycle crashes at intersections were identified and stratified by contributing factors after selecting the K and A severities. The fop five contributing factors were plotted and are displayed in Figure 18. At intersections, the most frequent contributing factor was failure to yield right of way (ROW) while turning left. One in 10 crashes at intersections was due to this failure.

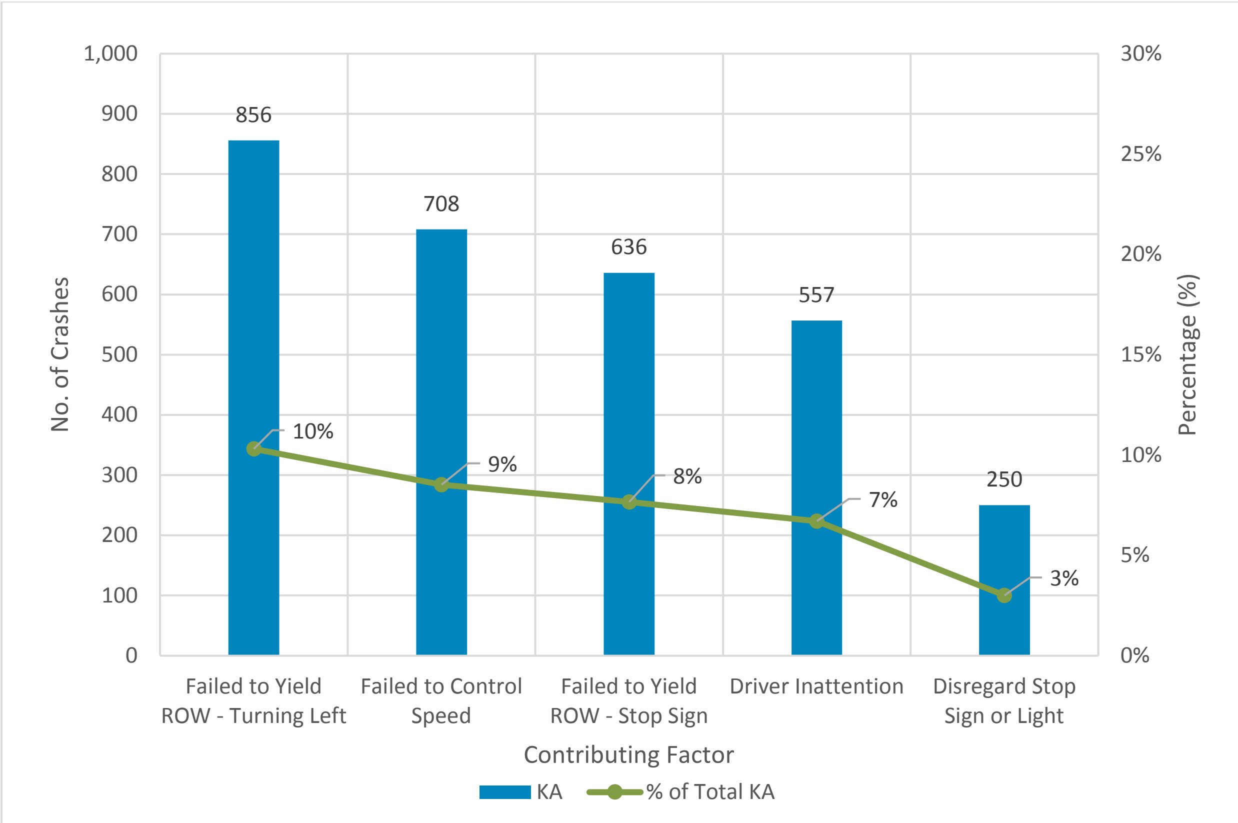


Figure 18: Top contributing factors for multi-vehicle intersection crashes involving motorcycles with K and A severity, 2010–2015.

5.2.1.1 Left Turns

To better understand the role of left turns, motorcycle-involved crashes at intersections were selected and stratified by collision type. Next, K and A crashes were selected before identifying the top five collision types. As indicated in Figure 19, the crash type of one vehicle turning left and one vehicle traveling straight in opposite directions accounted for 25 percent of intersection crashes. This was followed closely by right-angle collisions types at 23 percent. The remaining most common collision types were a single vehicle traveling straight at 15 percent, angle crashes with one vehicle traveling straight and one turning left at 9 percent, and rear-end crashes at 6 percent.

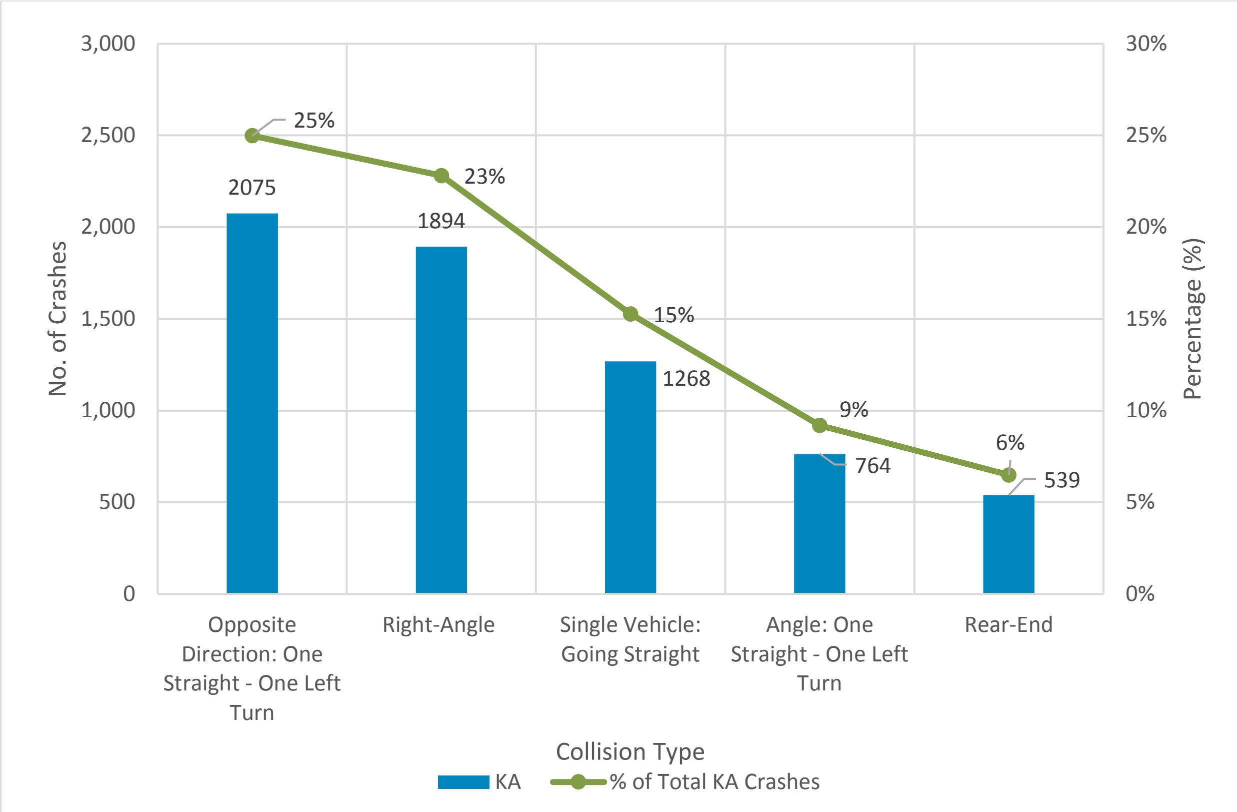


Figure 19: Top manner of collision for multi-vehicle intersection crashes involving motorcycles with K and A severity, 2010–2015.

5.2.1.2 FTYROW and Left Turns

As shown in Figure 18, the top contributing factor for intersection crashes involving motorcycles was failed to yield right of way—turning left. To further understand the interrelationship between the left turn maneuver and failure to yield right of way intersection crashes, a matrix of collision types and contribution factors among intersection crashes involving motorcycles was created. As shown in Table 16, by far the most crashes happen when one vehicle is turning left while the other vehicle is passing an intersection traveling straight due to failure to yield right of way.

Table 16: Frequency of manner of collision by contributing factors for K and A crashes, 2010–2015.

Contributing Factor	Manner of Collision				
	Single Vehicle: Going Straight	**Right-Angle**	**Angle: One Straight—One Left Turn**	**Rear-End**	**Opposite Direction: One Straight—One Left Turn**
Disregard Stop Sign or Light	34	119	17	0	15
Driver Inattention	78	61	18	38	37
Failed to Control Speed	213	31	17	160	19
Failed to Yield ROW—Stop Sign	49	381	163	0	5
Failed to Yield ROW—Turning Left	37	22	62	0	**714**

5.3 Single-Vehicle (Motorcycle) Crashes

Research hypotheses:

- *Approximately half of motorcycle crashes will be single-vehicle crashes involving the motorcycle colliding with the roadway or a fixed object in the environment.*
- *Curves with specific characteristics will be overrepresented among these crashes.*
- *Hot spots will occur more often in areas with certain types of curves.*
- *Other vehicles will play a non-contact role in single-vehicle crashes, although this may not be captured in the standard TxDOT CRIS fields.*

There was a total of 25,191 single-vehicle crashes with the primary driver recorded as a motorcycle driver. This amounted to approximately 49 percent of all motorcycle crashes. As shown in Figure 18 in the prior section, the most common contributing factors were failure to control speed, driver attention, failed to yield right of way—stop sign, failed to yield right of way—turning left, and disregarding a stop sign or light.

Among these single-vehicle crashes and with respect to the first harmful event, 65 percent involved an overturned motorcycle and 24 percent involved collision with a fixed object (see Table 17). Looking at K and A crashes only, 57 percent involved an overturned motorcycle and 32 percent involved collision with a fixed object.

Table 17: Frequency of first harmful event for K and A motorcycle crashes, 2010–2015.

	All Severity		K and A	
First Harmful Event	**Number of Crashes**	**Percent**	**Number of Crashes**	**Percent**
Overturned	16,306	65%	4,131	57%
Fixed Object	6,106	24%	2,343	32%
Animal	1,265	5%	412	6%
Parked Car	496	2%	120	2%
Other Object	394	2%	110	2%
Other Non-collision	413	2%	96	1%
Pedestrian	141	1%	58	1%
Pedal Cyclist	65	<1%	12	<1%
RR Train	4	<1%	2	<1%
Not Reported	1	<1%	0	0%
Total	25,191	100%	7,284	100%

For crashes where the first harmful event involved impact with a fixed object, the 10 most frequently impacted objects are provided in Table 18. These object types comprised 85 percent of all fixed objects struck. The type of object struck did not seem to impact crash severity since the percentages for each type of object did not vary by the two severity levels shown in Table 18.

Table 18: Frequency of type of object struck for K and A motorcycle crashes, 2010–2015.

	All Severity		K and A	
Type of Object Struck	**Number of Crashes**	**Percent**	**Number of Crashes**	**Percent**
Hit curb	1,771	29%	608	26%
Hit median barrier	812	13%	264	11%
Hit fence	477	8%	222	9%
Hit guardrail	431	7%	217	9%
Hit other fixed object	361	6%	123	5%
Hit tree, shrub, landscaping	335	5%	157	7%
Hit highway sign	306	5%	129	6%
Ditch	300	5%	86	4%
Hit concrete traffic barrier	255	4%	93	4%
Hit culvert headwall	147	2%	83	4%
Total	5,195	85%	1,982	85%

5.3.1 CURVE INVOLVEMENT

Rather than straight segments on highways, driving on curves requires more drivers to control speed and handling to a greater extent. It was assumed that the crashes due to failure to control speed or drive in a single lane would account for a greater proportion of the crashes on curves than straight segments. To examine whether more crashes occur on curves, single-vehicle crashes were identified for at-fault motorcyclists. Crashes were categorized as related to “failed to control speed” or “failed to drive in a single lane,” both of which are more difficult to maintain on curves. Next, motorcycle-involved crashes were stratified by location, curved and straight segments, severity, and rural versus urban locations.

For rural crashes, the crashes on curves due to failure to control speed or drive in a single lane were not overrepresented compared to straight segments with respect to K and A crashes, with a slightly larger percentage for all severities (13 percent for curves versus 12 percent for straight segments), as shown in Table 19. For rural areas, the similar percentages observed for curves and straight segments suggests that curves are not a particularly major issue in rural areas. However, for urban areas, a different pattern emerged. As shown in Table 20, the percentage of crashes on curves was markedly higher for K and A crashes as well as all severities combined. For example, 39 percent of K and A crashes on curves involved failure to control speed or drive in a single lane compared to 28 percent of K and A crashes among straight segments. A similar pattern was observed for all crash severities. As such, it can be concluded that the type of alignment affects motorcycle-involved crashes with the likelihood of a crash increase on curves compared to straight segments, but only in urban areas. However, this does not take into account the amount of mileage on curves versus straight segments.

Table 19: Frequency of failure to control speed or drive in a single lane among curves versus straight segments, K and A crashes in rural areas, 2010–2015.

	Rural					
	K and A			All Severity		
Alignment	**Target Crashes[1]**	**Total[2]**	**%**	**Target Crashes[1]**	**Total[2]**	**%**
Curve	249	1,942	12.8%	667	5,059	13.2%
Straight	250	2,057	12.2%	768	6,438	11.9%

[1] Single-vehicle crashes related to failure to control speed or drive in a single lane.
[2] Total single-vehicle crashes.

Table 20: Frequency of failure to control speed or drive in a single lane among curves versus straight segments, K and A crashes in urban areas, 2010–2015.

	Urban					
	K and A			All Severity		
Alignment	**Target Crashes[1]**	**Total[2]**	**%**	**Target Crashes[1]**	**Total[2]**	**%**
Curve	663	1,689	39.3%	1689	4,201	40.2%
Straight	889	3,223	27.6%	3223	14,798	21.8%

[1] Single-vehicle crashes related to failure to control speed or drive in a single lane.
[2] Total single-vehicle crashes.

In order to better understand how the radius of a curve may impact crash frequency, roadway configuration data were examined from the Texas roadway inventory.[33] First, horizontal curves were categorized by radius as less than 700 ft, greater than or equal to 700 ft, less than 1,400 ft, and greater than or equal to 1,400 ft. Next, motorcycle crashes were classified by these categories of curve radii. Finally, the proportions of horizontal curves and crashes were computed for all speed limits and for only those over 60 mph. For all speed limits, more motorcycle-involved crashes occurred at the curves with a radius of greater than 1,400 ft. For areas with a speed limit greater than 60 mph, motorcycle-involved crashes at the curve with a smaller radius (less than 700 ft) had a slightly larger proportion of the percentage of curves, as shown in Table 21. Cut points were selected based on standard recommendations for curve radius based on speed limits, with small radii recommended for lower speed limits.

Table 21: Frequency of crashes by curve radius, 2010–2015.

	All Speed Limits		Over 60 mph	
Radius (ft)	**% of Curves**	**% of Crashes**	**% of Curves**	**% of Crashes**
< 700	12%	10%	7%	10%
700–1400	19%	15%	14%	15%
≥ 1400	69%	75%	79%	75%

Figure 20 displays where the single motorcycle crashes of K and A severity occurring in rural areas are distributed geographically. These crashes are concentrated in areas outside of the large urban areas in Texas. This is likely the result of increased population density in these areas.

[33] GEO-HINI 2012.

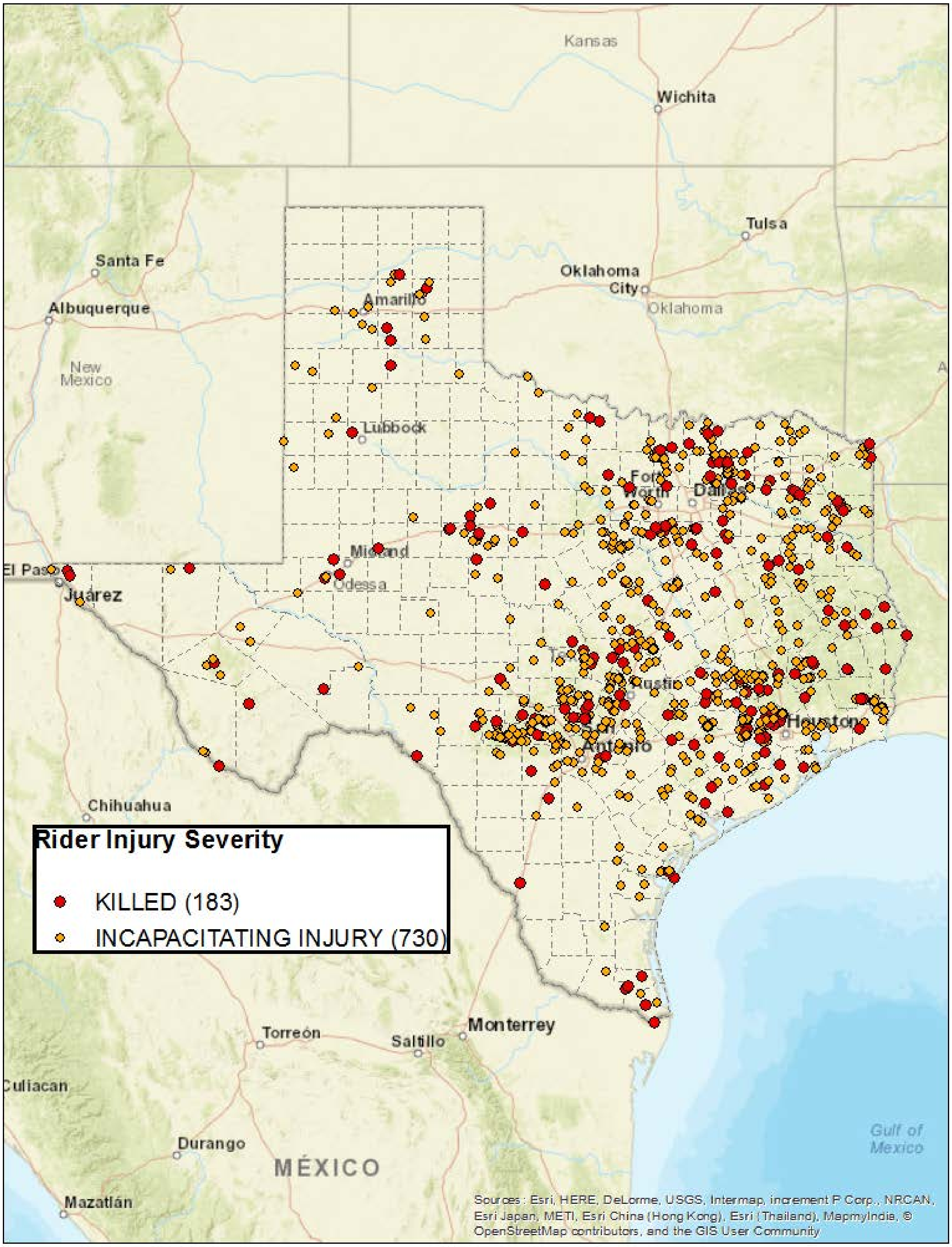


Figure 20: Geographic distribution of single motorcycle crashes on curves in rural areas, K and A severity (rider), 2010–2015.

5.4 Geographic Area and Type of Roadway Crash Characteristics

Research hypotheses:

- *The distribution of motorcycle crashes in rural versus urban areas will differ by type of roadway and other crash characteristics.*
- *The distribution of geographic, type of roadway, and other crash characteristics will vary by motorcycle versus passenger vehicles.*

To further identify variation with respect to type of roadway and other geographic and crash characteristics, a series of crash trees were constructed by rural versus urban geographic location as well as motorcycle versus passenger type of vehicle. The trees are developed by separating crashes into on and off-system categories and looking at roadway type, when available, and whether the crash is related to an intersection or not. Finally, crash types are determined for the resulting subcategories. Figure 21 provides an example of such a crash tree. This particular tree is for urban K and A motorcycle crashes. Figure 22 is the crash tree for rural K and A motorcycle crashes. Additional crash trees for passenger vehicles and all crash types are available in the appendix for comparison purposes.

Below are key observations with respect to urban K and A crash circumstances:

1. Approximately 60 percent of all severe motorcycle crashes occur on the state roadway system. This value is slightly higher than the 56 percent of all urban motorcycle crashes that occur on system. Approximately 61 percent of urban passenger car K and A crashes occur on the state system.

2. The majority (58 percent) of on-system crashes occur on arterials and frontage roads, indicating that major surface roads with intersections and driveways are where a significant portion of severe motorcycle crashes occur. Another 22 percent of severe motorcycle crashes occur on freeways, and 7 percent occur on ramps and flyovers. These values are similar to the distribution of severe passenger car crashes, although motorcycle crashes are somewhat more likely to occur on a ramp or flyover and less likely to occur on the main lanes than passenger car severe crashes. Only 13 percent of severe motorcycle crashes occur on on-system collector and local roadways.

3. Most (62 percent) severe urban motorcycle crashes do not occur at intersections. Single motorcycle roadway departure crashes are the most predominant (52 percent) non-intersection crash, and make-up a much higher percentage of severe non-intersection crashes than is true for passenger cars (24 percent). Many more motorcycle crashes involved a roadway departure (47 percent of all motorcycle non-intersection crashes) than passenger cars (13 percent of all passenger car non-intersection crashes).

4. Left turn crashes are the single largest type of severe crash at intersections and that is true more so for motorcycles (40 percent) than for passenger cars (30 percent). Severe

motorcycle crashes are more likely to be associated with left turns (40 percent) than motorcycle crashes in general (31 percent).

5. Right-angle crashes make up about 20 – 25 percent of intersection crashes. This range is generally less than the range of passenger car severe crashes associated with right angle crashes.

6. Rear end crashes make up about 12 – 20 percent of urban intersection severe crashes depending on the roadway type. Generally, this is less than passenger car involvement in rear end crashes.

Below are key observations with respect to rural K and A crash circumstances:

1. Approximately 67 percent of all rural severe motorcycle crashes occur on the state system. The percentage is somewhat higher than the percentage of all motorcycle crashes occurring on-system (61 percent) but less than the percentage of severe passenger car crashes occurring on-system (71 percent).

2. A majority (64 percent) of severe rural on-system motorcycle crashes occurs on arterials and frontage roads, and this percentage is higher than is the case for passenger cars (49 percent). Likewise, a lower percent of on-system severe motorcycle crashes occur on rural freeways (24 percent) than do severe passenger car crashes (45 percent).

3. Severe on and off system motorcycle crashes more often occur away from an intersection compared to at one. Approximately 83 percent of motorcycle crashes occur at locations along roadways.

4. Single motorcycle roadway departure crashes make up a significant portion of the severe non-intersection crashes (66 percent), whereas 43 percent of severe passenger car crashes involve a single vehicle running off the road.

5. Only 21 percent of all rural severe motorcycle crashes occur at intersections, and the vast majority of these are at unsignalized intersections. Left turn crashes are the predominant severe motorcycle crash type at rural intersections (36 percent).

