September 17, 2018

Analysis of Motorcycle Crashes in Texas, 2010–2017

Texas A&M Transportation Institute

Analysis of Motorcycle Crashes in Texas, 2010–2017

Center for Transportation Safety

Texas A&M Transportation Institute

College Station, Texas

By:

Eva M. Shipp, PhD
Research Scientist

Amber B. Trueblood, DrPH
Assistant Research Scientist

Marcie Perez
Associate Transportation Researcher

Myunghoon Ko, PhD, PE
Assistant Research Engineer

Lingtao Wu, PhD
Assistant Research Scientist

Cody Stewart
Assistant Transportation Researcher

Ashesh Pant
Associate Transportation Researcher

Byron Chigoy
Associate Research Scientist

Sponsor: Texas Department of Transportation (TxDOT)

Project Number: 2018-TTI-G-1YG-0100

Document Version: Final 1.1

September 17, 2018

Texas A&M Transportation Institute

Disclaimer

Table of Contents

List of Figures

List of Tables

Introduction

In 2017, there were 366,473 motorcycles registered in Texas. Motorcycles account for less than 2 percent of the total vehicles registered in Texas.[1] Despite accounting for a small percentage of vehicles on Texas roads, 14 percent of fatal crashes in Texas in 2016 and 2017 involved motorcycles. In 2017, there were 501 motorcycle riders who died on Texas roads.[2] In that same year, motorcycle riders sustained 2,103 suspected serious injuries. Although Texas experienced a decrease in motorcyclist fatalities from 2013 to 2015, the number of fatalities started increasing in 2016 and 2017 while motorcycle registrations have decreased. The occurrence of fatal and serious motorcycle crashes remains high, as do the medical and other costs endured by motorists and society at large.

Motorcycle riders are at a considerably increased risk of sustaining a fatal or nonfatal injury due to a crash. At the national level, fatalities per vehicle miles traveled (VMT) were nearly 28 times higher among motorcycle riders than passenger car occupants.[3] There are several reasons for the overrepresentation of motorcyclist crashes, including:

- Operating requirements for a motorcycle.
  - Ability to maintain balance.
  - Coordination of actions and sense.
  - Traction Management.
  - Acute awareness.
- Motorcycle conspicuity.
  - Size.
- Motorcycle as an open environment.
  - Heat.
  - Cold.
  - Poor weather conditions.
  - No protection in a crash from roadway, fixed objects, and other potential hazards.

Many of the injuries and fatalities sustained by motorcyclists are associated with high medical treatment and other costs that may also result in long-term consequences (e.g., morbidity). The medical costs combined with work loss costs for motorcyclist

---

[1] Fiscal year Registration Class Code Count and the Report of Rental Trailers (for all vehicles registered), prepared by Explore Inc. Available at https://www.txdmv.gov/reports-and-data/cat_view/13-publications/25-reports-data/65-vehicle-titles-registration.

[2] Based on data from the Texas Department of Transportation's Crash Records Information System.

[3] National Highway Traffic Safety Administration. (2018). Traffic Safety Facts 2016 Data: Motorcycles. DOT HS 812 492.

crash deaths in Texas were $665 million in 2013.[4] In addition, motorcycle riders who are diagnosed with a traumatic brain injury, spinal cord injury, or other serious injury may never achieve the same quality of life they enjoyed prior to the crash. These injuries impact 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 with an emphasis on the prevention of fatal and suspected serious injury crashes.

[4] Centers for Disease Control and Prevention. Motor Vehicle Crash Deaths: Costly but Preventable. Available at http://www.cdc.gov/motorvehiclesafety/pdf/statecosts/tx-2015costofcrashdeaths-a.pdf.

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.

Data Sources

This section provides a description of the individual data sets used, as well as a brief description of any data processing or review steps taken.

Motorcycle Crash Data

The Texas Department of Transportation (TxDOT) collects, processes, records, and codes all crash data submitted by police officers through the Texas Peace Officer's Crash Report (Form CR-3). Information from the crash report is entered into the Crash Records Information System (CRIS), an electronic database.

CRIS data from 2010–2017 were obtained and analyzed for this report. The data were extracted on May 21, 2018. For this report, motorcycle crashes are defined as crashes that involve at least one motorcycle, scooter, or moped, including police motorcycles and all-terrain vehicles.

Motorcycle Vehicle Identification Number Data

The vehicle identification numbers (VINs) were run through the National Highway Traffic Safety Administration (NHTSA) Batch VIN Decoder Tool for all motorcycles involved in fatal motorcycle-related crashes for 2010 to 2017.[5] The Batch VIN Decoder tool provides information on motorcycle type (e.g., scooter, moped, cruiser), as well as engine size and other vehicle information. These data were used for the analysis on mopeds versus motorcycles.

Manual Classification of Models

A Texas A&M Transportation Institute (TTI) researcher manually reviewed all unique makes, models, and model years involved in fatal crashes for 2017. The reviewer classified each category of motorcycle, engine size, and weight information (e.g., dry weight and wet weight).

---

[5] NHTSA. (2018, April 19). Vehicle API. Available at https://vpic.nhtsa.dot.gov/api/.

Motorcycle Rider Distance from Residence

Motorcycle riders' residential addresses were pulled from the crash data and geocoded using Texas A&M GeoServices for 2016 and 2017. Texas A&M GeoServices offers geographic information processing services, including geocoding and address processing.[6] This analysis was limited to 2016 and 2017 because the prior report analyzed data from 2010 to 2015.

Motorcycle Training Data

Riders have to complete the Basic Rider Course (BRC) to obtain a motorcycle driver's license (Class M). The BRC teaches riders how to operate a motorcycle, use personal protective equipment, and avoid dangerous situations.[7] Individual de-identified training data from 2017, which included gender, age, site name, and city, were provided by the Texas Department of Public Safety (TxDPS).

Motorcycle Vehicle Registration Data

Through a public records request, the Texas Department of Motor Vehicles provided the number of motorcycles registered by county for 2010 to 2017. The data included year, county, and number of motorcycles registered. Motorcycles were defined as vehicles that were classified as (4) antique motorcycles, (22) motorcycles, (67) OFCL motorcycles, (68) Pearl Harbor Motorcycle, and (69) Disabled Veteran Motorcycle.

Motorcycle Licensing Data

The number of Texas licenses by endorsement were obtained through an open records request to TxDPS. TxDPS provided the number of licenses by endorsement and gender for each county. There are four license classes plus Commercial Driver Licenses (CDL) based on vehicle type, vehicle weight, and number of passengers, including Class A, Class B, Class C, and Class M.[8] The following describe each class as per the Transportation Code Title 7 Subtitle B Chapter 521[9]:

- A Class A driver's license authorizes the holder of the license to operate:
    - (1) a vehicle with a gross vehicle weight rating of 26,001 pounds or more; or

[6] Texas A&M GeoServices. (2018, July 29). Texas A&M GeoServices. Available at http://geoservices.tamu.edu/.
[7] Texas Department of Public Safety. (2018, July 29). The Course for Motorcycle Riders. Available at https://www.dps.texas.gov/msb/thecourse.htm.
[8] Texas Department of Public Safety (2018, September 15). Classes of Driver Licenses. Available at: https://www.dps.texas.gov/DriverLicense/dlClasses.htm
[9] Transportation Code (2018, September 17). Chapter 521. Driver's Licenses and Certifications. Available at: https://statutes.capitol.texas.gov/Docs/TN/htm/TN.521.htm

        - (2) a combination of vehicles that has a gross combination weight rating of 26,001 pounds or more, if the gross vehicle weight rating of any vehicle or vehicles in tow is more than 10,000 pounds.
- A Class B driver's license authorizes the holder of the license to operate:
    - (1) a vehicle with a gross vehicle weight rating that is more than 26,000 pounds;
    - (2) a vehicle with a gross vehicle weight rating of 26,000 pounds or more towing:
        - (A) a vehicle, other than a farm trailer, with a gross vehicle weight rating that is not more than 10,000 pounds; or
        - (B) a farm trailer with a gross vehicle weight rating that is not more than 20,000 pounds; and
    - (3) a bus with a seating capacity of 24 passengers or more.
- A Class C driver's license authorizes the holder of the license to operate:
    - (1) a vehicle or combination of vehicles not described by Section 521.081 or 521.082; and
    - (2) a vehicle with a gross vehicle weight rating of less than 26,001 pounds towing a farm trailer with a gross vehicle weight rating that is not more than 20,000 pounds.
- A Class M driver's license authorizes the holder of the license to operate a motorcycle or moped as defined by Section 541.201.

Population

Two data sources were used for population information. First, population estimates were obtained by the Texas Demographic Center's population projection tool.[10] Unless otherwise specified, all data were downloaded using the 2000–2010 projection migration scenario selection. Second, population information was obtained for 2012–2016 from the American Community Survey for Texas counties.[11]

[10] Texas Demographic Center. 2014 Texas Population Projections by Migration Scenario Data Tool. Available at http://txsdc.utsa.edu/Data/TPEPP/Projections/Tool?fid=EE035840187342F595A96D23935C766D.
[11] United States Census Bureau. (2018). American FactFinder. Available at https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml.

Household Surveys

Travel surveys represent a sample of household demographic and travel characteristics for Monday through Friday weekdays during the school year. Both the National Household Travel Survey (NHTS) and the TxDOT Travel Survey Program (TSP) capture inter-urban travel data.[12] In addition, 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, 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.

Data from both the NHTS and TxDOT TSP were included in this project and are described below.

National Household Travel Survey

The Federal Highway Administration maintains the NHTS, which is a national source focused on personal and household travel, such as population, household, vehicle, and travel characteristics.[13]

TxDOT Travel Survey Program

The TxDOT TSP conducts travel surveys for 25 metropolitan planning organizations, or study areas, across the state on a 10-year rotational basis. The household travel survey is one type of survey that is performed for every study area. Data from this survey consists of demographic information for persons and households, vehicle data, and trip data for a respondent's assigned survey day.

Roadway Inventory/Vehicle Miles Traveled

Multi-year roadway data tables were obtained from the TxDOT and contain information on VMT.[14] This information is publicly available at

---

[12] Schiffer, Robert G. (2012). *NCHRP Report 735: Long-Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models*. National Cooperative Highway Research Program.
[13] Federal Highway Administration. (2018, July 30). *National Household Travel Survey*. Available at https://nhts.ornl.gov.
[14] TxDOT. (2018, July 30). Roadway Inventory. Available at https://www.txdot.gov/inside-txdot/division/transportation-planning/roadway-inventory.html.

https://www.txdot.gov/inside-txdot/division/transportation-planning/roadway-inventory.html.

Fatality Analysis Reporting System Data

Data from the NHTSA Fatality Analysis Reporting System (FARS) from 2015 were obtained and used to explore crash speed. FARS is a national data set focused on fatal motor vehicle crashes.[15] Data for the entire United States were utilized because the sample size for Texas was too small to produce stable estimates.

Motorcycle Crash Database Construction

The following steps were taken to develop the motorcycle crash database, which includes crashes involving a motorcycle in Texas from 2010 to 2017.

1. Full data extracts for the years 2010 to 2017 were requested and extracted on May 21, 2018. Each annual extract contains nine data tables:
    a. Charges table.
    b. Crash table.
    c. Damages table.
    d. Endorsements table.
    e. Lookup table.
    f. Person table.
    g. Primary person table.
    h. Restrictions table.
    i. Unit table.
2. The tables for the analysis were combined and filtered to make complete tables containing all the data related to motorcycle crashes for all eight years.
3. The crashes were identified by using the tables containing person information. Within those tables, individuals that were identified as a "driver of a motorcycle type vehicle" or "passenger/occupant on motorcycle type vehicle" were used to identify motorcycle-involved crashes.
4. Using the list of the motorcycle-involved crashes, all of the other tables involved in the analysis were filtered to create tables that only included information related to motorcycle crashes.
5. The following are the basic crash tables:
    a. MC_Crash_2010-2017_Table: Contains overall crash details for TxDOT reportable motorcycle crashes from 2010–2017.
    b. MC_Crash_Units_2010-2017_Table: Contains all the units involved in the TxDOT reportable motorcycle crashes from 2010–2017.
    c. MC_Crash_PrimPrsn_2010-2017_Table: Contains all the primary persons (drivers, motorcycle operators, pedestrians, cyclists) involved in the TxDOT reportable motorcycle crashes from 2010–2017.
    d. MC_Crash_Prsn_201-2017_Table: Contains all the non-primary

[15] NHTSA. (2018, July 30). Fatality Analysis Reporting System (FARS). Available at https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars.

persons (passengers, motorcycle passengers) involved in the TxDOT reportable motorcycle crashes from 2010–2017.

   e. All MCRiders 2010-2017_Table: Contains all the motorcycle operators and passengers in the TxDOT reportable motorcycle crashes from 2010–2017.
   f. MC_Crash_2010-2017_Table_W_MC_Severity: Contains the same data as in the above listed "MC_Crash_2010-2017_Table" and the additional variable "MC Crash Injury Severity," which gives the overall crash severity based on the injuries of the motorcycle rider.

6. In addition, training, licensing, registration, population, NHTS, local household travel survey, and VMT data were added to the database.

Curve Tool Construction

Data from the 2016 Texas Roadway Inventory with crash data were utilized to develop a curve analysis methodology.[16] The following steps were used:

1. Mapped the latitude and longitude points from the roadway inventory data.
2. Created roadway segments from the mapped latitude and longitude points.
3. Developed an online geographic information system (GIS)–based tool to identify curves.
   a. The tool uses several tests to determine if a segment is a curve, including:
      i. Minimum deflection angle.
      ii. Minimum ratio of a segment's deflection angle to its length.
      iii. Minimum contiguous curve segments required.
   b. To determine if a crash is curve related, the tool allows a user to define the maximum crash-to-nearby-curve distance in feet.

Crashes from the area known as "The Three Sisters" were utilized for an in-depth curve crash analysis. Results are found in the Curve Involvement section.

Data Analysis

This project utilized two categories of statistical analytical approaches:

- Descriptive statistical analysis.
- Geospatial analysis.

Various software packages were used to complete the analyses, including:

- ArcGIS 10.4.[17]

---

[16] TxDOT. (2018). Roadway Inventory. Available at https://www.txdot.gov/inside-txdot/division/transportation-planning/roadway-inventory.html.

[17] Environmental Systems Research Institute, Redlands, CA.

- MicroStrategy 10.8.[18]
- Microsoft Excel and Access 2016.[19]
- R V 3.4.4.[20]
- SAS 9.4.[21]
- SAS Enterprise Guide 7.15.[19]
- STATA SE 14.[22]

Descriptive Statistical Analysis

Descriptive measures comprise the majority of the analysis presented in this report, including counts and percentages or proportions. Descriptive measures were stratified by year, injury severity, demographics (e.g., age, gender), and other factors in order to make comparisons and identify factors that may play an important role in motorcycle crashes and the causation of fatal and suspected serious injuries.

In addition, rates were calculated as the number of crashes divided by the number of people in the population, the number of registered vehicles, or the VMT.

Last, crash trees were constructed to examine variation of crash characteristics. Crash trees are developed by separating crashes into on- and off-system categories, roadway type, and intersection-related status. Finally, crash types are determined for the resulting subcategories.

Geospatial Analysis

Geospatial analysis or mapping approaches were used to explore spatial patterns of motorcycle crashes, including counts of crashes by county, counts of motorcycle registrations by county, and distance from residence to crash site. Geospatial analysis allows for identification of spatial trends (e.g., hot spots for crashes) that may otherwise go unnoticed. All data mapped were classified using quantiles—classes with the same number of data values.

---

[18] MicroStrategy Inc., Tysons Corner, VA.
[19] Microsoft Corporation, Redmond, WA.
[20] R Core Team. (2013). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. Available at http://www.R-project.org/.
[21] SAS Institute Inc., Cary, NC.
[22] StataCorp LP, College Station, TX.

Results

Motorcycle Registrations, Training, and Licensing

The following section provides descriptive information on motorcycle registrations, training, and licensing in Texas.

Motorcycle Registrations

Figure 1 displays the number of motorcycle registrations by year for 2010 to 2017. There was a steady increase in the number of registered motorcycles from 2010–2014; however, since 2015, the number of registered motorcycles has been steadily declining. This could potentially be due to improvements in the economy. Motorcycles are an economical vehicle due to their low cost to purchase, as well as high fuel economy.

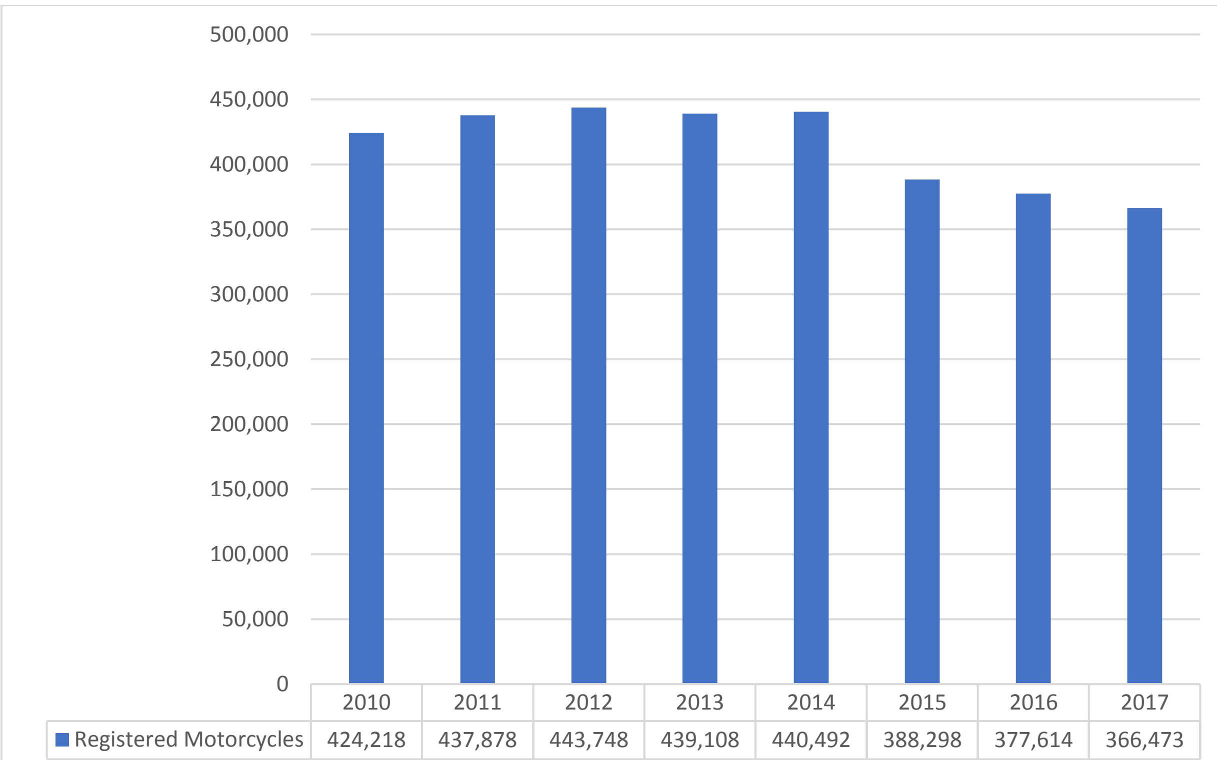


Figure 1: Number of Motorcycle Registrations by Year in Texas, 2010–2017

Figure 2 displays the variation in the number of motorcycle registrations by county in Texas in 2017. As expected, the counties with the highest number of motorcycle registrations correspond to the most populated areas of Texas. The top counties for motorcycle registrations include Bexar, Collin, Dallas, Denton, Ellis, Harris, Montgomery, Tarrant, Travis, and Williamson (data not shown).

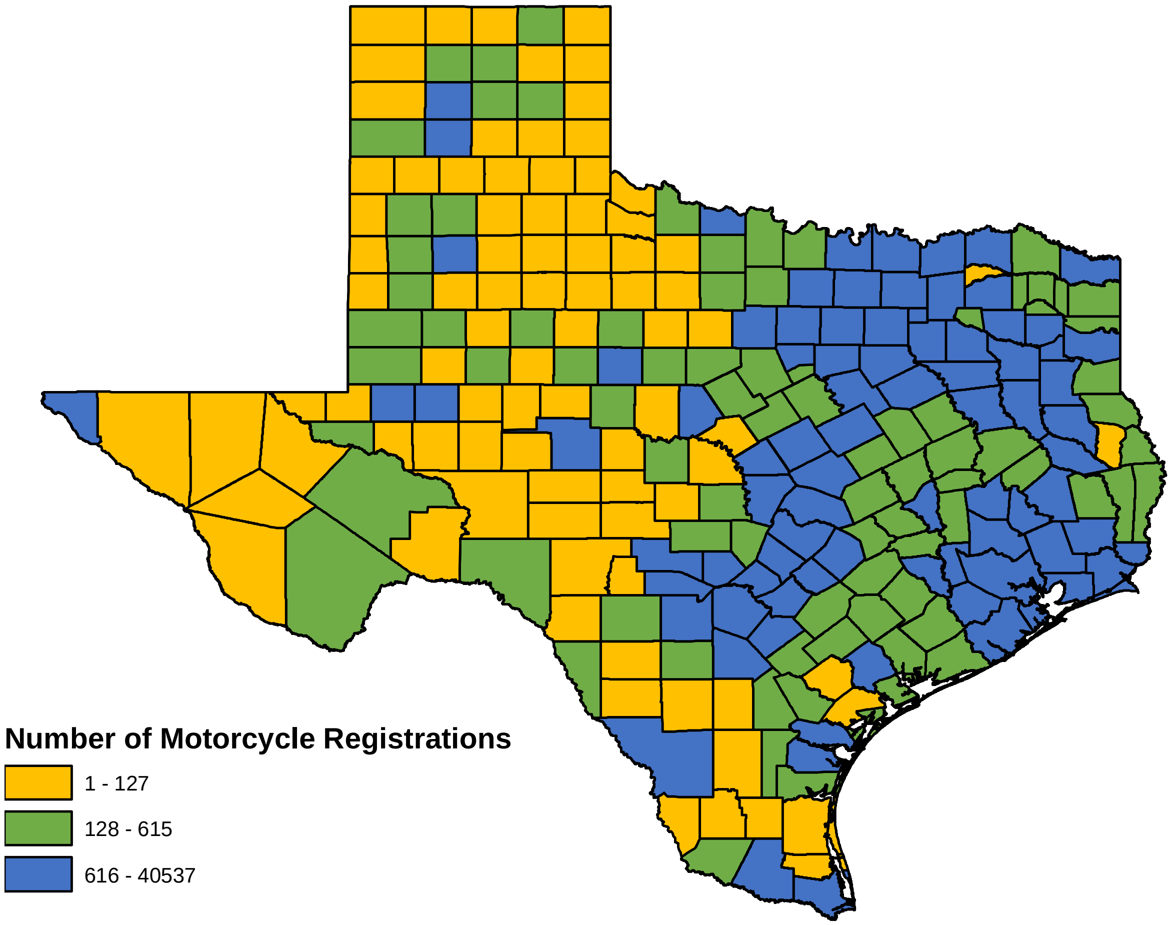


Figure 2: Motorcycle Registrations by County in Texas, 2017

Motorcycle Training

In 2017, there were 34,265 individuals who completed motorcycle training. Of these, a majority (82 percent; n=27,933) were male. Figure 3 shows the age categories of individuals trained. The top three age categories were 20 to 24 years old (13 percent; n=4,336), 25 to 29 years old (19 percent; n=6,455), and 30 to 34 years old (15 percent; n=5,216).

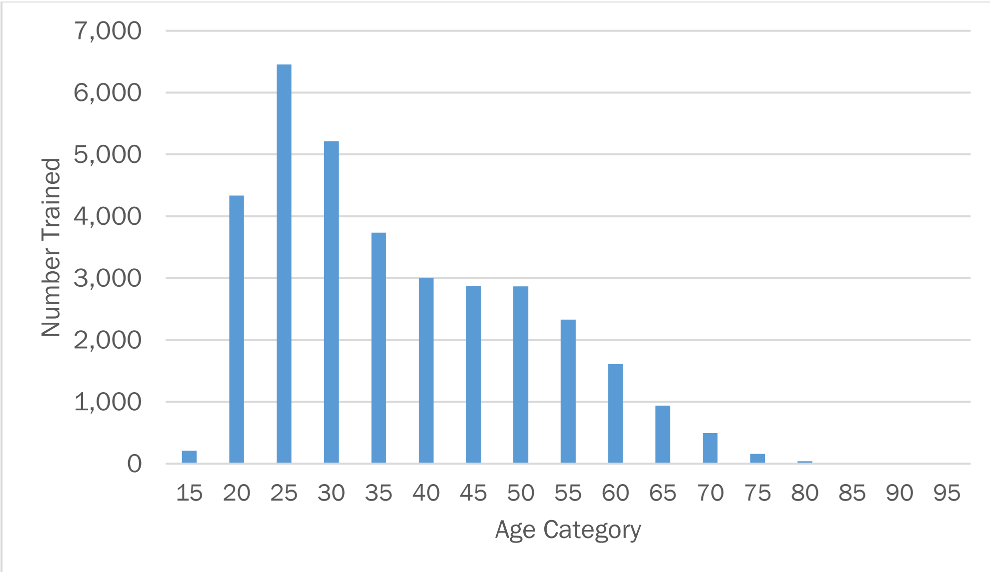


Figure 3: Age Category of Trained Individuals, 2017

Training locations that could be geocoded were mapped with their counts of number of individuals trained in 2017 (see Figure 4). It should be noted that not all training locations could be mapped due to insufficient address information. Training locations were clustered in highly populated, metropolitan areas with a limited number of training locations in rural areas.

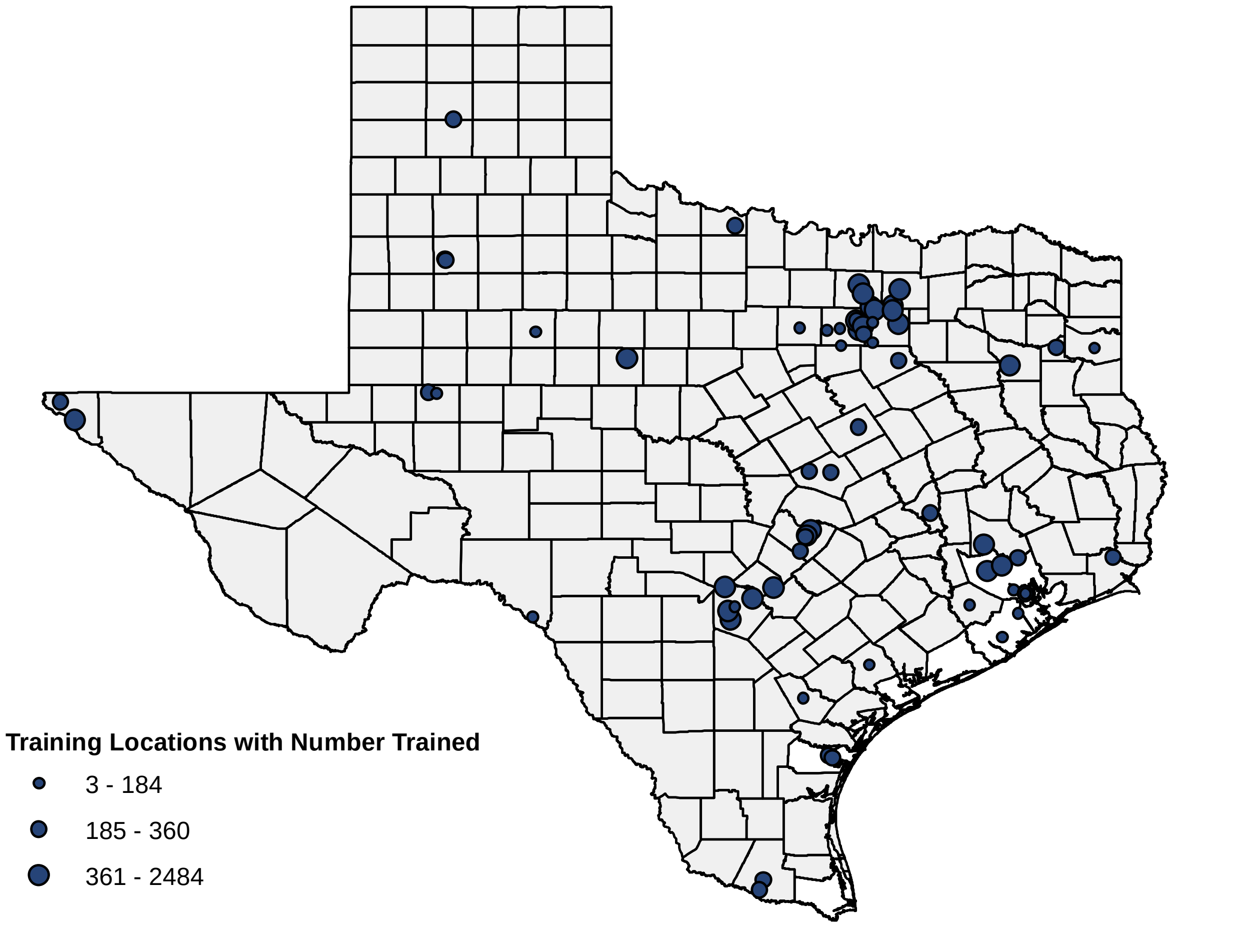


Figure 4: Training Locations with Number of Individuals Trained, 2017

Motorcycle Licensing

Motorcycle Licenses

Of all licenses in Texas, 6 percent (1,101,279) are Class M licenses, which authorize an individual to drive a motorcycle or moped/scooter. Of the Class M license holders, a hundred percent also have Class A (9 percent), B (3 percent), or C endorsements (88 percent). Table 1 shows the distribution of license classes for Class M license holders.

Table 1: M License Distribution by Class in Texas

License Type	Number of M Licenses	Percent of M Licenses
AM	101,024	9%
BM	178,820	3%
CM	968,393	88%
M	373	<1%
Total	**1,101,279**	**100%**

Next, gender distribution of Class M licenses was explored (see Table 2). Males accounted for 88 percent of Class M license holders, whereas 12 percent were female. Interestingly, there was a higher percentage of females with CM (14 percent) and M (16 percent) licenses compared to AM (2 percent) and BM (9 percent).

Table 2: M License Distribution by Class and Gender in Texas

License Type	Number of M Licenses		Total
	Female	Male	
AM	1,982 (2%)	99,042 (98%)	101,024
BM	2,696 (9%)	28,793 (91%)	31,489
CM	131,848(14%)	836,545 (86%)	968,393
M	59 (16%)	314 (84%)	373
Total	136,585 (12%)	964,694 (88%)	1,101,279

To explore the distribution of M licenses in Texas, the counts of Class M licenses were mapped by county (see Figure 5). Counties in large metropolitan areas had higher counts of Class M licenses compared to rural areas. Interestingly, counties along the coastline and in central Texas had higher numbers of Class M licenses compared to the rest of the state.

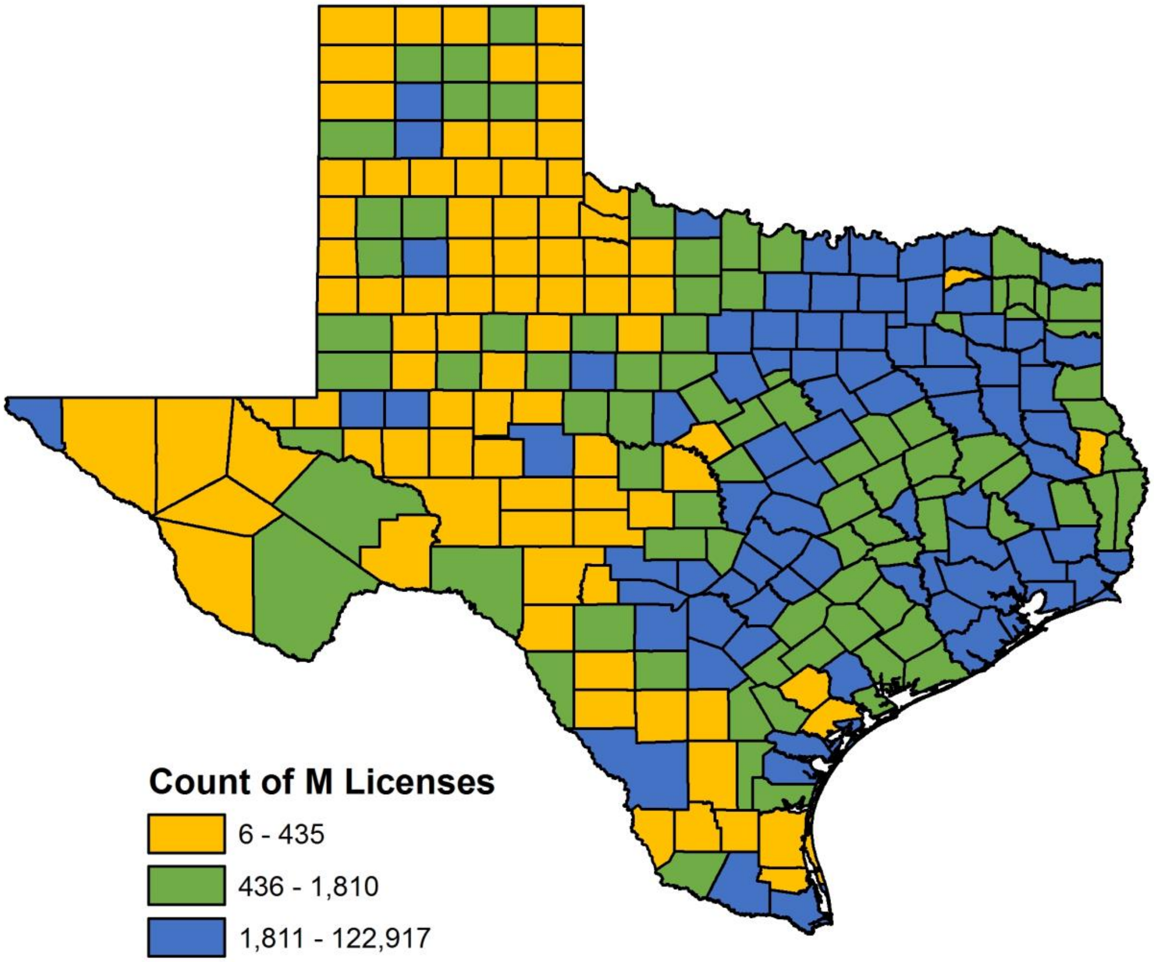


Figure 5: Count of Class M Licenses by County in Texas

Licensing and Crashes

A cross tabulation of driver's license class and injury severity for motorcycle operators found that 43 percent of the fatal motorcycle operators did not have a Class M license or were unlicensed. Table 3 displays the number for each driver's license class by injury severity.

