VISION ZERO BOULDER
SAFE STREETS REPORT

TECHNICAL APPENDIX

VISIONZERO
Safe Streets Boulder

2019

Contributors

CITY OF BOULDER

PUBLIC WORKS – TRANSPORTATION DIVISION

David Kemp, Senior Transportation Planner*
Amy Lewin, Senior Transportation Planner*
Michelle Melonakis, Transportation Operations Engineer for Signals and Lighting*
Mark Shisler, Transportation Engineer*
Kathleen Bracke, Interim Co-Director of Public Works for Transportation, GO Boulder Manager
Bill Cowern, Interim Co-Director of Public Works for Transportation, Principal Traffic Engineer
Mike Gardner-Sweeney, Transportation Operations Engineer
Joe Paulson, Transportation Operations Engineer for Signals and Lighting
Reese Shaw, GO Boulder Planning Specialist
Mary Ann Weideman, Interim Director of Public Works, Deputy City Manager
* Project Management Team

BOULDER POLICE DEPARTMENT

Chief Greg Testa
Deputy Chief Carey Weinheimer
Commander Kerry Yamaguchi
Traffic Sergeant Robyn VanDerLeest
Traffic Sergeant Fred Gerhardt

INFORMATION RESOURCES

Joe Simpson, GIS Analyst
Kate Gregory, GIS Technician

COMMUNICATIONS TEAM

Meghan Wilson, Communication Manager
Samantha Glavin, Communication Specialist

MUNICIPAL COURT

Linda Cooke, Presiding Judge

TRANSPORTATION ADVISORY BOARD MEMBERS

Johnny Drozdek
Tila Duhaime
Mark McIntyre
Bill Rigler
Alex Weinheimer
Jennifer Nicoll (former member)

CONSULTANT SERVICES

Jessica Hernandez, Apex Design
Stephanie Ball, Apex Design
Elaine C. Erb, Consultant
Tim Giesen, Straightline Design
Pete d'Oronzio, Pd' Programming, Inc.

Contents

The crash data reported in this document comes from the City of Boulder's Transportation Division database, which is derived from the Police Department's Record Management System. The information contained in these databases is updated periodically and may change over time.

For an electronic version of this document, please visit: https://bouldercolorado.gov/transportation/vision-zero

A. Crash Analysis Summary

Introduction

This is the technical appendix to support the Vision Zero Boulder: Safe Streets Report (SSR). The appendix summarizes the analyses completed by the City of Boulder Transportation Division during the development of the SSR. The SSR analysis identifies high-crash locations and their crash trends, which helps staff understand specific crash types and behaviors that are more likely to result in serious injuries and fatalities. It also informs education, enforcement, engineering, and evaluation recommendations to increase safety and move the city closer to its goals of zero serious injuries and fatalities due to traffic crashes.

The SSR analysis is updated every three years. The results in this appendix summarize the detailed analysis of crash data from 2015 through 2017 and compare this information with data from 2009 through 2014. This appendix contains a description of the crash data used in the analysis and a summary of the results of the analysis.

CRASH DATA

The crash data used in the SSR and summarized in this appendix was obtained from the City of Boulder's Police Department's Record Management System (police crash reports) and was imported into the City of Boulder Transportation Division's crash database program, Crash Magic. The crash data is primarily collected by the Police Department's crash investigation team when a member of that team completes a Colorado Traffic Accident Report form at the time of a crash. This form captures information about the location of the crash, people involved in the crash, a description of the crash, and various causal factors.

Sometimes information is not provided for all data fields, especially in the case of bicycle and pedestrian crashes, private property crashes, or hit-and-run crashes. The data from the reports is then entered into the Police Department's traffic crash records database by the records department. Prior to summarizing or analyzing the crash data, the Transportation Division conducts some data cleaning in an effort to amend incorrect, incomplete, or duplicated data related to crash location and injury severity. However, limitations still exist in terms of data completeness and accuracy.

Bicycle- and pedestrian-related crash information from the police crash reports was supplemented with additional data fields identified using the Pedestrian and Bicycle Crash Analysis Tool (PBCAT). PBCAT is a crash-typing software developed by the Federal Highway Administration to identify details associated with crashes between motor vehicles and pedestrians or bicyclists. PBCAT uses pre-crash actions of the persons involved in a crash to better understand the types of crashes occurring and to identify potential strategies to mitigate them. The information in the PBCAT fields was filled in by the research team based on a review of the narrative of each individual report.

Counter reports are not included in the analyses summarized in this appendix. Counter reports are reports that are completed either online or in-person by people involved in traffic crashes within the city under circumstances where there was no on-scene investigation, no injuries, and no major damage to vehicles. Because counter reports are not completed by crash investigation officers, they often lack accurate information such as crash location and crash type, which are needed for an accurate analysis of crash data.

Glossary of Terms

Buffered Bike Lane: Conventional bike lanes paired with a designated buffer space separating the bicycle lane from the adjacent vehicle travel and/or parking lane.

Green Pavement Markings: Often used to highlight locations where motorists merge across or turn across a bike lane. They are used to draw attention to bicyclists and increase safety and travel comfort.

Pedestrian Head-Start or Leading Pedestrian Interval: Gives pedestrians the opportunity to enter an intersection before vehicles are given a green indication. With this head start, pedestrians can better establish their presence in the crosswalk.

Permitted-Only Phasing: Displayed with a green ball or a flashing yellow arrow display. The vehicle may turn left but must yield to oncoming traffic and cyclists and pedestrians in the crosswalk.

Protected Bike Lane: Bike lanes that use planters, curbs, parked cars or posts to physically separate bike and vehicle traffic.

Protected/Permitted Phasing: A portion of the left-turn phase first has a green arrow, allowing left turns while oncoming traffic has a red light (protected), and then has a green ball or flashing yellow arrow (permitted).

Protected-Only Phasing: Displayed with a green arrow first, followed by a flashing yellow arrow, and lastly a red arrow. The vehicle may turn left with right-of-way and will not conflict with any other movements (oncoming traffic has a red light).

Right-Turn Bypass: Allows right-turning traffic to bypass the intersection via a designated lane, providing additional capacity for the through and right-turning movements and better structure and organization of the interaction between turning vehicles and pedestrians and cyclists.

Serious Injury: An injury with a severity of three out of a maximum of four or that is evidently incapacitating, as defined by the State of Colorado Traffic Accident Report.

Signalized Intersection: Any at-grade junction of two or more roads at which the right-of-way for motorists, bicyclists and pedestrians is controlled by a traffic signal.

Signed Controlled Intersection: Any at-grade junction of two or more roads at which the right-of-way for motorists, bicyclists and pedestrians is controlled by signing (e.g. stop sign and yield sign).

Speeding: The estimated speed of the traveler was greater than the speed limit or the traveler "exceeded safe/posted speed" only in good weather.

Speed as a Factor: When the speed of the traveler was a significant factor in the severity of the crash.

Traffic Control: Markers, signs and signal devices used to inform, guide and control traffic, including pedestrians, vehicles and bicyclists (e.g., striping, signing, signals, etc.).

Uncontrolled Intersection: Any at-grade junction of two or more roads/driveways at which the right-of-way for motorists, bicyclists and pedestrians is not controlled by a traffic signal or signing and right-of-way is defined by the "rules of the road."

Unsignalized Intersection: Any at-grade junction of two or more roads at which the right-of-way for motorists, bicyclists and pedestrians is not controlled by a traffic signal.

Vision Zero: Vision Zero is the Boulder community's goal to reduce the number of traffic-related serious injuries and fatalities to zero. At its core, this goal is inspired by the belief that traffic crashes are preventable, and even one fatality is too many.

BOULDER COUNTY MULTIMODAL TRANSPORTATION STANDARDS: STREET FUNCTIONAL CLASSIFICATION[1]

Arterial Roadway: Provides for the movement of through travel between minor and major population and employment centers and across urban areas. While the primary purpose of this type of roadway is the movement of people between major population and employment centers, some access to abutting land uses may be permitted. A principal arterial is usually a divided multi-lane facility. A minor arterial is a two-lane facility.

Collector Roadway: Connects adjacent land uses to the arterial network and provides some access to adjacent land uses. A collector is a two-lane facility.

Residential Collector Roadway: Provides for internal movement within a residential area connecting local access to collector roads and/or minor arterials and provides some access to adjacent land uses. A residential collector is a two-lane facility.

Local Roadway: Provides access to specific land uses, particularly residential. Roads of these classifications are two-lane facilities, although in isolated cases, one-lane roads may exist (town sites, forest access, etc.).

CRASH TYPES

Animal: A vehicle collides with a domestic or wild animal.

Approach-Turn: One vehicle turns left in front of another vehicle traveling in the opposite direction.

At-Fault: In this analysis, a person is considered at-fault in a traffic crash if they were issued a citation by an officer. Note that when people walking and bicycling are at-fault but are severely injured in a crash, they are often not issued a citation.

Bicycle: Any crash involving a bicyclist.

Fixed-Object: A single vehicle collides with a fixed object. Examples: curb, tree, sign, boulder.

Head-On: A vehicle collides with the front of another vehicle traveling in the opposite direction.

Impaired: Crashes involving a person suspected of, or charged with, driving under the influence of alcohol or drugs (DUI). A person is considered suspected of a DUI when a police officer notes this on the accident report.

Overtaking-Turn: One vehicle turns in front of another vehicle traveling in the same direction. Example: right-turn from left lane.

Overturning: A single vehicle tips over onto its side or roof.

Parked-Vehicle: A vehicle collides with a parked vehicle while traveling on the roadway or maneuvering into or out of a parking space.

Pedestrian: Any crash involving a pedestrian.

[1] Source: Boulder County Multimodal Transportation Standards, July 2012, https://assets.bouldercounty.org/wp-content/uploads/2017/02/multi-modal-standards.pdf

Pedestrian-Dash: The pedestrian ran into the roadway and was struck by a vehicle whose view of the pedestrian was not obstructed.

Pedestrian-Dart-Out: The pedestrian walked or ran into the roadway and was struck by a motorist whose view of the pedestrian was blocked until an instant before impact.

Rear-End: A vehicle collides with the rear end of another vehicle traveling ahead of it in the same direction.

Right-Angle: Two vehicles traveling in perpendicular directions collide at approximately a right angle, often referred to as a broadside or T-bone crash. This crash type can occur at uncontrolled intersections or as a result of one vehicle running a red light.

Severe: Throughout this document, serious injury crashes and fatal crashes are often referred to collectively as "severe crashes." Serious injury crashes are crashes where one or more persons involved in the crash incurred an injury that is evidently incapacitating. Such injuries may include severe lacerations, broken bones, internal injuries, or any injury that requires transportation to a hospital for treatment.

Sideswipe-Same-Direction: A vehicle collides with the side of another vehicle traveling in the same direction, often due to improper lane changes.

Sideswipe-Opposite-Direction: A vehicle collides with the side of another vehicle traveling in the opposite direction.