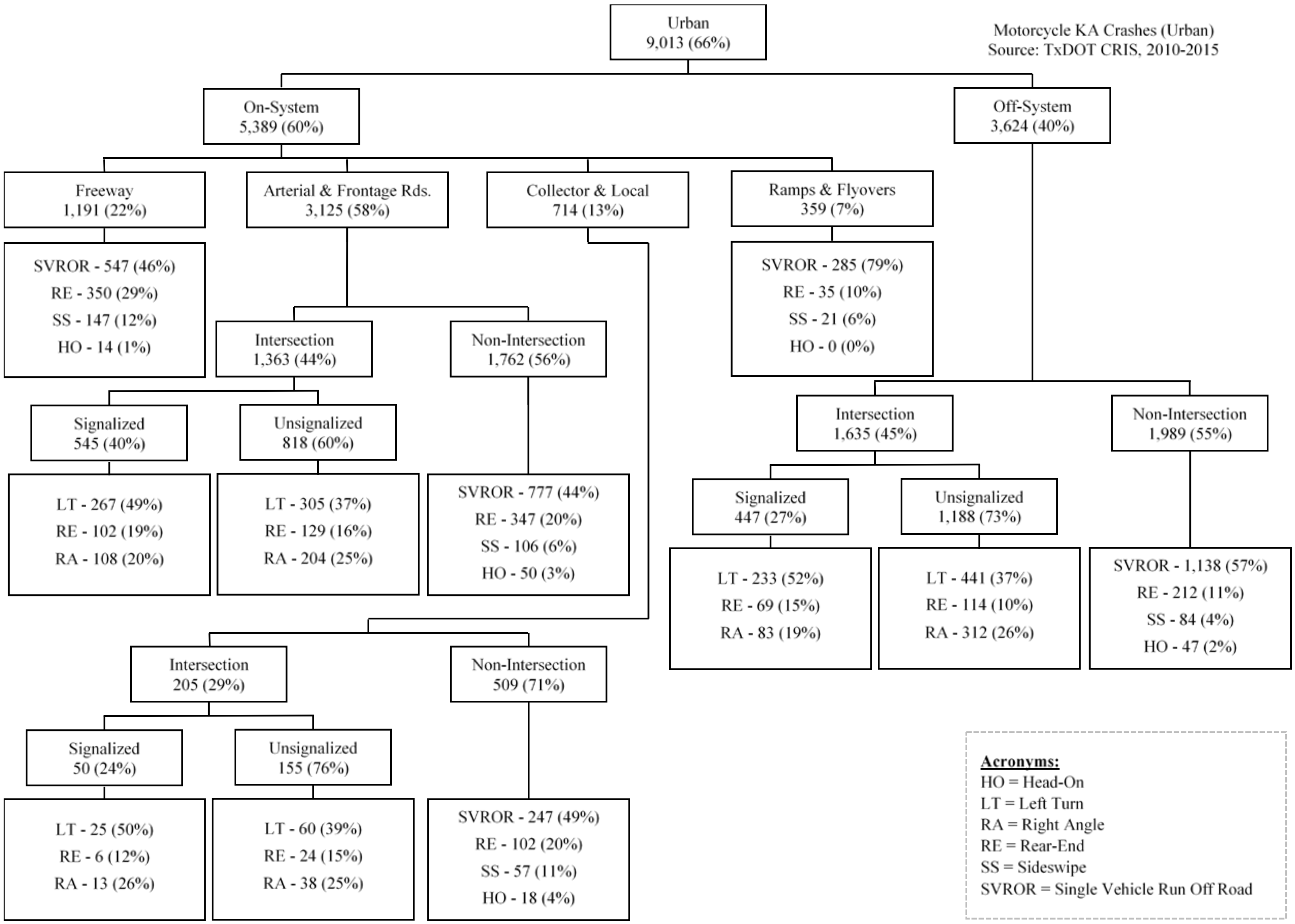


Figure 21: Crash Tree Diagram of Motorcycle K and A Crashes in Urban Area.

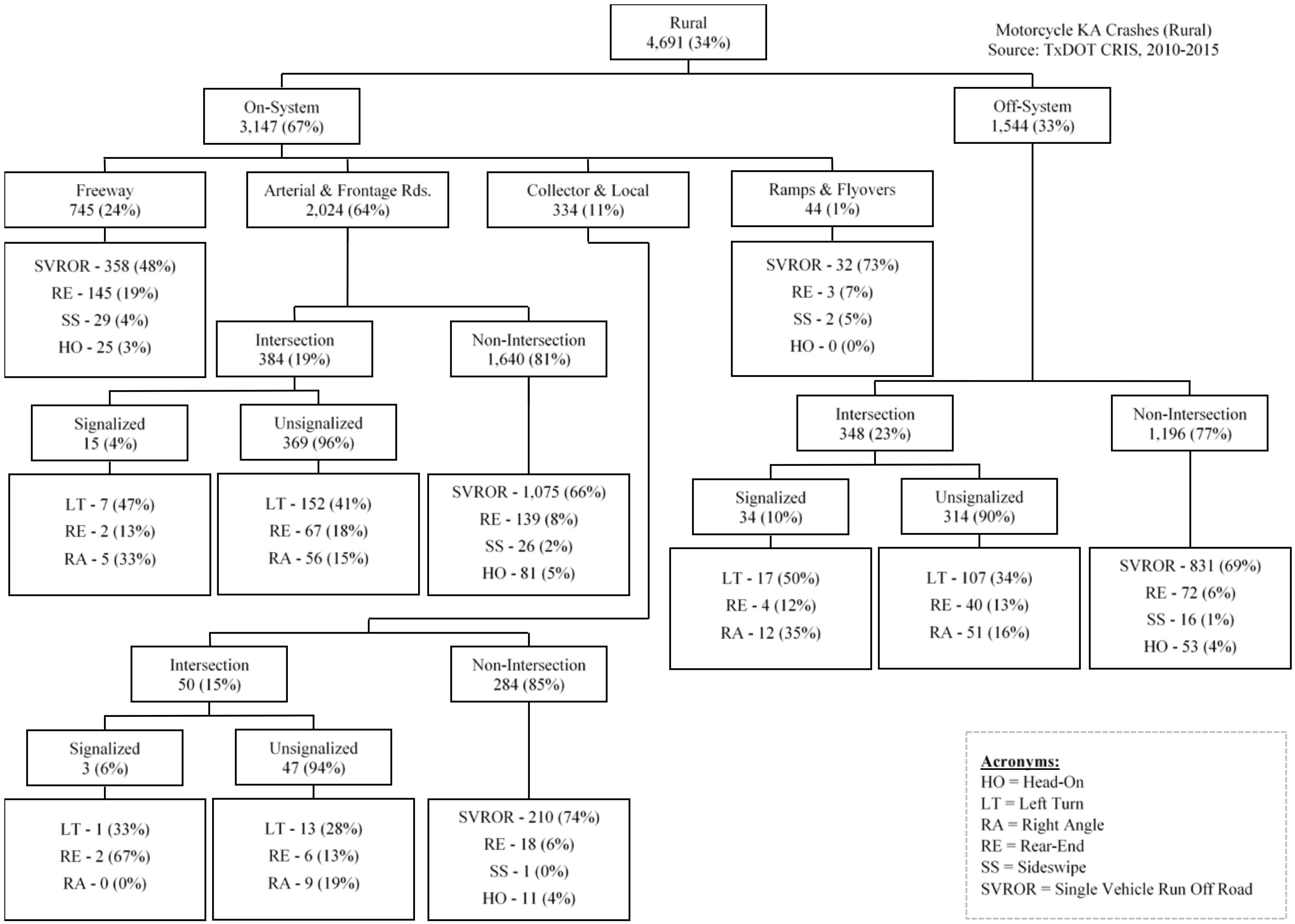


Figure 22: Crash Tree Diagram of Motorcycle K and A Crashes in Urban Area.

6 Person Factors

Person-level variables, such as age and gender, often play key roles in the occurrence of crashes. These variables are considered with respect to motorcycle crashes alone and as compared to their frequency in crashes not involving motorcycles. The analysis presented in this section focuses on age, gender, impaired driving, having a motorcycle license endorsement, receipt of motorcycle training, violations, and helmet use.

KEY POINTS

- Males account for 93 percent of motorcycle drivers involved in crashes.
- 10 percent of motorcycles in crashes were carrying a passenger.
- Approximately 50 percent of motorcyclists involved in crashes had an "M" license certification.
- Males had a higher percentage of not wearing helmets in crashes compared to females.

6.1 Age

Research hypothesis:

- *The distribution of age among motorcycle drivers involved in crashes will differ from the distribution of age among drivers of passenger vehicles.*

Since the age distribution of registered motorcyclists is not readily available, there are limits with respect to the analysis of motorcyclist age and crash risk. As another way to do the analysis, researchers used the comparison group method. The age distributions between motorcyclists and passenger car motorists were compared to identify the overrepresented age groups.

Based on the data in Table 22, motorcyclists in the age groups of 36 to 65 years old are overrepresented compared to passenger car drivers for all crash severities as well as just K and A crashes (data not shown). Often in crash research, it is concluded that young and old groups have an increased risk of adverse crash events than middle-age groups. Reasons for this pattern include that younger motorists are less experienced and more prone to riskier behavior, while older drivers may be more likely to sustain injuries since they are more fragile physically. The reason for the inconsistency observed in this table is that it does not include the amount of time spent driving the motorcycle or passenger vehicle. These age difference may be attributable to the amount of time that different age groups drive motorcycle versus passenger vehicles.

Table 22: Age distribution for motorcycle versus passenger vehicle drivers involved in crashes, 2010–2015.

Age Group	Motorcyclist[1]	PC Drivers[2]	Percentage Motorcyclists	Percentage PC Drivers	Diff. (% Motorcyclist – % PC Drivers)
15	135	702	1.5%	2.6%	−1.1%
16–20	498	4,188	5.5%	15.4%	−9.8%
21–25	1,181	5,067	13.1%	18.6%	−5.5%
26–35	1,978	6,327	22.0%	23.2%	−1.2%
36–45	1,769	3,784	19.7%	13.9%	5.8%
46–55	1,920	2,879	21.4%	10.6%	10.8%
56–65	1,156	1,982	12.9%	7.3%	5.6%
66–70	228	762	2.5%	2.8%	−0.3%
71–75	79	544	0.9%	2.0%	−1.1%
76+	43	1,004	0.5%	3.7%	−3.2%
Total	8,987	27,239	100%	100%	n/a

[1] At-fault motorcyclists.

[2] At-fault passenger car (PC) drivers.

To explore this issue further, the age distribution of K and A driver injuries were compared with the age distribution of trip making behavior among motorcycle drivers. Figure 9 in Section 4 provides data on the distribution of trip making by age groups. This comparison was made for two common types of motorcycle crashes, single motor vehicle run-off-road and left turn crashes. These distributions were stratified by rural and urban crash locations and displayed in Table 23.

As shown in Table 23, the distribution of age for K and A crashes differs from the distribution of age in terms of trip making behavior for motorcycle drivers. As an example, the age groups ranging from 16-44 years account for 50 percent of the K and A injuries, but these drivers only account for 30 percent of the motorcycle trips for single motor vehicle run-off-road crashes in rural areas. This same pattern is observed for urban crashes of this type and for left turn crashes in rural and urban areas. Collectively, when trip making is taken into account, or the fact that the younger age groups drive motorcycles less frequently, the data indicate that these younger age groups may be at a greater risk of severe injuries while riding motorcycles.

Table 23: Age distribution of K and A driver injuries and trip making for and for 2010–2015.

	Rural			Urban		
Age Group	**Distribution K & A**	**Distribution of Trips**	**Over or Under Represented**	**Distribution K & A**	**Distribution of Trips**	**Over or Under Represented**
Single Motor vehicle run-off-road						
16-24	12%	5%	Over	17%	5%	Over
25-34	18%	10%	Over	26%	10%	Over
35-44	20%	15%	Over	23%	15%	Over
45-54	24%	35%	Under	20%	35%	Under
55-64	19%	25%	Under	10%	25%	Under
>64	7%	10%	Under	3%	10%	Under
Left turn crashes						
16-24	17%	5%	Over	21%	5%	Over
25-34	19%	10%	Over	24%	10%	Over
35-44	19%	15%	Over	20%	15%	Over
45-54	24%	35%	Under	20%	35%	Under
55-64	17%	25%	Under	12%	25%	Under
>64	5%	10%	Under	3%	10%	Under

6.2 Gender

Research hypothesis:
The distribution of age and gender among motorcycle drivers involved in crashes will differ from the distribution of age among drivers of passenger vehicles.

Table 24 displays the distribution of gender among motorcycle drivers by crash severity. Overall, drivers involved in crashes were mostly male (93 percent), while passengers involved in crashes were mostly female (85 percent). Among drivers, 26 percent of males experienced a K or A injury compared to 23 percent of females, indicating that female drivers tend to sustain slightly less severe injuries.

Table 24: Distribution of gender among motorcycle drivers and riders by severity, 2010–2015.

Driver							
	Unknown severity	**O**	**C**	**B**	**A**	**K**	**Total**
Male	480 (1.0%)	6,415 (13.3%)	10,043 (20.8%)	18,877 (39.0%)	10,018 (20.7%)	2,535 (5.2%)	48,368 (100%)
Female	14 (0.4%)	331 (10.5%)	757 (23.9%)	1,336 (42.3%)	622 (19.7%)	102 (3.2%)	3,162 (100%)
Unknown	378 (86.3%)	35 (8.0%)	9 (2.1%)	9 (2.1%)	7 (1.6%)	0 (0%)	438 (100%)
Total	872 (1.7%)	6,781 (13.0%)	10,809 (20.8%)	20,222 (38.9%)	10,647 (20.5%)	2,637 (5.1%)	51,968 (100%)
Passenger							
	Unknown severity	**O**	**C**	**B**	**A**	**K**	**Total**
Male	11 (1.5%)	193 (27.0%)	127 (17.8%)	256 (35.8%)	116 (16.2%)	12 (1.7%)	715 (100%)
Female	31 (0.7%)	585 (13.8%)	833 (19.7%)	1,633 (38.6%)	980 (23.2%)	167 (3.9%)	4,229 (100%)
Unknown	7 (25.9%)	16 (59.3%)	1 (3.7%)	1 (3.7%)	2 (7.4%)	0 (0%)	27 (100%)
Total	49 (1.0%)	794 (16.0%)	961 (19.3%)	1,890 (38.0%)	1,098 (22.1%)	179 (3.6%)	4,971 (100%)

According to the TxDOT Household Travel Survey, 15 percent of total trips by motorcycles were made by female motorcycle drivers. Considering the crash proportions and the exposure on highways by gender, the risk of a crash among female motorcycle drivers may be relatively low, as indicated in Section 4.

6.3 Impaired Motorcycle Drivers

Research hypotheses:

- *Almost half of motorcycle driver fatalities will involve drug or alcohol impairment.*
- *Among DUI crashes, the average BAC will differ between drivers of motorcycles vs. other vehicles.*

6.3.1 BAC LEVELS

As described in Section 5, DUI crashes involving motorcycles are of a greater severity compared to non-motorcycle DUI crashes. This section examines the distribution of blood alcohol content (BAC) levels among individual motorcycle drivers and other drivers. It also considers whether there is an association between DUI and manner of collision and road part as well as violations.

The average recorded BAC for all drivers with a BAC greater than 0.00 g/dL was 0.17 g/dL from 2010–2015. A crash is categorized as DUI when the driver is impaired with a BAC level greater than 0.00 g/dL or above. For crashes by impaired motorcycle drivers, the average recorded BAC was 0.15 g/dL, which is considerably lower than the average BAC (0.17 g/dL) for non-motorcycle drivers. For motorcycle drivers, the average BAC level (0.15 g/dL) was consistent across the injury severity categories. For non-motorcycle drivers, the average BAC level was consistent across the injury severity categories with the exception of fatal injury, which was 0.18 g/dL rather than 0.17 g/dL

6.3.2 CONTRIBUTING FACTORS, MANNER OF COLLISION, AND ROAD PART

Research hypotheses:

- *Among DUI crashes, describe the moving violations or actions that actually caused the crash.*
- *Passenger-carrying motorcycles will not be overrepresented in the accident data.*

Table 25 presents a comparison of motorcycle drivers in DUI and non-DUI crashes as well as passenger vehicle DUI drivers with respect to selected contributing factors. The frequency of crashes by at-fault motorcycle drivers were stratified by DUI (alcohol and drug) and non-DUI. Then, the crashes were categorized by the contributing factors. A positive difference in percentages, as displayed in the last two columns of Table 25, indicate that the DUI motorcycle driver is more likely to have the contribution factor of interest.

Speeding over the limit or traveling at an unsafe speed were more likely among DUI motorcycle drivers when compared to DUI passenger vehicle drivers or non-DUI motorcycle drivers. DUI motorcycle drivers seemed to have a particular problem with traveling at an unsafe speed (6 percent greater than non-DUI motorcycle drivers and 14 percent greater than DUI passenger vehicle drivers). With respect to failure to drive in a single lane, DUI motorcycle drivers were slightly overrepresented (excess of 4 percent) compared to non-DUI motorcycle drivers, but virtually no difference was observed when compared to DUI passenger vehicle drivers. Finally, there appeared to be little to no difference with respect to fleeing or evading police when comparing DUI motorcycle drivers to non-DUI motorcycle drivers or DUI passenger vehicle drivers.

Table 25: Comparison of DUI and non-DUI motorcycle drivers and passenger drivers with respect to selected contributing factors for all injury severities, 2010–2015.

Contributing Factor	No. of Crashes			% of Crashes			Difference in %	
	MC DUI Driver	MC Non-DUI Driver	PC DUI Driver	MC DUI Driver	MC Non-DUI Driver	PC DUI Driver	MC DUI vs. Non-DUI	MC DUI vs. PC
Failed to Drive in Single Lane	153	1,772	4,461	10.4%	6.2%	11.1%	4.2%	−0.7%
Fleeing or Evading Police	32	466	269	2.2%	1.6%	0.7%	0.6%	1.5%
Unsafe Speed	313	4,384	2,958	21.4%	15.4%	7.4%	6.0%	14.0%
Speeding (over limit)	90	841	701	6.1%	2.9%	1.7%	3.2%	4.4%
Total	1,410	28,026	40,156	n/a				

Tables 26 and 27 display differences between DUI motorcycle drivers and non-DUI motorcycle drivers with respect to crash location on a curve, failure to yield the right of way, and single-vehicle run-off-road for all injury severities. These characteristics were selected based on findings reported in Section 5. For all driver injury severities, DUI motorcycle drivers were less likely to be involved in a single-vehicle run-off-road crash. However, they were more likely than non-DUI motorcycle drivers to be involved in a single-vehicle run-off-road crash if the DUI motorcycle driver experienced a K or A crash (74 percent for DUI versus 57 percent for non-DUI). There is some evidence that curves may be more difficult for DUI motorcycle drivers given a slight excess in percentages (3 percent for all severities and 2 percent for K and A driver injuries). There was little difference between the two groups with respect to failure to yield right of way, meaning DUI probably was not a factor.

Table 26: Comparison of DUI and non-DUI motorcycle drivers and passenger drivers with respect to location on a curve, failure to yield the right of way, and single-vehicle run-off-road for all injury severities, 2010–2015.

	No. of MC Drivers		% of MC Drivers		Difference in %
	DUI	**Non-DUI**	**DUI**	**Non-DUI**	**DUI vs. Non-DUI**
All crashes	3,645	48,379	n/a		
Curve	571	5,977	15.7%	12.4%	3.3%
FTYROW	30	766	0.8%	1.6%	−0.8%
Single vehicle crashes	2,653	22,825	n/a		
Run-off-road	1,822	18,755	68.7%	82.2%	−13.5%

Table 27: Comparison of DUI and non-DUI motorcycle drivers and passenger drivers with respect to location on a curve, failure to yield the right of way, and single-vehicle run-off-road for K and A driver injury, 2010–2015.

	No. of MC Drivers		% of MC Drivers		Difference in %
	DUI	**Non-DUI**	**DUI**	**Non-DUI**	**DUI vs. Non-DUI**
All crashes	2,116	11,171	n/a		
Curve	367	1,687	17.3%	15.1%	2.2%
FTYROW	18	188	0.9%	1.7%	−0.8%
Single vehicle crashes	1,424	5,552	n/a		
Run-off-road	1,057	3,148	74.2%	56.7%	17.5%

6.4 Passengers

Research hypothesis:
Overall, from 2010–2015, approximately 10 percent of motorcycles will involve crashes including a passenger.

About 10 percent of motorcycles involved at a crash were carrying a passenger. However, it is hard to conclude that passenger-carrying motorcycles are not overrepresented in the crash data because of no information on the trip proportion by passenger-carrying motorcycles. Table 28 displays the distribution of crash severity by driver versus passenger. Overall, passengers do not appear to sustain injuries of greater severity than drivers. Most passengers of motorcycles were female. For all severity levels and K and A crashes, females accounted for 85 percent and 87 percent of all occupants, respectively. About 90 percent of passengers who died or were severely injured were female (data not shown).

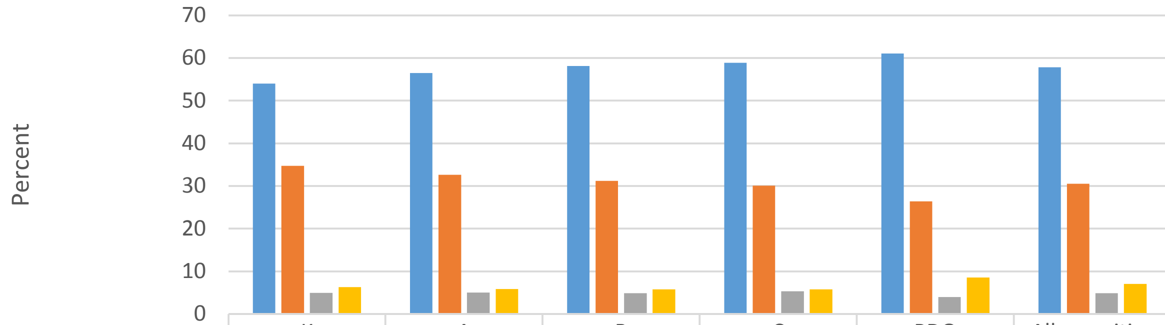
Table 28: Injury severity by driver versus rider, 2010–2015.