Table 3: Driver's License Class by Injury Severity, 2010–2017

Driver's License Class	Fatal Injury	Suspected Serious Injury	Non-Incapacitating Injury	Possible Injury	Not Injured	No Data/ Unknown
Class A	143	475	804	389	253	15
Class B	26	69	152	73	42	4
Class C	1,094	4,220	7,451	3,929	2,186	118
Class M	7	94	224	170	106	5
Class A and M	240	896	1,442	704	573	22
Class B and M	45	221	455	260	171	1
Class C and M	1,570	6,596	12,936	7,162	4,748	193
Unlicensed	214	857	1,445	868	435	30
Other/Out of State	190	727	1,378	715	662	19
No Data	60	314	502	326	252	911
Total	3,589	14,469	26,789	14,596	9,428	44

Motorcycle Crash Statistics

Counts of Crashes by Year

From 2010 to 2017, there were 68,877 motorcycle-involved crashes in Texas. Figure 6 displays the number of motorcycle-involved crashes by year from 2010 to 2017. On average, there were 8,610 motorcycle-involved crashes annually for the time period, with a range of 7,681 to 9,238 crashes.

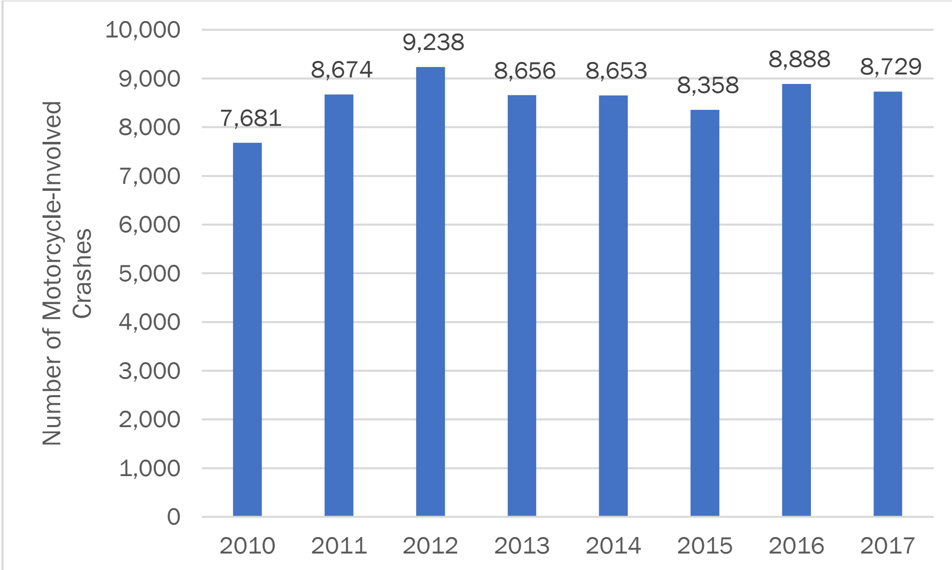


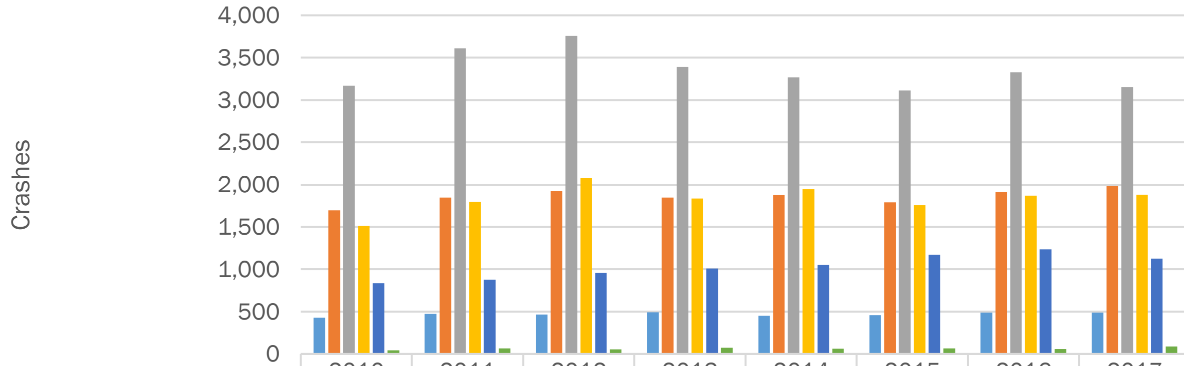
Figure 6: Texas Motorcycle-Involved Crashes by Year, 2010–2017

Crash Severity

Frequency of Motorcycle Crashes by Crash Severity and Year

Crash severity is assigned to a crash based on the highest level of injury sustained by any one individual involved in the crash. Crash severity is defined using the KABCO scale, in which injuries are defined as Killed (Fatal) (K), Suspected Serious Injury (Incapacitating Injury) (A), Non-Incapacitating Injury (B), Possible Injury (C), Not Injured (O).[23] Figure 7 illustrates the number of crashes by crash severity. It is important to note that Figure 7 does not illustrate the highest level of injury sustained by a motorcycle rider.

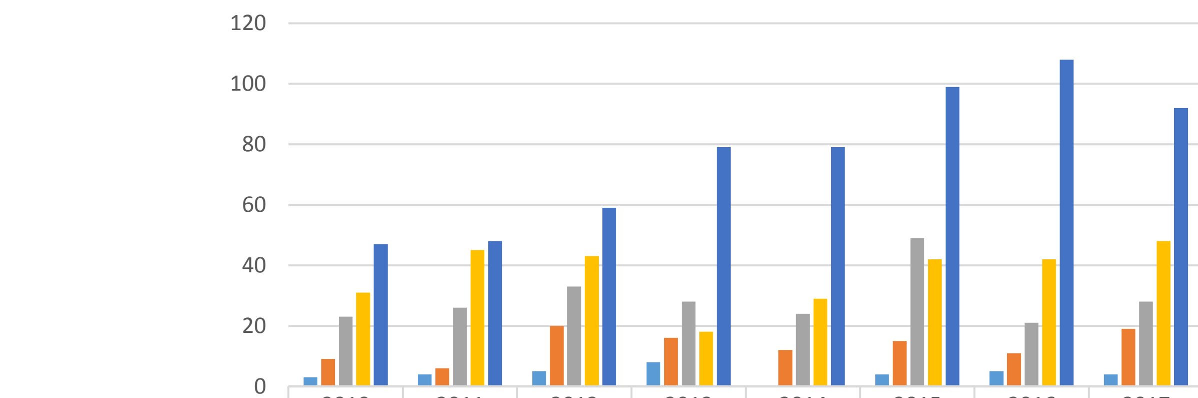
[23] Federal Highway Administration. (2018, July 29). KABCO Injury Classification Scale and Definitions. Available at https://safety.fhwa.dot.gov/hsip/spm/conversion_tbl/pdfs/kabco_ctable_by_state.pdf.



	2010	2011	2012	2013	2014	2015	2016	2017
Fatal	427	473	465	494	451	459	488	490
Suspected Serious Injury	1,698	1,849	1,922	1,848	1,876	1,792	1,911	1,988
Non-Incapacitating Injury	3,167	3,611	3,757	3,392	3,268	3,113	3,327	3,155
Possible Injury	1,511	1,800	2,081	1,837	1,946	1,756	1,870	1,881
Non-Injury	836	876	957	1,011	1,052	1,172	1,234	1,126
Unknown	42	65	56	74	60	66	58	89

Figure 7: Motorcycle-Involved Crashes by Crash Severity, 2010–2017

Figure 8 illustrates the number of crashes where a motorcyclist did not sustain the higher level of injury in the crash. The low crash counts illustrate that in a crash, it is typically the motorcycle rider who sustains the most severe injury. Directly comparing crash severity level to the highest level of injury sustained by motorcycle riders shows that annually, 97 to 99 percent of the crash severities align with the highest level of injury sustained by the motorcycle rider.

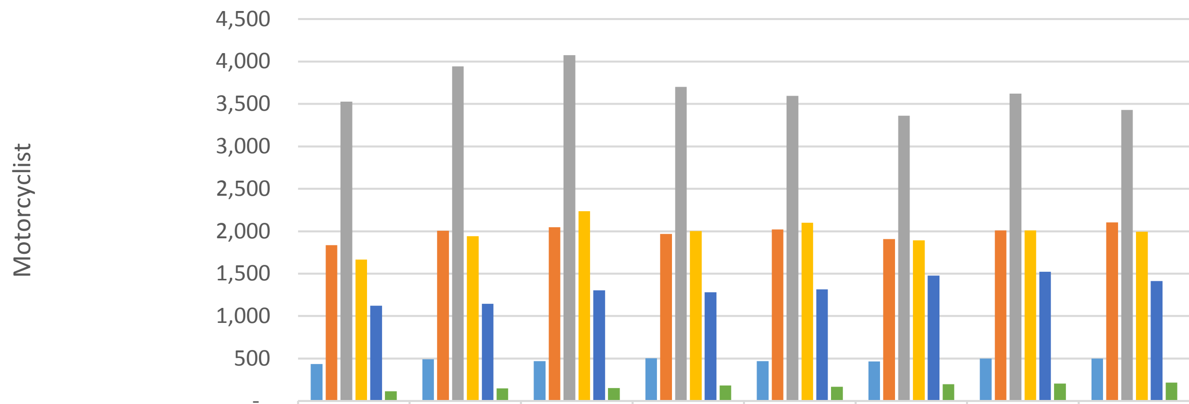


	2010	2011	2012	2013	2014	2015	2016	2017
Fatal	3	4	5	8	0	4	5	4
Suspected Serious Injury	9	6	20	16	12	15	11	19
Non-Incapacitating Injury	23	26	33	28	24	49	21	28
Possible Injury	31	45	43	18	29	42	42	48
Non-Injury	47	48	59	79	79	99	108	92

Figure 8: Crashes Where a Motorcycle Rider Did Not Sustain the Highest Level of Injury in the Crash, 2010–2017

Rider Severity

Over the 2010 to 2017 time period, there were 76,807 motorcycle operators or passengers involved in crashes. Of those, 3,835 (5 percent) were killed and 15,901 (21 percent) sustained a suspected serious injury. Figure 9 illustrates the number of fatalities and injuries for motorcycle riders (operators and passengers) from 2010 to 2017.

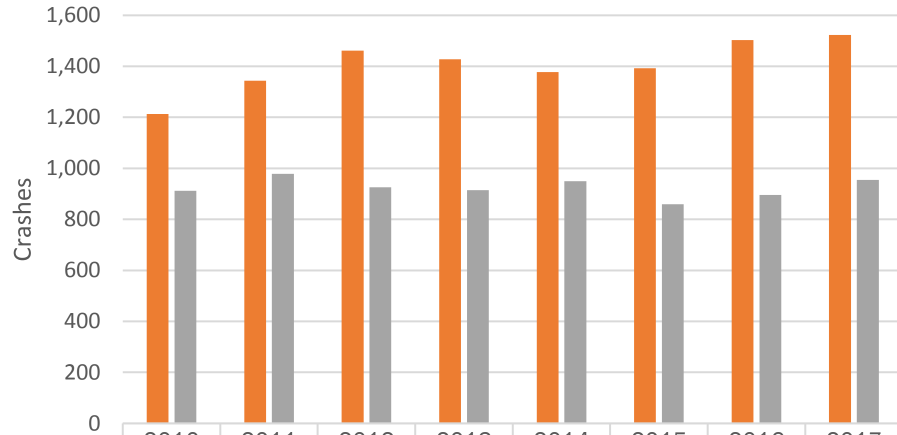


	2010	2011	2012	2013	2014	2015	2016	2017
Killed	437	491	471	503	468	464	500	501
Suspected Serious Injury	1,835	2,007	2,047	1,969	2,022	1,907	2,011	2,103
Non-Incapacitating Injury	3,527	3,944	4,075	3,700	3,594	3,361	3,620	3,430
Possible Injury	1,667	1,942	2,236	2,003	2,101	1,894	2,011	1,994
Not Injured	1,121	1,144	1,305	1,281	1,316	1,476	1,523	1,412
Unknown	116	150	153	184	169	199	205	218

Figure 9: Motorcyclist Operator and Passenger Fatalities and Injuries, 2010–2017

Urbanization

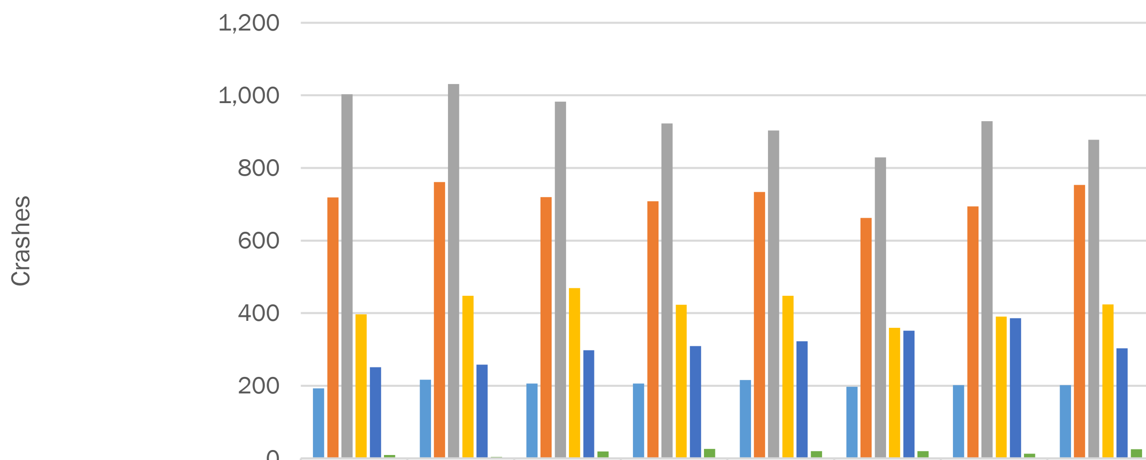
The analysis presented here further explored fatal and suspected serious injury motorcycle crashes. Figure 10 shows the fatalities and suspected serious injury crashes by urbanization status. Of the fatalities and suspected serious injuries, 60 percent (n=11,241) occurred in urban areas and 40 percent (n=7,390) occurred in rural areas.



	2010	2011	2012	2013	2014	2015	2016	2017
Urban	1,213	1,344	1,461	1,428	1,377	1,392	1,503	1,523
Rural	912	978	926	914	950	859	896	955

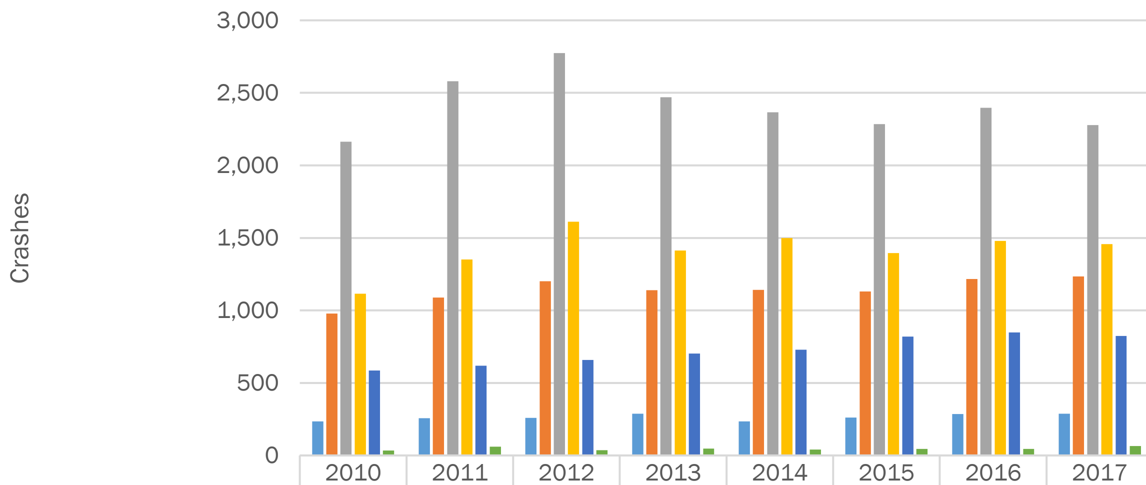
Figure 10: Fatal and Suspected Serious Injury Crashes by Urbanization, 2010–2017

To further explore the role of urbanization on crash severity, crash severity was examined by crash year for rural and urban crashes. Figure 11 and Figure 12 display the number of crashes by year and crash severity for rural and urban crashes. Overall, rural areas had a higher percentage of fatal crashes (8 percent; n=1,639) and suspected serious crashes (28 percent; n=5,751) compared to urban areas, which had 4 percent (n=2,108) fatal crashes and 19 percent (n=9,133) suspected serious crashes.



	2010	2011	2012	2013	2014	2015	2016	2017
Fatal	193	217	206	206	216	197	202	202
Suspected Serious Injury	719	761	720	708	734	662	694	753
Non-Incapacitating Injury	1,003	1,031	983	923	903	829	929	878
Possible Injury	397	448	469	423	448	360	391	424
Not Injured	251	258	298	309	323	352	386	303
Unknown	9	4	19	26	20	20	13	25

Figure 11: Rural Motorcycle-Involved Crashes by Injury Severity, 2010–2017



	2010	2011	2012	2013	2014	2015	2016	2017
Fatal	234	256	259	288	235	262	286	288
Suspected Serious Injury	979	1,088	1,202	1,140	1,142	1,130	1,217	1,235
Non-Incapacitating Injury	2,164	2,580	2,774	2,469	2,365	2,284	2,398	2,277
Possible Injury	1,114	1,352	1,612	1,414	1,498	1,396	1,479	1,457
Not Injured	585	618	659	702	729	820	848	823
Unknown	33	61	37	48	40	46	45	64

Figure 12: Urban Motorcycle-Involved Crashes by Injury Severity, 2010–2017

Single-Vehicle and Multiple-Vehicle Motorcycle Crashes by Injury Severity

Approximately half of the crashes involved multiple vehicles (52 percent) and half (48 percent) single motor vehicles (data not shown). Table 4 shows crash severity for single- and multiple-vehicle crashes, and Table 5 shows the percentages of crash severity for single and multiple vehicles. Interestingly, there were higher percentages of unknown, no injury, possible injury, and suspected serious injury for single-vehicle crashes. However, there were higher percentages of non-incapacitating injuries and fatalities for multiple-vehicle crashes involving motorcycles.

Table 4: Crash Severity by Single-Vehicle and Multiple-Vehicle Motorcycle-Involved Crashes, 2010–2017

	Fatal	Suspected Serious Injury	Non-Incapacitating Injury	Possible Injury	No Injury	Unknown	Total
Multiple Vehicle	6,012	1,860	8,309	12,246	6,983	67	35,477
Single Vehicle	2,252	1,887	6,373	14,544	7,901	443	33,400
Total	8,264	3,747	14,682	26,790	14,884	510	68,877

Table 5: Crash Severity Percentages for Single-Vehicle and Multiple-Vehicle Motorcycle-Involved Crashes, 2010–2017

	Fatal	Suspected Serious Injury	Non-Incapacitating Injury	Possible Injury	No Injury	Unknown	Total
Multiple Vehicle	16.95%	5.24%	23.42%	34.52%	19.68%	0.19%	100.00%
Single Vehicle	6.74%	5.65%	19.08%	43.54%	23.66%	1.33%	100.00%
Total	23.69%	10.89%	42.50%	78.06%	43.34%	1.52%	100.00%

Fatalities and Injuries Based on Population Size, Registrations, and Vehicle Miles Travelled

Population

Overall in Texas, the annual average rate of motorcycle crashes was 33 per 100,000 population from 2012–2016. Table 6 and Table 7 present the 10 counties with the highest counts and rates of motorcycle crashes. The counties with the top count of fatal and suspected serious injury crashes are largely in metropolitan areas. Harris County had the highest count of crashes (6,157 with a rate of 139 per 100,000) from 2012–2016. Meanwhile, the top 10 counties based on crash rate are largely in rural areas with smaller population sizes. Real County, located near San Antonio, Texas, had the highest crash rate, at 4,659 per 100,000 population from 2012–2016 (156 crashes). The distribution of motorcycle crash rates by county was mapped to identify spatial trends. This analysis confirmed that rural areas outside large metropolitan areas tend to have higher rates of motorcycle crashes (see Figure 13). The Appendix presents counts and rates for motorcycle crashes for every county in Texas with more than 10 motorcycle crashes from 2012–2016 (see Table 44).

Table 6: Top 10 Counties for Motorcycle Crashes Based on Count, 2012–2016

County	All Motorcycle Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Harris	6,157	4,434,257	139	28
Dallas	3,624	2,513,054	144	29
Bexar	3,449	1,858,699	186	37
Tarrant	3,212	1,947,529	165	33
Travis	2,711	1,148,176	236	47
El Paso	1,671	833,592	200	40
Collin	1,101	886,633	124	25
Denton	1,052	754,650	139	28
Bell	825	330,859	249	50
Montgomery	807	518,849	156	31

Table 7: Top 10 Counties for Motorcycle Crashes Based on Rate, 2012–2016

County	All Motorcycle Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Real	156	3,348	4,659	932
Edwards	46	2,028	2,268	454
Matagorda	450	36,719	1,226	245
Bandera	180	21,015	857	171
Jeff Davis	19	2,221	855	171
Somervell	56	8,673	646	129
Kimble	27	4,453	606	121
Martin	32	5,451	587	117
Blanco	63	10,918	577	115
Mason	21	4,064	517	103

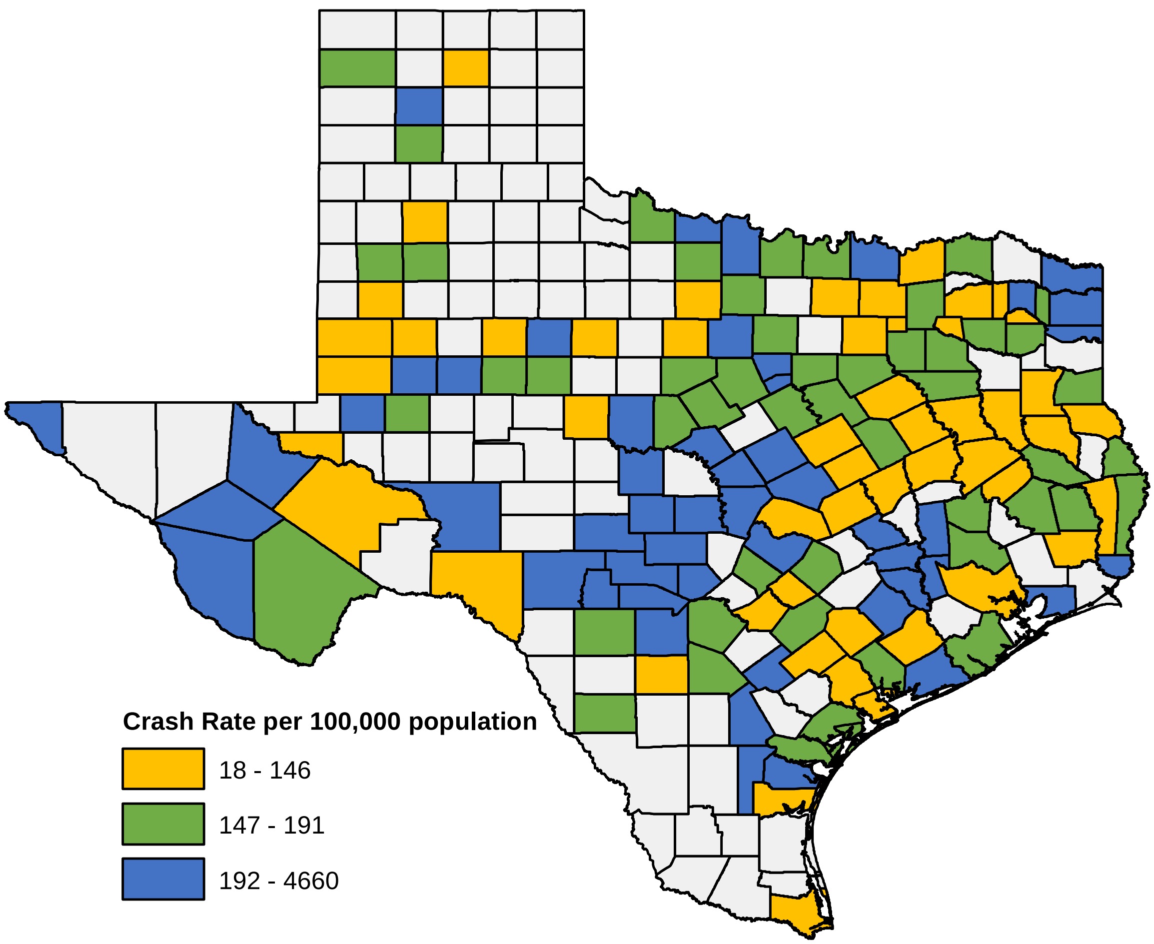


Figure 13: Motorcycle Crash Rate by County, 2012–2016

Overall in Texas, the annual average rate of fatal and suspected serious injuries was nine per 100,000 population from 2012 to 2016. Table 8 and Table 9 present the 10 counties with the highest counts and rates of fatal and suspected serious injury crashes. The counties with the highest counts of fatal and suspected serious injury crashes are in large metropolitan areas. Harris County had the highest count of fatal and suspected serious injury crashes (1,369 crashes at a rate of 31 per 100,000) from 2012 to 2016. Meanwhile, the top 10 counties based on crash rates are largely in rural areas with smaller population sizes. Real County, located near San Antonio, Texas, had the highest fatal and suspected serious injury crash rate, at 2,419 per 100,000 population, from 2012 to 2016 (81 crashes). The distribution of motorcycle fatal and suspected serious injury crash rates by county was mapped to identify spatial trends. The spatial analysis confirms that rural areas outside large metropolitan areas tend to have higher rates of fatal and suspected serious injury crashes (see Figure 14). The Appendix presents counts and rates for fatal and suspected serious injury motorcycle crashes for every county in Texas with more than 10 motorcycle crashes from 2012–2016 (see Table 45).

Table 8: Top 10 Counties for Fatal and Suspected Serious Injury Motorcycle Crashes Based on Counts, 2012–2016

County	Fatal and Suspected Serious Injury Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Harris	1,369	4,434,257	31	6
Dallas	973	2,513,054	39	8
Tarrant	914	1,947,529	47	9
Bexar	666	1,858,699	36	7
Travis	566	1,148,176	49	10
Collin	307	886,633	35	7
Denton	289	754,650	38	8
El Paso	251	833,592	30	6
Montgomery	247	518,849	48	10
Bell	218	330,859	66	13

Table 9: Top 10 Counties for Fatal and Suspected Serious Injury Motorcycle Crashes Based on Rate, 2012–2016

County	Fatal and Suspected Serious Injury Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Real	81	3,348	2,419	484
Edwards	20	2,028	986	197
Bandera	78	21,015	371	74
Somervell	29	8,673	334	67
Blanco	29	10,918	266	53
Mills	11	4,871	226	45
Hamilton	17	8,232	207	41
Gillespie	46	25,732	179	36
Marion	18	10,191	177	35
San Jacinto	44	27,172	162	32

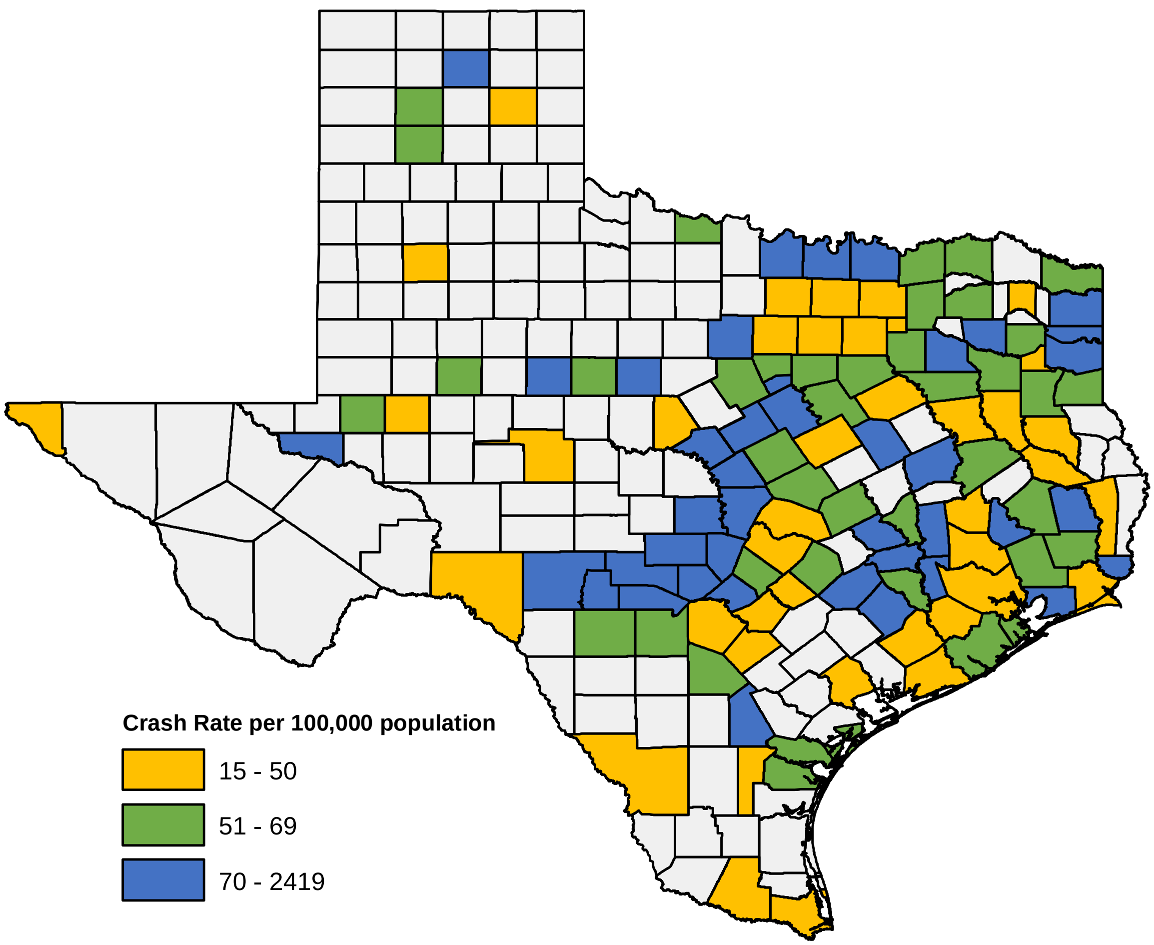
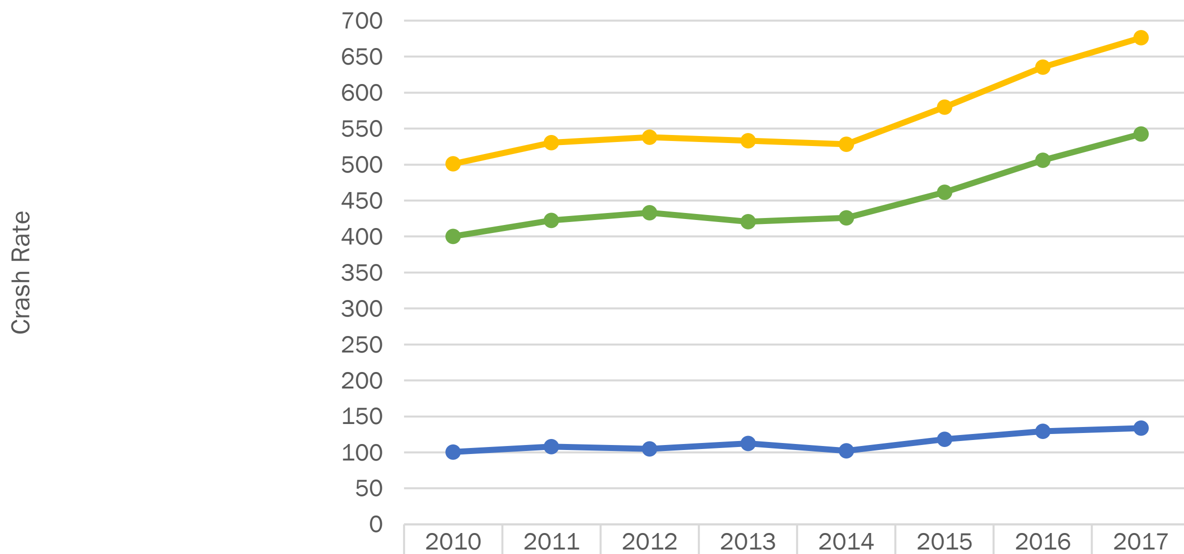


Figure 14: Motorcycle Fatal and Suspected Serious Injury Crash Rate by County, 2012–2016

Registrations

Figure 15 presents the rates of fatal and suspected serious injuries over time from 2010–2017 based on the number of registered motorcycles. Overall, rates were fairly stable from 2010–2014; however, as registrations decreased, there was an increase in all rates for 2015–2017. In 2017, the fatal and suspected serious injury crash rate was 676 per 100,000 motorcycles registered. In comparison, the fatal and suspected serious injury crash rate for all vehicles in Texas was 75 per 100,000 vehicles registered in 2016 (2017 registrations not available). The rate for motorcycles is about eight times the rate for all vehicles.



	2010	2011	2012	2013	2014	2015	2016	2017
Suspected Serious Injury Crash Rate	400.27	422.26	433.13	420.85	425.89	461.50	506.07	542.47
Fatal Crash Rate	100.66	108.02	104.79	112.50	102.39	118.21	129.23	133.71
Fatal and Suspected Serious Injury Crash Rate	500.92	530.28	537.92	533.35	528.27	579.71	635.30	676.18

Figure 15: Rates of Fatal and Suspected Serious Injury Crashes Based on Motorcycle Vehicle Registrations by Year

Rates of motorcycle crashes per motorcycle registrations were explored for all crashes and fatal and suspected serious injury crashes (see Table 10 and Table 11). Real County had the highest rate for all motorcycle crashes, with 30,488 per 100,000 motorcycles registered. Meanwhile, Jeff Davis County had the highest fatal and suspected serious injury crash rate, with 13,636 per 100,000 motorcycles registered. The Appendix presents crash rates per 100,000 motorcycle registrations for every county in Texas with more than 10 motorcycle crashes in 2017 (see Table 45).