Overview of City of Boulder Crashes

Between 2015 and 2017, an average of 2,970 crashes occurred per year in which a Boulder police officer responded. Figure 1 shows the total crashes each year since 2009. Severe crashes are shown in orange, all other crashes are shown in gray. The number of annual crashes has increased since 2009. Figure 2 shows the 3-year annual average, which smooths out annual variability and demonstrates trends over time.

Figure 1: Annual Crashes (2009-2017)

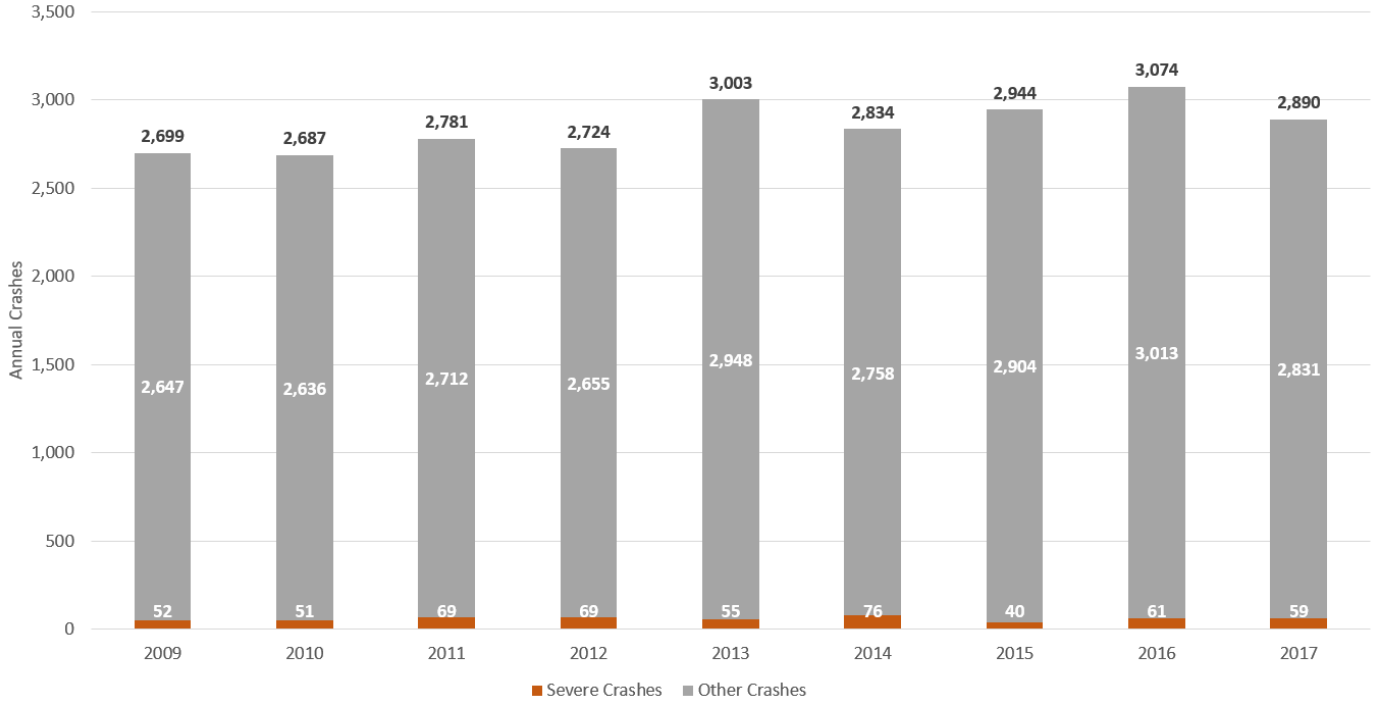


Figure 2: Total and Severe Crashes (3-year annual average)

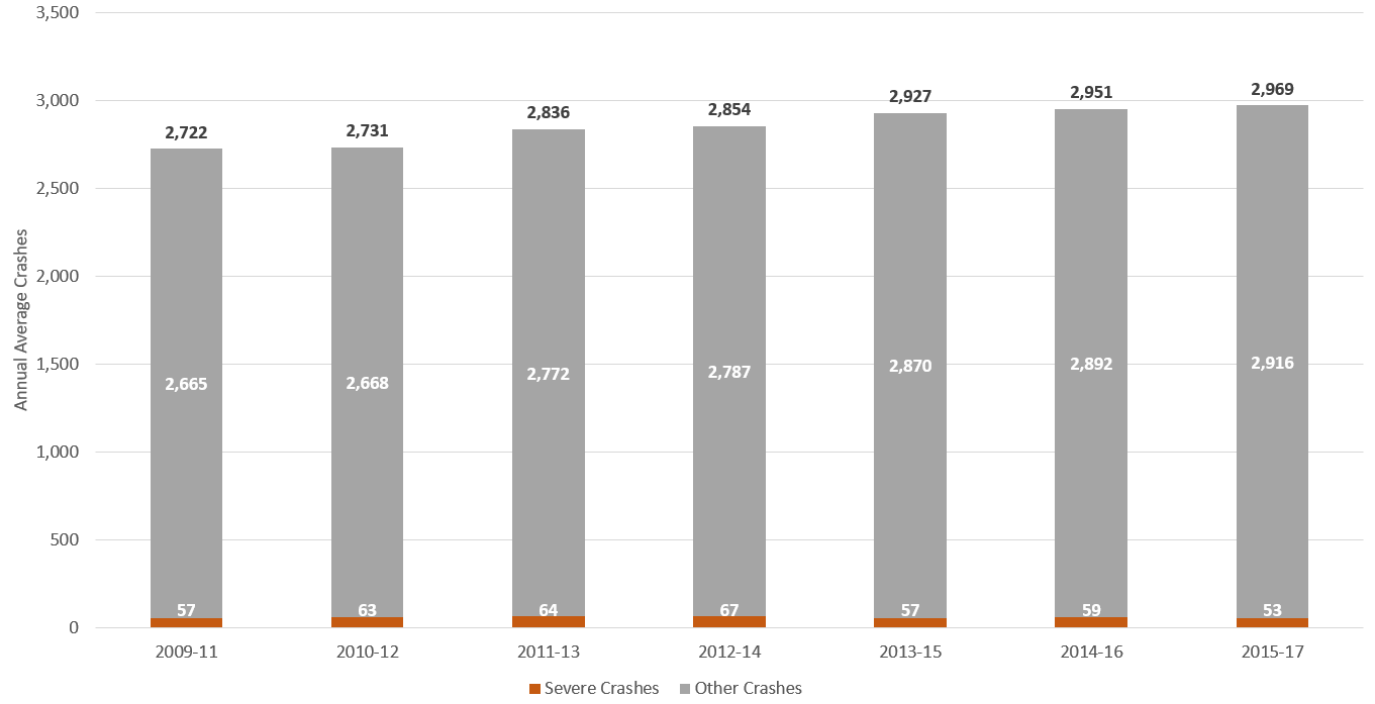
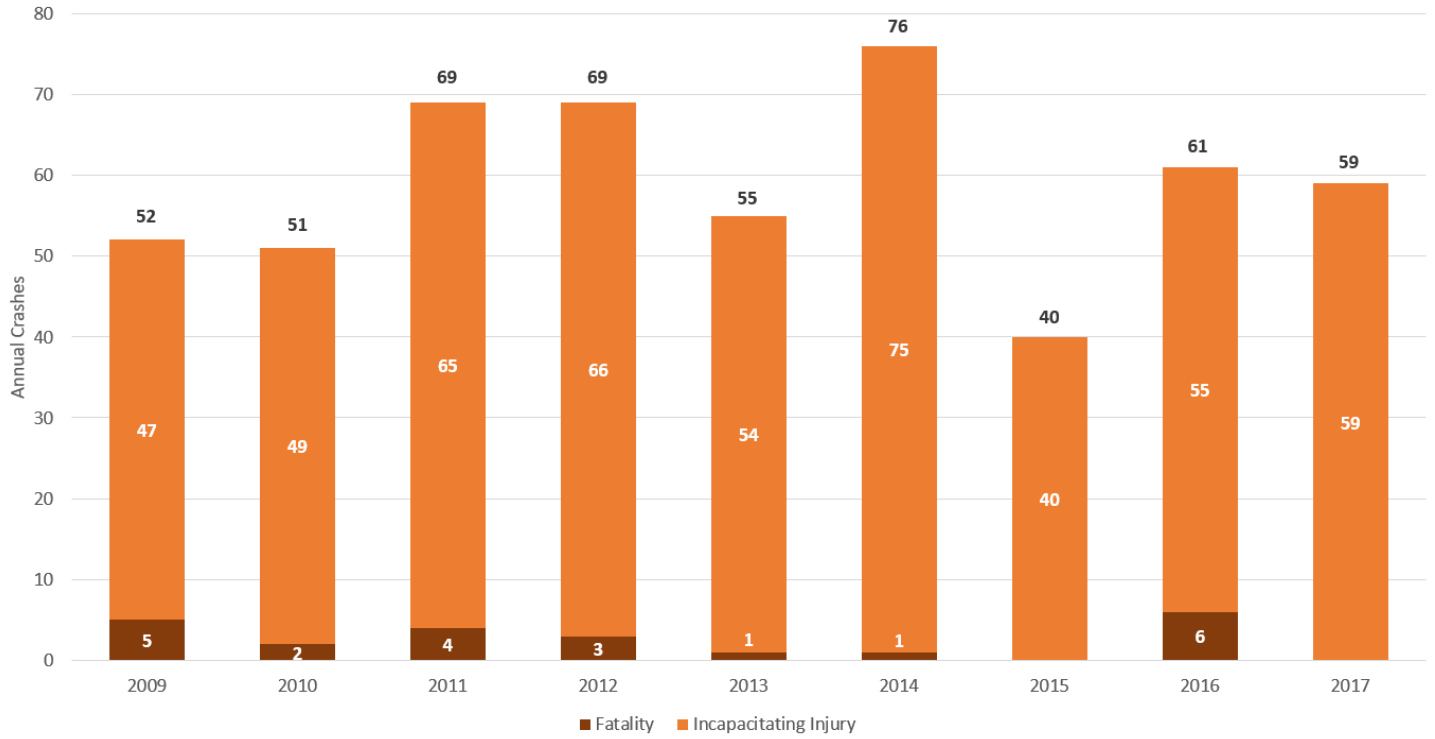


Figure 3 shows the severe crashes broken out by serious injury and fatal crashes per year. While the number of total crashes has grown since 2009, the number of severe crashes has remained approximately the same. In 2016, there were six crashes that resulted in seven fatalities (one crash resulted in two fatalities).

Figure 3: Annual Serious Injury and Fatal Crashes (2009-2017)



Of the 160 severe crashes between 2015 and 2017, 115 (72%) occurred on arterial roadways, 17 (11%) occurred on residential collectors, and 21 (13%) occurred on local roadways. The remaining seven severe crashes occurred on the path system, on private roads or in parking lots.