Injury Severity	Driver	Passenger	Total
Unknown injuries	876 (1.7%)	49 (1.0%)	925 (1.6%)
Non-injuries	6,781 (13.0%)	794 (16.0%)	7,575 (13.3%)
Possible injuries	10,813 (20.8%)	962 (19.3%)	11,775 (20.7%)
Non-incapacitating injuries	20,234 (38.9%)	1,891 (38.0%)	22,125 (38.8%)
Incapacitating injuries	10,650 (20.5%)	1,100 (22.1%)	11,750 (20.6%)
Fatalities	2,637 (5.1%)	179 (3.6%)	2,816 (4.9%)
Total	51,991 (100%)	4,975 (100%)	56,966 (100%)

6.5 License

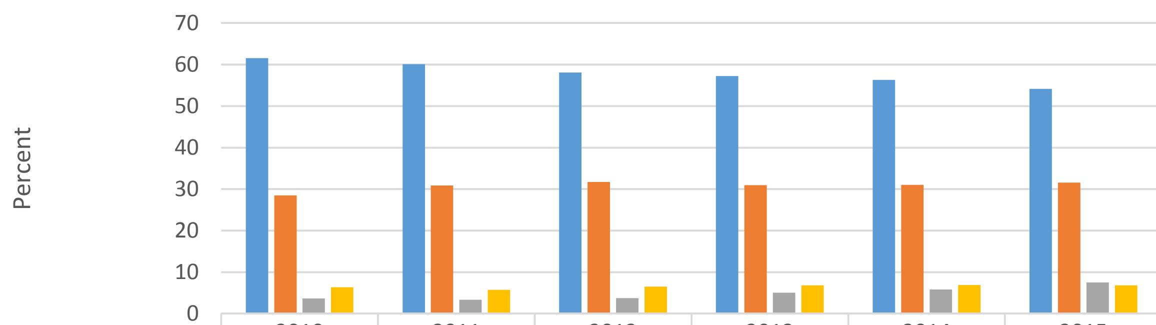
Research hypothesis:
Motorcycle riders in crashes who were without motorcycle license, without any license, or with license revoked will be overrepresented.

Motorcycle drivers are required to obtain an "M" license certification. Receipt of this endorsement implies that the driver is more knowledgeable regarding how to safely operate a motorcycle than individuals without this designation. Consequently, motorcycle drivers involved in crashes were selected from all injury severity categories. The distribution of "M" license certification was computed for each injury severity category. Overall, the percentage with an "M" certification decreased as injury severity increased from 61 percent for property damage only (PDO) crashes to 54 percent for K crashes, as shown in Figure 23. Data were examined by year and gender, as shown in Figures 24 and 25. From 2014 to 2015, there was a general decline in the proportion of motorcycle drivers involved in crashes who had an "M" certification. For example, for males, the proportion with an "M" certification declined from 62 percent in 2010 to 54 percent in 2015. A similar trend was observed for females.



	K	A	B	C	PDO	All severities
M license	54.02	56.51	58.16	58.85	61.06	57.8
Licensed not M	34.74	32.59	31.18	30.09	26.41	30.51
Unlicensed	4.92	5.04	4.88	5.29	3.97	4.85
Unknown / Invalid	6.31	5.87	5.78	5.77	8.56	7.07

Figure 23: Distribution of motorcycle license certification by driver injury severity.



	2010	2011	2012	2013	2014	2015
M	61.59	60.06	58.09	57.2	56.3	54.18
Licensed not M	28.44	30.87	31.72	30.96	31	31.53
Unlicensed	3.61	3.37	3.7	5.01	5.84	7.5
Unknown, Invalid	6.35	5.7	6.49	6.83	6.86	6.79

Figure 24: Distribution of motorcycle license certification by year for males.

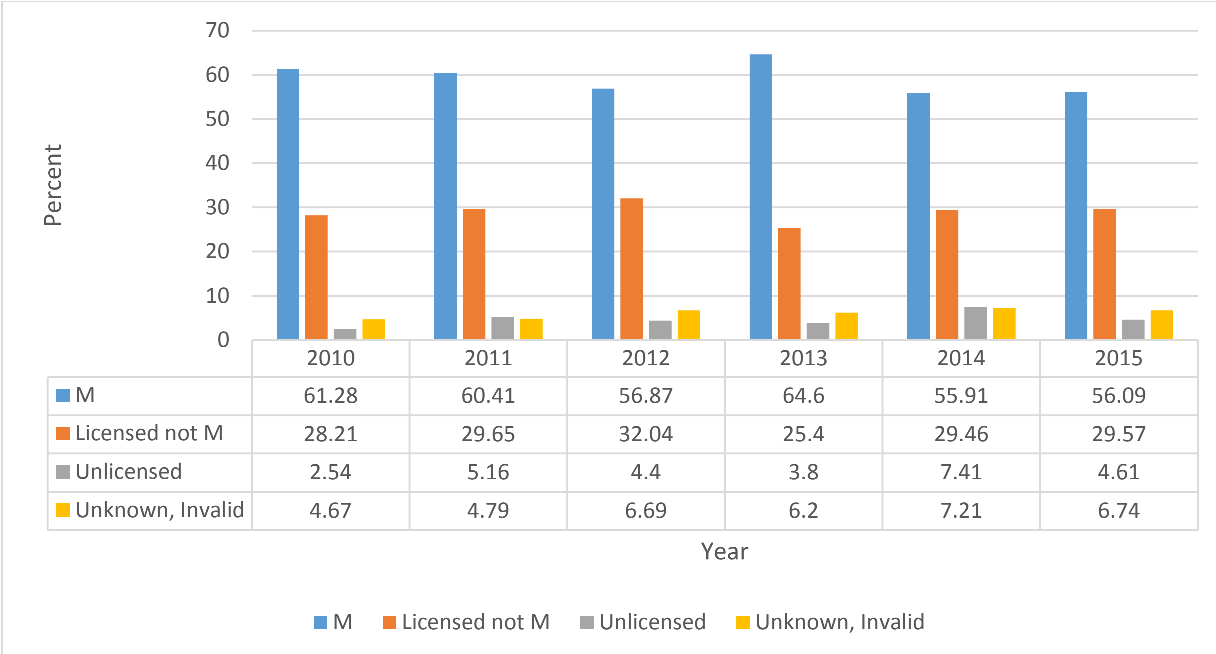


Figure 25: Distribution of motorcycle license certification by year for females.

In terms of age, the percentage of drivers involved in crashes who had a motorcycle endorsement on their license increased from 41 percent among those younger than age 21 years to 80 percent among those ages 70 to 79 years before dropping slightly to 72 percent among those 80 to 89 years of age. This could be the result of older drivers having a longer period of time to acquire their motorcycle endorsement simply as a function of aging. Data are displayed in Table 29.

Table 29: Distribution of motorcycle license by age group, 2010–2015.

	Unknown	Non-motorcycle	Motorcycle	Unlicensed	Other/ Out of State	Total
Under 21	5.0%	34.0%	40.5%	16.8%	3.7%	100%
21–29	2.8%	39.3%	45.2%	6.8%	5.8%	100%
30–39	2.3%	36.3%	51.1%	4.9%	5.4%	100%
40–49	0.5%	29.6%	62.5%	2.7%	4.8%	100%
50–59	1.3%	19.1%	73.5%	1.3%	4.7%	100%
60–69	0.5%	13.7%	78.6%	0.6%	6.6%	100%
70–79	0.2%	11.5%	80.7%	0.6%	7.0%	100%
80–89	0.0%	20.8%	72.2%	0.0%	6.9%	100%
Over 89	33.3%	33.3%	33.3%	0.0%	0.0%	100%
Total	1.9%	30.5%	57.5%	4.8%	5.3%	100%

6.6 Training

Research hypotheses:

- *Motorcycle drivers with training will be overrepresented in crash data.*
- *Injury severity will be similar among those with and without training.*

Overall, in 2015, 21,199 people took the Basic Rider Course (BRC). Of these, 17 percent were female and 83 percent were male. With respect to age, the majority (39 percent) were ages 20–29 years, followed by 30–39 years (20 percent), 40–49 years (16 percent), 50–59 years (12 percent), 15–19 years (10 percent), and 60+ years (4 percent). The vast majority (91.30 percent) of course enrollees passed the course.

To examine the potential association between training and motorcycle crashes, training data representing motorcycle drivers that took the BRC were linked to the CRIS data. Of those with a crash record linked to a training record, 3 percent of motorcycle drivers died due to a crash. After taking the BRC, 5 percent of drivers were involved in more than one crash. Of the crashes involving a BRC driver, 17 percent occurred before the driver completed the course. Of the motorcycle drivers killed from 2012–2015, 6 percent had been involved in a previous crash during the same time period.

Table 30 displays the average number of days between the crash date and training date based on crash status (e.g., before or after class) for one motor vehicle collision. One motor vehicle collision was selected since the fault can most easily be attributed to the motorcycle driver. Those who crashed before training had an average of 482 days before completing the training following the crash, with a range of 5 to 2,082 days. The average number of days between when a driver had a crash and took the BRC was more than a year. Those who crashed after training had an average of 289 days before their crash, with a range of 0 days to 1,277 days. This finding shows the average number of days between the time a motorcycle driver took the BRC and had a crash was less than a year.

Table 31 displays the frequency of motorcycle driver crash status (e.g., before or after class) and injury severity. Those who crashed before completing training were most likely to have injury severities classified as non-incapacitating, possible injury, and not injured. Those crashing before taking the course were most likely to be classified as non-incapacitating or possible injury. Overall, no major differences in injury severity were detected.

Table 30: Average number of days between crash date and training date for one motor vehicle crash, 2012–2015.

	Average Number of Days (Min, Max)
Crash after Class	289 (0, 1377)
Crash before Class	−482 (−2082, −5)

Table 31: Frequency of motorcycle drivers' injury severities based on training and crash date for one motor vehicle crash, 2012–2015.

Injury Severity	Crash after Class N (%)	Crash before Class N (%)	Total
K	51 (4.4%)	0 (0.0%)	51
A	182 (15.7%)	35 (15.6%)	217
B	545 (46.9%)	100 (44.6%)	645
C	265 (22.8%)	53 (23.7%)	318
O	114 (9.8%)	35 (15.6%)	149
Unknown	6 (0.5%)	1 (0.5%)	7
Total	1,163	224	1,387

6.7 Helmet Use

Research hypotheses:

- *Approximately 65 percent of the motorcycle riders in traffic will use safety helmets, but only 40 percent of the crash-involved motorcycle riders will use helmets at the time of an accident.*
- *The distribution of helmet use will differ by age.*
- *The prevalence of helmet use will differ between drivers and riders.*
- *Explore the comparison of injury severity and helmet use.*

To explore the impact of helmet use, crashes from 2010–2015 were analyzed based on helmet use. As shown in Table 32, males were more likely to have not worn a helmet at the time of the crash compared to females—37 percent and 29 percent, respectively. Meanwhile, females were more likely to have not had their helmet damaged in a crash if they were using one, compared to males—27 percent and 20 percent, respectively. Similar helmet use patterns were observed for the remaining categories.

Table 32: Helmet use by gender, all severities, 2010–2015.

Helmet Use	Gender N (%)		
	Male	Female	Unknown
Worn, damaged	11,531 (23.8%)	752 (23.8%)	14 (3.2%)
Worn, not damaged	9,549 (19.7%)	844 (26.7%)	25 (5.7%)
Worn, unknown damage	3,651 (7.5%)	294 (9.3%)	41 (9.3%)
Not worn	18,001 (37.2%)	922 (29.1%)	24 (5.5%)
Unknown if worn	5,647 (11.7%)	343 (10.8%)	335 (76.3%)
Not applicable	12 (0.0%)	8 (0.3%)	0 (0.0%)
Total	48,391	3,163	439

Table 33 displays helmet use by age groups. Helmet use was similar when stratified by age categories. However, there were differences in the not-worn categories. Those aged 80–89 had the highest percentage of helmet use classified as not worn, followed by those aged 40–49, 50–59, and 30–39 years old. As expected, these age groups also had lower percentages of riders that had worn a helmet.

Table 33: Helmet use by age, all severities, 2010–2015.

Helmet Use	Age Groups N (%)								
	Under 21	21–29	30–39	40–49	50–59	60–69	70–79	80–89	Over 89*
Worn, damaged	1,102 (28.9%)	3,756 (28.4%)	2,284 (22.5%)	1,991 (19.8%)	1,924 (20.7%)	964 (25.5%)	199 (31.8%)	21 (29.2%)	0 (0.0%)
Worn, not damaged	836 (22.0%)	2,761 (20.9%)	1,980 (19.5%)	1,872 (18.6%)	1,789 (19.2%)	901 (23.8%)	158 (25.2%)	23 (31.9%)	0 (0.0%)
Worn, unknown damage	334 (8.8%)	1,157 (8.8%)	728 (7.2%)	672 (6.7%)	633 (6.8%)	295 (7.8%)	56 (8.9%)	1 (1.4%)	0 (0.0%)
Not worn	1,157 (30.4%)	3,970 (30.1%)	3,940 (38.8%)	4,345 (43.3%)	3,893 (41.8%)	1,257 (33.2%)	165 (26.4%)	23 (31.9%)	5 (83.3%)
Unknown if worn	374 (9.8%)	1,555 (11.8%)	1,231 (12.1%)	1,159 (11.5%)	1,074 (11.5%)	367 (9.7 %)	47 (7.5%)	4 (5.6 %)	1 (16.7%)
Not applicable	5 (0.1%)	6 (0.0%)	2 (0.0%)	1 (0.0%)	0 (0.0%)	3 (0.1%)	1 (0.2%)	0 (0.0%)	0 (0.0%)
Total	3,808	13,205	10,165	10,040	9,313	3,787	626	72	6

* Small sample size limits interpretation.

To better understand the role of helmet use and injury severity, motorcycle crashes were stratified by injury severity. As shown in Table 34, those in the helmet use category of not worn had the highest percent of fatal injuries (52 percent). Those classified as worn and not damaged had the highest percentage of no injuries (39 percent). The data show that injury severity is associated with helmet use.

Table 34: Helmet use by injury severity, 2010–2015.

Helmet Use	Injury Severity Classification N (%)					
	Unknown Severity	O	C	B	A	K
Worn, damaged	51 (5.8%)	670 (9.9%)	2,210 (20.4%)	5,284 (26.1%)	3,171 (29.8%)	911 (34.5%)
Worn, not damaged	76 (8.7%)	2,642 (39.0%)	2,602 (24.1%)	3,882 (19.2%)	1,091 (10.2%)	124 (4.7%)
Worn, unknown damage	105 (12.0%)	351 (5.2%)	994 (9.2%)	1,694 (8.4%)	750 (7.0%)	92 (3.5%)
Not worn	157 (17.9%)	2,088 (30.8%)	3,366 (31.1%)	7,265 (35.9%)	4,708 (44.2%)	1,362 (51.6%)
Unknown if worn	486 (55.5%)	1,019 (15.0%)	1,640 (15.2%)	2,103 (10.4%)	929 (8.7%)	148 (5.6%)
Not applicable	1 (0.1%)	11 (0.2%)	1 (0.0%)	6 (0.0%)	1 (0.0%)	0 (0.0%)
Total	876	6,781	10,813	20,234	10,650	2,637

As Table 35 illustrates, DUI motorcycle drivers were more likely to have not worn a helmet compared to the non-DUI motorcycle drivers—67 percent and 34 percent, respectively. Non-DUI motorcycle drivers were more likely to have worn a helmet that was not damaged compared to DUI motorcycle drivers—21 percent and 5 percent, respectively.

Table 35: Helmet use by DUI, all severities, 2010–2015.

Helmet Use	DUI N (%)	Non-DUI N (%)
Worn, damaged	637 (17.5%)	11,666 (24.1%)
Worn, not damaged	191 (5.1%)	10,229 (21.1%)
Worn, unknown damage	114 (3.1%)	3,874 (8.0%)
Not worn	2,455 (67.4%)	16,501 (34.1%)
Unknown if worn	248 (6.8%)	6,088 (12.6%)
Not applicable	0 (0.0%)	20 (0.04%)
Total	3,645	48,378

Table 36 displays helmet use by driver and passenger. Overall, motorcycle passengers had a higher proportion of not wearing helmets compared to operators—47 percent and 36 percent, respectively.

Table 36: Helmet use by operator and passenger, all severities, 2010–2015.

Helmet Use	**Operator N (%)**	**Passenger N (%)**
Worn, damaged	12,303 (23.7%)	806 (16.2%)
Worn, not damaged	10,420 (20.0%)	860 (17.3%)
Worn, unknown damage	3,988 (7.7%)	348 (7.0%)
Not worn	18,956 (36.4%)	2,339 (47.0%)
Unknown if worn	6,336 (12.2%)	487 (9.8%)
Not applicable	20 (0.0%)	138 (2.8%)
Total	52,023	4,978

7 Vehicle Factors

KEY POINTS

- There is no evidence to support the notion that motorcycle color plays a role in conspicuity.
- A higher proportion of fatal crashes for motorcycle and four-wheeled vehicle crashes occurred during dark conditions.
- An analysis of contributing factors related to conspicuity among non-motorcycle vehicles that are likely to be at fault suggest that these vehicles crashed with motorcycles because the driver did not see the motorcycle.
- Among crashes, cruisers and sport bikes were the most common types of motorcycles, while the most common engine size was 500–999cc and 1000–1499cc.

7.1 Conspicuity

Research hypotheses:

- *The failure of motorists to detect and recognize motorcycles in traffic will play a large role in crashes with motorcycles.*
- *Vehicle size will play a large role in motorcycle crashes.*

- *Vehicle color will not affect the possibility of motorcycles being involved in crashes.*
- *Dark conditions will be associated with greater crash severity.*

7.1.1 VEHICLE SIZE

In order to examine whether the failure of motorists to detect and recognize motorcycles in traffic plays a large role in crashes with motorcycles, multi-vehicle crashes were categorized by vehicle types as motorcycle, passenger car, sport utility vehicle, pickup truck, or large truck. Single-vehicle crashes were excluded from this analysis. Vehicles considered to be at fault due to conspicuity issues were those with a contributing factor assigned to the vehicle as follows: (1) changed lane when unsafe, (2) driver inattention, (3) failed to yield right of way—turning left, (4) failed to yield right of way—turn on red, (5) failed to yield right of way—yield sign, or (6) impaired visibility. The vehicle considered to be not at fault was assigned contributing factors. Crashes were grouped by vehicle type considered at fault. Then, these groups of crashes were stratified by the other type of vehicle that was involved in the crash. These types were grouped as motorcycle, large vehicle, and all crashes. Finally, the proportion of the crashes where the vehicle was at fault due to a conspicuity issue was calculated.

The data in Figure 26 show that vehicles larger than motorcycles had difficulty detecting the motorcycles, which conceivably increased the risk of a crash. When the vehicle at fault was a passenger vehicle, SUV, pickup, or large vehicle that crashed with a motorcycle, 42 to 47 percent of these crashes involved a conspicuity issue. When these at-fault vehicles crashed with large vehicles, the percentage was much lower, ranging from 30 to 35 percent. When the motorcycle was deemed to be at fault, there was little to no difference in the proportion that was related to a conspicuity issue when comparing motorcycles (24 percent) to large vehicles (23 percent).

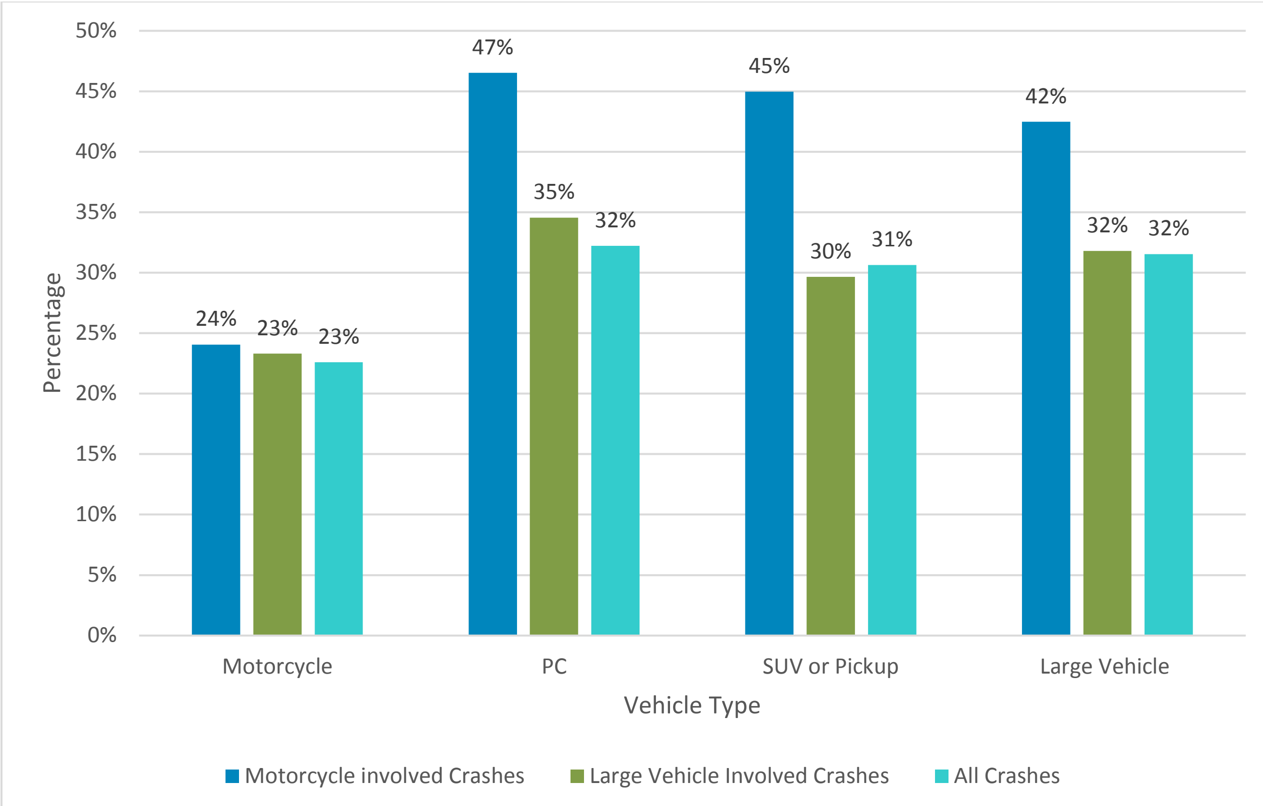


Figure 26: Frequency of conspicuity factors playing a role in multi-vehicle collisions by vehicle type, all severities, 2010–2015.

7.1.2 COLOR

To explore the impact of the color of a motorcycle on conspicuity, crashes of all severities from 2013–2105 were categorized as single-vehicle or multi-vehicle. Then, no-fault status was assigned based on the contributing factors for each unit. Units with no contributing factors identified were categorized as a no-fault vehicle. Vehicle colors were categorized as bright (white, beige, bronze, copper, gold, green, orange, pink, red, silver, teal, and yellow) or dark (black, blue, brown, camouflage, gray, maroon, purple, and tan). Next, the frequency of crashes was computed by vehicle color category and vehicle type, as displayed in Table 37. For no-fault vehicles that were passenger cars or large vehicles, the proportions between bright and dark colors were similar. It can be concluded that vehicle color does not affect the possibility of these vehicle types being involved in crashes. However, for no-fault motorcycles, the proportion of dark vehicle color was more than twice that of bright-colored motorcycles. Despite this difference, there is not sufficient evidence to suggest that motorcycle color plays a significant role in conspicuity since the distribution of color is the same for single-vehicle and multi-vehicle motorcycle crashes. If motorcycle color was a significant factor, differences in the proportions of motorcycle color by single- versus multi-vehicle status would be expected.

Table 37: Frequency of bright versus dark vehicle colors, 2013–2015.