Table 10: Top 10 Counties for Crash Rate per 100,000 Motorcycle Registrations, 2017

County	Number of Motorcycle Registrations	Motorcycle Crashes	Fatal and Suspected Serious Injury Crashes	Crash Rate per 100,000	Fatal and Suspected Serious Injury Crash Rate per 100,000
Real	82	25	9	30,488	10,976
Edwards	36	9	4	25,000	11,111
Jeff Davis	44	7	6	15,909	13,636
Oldham	20	3	1	15,000	5,000
Hudspeth	31	4	2	12,903	6,452
El Paso	3,336	313	61	9,382	1,829
Roberts	22	2	2	9,091	9,091
Reeves	127	11	4	8,661	3,150
Cottle	15	1	1	6,667	6,667
Somervell	231	15	9	6,494	3,896

Table 11: Top 10 Counties for Fatal and Suspected Serious Injury Crash Rate per 100,000 Motorcycle Registrations, 2017

County	Number of Motorcycle Registrations	Motorcycle Crashes	Fatal and Suspected Serious Injury Crashes	Crash Rate per 100,000	Fatal and Suspected Serious Injury Crash Rate per 100,000
Jeff Davis	44	7	6	15,909	13,636
Edwards	36	9	4	25,000	11,111
Real	82	25	9	30,488	10,976
Roberts	22	2	2	9,091	9,091
Cottle	15	1	1	6,667	6,667
Hudspeth	31	4	2	12,903	6,452
Donley	37	2	2	5,405	5,405
Oldham	20	3	1	15,000	5,000
Martin	73	3	3	4,110	4,110
Somervell	231	15	9	6,494	3,896

Vehicle Miles Traveled (VMT)

Motorcycle VMT

VMT by motorcycles was estimated using odometer readings from travel survey data, including NHTS and TxDOT TSP data. 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 traveled per motorcycle by the number of registered motorcycles in Texas. The results of this analysis are presented in Table 12. The team recommends using the average motorcycle VMT value for calculating crash and injury rates because it is the most conservative estimate.

The estimated cumulative miles of travel by motorcycles ranges from 920 to 2,139 million miles, which accounts for approximately 0.5 percent to 1.1 percent of total VMT in Texas. In 2016, motorcycle travel as reported in highway statistics was 0.6 percent of total VMT in the United States.[24] In comparison, the motorcycle VMT based on the TxDOT TSP and NHTS combined accounted for 0.7 percent of total Texas VMT. This difference is likely due to differences in VMT calculations. Consequently, the team recommends using the average motorcycle VMT value for calculating crash and injury rates because it is the most conservative estimate.

Table 12: 2016 Texas Statewide Motorcycle VMT (millions)

Data Source	Average Annual Motorcycle Mileage	Annual Motorcycle VMT (millions)
TxDOT TSP	5,665	2,139
NHTS	2,436	920
TxDOT TSP and NHTS Combined	3,681	1,390

Motorcycle VMT 2014 and 2016 Comparison

This study is the second time motorcycle VMT has been calculated for Texas. A comparison of the calculated Texas motorcycle statewide VMT between the two years calculated—2014 and 2016—found a decrease in VMT estimates (see Table 13). On average, there was a 26 percent reduction in the annual motorcycle VMT estimates in 2016 compared to 2014. Based on further investigation, the reduction in motorcycle registrations, as previously discussed, along with changes in the NHTS estimates both played significant roles in the change in the VMT estimates. When controlling for the reductions in registrations, the VMT decreased by 12 percent due to NHTS changes alone.

Results from the calculated motorcycle VMT estimates should be interpreted with caution since this is only the second data point from the NHTS. Future research is needed to determine causes of reductions in travel via motorcycles, as well as limitations in the application of travel survey data to motorcycle VMT estimation.

[24] Federal Highway Administration. (2018). Highway Statistics 2016. Available at https://www.fhwa.dot.gov/policyinformation/statistics/2016/.

Table 13: Comparison of 2014 and 2016 Texas Statewide Motorcycle VMT (millions)

	2016		2014		Comparison
Data Source	Average Annual Motorcycle Mileage	Annual Motorcycle VMT (millions)	Average Annual Motorcycle Mileage	Annual Motorcycle VMT (millions)	Percent Decrease in Annual Motorcycle VMT
TxDOT TSP	5,665	2,139	5,665	2,496	14%
2016 NHTS	2,436	920	3,373	1,486	38%
TxDOT TSP and NHTS Combined	3,681	1,390	4,224	1,861	25%

Fatality and Suspected Serious Injury Crash and Injury Rates

To explore differences in crash rates and travel exposure, crash rates and injury rates per 100 million VMT were calculated for 2016 (see Table 14). The motorcycle fatal crash rate per VMT is 27 times higher for motorcycles compared to the rate for all vehicles in 2016. The fatality crash rate of 35 fatalities per 100 million VMT is higher than the 25 fatalities per 100 million VMT reported by the NHTSA for the national level.[25] However, the all-vehicle fatal crash rate is also higher than that of the national average.

Table 14: Crash and Injury Rates per 100 million VMT for Motorcycles versus All Vehicles for Texas, 2016

	Fatal Crash Rate	Suspected Serious Injury Crash Rate	Fatal and Suspected Serious Injury Crash Rate	Total Crash Rate
Motorcycles	35.1	137.5	172.6	639.4
All Vehicles	1.3	5.6	6.9	241.7

[25] NHTSA. (2018). Traffic Safety Facts 2016 Data: Motorcycles. DOT HS 812 492.

Temporal and Spatial Patterns of Fatalities and Injuries

Roadways

Roadways reported in CRIS were analyzed for motorcycle crash fatalities for 2010-2017 to identify the top roadways for a fatality (see Table 15). Interstate 45 in Harris County had the highest number of fatalities reported for 2010-2017. Interestingly, 50 percent (n=5) of the top 10 roadways for motorcycle fatalities are in Harris County.

Table 15: Top 10 Roadways for Motorcycle Fatalities, 2010-2017

Rank	Derived Road	County	Fatalities
1	IH0045	Harris	35
2	SL0008	Harris	28
3	IH0010	Harris	25
3	IH0410	Bexar	25
5	IH0030	Dallas	24
6	IH0010	El Paso	23
7	IH0010	Bexar	21
7	FM1960	Harris	21
9	IH0635	Dallas	20
10	IH0610	Harris	19

Weekend/Weekday

Of the motorcycle crashes, a majority (65 percent) occurred on weekdays (i.e., Monday to Friday), as shown in Figure 16. Approximately 35 percent occurred on weekends (i.e., Saturday and Sunday).

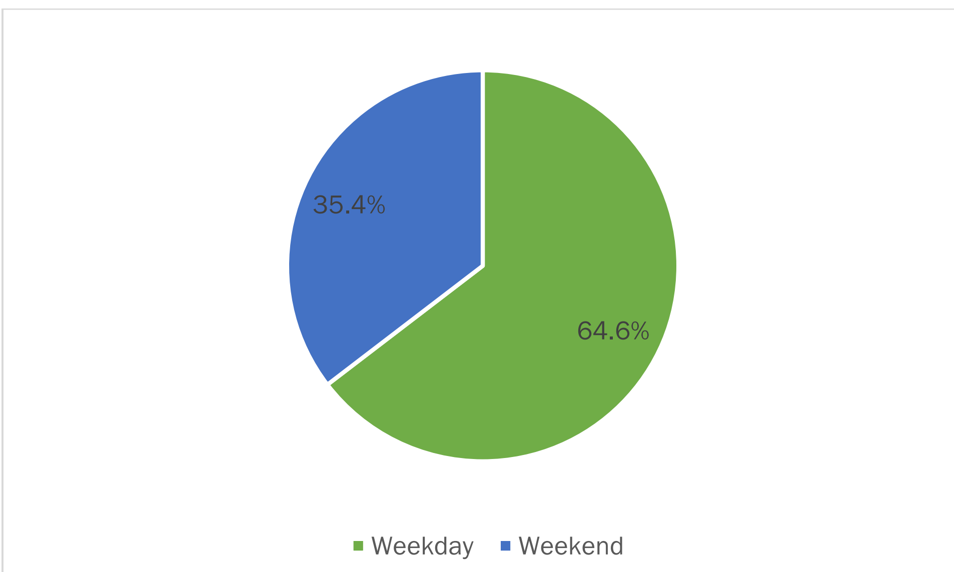


Figure 16: Crashes by Weekday or Weekend

Next, weekday status was explored by crash severity. Table 16 shows the percentage of crashes by crash severity and weekday status. Interestingly, weekend crashes had a higher percentage of crashes with fatalities and suspected serious injuries compared to weekday crashes. Weekday crashes had a higher percentage of crashes with no injury, possible injury, and non-incapacitating injury.

Table 16: Weekday Status by Crash Severity, 2010–2017

	Fatal	Suspected Serious Injury	Non-Incapacitating Injury	Possible Injury	Non-Injury	Unknown
Weekday	4.9%	20.3%	39.3%	22.1%	13.4%	13.4%
Weekend	6.4%	24.0%	38.1%	19.8%	11.5%	11.5%

Seasons

Seasonal differences were explored for crashes. Seasons were defined by month, including spring (March to May), summer (June to August), fall (September to November), and winter (December to February). Figure 17 shows the frequency of motorcycle crashes by season. There was a higher percentage of crashes that occurred in the spring (29 percent) compared to the other seasons. However, there were very similar numbers of crashes in the spring, summer, and fall. In addition, the fewest percentages of crashes occurred in the winter (17 percent).

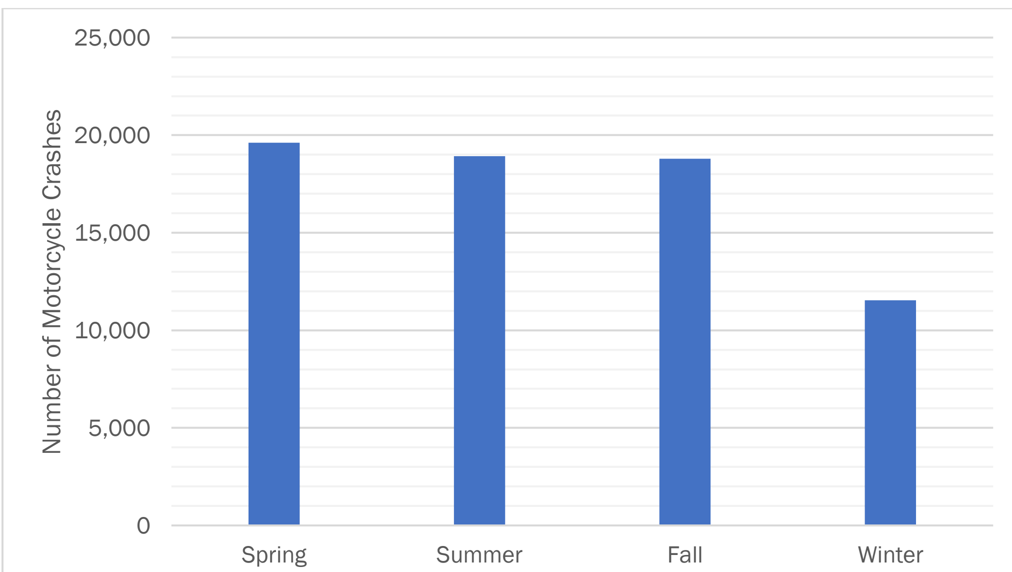


Figure 17: Frequency of Motorcycle Crashes by Season, 2010–2017

Distance from Crash to Residence

Distance from a crash location to a motorcycle driver's address was calculated for fatal motorcycle crashes with crash coordinates and a home address that could be assigned coordinates in Texas from 2016 to 2017. Table 17 displays the distribution of miles for straight-line paths from crash location to residence location. Overall, fatalities happened rather close to residences, indicating relatively short trip durations. The average distance for all fatal crashes to all residences was 22 miles. As may be expected, the average distance for fatal rural crashes was higher, with an average of 31 miles. These findings are similar to prior analyses[26], which looked at distance from crash to residence address for fatal motorcycle crashes from 2010 to 2015. Previously, the average distance was 27 miles for fatal crashes and 48 miles for rural fatal crashes. The differences in values may be a result of a decrease in riding due to an improved economy. In addition to decreases in motorcycle registrations during improved economic times, the team has heard anecdotal evidence that supports the idea that individuals ride motorcycles during poor economic times because they are an affordable means of transportation and are fuel efficient.

Table 17: Distribution of Distance (Miles) from Crash to Residence Address, 2016–2017

	All Geographies	Rural Only
Mean	22	31
Standard Deviation	49	59
Minimum	0.05	0.08
Maximum	480	480
Total Crashes	852	377

To explore potential spatial patterns relating to distances from crash to residence, values were plotted for all fatal motorcycle crashes and rural fatal motorcycle crashes (see Figure 18 and Figure 19). The maps illustrate that rural crashes tend to occur farther away from residences, as evidenced by less clustering of crash and residence locations for rural crashes.

[26] Shipp, E.M., Wunderlich, R., Perez, M., Ko, M., Pant, A., Martin, M., Chigoy, B., Trueblood, A.B. 2016. Project 2016-TTI-G-1YG-0029 Final Report, Comprehensive Analysis of Motorcycle Crashes in Texas: A Multi-Year Snapshot.

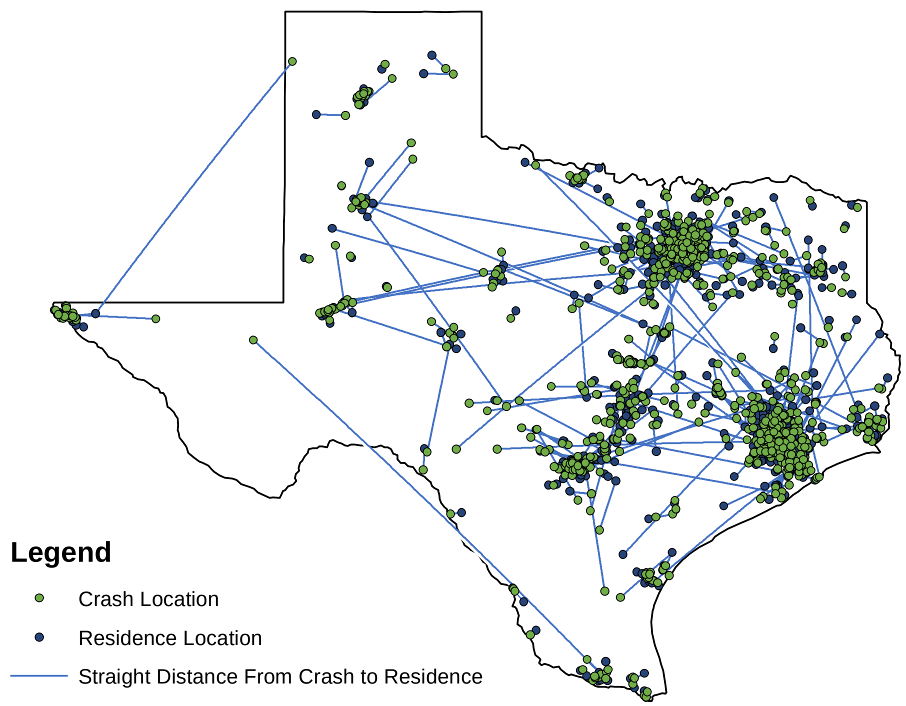


Figure 18: Straight-Line Distances between Residence and Crash Location for Fatal Motorcycle Crashes, 2016–2017

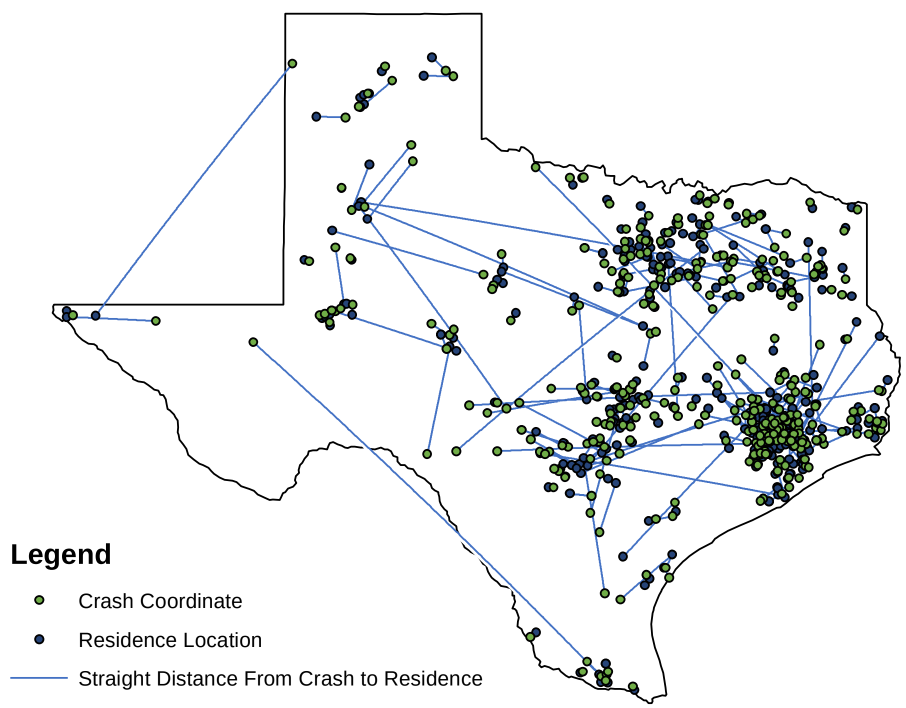


Figure 19: Straight-Line Distances between Residence and Crash Location for Rural Fatal Motorcycle Crashes, 2016–2017

Motorcycle Crash Trees

To examine variation with respect to geographic and crash characteristics, a series of crash trees were constructed. Figure 20 through Figure 23 display the crash trees for fatal and suspected serious injury motorcycle crashes from 2010 to 2017 by urbanization status.

Urban

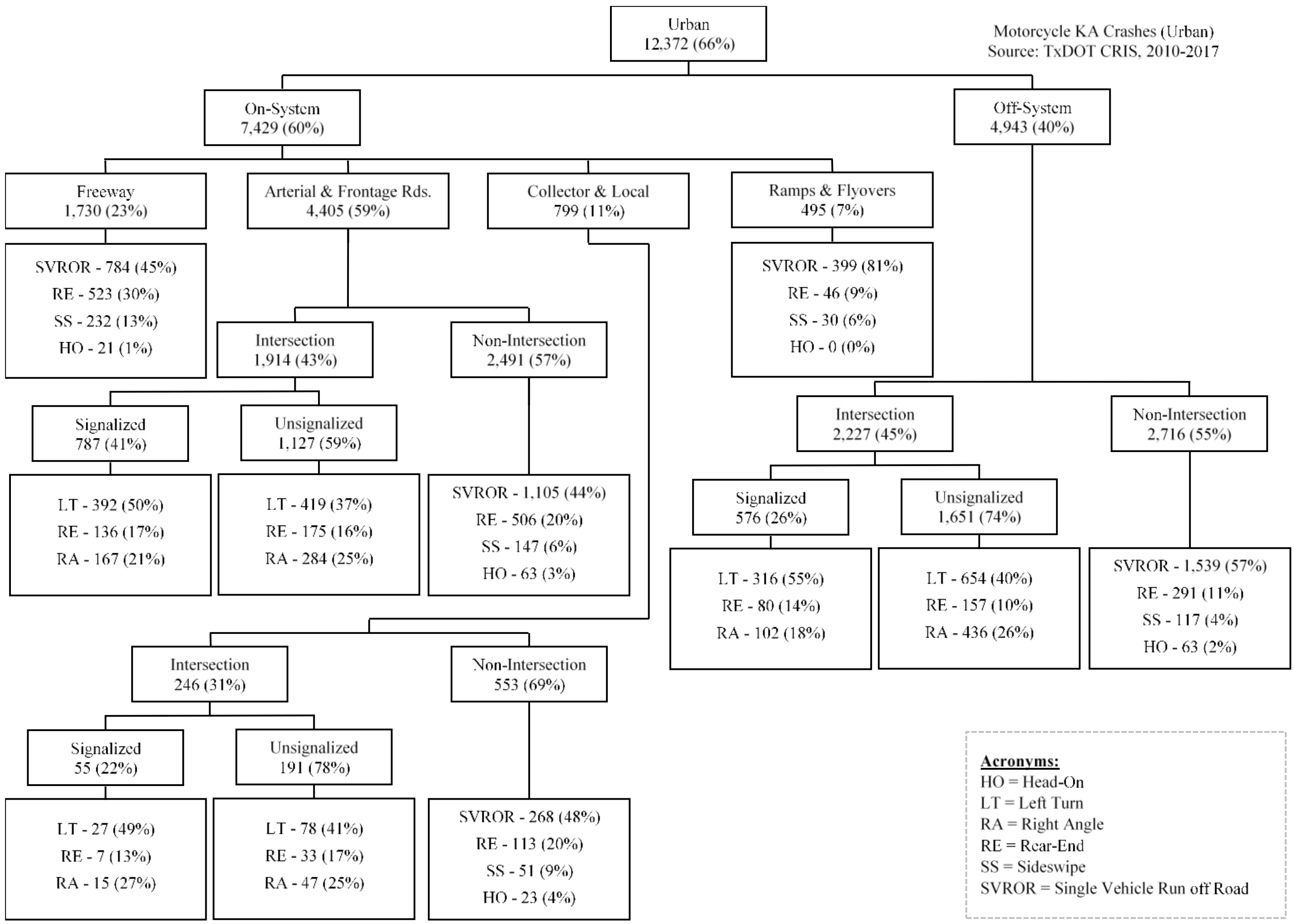


Figure 20: Crash Tree Diagram of Motorcycle Fatal and Suspected Serious Injury Crashes in Urban Areas

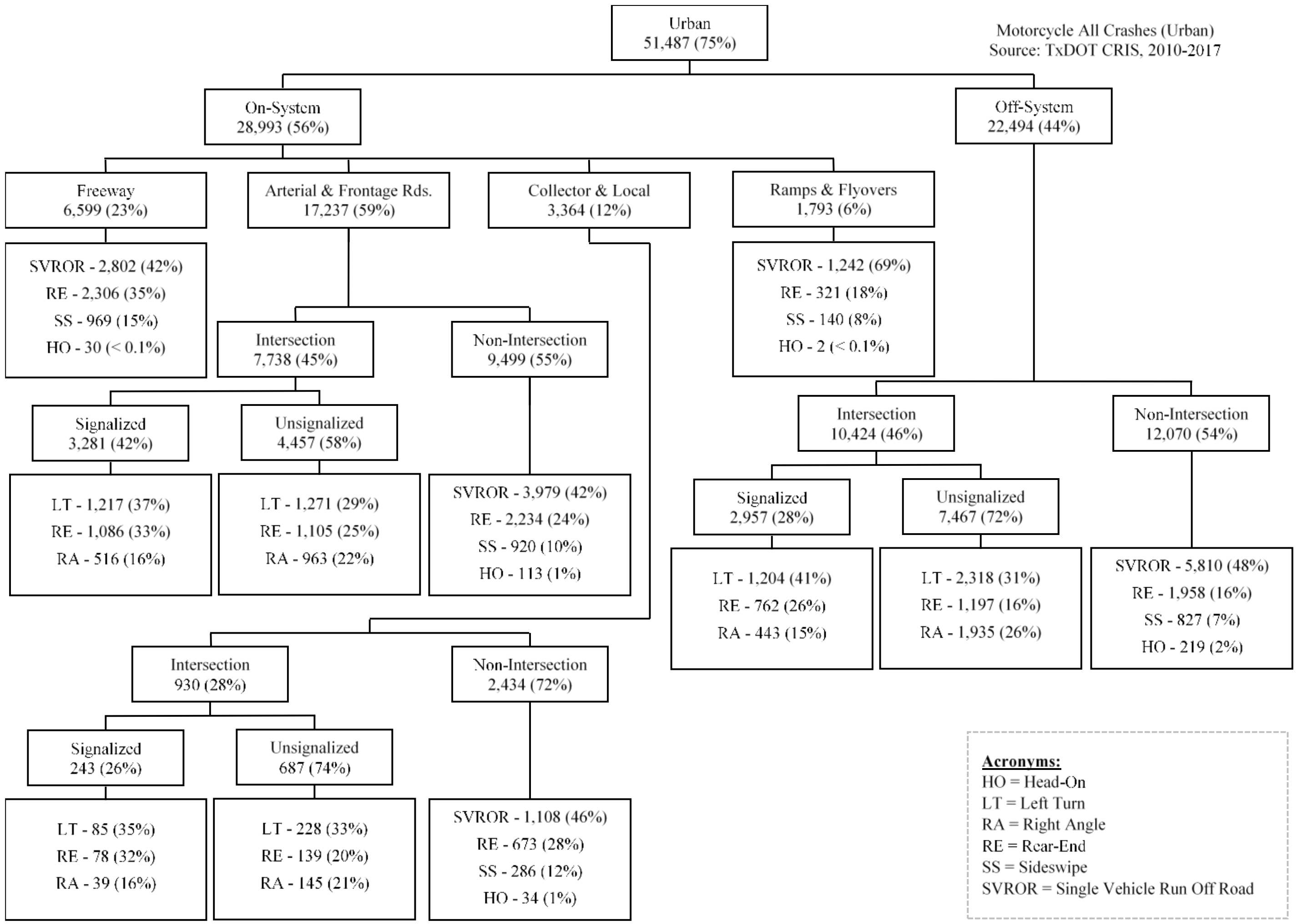


Figure 21: Crash Tree Diagram of All Motorcycle Crashes in Urban Areas

Rural

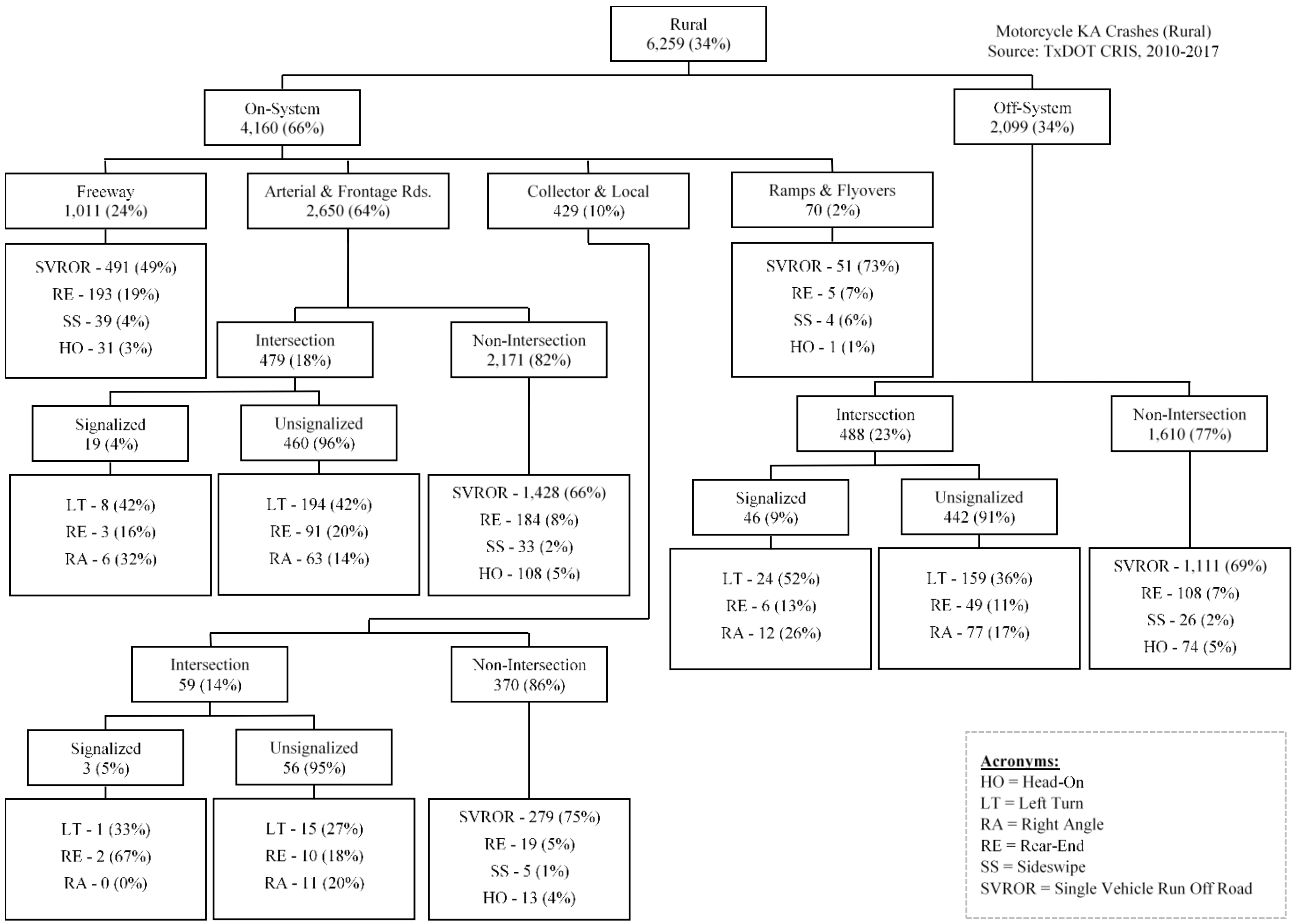


Figure 22: Crash Tree Diagram of Motorcycle Fatal and Suspected Serious Injury Crashes in Rural Areas

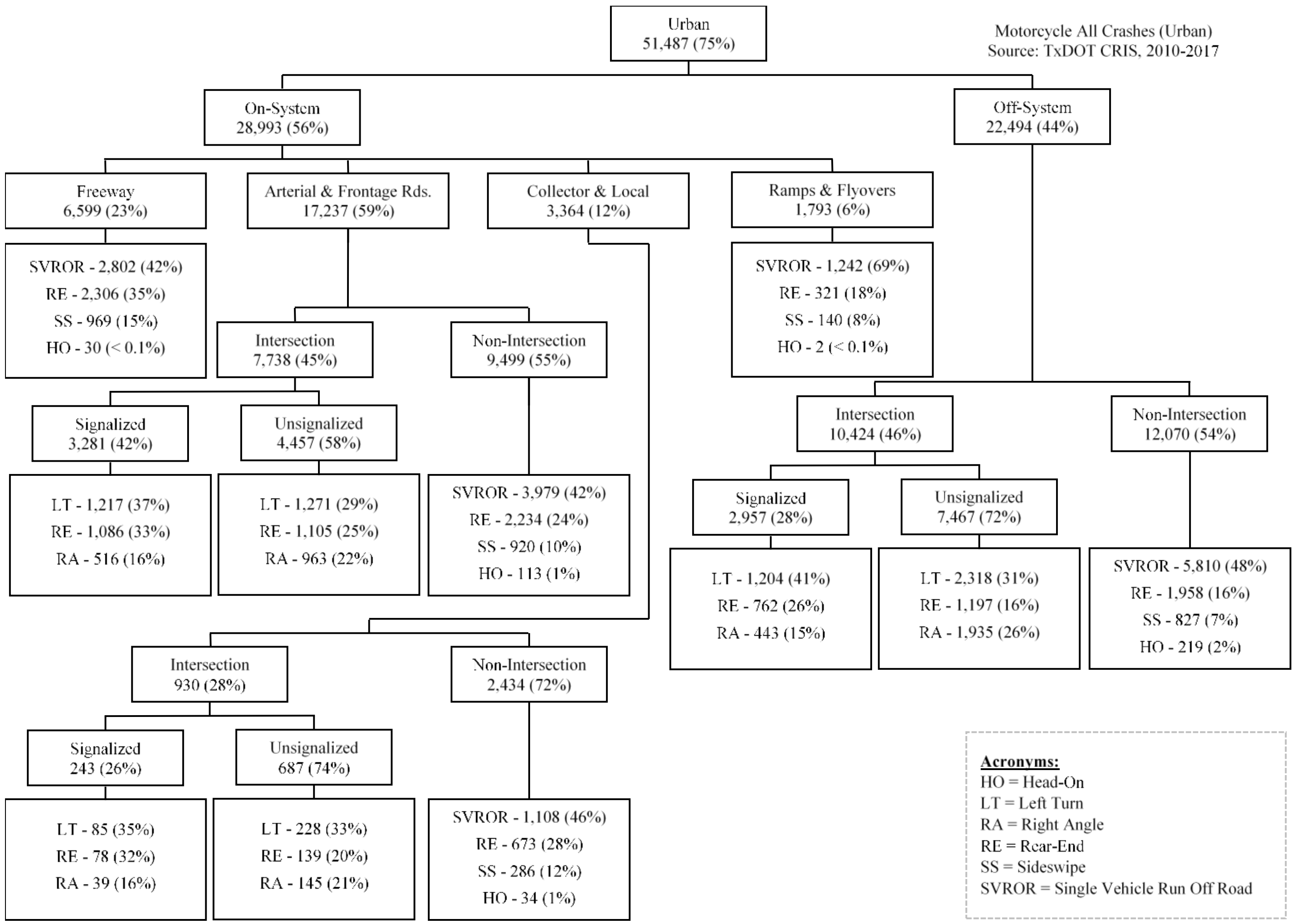


Figure 23: Crash Tree Diagram of All Motorcycle Crashes in Rural Areas

Demographic Factors

Motorcycle Operators

Age

The average age of motorcycle operators involved in a crash was 39 years old. Figure 24 shows the age categories of motorcycle operators involved in crashes. A majority of operators were aged 25 to 34 years old (24 percent, n=17,038). The next leading age categories had a similar percentage of operators, including 16 to 24 years old (19 percent; n=13,176), 35 to 44 years old (18 percent; n=12,882), and 45 to 54 years old (19 percent; n=13,427).

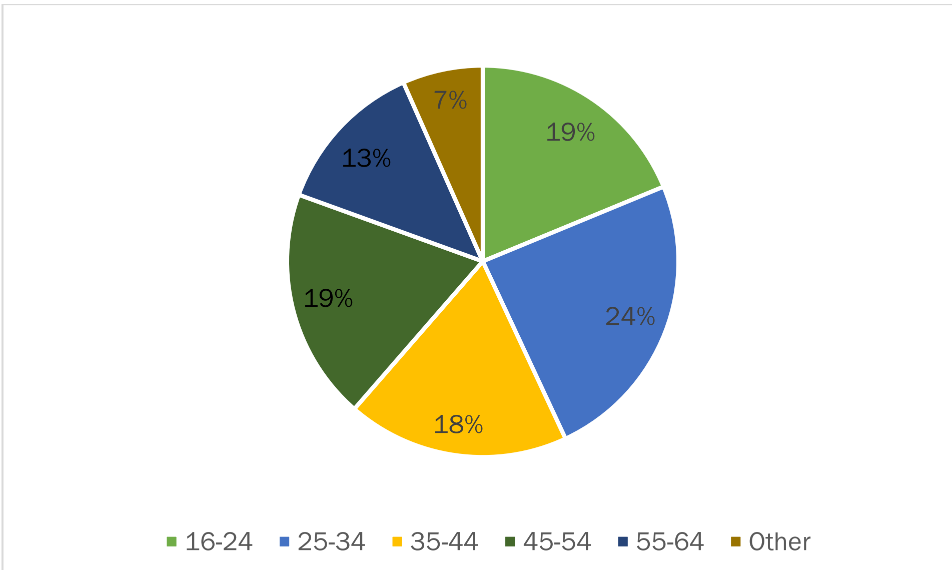


Figure 24: Age Category of Motorcycle Operators in Crashes, 2010–2017

Gender

Figure 25 shows the gender breakdown of motorcycle operators involved in crashes from 2010 to 2017. A majority of drivers were male (93 percent; n=65,436) compared to females (6 percent; n=4,078).