AVERAGE DAILY TRAFFIC AND CRASH OCCURRENCE

The following three figures show when crashes are occurring compared to the distribution of average daily traffic (ADT) in the City of Boulder during the same time period. Crashes are most frequent during the months of August, September, and October. Compared to average daily traffic, crashes tend to be overrepresented during the same months (Figure 4). Figure 5 shows that crashes are more common on weekdays than weekends. Compared to average daily traffic, crashes are overrepresented Tuesdays through Fridays.

Figure 4: Crashes by Month of Year (2015-2017)

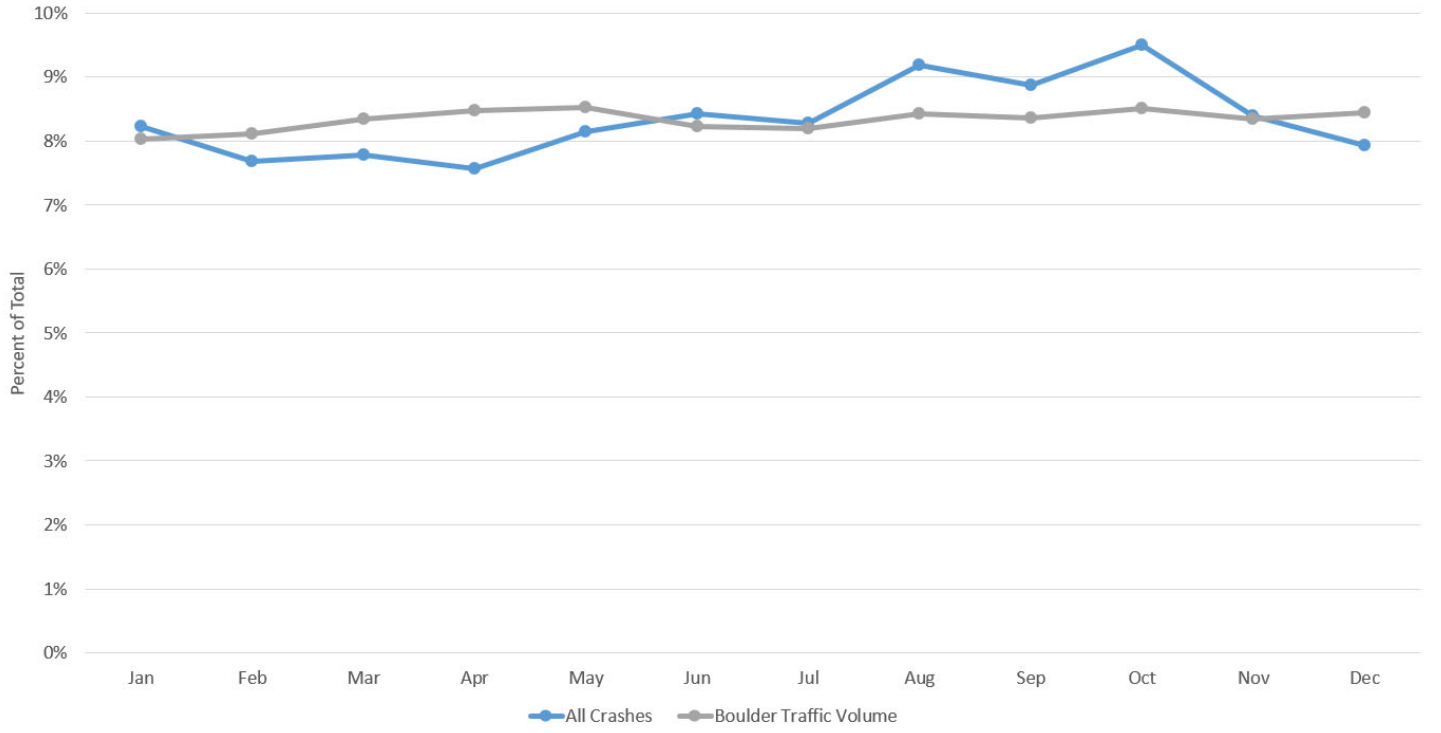
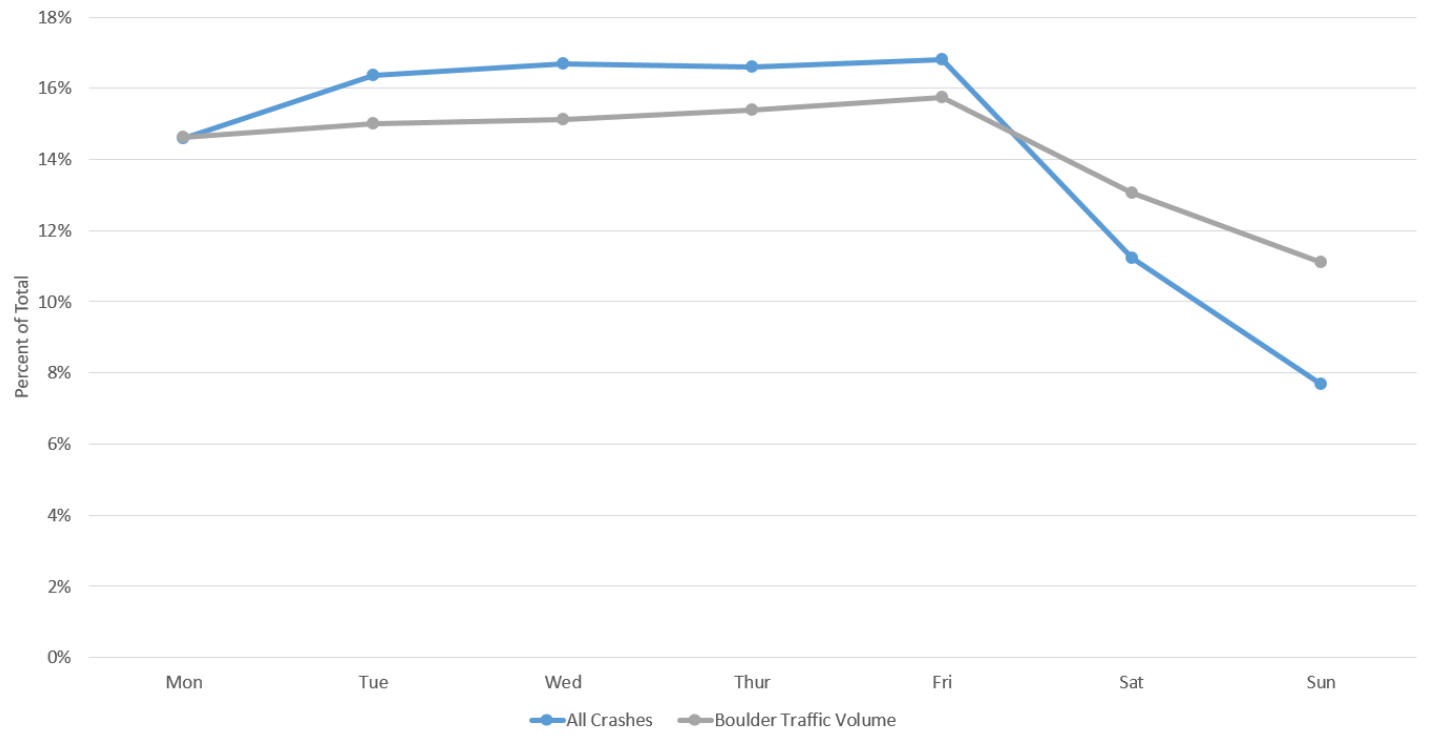
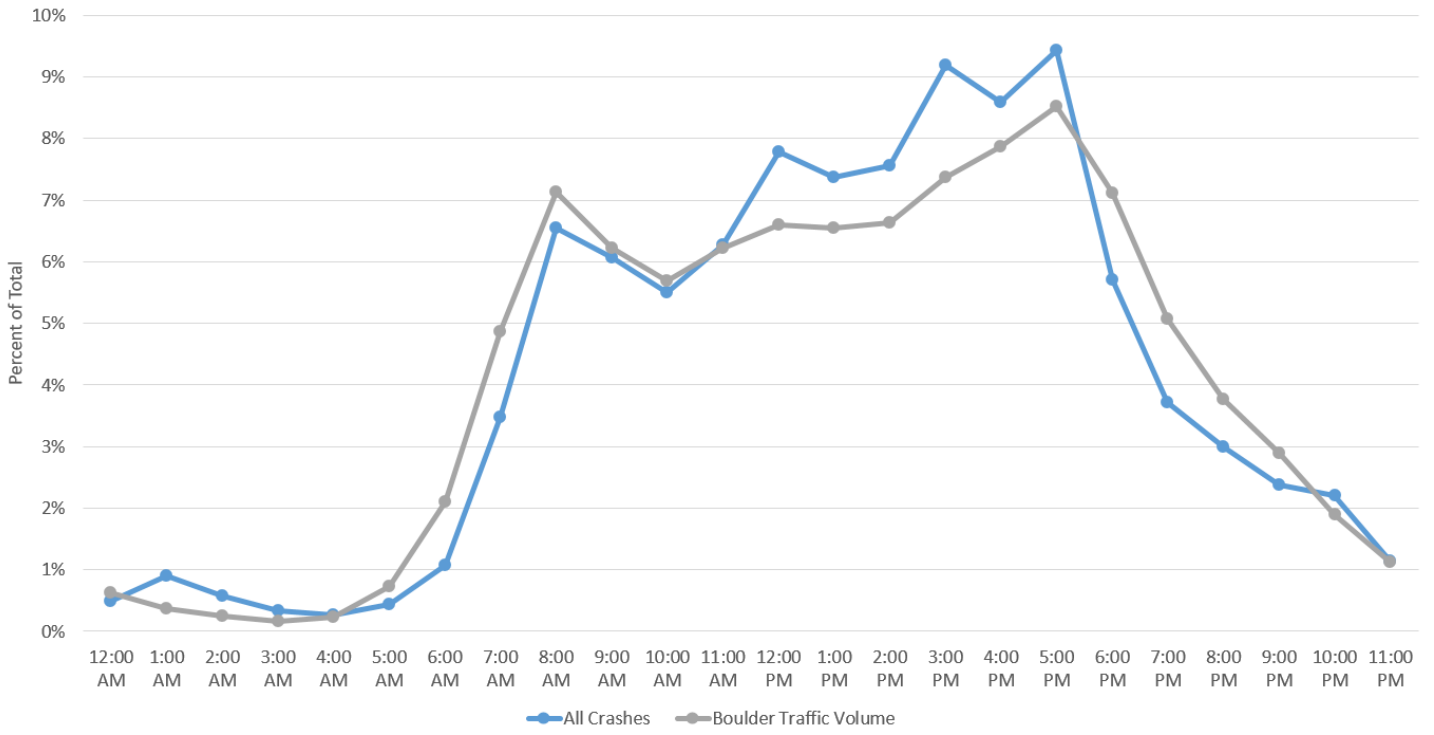


Figure 5: Crashes by Day of Week (2015-2017)



Crashes tend to occur more often in the afternoon between noon and 5 p.m. This corresponds to the time of day when traffic volumes are the highest, although crashes are overrepresented during these hours, as well as between 1 and 3 a.m. (Figure 6).