Vehicle Type	Motorcycle				Passenger Car			
Vehicle Color	Freq. of Crashes		Percentage		Freq. of Crashes		Percentage	
	Multi-Vehicle	Single-Vehicle	Multi-Vehicle	Single-Vehicle	Multi-Vehicle	Single-Vehicle	Multi-Vehicle	Single-Vehicle
Bright	2,682	928	31.8%	31.9%	290,405	35,120	48.9%	48.3%
Dark	5,623	1,939	66.6%	66.7%	291,639	35,719	49.1%	49.1%
Unknown	139	38	1.6%	1.3%	11,927	1,887	2.0%	2.6%
Total	8,444	2,905			593,971	72,726		
Vehicle Type	**SUV or Pickup**				**Large Vehicle**			
Vehicle Color	**Freq. of Crashes**		**Percentage**		**Freq. of Crashes**		**Percentage**	
	Multi-Vehicle	**Single-Vehicle**	**Multi-Vehicle**	**Single-Vehicle**	**Multi-Vehicle**	**Single-Vehicle**	**Multi-Vehicle**	**Single-Vehicle**
Bright	268,894	32,826	51.7%	51.5%	46,844	6,854	66.8%	65.7%
Dark	241,758	29,426	46.5%	46.1%	20,593	3,128	29.4%	30.0%
Unknown	9,712	1,511	1.9%	2.4%	2,669	455	3.8%	4.4%
Total	520,364	63,763			70,106	10,437		

7.1.3 LIGHT CONDITIONS

Since light conditions could also play an important role in whether another vehicle collides with a motorcycle simply because the driver did not see the motorcycle, researchers categorized crashes involving motorcycles (2010–2015) and those involving four-wheeled vehicle types (excluding pedestrians and two-wheeled modes; 2013–2015) according to light conditions and conspicuity factors, as shown in Table 38. Proportions of motorcycle-involved crashes and other crashes by light conditions and conspicuity factors were then compared, as displayed in Table 38.

Table 38: Categories of light conditions and conspicuity factors.

Light Conditions	Conspicuity Factors
- Daylight - Dark - Dawn, dusk	- Changed Lane When Unsafe - Driver Inattention - Failed to Yield ROW—Turning Left - Failed to Yield ROW—Turn on Red - Failed to Yield ROW—Yield Sign - Impaired Visibility

As shown in Table 39, the proportion of fatal crashes for motorcycle-involved and four-wheeled-vehicle crashes during dark conditions was higher than for other severity types. For example, for fatal crash severity, the proportion of motorcycle-involved and other-vehicle-involved crashes was 33 percent and 35 percent, respectively. This proportion was higher than the proportions for any of the other severity types. This finding means that a crash is likely to be more severe when it occurs during dark conditions. For the remaining severity types, the proportions of motorcycle-involved crashes during dark conditions and dawn or dusk were higher than ones for four-wheeled vehicle types. This finding indicates that conditions other than daylight may be increasing the likelihood that a motorcycle will not be seen by another motorist.

Table 39: Proportion of crashes involving motorcycle versus four-wheeled vehicle types by severity, conspicuity factors, and light conditions.

Severity Types	Light Condition	MC Involved	Other Vehicles	Conspicuity Factors	
				MC Involved	Other Vehicles
K	Daylight	53.4%	55.2%	59.7%	59.3%
	Dark	41.1%	40.9%	33.1%	35.4%
	Dawn, Dusk	5.3%	3.9%	7.0%	5.1%
A, B, C	Daylight	71.4%	75.4%	70.5%	75.6%
	Dark	25.8%	22.3%	26.7%	22.0%
	Dawn, Dusk	2.5%	2.2%	2.5%	2.2%
Property damage only	Daylight	73.6%	76.4%	69.5%	76.8%
	Dark	24.0%	21.2%	27.4%	20.9%
	Dawn, Dusk	2.1%	2.0%	2.8%	2.1%
All	Daylight	71%	76%	70%	76%
	Dark	26%	22%	27%	21%
	Dawn, Dusk	3%	2%	3%	2%

Note: Data for motorcycles cover 2010–2015; data for other vehicle types cover 2013–2015.

7.2 Engine Size

Research hypothesis:

- *Engine size will contribute to crash risk. (The distribution of engine size and motorcycle type will be described by crash severity. Other factors will also be described, such as helmet use and engine size, by type of motorcycle.*

All fatal motorcycle crashes and a random sample of nonfatal crashes were selected. Engine size and type of motorcycle were determined based on the VIN for the motorcycle recorded in CRIS (see Section 2 for additional information on the methods). Next, the motorcycle type was stratified by engine size and helmet use. Nonfatal and fatal crash types were stratified by both motorcycle type and engine size; see Figures 27 and 28.

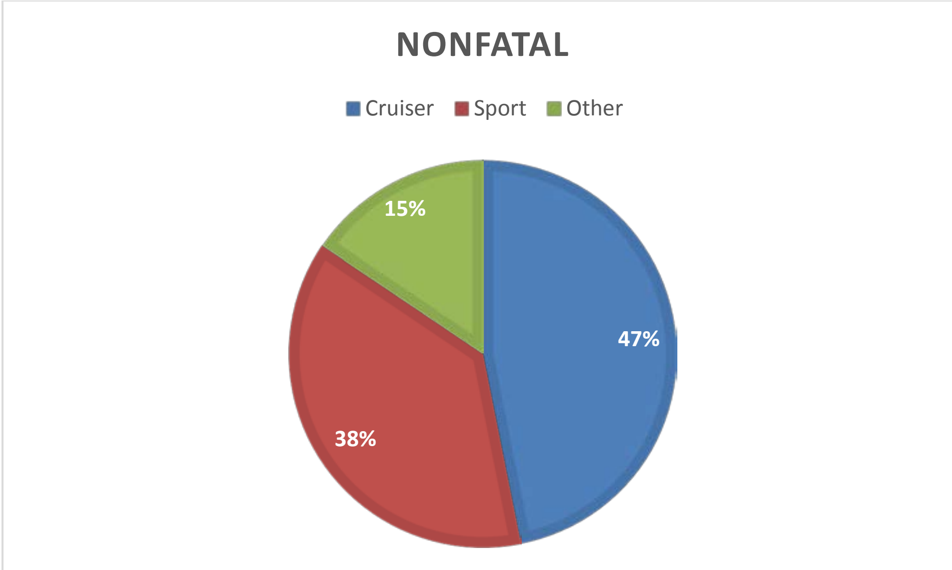


Figure 27: Motorcycle type for nonfatal crashes, 2015.

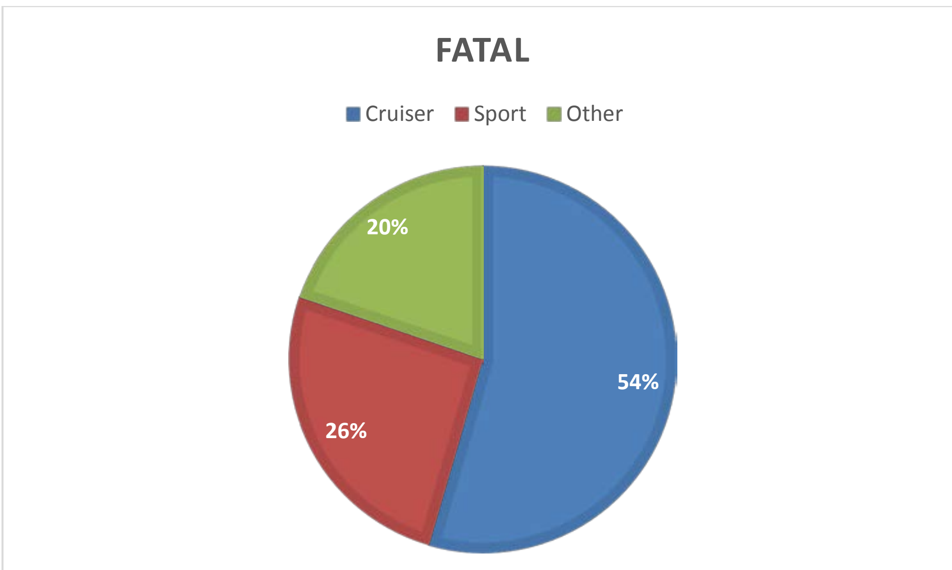


Figure 28: Motorcycle type for fatal crashes, 2015.

As Figures 29 and 30 illustrate, the distribution of type of motorcycle and engine size was similar for nonfatal and fatal crashes. Of all the nonfatal and fatal crashes in the sample, about half involved cruisers. The second highest category was sport bikes. With respect to engine size for nonfatal crashes, the majority (44 percent) had an engine size of 1000–1499cc, followed by 30 percent in the 500–999cc category and 23 percent in the highest category (1500+cc). For fatal crashes, the majority (34 percent) were in the 500–999cc category, followed by 33 percent in the 1000–1499cc category and 26 percent in the 1500+cc category.

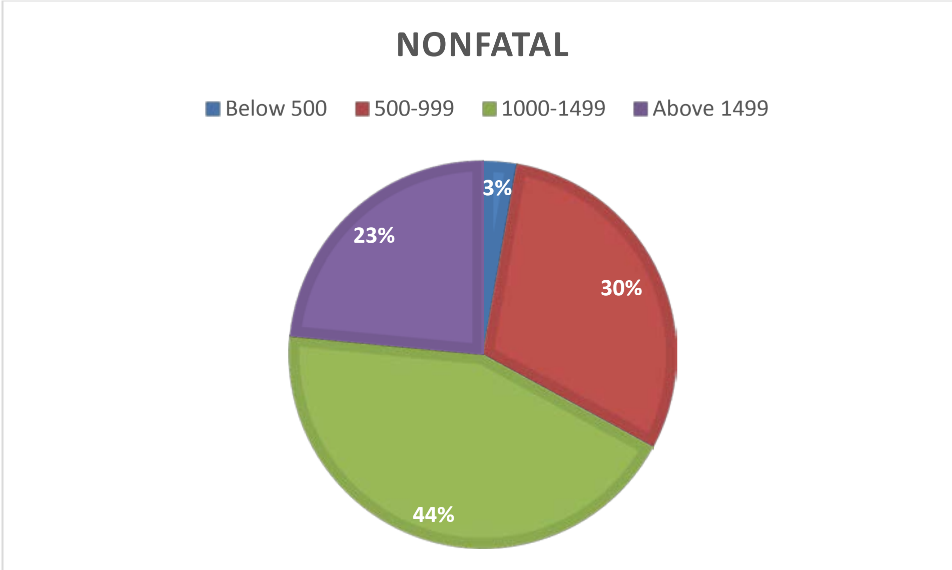


Figure 29: Motorcycle engine size (cc) for nonfatal crashes, 2015.

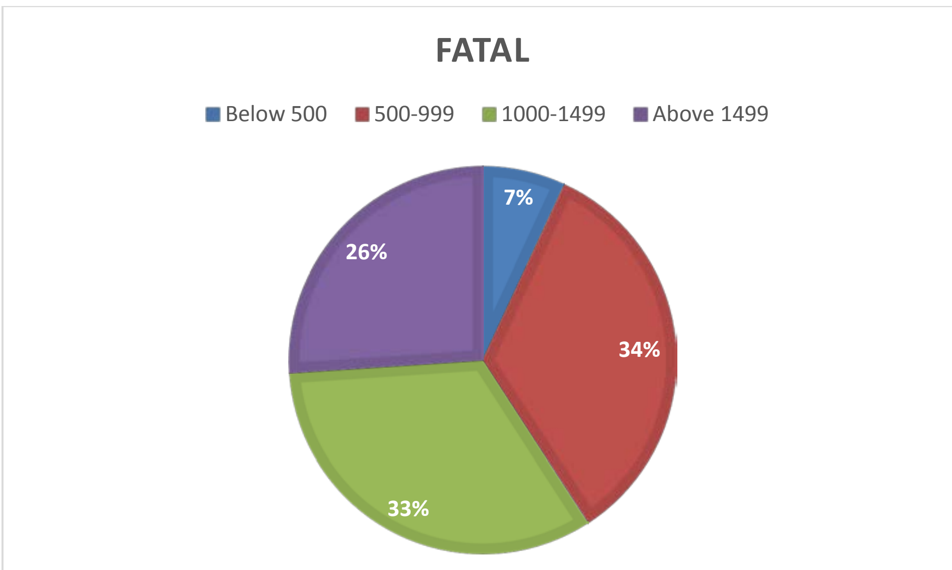


Figure 30: Motorcycle engine size (cc) for fatal crashes, 2015.

Tables 40 and 41 display the distribution of each engine size category by motorcycle type and stratified by nonfatal and fatal crashes. Emphasis is on the two most common motorcycle types. For cruisers involved in nonfatal crashes, a larger proportion was in the lower engine size categories as compared to fatal crashes. The same pattern was observed for sport motorcycles. Interpretation of these data is limited by not having detailed information on the motorcycles not involved in crashes. In addition, the analysis could be further enriched by adding horsepower since engine size may not adequately capture the power or top speeds associated with specific motorcycle make and models.

Table 40: Distribution of motorcycle type by engine size (cc) for nonfatal crashes, 2015.

Motorcycle Type and Engine Size (Nonfatal)					
	<500	**500–999**	**1000–1499**	**1500+**	**Grand Total**
Cruiser	1.2%	22.1%	36.8%	40.0%	100.0%
Dirt Bike	100.0%	0.0%	0.0%	0.0%	100.0%
Dual Sport	0.0%	100.0%	0.0%	0.0%	100.0%
Dual-Sport/ADV	23.1%	53.9%	23.1%	0.0%	100.0%
Quad	50.0%	50.0%	0.0%	0.0%	100.0%
Scooter	100.0%	0.0%	0.0%	0.0%	100.0%
Sport	9.3%	60.5%	30.2%	0.0%	100.0%
Sport—Touring	0.0%	42.9%	57.1%	0.0%	100.0%
Standard	12.5%	87.5%	0.0%	0.0%	100.0%
Touring	0.0%	0.0%	30.8%	69.2%	100.0%
Trike	0.0%	40.0%	20.0%	40.0%	100.0%

Table 41: Distribution of motorcycle type by engine size (cc) for fatal crashes, 2015.

Motorcycle Type and Engine Size (Fatal)					
	<500	**500–999**	**1000–1499**	**1500+**	**Grand Total**
ADV	0.0%	33.3%	66.7%	0.0%	100.0%
Cruiser	0.0%	11.9%	45.5%	42.6%	100.0%
Dirt Bike	66.7%	33.3%	0.0%	0.0%	100.0%
Dual Sport	0.0%	100.0%	0.0%	0.0%	100.0%
Quad	60.0%	40.0%	0.0%	0.0%	100.0%
Scooter	66.7%	33.3%	0.0%	0.0%	100.0%
Sport	2.5%	53.1%	43.2%	1.2%	100.0%
Sport—Touring	0.0%	0.0%	75.0%	25.0%	100.0%
Standard	0.0%	33.3%	66.7%	0.0%	100.0%
Touring	0.0%	0.0%	40.0%	60.0%	100.0%

8 Environmental Factors

KEY POINTS

- 95 percent of K and A motorcycle crashes occur with dry surface conditions.
- 84 percent of motorcycle crashes occur in clear weather.
- Crashes with animals in rural areas were more severe than in urban areas.
- Summer had the highest concentration of motorcycle crashes seasonally.
- Fatalities happened rather close to home addresses, indicating relatively short trip durations.

8.1 Weather

Research hypotheses:

- *The failure of motorists to detect weather will not be a factor in 98 percent of motorcycle accidents.*
- *Approximately 94 percent of the motorcycle crashes will occur under dry surface conditions.*
- *Dark conditions will be associated with greater crash severity.*

CRIS data do not include the variables that can be used to ascertain potential weather conditions at the time of a crash as observed by a peace officer. These variables include roadway surface conditions, light conditions, and weather conditions.

As shown in Table 42, the vast majority (95 percent) of K and A motorcycle crashes occurred with dry surface conditions. This is likely to be a function of the fact that most motorcycle driving is done during favorable weather conditions as opposed to poor weather conditions such as rain. This proportion does not vary greatly by crash severity.

Table 42: Frequency of motorcycle crashes by surface conditions and crash severity, 2010–2015.

	All Severity		**K and A**	
Surface Condition	**Number of Crashes**	**Percent**	**Number of Crashes**	**Percent**
Dry	47,847	94%	12,959	95%
Wet	2,192	4%	500	4%
Sand, mud, dirt	379	1%	106	1%
Other (explain in narrative)	360	1%	85	1%
Standing water	130	<1%	28	<1%
Unknown	76	<1%	14	<1%
Ice	39	<1%	10	<1%
Snow	4	<1%	0	0%
Slush	1	<1%	0	0%
Total	51,028	100%	13,702	100%

With respect to light conditions, Table 43 displays the frequency of crashes by light conditions. Approximately 67 percent of the motorcycle crashes occurred in the daylight and 30 percent occurred in the dark. However, looking at K and A crashes, 60 percent occurred in the daylight and 37 percent occurred in the dark. This finding indicates that dark conditions may be associated with greater crash severity.

Table 43: Frequency of motorcycle crashes by light conditions and crash severity, 2010–2015.

	All Severity		**K and A**	
Light Condition	**Number of Crashes**	**Percent**	**Number of Crashes**	**Percent**
Daylight	33,955	67%	8,166	60%
Dark	15,556	30%	5,062	37%
Dawn/Dusk	1,392	3%	438	3%
Unknown	118	<1%	32	<1%
Other (explain in narrative)	7	<1%	4	<1%
Total	51,028	100%	13,702	100%

With respect to overall weather conditions, Table 44 displays the crash frequency by severity. Approximately 84 percent of the motorcycle crashes occurred in clear weather with little to no variation in the proportions by crash severity, similar to the pattern observed for road surface conditions.

Table 44: Frequency of motorcycle crashes by weather conditions and crash severity, 2010–2015.

	All Severity		**K and A**	
Weather Condition	**Number of Crashes**	**Percent**	**Number of Crashes**	**Percent**
Clear	43,058	84%	11,496	84%
Cloudy	6,230	12%	1,799	13%
Rain	1,341	3%	279	2%
Fog	130	<1%	50	<1%
Severe crosswinds	103	<1%	25	<1%
Unknown	92	<1%	23	<1%
Other	29	<1%	12	<1%
Blowing sand/snow	19	<1%	3	<1%
Sleet/hail	14	<1%	3	<1%
Snow	12	<1%	2	<1%
Total	51,028	100%	13,702	100%

8.1.1 SEASONAL CHANGE

Research hypothesis:
Hot spots will vary by time of year or season.

Since weather patterns vary by season and motorcycle riders may prefer good weather conditions, it is reasonable to expect the frequency of crashes to also vary by month and season. Figure 31 displays how the variation occurs by month. The frequency of crashes increased during months when the weather in Texas tends to be cooler and less rainy, such as March to June and September to October, and decreased during exceptionally hot months (July to August) and cold months (January to February and December).

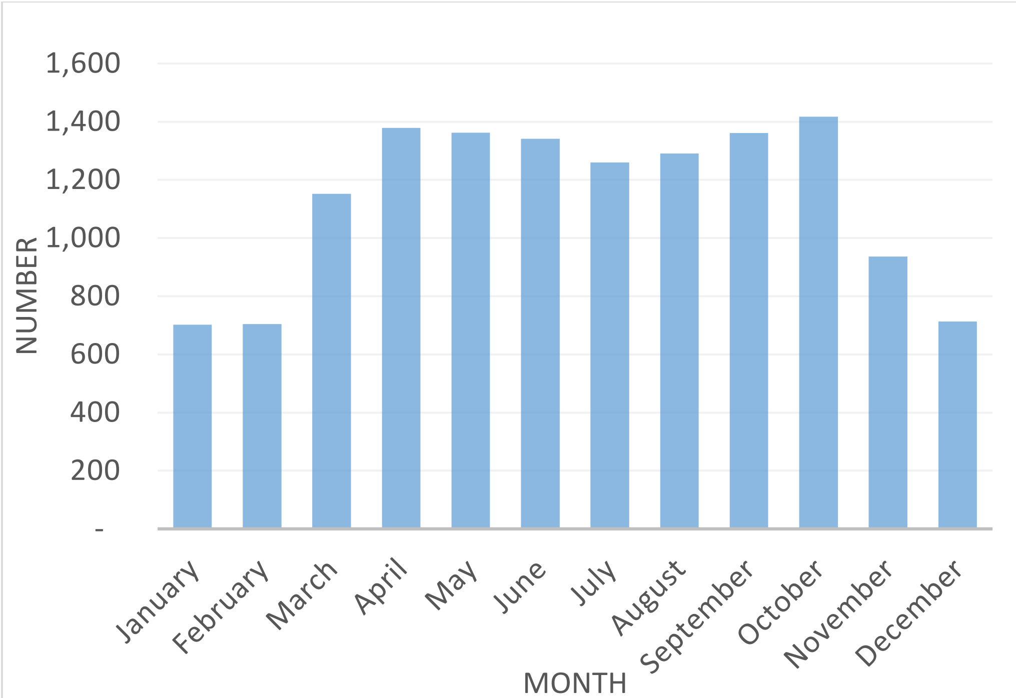


Figure 31: Frequency of K and A motorcycle crashes by month, 2010–2015.

A spatial analysis revealed similar changes by the four traditional seasons of spring, summer, fall, and winter, as shown in Figures 32–35. The colored areas on the maps indicate a higher density of crashes. The highest density of crashes occurred in the red areas, or hot spots. Regardless of the season, the Dallas metropolitan area consistently was identified as the area with the highest motorcycle crash concentration, followed by the Houston, San Antonio, and Austin metropolitan areas. The season with the highest concentration overall was summer, followed by fall, spring, and winter.