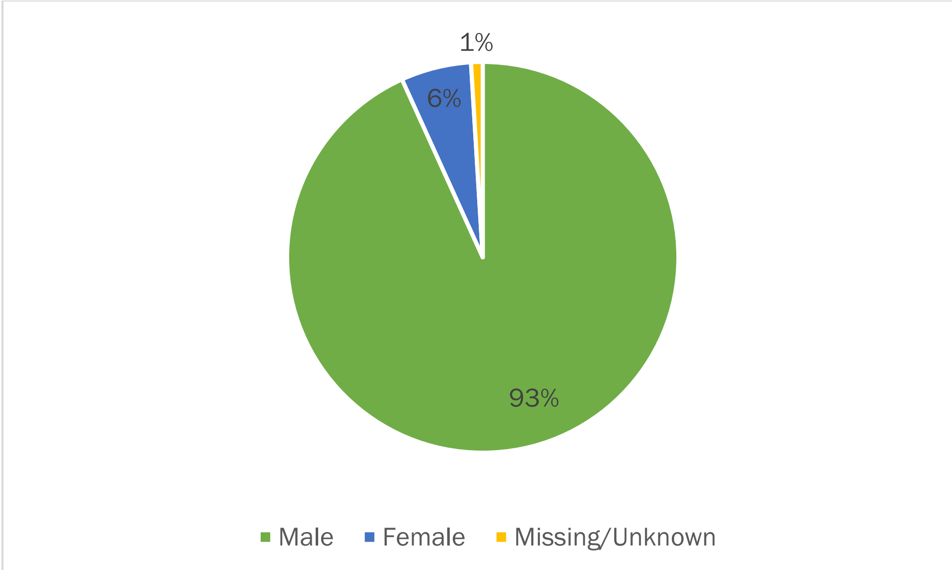


Figure 25: Gender Category of Motorcycle Operators in Crashes, 2010–2017

Motorcycle Passengers

Age

The average age of motorcycle passengers involved in a crash was 35 years old. Figure 26 shows the age categories of motorcycle passengers involved in crashes. The top four age categories of motorcycle passengers were 45 to 54 years old (20 percent; n=1,330), 16 to 24 years old (19 percent; n=1,257), 25 to 34 years old (18 percent; n=1,193), and 35 to 44 years old (18 percent; n=1,149).

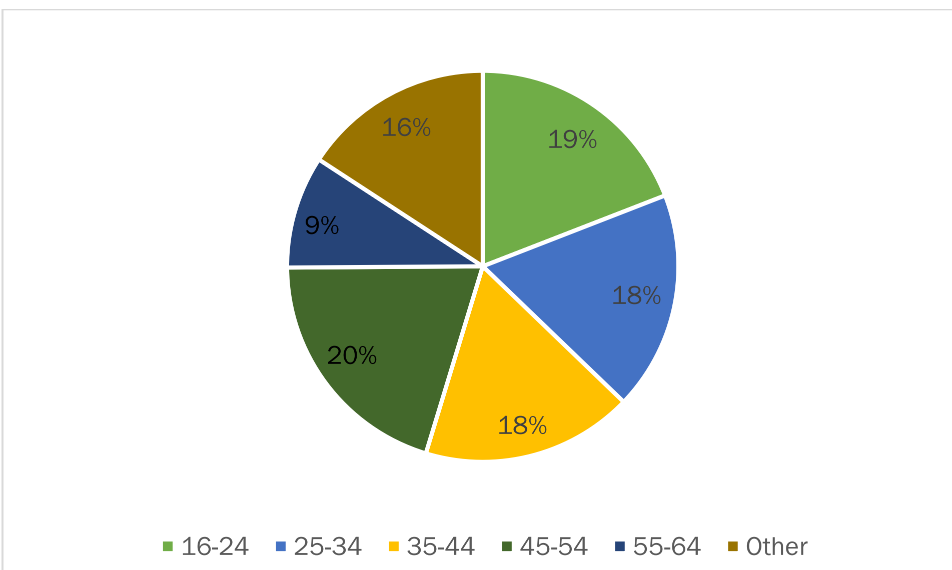


Figure 26: Age Category of Motorcycle Passengers in Crashes, 2010–2017

Gender

Figure 27 shows the gender breakdown of motorcycle passengers involved in crashes from 2010 to 2017. A majority of passengers were female (85 percent) compared to male (15 percent).

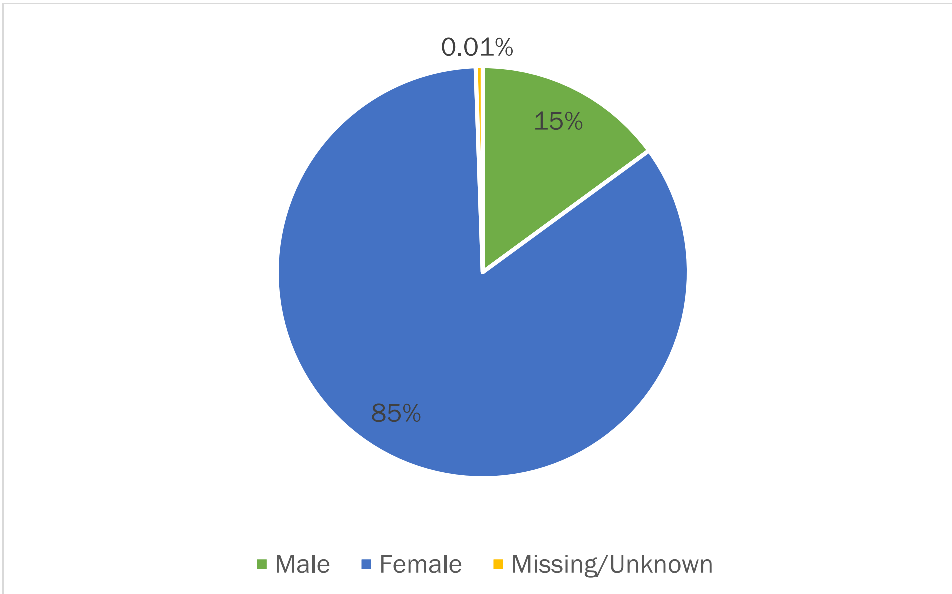
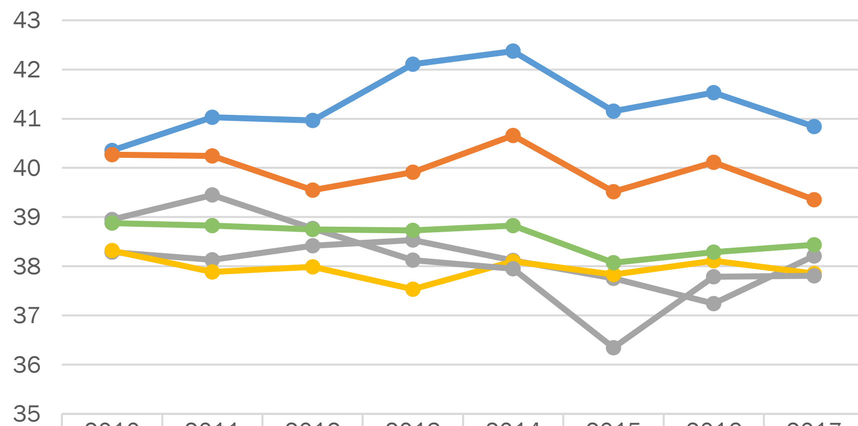


Figure 27: Gender Breakdown of Passengers in Motorcycle Crashes, 2010–2017

Motorcycle Riders

Demographics for motorcycle riders (operators and passengers) were further explored. Figure 28 displays the average age of motorcycle riders by injury severity from 2010 to 2017. The average age of a motorcycle rider involved in a crash was 39 years old. Interestingly, the average age of motorcycle riders killed in a crash was 41 years old.



	2010	2011	2012	2013	2014	2015	2016	2017
KILLED	40	41	41	42	42	41	42	41
SUSPECTED SERIOUS INJURY	40	40	40	40	41	40	40	39
NON-INCAPACITATING INJURY	38	38	38	39	38	38	37	38
POSSIBLE INJURY	38	38	38	38	38	38	38	38
NOT INJURED	39	39	39	38	38	36	38	38
ALL RIDERS	39	39	39	39	39	38	38	38

Figure 28: Crashes by Average Age of Motorcycle Riders, 2010–2017

Ratio Age Graphs

Figure 29 displays the proportion of motorcycle riders with fatal injuries relative to the proportion of the population by age and gender. This analysis allows for identifying the age and gender groups that are experiencing more fatal injuries than expected based on population size. An index value is calculated as the proportion of riders with fatal injuries in each age and gender group divided by the proportion of the population in that age and gender group. An index value greater than 1 means that an age and gender group is overrepresented with respect to the frequency of fatal injuries among motorcycle riders. As shown in Figure 29, none of the age groups for females are overrepresented. However, males are overrepresented for nearly every age group.

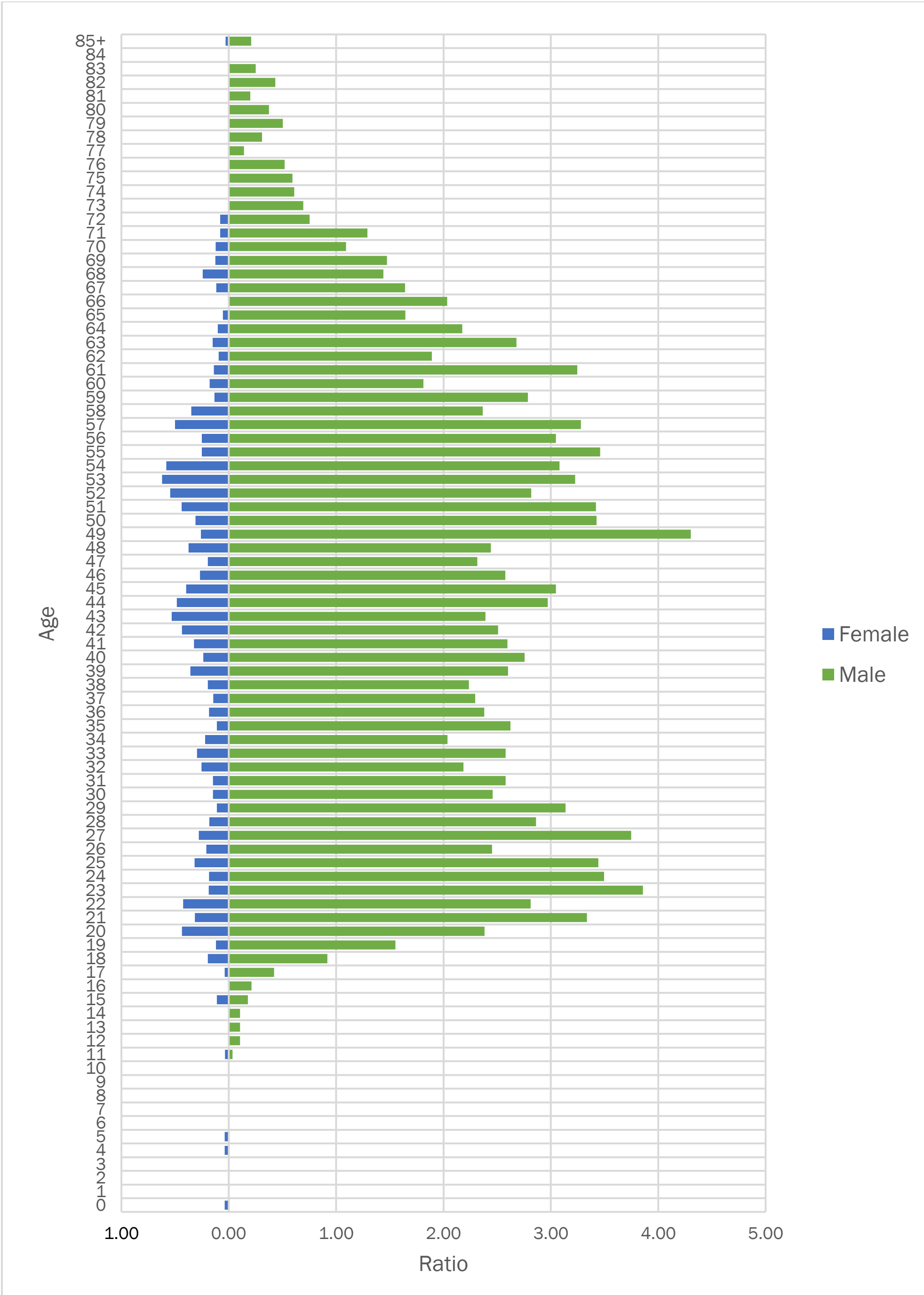
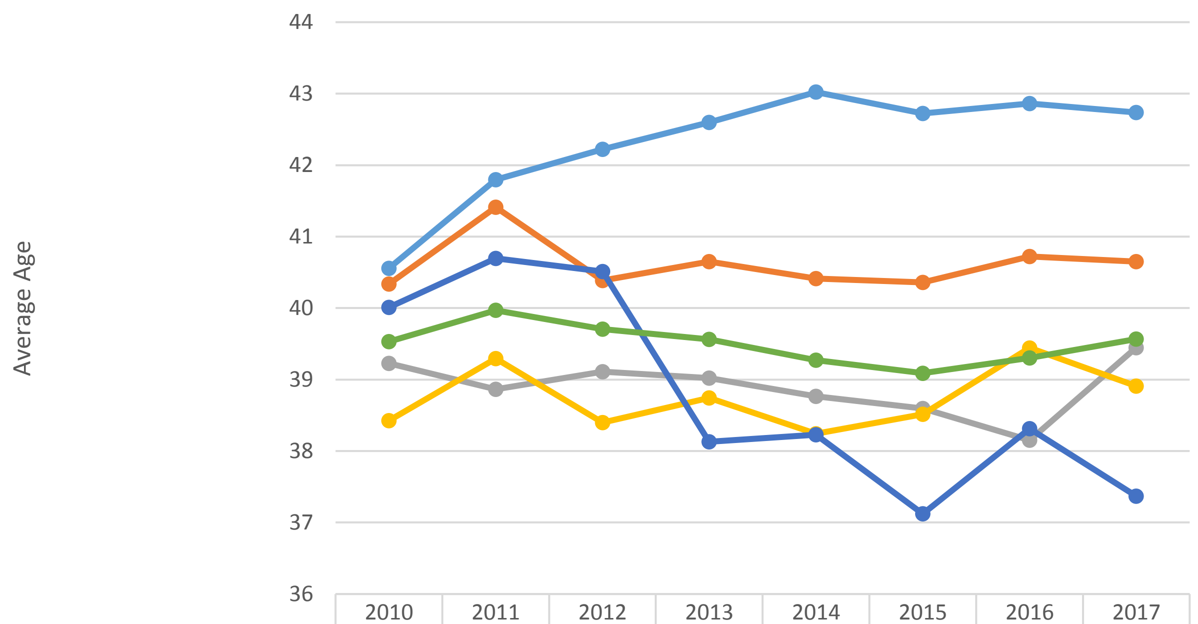


Figure 29: Ratio of Motorcycle Riders with Fatal Injuries Relative to the Proportion of the Population by Age and Gender

Age and Helmet Use

To explore potential age differences and helmet use, the ages of riders without a helmet were stratified by injury severity (see Figure 30). The average age of riders without a helmet was 40 years old, which is slightly older compared to the average age of all riders (39 years old). Interestingly, riders with fatal injuries who were not wearing a helmet had an average age of 42 years old, compared to 38 years old for riders not injured who were not wearing a helmet.



	2010	2011	2012	2013	2014	2015	2016	2017
Killed	41	42	42	43	43	43	43	43
Suspected Serious Injury	40	41	40	41	40	40	41	41
Non-Incapacitating Injury	39	39	39	39	39	39	38	39
Possible Injury	38	39	38	39	38	39	39	39
Not Injured	40	41	41	38	38	37	38	37
All Riders	40	40	40	40	39	39	39	40

Figure 30: Average Age of Riders Who Were Not Wearing a Helmet by Injury Severity, 2010–2017

Other Vehicle Drivers

Age

The average age of other vehicle drivers in motorcycle-involved crashes was 40 years old. Figure 31 shows the age breakdown of non-motorcycle drivers in the motorcycle-involved crashes from 2010 to 2017. The two most common age groups of other drivers included 16 to 24 years old (21 percent; n=8,793) and 25 to 34 years old (20 percent; n=8,618).

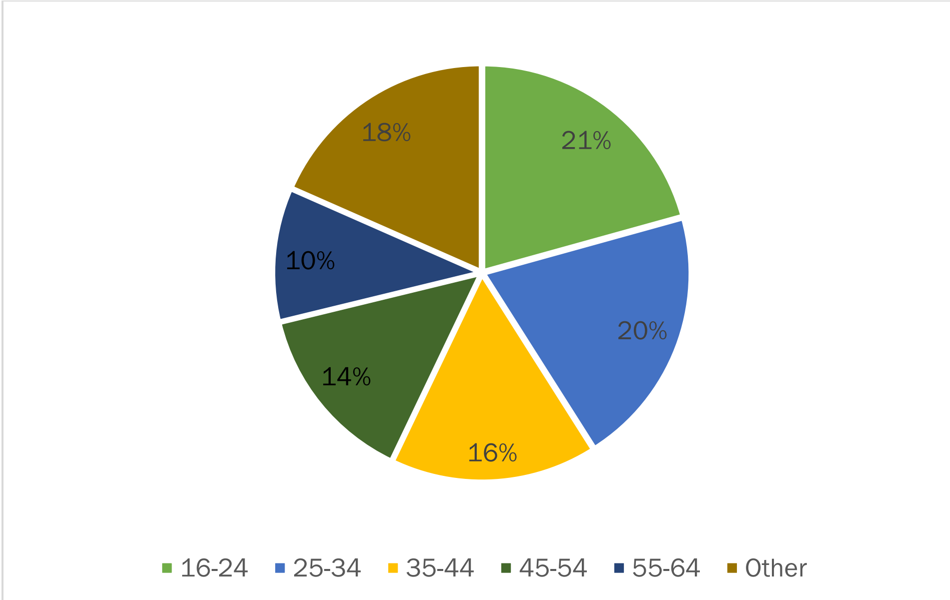


Figure 31: Age Category of Other Drivers in Motorcycle-Involved Crashes, 2010–2017

Gender

Figure 32 shows the gender breakdown of non-motorcycle drivers in motorcycle-involved crashes from 2010 to 2017. A majority of drivers were male (53 percent; n=22,399) compared to female (40 percent; n=17,098).

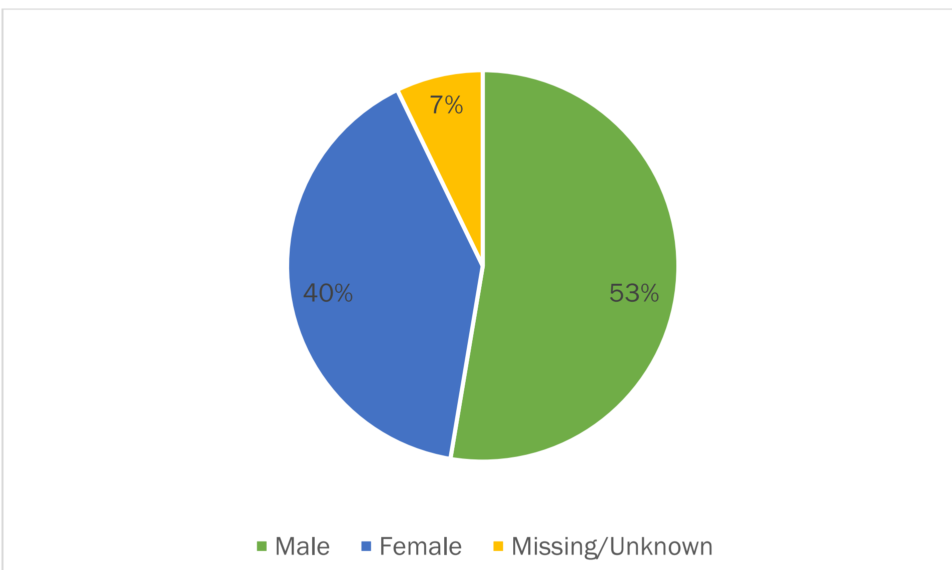


Figure 32: Gender Breakdown of Other Drivers in Motorcycle-Involved Crashes, 2010–2017

Other Vehicle Passengers

Age

The average age of other vehicle passengers in motorcycle-involved crashes was 24 years old. Figure 33 shows the ages of non-motorcycle passengers in motorcycle-involved crashes from 2010 to 2017. A majority of passengers were classified as other (47 percent; n=9,371) or were 16 to 24 years old (23 percent; n=4,562).

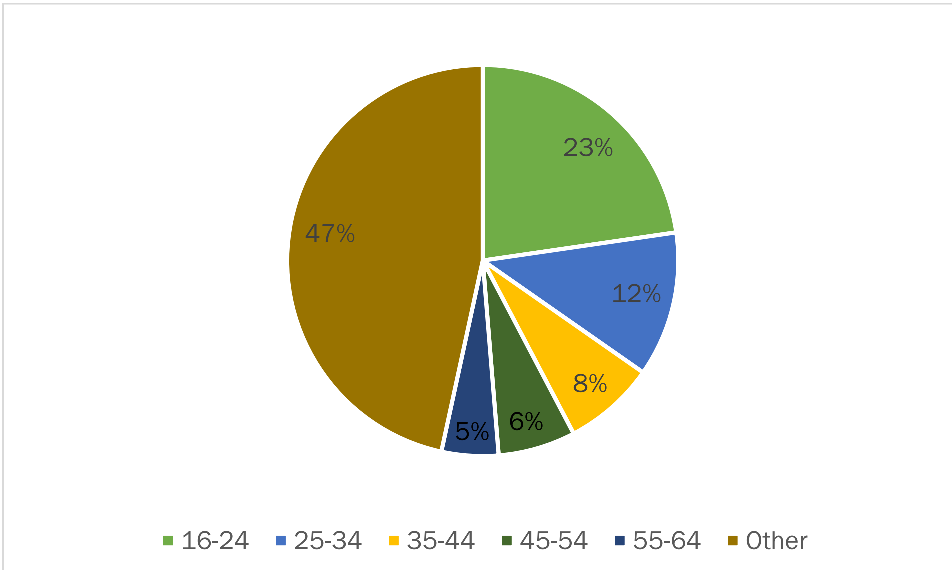


Figure 33: Age Category of Other Passengers in Motorcycle-Involved Crashes, 2010–2017

Gender

Figure 34 shows the gender breakdown of non-motorcycle passengers in motorcycle-involved crashes from 2010 to 2017. A majority of passengers were male (53 percent; n=10,741) compared to female (46 percent; n=9,295).

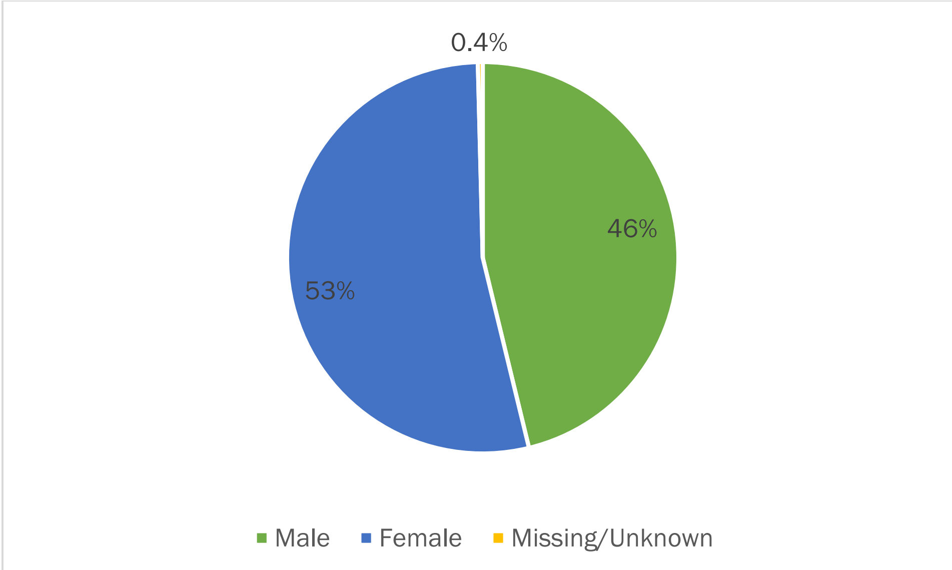


Figure 34: Gender Breakdown of Other Passengers in Motorcycle-Involved Crashes, 2010–2017

Speeding Involvement

Posted Speed Limit

The distribution of the posted speed limits in miles per hour (mph) was compared to crash severity. Figure 35 displays these distributions using vertical box plots. A legend for interpreting the box plots is included. As displayed in Figure 35, 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 compared to the posted speed limit.

- Horizontal line=Median
- Top of the box/upper hinge=75th percentile
- Bottom of box/lower hinge=25th percentile
- Upper horizontal line/top whisker=largest non-outlying value
- Bottom horizontal line/bottom whisker=smallest non-outlying value
- Dots=outlying values

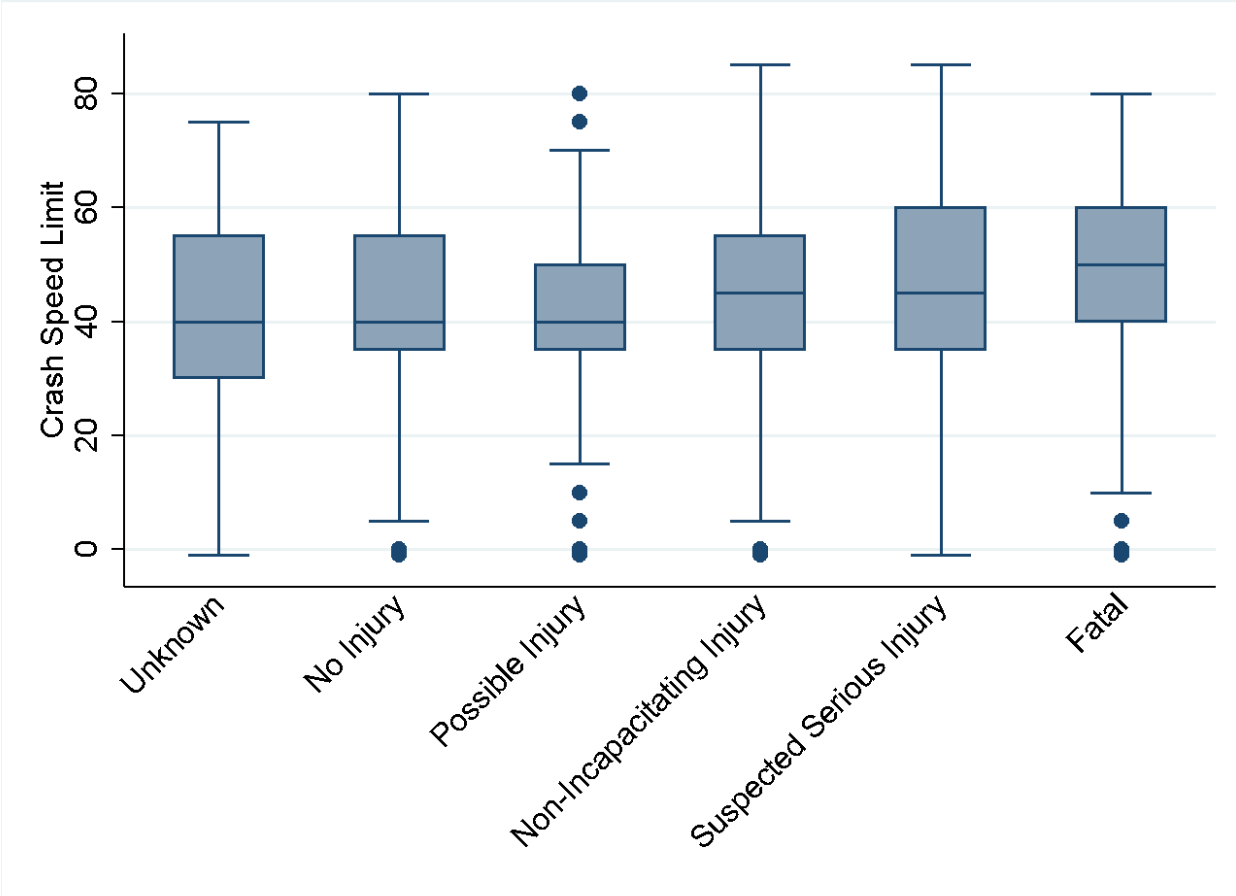


Figure 35: Distribution of Crash Speed Limit by Crash Severity, 2010–2017

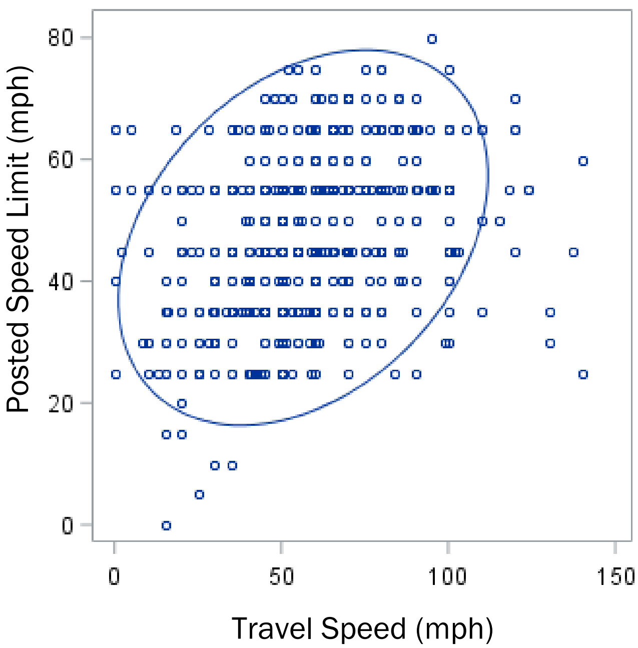
Table 18 shows posted speed limits by crash severity. This distribution supports the findings from the histograms; there is a slight increase in crash severity percentages for 45–64 mph and 65+ mph.

Table 18: Speed Limit by Crash Severity, 2010–2017

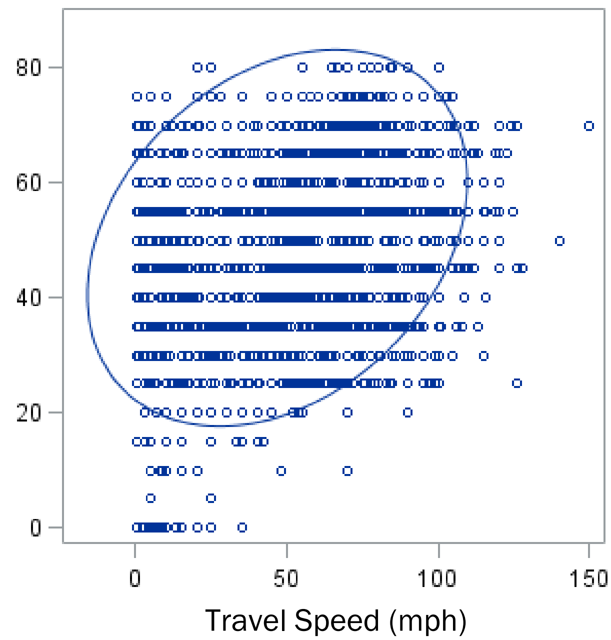
Speed Limit	Fatal	Suspected Serious Injury	Non-Incapacitating Injury	Possible Injury	Non-Injury	Unknown
0–14	1%	2%	2%	2%	2%	4%
15–24	0%	1%	1%	1%	1%	1%
25–44	32%	39%	45%	49%	47%	52%
45–64	47%	42%	39%	37%	38%	32%
Over 65	20%	17%	13%	10%	12%	13%

Speed FARS Analysis

A sub-analysis utilizing 2015 FARS data was conducted to explore speed's relationship to crashes. All at-fault crashes for the United States were included because the sample size for Texas was too small to make any meaningful comparisons. First, at-fault vehicle information was determined using crash contributing factors (driver factor), valid vehicle travel speed at the time of a crash, and posted speed limit at the location of the crash. There were 7,941 vehicles that were at fault and categorized as a motorcycle or other vehicle. Figure 36 illustrates the relationship between travel speeds and posted speed limits at the crash location through scatterplots. The ellipse in the scatterplots represents the areas of predicted speed distribution within a 95 percent confidence level. The ellipse for motorcycles is located more toward 50 and 100 mph compared to the ellipse for other vehicles, which is located more toward 0 mph. This shift indicates that crash travel speeds for at-fault motorcycles are higher than those of other vehicles.



a. Motorcycles



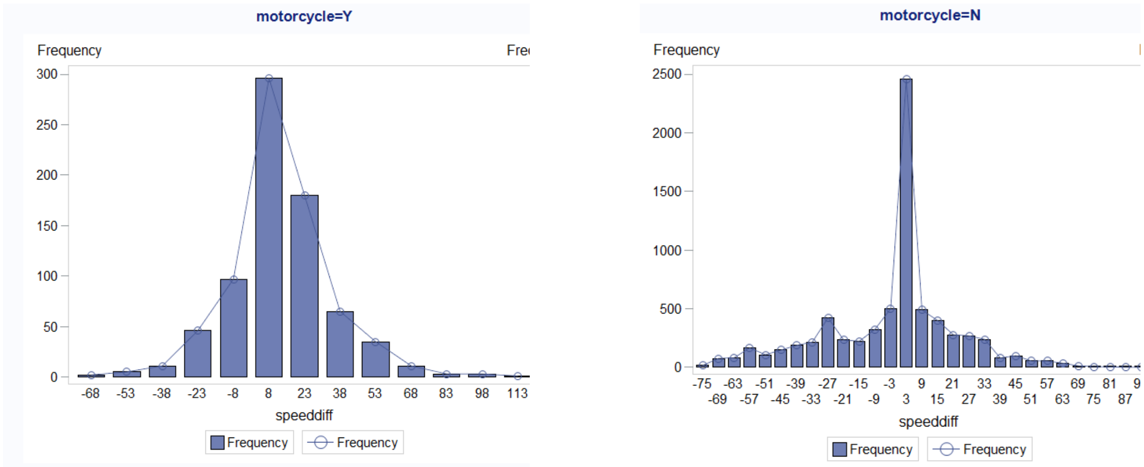
b. Other vehicles

Figure 36: Travel Speeds and Posted Speed Limits

The speed difference between travel speed and posted speed limit at the crash was calculated using Equation 1. A positive speed difference means the vehicle travel speed at the time of a crash is higher than a posted speed limit. In contrast, a negative value means the vehicle speed at the time of a crash is lower than the posted speed limit.

$$\text{Speed Difference (mph)} = \text{Travel Speed} - \text{Speed Limit} \quad (1)$$

The distribution of the speed difference calculated by two categories—motorcycles and all other vehicles—is presented in Figure 37.



a. Motorcycles b. Other vehicles

Figure 37: Distribution of Speed Difference

For motorcycle at-fault crashes, the frequency of speed difference is distributed in the center of 8 mph, which means the most frequent motorcycle travel speed at the time of a crash is 8 mph faster than the posted speed limit. For the other vehicles, 3 mph under the speed limit is the most frequent speed difference. Over-speeding, relative to the posted speed limit, is more of an issue for the motorcycle-involved crashes than for the other vehicle crashes.