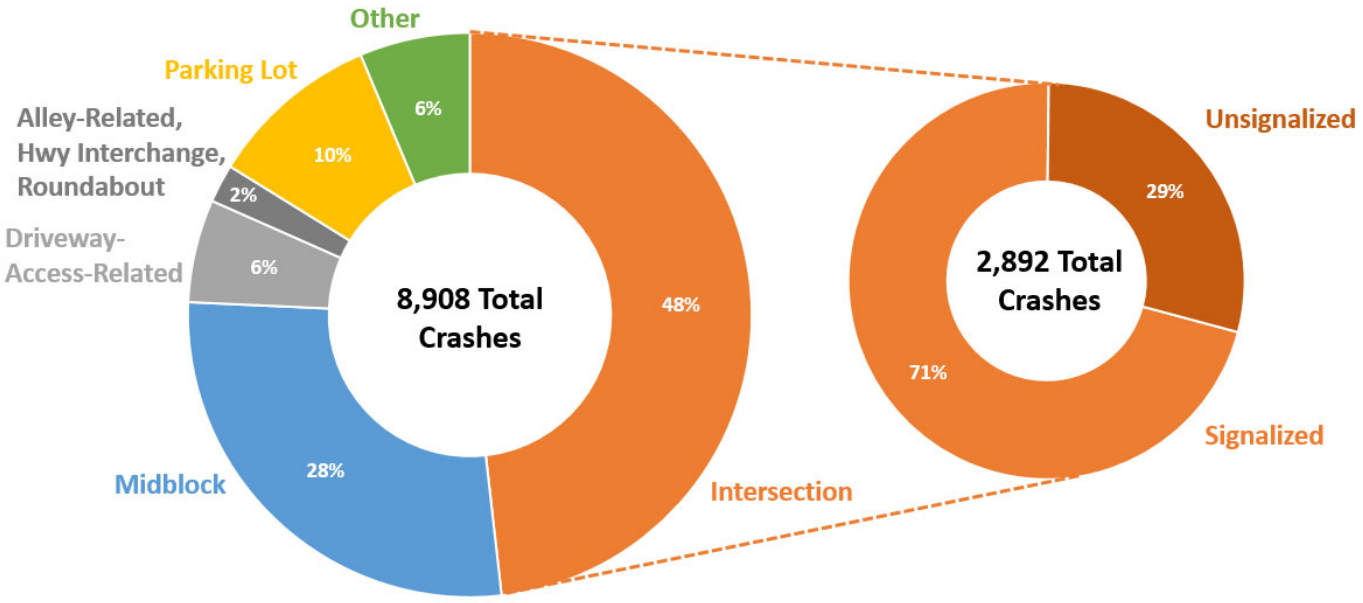
Figure 6: Crashes by Time of Day (2015-2017)



CRASH LOCATIONS

Almost half of all crashes occur at an intersection and about one third occur midblock. Of crashes that take place at an intersection, most occur at a signalized intersection (Figure 7).

Figure 7: Location of Crashes, 2015-2017



Between 2015 and 2017, rear-end crashes were the most common crash type, accounting for 37% of all crashes. The next most common crash type were right-angle crashes (10%), followed by sideswipe-same-direction, parked-vehicle, and approach-turn crashes, all accounting for 9% of total crashes. The distribution of crash types has remained relatively the same since 2009 (Figure 8). Figure 9 shows the most common serious injury and fatal crash types. Bicycle- and pedestrian-related crashes represented the highest percentage of severe crashes, followed by approach-turn, fixed-object, and rear-end crashes. It should be noted that some bicycle and pedestrian crashes were also approach- or right-angle crashes but were not included in these categories to avoid double-counting.

Figure 8: Crash Type (3-year annual average)

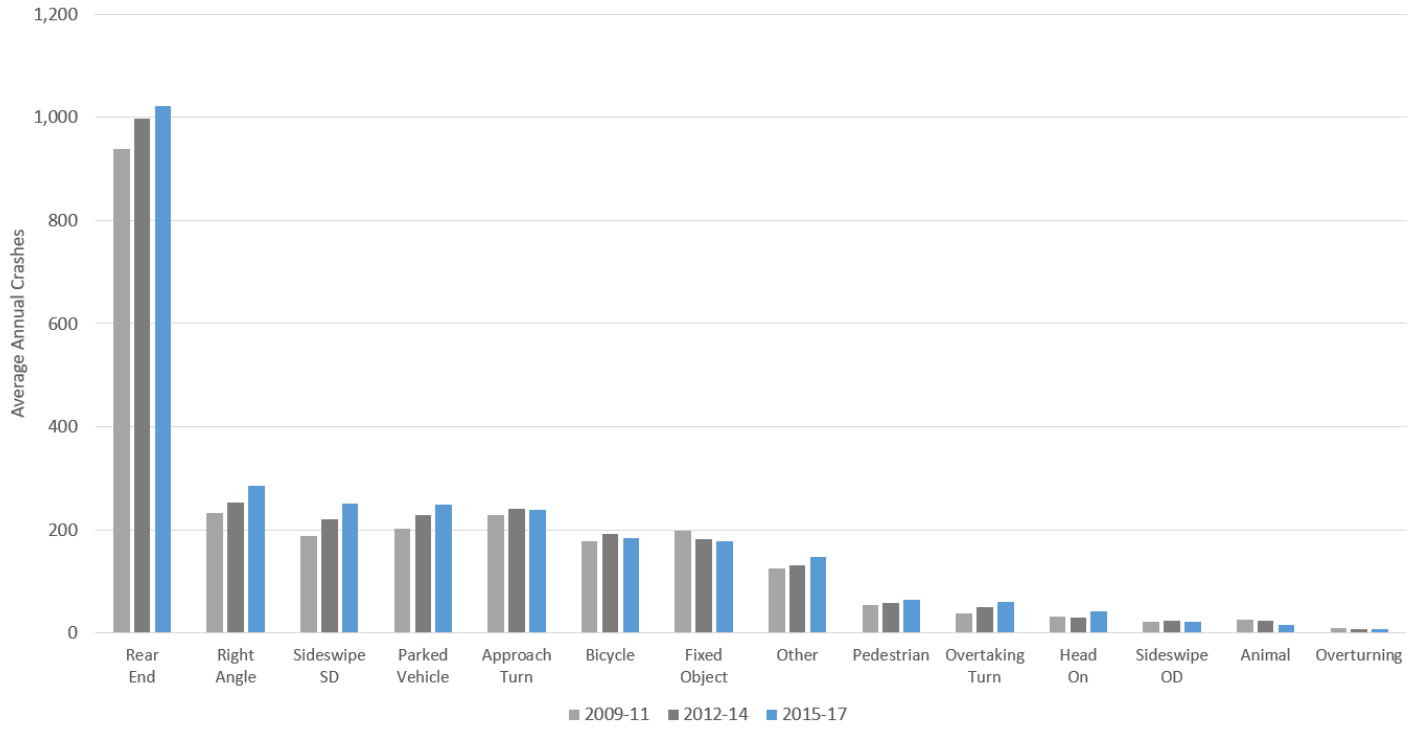
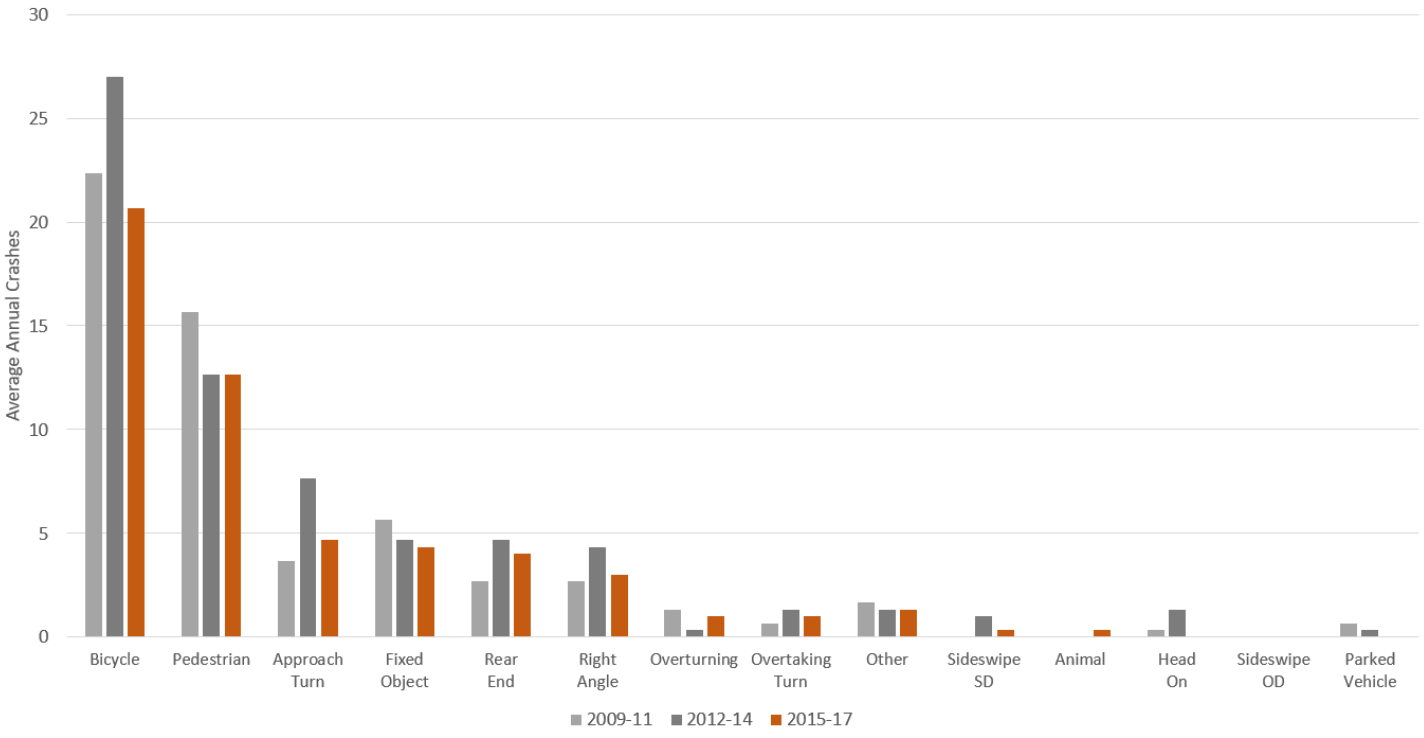