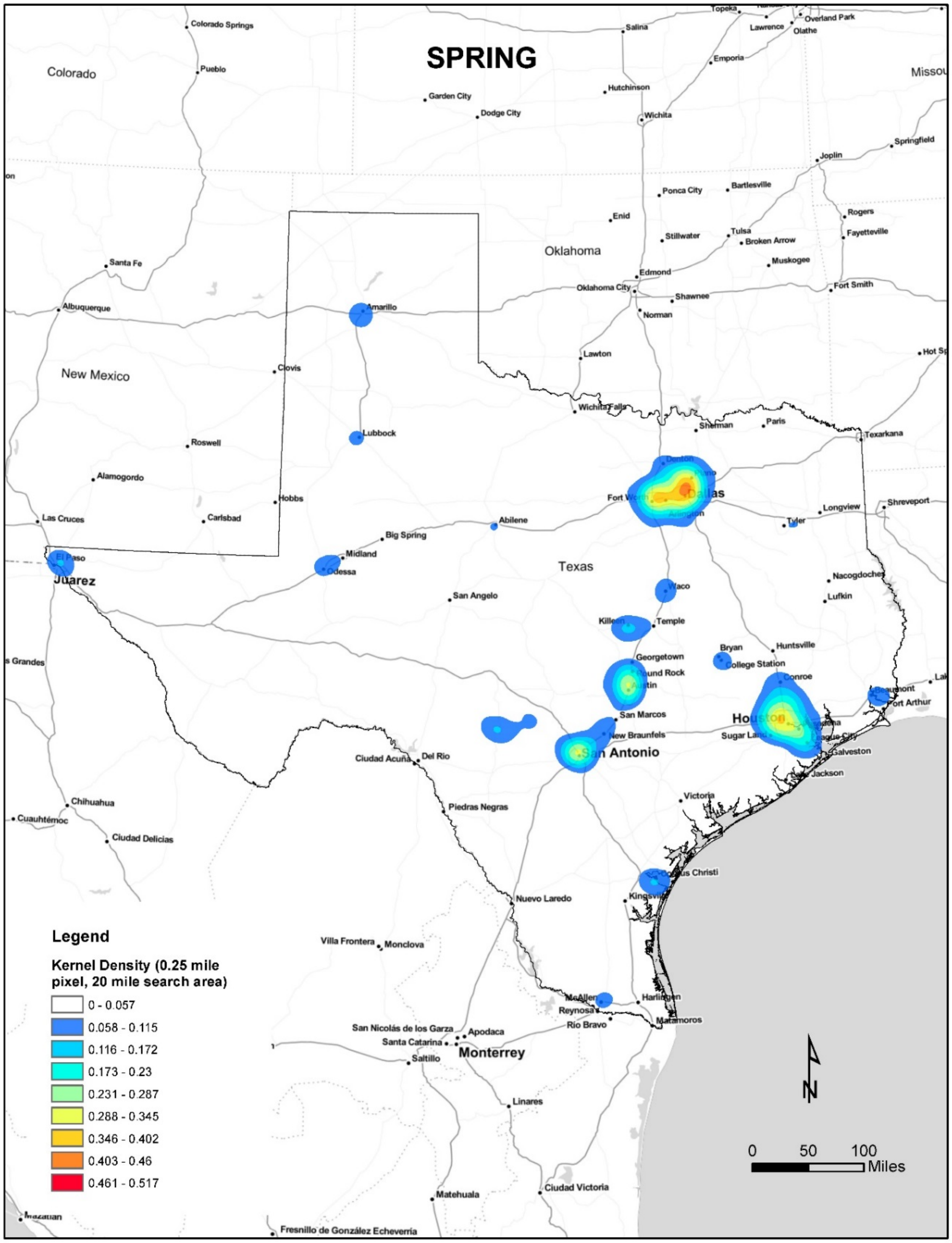


Figure 32: Areas with high concentrations of motorcycle crashes in the spring season, 2010–2015.

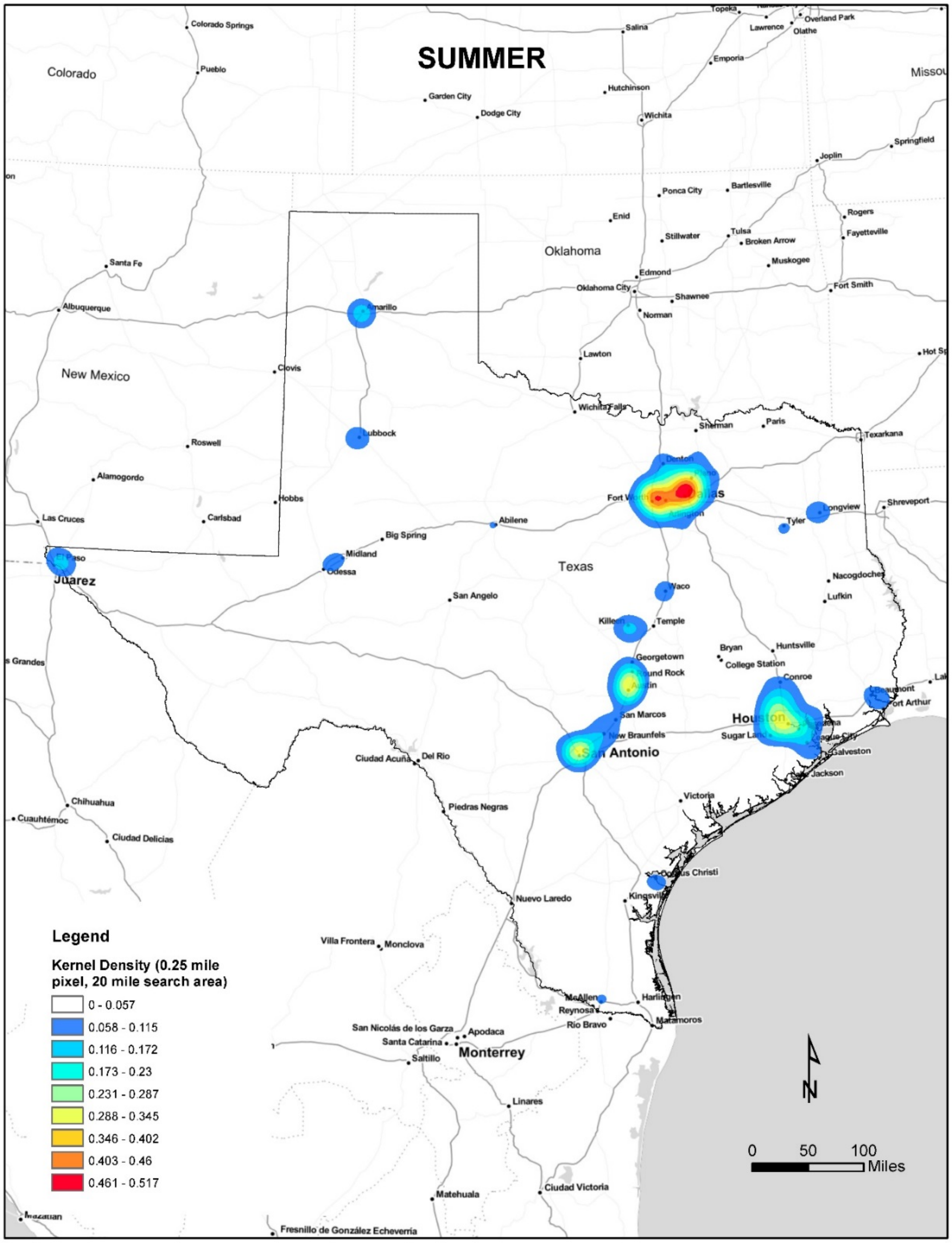


Figure 33: Areas with high concentrations of motorcycle crashes in the summer season, 2010–2015.

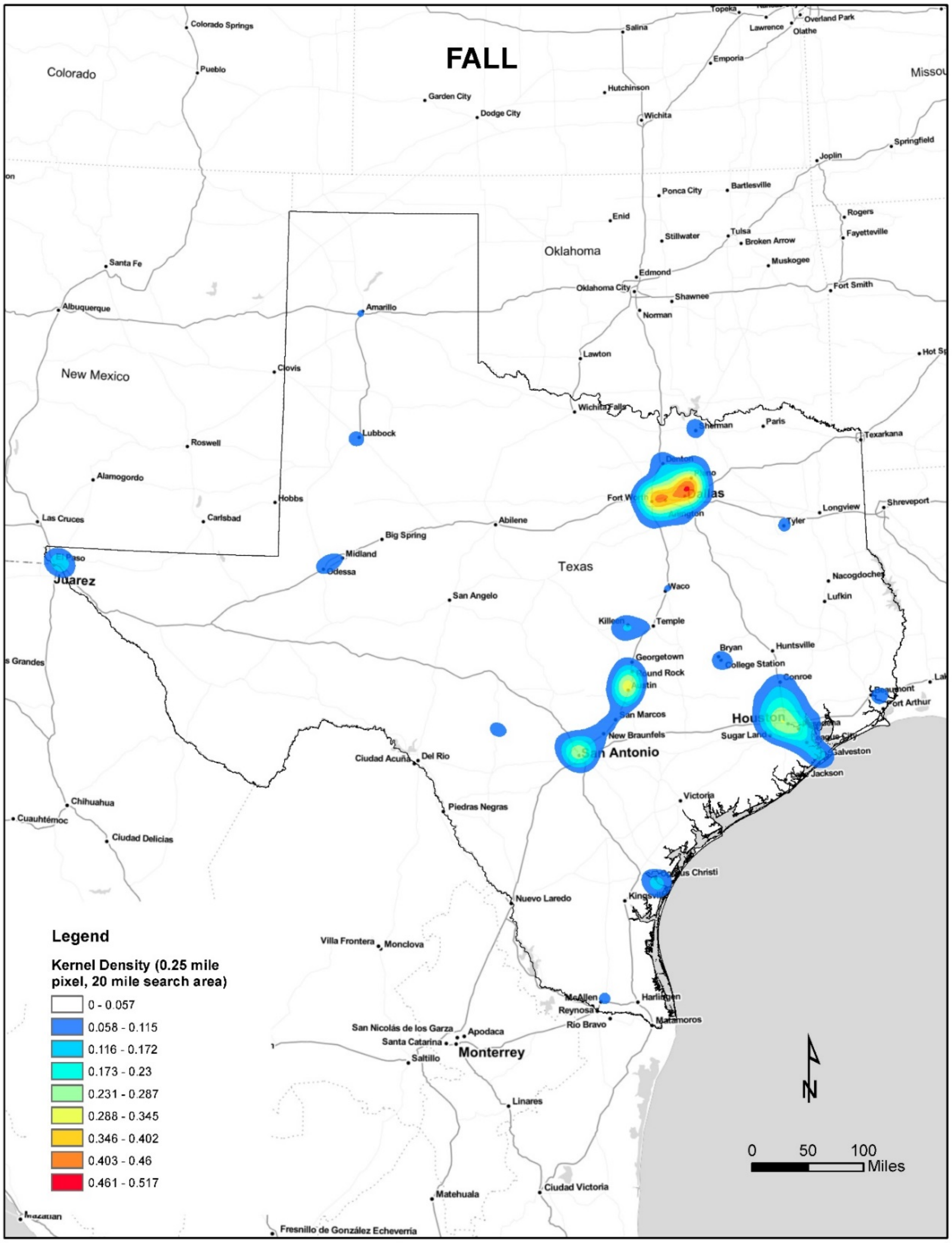


Figure 34: Areas with high concentrations of motorcycle crashes in the fall season, 2010–2015.

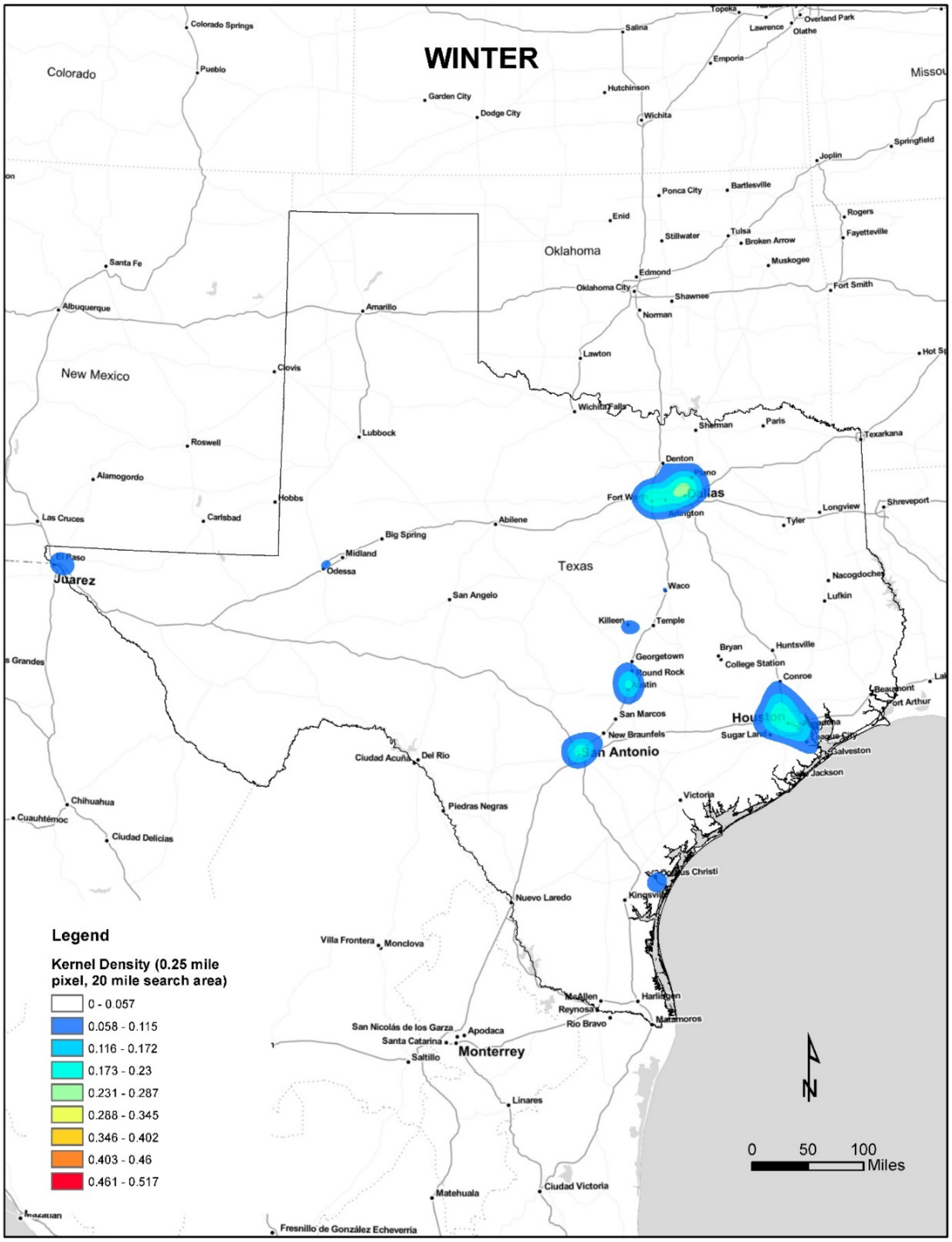


Figure 35: Areas with high concentrations of motorcycle crashes in the winter season, 2010–2015.

8.1.2 COLLISIONS WITH ANIMALS

Research hypothesis:
The failure of motorists to detect animals on the roadway will be a factor for crashes in certain geographic areas.

To begin to understand the spatial distribution of motorcycle collisions with animals, crashes occurring in rural areas involving motorcycles and animals were plotted for 2010–2015; see Figures 36 and 37. In the figures, each point represents a single crash. Each crash severity is represented by a different color, with fatal crashes shown in red. Overall, the crashes were concentrated in rural areas outside the major areas in Texas. There was not a distinct geographic area with an excessive number of severe crashes, as represented by the individual points on the map.

However, a pattern emerged with respect to the distribution of these crashes by rural versus urban status. From 2010–2015, 78 percent of fatalities and injuries sustained by motorcycle riders due to a collision with an animal occurred in rural areas. As shown in Table 45, the severity of these injuries was greater in rural areas compared to urban areas. This finding may be due to the fact that collisions in rural areas are likely to involve wild animals, which tend to be larger in size than animals in urban areas, which tend to be household pets such as smaller cats and dogs.

Table 45: Frequency of person injury severity for rural versus urban status for motorcycle riders involved in crashes with animals, 2010–2015.

	K	A	B	C	Total
Rural	4.1	31.9	48.7	15.3	100.0
Urban	0.5	18.2	54.2	27.1	100.0

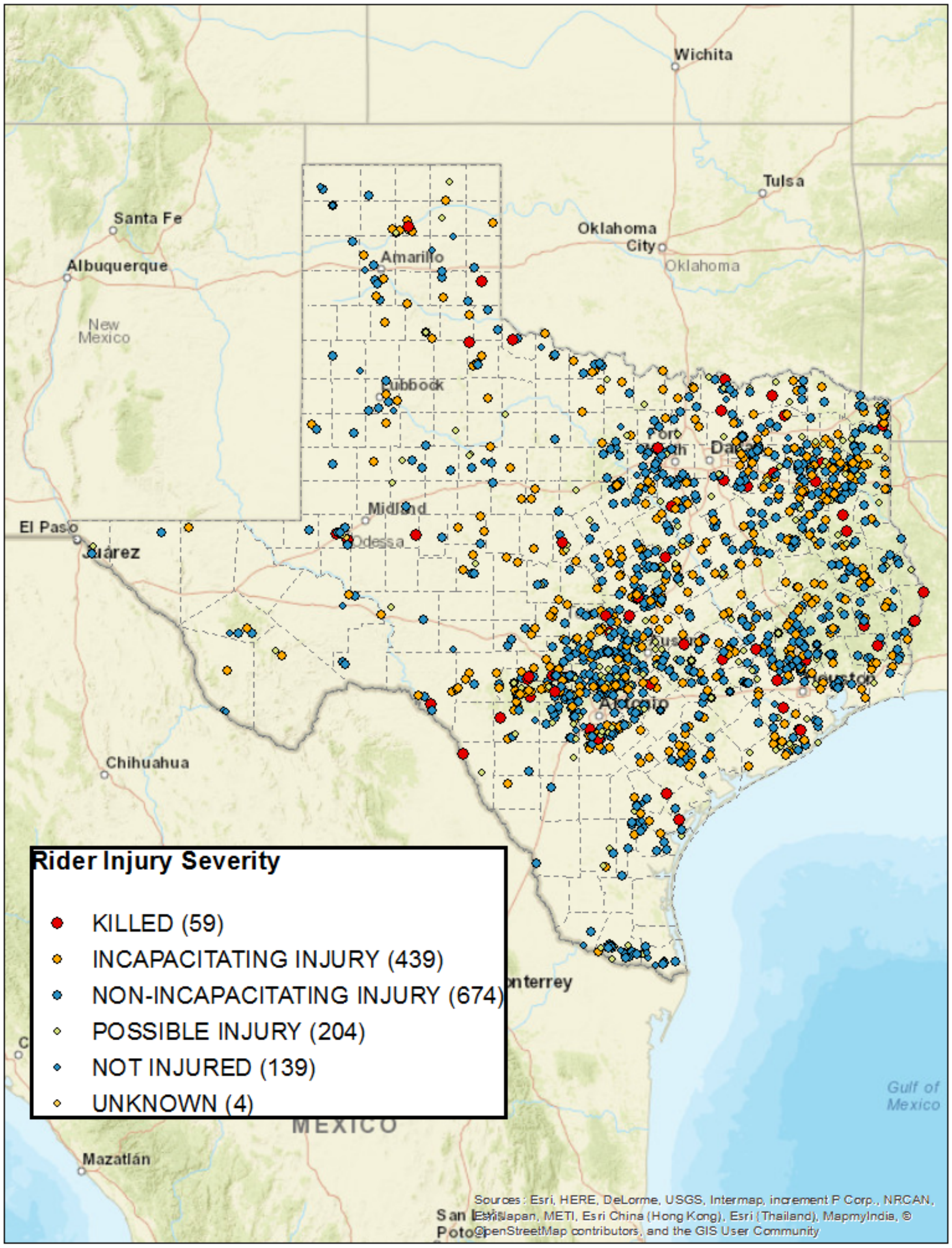


Figure 36: Geographic distribution of motorcycle collisions with animals, all severities, rural areas, 2010–2015.

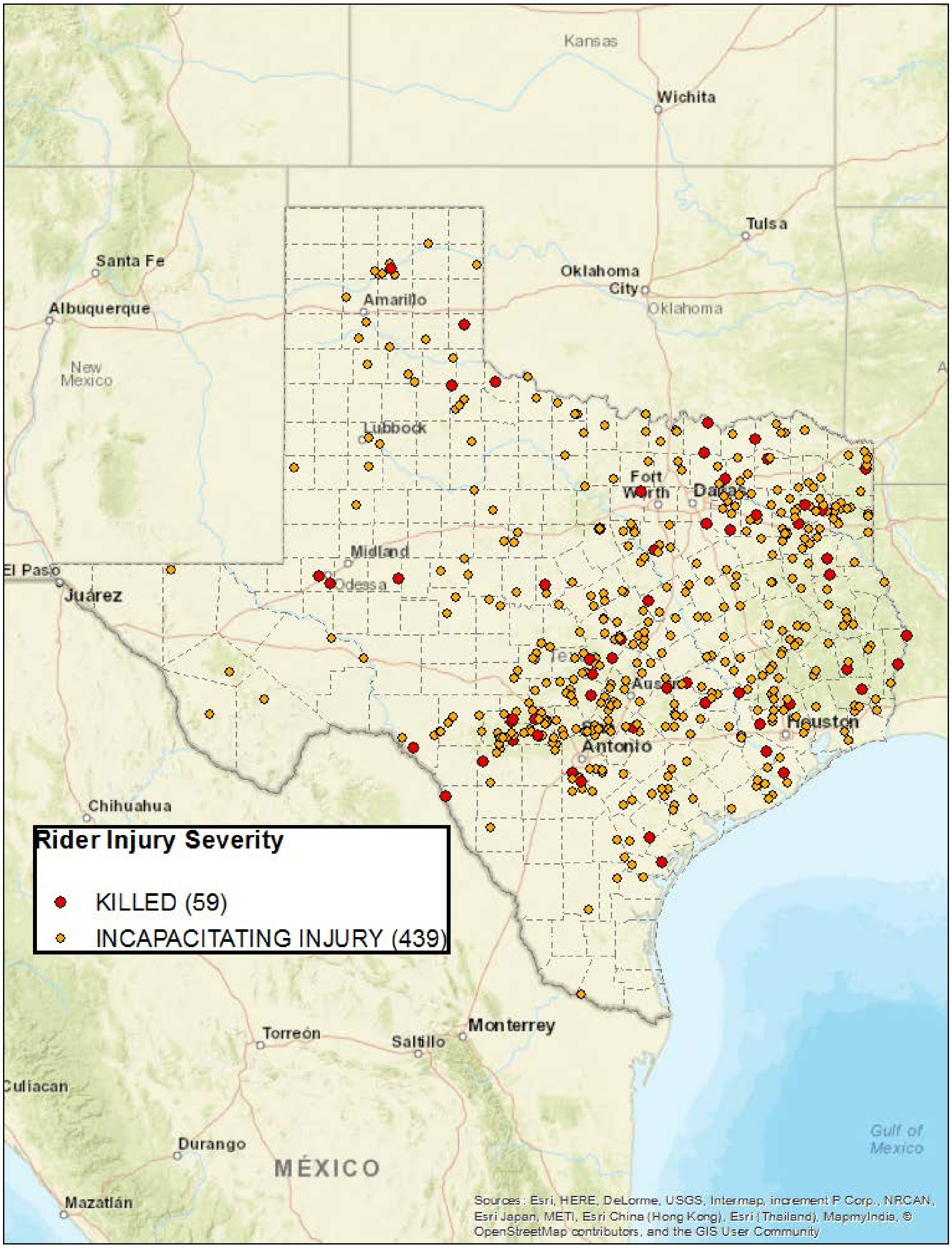


Figure 37: Geographic distribution of motorcycle collisions with animals, K and A crashes, rural areas, 2010–2015.

8.1.3 DISTANCE FROM CRASH TO RESIDENCE

Research hypothesis:
Most motorcycle crashes will involve a short trip associated with shopping, errands, friends, entertainment, or recreation, and the crash is likely to happen a very short distance from the trip origin.