Impairment

There were 5,438 impaired driving crashes involving motorcycles from 2010 to 2017. Of the impaired driving crashes involving motorcycles, 5,599 of the units were motorcycles. Approximately 83 percent (n=4,644) of these motorcycle operators were identified as driving impaired. Figure 38 displays the motorcycle operator injury severity by impairment status from 2010–2017.

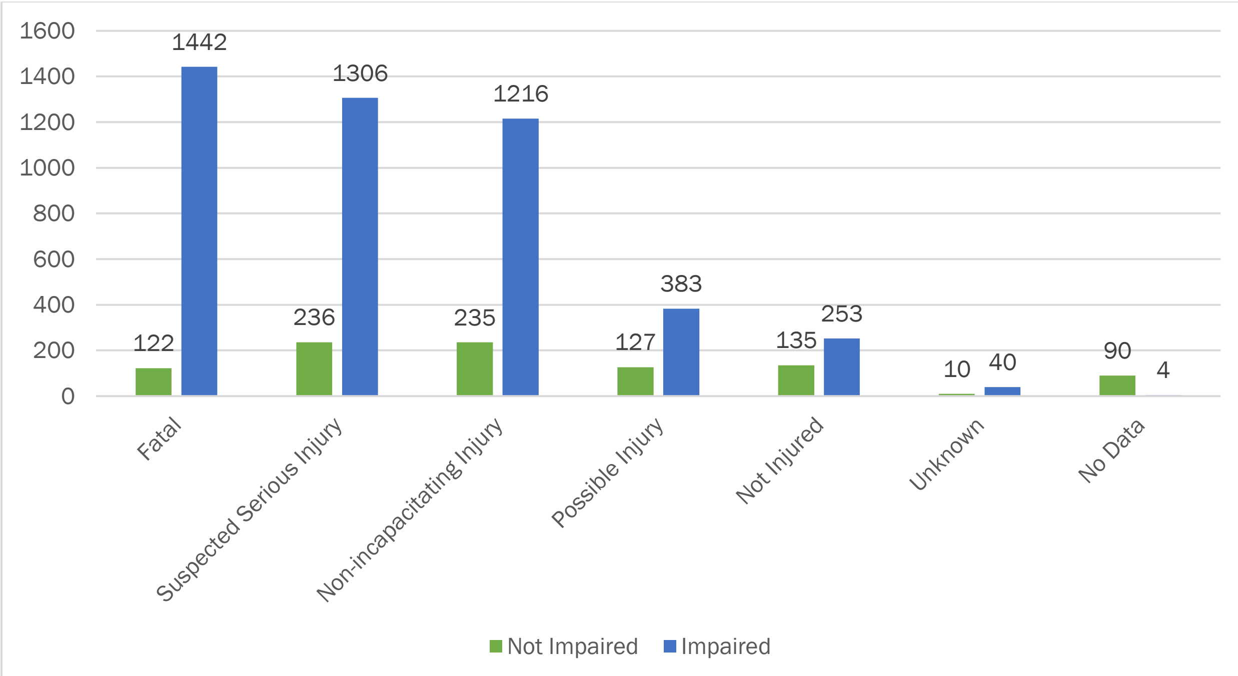


Figure 38: Motorcycle Operator Injury Severity by Impairment Status, 2010–2017

Of the impaired motorcycle operators, 43 percent (n=2,003) had a blood alcohol concentration (BAC) reported. The range of BAC values reported was 0.001 to 0.76 mg of alcohol per 100 mL of blood. The average reported BAC value was 0.15 mg of alcohol per 100 mL of blood. Figure 39 displays the frequency of reported BAC values for impaired motorcycle operators.

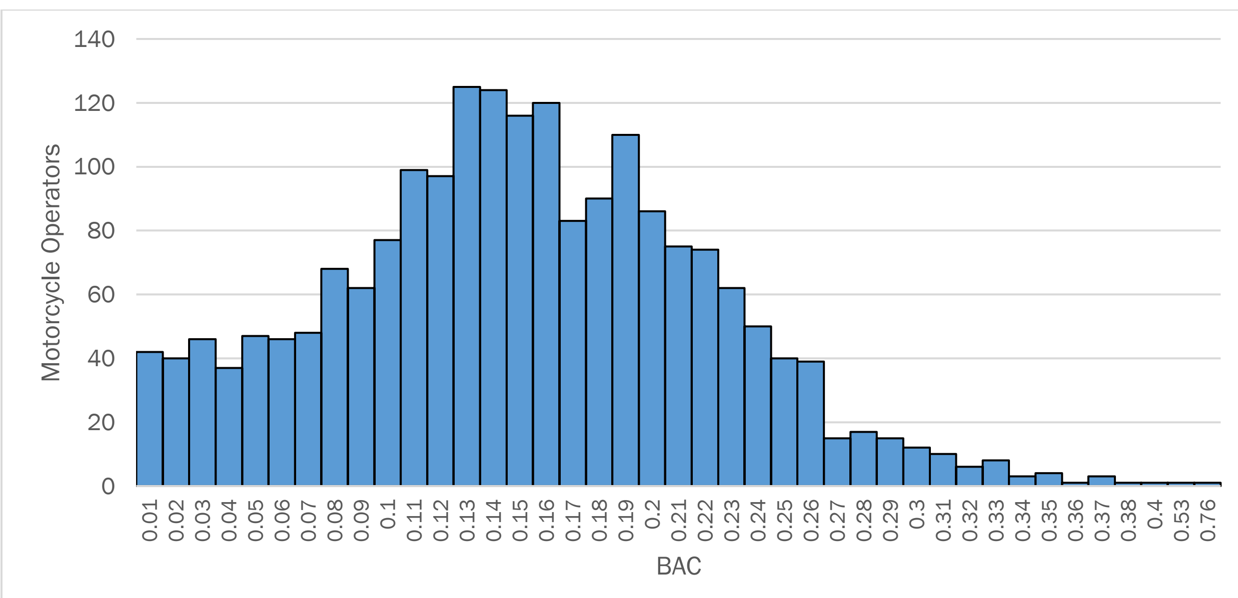


Figure 39: BAC Values for Impaired Motorcycle Operators, 2010–2017

Next, contributing factors associated with impaired motorcycle operators were explored and revealed that besides any alcohol or drug factors, speed-related contributing factors were assigned to 52 percent (n=2,396) of the operators, including:

- Unsafe speed.
- Speeding (over limit).
- Failed to control speed.

Single-Vehicle versus Multi-Vehicle Crash

Fifty-seven percent of the impaired driving crashes were single-vehicle motorcycle crashes. Table 19 shows the frequency of impaired driving crashes involving motorcycles by crash type for 2010–2017.

Table 19: Frequency of Impaired Driving Crashes by Crash Type, 2010–2017

Crash Type	Count	Percent of Total
Single-Vehicle Crash	3,082	57%
Multi-Vehicle Crash	2,356	43%
Total	5,438	100%

Licensing

Of the 5,110 motorcycle operators with license class information, 51 percent of those driving impaired did not have a Class M license. Table 20 displays motorcycle license status by impairment status for motorcycle operators from 2010–2017.

Table 20: Motorcycle License Status by Impairment Status, 2010–2017

M Class License	Not Impaired	Impaired
Yes	64%	49%
No	36%	51%

Helmet Use

Approximately 66 percent (n=3,070) of motorcycle operators riding impaired were not wearing a helmet when they crashed. Figure 40 shows the percentages of helmet usage by impairment status.

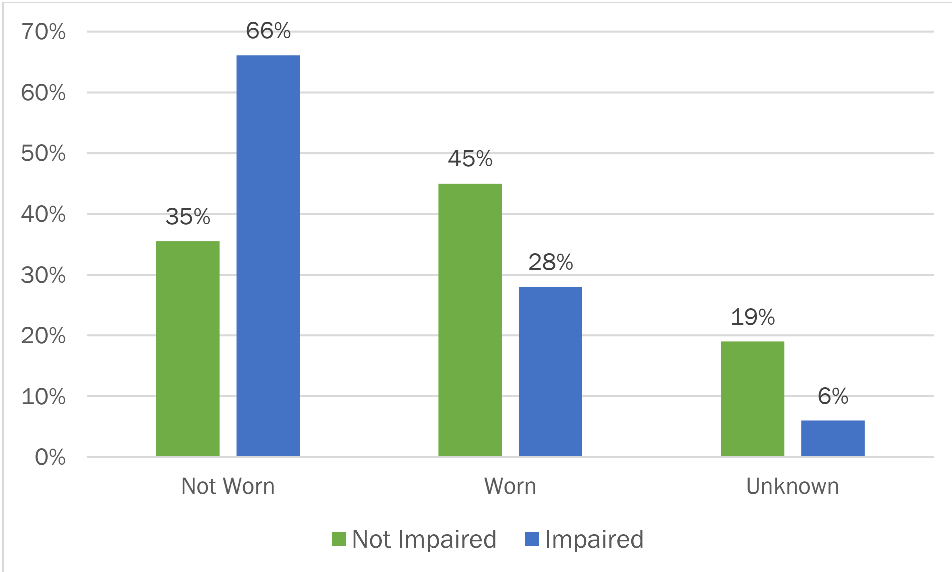
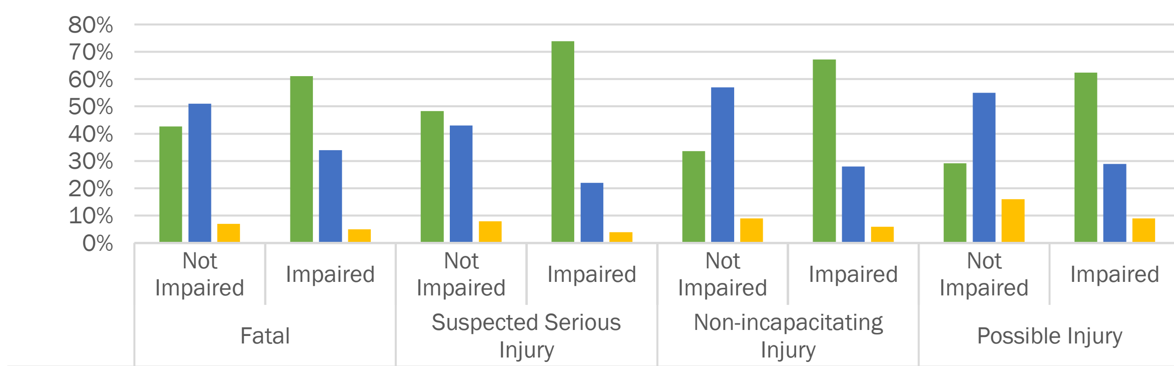


Figure 40: Helmet Use by Impairment Status, 2010–2017

Next, a comparison of injury severity and helmet use for impaired motorcycle operators and non-impaired operators was conducted and found that at all injury levels, impaired riders were less likely to be wearing a helmet (see Figure 41).



	Fatal: Not Impaired	Fatal: Impaired	Suspected Serious Injury: Not Impaired	Suspected Serious Injury: Impaired	Non-incapacitating Injury: Not Impaired	Non-incapacitating Injury: Impaired	Possible Injury: Not Impaired	Possible Injury: Impaired
Not Worn	43%	61%	48%	74%	34%	67%	29%	62%
Worn	51%	34%	43%	22%	57%	28%	55%	29%
Unknown	7%	5%	8%	4%	9%	6%	16%	9%

Figure 41: Helmet Use by Injury Severity and Impairment Status, 2010–2017

Non-Motorcycle Drivers

From 2010–2017, there were 2,596 non-motorcycle drivers involved in motorcycle crashes. Of those, 37 percent (n=967) were identified as impaired. Figure 42 displays the injury severity of non-motorcycle drivers involved in motorcycle crashes by impairment status from 2010–2017.

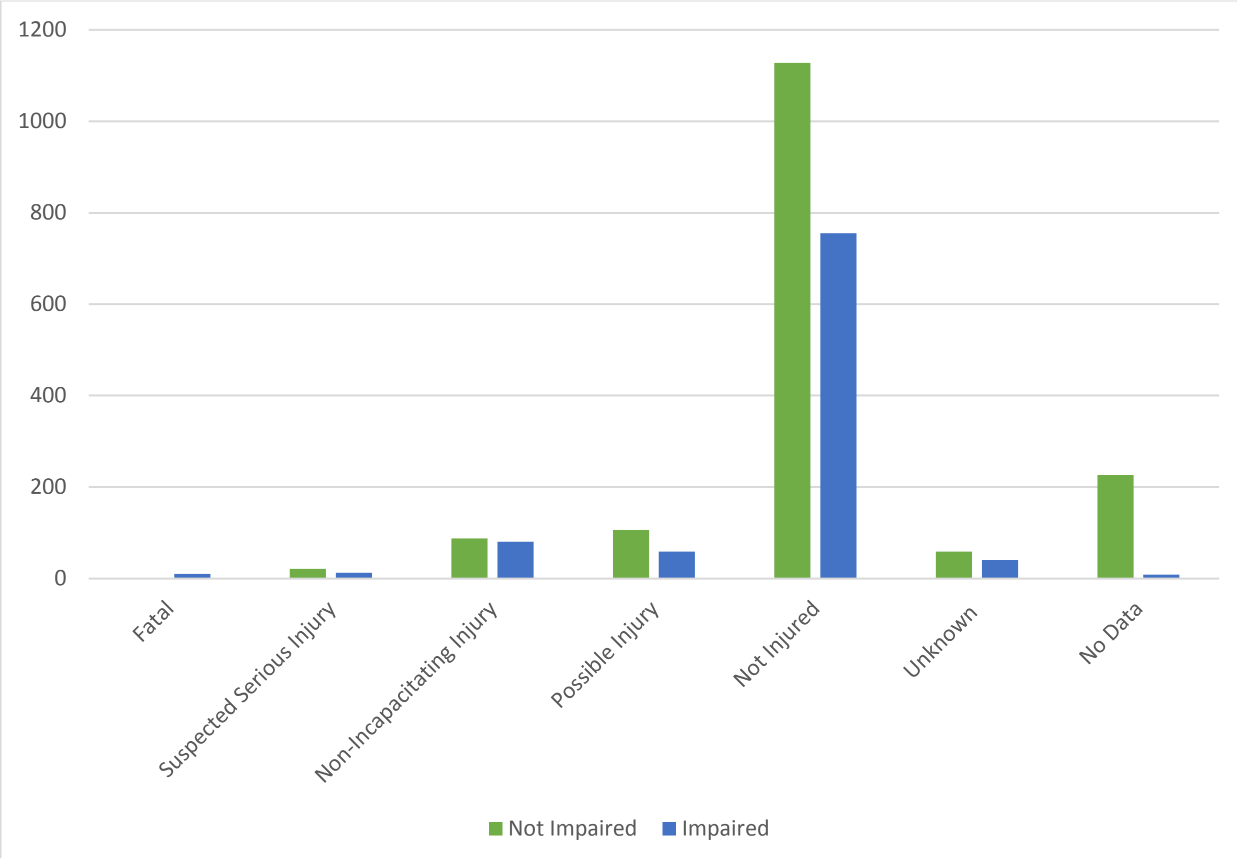


Figure 42: Injury Severity of Non-Motorcycle Drivers Involved in Motorcycle Crashes by Impairment Status, 2010–2017

Of the impaired non-motorcycle drivers involved in a motorcycle crash, 24 percent (n=230) failed to yield the right of way. Approximately 67 percent (n=154) of impaired non-motorcycle drivers who failed to yield the right of way were involved in intersection crashes, and 28 percent (n=65) were involved in driveway-access-related crashes (data not shown).

Environmental Factors

There are three variables that provide insight into environmental conditions at the time of motorcycle-involved crashes: weather conditions, surface conditions, and light conditions.

Weather Conditions

Table 21 shows the frequency of motorcycle-involved crashes by weather condition and crash severity. Approximately 84 percent of motorcycle-involved crashes occurred in clear weather conditions regardless of crash severity. There was a slightly higher percentage of cloudy weather conditions for fatal and suspected serious injury crashes.

Table 21: Frequency of Motorcycle Crashes by Weather Condition and Crash Severity, 2010–2017

	All Severities		Fatal and Suspected Serious Injury	
Weather Condition	Number of Crashes	Percent	Number of Crashes	Percent
Unknown	112	0.2%	24	0.1%
Rain	1,889	2.7%	375	2.0%
Sleet/Hail	18	0.0%	3	0.0%
Snow	14	0.0%	4	0.0%
Fog	171	0.3%	69	0.4%
Blowing Sand/Snow	24	0.0%	4	0.0%
Severe Crosswinds	132	0.2%	49	0.3%
Other (Explain in Narrative)	34	0.1%	14	0.1%
Clear	57,962	84.2%	15,606	83.8%
Cloudy	8,521	12.4%	2,483	13.3%

Surface Conditions

Table 22 shows the frequency of motorcycle-involved crashes by surface condition and crash severity. A majority of crashes occurred in dry conditions regardless of crash severity, including 94 percent of all crashes and 95 percent of all fatal and suspected serious injury crashes. This finding is likely to be a function of the fact that most motorcycle driving is done during favorable weather conditions. The proportion of surface conditions did not vary greatly by crash severity.

Table 22: Frequency of Motorcycle Crashes by Surface Condition and Crash Severity, 2010–2017

	All Severities		Fatal and Suspected Serious Injury	
Surface Condition	Number of Crashes	Percent	Number of Crashes	Percent
Unknown	91	0.1%	17	0.1%
Dry	64,569	93.8%	17,651	94.7%
Wet	3,076	4.5%	680	3.7%
Standing Water	170	0.3%	34	0.2%
Slush	1	0.0%	0	0.0%
Ice	44	0.1%	11	0.1%
Other (Explain in Narrative)	452	0.7%	107	0.6%
Snow	4	0.0%	0	0.0%
Sand, Mud, Dirt	470	0.7%	131	0.7%

Light Conditions

Table 23 displays the frequency of crashes by light condition and crash severity. A majority of crashes occurred during daylight regardless of crash severity, including 66 percent of all crashes and 59 percent of all fatal and suspected serious injury crashes. Of importance, there was a higher percentage of fatal and suspected serious injury crashes at dark, night lighted and dark, lighted compared to all severities. This finding indicates that dark lighting conditions may be associated with greater crash severity.

Table 23: Frequency of Motorcycle Crashes by Light Condition and Crash Severity, 2010–2017

	All Severities		Fatal and Suspected Serious Injury	
Light Condition	Number of Crashes	Percent	Number of Crashes	Percent
Unknown	128	0.2%	34	0.2%
Daylight	45,578	66.2%	11,060	59.4%
Dawn	572	0.8%	175	0.9%
Dark, Not Lighted	7,888	11.5%	3,127	16.8%
Dark, Lighted	13,192	19.2%	3,767	20.2%
Dusk	1,224	1.8%	388	2.1%
Dark, Unknown Lighting	282	0.4%	74	0.4%
Other (Explain in Narrative)	13	0.0%	6	0.0%

Intersections

Left Turns

To better understand the role of left turns, multi-vehicle (two or more) crashes involving motorcycles at intersections were selected and stratified by collision type. Next, fatal and suspected serious injury crashes were selected before identifying the top five collision types at intersections. As indicated in Figure 43, the crash type of one vehicle turning left and one vehicle traveling straight in opposite directions accounted for 39 percent of intersection fatal or suspected serious injury crashes. This was followed closely by right-angle collision types (i.e., both vehicles going straight) at 35 percent. The remaining most common collision types were an angle collision with one vehicle going straight and one vehicle turning left, at 14 percent; a collision in the same direction with one vehicle traveling straight and one turning left, at 6 percent; and an angle collision between one vehicle traveling straight and one turning right, at 2 percent.

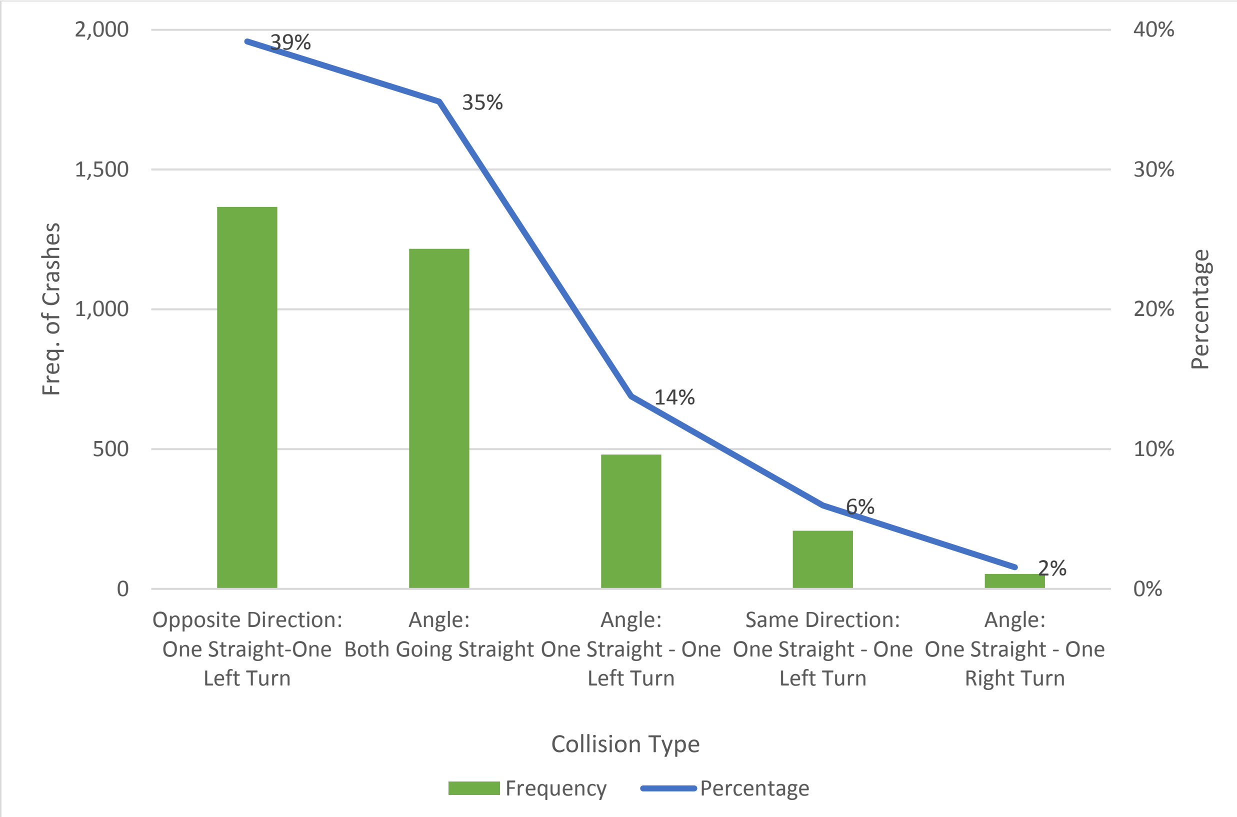


Figure 43: Top Manner of Collision for Multi-Vehicle Intersection Crashes Involving a Motorcycle with Fatal and Suspected Serious Injury Severity, 2010–2017

Failed to Yield Right of Way (FTYROW) and Left Turns

The top contributing factor for intersection multi-vehicle fatal or suspected serious injury crashes involving motorcycles in 2010–2017 was FTYROW—turning left, and about 30 percent of the intersection crashes were attributed to this factor. Particularly in collisions between one vehicle turning left and one vehicle traveling straight in opposite directions, the contributing factor of FTYROW—turning left was predominant and accounted for 74 percent.

To further understand the interrelationship between the left-turn maneuver and FTYROW intersection crashes, a matrix of collision types and contribution factors among intersection multi-vehicle fatal or suspected serious injury crashes involving motorcycles was created. As shown in Table 24, by far the greatest number of crashes happened when one vehicle was turning left while the other vehicle was passing an intersection traveling straight due to FTYROW.

Table 24: Frequency of Manner of Collision by Contributing Factors for Multi-Vehicle Intersection Crashes Involving Motorcycles with K and A Severity, 2010–2017

	Manner of Collision				
Contributing Factor	Opposite Direction: One Straight—One Left Turn	Angle: Both Going Straight	Angle: One Straight—One Left Turn	Same Direction: One Straight—One Left Turn	Angle: One Straight—One Right Turn
FTYROW—Turning Left	862 (33%)	23 (<1%)	77 (19%)	11 (3%)	1 (<1%)
FTYROW—Stop Sign	6 (<1%)	473 (20%)	212 (51%)	0 (0%)	17 (16%)
Disregard Stop and Go Signal	79 (3%)	176 (7%)	34 (8%)	0 (0%)	4 (4%)
Disregard Stop Sign or Light	24 (<1%)	168 (7%)	25 (6%)	1 (<1%)	7 (6%)
Driver Inattention	175 (7%)	184 (8%)	64 (16%)	29 (7%)	9 (8%)
Number of Target Crashes	2,642	2,419	412	409	109

Driving Under the Influence (DUI)

To examine the impact of DUI in crashes involving motorcycles, the frequency of DUI crashes involving motorcycles in intersection versus non-intersection crashes was compared for 2010–2017 (see Table 25). Of all severity crashes involving motorcycles, DUI crashes accounted for 2 percent of all intersection crashes and 4 percent of non-intersection crashes. For fatal or suspected serious injury severity, similarly, the percentage of DUI non-intersection crashes was higher than that of the intersection crashes.

Table 25: Frequency of DUI Crashes Involving Motorcycles by Severity and Intersection/Non-Intersection, 2010–2017

	Fatal or Suspected Serious Injury Crashes			All Severity Crashes		
Category	DUI	Non-DUI	Percent of DUI to Non-DUI	DUI	Non-DUI	Percent of DUI to Sum
Intersection	849	5,180	16%	1,569	22,947	7%
Non-Intersection	2,336	10,266	23%	3,792	40,569	9%

Signal Type/Traffic Control

The greatest number of intersection crashes involving motorcycles occurred at stop sign controlled intersections, followed by signal controlled, marked lane, no-traffic control, and center stripe/divider intersections. Although there were fewer crashes at the intersections controlled by a center stripe/divider, the proportion of fatal and suspected serious injury crashes out of all severities was higher than other control types, as shown in Figure 44. An example layout of an intersection controlled by a center stripe/divider is shown in Figure 45.

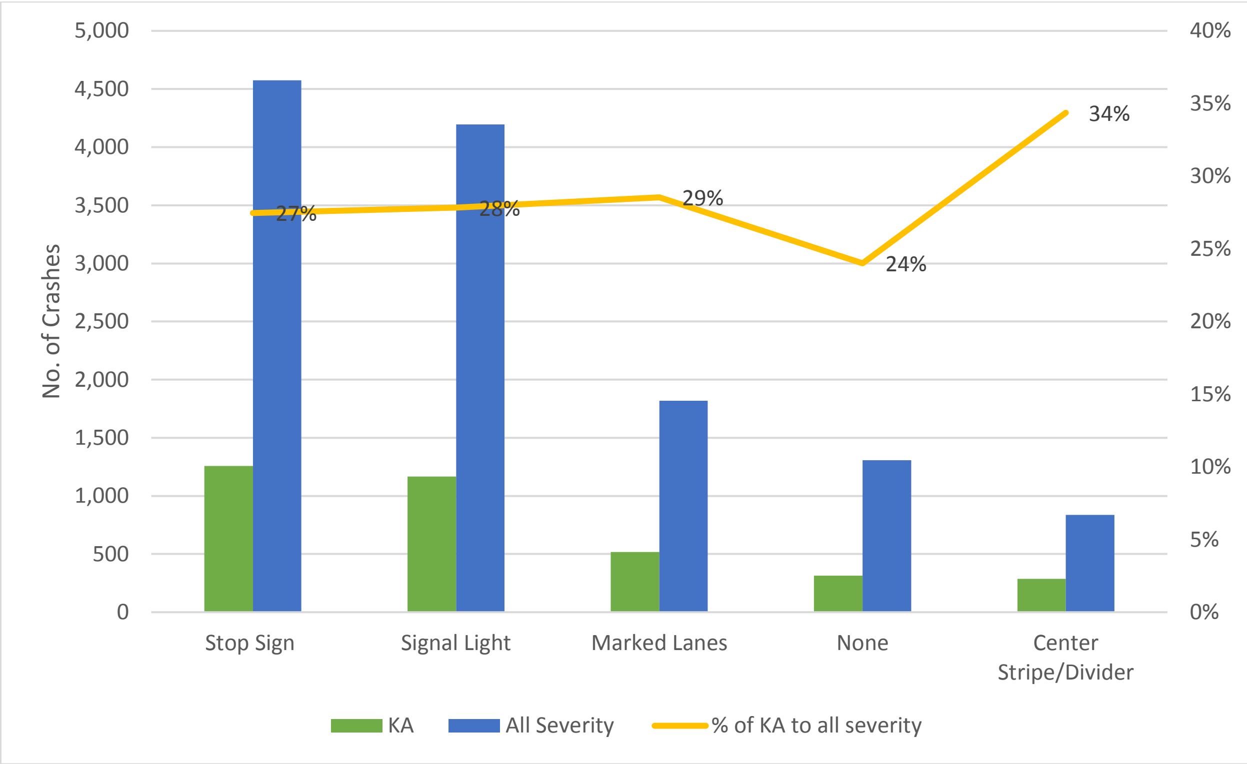


Figure 44: Frequency of Intersection Crashes by Traffic Control Types, 2010 to 2017

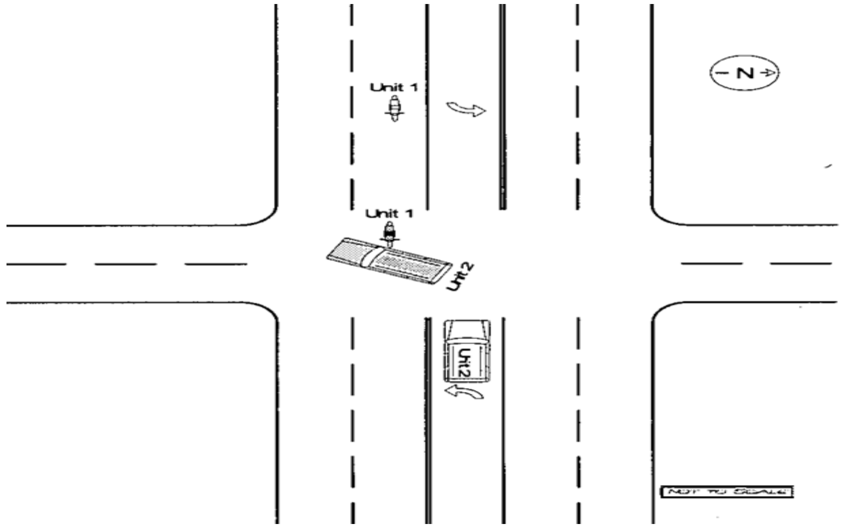


Figure 45: Intersection Layout Controlled by Center Stripe/Divider

Curve Involvement

Roadway curves can present a unique challenge to roadway safety for motorcycle riders. Specific challenges that curves present include limited sight distance, wide variation in speed limits, quick changes in speed limits, and variation in curve radii. Consequently, not all curves can be treated the same by motorists. Motorcycles are particularly at risk of crashing on curves because they are less stable with only two wheels. Curves require a greater skill level to negotiate successfully and safely. In CRIS, curve-related crashes can be identified using data from curve type or roadway alignment.

Curve Involvement and General Characteristics

On average, 1,852 riders were affected by crashes on curves each year from 2010–2017, including 149 fatalities per year and 490 suspected serious injuries per year. Approximately 19 percent (n=13,376) of all on-system crashes occurred on curves. Table 26 displays the frequency of rider injury severity by curve status. Overall, a higher proportion of fatalities and suspected serious injuries occurred on curves (35 percent) compared to non-curved roadways (23 percent). This pattern suggests that crashes on curves are more severe. Fatal and suspected serious injury crashes that are curve related also are more likely to be single-vehicle crashes compared to non-curve-related crashes. Approximately 85 percent of curve-related crashes involving motorcycles are single-vehicle crashes compared to 41 percent of crashes that are not curve related.

Overall, for fatal and suspected serious injury crashes among motorcycle riders involved in crashes on curves, 56 percent occurred in rural areas and 44 percent in urban areas in 2010–2017. Similar to non-curve crashes, the majority (59 percent) of fatal and suspected injury crashes occurred in daylight. An additional 38 percent occurred under dark lighting conditions. The remaining 3 percent of crashes occurred under daylight or dusk lighting conditions. Also similar to non-curve-related crashes, the majority (95 percent) of fatal and suspected injury crashes occurred under dry surface conditions. Only 4 percent occurred with a wet surface condition. Therefore, lighting and surface conditions do not appear to play a larger role in the occurrence of curve-related crashes than they do in non-curve-related crashes.

Table 26: Frequency of Riders Involved in Curve-Related Crashes versus Non-Curve-Related Crashes, 2010–2017

	Fatal	Suspected Serious Injury	Non-Incapacitating Injury	Possible Injury	Non-Injury	Unknown Injury	Total Rider Injury
Curve	1,191 (8%)	3,933 (27%)	5,768 (39%)	2,279 (15%)	1,399 (9%)	245 (2%)	14,815 (100%)
Non-Curve	2,642 (4%)	11,966 (19%)	23,447 (38%)	13,545 (22%)	9,160 (15%)	1,141 (2%)	61,901 (100%)

Injury Severity for Motorcycle Riders versus Automobile Drivers and Passengers for Curve-Related Crashes

Table 27 displays the frequency of injury by severity for motorcycle riders compared to automobile drivers and passengers from 2010–2017. Overall, motorcycle riders experienced more severe injuries compared to automobile drivers and passengers. For example, 35 percent of motorcycle riders sustained a fatal or suspected serious injury compared to only 3 percent of drivers and passengers in automobiles. Similarly, only 9 percent of motorcycle riders did not experience an injury, compared to 71 percent of drivers and passengers in automobiles.