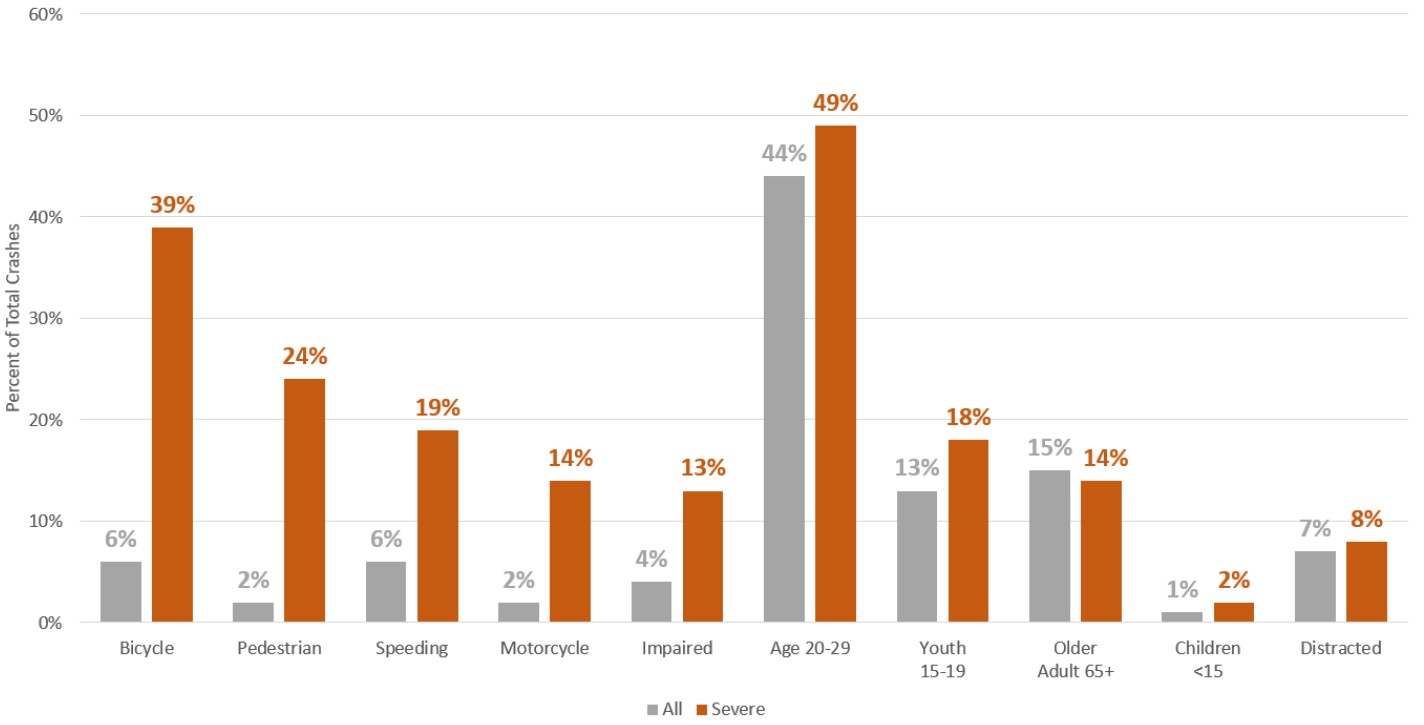
Figure 9: Severe Crash Type (3-year annual average)



Overrepresentation of Severe Crashes

When developing an action plan for reducing severe crashes, it is important to understand which crash types and factors are more likely to result in serious injuries or fatalities. By comparing the percent of overall crashes to the percent of severe crashes for each type of crash, the overrepresented categories were identified. Figure 10 shows the results of this comparison. Detailed analysis for the overrepresented areas follows. This information provides direct guidance for safety enhancement recommendations.

Figure 10: Severe Crash Analysis (2015-2017)



People Walking

The total number of annual crashes involving a person walking has been increasing at a rate of about two crashes per year, or 4% annually from 2009 to 2017 (Figure 11). Between 2015 and 2017, pedestrian crashes accounted for 2% of total crashes and 24% of severe crashes. Figure 12 shows a slight upward trend in pedestrian crashes when viewed by the three-year annual rolling average.

Figure 11: Pedestrian Crashes by Year (2009-2017)

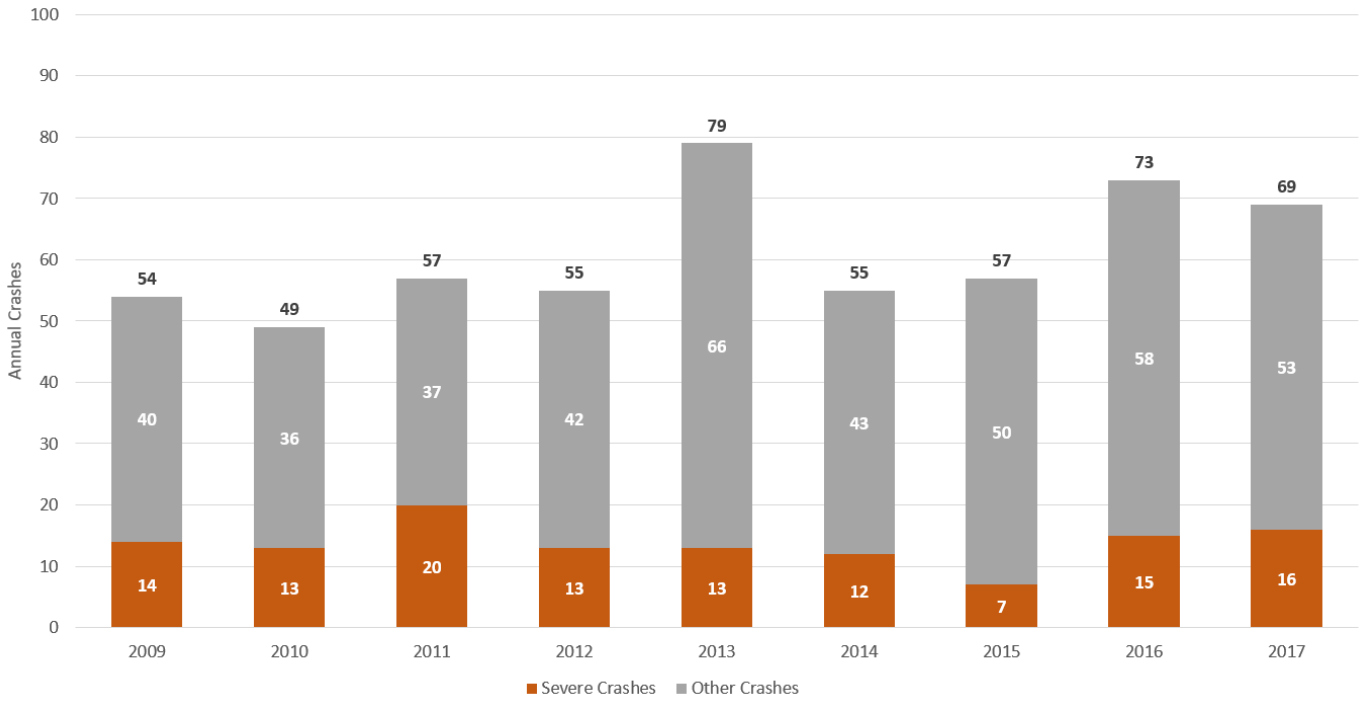


Figure 12: Pedestrian Crashes (3-year annual average)

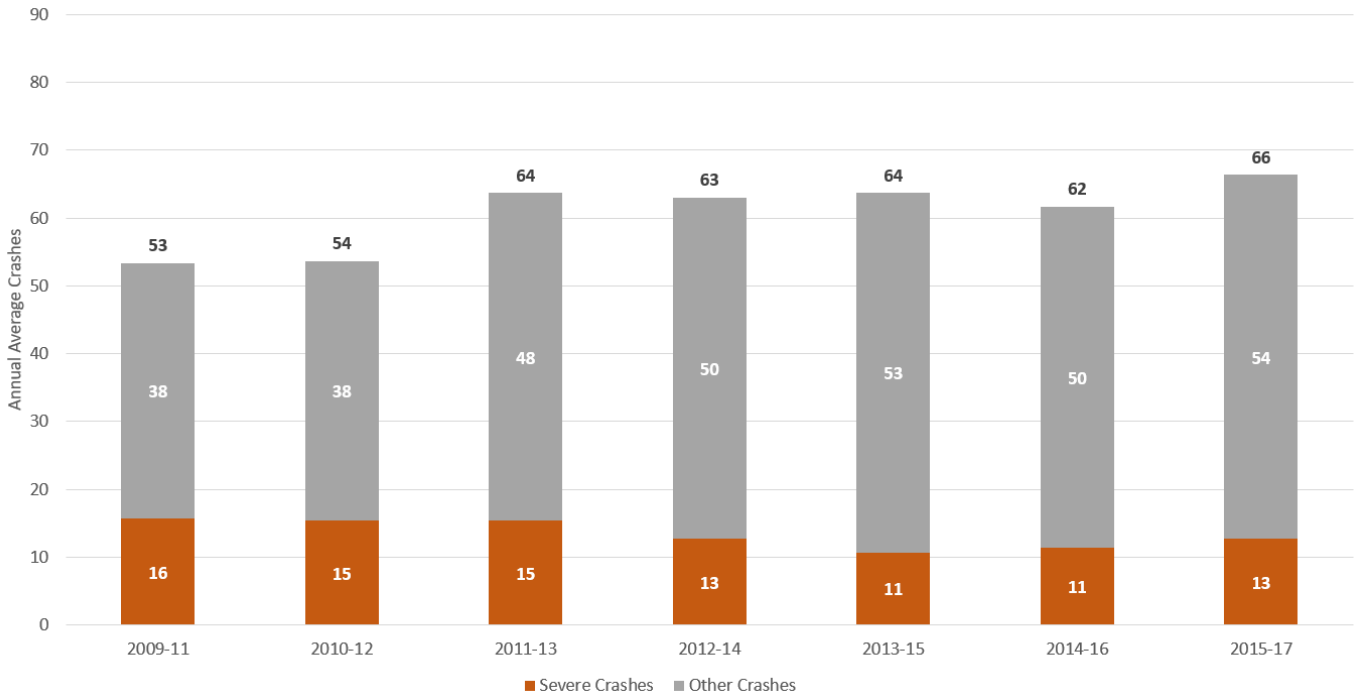
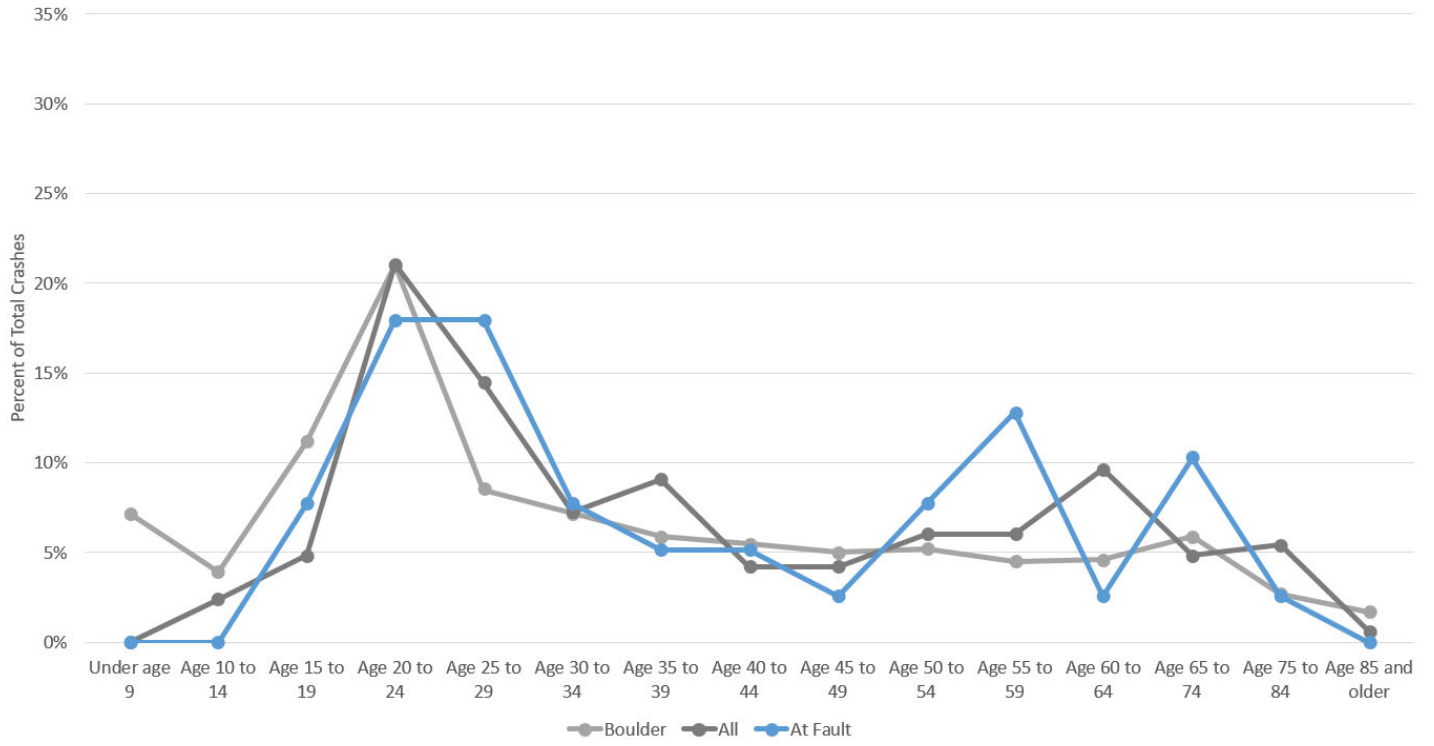