To understand the relationship between possible point of origin and distance to a crash, researchers performed a geospatial analysis to describe the distance from the home address to the crash location. For the years 2010–2015, fatal motorcycle crashes with crash coordinates and a home address in the state of Texas were selected. Overall, fatalities happened rather close to home addresses, indicating relatively short trip durations. For all fatal crashes, median and mean distance were 8 miles and 27 miles, respectively. Distances ranged from 0.03 miles to 654 miles. Since the median is markedly smaller than the mean, a larger number of crashes are occurring closer than 27 miles from home. As may be expected, the distances associated with fatal rural crashes, overall, were greater. The median was 18 miles, while the mean was 48 miles. The range was 0.06 miles to 552 miles. Again, the median is much lower than the mean, indicating that a higher number of fatal, rural crashes are occurring less than 48 miles from home. Related data are displayed in Table 46. Figure 38 displays the plotted crashes and home addresses along with the straight line distance between them. The longer lines illustrate that although the majority of crashes occurred closer to home, many drivers traveled considerable distances across the state.

Table 46: Distribution of distance (miles) from home address to crash location, 2010–2015.

	All Geographies	**Rural Only**
Mean	26.6	48.1
Standard Error	1.3	3.0
Median	7.7	18.3
Standard Deviation	62.8	76.0
Sample Variance	3,941.0	5,782.0
Kurtosis	33.4	11.2
Skewness	5.2	3.0
Range	653.9	552.0
Minimum	0.03	0.06
Maximum	653.9	552.0
Sum	66,410.5	30,189.4
Total Crashes	2,496	628

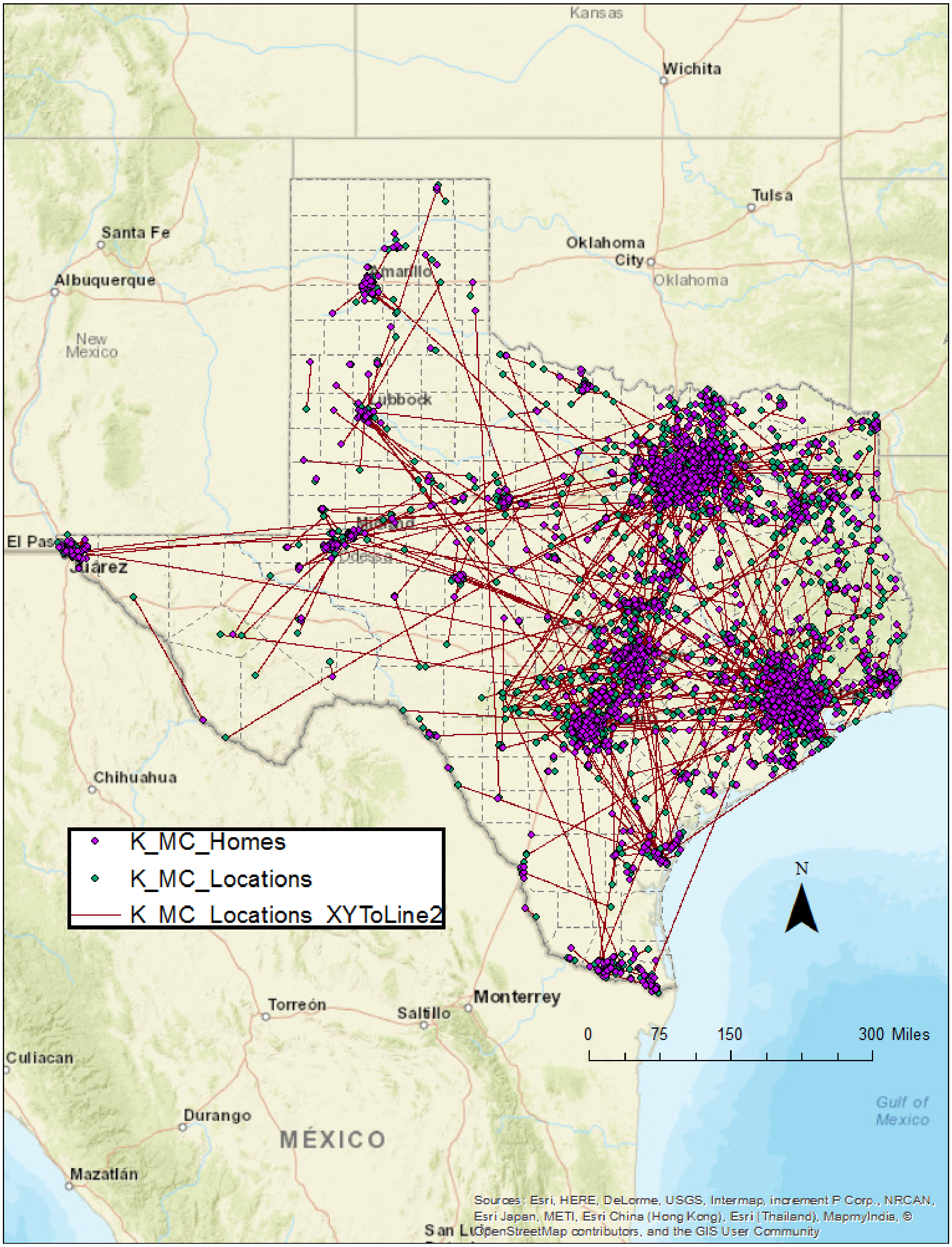


Figure 38: Straight line distances between home address and crash location, fatal crashes, 2010–2015.

9 Multiple Factors: Cross-Cutting Analyses

KEY POINTS

The follow factors were associated with fatal motorcycle crashes: (a) being male, (b) being older than age 40, (c) speeding over posted limited or unsafe speed, (d) not using a helmet, (e) having a positive blood alcohol test, (f) driving in the dark or at dawn/dusk, (g) driving in cloudy or poor weather conditions, (h) driving in an N or P curve configuration, (i) being involved in a head-on crash, (j) being involved in an intersection crash and failing to yield the right of way, (k) disregarding a stop sign or traffic signal, and (l) overturning as well as hitting a variety of different objects.

Research focus:
Determine which crash, vehicle, and person characteristics are associated with fatal accidents.

Thus far, in this report, the described analysis largely was descriptive in nature with counts and percentages reported. This method facilitated understanding how many crashes occurred in different groups, for example, comparing the percentage of drivers using helmets who were killed in crashes versus the percentage of drivers not using helmets who were killed in crashes. The focus of this section is to describe the use of additional statistical tools to estimate how strongly key variables are associated with fatalities among motorcycle drivers. The goal was to have additional information for identifying and prioritizing areas to be addressed by countermeasures or other interventions. This goal was informed by the use of statistical modeling tools that enable estimating the relative risk of being killed in a motorcycle crash given exposure to a variable such as not using a helmet.

For this analysis, logistic regression was used to estimate odds ratios, a type of relative risk measure. The odds ratio is a positive value, where a value of 1 means that there is no association between a variable and an outcome, such as experiencing a fatality. If a variable is associated with fatality in drivers in a manner that is thought to increase the risk of fatality, then the odds ratio will be greater than 1. The further the odds ratio is from 1, the more strongly that exposure or variable is associated with fatality. More specifically, the odds ratio is interpreted as the ratio of the odds that a fatality occurred among those with an exposure to the odds that a fatality occurred among those without the exposure. Example interpretations are provided below. Along with the odds ratio, measures of the stability of the odds ratio were also computed. The 95 percent confidence interval is an indicator of the amount of variability in the data. The wider the confidence interval, the more variability in the data, and the less stable the estimate. If the 95 percent confidence interval includes the null value of 1, the result is not statistically significant. For example, for the variable gender, a comparison group is identified, such as females. The comparison group is assigned a value of 1 since it is considered to be unexposed. Males are then compared to females with respect to fatality. If the 95 percent confidence interval includes the null value of 1, then males are no different from females with respect to the occurrence of fatality among motorcycle drivers. This finding was not the case in this analysis, as discussed below, but it is provided here as an example interpretation.

When multiple variables are entered in the model, adjusted odds ratios and related 95 percent confidence intervals are computed. Adjusted odds ratios are the measure of relative risk if all other exposures or variables in the model are held constant. Said another way, the contribution of other variables is removed, theoretically.

The model displayed in Table 47 was constructed by selecting candidate variables identified in this report, and other published literature, as potentially associated with fatality among motorcycle drivers. Each variable was entered in the model using a forward selection process. Only those variables that were statistically significant (95 percent confidence interval excluded 1) were retained in the final model. The contribution of variables also was assessed in different ways including the use of Akaike Information Criterion and Bayesian Information Criterion.

As noted above, variables in the model, especially those with high odds ratios and narrow confidence intervals that do not include 1, should be strongly considered as possible points for implementation of countermeasures or other interventions if feasible. As Table 46 shows, the following exposures or variables were associated with fatality among motorcycle drivers involved in crashes in Texas from 2010–2015: (a) being male, (b) being older than age 40, (c) speeding over posted limited or unsafe speed, (d) not using a helmet, (e) having a positive blood alcohol test, (f) driving in the dark or at dawn/dusk, (g) driving in cloudy or poor weather conditions, (h) driving in N or P curve configurations, (i) being involved in a head-on crash, (j) being involved in an intersection crash and failing to yield the right of way, (k) disregarding a stop sign or traffic signal, and (l) overturning as well as hitting a variety of different objects. For the weather condition variables, the odds ratio for rain was less than 1, suggesting that it actually protects against fatality. This finding is likely to be an artifact of the data because motorcycle drivers tend to avoid rainy conditions. Consequently, very few if any crashes actually occur under rainy conditions, making it appear as though it could be protective. Regarding objects struck, Table 46 lists those with the highest to lowest odds ratios as hit end or side of bridge; hit culvert headwalls; hit guardrail; hit a pole or post; hit an embankment; hit housing structure, mailbox, tree, shrub, or landscape; hit sign (commercial or highway); hit barrier or retaining wall; and hit a curb. Of note, perhaps one of the most important variables for intervention, based on this analysis, is driving under the influence of alcohol.

Table 47: Adjusted associations between selected variables and fatality among motorcycle drivers, 2010–2015.

Variable	Killed (N=2,436) N (%)	Survived (N=41,951) N (%)	Adjusted OR	95% CI
Driver Gender				
Female	88 (3.6%)	2,644 (6.3%)	1.00	
Male	2,348 (96.4%)	39,307 (93.7%)	1.53	1.22–1.92
Driver Age				
<20–29	681 (28.0%)	14,012 (33.4%)	1.00	
30–39	449 (18.4%)	8,308 (19.8%)	0.97	0.85–1.11
40–49	509 (20.9%)	8,246 (19.7%)	1.18	1.03–1.34
50–59	507 (20.8%)	7,639 (18.2%)	1.37	1.20–1.56
60–69	246 (10.1%)	3,146 (7.5%)	1.93	1.64–2.27
70+	44 (1.8%)	600 (1.4%)	1.84	1.32–2.57
Speed				
No	1,815 (74.5%)	37,542 (89.5%)	1.00	
Yes	621 (24.5%)	4,409 (10.5%)	1.80	1.60–2.01
Helmet Use				
Worn	1,327 (54.6%)	17,008 (40.5%)	1.00	
Not Worn	1,109 (45.5%)	24,943 (59.5%)	1.32	1.21–1.45
Driver BAC >=0.08 g/dL				
No	1,887 (77.5%)	41,370 (98.6%)	1.00	
Yes	549 (22.5%)	581 (1.4%)	11.83	10.25–13.65
Head-on Crash				
No	2,299 (94.4%)	41,487 (98.9%)	1.00	
Yes	137 (5.6%)	464 (1.1%)	11.28	8.99–14.16
Light Condition				
Daylight	1,221 (50.1%)	28.651 (68.3%)	1.00	
Dark, Lighted	563 (23.1%)	7,441 (17.7%)	1.48	1.31–1.67
Dark, Not Lighted	543 (22.3%)	4,584 (10.9%)	1.60	1.42–1.81
Dark, Unknown	8 (0.3%)	145 (0.4%)	1.14	0.53–2.46
Dawn	39 (1.6%)	367 (0.9%)	2.72	1.90–3.89
Dusk	62 (2.6%)	763 (1.8%)	1.33	0.99–1.79

Weather				
Clear	2,021 (83.0%)	35,529 (84.7%)	1.00	
Cloudy	342 (14.0%)	5,074 (12.1%)	1.18	1.03–1.34
Rainy	38 (1.6%)	1,123 (2.7%)	0.57	0.41–0.81
Other poor conditions	35 (1.4%)	225 (0.5%)	2.62	1.77–3.87
Curve Configuration				
No curve	1,966 (80.7%)	36,668 (87.4%)	1.00	
N	444 (18.2%)	5,077 (12.1%)	1.39	1.21–1.56
P	11 (0.5%)	72 (0.2%)	3.72	1.90–7.27
S	15 (0.6%)	134 (0.3%)	1.23	0.67–2.27
Intersection-Related Failed to Yield Right of Way				
No	2,086 (85.6%)	37,093 (88.4%)	1.00	
Yes	350 (14.4%)	4,858 (11.6%)	3.66	3.19–4.19
Type of Object Struck				
No object struck	470 (19.3%)	20,354 (48.5%)	1.00	
Overturned	1,153 (47.3%)	15,345 (36.6%)	3.66	3.24–4.14
Hit curb	154 (6.3%)	1,492 (3.6%)	5.35	4.33–6.62
Hit culvert headwall	38 (1.6%)	118 (0.3%)	12.29	7.96–18.96
Hit guardrail	86 (3.5%)	364 (0.9%)	9.90	7.42–13.22
Embankment	15 (0.6%)	88 (0.2%)	6.42	3.45–11.95
Hit pole or post	35 (1.4%)	171 (0.4%)	8.92	5.87–13.55
Hit sign (commercial or hwy)	47 (1.9%)	292 (0.7%)	6.28	4.37–9.02
Hit barrier, retaining wall	117 (4.8%)	993 (2.4%)	5.86	4.61–7.44
Hit end or side of bridge	32 (1.3%)	34 (0.1%)	46.21	26.67–80.06
Hit housing structure,	169 (6.9%)	925 (2.2%)	6.83	5.47–8.51
mailbox, tree, shrub, or				
landscape	120 (4.9%)	1,775 (4.2%)	3.17	2.52–3.97
Other object type				
Disregarded Stop Sign/Traffic Signal				
No	2,358 (96.8%)	41,470 (98.9%)	1.00	
Yes	78 (3.2%)	481 (1.2%)	4.34	3.26–5.76

Note: n=44,387 motorcycle drivers with complete data. A multiple logistic regression model was constructed using a forward selection process. 95% CIs that include the null value of 1.00 are not statistically significant. This means that the group with a 95% CI that includes 1.00 is not statistically different from the comparison group indicated by an OR=1.00. Year of crash made no contribution to the model.

10 Discussion and Recommendations

This study comprised a comprehensive analysis of motorcycle-involved crashes occurring in Texas from 2010 to 2015. Although the number of motorcycle riders killed each year on the roads in Texas is decreasing and the rates of motorcycle crashes are relatively stable, a considerable number of motorcycles are involved in crashes each year. In 2015, there were 7,127 motorcycle-involved crashes. Of great concern, nearly one-third of these crashes involved a death or incapacitating injury. The rate of these severe crashes based on population size is 3.5 times the rate for the state of Texas overall. Based on recent trends involving dramatic increases in the number of motorcycle registrations in Texas over the last decade, motorcycles as a traffic safety issue will likely continue to be an area of concern for Texas. At present, over 400,000 motorcycles are registered in Texas each year.

Based on the findings discussed in this report, there are several areas that should be considered when implementing countermeasures or designing new countermeasures or other types of interventions and programs. These key findings are briefly discussed below along with comparisons to other reports, such as the Hurt Report.[34] The Appendix contains a comparison of applicable findings with those from the Hurt Report.

One of the more notable contributions of this report is the estimation of exposure based on VMT. Previously, rates for motorcycle crashes in Texas could only be based on population size or number of registered motorcycles. Both of these denominators have limitations since they do not actually capture the number of motorcycle operators driving on the road, the number of motorcycles actually being driven, or the frequency of their use. VMT estimates are beneficial since they support computing rates based on distance driven or time at risk of being involved in a crash. When VMT is used to compute rates for comparison with Texas for all vehicles, the results are astonishing. For 2014, the fatal crash rate for motorcycles was 24 per 100 million vehicle miles traveled. This is approximately 18 times the rate for Texas overall in that same year. The rate of fatal injury was 25 per 100 million vehicle miles traveled, which is in line with the rate reported by NHTSA for the nation in 2014.[35]

The total VMT is much lower than passenger vehicle VMT for the state since, overall, there are far fewer motorcycles than passenger vehicles on the road. In addition, among households with motorcycles, only 8 percent made a weekday trip, while 3 percent made a weekend trip. The bulk of motorcycle trips in Texas are of short distances, with 75 to 80 percent of daily mileage totaling 50 miles or less. These findings are also similar to the Hurt Report. Overall, male motorcycle operators between 36 to 64 years of age with higher incomes are responsible for the majority of trip making. This finding is mirrored by the distribution of crashes to some extent in that the majority of K and A crashes involve male motorcycle drivers. With respect to age, drivers in the 36 to 64 age group are overrepresented in motorcycle crashes as compared to drivers involved in passenger vehicle crashes. This finding is of interest, especially given that the older age groups were more likely to have had a motorcycle endorsement on their driver's license. The distribution of age in crashes examined in the Hurt Report differed markedly. In that study, the groups overrepresented were in the 16- to 24-year-old age group, with underrepresentation in the 30- to 50-year-old age group.

In line with the Hurt Report, the majority of crashes occurred with clear weather conditions (84 percent) and dry pavement (94 percent). This finding is likely due to the fact that motorcycles riders often avoid poor conditions. Similarly, approximately 67 percent of crashes occurred during daylight, with crashing in dark, dawn, or dusk lighting conditions associated with fatality among motorcycle drivers.

One of the exposures of greatest concern is driving under the influence. Approximately half of fatal crashes in the Hurt Report involved alcohol. In this report, the percentage was not much lower, at 44 percent. Of additional concern, DUI was a factor in only 3 percent of non-injury

[34] Hurt, HH, Ouellet JV, Thom, DR. 1981. Motorcycle accident cause factors and identification of countermeasures volume I: Technical Report. DOT HS-5-01160US DOT NHTSA. Available at http://isddc.dot.gov/OLPFiles/NHTSA/013695.pdf.

[35] National Center for Statistics and Analysis. 2016 June. Motorcycles: 2014 data (Traffic Safety Facts. Report No. DOT HS 812 292). Washington, DC: National Highway Traffic Safety Administration.

crashes, but this percentage rose dramatically as crash severity increased to 12 percent for A crashes and 44 percent for K crashes. Having a BAC above 0.08 g/dL contributed significantly to fatality among motorcycle drivers. Speed was a contributing factor in a large proportion of crashes as well. Only 7 percent of non-injury crashes involved speeding as a contributing factor compared to 19 percent of A crashes and 30 percent of K crashes. DUI motorcycle drivers seem to have a particular problem with traveling at an unsafe speed compared to non-DUI motorcycle drivers as well as DUI passenger car drivers.

Helmet use rates in Texas are remarkably high, at 66 percent in 2015, for a state without helmet use legislation.[36] Despite this, a number of riders involved in crashes were not using a helmet, which appears to be associated with injury severity, with 52 percent of fatalities involving riders not using a helmet. Overall, 36 percent of those involved in crashes were not using a helmet. This percentage is only slightly lower than the estimate in the Hurt Report.[37] Of particular concern, 67 percent of DUI drivers were not using a helmet compared to only 13 percent of non-DUI drivers. Further, middle-aged drivers also appear to use a helmet less frequently. The groups the least likely to use a helmet are 30 to 59 years old. Finally, 47 percent of passengers used a helmet compared to 36 percent of drivers, yet a higher proportion of males did not use a helmet compared to females, at 37 versus 29 percent.

Approximately 49 percent of all motorcycle crashes are single-vehicle crashes. The proportion reported in the Hurt Report was only about 25 percent. For these crashes, the first harmful event was most often overturning followed by hitting a fixed object. The most commonly struck objects were curbs, median barriers, and guardrails. Among single motor vehicle crashes, results also suggest that motorcycles may have difficulty maintaining control of the vehicle on curves compared to straight segments in urban but not rural areas.

For collisions with other vehicles, 90 percent involved a passenger vehicle, which is similar to the Hurt Report findings. The top contributing factors for collisions that are intersection related were failure to yield the right of way—turning left or stop sign, failure to control speed, driver inattention, and disregard of stop sign or signal. With respect to multi-vehicle crashes, researchers also found evidence that conspicuity factors played a role in over 40 percent of motorcycle crashes with passenger cars, SUVs or pickups, and large vehicles. In these cases, the other vehicle, not the motorcycle, was the vehicle indicated to be at fault due to a conspicuity issue.

A limitation of these analyses is that very little information is available on motorcycle drivers and passengers who were not involved in crashes. This needs to be considered when interpreting these data. This limitation highlights the need for data on motorists not involved in

[36] Texas A&M Transportation Institute. 2015 Occupant Protection Survey Results. Available at https://tti.tamu.edu/group/cts/2015-occupant-protection-survey-results/.

[37] Hurt, HH, Ouellet JV, Thom DR. 1981. Motorcycle accident cause factors and identification of countermeasures volume I: Technical Report. DOT HS-5-01160US DOT NHTSA. Available at http://isddc.dot.gov/OLPFiles/NHTSA/013695.pdf.

crashes in order to identify risk factors for crashes and injuries with greater specificity and precision. This could be addressed by naturalistic driving studies that focus on motorcycles specifically and that include Texas given its large size and unique population. Much has been gained by conducting similar naturalistic driving studies with passenger vehicles on a large scale, such as the Strategic Highway Research Program 2 (SHRP2) study that follows approximately 3,100 drivers in Seattle, Washington; Bloomington, Indiana; Buffalo, New York; State College, Pennsylvania; Durham, North Carolina; and Tampa, Florida.[38] It may also be fruitful to explore how to add additional data to the CRIS records given recent advances in data science. As an example, the NHTSA VIN Decoder[39] has batch processing capabilities that could eventually support efficiently adding motorcycle characteristics, such as engine size, type, and other information, to the CRIS data.

These findings represent only motorcycle drivers and passengers involved in crashes in Texas. Consequently, findings may not be applicable to other geographic locations. Other areas in the United States or other countries may differ greatly from Texas in terms of environment and demographic characteristics.

In summary, motorcycle riders are an important segment of the traffic population in Texas. Although fewer and fewer motorcycle riders are dying each year, there remains a disparity with respect to the frequency of crashes and injury severity when compared to other motorists. Many safety programs that target DUI, speeding, and other issues benefit all drivers and could be effective for motorcycle drivers as well. However, the results presented in this report indicate that tailored programs also may be required to continue to drive motorcycle deaths toward zero.

[38] Strategic Highway Research Program. Study Centers. Available at http://www.shrp2nds.us/.

[39] National Highway Traffic Safety Administration. VIN Decoder. Available at https://vpic.nhtsa.dot.gov/decoder/.

Appendix

Table A1: Rates of fatalities and incapacitating injuries by county, 2015.