Table 27: Frequency of Injury by Severity among Motorcycle Riders Compared to Automobile Drivers and Passengers Involved in Curve-Related Crashes, 2010–2017

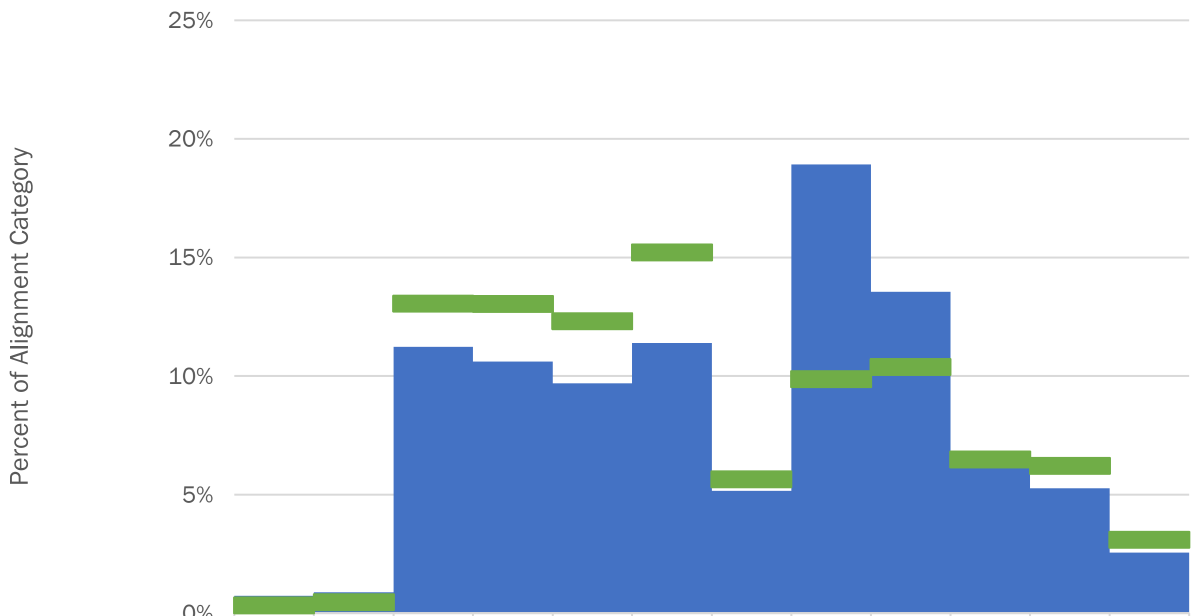
	Fatality	Suspected Serious Injury	Non-Incapacitating Injury	Possible Injury	Non-Injury	Unknown Injury	Total Rider Injury
Motorcycle Riders	1,191 (8%)	3,933 (27%)	5,768 (39%)	2,279 (15%)	1,399 (9%)	245 (2%)	14,815 (100%)
Drivers & Passengers (Automobile)	4,425 (1%)	15,450 (2%)	54,405 (9%)	73,933 (12%)	448,630 (71%)	33,798 (5%)	630,641 (100%)

Curves and Contributing Factors

For fatal and suspected injury crashes that were curve related, the most common contributing factors were unsafe speed (26 percent) and failed to control speed (14 percent). An additional 4 percent were coded as speeding over the limit. Therefore, approximately one-third of crashes involved an issue with speed. Common contributing factors also included failure to drive in a single lane (8 percent), driver inattention (8 percent), under the influence of alcohol (7 percent), had been drinking (5 percent), and faulty evasive action (5 percent).

Curves and Posted Speed Limits

Figure 46 displays the frequency of curve- and non-curve-related crashes by posted speed limit in miles per hour. Approximately 48 percent of curve-related crashes occurred in areas with a posted speed of 55 mph or above. Only about 35 percent of non-curve-related crashes occurred in areas with a posted speed limit of 55 mph or above.



	20	25	30	35	40	45	50	55	60	65	70	75
Curve Alignment	1%	1%	11%	11%	10%	11%	5%	19%	14%	7%	5%	3%
Straight Alignment	0%	0%	13%	13%	12%	15%	6%	10%	10%	6%	6%	3%

Posted Speed Limit (mph)

Figure 46: Frequency of Curve and Non-Curve Fatal and Suspected Serious Injury Crashes by Posted Speed Limit, 2010 to 2017

Curves and Impairment

Given that curves require greater balance and driver attention, impairment by drugs or alcohol could further increase the risk of crashing. Table 28 and Table 29 display the frequency of fatal and suspected serious injuries among motorcycle riders by curve and impairment status. Approximately 24 percent of curve-related crashes involving a rider fatality or suspected serious injury involved an impaired rider, compared to 14 percent of non-curve-related crashes (see Table 28). Examining the data another way, 38 percent of riders who were impaired and sustained a fatal or suspected serious injury had a curve-related crash, compared to 23 percent of riders who were not impaired (see Table 29). These patterns suggest as association between impairment and curves among riders sustaining fatal or suspected serious injuries.

Table 28: Frequency of Fatal and Serious Injuries among Impaired and Non-Impaired Riders by Curve Status, 2010–2017

	DUI Rider		Non-DUI Rider		Total Rider Fatality & Suspected Serious Injuries
	Fatality	Suspected Serious Injury	Fatality	Suspected Serious Injury	
Curve	615 (12%)	605 (12%)	576 (11%)	3,328 (65%)	5,124 (100%)
Non-Curve	973 (7%)	974 (7%)	1,657 (11%)	10,948 (75%)	14,552 (100%)

Table 29: Frequency of Fatal and Serious Injuries Resulting from Crashes on Curve-Related and Non-Curve-Related Roadways by Impairment Status, 2010–2017

	Curve		Non-Curve		Total Rider Fatality & Suspected Serious Injury
	Fatality	Suspected Serious Injury	Fatality	Suspected Serious Injury	
DUI Rider	615 (19%)	605 (19%)	973 (31%)	974 (31%)	3,167 (100%)
Non-DUI Rider	576 (3%)	3,328 (20%)	1,657 (10%)	10,948 (66%)	16,509 (100%)

Curve Tool Analysis

Anecdotal evidence from prior motorcycle crash analyses suggested that not all curve-related crashes were being identified. To examine this issue, the study team developed the GIS Curve Identification Tool and tested it on a popular area for motorcycle riders known as “The Three Sisters,” or RM335, RM336, and RM337. A total of 293 crashes were identified as occurring on these roadways from 2010 to 2017. A total of 370 motorcycle riders were involved in these crashes during this time period as follows: RM335 (61 riders), RM336 (100 riders), and RM337 (209 riders).

As shown in Figure 47, the majority of riders were operators for all the injury severity categories.

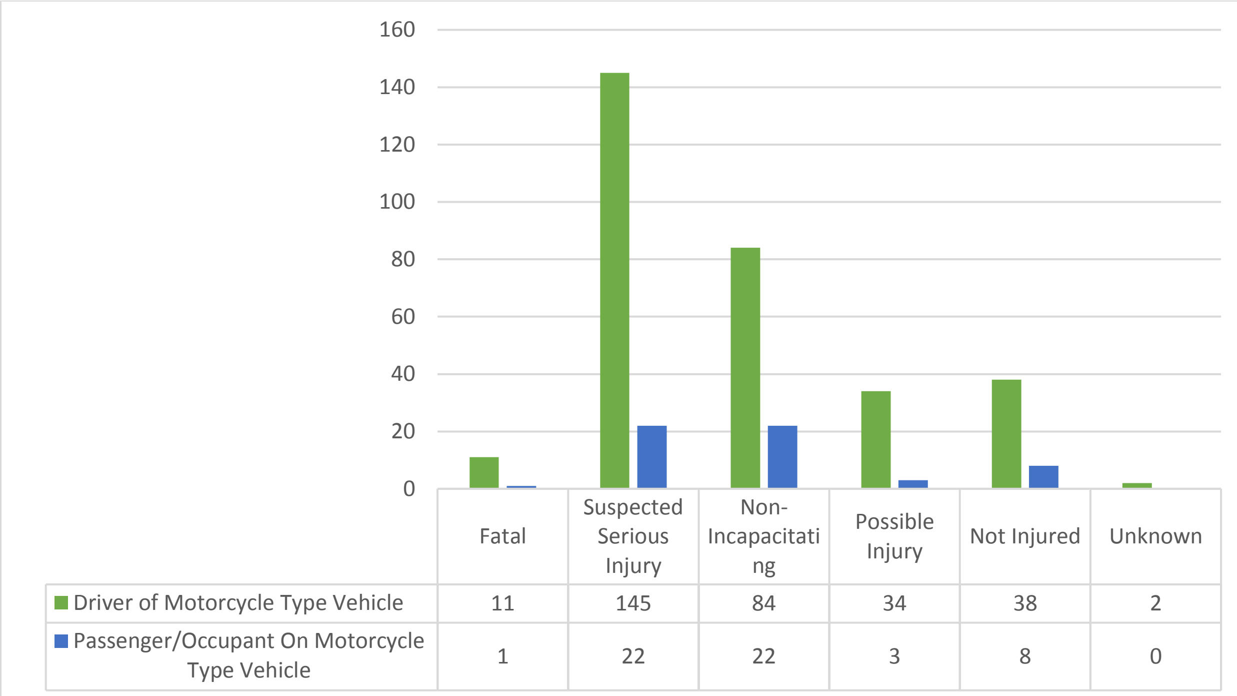


Figure 47: Frequency of Type of Rider for Crashes on "The Three Sisters," 2010 to 2017

Based on the GIS Curve Identification Tool, 248 (67 percent) of the riders were involved in crashes on a curve, as show in Table 30. The results of the GIS Curve Identification Tool can be compared to two variables in the CRIS data: the roadway inventory data appended to the crash record and the police officer's assessment coded under "road alignment" in his or her attempt to capture the geometric characteristics of the roadway. A comparison of the GIS Curve Identification Tool results and the roadway inventory data appended to the CRIS data shows that 84 (23 percent) riders were not identified as being involved in a crash on a curve if the GIS Curve Identification Tool is considered to be the "gold standard." Similarly, the GIS Curve Identification Tool did not identify 24 (20 percent) of the riders as being on a curve if the CRIS data are considered to be the gold standard.

Table 30: Comparison of Crashes Identified as Occurring on a Curve by the GIS Curve Identification Tool versus Curve Type in CRIS, 2010–2017

	GIS Curve Identification Tool		
Curve Type (CRIS)	**On a Curve**	**Not a Curve**	**Total**
Normal Curve	164	24	188
Not a Curve	84	98	182
Total	248	122	370

When the GIS Curve Identification Tool was compared to the road alignment variable (police officer's assessment), it was found that 5 percent of riders were in crashes on a straightaway that the GIS Curve Identification Tool identified as occurring on a curve, as shown in Table 31. Twenty-two percent of the riders were in crashes that the officer assigned as curved road alignment, but the GIS tool did not identify the location as a curve.

Table 31: Comparison of Crashes Identified as Occurring on a Curve by the GIS Curve Identification Tool versus Road Alignment in CRIS, 2010–2017

	GIS Curve Identification Tool		
Road Alignment (CRIS)	On a Curve	Not a Curve	Total
Straight, level	2%	5%	7%
Straight, grade	3%	6%	9%
Straight, hillcrest	0%	1%	1%
Curve, level	15%	6%	21%
Curve, grade	44%	12%	55%
Curve, hillcrest	2%	4%	6%
Unknown	0%	0%	0%
Total	67%	33%	100%

The crashes for the 78 riders comprising the 22 percent that were not identified as being on a curve by the GIS Curve Identification Tool but identified as such by the officer were visually inspected by plotting them on maps. Figure 48 to Figure 50 display the maps.

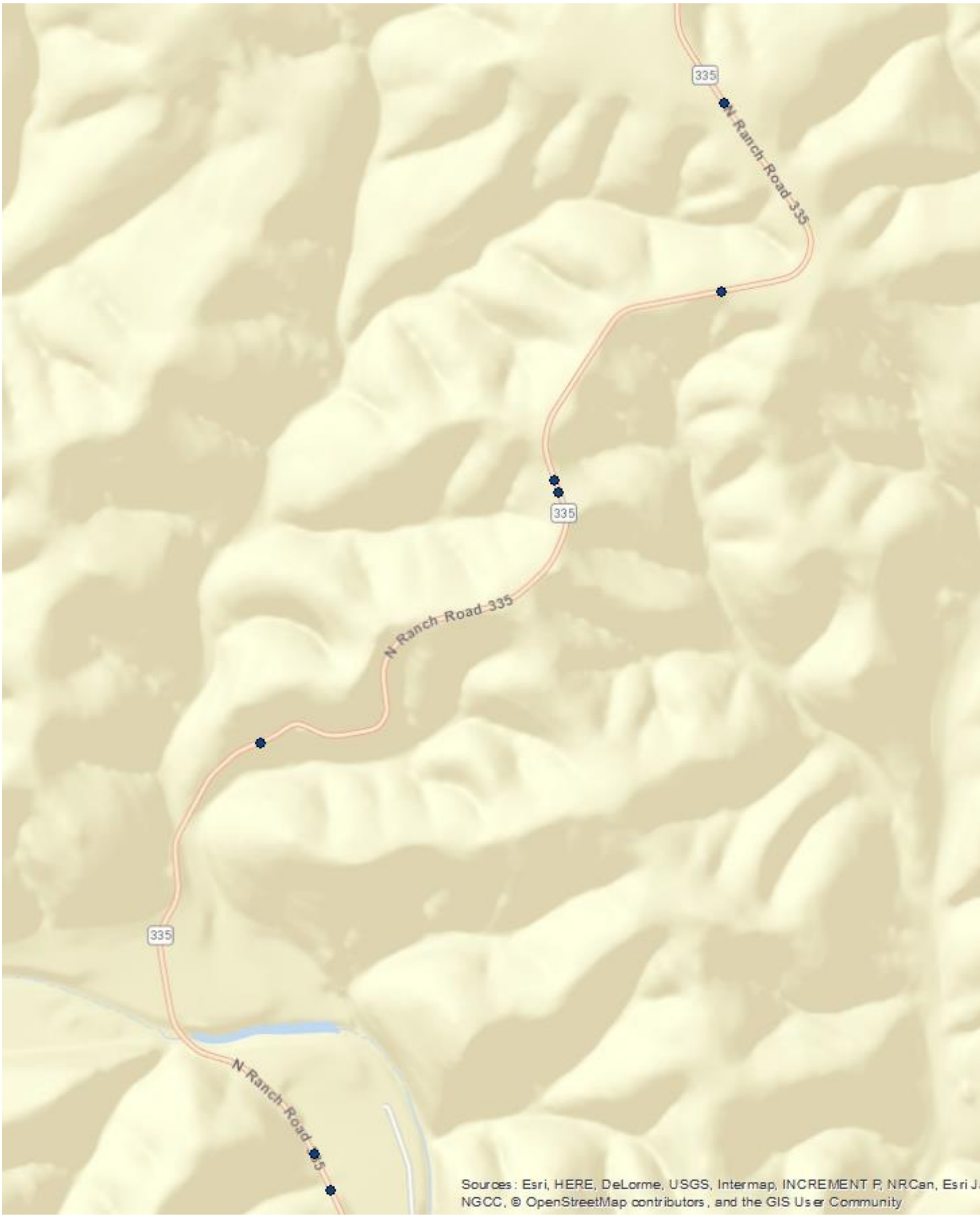


Figure 48: Example of Misidentified Crashes Assigned between Curves on RM335

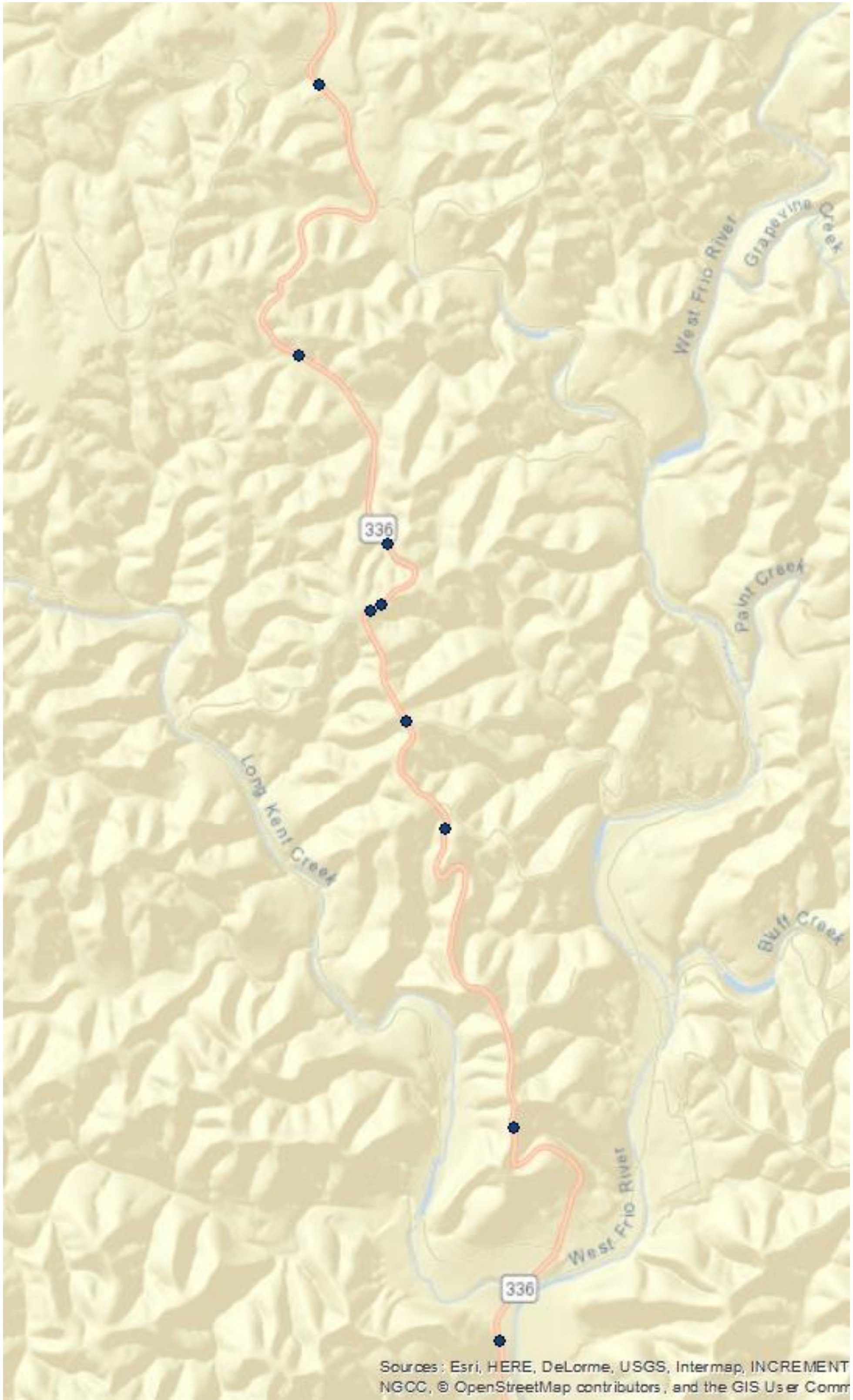


Figure 49: Example of Misidentified Crashes Assigned between Curves on RM336

Figure 50: Example of Misidentified Crashes Assigned between Curves on RM337

Table 32 displays a comparison of the three different variables that identify a rider as being involved in a crash on a curve. Findings suggest that the GIS Curve Identification Tool identified more of the riders as being on the curve than did the appended roadway inventory data but less than did the officer assessment (road alignment). Assuming that crash coordinates in the crash data are correct, some of the differences between the GIS Curve Identification Tool and the police officer reported road alignment may be attributable to the subjective nature of the reporting process. The police officer may be taking into account the characteristics of a larger section of the roadway or the details of the crash given to him or her by the rider or witnesses.

Table 32: Comparison of Crashes Identified as Occurring on a Curve by the Curve Type, GIS Curve Identification Tool, and Road Alignment, 2010–2017

Curve	Curve Type (Roadway Inventory)	GIS Tool	Road Alignment (Officer)
No	182	122	65
Yes	188	248	305
Total	370	370	370

The settings on the GIS Curve Identification Tool can be changed to allow for more of the roadway to be identified as a curve. This is an important consideration for analyzing crashes on particularly curvy roadways.

For riders sustaining fatal injuries, the GIS Curve Identification Tool and the police officers classified the same percentage of the riders as being involved in a crash on a curve. However, based on the roadway inventory variable, only about 50 percent of the riders were identified as being involved in a crash on a curve. Based on the roadway inventory data, approximately 50 percent of riders were classified as being involved in a crash on a curve regardless of injury severity. The police officer classified about 20 percent more of the crashes in the other injury severity categories as being involved in a crash on a curve, compared to the GIS Curve Identification Tool. Again, this difference could be a function of the subjective nature of crash reporting and the officer's ability to base his or her assessment on not only what he or she sees in the field but also other evidence such as witness reports. Table 33 displays these data.

Table 33: Frequency of Injury Severity by Curve Assignment Based on the GIS Curve Identification Tool, Roadway Data, and Road Alignment, 2010–2017

		Fatal	Suspected Serious Injury	Non-Incapacitating Injury	Possible Injury	Not Injured	Total Injury
GIS Tool	On a Curve	83%	65%	67%	65%	70%	67%
GIS Tool	Not on a Curve	17%	35%	33%	35%	30%	33%
Road Alignment	Curve	83%	84%	83%	86%	72%	82%
Road Alignment	Straight	17%	16%	17%	14%	28%	17%
Road Alignment	Unknown	0%	1%	0%	0%	0%	1%
Roadway Data	Normal Curve	58%	51%	47%	57%	50%	51%
Roadway Data	Not a Curve	42%	49%	53%	43%	50%	49%

The GIS Curve Identification Tool allowed for assigning riders to crashes on the inside or the outside of a curve, as shown in Figure 51.

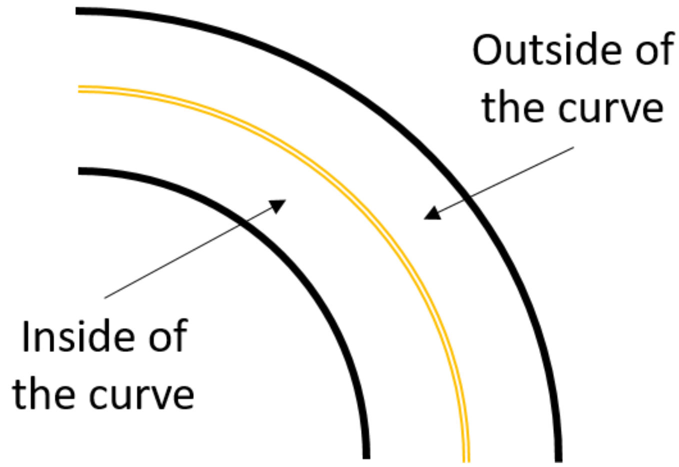


Figure 51: Illustration of the Inside versus the Outside of a Curve

Examining the inside versus the outside of the curve with respect to crash location may be important with regard to different crash causation factors. In both categories, the top three contributing factors assigned to the rider were unsafe speed, driver inattention, and failed to heed warning sign. For those classified as being inside the curve, the fourth most assigned contributing factor was failed to control speed. However, for riders on the outside of the curve, the fourth contributing factor was faulty evasive action. These data are shown in Figure 52.

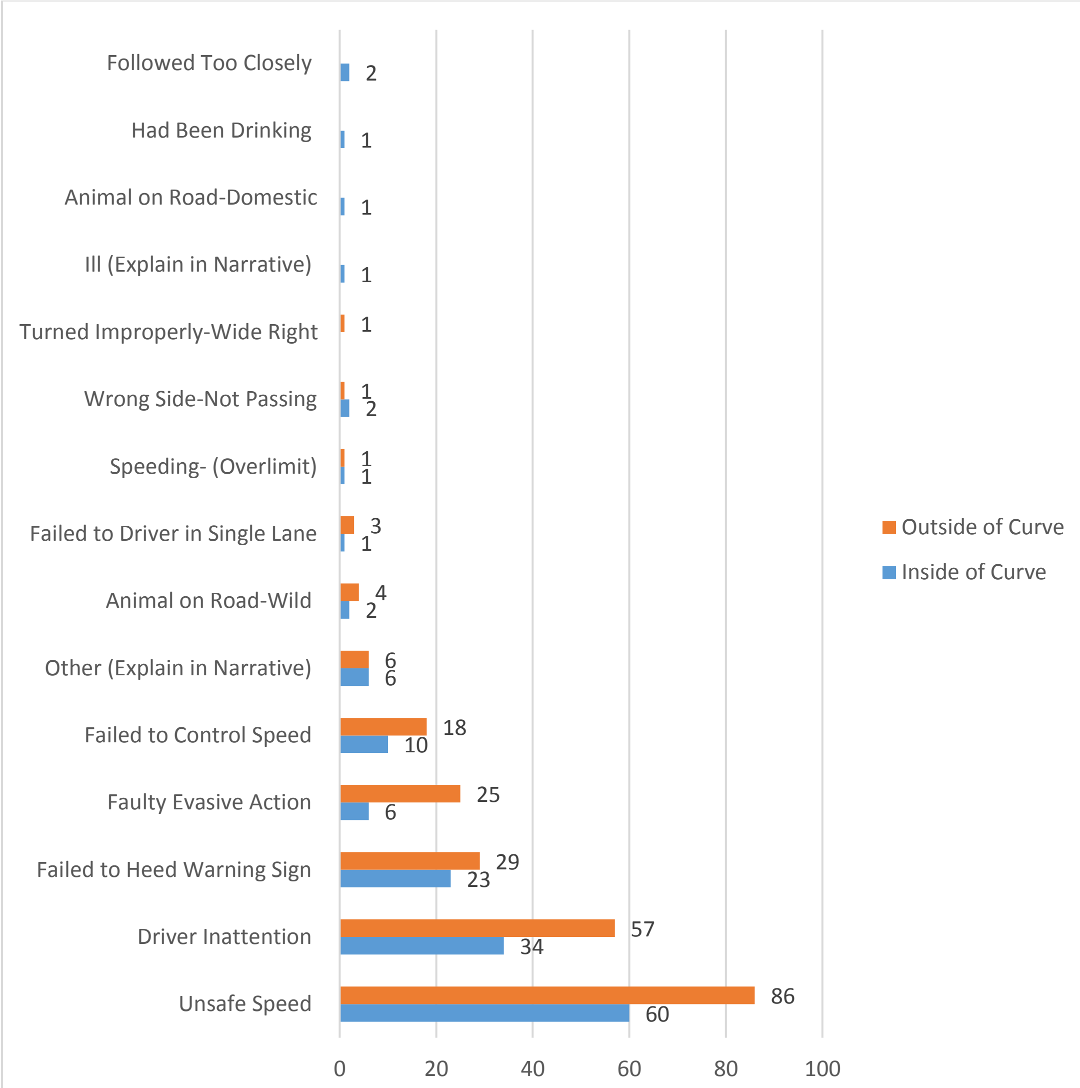


Figure 52: Frequency of Contributing Factors by the Inside versus the Outside of a Curve

Conspicuity

Three fields collected in a crash report can be used to explore the role of motorcycle conspicuity in crashes: vehicle size, vehicle color, and light conditions.

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 (SUV), pickup truck, and van. 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. Crashes were grouped by vehicle type considered at fault. These types were grouped as motorcycle, passenger car, SUV, pickup, and van. Finally, the percentage of the crashes where the vehicle was at fault due to a conspicuity issue was calculated. As shown in Figure 53, in multi-vehicle crashes involving motorcycles, when the vehicle at fault was a passenger vehicle, SUV, pickup, or van that crashed with a motorcycle, 47 to 51 percent of these crashes involved a conspicuity issue. When a motorcycle was deemed to be at fault, 25 percent of the crashes involved a conspicuity issue. The proportion of a conspicuity issue to a motorcyclist was lower than that of other motorists. It does mean that drivers in vehicles larger than motorcycles had difficulty detecting the motorcycles, which conceivably increased the risk of a crash.

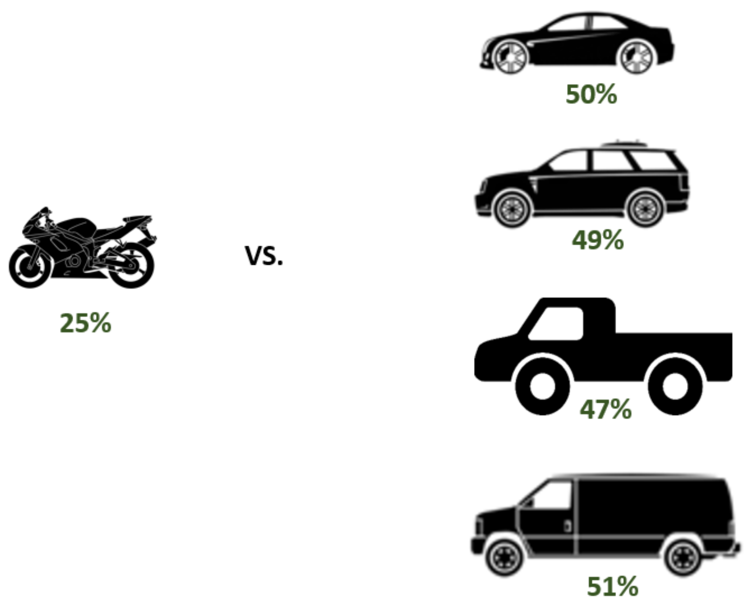


Figure 53: Frequency of Conspicuity Factors Playing a Role in Multi-Vehicle Collisions by Vehicle Type for All Severities, 2010–2017

Color

To explore the impact of the color of a motorcycle on conspicuity, all severity crashes during 2010–2107 were categorized as single-vehicle or multi-vehicle crashes. 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 of a no-fault vehicle were identified. Next, the frequency of crashes was computed by vehicle color category and conspicuity issues, as displayed in Table 34. The proportion of the crashes that involved conspicuity issues was higher when the colors of no-fault vehicles were dark versus bright. This evidence suggests that vehicle color plays a significant role in conspicuity.

Table 34: Frequency of Crashes by Vehicle Colors and Conspicuity Issues, 2010–2017

Color		Conspicuity-Related Crashes			
		No	Yes	Total	Percent of Yes
	Purple	133	151	284	47%
	Orange	290	333	623	47%
	Black	4,840	5,832	10,672	45%
	Yellow	251	323	574	44%
	Blue	1,575	2,185	3,760	42%
	Maroon	573	825	1,398	41%
	Red	1,351	2,020	3,371	40%
	Green	439	726	1,165	38%
	Silver	1,021	1,753	2,774	37%
	Gray	738	1,423	2,161	34%
	White	1,470	3,020	4,490	33%
	Brown	96	200	296	32%
	Beige	65	146	211	31%
	Gold	130	301	431	30%
	Tan	133	327	460	29%

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 (2010–2017) according to light conditions and conspicuity issues. Proportions of motorcycle-involved multi-vehicle crashes by light conditions and conspicuity issues were then compared, as displayed in Table 35.

As shown in Table 35, many crashes occurred in daylight conditions. The percentage of crashes related to conspicuity issues in daylight conditions was 23 percent, while 12 to 22 percent of conspicuity-related crashes occurred in dark conditions. The percentages of crashes related to conspicuity issues in dark conditions were lower than those in daylight conditions. Researchers did not find that dark conditions were increasing the likelihood of crashes related to conspicuity issues.

Table 35: Proportion of Multi-Vehicle Crashes by Conspicuity Factors and Light Conditions

Light Condition	Conspicuity-Related Crashes			
	Yes	No	Total	Percent
Daylight	10,357	35,221	45,578	23%
Dawn	146	426	572	26%
Dark, Not Lighted	911	6,977	7,888	12%
Dark, Lighted	2,955	10,237	13,192	22%
Dusk	243	981	1,224	20%
Dark, Unknown Lighting	52	230	282	18%

Direction of Collision Force

The team collected information on the deformation of the other vehicle in motorcycle-involved multi-vehicle crashes in the TxDOT CRIS data set, 2010 to 2017. The severity information of each vehicle in the crash was identified as well as the overall crash severity. For example, the overall crash severity is A (suspected serious injury) when the severity of Vehicle 1 is C (possible injury) and the severity of the motorcycle is A. Table 36 presents the severity information by vehicle unit and overall crash. A description and illustration of the direction of collision force is presented in the Appendix. A non-motorcycle vehicle includes a passenger car, SUV, truck, bus, and van.