Figure 13 shows the ages of pedestrians involved in crashes compared to the total Boulder population. The dark grey line represents all pedestrians involved in crashes and the blue line represents the ages of pedestrians involved in crashes where the pedestrian is at-fault or given a citation by the responding police officer. It should be noted that when people walking are severely injured in a crash they are often not given a citation when they are at-fault. Between 2015 and 2017, pedestrians ages 25-29, 59-59, and 65-74 were overrepresented in crashes involving an at-fault pedestrian.

Figure 13: Age of Pedestrians Involved in Crashes (2015-2017)



PEDESTRIAN CRASH LOCATIONS

Figure 14 shows the locations of crashes involving pedestrians. Figure 15 shows that about 58% of pedestrian crashes occurred within a crosswalk and 26% within the roadway (not at a crosswalk) between 2015 and 2017. Pedestrian crashes within a crosswalk occur when a pedestrian crosses an intersection of two roadways, or an intersection of a roadway and a driveway, or crosses the street midblock via a designated crosswalk. Pedestrian crashes within roadways occur when a pedestrian crosses a roadway not at an intersection or crosswalk or walks along a roadway within the travel lane. About 50% of severe pedestrian crashes occurred within crosswalks and 42% occurred within roadways. The number of severe pedestrian crashes within roadways has increased since 2014 (Figure 16). Note that in this section, the total crashes rather than annual averages are used due to the low numbers of pedestrian crashes.

Figure 14: Locations of Crashes Involving Pedestrians (2015-2017)

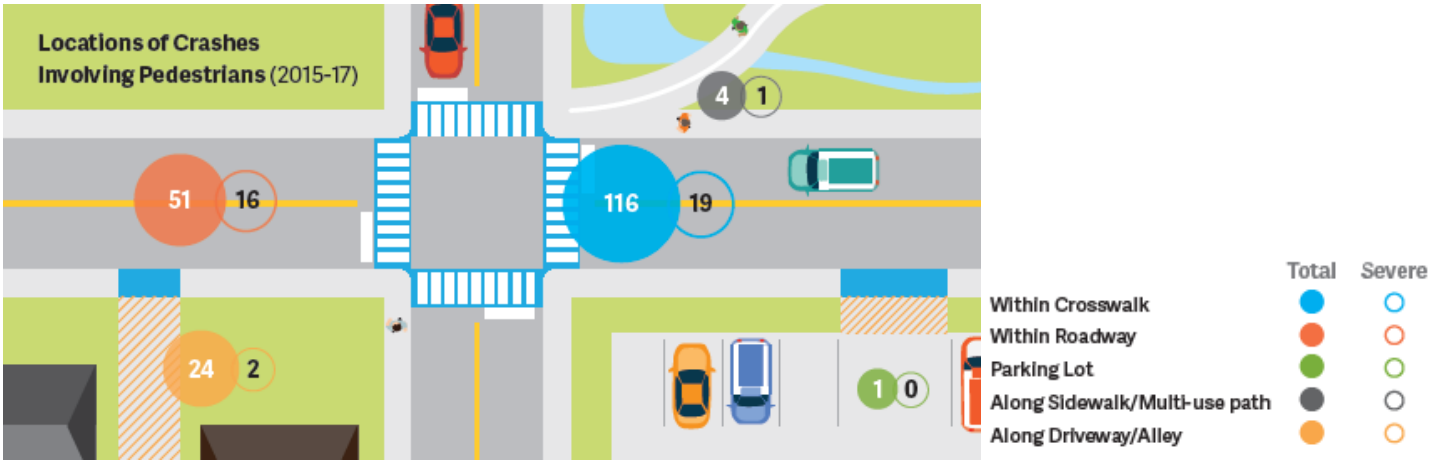


Figure 15: Location of Pedestrian Crashes (3-year totals)

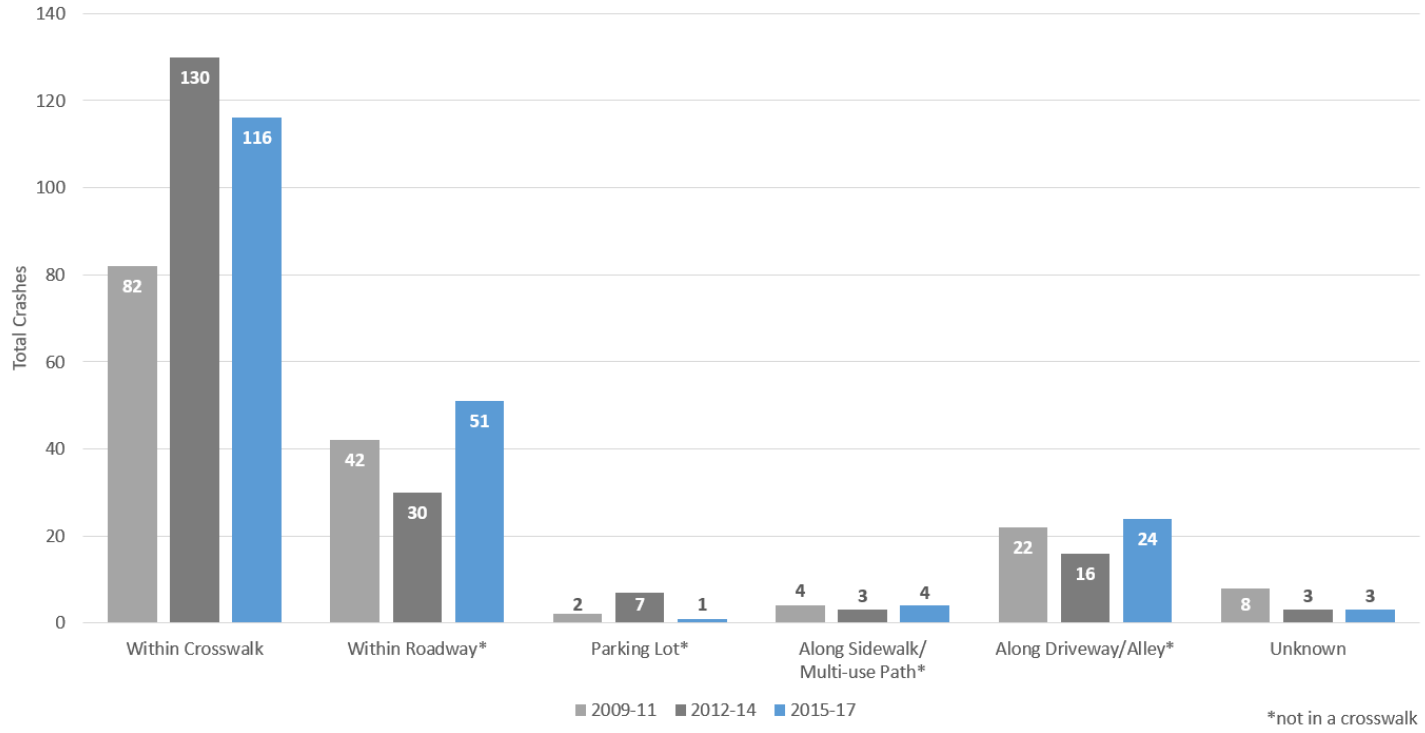
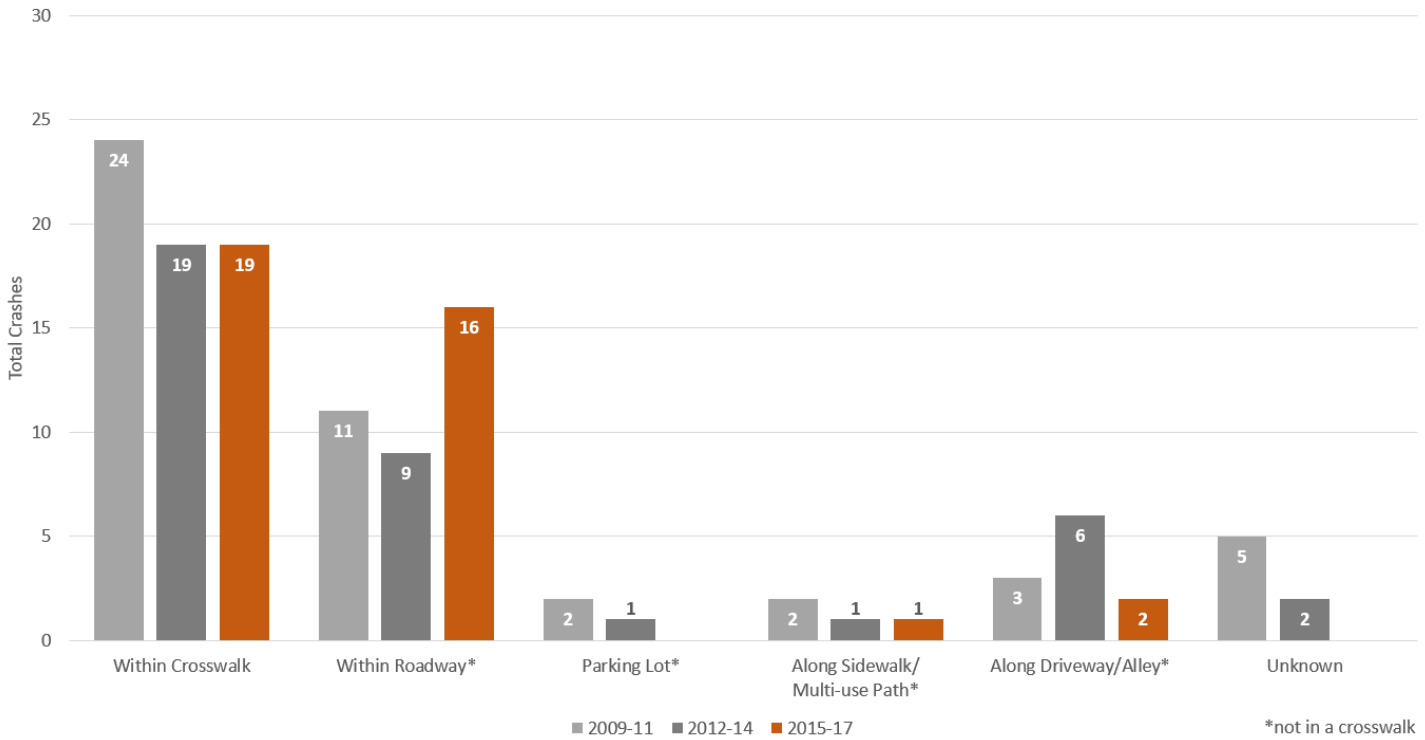