Counties	Population	Fatalities (K)	Incapacitating Injuries (A)	Fatalities and Incapacitating Injuries (K and A)	Fatality Rates per 100,000 (K)	Incapacitating Injury Rates per 100,000 (A)	Fatality and Incapacitating Injury Rates per 100,000 (K and A)	Five or Fewer K and A Injuries
Anderson	57,580	1	2	3	1.7	3.5	5.2	Yes
Andrews	18,105	0	0	0	0.0	0.0	0.0	Yes
Angelina	88,255	1	6	7	1.1	6.8	7.9	No
Aransas	25,350	1	3	4	3.9	11.8	15.8	Yes
Archer	8,715	0	3	3	0.0	34.4	34.4	Yes
Armstrong	1,947	0	2	2	0.0	102.7	102.7	Yes
Atascosa	48,435	2	4	6	4.1	8.3	12.4	No
Austin	29,563	0	4	4	0.0	13.5	13.5	Yes
Bailey	7,210	0	0	0	0.0	0.0	0.0	Yes
Bandera	21,269	1	14	15	4.7	65.8	70.5	No
Bastrop	80,527	2	5	7	2.5	6.2	8.7	No
Baylor	3,618	0	0	0	0.0	0.0	0.0	Yes
Bee	32,874	1	4	5	3.0	12.2	15.2	Yes
Bell	334,941	8	32	40	2.4	9.6	11.9	No
Bexar	1,897,753	28	99	127	1.5	5.2	6.7	No
Blanco	11,004	2	3	5	18.2	27.3	45.4	Yes
Borden	648	0	1	1	0.0	154.3	154.3	Yes
Bosque	17,891	1	6	7	5.6	33.5	39.1	No
Bowie	93,389	5	4	9	5.4	4.3	9.6	No
Brazoria	346,312	3	25	28	0.9	7.2	8.1	No
Brazos	215,037	1	21	22	0.5	9.8	10.2	No
Brewster	9,145	0	1	1	0.0	10.9	10.9	Yes
Briscoe	1,505	0	0	0	0.0	0.0	0.0	Yes
Brooks	7,230	0	0	0	0.0	0.0	0.0	Yes
Brown	37,896	2	2	4	5.3	5.3	10.6	Yes
Burleson	17,460	0	3	3	0.0	17.2	17.2	Yes
Burnet	45,463	1	13	14	2.2	28.6	30.8	No
Caldwell	40,522	0	1	1	0.0	2.5	2.5	Yes
Calhoun	21,895	0	2	2	0.0	9.1	9.1	Yes
Callahan	13,557	0	2	2	0.0	14.8	14.8	Yes
Cameron	422,156	7	17	24	1.7	4.0	5.7	No
Camp	12,682	0	3	3	0.0	23.7	23.7	Yes
Carson	5,969	0	1	1	0.0	16.8	16.8	Yes
Cass	30,313	1	3	4	3.3	9.9	13.2	Yes
Castro	7,656	0	0	0	0.0	0.0	0.0	Yes
Chambers	38,863	1	5	6	2.6	12.9	15.4	No
Cherokee	51,542	0	5	5	0.0	9.7	9.7	Yes
Childress	7,088	0	0	0	0.0	0.0	0.0	Yes
Clay	10,360	0	1	1	0.0	9.7	9.7	Yes
Cochran	2,953	0	2	2	0.0	67.7	67.7	Yes
Coke	3,238	0	0	0	0.0	0.0	0.0	Yes

Counties	Population	Fatalities (K)	Incapacitating Injuries (A)	Fatalities and Incapacitating Injuries (K and A)	Fatality Rates per 100,000 (K)	Incapacitating Injury Rates per 100,000 (A)	Fatality and Incapacitating Injury Rates per 100,000 (K and A)	Five or Fewer K and A Injuries
Coleman	8,338	0	0	0	0.0	0.0	0.0	Yes
Collin	914,127	10	50	60	1.1	5.5	6.6	No
Collingsworth	3,044	0	0	0	0.0	0.0	0.0	Yes
Colorado	20,870	2	5	7	9.6	24.0	33.5	No
Comal	129,048	5	17	22	3.9	13.2	17.1	No
Comanche	13,430	0	0	0	0.0	0.0	0.0	Yes
Concho	4,081	0	2	2	0.0	49.0	49.0	Yes
Cooke	39,229	3	2	5	7.7	5.1	12.8	Yes
Coryell	75,503	0	7	7	0.0	9.3	9.3	No
Cottle	1,426	0	0	0	0.0	0.0	0.0	Yes
Crane	5,048	0	0	0	0.0	0.0	0.0	Yes
Crockett	3,710	0	0	0	0.0	0.0	0.0	Yes
Crosby	5,977	0	0	0	0.0	0.0	0.0	Yes
Culberson	2,236	1	0	1	44.7	0.0	44.7	Yes
Dallam	7,121	0	1	1	0.0	14.0	14.0	Yes
Dallas	2,553,385	41	158	199	1.6	6.2	7.8	No
Dawson	13,520	1	1	2	7.4	7.4	14.8	Yes
Deaf Smith	18,952	0	0	0	0.0	0.0	0.0	Yes
Delta	5,217	0	0	0	0.0	0.0	0.0	Yes
Denton	780,612	6	52	58	0.8	6.7	7.4	No
DeWitt	20,797	0	4	4	0.0	19.2	19.2	Yes
Dickens	2,206	0	0	0	0.0	0.0	0.0	Yes
Dimmit	10,980	0	1	1	0.0	9.1	9.1	Yes
Donley	3,499	0	0	0	0.0	0.0	0.0	Yes
Duval	11,388	0	0	0	0.0	0.0	0.0	Yes
Eastland	18,171	1	3	4	5.5	16.5	22.0	Yes
Ector	159,436	9	11	20	5.6	6.9	12.5	No
Edwards	1,894	0	2	2	0.0	105.6	105.6	Yes
El Paso	835,593	15	39	54	1.8	4.7	6.5	No
Ellis	163,632	6	16	22	3.7	9.8	13.4	No
Erath	41,122	1	3	4	2.4	7.3	9.7	Yes
Falls	17,142	0	0	0	0.0	0.0	0.0	Yes
Fannin	33,693	0	2	2	0.0	5.9	5.9	Yes
Fayette	25,110	2	5	7	8.0	19.9	27.9	No
Fisher	3,827	0	0	0	0.0	0.0	0.0	Yes
Floyd	5,901	0	0	0	0.0	0.0	0.0	Yes
Foard	1,220	0	0	0	0.0	0.0	0.0	Yes
Fort Bend	716,087	3	12	15	0.4	1.7	2.1	No
Franklin	10,651	0	0	0	0.0	0.0	0.0	Yes
Freestone	19,691	0	0	0	0.0	0.0	0.0	Yes
Frio	18,793	1	1	2	5.3	5.3	10.6	Yes
Gaines	20,051	1	3	4	5.00	15.0	20.0	Yes
Galveston	322,225	12	36	48	3.7	11.	14.9	No
Garza	6,415	0	1	1	0.0	15.6	15.6	Yes
Gillespie	25,963	0	9	9	0.0	34.7	34.7	No

Counties	Population	Fatalities (K)	Incapacitating Injuries (A)	Fatalities and Incapacitating Injuries (K and A)	Fatality Rates per 100,000 (K)	Incapacitating Injury Rates per 100,000 (A)	Fatality and Incapacitating Injury Rates per 100,000 (K and A)	Five or Fewer K and A Injuries
Glasscock	1,315	0	0	0	0.0	0.0	0.0	Yes
Goliad	7,531	0	0	0	0.0	0.0	0.0	Yes
Gonzales	20,573	1	1	2	4.9	4.9	9.7	Yes
Gray	23,210	0	0	0	0.0	0.0	0.0	Yes
Grayson	125,467	3	18	21	2.4	14.4	16.7	No
Gregg	124,108	1	9	10	0.8	7.3	8.1	No
Grimes	27,512	1	5	6	3.6	18.2	21.8	No
Guadalupe	151,249	2	10	12	1.3	6.6	7.9	No
Hale	34,360	0	0	0	0.0	0.0	0.0	Yes
Hall	3,138	0	0	0	0.0	0.0	0.0	Yes
Hamilton	8,159	1	2	3	12.3	24.5	36.8	Yes
Hansford	5,610	0	1	1	0.0	17.8	17.8	Yes
Hardeman	3,840	0	0	0	0.0	0.0	0.0	Yes
Hardin	55,865	2	6	8	3.58	10.7	14.3	No
Harris	4,538,028	47	216	263	1.04	4.8	5.8	No
Harrison	66,746	7	13	20	10.49	19.5	30.0	No
Hartley	6,193	0	0	0	0.00	0.0	0.0	Yes
Haskell	5,737	0	0	0	0.00	0.0	0.0	Yes
Hays	194,739	1	20	21	0.51	10.3	10.8	No
Hemphill	4,264	1	0	1	23.45	0.0	23.5	Yes
Henderson	79,545	7	5	12	8.80	6.3	15.1	No
Hidalgo	842,304	4	15	19	0.47	1.8	2.3	No
Hill	34,855	2	4	6	5.74	11.5	17.2	No
Hockley	23,433	0	2	2	0.00	8.5	8.5	Yes
Hood	55,423	0	3	3	0.00	5.4	5.4	Yes
Hopkins	36,223	0	3	3	0.00	8.3	8.3	Yes
Houston	22,785	2	2	4	8.78	8.8	17.6	Yes
Howard	37,206	1	4	5	2.69	10.6	13.4	Yes
Hudspeth	3,379	0	0	0	0.00	0.0	0.0	Yes
Hunt	89,844	1	14	15	1.11	15.6	16.7	No
Hutchinson	21,734	2	1	3	9.20	4.6	13.8	Yes
Irion	1,554	0	0	0	0.00	0.0	0.0	Yes
Jack	8,878	1	0	1	11.26	0.0	11.3	Yes
Jackson	14,816	1	0	1	6.75	0.0	6.8	Yes
Jasper	35,506	1	5	6	2.82	14.1	16.9	No
Jeff Davis	2,156	0	0	0	0.00	0.0	0.0	Yes
Jefferson	254,308	4	16	20	1.57	6.3	7.9	No
Jim Hogg	5,200	0	0	0	0.00	0.0	0.0	Yes
Jim Wells	41,382	0	1	1	0.00	2.4	2.4	Yes
Johnson	159,990	5	20	25	3.13	12.5	15.6	No
Jones	19,970	1	0	1	5.01	0.0	5.0	Yes
Karnes	14,975	0	0	0	0.00	0.0	0.0	Yes
Kaufman	114,690	2	16	18	1.7	14.0	15.7	No
Kendall	40,384	3	6	9	7.4	14.9	22.3	No
Kenedy	407	0	0	0	0.0	0.0	0.0	Yes

Counties	Population	Fatalities (K)	Incapacitating Injuries (A)	Fatalities and Incapacitating Injuries (K and A)	Fatality Rates per 100,000 (K)	Incapacitating Injury Rates per 100,000 (A)	Fatality and Incapacitating Injury Rates per 100,000 (K and A)	Five or Fewer K and A Injuries
Kent	764	0	1	1	0.0	130.9	130.9	Yes
Kerr	50,955	3	7	10	5.9	13.7	19.6	No
Kimble	4,388	0	1	1	0.0	22.8	22.8	Yes
King	282	0	0	0	0.0	0.0	0.0	Yes
Kinney	3,549	0	0	0	0.0	0.0	0.0	Yes
Kleberg	31,857	0	3	3	0.0	9.4	9.4	Yes
Knox	3,860	0	0	0	0.0	0.0	0.0	Yes
La Salle	7,631	0	1	1	0.0	13.1	13.1	Yes
Lamar	49,440	1	6	7	2.0	12.1	14.2	No
Lamb	13,385	0	0	0	0.0	0.0	0.0	Yes
Lampasas	20,588	0	2	2	0.0	9.7	9.7	Yes
Lavaca	19,836	0	3	3	0.0	15.1	15.1	Yes
Lee	16,898	0	1	1	0.0	5.9	5.9	Yes
Leon	17,086	0	4	4	0.0	23.4	23.4	Yes
Liberty	79,654	1	4	5	1.3	5.0	6.3	Yes
Limestone	23,320	0	2	2	0.0	8.6	8.6	Yes
Lipscomb	3,569	0	0	0	0.0	0.0	0.0	Yes
Live Oak	12,229	0	5	5	0.0	40.9	40.9	Yes
Llano	19,796	0	4	4	0.0	20.2	20.2	Yes
Loving	112	0	0	0	0.0	0.0	0.0	Yes
Lubbock	299,453	3	15	18	1.0	5.0	6.0	No
Lynn	5,724	0	1	1	0.0	17.5	17.5	Yes
Madison	14,065	1	3	4	7.1	21.3	28.4	Yes
Marion	10,160	0	4	4	0.0	39.4	39.4	Yes
Martin	5,641	0	0	0	0.0	0.0	0.0	Yes
Mason	4,032	0	1	1	0.0	24.8	24.8	Yes
Matagorda	36,770	2	6	8	5.4	16.3	21.8	No
Maverick	57,706	0	0	0	0.0	0.0	0.0	Yes
McCulloch	8,341	0	1	1	0.0	12.0	12.0	Yes
McLennan	245,671	5	14	19	2.0	5.7	7.7	No
McMullen	820	0	0	0	0.0	0.0	0.0	Yes
Medina	48,417	1	3	4	2.1	6.2	8.3	Yes
Menard	2,164	0	0	0	0.0	0.0	0.0	Yes
Midland	161,077	4	10	14	2.5	6.2	8.7	No
Milam	24,513	0	1	1	0.0	4.1	4.1	Yes
Mills	4,900	0	1	1	0.0	20.4	20.4	Yes
Mitchell	9,067	0	2	2	0.0	22.1	22.1	Yes
Montague	19,262	0	0	0	0.0	0.0	0.0	Yes
Montgomery	537,559	11	39	50	2.1	7.3	9.3	No
Moore	22,255	0	1	1	0.0	4.5	4.5	Yes
Morris	12,516	1	3	4	8.0	24.0	32.0	Yes
Motley	1,148	0	0	0	0.0	0.0	0.0	Yes
Nacogdoches	65,664	0	4	4	0.0	6.1	6.1	Yes
Navarro	48,323	2	6	8	4.2	12.4	16.6	No
Newton	13,986	1	1	2	7.2	7.2	14.3	Yes

Counties	Population	Fatalities (K)	Incapacitating Injuries (A)	Fatalities and Incapacitating Injuries (K and A)	Fatality Rates per 100,000 (K)	Incapacitating Injury Rates per 100,000 (A)	Fatality and Incapacitating Injury Rates per 100,000 (K and A)	Five or Fewer K and A Injuries
Nolan	15,107	0	0	0	0.0	0.0	0.0	Yes
Nueces	359,715	8	20	28	2.2	5.6	7.8	No
Ochiltree	10,747	0	0	0	0.0	0.0	0.0	Yes
Oldham	2,069	2	0	2	96.7	0.0	96.7	Yes
Orange	84,260	2	6	8	2.4	7.1	9.5	No
Palo Pinto	27,895	1	2	3	3.6	7.2	10.8	Yes
Panola	23,766	0	2	2	0.0	8.4	8.4	Yes
Parker	126,042	2	8	10	1.6	6.4	7.9	No
Parmer	9,749	0	0	0	0.0	0.0	0.0	Yes
Pecos	16,203	1	1	2	6.2	6.2	12.3	Yes
Polk	46,972	1	4	5	2.1	8.5	10.6	Yes
Potter	121,802	2	18	20	1.6	14.8	16.4	No
Presidio	6,876	0	2	2	0.0	29.1	29.1	Yes
Rains	11,161	0	3	3	0.0	26.9	26.9	Yes
Randall	130,269	5	7	12	3.8	5.4	9.2	No
Reagan	3,792	0	0	0	0.0	0.0	0.0	Yes
Real	3,307	2	16	18	60.5	483.8	544.3	No
Red River	12,455	0	0	0	0.0	0.0	0.0	Yes
Reeves	14,732	0	1	1	0.0	6.8	6.8	Yes
Refugio	7,289	0	3	3	0.0	41.2	41.2	Yes
Roberts	916	0	1	1	0.0	109.2	109.2	Yes
Robertson	16,659	0	4	4	0.0	24.0	24.0	Yes
Rockwall	90,861	0	6	6	0.0	6.6	6.6	No
Runnels	10,551	1	1	2	9.5	9.5	19.0	Yes
Rusk	53,070	1	7	8	1.9	13.2	15.1	No
Sabine	10,368	0	0	0	0.0	0.0	0.0	Yes
San Augustine	8,473	0	1	1	0.0	11.8	11.8	Yes
San Jacinto	27,413	2	7	9	7.3	25.5	32.8	No
San Patricio	67,357	1	8	9	1.5	11.9	13.4	No
San Saba	5,901	0	0	0	0.0	0.0	0.0	Yes
Schleicher	3,211	0	0	0	0.0	0.0	0.0	Yes
Scurry	17,615	0	2	2	0.0	11.4	11.4	Yes
Shackelford	3,350	0	0	0	0.0	0.0	0.0	Yes
Shelby	25,402	0	1	1	0.0	3.9	3.9	Yes
Sherman	3,072	0	0	0	0.0	0.0	0.0	Yes
Smith	222,936	9	21	30	4.0	9.4	13.5	No
Somervell	8,739	0	4	4	0.0	45.8	45.8	Yes
Starr	63,795	0	1	1	0.0	1.6	1.6	Yes
Stephens	9,440	2	0	2	21.2	0.0	21.2	Yes
Sterling	1,352	0	0	0	0.0	0.0	0.0	Yes
Stonewall	1,410	0	0	0	0.0	0.0	0.0	Yes
Sutton	3,913	0	0	0	0.0	0.0	0.0	Yes
Swisher	7,533	0	2	2	0.0	26.6	26.6	Yes
Tarrant	1,982,498	24	168	192	1.2	8.5	9.7	No
Taylor	136,051	5	20	25	3.7	14.7	18.4	No

Counties	Population	Fatalities (K)	Incapacitating Injuries (A)	Fatalities and Incapacitating Injuries (K and A)	Fatality Rates per 100,000 (K)	Incapacitating Injury Rates per 100,000 (A)	Fatality and Incapacitating Injury Rates per 100,000 (K and A)	Five or Fewer K and A Injuries
Terrell	837	0	1	1	0.0	119.5	119.5	Yes
Terry	12,739	0	0	0	0.0	0.0	0.0	Yes
Throckmorton	1,579	0	0	0	0.0	0.0	0.0	Yes
Titus	32,623	2	1	3	6.1	3.1	9.2	Yes
Tom Green	118,105	1	8	9	0.9	6.8	7.6	No
Travis	1,176,558	23	83	106	2.0	7.1	9.0	No
Trinity	14,402	1	1	2	6.9	6.9	13.9	Yes
Tyler	21,347	1	1	2	4.7	4.7	9.4	Yes
Upshur	40,603	1	5	6	2.5	12.3	14.8	No
Upton	3,651	0	1	1	0.0	27.4	27.4	Yes
Uvalde	27,245	1	1	2	3.7	3.7	7.3	Yes
Val Verde	48,988	3	1	4	6.1	2.0	8.2	Yes
Van Zandt	53,547	1	3	4	1.9	5.6	7.5	Yes
Victoria	92,382	0	7	7	0.0	7.6	7.6	No
Walker	70,699	0	5	5	0.0	7.1	7.1	Yes
Waller	48,656	0	2	2	0.0	4.1	4.1	Yes
Ward	11,721	0	1	1	0.0	8.5	8.5	Yes
Washington	34,765	3	3	6	8.6	8.6	17.3	No
Webb	269,721	1	9	10	0.4	3.3	3.7	No
Wharton	41,486	2	2	4	4.8	4.8	9.6	Yes
Wheeler	5,657	0	0	0	0.0	0.0	0.0	Yes
Wichita	131,705	3	14	17	2.3	10.6	12.9	No
Wilbarger	13,027	0	2	2	0.0	15.4	15.4	Yes
Willacy	21,903	0	0	0	0.0	0.0	0.0	Yes
Williamson	508,514	7	30	37	1.4	5.9	7.3	No
Wilson	47,520	0	3	3	0.0	6.3	6.3	Yes
Winkler	8,005	0	0	0	0.0	0.0	0.0	Yes
Wise	62,953	0	2	2	0.0	3.2	3.2	Yes
Wood	43,356	2	10	12	4.6	23.1	27.7	No
Yoakum	8,546	0	0	0	0.0	0.0	0.0	Yes
Young	18,270	0	0	0	0.0	0.0	0.0	Yes
Zapata	14,374	0	1	1	0.0	7.0	7.0	Yes
Zavala	12,235	0	0	0	0.0	0.0	0.0	Yes
Total	**27,469,114**	452	1864	2316	1.7	6.8	8.4	N/A

Note: Rate estimates for counties with fewer than five cases are not considered stable.

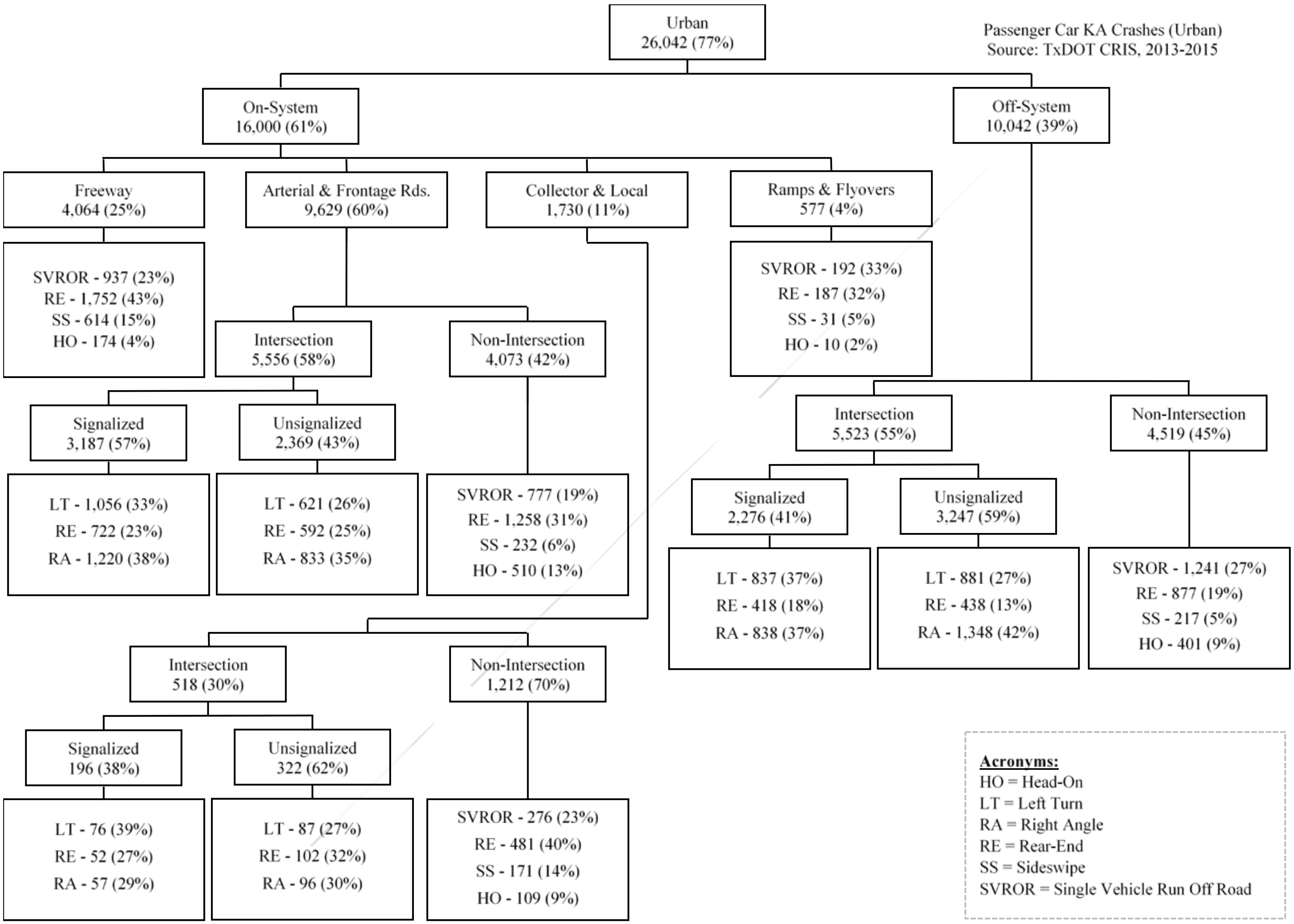


Figure A1: Crash Tree Diagram of Passenger Car KA Crashes in Urban Area.