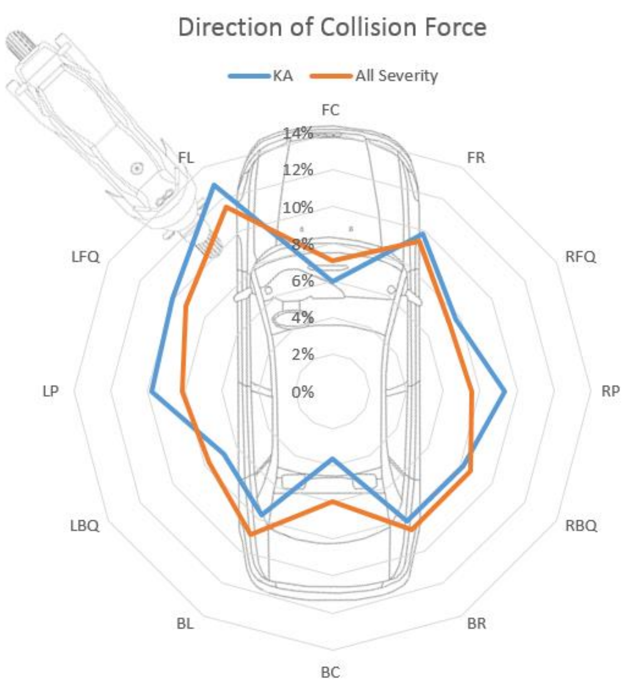
Table 36: Injury Severity by Vehicle for Motorcycle-Involved Multi-Vehicle Crashes

	Collision Force Direction	Motorcycle-Involved Multi-Vehicle Crashes: Motorcycle Severity: Fatal & Suspected Serious Injury	Motorcycle Severity: All	Non-Motorcycle Vehicle Severity: Fatal & Suspected Serious Injury	Non-Motorcycle Vehicle Severity: All	Crash Severity: Fatal & Suspected Serious Injury	Crash Severity: All
Concentrated Impacts	FC	373 (5%)	1,685 (5%)	6 (3%)	1,746 (5%)	374 (5%)	1,746 (5%)
	FL	800 (10%)	2,787 (9%)	18 (10%)	2,864 (9%)	809 (10%)	2,864 (9%)
	FR	613 (8%)	2,232 (7%)	13 (8%)	2,327 (7%)	617 (8%)	2,327 (7%)
	BC	228 (3%)	1,443 (5%)	2 (1%)	1,472 (5%)	229 (3%)	1,472 (5%)
	BL	484 (6%)	2,172 (7%)	3 (2%)	2,211 (7%)	486 (6%)	2,211 (7%)
	BR	507 (6%)	2,116 (7%)	7 (4%)	2,139 (7%)	511 (6%)	2,139 (7%)
	LP	612 (8%)	1,966 (6%)	34 (20%)	2,011 (6%)	617 (8%)	2,011 (6%)
	RP	583 (7%)	1,833 (6%)	17 (10%)	1,874 (6%)	587 (7%)	1,874 (6%)
	LFQ	628 (8%)	2,226 (7%)	12 (7%)	2,282 (7%)	630 (8%)	2,282 (7%)
	RFQ	485 (6%)	1,745 (6%)	10 (6%)	1,813 (6%)	487 (6%)	1,813 (6%)
	LBQ	428 (5%)	1,867 (6%)	3 (2%)	1,904 (6%)	428 (5%)	1,904 (6%)
	RBQ	512 (7%)	2,103 (7%)	5 (3%)	2,142 (7%)	512 (7%)	2,142 (7%)
Distributed Impacts	FD	855 (11%)	3,386 (11%)	27 (16%)	3,597 (11%)	863 (11%)	3,597 (11%)
	BD	292 (4%)	1,720 (6%)	9 (5%)	1,826 (6%)	296 (4%)	1,826 (6%)
	LD	219 (3%)	949 (3%)	5 (3%)	968 (3%)	220 (3%)	968 (3%)
	RD	205 (3%)	911 (3%)	2 (1%)	943 (3%)	207 (3%)	943 (3%)
Total		7,824 (100%)	31,141 (100%)	173 (100%)	32,119 (100%)	7,873 (100%)	32,119 (100%)

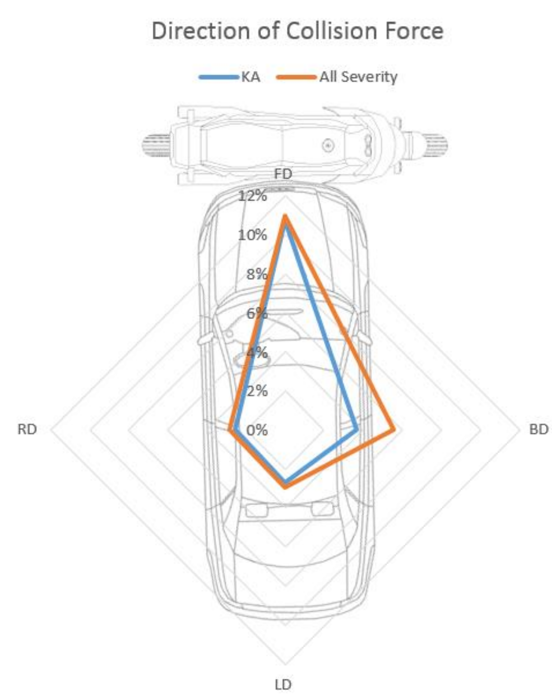
In collisions of motorcycles with other vehicles, the occupant (including a motorcyclist) of the motorcycle has more severe injuries than the occupant (including a driver) of the other vehicle.

Figure 54 shows the direction of collision force between a motorcycle and another vehicle (the diagram does not apply to collisions with other motorcycles, pedestrians, bicyclists, agricultural vehicles, and ATVs). Figure 54(a) provides the concentrated impact areas of the other vehicle colliding with a motorcycle, while Figure 54(b) shows the distributed areas from a parallel impact. The percentages represent the frequency of specific collision direction to all motorcycles involved in multi-vehicle crashes. In the collision direction by concentrated area, the percentages of all severity crashes are evenly distributed (6 to 9 percent), except the front and back ends. Among the areas, the front-left (FL) area accounts for the highest proportion (9 percent). For fatal or suspected serious injury severity levels, the distribution is similar to that of all severities.

In the collision direction by distributed area, the front-end damage (FD) accounts for the highest percentage in all severity and fatal or suspected serious injury levels.



a. Collision Direction by Concentrated Area



b. Collision Direction by Distributed Area

Figure 54: Direction of Collision Force for Multi-Vehicle Crashes Involving a Motorcycle

Vehicle Identification Analysis

VINs were used to obtain information not readily available in crash reports, including motorcycle type, motorcycle weight, and engine size. This approach also allowed for assessing the feasibility of identifying mopeds. This analysis was based only on 2017 data.

Motorcycle Type

The motorcycle type was stratified by the engine size category. The three leading motorcycle types involved in a fatal crash were sport (36 percent), cruiser (34 percent), and touring (25 percent) in 2017. The remaining 5 percent of fatal crashes involved all other types of motorcycles. Figure 55 and Figure 56 display the frequency of each motorcycle type involved in a fatal crash in 2017.

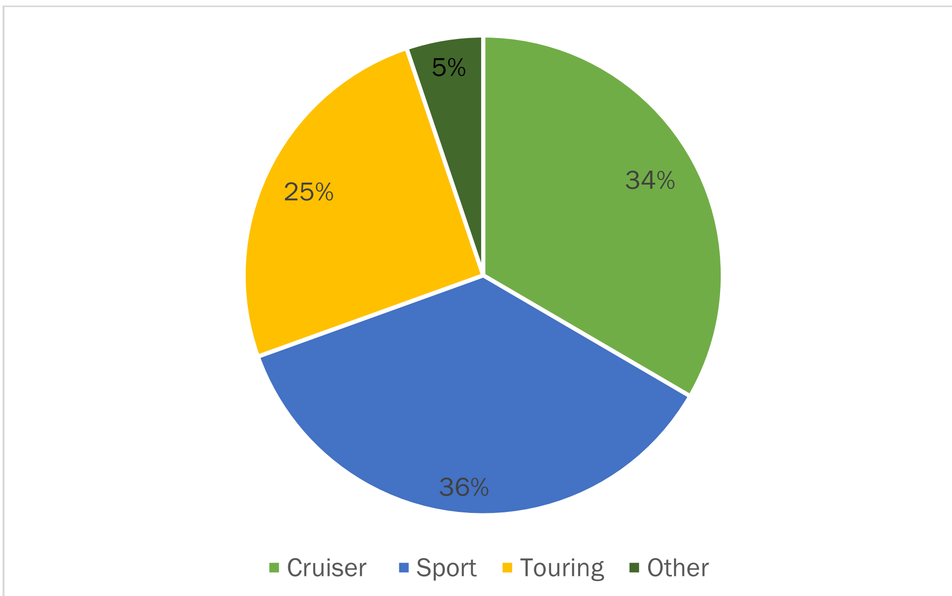


Figure 55: Motorcycle Types for Fatal Crashes (Condensed), 2017

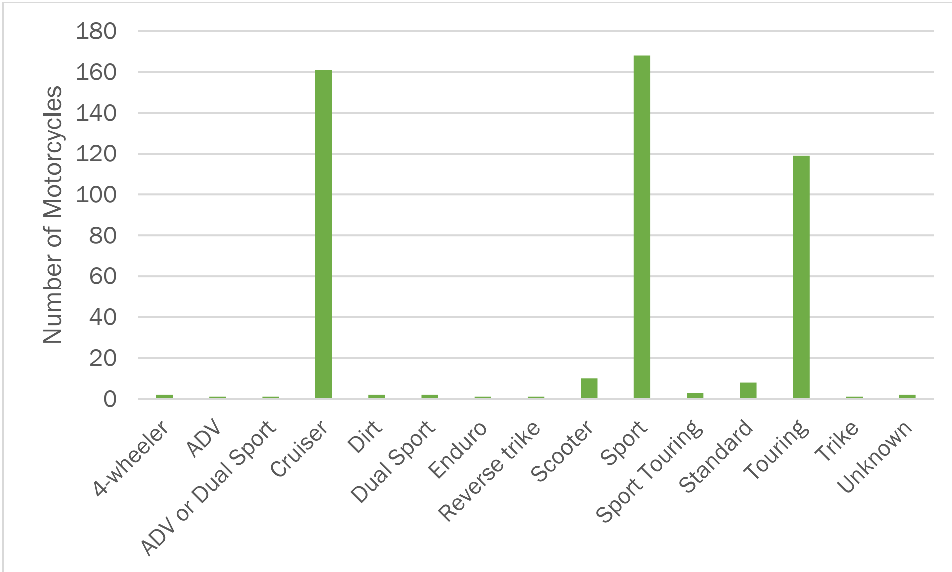


Figure 56: Motorcycle Types for Fatal Crashes, 2017

Motorcycle Weight

The make and model of each motorcycle was identified by a manual review of each crash record. Both the average dry weight and wet weight were classified. Dry weight is typically defined as the vehicle weight without fuel, oil, coolant, and battery. Neither dry weight nor wet weight typically includes passengers or cargo. The average dry weight was 567pounds(lbs), and the average wet weight was 605 lbs. Table 37 shows the average dry weight and average wet weight for each motorcycle type.

Table 37: Average Dry and Wet Weights by Motorcycle Type for Fatal Crashes, 2017

Motorcycle Type	Average Dry Weight (lbs)	Average Wet Weight (lbs)
4-wheeler	759.0	760.0
ADV	N/A	472.0
ADV or Dual Sport	492.0	564.0
Cruiser	612.5	649.4
Dirt	175.0	N/A
Dual Sport	304.0	454.0
Enduro	250.0	N/A
Reverse Trike	864.0	N/A
Scooter	213.6	366.0
Sport	392.5	448.9
Sport Touring	499.5	657.00
Standard	461.5	461.4
Touring	784.9	826.3
Trike	N/A	1,082.0
Unknown	505.0	N/A
All	**567.3**	**604.6**

Engine Size

Horsepower was classified into <500 cc, 500–999 cc, 1,000–1,499 cc, and 1,500+ cc. For fatal crashes, the majority (39 percent) of motorcycles were in the 500–999 cc category, followed by 28 percent in the 1,500+ cc and 26 percent in the 1,000–1,499 cc categories. Figure 57 displays the distribution of motorcycle engine size for fatal crashes in 2017.

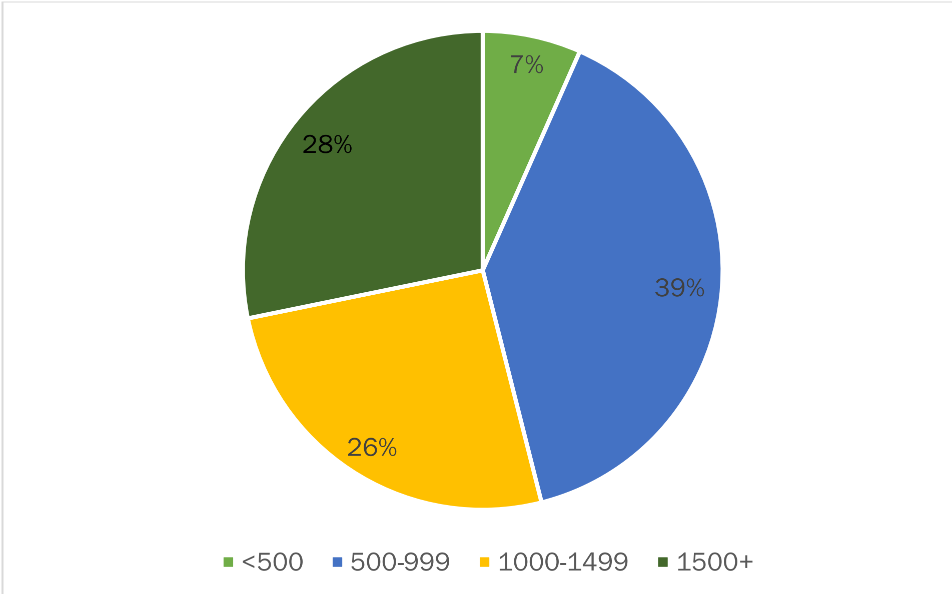


Figure 57: Motorcycle Engine Size (cc) for Fatal Crashes, 2017

Motorcycle weight and engine size/horsepower affect the power-to-weight ratio, which is highly correlated with performance and often style of operation. This is also reflected in the motorcycle type categories (e.g., sport, cruiser, and touring).

Next, the distribution of engine size by motorcycle type was explored for fatal crashes in 2017. The three most common motorcycle types were again characterized by different engine sizes (cc). A majority of cruisers were in the 1,000–1,499 cc category, while a majority of sport bikes were in the 500–999 cc category and a majority of touring motorcycles were in the 1,500+ cc category. Approximately 31 percent of the <500 cc motorcycles were actually scooters. Table 38 displays the distribution of motorcycle engine size by motorcycle type for fatal crashes in 2017.

Table 38: Distribution of Motorcycle Type by Engine Size (cc) for Fatal Crashes, 2017

Motorcycle Type	<500	500–999	1,000–1,499	1,500+	Total
4-wheeler	1 (50.0%)	1 (50.0%)	0 (0%)	0 (0%)	2
ADV	0 (0%)	1 (100.0%)	0 (0%)	0 (0%)	1
ADV or Dual Sport	0 (0%)	0 (0%)	1 (100.0%)	0 (0%)	1
Cruiser	3 (1.9%)	38 (23.6%)	74 (45.3%)	47(29.2%)	161
Dirt	1 (50.0%)	0 (0%)	1 (50.0%)	0 (0%)	2
Dual Sport	1 (50.0%)	1 (50%)	0 (0%)	0 (0%)	2
Enduro	1 (100.0%)	0 (0%)	0 (0%)	0 (0%)	1
Reverse Trike	0 (0%)	1 (100.0%)	0 (0%)	0 (0%)	1
Scooter	10 (100.0%)	0 (0%)	0 (0%)	0 (0%)	10
Sport	12 (7.1%)	143 (85.1%)	13 (7.7%)	0 (0%)	168
Sport Touring	0 (0%)	1 (33.3%)	2 (66.7%)	0 (0%)	3
Standard	3 (37.5%)	4 (50.0%)	0 (0%)	1 (12.5%)	8
Touring	0 (0%)	0 (0%)	33 (27.7%)	86 (72.3%)	119
Trike	0 (0%)	0 (0%)	0 (0%)	1 (100.0%)	1
Unknown	0 (0%)	0 (0%)	1 (50.0%)	1 (50.0%)	2
Total	**32 (6.6%)**	**190 (39.4%)**	**124 (25.7%)**	**136 (28.2%)**	**482**

Motorcycles versus Mopeds and Scooters

As indicated in the section above, not all vehicles classified as motorcycles in the crash data are in fact motorcycles. A number of these vehicles are mopeds and scooters. Typically, mopeds and scooters are smaller and less powerful than motorcycles with respect to engine size and horsepower. These difference can lead to unique crash factors and crash circumstances when compared to motorcycles. From 2010 to 2017, 2,531 riders crashed while on a moped or scooter (all injury severities). The number of riders varied each year, as shown in Figure 58. The number increased from 2010 to 2012 and then started decreasing until 2016, with a small increase in 2017. In this section, “motorcycles” does not include scooters/mopeds. Statistics for motorcycles exclude scooters/mopeds, which are given separately.

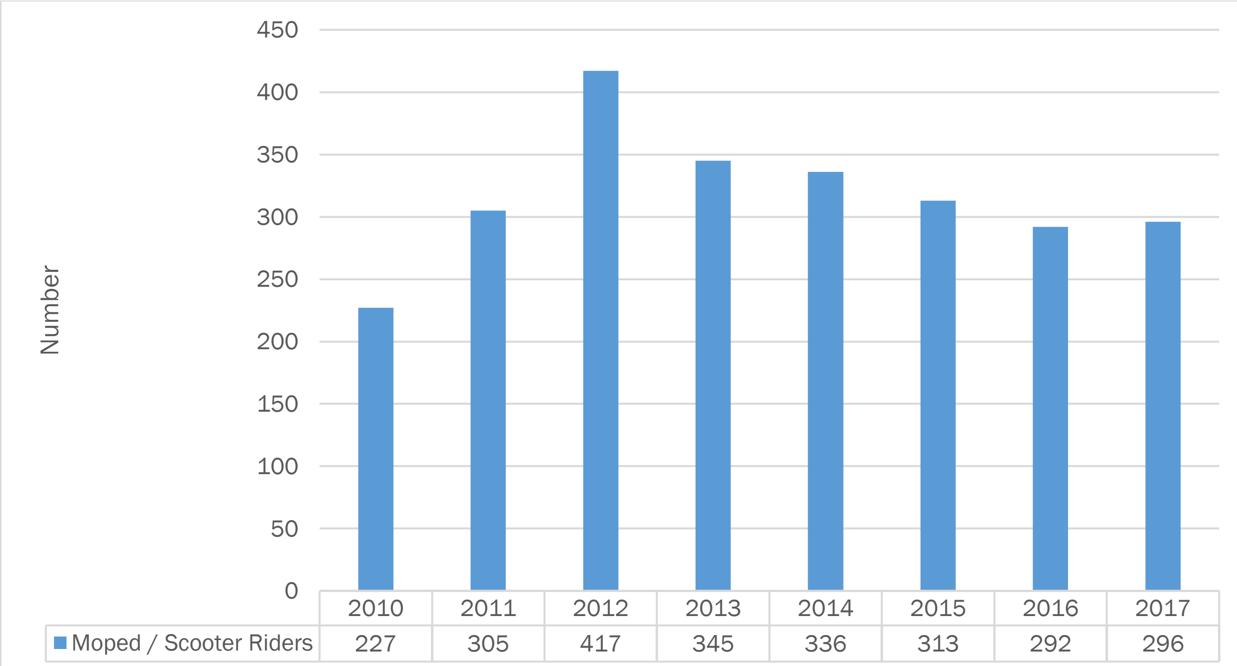


Figure 58: Crashes Involving Mopeds and Scooters, All Injury Severities, 2010–2017

Compared to motorcycle riders in crashes, moped and scooter riders are injured more often, but their injuries tend to be categorized as less severe (see Table 39). As an example, from 2010–2017, 14 percent of motorcycle riders were not injured, compared to only 8 percent of moped/scooter riders. However, 26 percent of motorcycle riders sustained a fatal or suspected serious injury, compared to 19 percent of moped/scooter riders. The majority (72 percent) of moped/scooter riders sustained a non-incapacitating or possible injury.

Table 39: Distribution of Injury Severity among Motorcycle Riders versus Moped/Scooter Riders, 2010–2017

	Fatality	Suspected Serious Injury	Non-Incapacitating Injury	Possible Injury	Non-Injury	Unknown Injury	Total Rider Injury
Motorcycle Riders	5%	21%	38%	21%	14%	1%	100%
Scooter/Moped Riders	2%	17%	49%	23%	8%	1%	100%

Similar to motorcycle crashes, only 5 percent of moped/scooter crashes involved a passenger. Although the average age (38 years) of a moped/scooter operator was similar to motorcycle operators (39 years) involved in crashes, the average age of the passenger was lower (27 years for mopeds/scooters versus 37 years for motorcycles). With respect to gender, the proportion of female operators was much higher among mopeds/scooters (23 percent) than motorcycles (5 percent) involved in crashes (see Figure 59).

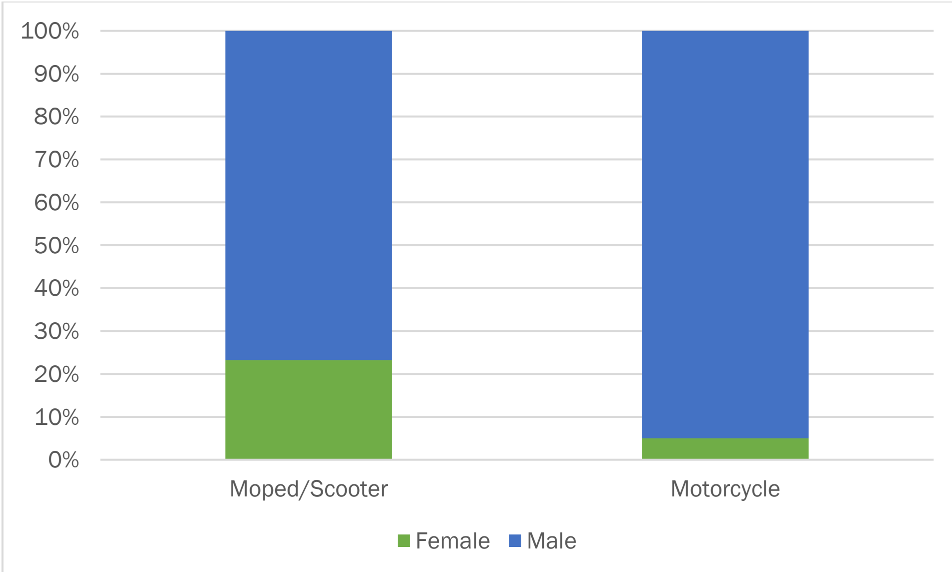


Figure 59: Gender Distribution among Moped/Scooter versus Motorcycle Operators, All Injury Severities, 2010–2017

Not using a helmet was more prevalent among moped/scooter riders (42 percent) compared to motorcycle riders (36 percent) for all injury severities, as shown in Table 40. Similar to motorcycle riders, lack of helmet use increased as injury severity increased.

Table 40: Lack of Helmet Use among Motorcycle Riders versus Moped/Scooter Riders by Injury Severity, 2010–2017

	Fatality	Suspected Serious Injury	Non-Incapacitating Injury	Possible Injury	Non-Injury	Unknown Injury	All Injury Severities
Motorcycle Riders	50%	43%	35%	31%	30%	21%	36%
Scooter/ Moped Riders	52%	51%	40%	40%	36%	47%	42%

Unlike motorcycle crashes, moped/scooter crashes are largely an urban phenomenon. Approximately 78 percent of fatal and suspected serious injuries occurred in urban areas. Table 41 displays the top five cities for fatal and suspected serious injuries among moped/scooter riders.

Table 41: Top Cities with Fatal and Suspected Serious Injuries among Moped/Scooter Riders, 2010–2017

City	Count of Fatalities and Suspected Serious Injuries
Austin	68
Dallas	60
Houston	30
Fort Worth	21
San Antonio	20

In accordance with a higher prevalence of urban areas for crashes involving mopeds/scooters, a higher proportion (43 percent) of fatal and serious injuries among moped/scooter riders involved intersections compared to motorcycles (32 percent).

Similar to motorcycle riders, 48 percent of moped/scooter riders were involved in single-vehicle crashes. Table 42 displays the distribution of the manner of collision for each injury severity category for moped/scooter riders. The most common manner of collision for fatalities, suspected serious injuries, non-incapacitating injuries, and possible injuries was single motor vehicle.

Table 42: Distribution of Manner of Collision by Injury Severity among Moped/Scooter Riders, 2010–2017

	Fatality	Suspected Serious Injury	Non-Incapacitating Injury	Possible Injury	Non-Injury	Unknown Injury	All Injury Severities
Single Motor Vehicle	37%	52%	52%	46%	25%	18%	48%
Same Direction	27%	13%	20%	23%	40%	41%	22%
Angle	17%	19%	16%	21%	21%	24%	18%
Opposite Direction	19%	16%	12%	11%	14%	18%	12%

Crashes involving multiple vehicles are classified as (1) same direction—vehicles involved in the crash were traveling in the same direction prior to the crash; (2) angle—vehicles involved in the crash were traveling at an angle to each other prior to the crash (this often results in a 90-degree crash, also known as a T-bone crash); or (3) opposite direction—vehicles involved in the crash were traveling in opposite directions prior to the crash.

For multi-vehicle crashes, the largest proportion were categorized as same direction (22 percent), followed by angle (18 percent) and opposite direction (12 percent). For the large percentage of multi-vehicle moped/scooter riders classified as being involved in a same-direction crash, 14 riders were killed from 2010 to 2017. Approximately 57 percent were classified as being in a same-direction (both going straight) rear-end crash, as shown in

Figure 60. In comparison, 45 percent of motorcycle riders who were killed had this classification.

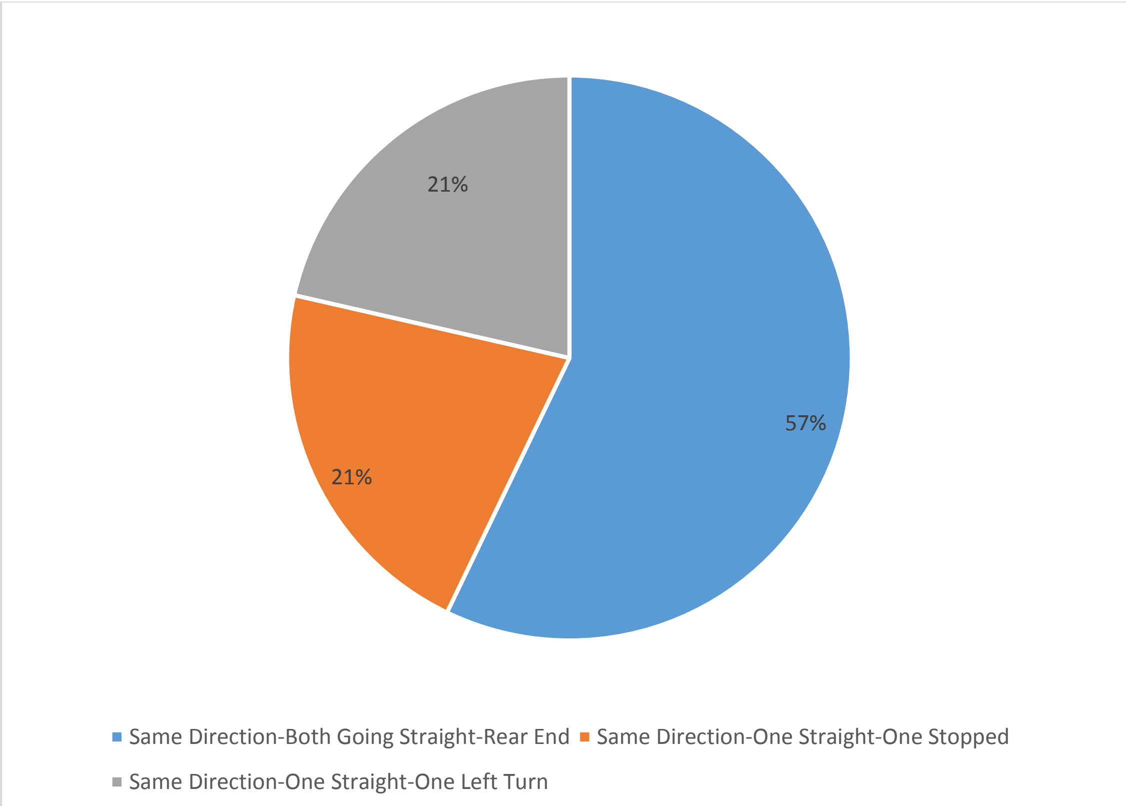


Figure 60: Manner of Collision for Multi-Vehicle Moped/Scooter Crashes, Fatalities, 2010–2017

A review of the crash reports found that of the eight moped/scooter riders killed in a rear-end crash, seven were a situation where the other vehicle struck the moped/scooter from behind, causing the rider's death. In all the crashes, both vehicles were moving in the same direction. Although the other categories did not specify that they were rear-end, the crashes were similar.

To further understand interactions between vehicles, crashes were identified as intersection or intersection related based on the intersection-related variable. As shown in Table 43, 43 percent of moped/scooter riders who sustained a fatal or suspected serious injury were in intersection or intersection-related crashes, compared to 32 percent of motorcycle riders.

Table 43: Distribution of Manner of Collision by Injury Severity among Moped/Scooter Riders, 2010–2017

Intersection Related	Fatal & Suspected Serious Injury Moped/Scooter	Fatal & Suspected Serious Injury Motorcycle
Intersection	28%	20%
Intersection Related	15%	12%
Driveway Access	11%	11%

Non-Intersection	46%	57%
Total	100%	100%

Discussion and Conclusion

Discussion

This study focused on motorcycle-involved crashes occurring in Texas from 2010 to 2017 and builds on the researchers' prior analysis of motorcycle-involved crashes from 2010 to 2015. After a small decline in rider fatalities from 2010 to 2015, the number of rider fatalities began to increase in 2016 and 2017. From 2015 to 2017, there was an almost 8 percent increase in rider fatalities, from 464 to 501. While fatalities have increased, there has been a steady decline in the number of registered motorcycles since 2015. As the number of motorcycles on the roads decreases, one would expect the number of fatalities and injuries to also decrease. However, this was not the case based on the present analysis, assuming the number of registered motorcycles is a true indicator of the number of motorcycles on the roadways or their annual VMT. In addition, motorcycles make up a small proportion of the number of vehicles on the roadway overall, yet they make a disproportionate contribution to the number of fatal and suspected serious injuries due to motor vehicle crashes on Texas roadways.

Based on this analysis, motorcycles will likely continue to be a traffic safety issue for Texas. This report identified several areas that should be considered when implementing countermeasures or designing new countermeasures. These findings are briefly discussed below.

Motorcycle Crashes and Severity

First, the analysis found that motorcycle riders typically sustain the most severe injury in a crash. Approximately 97 percent to 99 percent of the crash severities align with the highest level of injury sustained by the motorcycle rider.

Overall, motorcycle riders experienced more severe injuries compared to automobile drivers and passengers. Thirty-five percent of motorcycle riders sustained a fatal or suspected serious injury compared to only 3 percent of drivers and passengers in automobiles. Similarly, only 9 percent of motorcycle riders did not experience an injury compared to 71 percent of drivers and passengers in automobiles. For fatal and suspected injury crashes that were curve related, the most common contributing factors were unsafe speed and failure to control speed. An additional 4 percent were coded as speeding over the limit.

There were also higher percentages of unknown, no injury, possible injury, and suspected serious injury for single-vehicle crashes. There were higher percentages of non-incapacitating injuries and fatalities for multiple-vehicle crashes involving motorcycles.

In addition, there were spatial patterns identified for motorcycle crashes. Counties with the top counts of fatal and suspected serious injury crashes are in metropolitan areas, whereas counties with the top crash rates are largely in rural areas with smaller population sizes. When accounting for injuries, it was found that rural areas had a higher percentage of fatal and suspected serious injury crashes compared to urban areas (60 percent and 40 percent, respectively). Next, it was found that motorcycle fatalities occurred close to residences, indicating relatively short trip durations.

Next, a majority of motorcycle crashes occurred on weekends (65 percent). Weekend crashes had a higher percentage of crashes with fatalities and suspected serious injuries compared to weekday crashes. There was a higher percentage of crashes that occurred in the spring compared to the other seasons. The fewest percentages of crashes occurred in the winter.

Rates

The fatal and suspected serious injury crash rate for motorcycles was about eight times the rate for all vehicles. The motorcycle fatal crash rate per VMT was 27 times higher for motorcycles compared to the rate for all vehicles in 2016.

Speeding

Crash severity percentages were slightly higher for roads with higher posted speed limits of 45–64 mph and 65+ mph. Crash travel speeds for at-fault motorcycles were higher than for other vehicles. For motorcycle at-fault crashes, the most frequent motorcycle travel speed at the time of a crash was 8 mph faster than the posted speed limit; for other vehicles, travel speed at the time of a crash was 3 mph under the speed limit. Over-speeding, relative to the posted speed limit, is more of an issue for motorcycle-involved crashes than for the other vehicle crashes.

Impairment

Among contributing factors associated with impaired motorcycle operators besides alcohol or drug factors, speed-related contributing factors were assigned to 52 percent of the operators. Fifty-one percent of those driving impaired did not have a Class M license. Sixty-six percent of motorcycle operators riding impaired were not wearing a helmet when they crashed. At all injury levels, impaired riders were less likely to be wearing a helmet compared to non-impaired operators.

Environmental Conditions

There was a slightly higher percentage of cloudy weather conditions for fatal and suspected serious injury crashes. A majority of crashes occurred in dry conditions regardless of crash severity. The proportion of surface conditions did not vary greatly by crash severity. A majority of crashes occurred during daylight regardless of crash severity. However, there was a higher percentage of fatal and suspected serious injury crashes at dark, night lighted and dark, lighted compared to all severity crashes.

Intersections

A crash type of one vehicle turning left and one vehicle traveling straight in opposite directions accounted for 39 percent of intersection fatal or suspected serious injury crashes. For such crashes, FTYROW—turning left was the predominant contributing factor and accounted for 74 percent. For all severity crashes as well as fatal or suspected serious injury crashes, the percentage of DUI non-intersection crashes was higher than the percentage of DUI intersection crashes. The proportion of fatal and suspected serious injury crashes out of all severities was higher at intersections controlled by a center stripe/divider than by other control types.

Curves

Eighty-five percent of curve-related crashes involving motorcycles were single-vehicle crashes compared to 41 percent of crashes that were not curve related. Overall, for fatal and suspected serious injury crashes among motorcycle riders involved in crashes on curves, 56 percent occurred in rural areas and 44 percent in urban areas. Lighting and surface conditions did not play a larger role in the occurrence of curve-related crashes than they did in non-curve-related crashes.

Approximately 48 percent of curve-related crashes occurred in areas with a posted speed of 55 mph or above. Only about 35 percent of non-curve-related crashes occurred in areas with a posted speed limit of 55 mph or above. Approximately 24 percent of curve-related crashes resulting in a rider fatality or suspected serious injury involved an impaired rider, compared to 14 percent of non-curve-related crashes.

Conspicuity

For multi-vehicle crashes involving at least one motorcycle, when the vehicle at fault was a passenger vehicle, SUV, pickup, or van that crashed with a motorcycle, 47 percent to 51 percent involved a conspicuity issue. When a motorcycle were deemed to be at fault, 25 percent of the crashes involved a conspicuity issue. The proportion of a conspicuity issue to a motorcyclist was lower than that of other motorists, meaning drivers in other vehicles had difficulty detecting the motorcycles, which conceivably increased the risk of a crash. The proportion of the crashes involving conspicuity issues was higher when the colors of no-fault vehicles were dark versus bright. The percentages of crashes related to conspicuity issues in dark conditions were lower than in daylight conditions.

Mopeds versus Motorcycles

Compared to motorcycle riders in crashes, moped and scooter riders were injured more often, but their injuries tended to be categorized as less severe. The proportion of female operators was much higher among mopeds/scooters than motorcycles involved in crashes. Not using a helmet was more prevalent among moped/scooter riders compared to motorcycle riders for all injury severities. Lack of helmet use increased as injury severity increased. Moped/scooter crashes were largely an urban phenomenon, with almost 78 percent of fatal and suspected serious injuries occurring in urban areas. In accordance with this, a higher proportion of fatal and serious injuries among moped/scooter riders involved intersections, compared to motorcycle riders.