Figure 16: Location of Severe Pedestrian Crashes (3-year totals)



For crashes that take place within crosswalks, most pedestrian crashes occurred at signalized intersections. Very few crashes occurred at midblock crosswalks (Figure 17). Of severe pedestrian crashes, almost 80% of crashes occurred at signalized intersections. Since 2009, severe pedestrian crashes occurring at signalized intersections have increased and decreased at signed intersections (Figure 18).

Figure 17: Pedestrian Crashes Within Crosswalks (3-year totals)

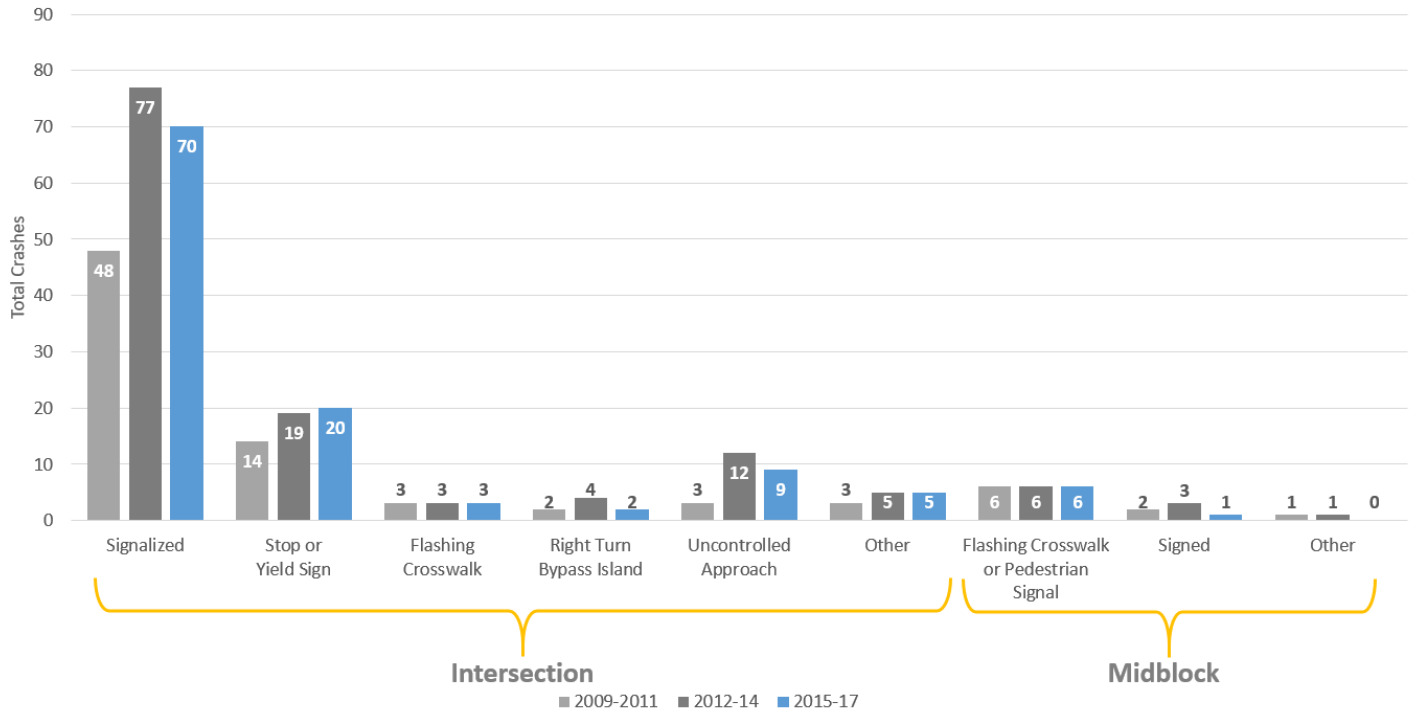
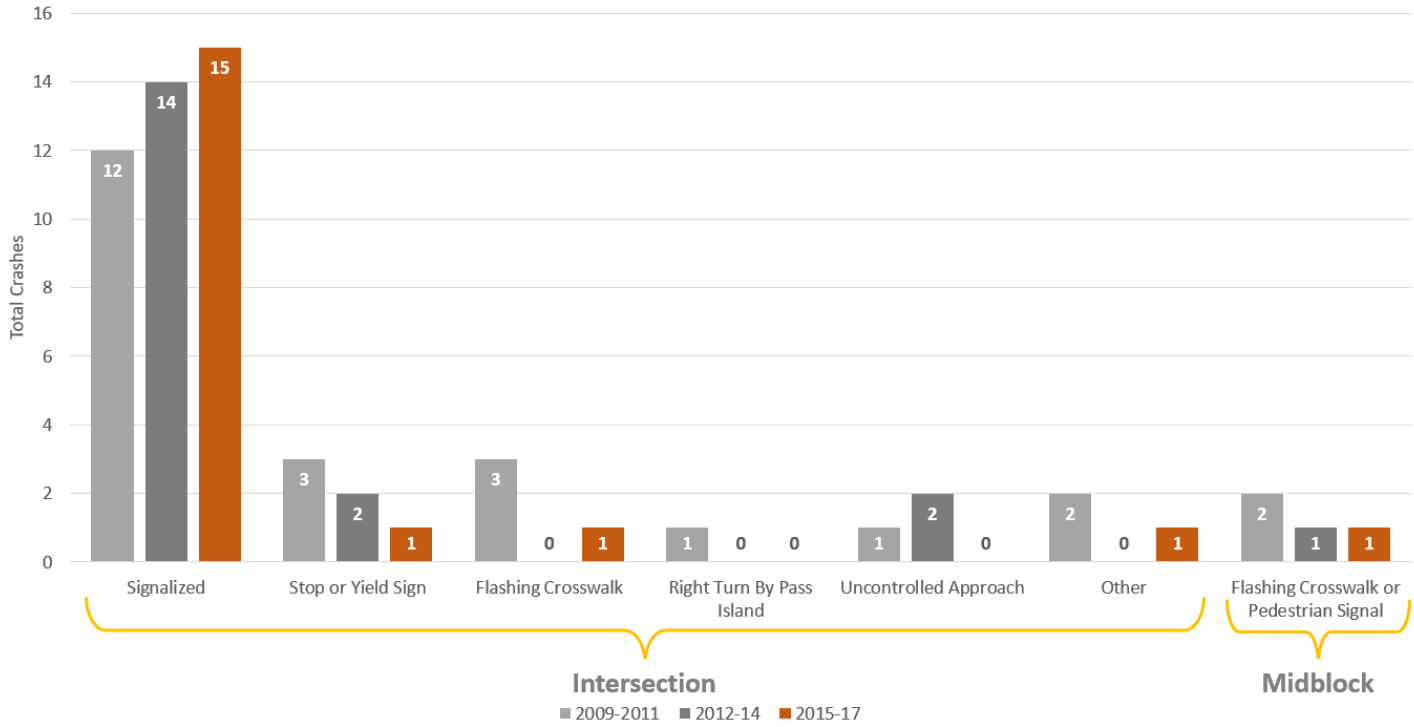


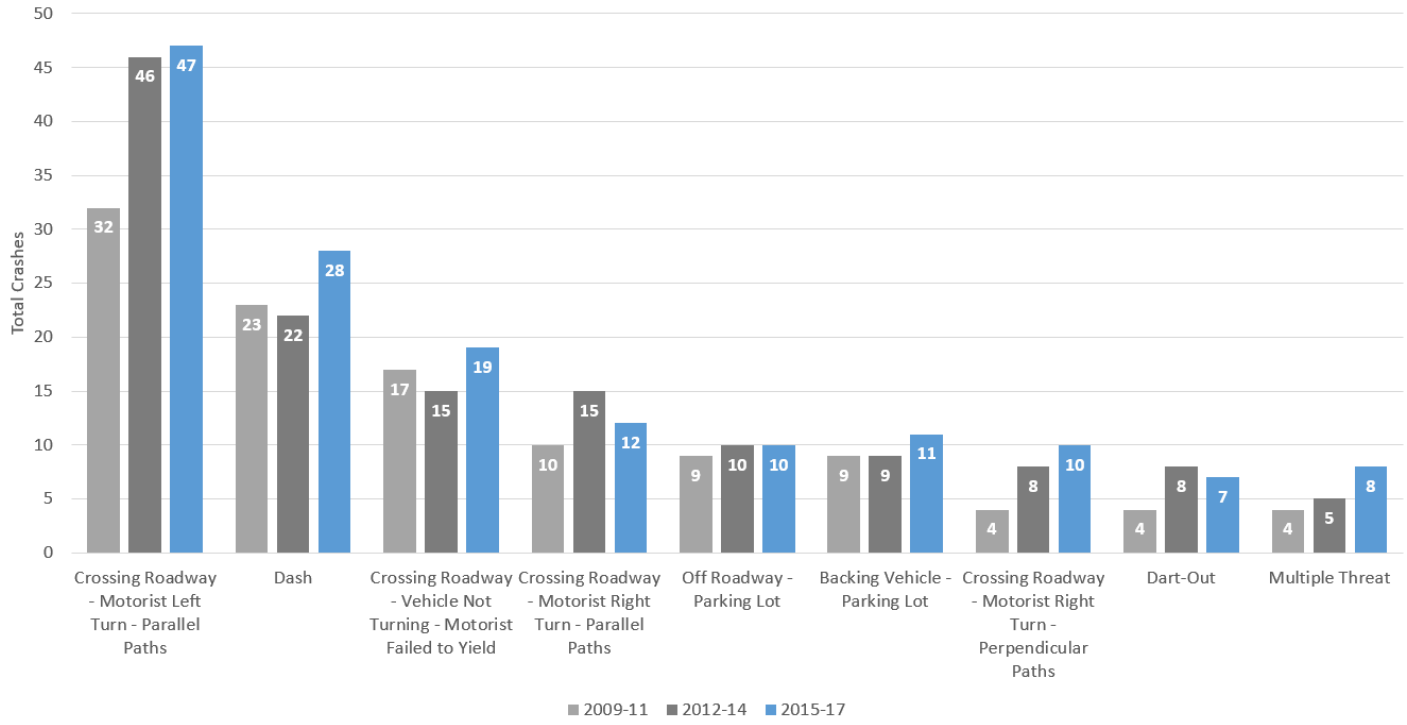
Figure 18: Severe Pedestrian Crashes Within Crosswalks (3-year totals)



PEDESTRIAN CRASH TYPES

The number of pedestrians hit by a turning vehicle while crossing a roadway has been increasing. Between 2015 and 2017, 24% of pedestrian crashes occurred when a pedestrian was crossing a roadway and a vehicle was turning left and 14% were pedestrian-dash crashes (Figure 19).