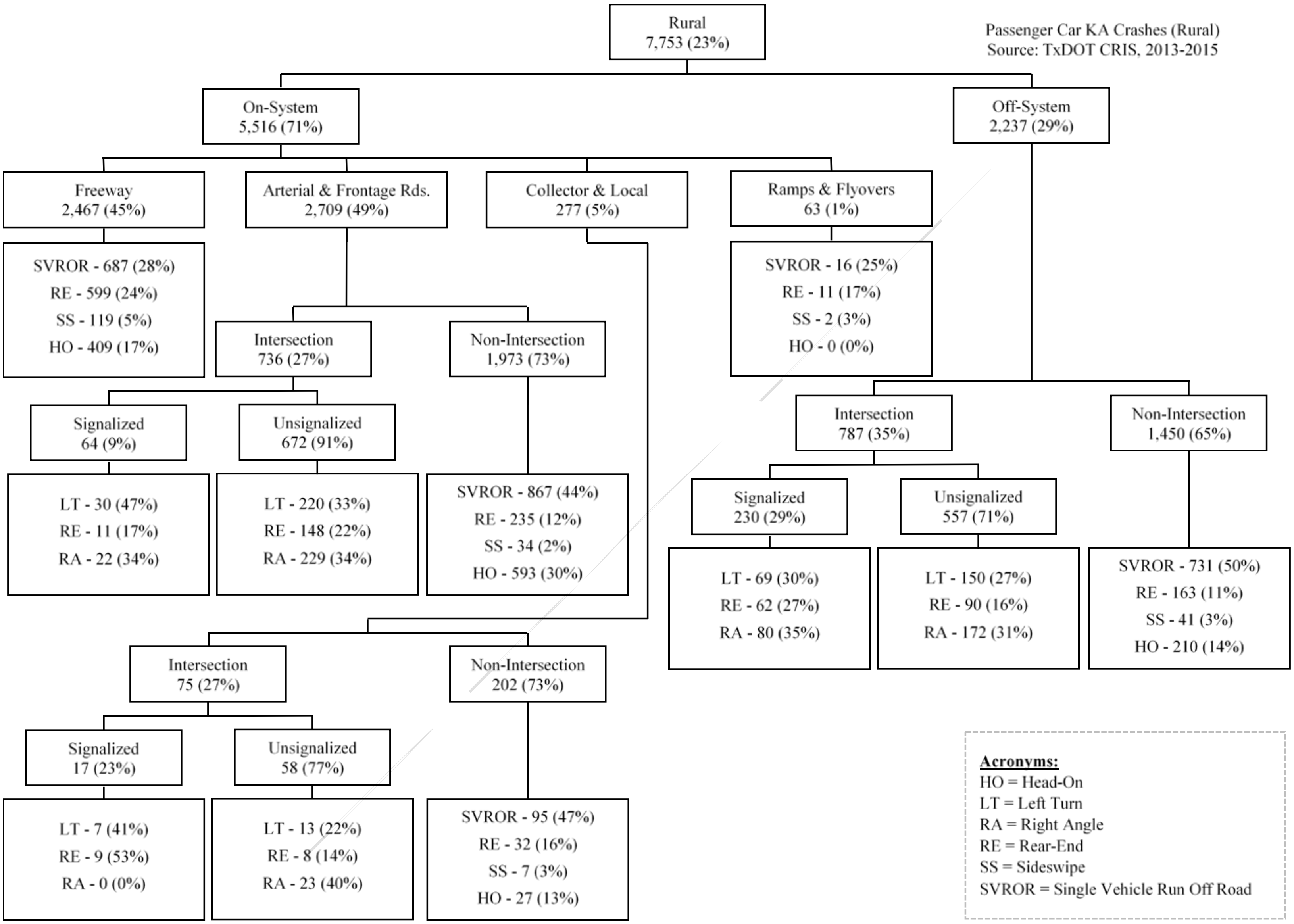


Figure A2: Crash Tree Diagram of Passenger Car KA Crashes in Rural Area.

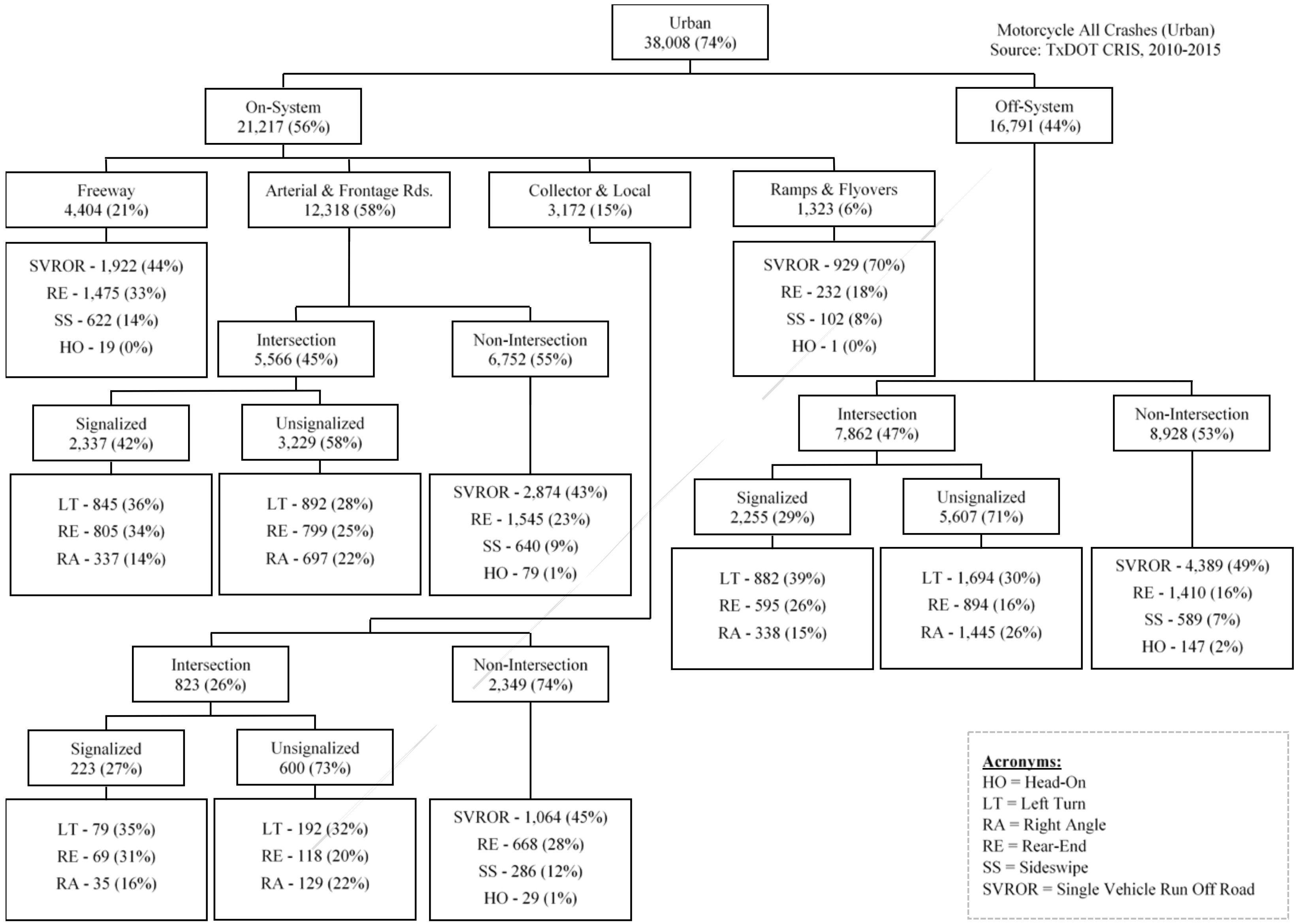


Figure A3: Crash Tree Diagram of All Motorcycle Crashes in Urban Area.

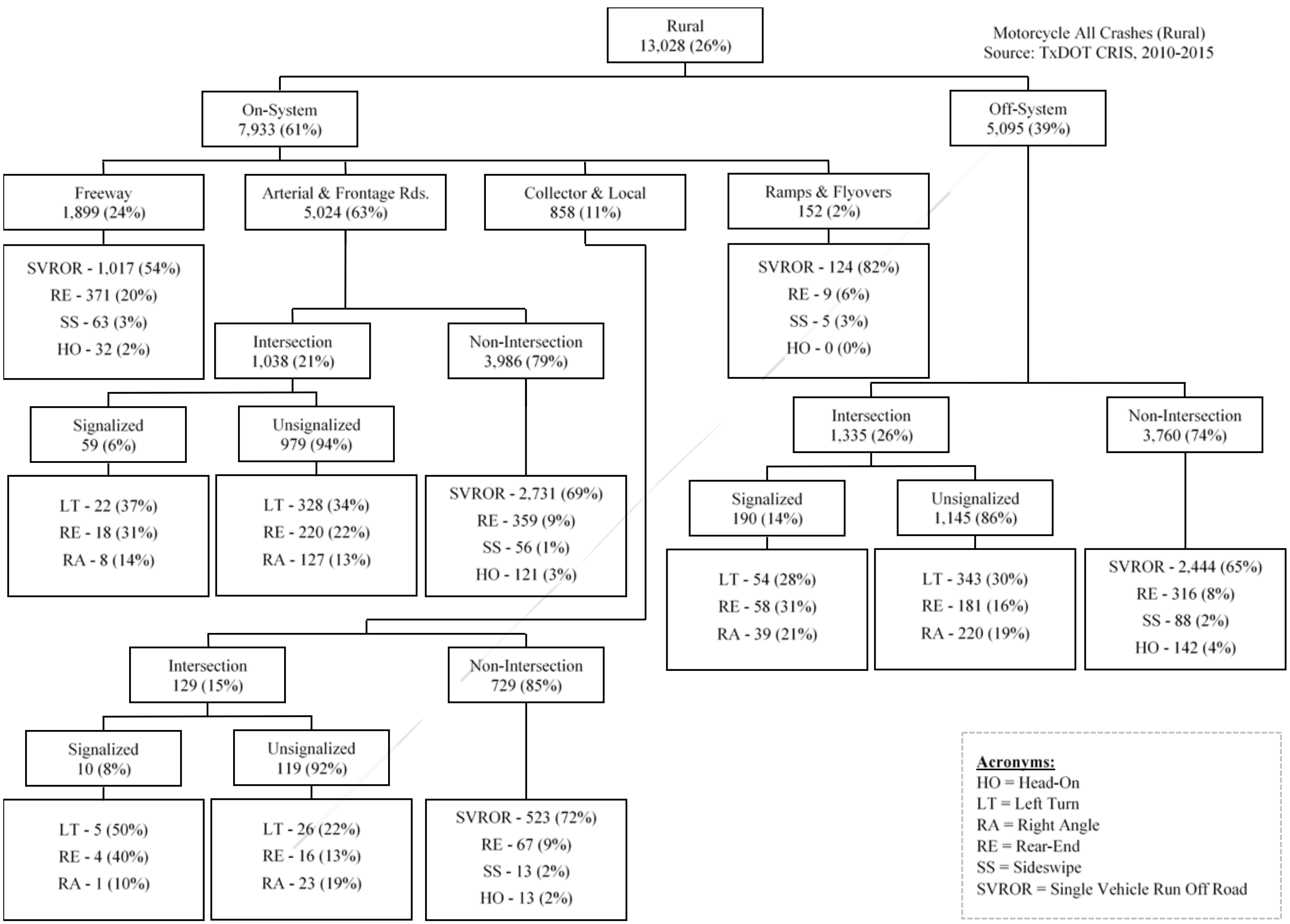


Figure A4: Crash Tree Diagram of All Motorcycle in Rural Area.

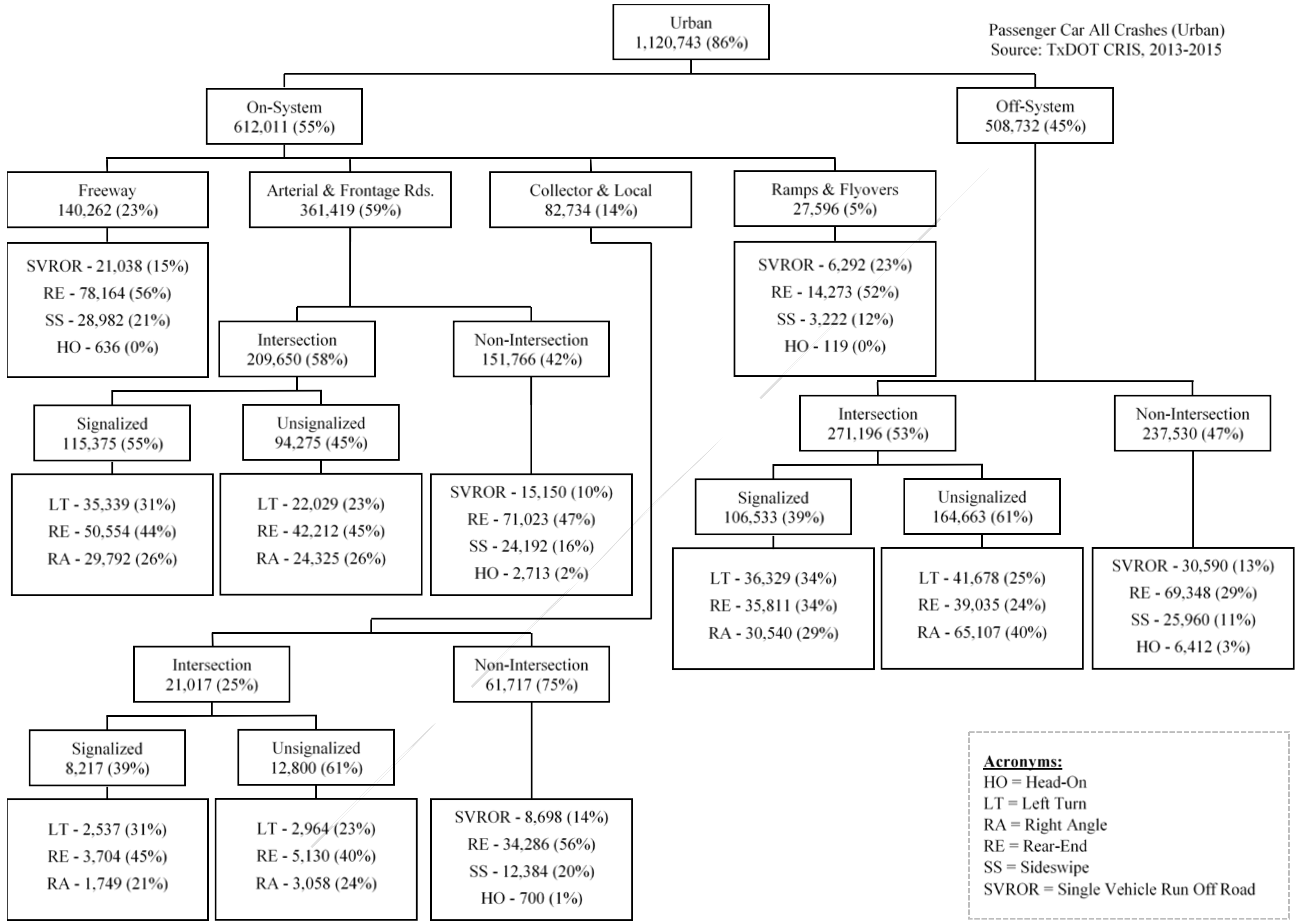


Figure A5: Crash Tree Diagram of All Passenger Car Crashes in Urban Area.

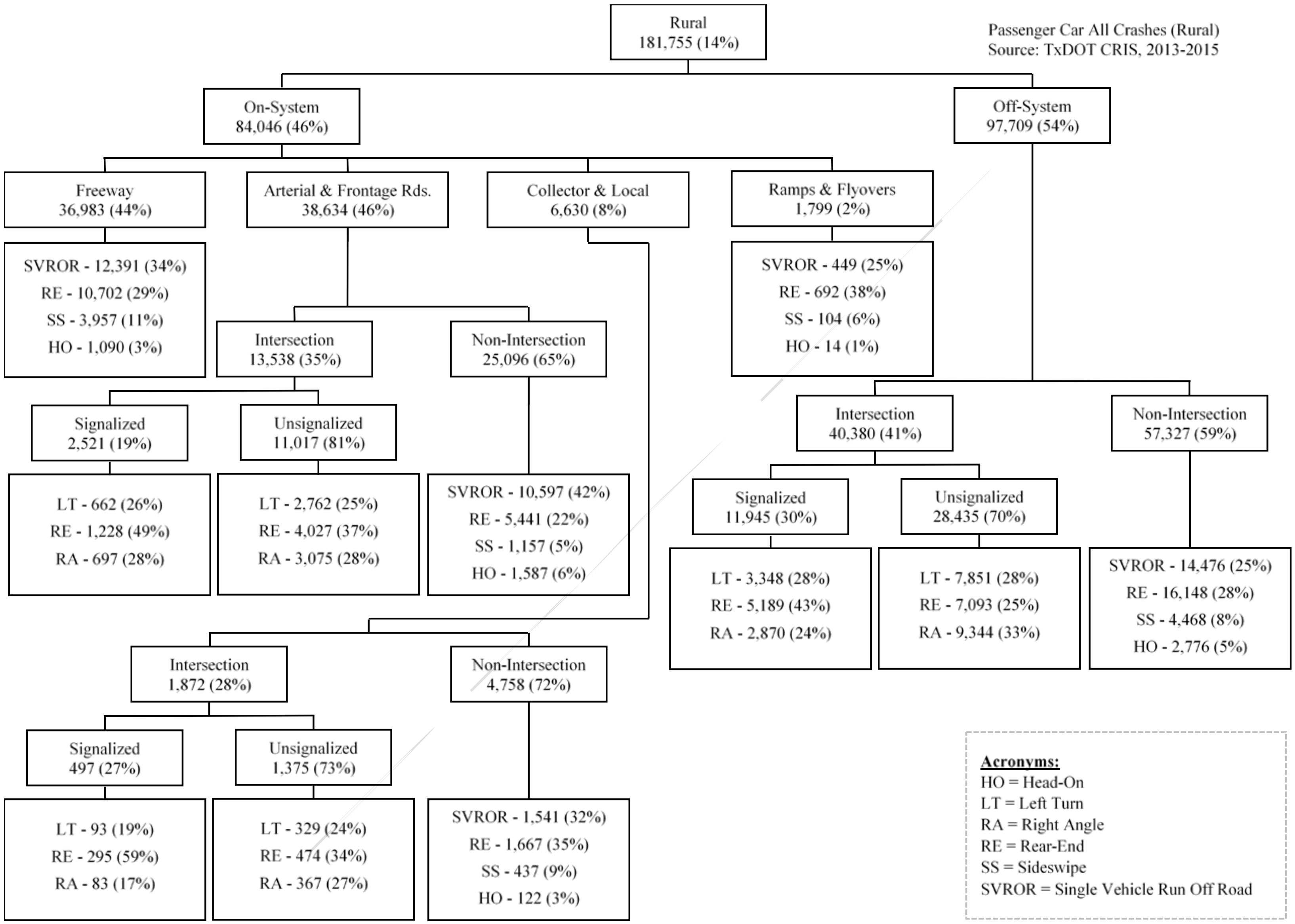


Figure A6: Crash Tree Diagram of All Motorcycle Crashes in Rural Area.

Table A2: Comparison of findings with the Hurt Report.

Category	Potential Finding	Hurt Study	TTI Study	Note
Crash	1. About half of MC crashes involve a collision with a passenger automobile.	Yes	Yes	Section 5.2
	2. Among intersection crashes, left turns and failure to yield right of way are prominent factors.	Yes	Yes	Section 5.2.1 Section 5.2.2
	3. Most single MC crashes involve colliding with the roadway or a fixed object in the environment.	Yes	Yes	Section 5.3
	4. Curves with specific characteristics are overrepresented at single-vehicle crashes.	–	Yes	Section 5.3.1
	5. Other vehicles (parked car) play a non-contact role in single MC crashes.	No	Yes	Section 5.3
	6. Crash severity increases with speed and DUI factors.	Yes	Yes	Section 5.1
	7. MC crashes are likely to happen a very short distance from the trip origin.	Yes	Yes	Section 8.1.3
Environ-ment	1. Collision with animals on the roadway is a factor in certain geographic areas.	–	Yes	Section 8.1.2
	2. Hot spots vary by time of year or season.	–	Yes	Section 8.1.1
Person	1. Younger MC riders are overrepresented.	Yes	No	Section 6.1
	2. Female MC riders are overrepresented.	Yes	No	Section 6.2
	3. DUI MC crashes may occur in closer proximity to alcohol outlets than non-DUI crashes.	–	Yes	Section 5.1.1.1
	4. Among DUI MC crashes, speeding violations are overrepresented.	–	Yes	Section 6.3.2
	5. MC riders in crashes who were without license or with license revoked are overrepresented.	Yes	Yes	Section 6.5
	6. MC drivers with training are overrepresented in crash data.	Yes	Yes	Section 6.6
	7. Injury severity is similar among those with and without training.	–	Yes	Section 6.6
	8. Crash-involved MC riders were significantly not wearing helmets at the time of the crash.	Yes	Yes	Section 6.7
	9. Injury severity is associated with helmet use.	–	Yes	Section 6.7
	10. Percentages of riders that had worn a helmet are different with age.	–	Yes	Section 6.7
Vehicle	1. Vehicle size may play a large role in MC crashes.	No	Yes	Section 7.1.1
	2. Vehicle color does not affect the possibility of motorcycles being involved crashes.	Yes	Yes	Section 7.1.2
	3. Engine size may contribute to crash risk.	Yes	No	Section 7.2
Weather	1. MC crashes occur under dry surface conditions.	–	Yes	Section 8.1
	2. Dark conditions may be associated with greater crash severity.	–	Yes	Section 8.1