Licensing

Of all licenses in Texas, 7 percent were Class M licenses. Of the Class M licenses, all also had Class A, B, or C endorsements. Counties in large metropolitan areas had higher counts of Class M licenses compared to rural areas. Counties along the coastline and in central Texas had higher numbers of Class M licenses compared to the rest of the state. Forty-three percent of motorcycle operators involved in a fatal crash did not have a Class M license or were unlicensed.

Conclusion

Despite comprising a small portion of vehicles on roads, motorcycle riders contribute a considerable number of fatalities and injuries due to crashes in Texas. Recent data suggest that the number of fatalities and suspected serious injuries may be increasing following a decline in the number of these injuries, which terminated in 2015. This report identified several areas that should be considered when designing and implementing countermeasures.

Appendix

Crash Rates

Population

Table 44: Motorcycle Crash Rates per 100,000 Population, 2012–2016

County	Fatal or Suspected Serious Injury Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Anderson	76	57,772	131.55	26.31
Andrews	22	17,215	127.80	25.56
Angelina	142	87,657	162.00	32.40
Aransas	43	24,729	173.88	34.78
Archer	16	8,750	182.86	36.57
Atascosa	71	47,710	148.82	29.76
Austin	57	29,107	195.83	39.17
Bandera	180	21,015	856.53	171.31
Bastrop	142	78,286	181.39	36.28
Bell	825	330,859	249.35	49.87
Bexar	3,449	1,858,699	185.56	37.11
Bosque	29	17,953	161.53	32.31
Bowie	210	93,483	224.64	44.93
Brazoria	533	338,419	157.50	31.50
Brewster	16	9,188	174.14	34.83
Brown	66	37,935	173.98	34.80
Burleson	55	17,417	315.78	63.16
Burnet	152	44,584	340.93	68.19
Caldwell	46	39,848	115.44	23.09
Calhoun	31	21,805	142.17	28.43
Cameron	404	418,785	96.47	19.29
Camp	13	12,631	102.92	20.58
Cass	63	30,346	207.61	41.52
Chambers	106	38,072	278.42	55.68
Cherokee	72	51,257	140.47	28.09
Clay	25	10,367	241.15	48.23
Coleman	17	8,476	200.57	40.11
Collin	1,101	886,633	124.18	24.84
Colorado	60	20,792	288.57	57.71

County	Fatal or Suspected Serious Injury Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Comanche	24	13,506	177.70	35.54
Cooke	71	38,878	182.62	36.52
Coryell	149	75,710	196.80	39.36
Crockett	12	3,836	312.83	62.57
Dallas	3,624	2,513,054	144.21	28.84
Dawson	11	13,317	82.60	16.52
Denton	1,052	754,650	139.40	27.88
Dewitt	19	20,660	91.97	18.39
Dimmit	18	10,842	166.02	33.20
Eastland	31	18,252	169.84	33.97
Ector	359	153,177	234.37	46.87
Edwards	46	2,028	2268.24	453.65
El Paso	1,671	833,592	200.46	40.09
Ellis	270	160,225	168.51	33.70
Erath	64	40,641	157.48	31.50
Falls	18	17,265	104.26	20.85
Fannin	43	33,757	127.38	25.48
Fisher	14	3,847	363.92	72.78
Franklin	12	10,571	113.52	22.70
Freestone	21	19,585	107.22	21.44
Frio	14	18,542	75.50	15.10
Gaines	20	19,485	102.64	20.53
Gillespie	100	25,732	388.62	77.72
Gonzales	32	20,370	157.09	31.42
Grayson	303	124,231	243.90	48.78
Grimes	124	27,140	456.89	91.38
Guadalupe	188	147,313	127.62	25.52
Hale	33	35,007	94.27	18.85
Hardin	81	55,624	145.62	29.12
Harris	6,157	4,434,257	138.85	27.77
Hartley	11	5,966	184.38	36.88
Hays	343	185,686	184.72	36.94
Henderson	124	79,213	156.54	31.31
Hill	62	34,901	177.65	35.53
Hockley	35	23,377	149.72	29.94
Hood	104	54,217	191.82	38.36
Hopkins	52	35,844	145.07	29.01

County	Fatal or Suspected Serious Injury Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Houston	23	22,802	100.87	20.17
Howard	72	36,423	197.68	39.54
Hunt	156	89,068	175.15	35.03
Hutchinson	28	21,782	128.55	25.71
Jack	16	8,866	180.46	36.09
Jackson	22	14,678	149.88	29.98
Jasper	49	35,640	137.49	27.50
Jeff Davis	19	2,221	855.47	171.09
Jim Wells	81	41,486	195.25	39.05
Johnson	289	157,544	183.44	36.69
Jones	22	19,944	110.31	22.06
Karnes	29	14,984	193.54	38.71
Kaufman	195	111,830	174.37	34.87
Kendall	140	39,010	358.88	71.78
Kerr	149	50,505	295.02	59.00
Kimble	27	4,453	606.33	121.27
Kleberg	32	31,877	100.39	20.08
Lamar	83	49,626	167.25	33.45
Lampasas	49	20,357	240.70	48.14
Lavaca	16	19,654	81.41	16.28
Leon	22	16,923	130.00	26.00
Limestone	43	23,469	183.22	36.64
Live Oak	39	11,976	325.65	65.13
Llano	54	19,624	275.17	55.03
Lubbock	503	294,682	170.69	34.14
Marion	47	10,191	461.19	92.24
Martin	32	5,451	587.05	117.41
Mason	21	4,064	516.73	103.35
Matagorda	450	36,719	1225.52	245.10
McCulloch	18	8,242	218.39	43.68
McLennan	44	243,394	18.08	3.62
Medina	99	47,920	206.59	41.32
Midland	262	155,817	168.15	33.63
Milam	32	24,372	131.30	26.26
Mills	21	4,871	431.12	86.22
Mitchell	14	8,995	155.64	31.13
Montague	35	19,384	180.56	36.11

County	Fatal or Suspected Serious Injury Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Montgomery	807	518,849	155.54	31.11
Morris	22	12,653	173.87	34.77
Nacogdoches	92	65,556	140.34	28.07
Navarro	68	48,177	141.15	28.23
Newton	23	14,138	162.68	32.54
Nolan	24	15,017	159.82	31.96
Nueces	709	355,667	199.34	39.87
Orange	162	83,751	193.43	38.69
Palo Pinto	89	27,922	318.75	63.75
Panola	35	23,771	147.24	29.45
Parker	233	123,601	188.51	37.70
Pecos	20	15,826	126.37	25.27
Polk	89	46,583	191.06	38.21
Potter	284	121,883	233.01	46.60
Presidio	18	7,144	251.96	50.39
Rains	15	11,087	135.29	27.06
Randall	205	128,603	159.41	31.88
Real	156	3,348	4659.50	931.90
Reeves	40	14,438	277.05	55.41
Refugio	12	7,315	164.05	32.81
Robertson	19	16,537	114.89	22.98
Rockwall	117	88,010	132.94	26.59
Runnels	12	10,411	115.26	23.05
Rusk	66	53,197	124.07	24.81
Sabine	17	10,367	163.98	32.80
San Patricio	123	66,706	184.39	36.88
Scurry	21	17,314	121.29	24.26
Shelby	24	25,705	93.37	18.67
Somervell	56	8,673	645.68	129.14
Stephens	14	9,787	143.05	28.61
Terry	17	12,724	133.61	26.72
Titus	63	32,592	193.30	38.66
Travis	2,711	1,148,176	236.11	47.22
Trinity	16	14,360	111.42	22.28
Tyler	33	21,371	154.41	30.88
Upshur	76	40,295	188.61	37.72
Uvalde	46	27,055	170.02	34.00

County	Fatal or Suspected Serious Injury Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Val Verde	60	48,862	122.79	24.56
Van Zandt	99	53,070	186.55	37.31
Victoria	96	90,989	105.51	21.10
Walker	111	69,926	158.74	31.75
Waller	126	47,049	267.81	53.56
Ward	16	11,396	140.40	28.08
Washington	106	34,544	306.86	61.37
Wharton	48	41,377	116.01	23.20
Wichita	254	132,148	192.21	38.44
Wilbarger	23	13,061	176.10	35.22
Williamson	602	490,619	122.70	24.54
Wood	76	43,198	175.93	35.19
Young	13	18,275	71.14	14.23
Total	30,219	18,450.284	167.01	33.40

Table 45: Fatal or Suspected Serious Injury Motorcycle Crash Rates per 100,000 Population, 2012–2016

County	Fatal or Suspected Serious Injury Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Anderson	16	57,772	27.70	5.54
Angelina	36	87,657	41.07	8.21
Aransas	13	24,729	52.57	10.51
Atascosa	24	47,710	50.30	10.06
Austin	16	29,107	54.97	10.99
Bandera	78	21,015	371.16	74.23
Bastrop	50	78,286	63.87	12.77
Bell	218	330,859	65.89	13.18
Bexar	666	1,858,699	35.83	7.17
Blanco	29	10,918	265.62	53.12
Bosque	14	17,953	77.98	15.60
Bowie	51	93,483	54.56	10.91
Brazoria	175	338,419	51.71	10.34
Brazos	109	209,896	51.93	10.39
Brown	18	37,935	47.45	9.49

County	Fatal or Suspected Serious Injury Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Burleson	24	17,417	137.80	27.56
Burnet	59	44,584	132.33	26.47
Caldwell	19	39,848	47.68	9.54
Callahan	13	13,596	95.62	19.12
Cameron	106	418,785	25.31	5.06
Cass	23	30,346	75.79	15.16
Chambers	31	38,072	81.42	16.28
Cherokee	25	51,257	48.77	9.75
Collin	307	886,633	34.63	6.93
Colorado	20	20,792	96.19	19.24
Comal	123	124,234	99.01	19.80
Cooke	27	38,878	69.45	13.89
Coryell	43	75,710	56.80	11.36
Dallas	973	2,513,054	38.72	7.74
Denton	289	754,650	38.30	7.66
Ector	102	153,177	66.59	13.32
Edwards	20	2,028	986.19	197.24
Ellis	94	160,225	58.67	11.73
El Paso	251	833,592	30.11	6.02
Erath	27	40,641	66.44	13.29
Fannin	19	33,757	56.28	11.26
Fayette	20	24,909	80.29	16.06
Fort Bend	103	683,756	15.06	3.01
Galveston	179	314,485	56.92	11.38
Gillespie	46	25,732	178.77	35.75
Gray	11	23,028	47.77	9.55
Grayson	105	124,231	84.52	16.90
Gregg	58	123,283	47.05	9.41
Grimes	40	27,140	147.38	29.48
Guadalupe	62	147,313	42.09	8.42
Hamilton	17	8,232	206.51	41.30
Hardin	33	55,624	59.33	11.87
Harris	1,369	4,434,257	30.87	6.17
Harrison	56	66,431	84.30	16.86
Hays	107	185,686	57.62	11.52
Henderson	41	79,213	51.76	10.35
Hidalgo	140	828,334	16.90	3.38

County	Fatal or Suspected Serious Injury Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Hill	21	34,901	60.17	12.03
Hood	34	54,217	62.71	12.54
Hopkins	20	35,844	55.80	11.16
Houston	15	22,802	65.78	13.16
Howard	22	36,423	60.40	12.08
Hunt	55	89,068	61.75	12.35
Hutchinson	17	21,782	78.05	15.61
Jasper	16	35,640	44.89	8.98
Jefferson	110	252,993	43.48	8.70
Jim Wells	13	41,486	31.34	6.27
Johnson	108	157,544	68.55	13.71
Kaufman	62	111,830	55.44	11.09
Kendall	41	39,010	105.10	21.02
Kerr	69	50,505	136.62	27.32
Lamar	33	49,626	66.50	13.30
Lampasas	15	20,357	73.68	14.74
Leon	15	16,923	88.64	17.73
Liberty	44	78,598	55.98	11.20
Limestone	19	23,469	80.96	16.19
Live Oak	13	11,976	108.55	21.71
Llano	22	19,624	112.11	22.42
Lubbock	96	294,682	32.58	6.52
Marion	18	10,191	176.63	35.33
Matagorda	18	36,719	49.02	9.80
McLennan	121	243,394	49.71	9.94
Medina	30	47,920	62.60	12.52
Midland	77	155,817	49.42	9.88
Milam	13	24,372	53.34	10.67
Mills	11	4,871	225.83	45.17
Montague	14	19,384	72.22	14.44
Montgomery	247	518,849	47.61	9.52
Nacogdoches	26	65,556	39.66	7.93
Navarro	21	48,177	43.59	8.72
Nolan	11	15,017	73.25	14.65
Nueces	183	355,667	51.45	10.29
Orange	67	83,751	80.00	16.00
Palo Pinto	22	27,922	78.79	15.76

County	Fatal or Suspected Serious Injury Crashes	Population	Rate per 100,000	Annual Average Rate per 100,000
Panola	13	23,771	54.69	10.94
Parker	59	123,601	47.73	9.55
Polk	30	46,583	64.40	12.88
Potter	82	121,883	67.28	13.46
Randall	64	128,603	49.77	9.95
Real	81	3,348	2419.35	483.87
Rockwall	34	88,010	38.63	7.73
Rusk	32	53,197	60.15	12.03
San Jacinto	44	27,172	161.93	32.39
San Patricio	42	66,706	62.96	12.59
Smith	121	219,745	55.06	11.01
Somervell	29	8,673	334.37	66.87
Tarrant	914	1,947,529	46.93	9.39
Taylor	85	135,234	62.85	12.57
Titus	14	32,592	42.96	8.59
Tom Green	50	116,264	43.01	8.60
Travis	566	1,148,176	49.30	9.86
Tyler	17	21,371	79.55	15.91
Upshur	24	40,295	59.56	11.91
Uvalde	18	27,055	66.53	13.31
Val Verde	21	48,862	42.98	8.60
Van Zandt	38	53,070	71.60	14.32
Victoria	40	90,989	43.96	8.79
Walker	29	69,926	41.47	8.29
Waller	42	47,049	89.27	17.85
Ward	11	11,396	96.53	19.31
Washington	35	34,544	101.32	20.26
Webb	58	266,006	21.80	4.36
Wharton	16	41,377	38.67	7.73
Wichita	67	132,148	50.70	10.14
Williamson	183	490,619	37.30	7.46
Wilson	19	46,444	40.91	8.18
Wise	27	62,089	43.49	8.70
Wood	32	43,198	74.08	14.82
Total	11,171	25,661,800	43.53	8.71

Motorcycle Registrations

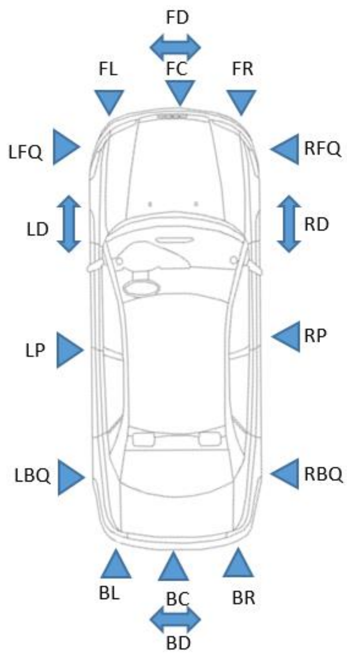
Table 46: Motorcycle Crash Rates per 100,000 Motorcycles Registered, 2017

County	Number of Motorcycle Registrations	Motorcycle Crashes	Fatal and Suspected Serious Injury Crashes	Crash Rate per 100,000	Fatal and Suspected Serious Injury Crash Rate per 100,000
Bandera	776	30	17	3865.98	2190.72
Bell	7,673	169	39	2202.53	508.28
Bexar	21,762	724	136	3326.90	624.94
Bowie	1,431	40	11	2795.25	768.69
Brazoria	6,145	108	32	1757.53	520.75
Brazos	2,690	99	23	3680.30	855.02
Cameron	3,140	57	16	1815.29	509.55
Collin	12,665	242	74	1910.78	584.29
Comal	4,140	47	15	1135.27	362.32
Dallas	21,887	731	215	3339.88	982.32
Denton	12,691	229	64	1804.43	504.29
Ector	2,310	45	19	1948.05	822.51
El Paso	3,336	313	61	9382.49	1828.54
Ellis	10,815	59	24	545.54	221.91
Fort Bend	7,456	77	22	1032.73	295.06
Galveston	6,943	152	48	2189.26	691.34
Grayson	2,985	69	26	2311.56	871.02
Gregg	1,795	50	22	2785.52	1225.63
Grimes	511	25	13	4892.37	2544.03
Guadalupe	3,213	43	20	1338.31	622.47
Harris	40,537	1,272	299	3137.87	737.60
Hays	3,686	71	27	1926.21	732.50
Henderson	1,714	22	12	1283.55	700.12
Hidalgo	4,878	138	39	2829.03	799.51
Jefferson	2,934	97	24	3306.07	818.00
Johnson	3,932	63	27	1602.24	686.67
Kaufman	2,207	50	20	2265.52	906.21
Kerr	1,312	41	14	3125.00	1067.07
Liberty	1,396	29	12	2077.36	859.60
Lubbock	3,266	95	27	2908.76	826.70
McLennan	3,863	89	29	2303.91	750.71
Midland	2,360	59	16	2500.00	677.97
Montgomery	10,275	189	77	1839.42	749.39
Nueces	4,590	128	22	2788.67	479.30
Potter	1,845	70	23	3794.04	1246.61
Smith	3,268	83	22	2539.78	673.19

County	Number of Motorcycle Registrations	Motorcycle Crashes	Fatal and Suspected Serious Injury Crashes	Crash Rate per 100,000	Fatal and Suspected Serious Injury Crash Rate per 100,000
Tarrant	28,750	639	162	2222.61	563.48
Taylor	2,472	86	23	3478.96	930.42
Tom Green	2,060	32	17	1553.40	825.24
Travis	16,750	510	117	3044.78	698.51
Van Zandt	1,020	24	12	2352.94	1176.47
Victoria	1,364	40	14	2932.55	1026.39
Wichita	2,642	51	13	1930.36	492.05
Williamson	8,831	126	36	1426.79	407.65

Collision Direction of Force

Code	Description
FC	Front End Damage Concentrated Impact
FD	Front End Damage Distributed Impact
FL	Front End (Left) Damage Partial Contact
FR	Front End (Right) Damage Partial Contact
BC	Back End Damage Concentrated Impact
BD	Back End Damage Distributed Impact
BL	Back End (Left) Damage Partial Contact
BR	Back End (Right) Damage Partial Contact
LP	Left Side Damage Angular Impact
RP	Right Side Damage Angular Impact
LFQ	Left Front Quarter Damage Angular Impact
RFQ	Right Front Quarter Damage Angular Impact
LBQ	Left Back Quarter Damage Angular Impact
RBQ	Right Back Quarter Damage Angular Impact
LD	Distributed Left Side Damage Parallel Impact
RD	Distributed Right Side Damage Parallel Impact
L&T	Left Side and Top Damage Rollover Effects
R&T	Right Side and Top Damage Rollover Effects


FD
FL
FC
FR
LFQ
RFQ
LD
RD
LP
RP
LBQ
RBQ
BL
BC
BR
BD

Passenger Vehicle Crash Trees

Urban Crash Trees

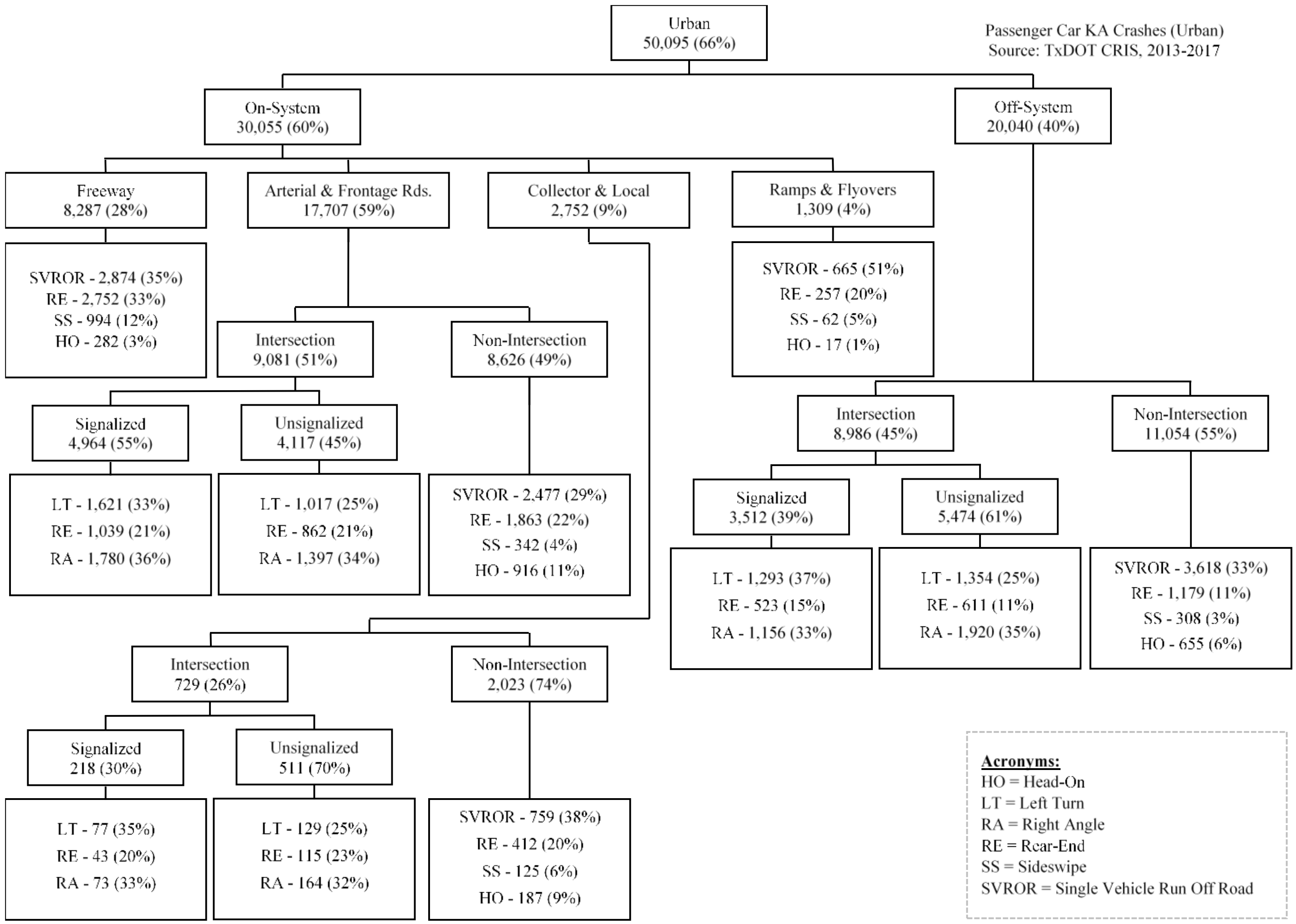


Figure 61: Crash Tree Diagram of Passenger Car KA Crashes in Urban Areas

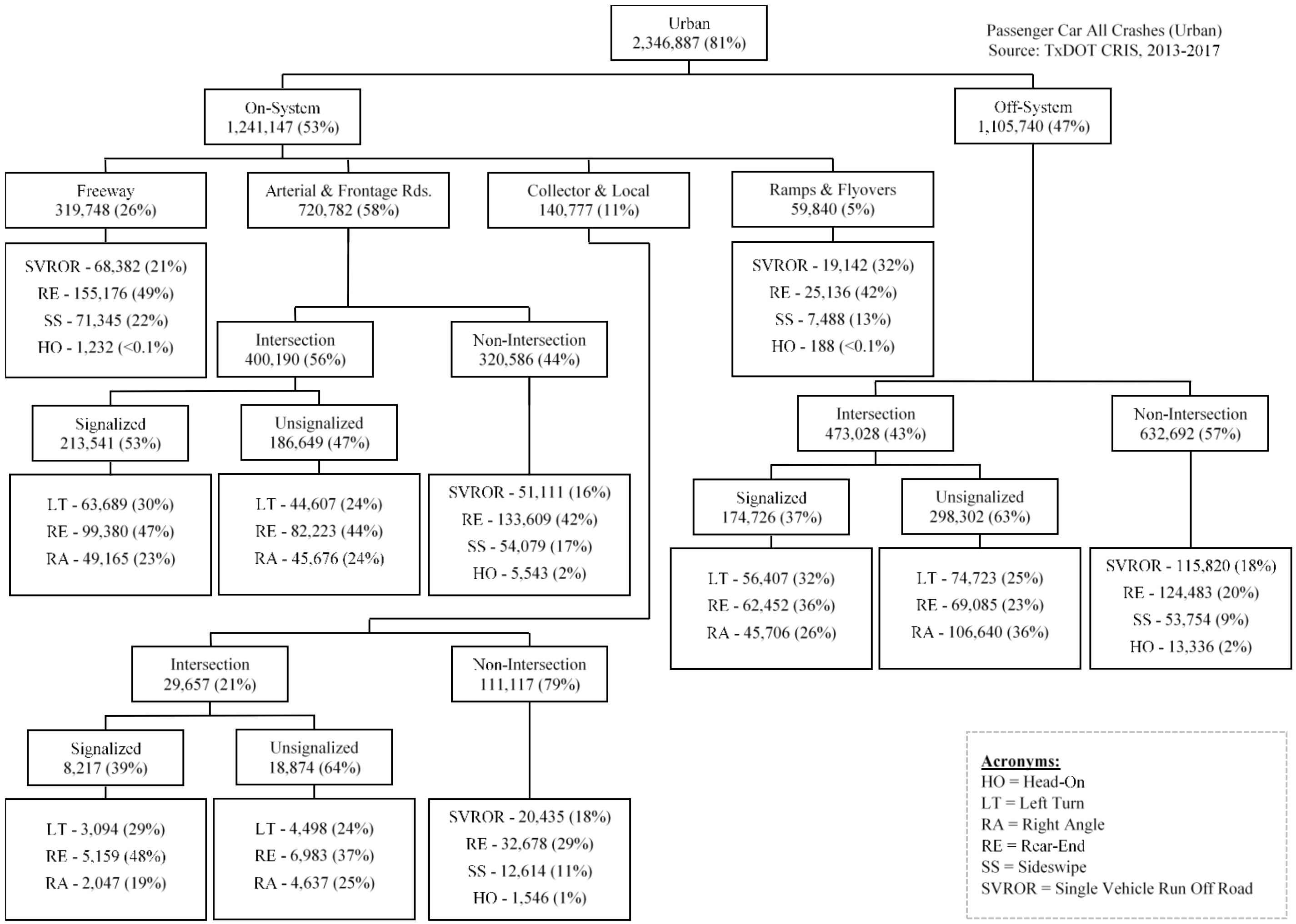


Figure 62: Crash Tree Diagram of All Passenger Car Crashes in Urban Areas

Rural Crash Trees

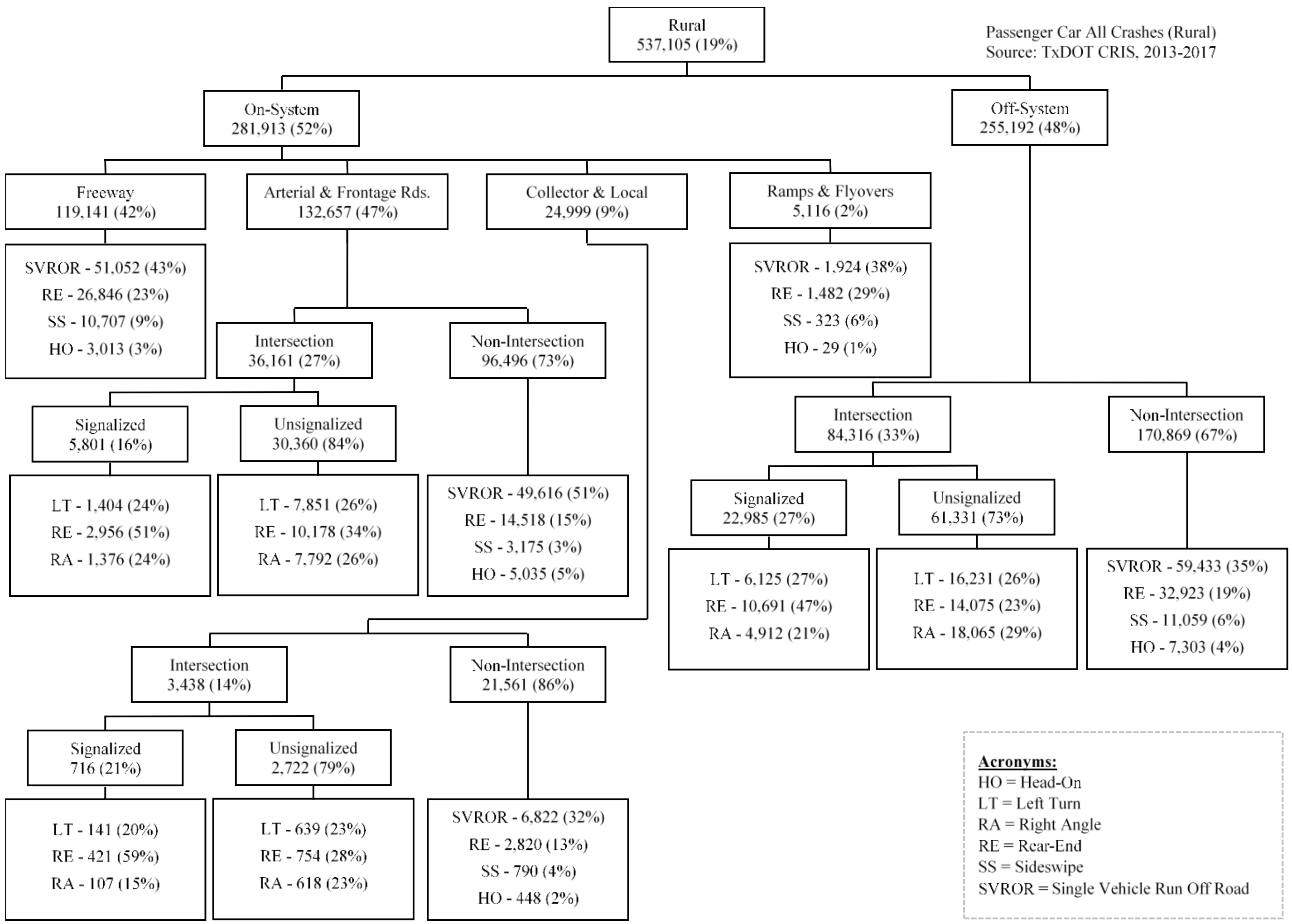


Figure 63: Crash Tree Diagram of All Passenger Car Crashes in Rural Areas

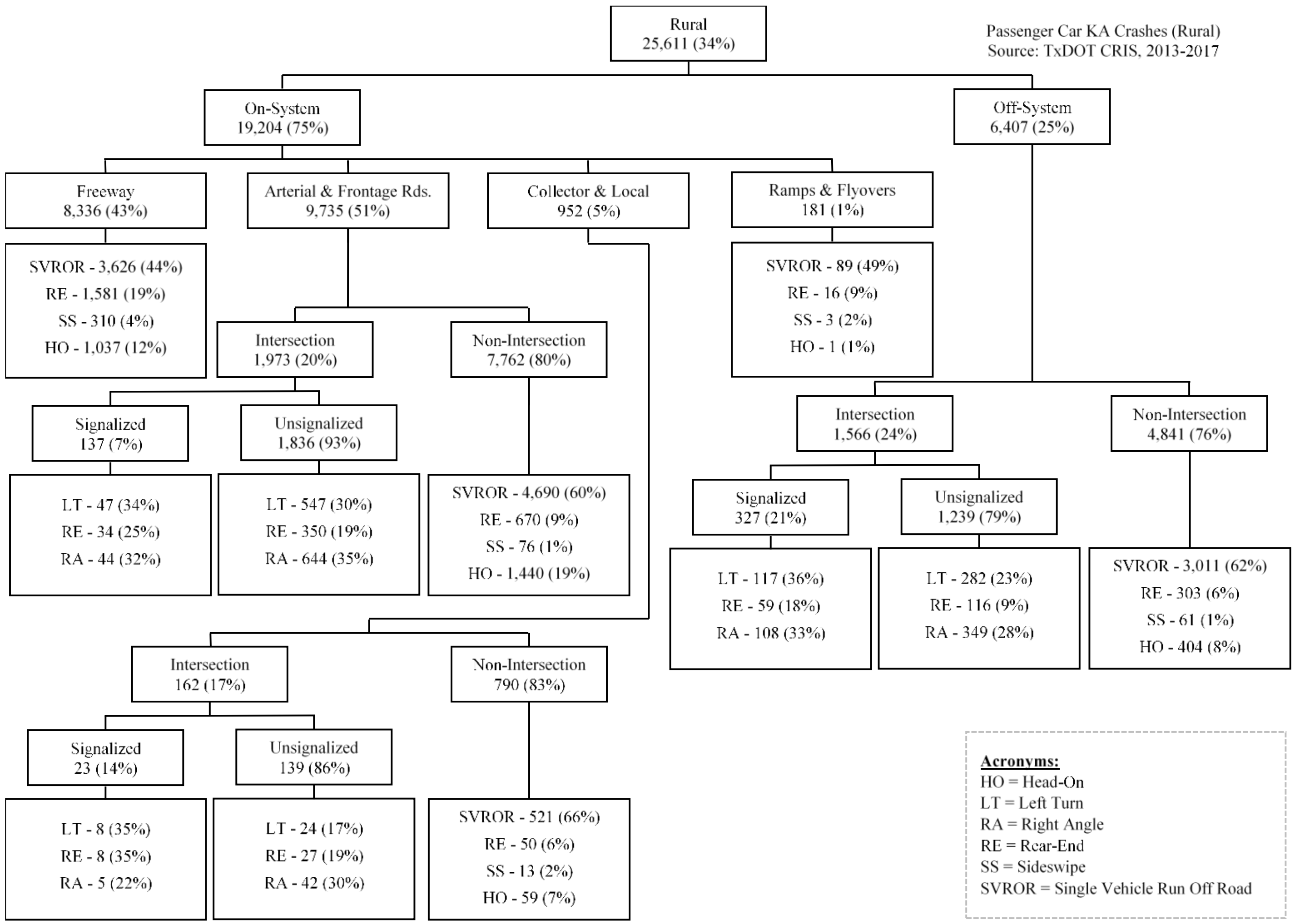


Figure 64: Crash Tree Diagram of Passenger Car Fatal or Suspected Serious Injury Crashes in Rural Areas