Figure 19: Most Common Pedestrian Crash Type (3-year totals)



Of all severe pedestrian crashes that occurred between 2015 and 2017, 24% occurred when a pedestrian was crossing a roadway and a vehicle was turning left. About 20% of severe pedestrian crashes occurred when a pedestrian dashed across a roadway (Figure 20). One out of every three pedestrian-dash crashes resulted in a severe injury.

Figure 20: Most Common Severe Pedestrian Crash Type (3-year totals)

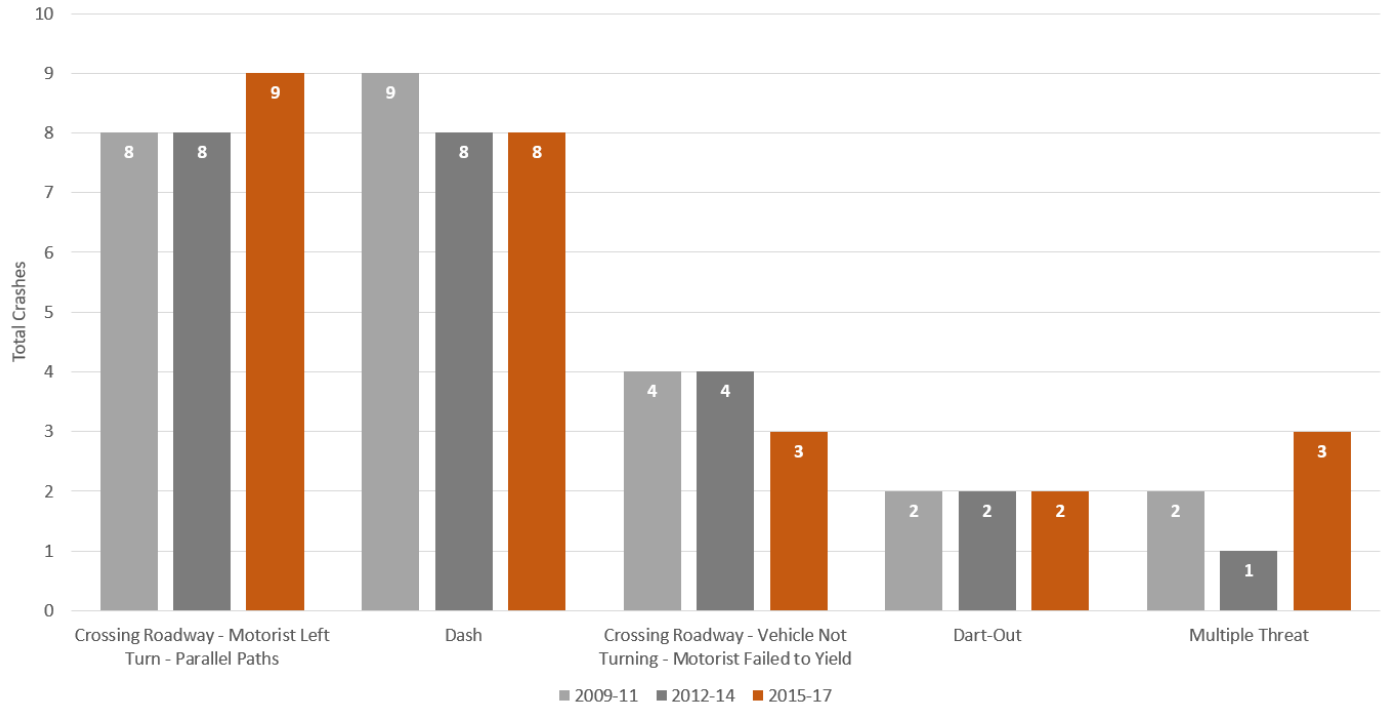
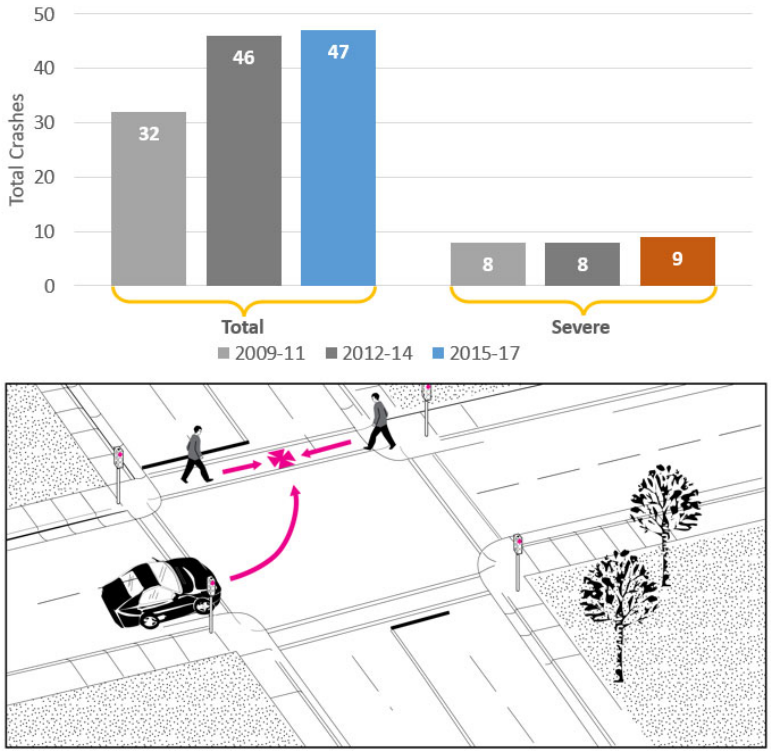


Figure 21 through Figure 25 show additional details on the most common pedestrian crash types along with a diagram to explain how these types of crashes occur.

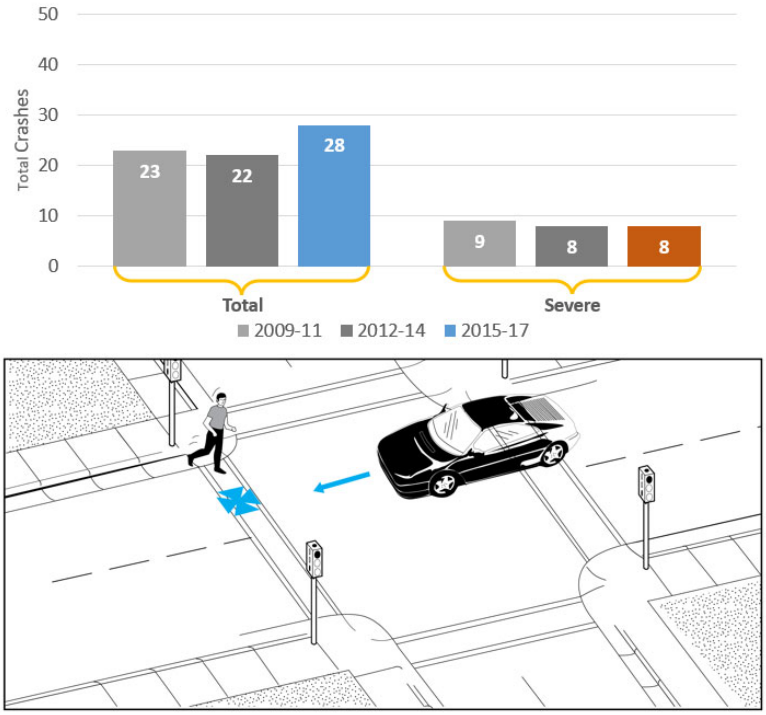
Pedestrians being hit by a left-turning motorist accounted for one quarter of all pedestrian crashes, and, of those, one out of five resulted in a severe injury (Figure 21).

Figure 21: Crossing Roadway – Motorist Left Turn – Parallel Paths (3-year totals)



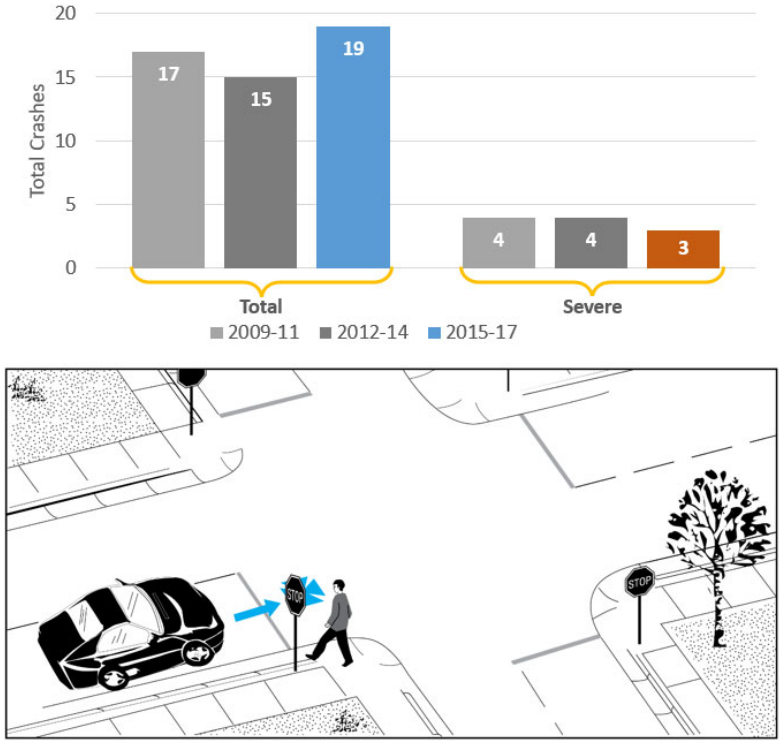
One out of every three dash-out crashes resulted in a severe injury (Figure 22).

Figure 22: Pedestrian Dash (3-year totals)



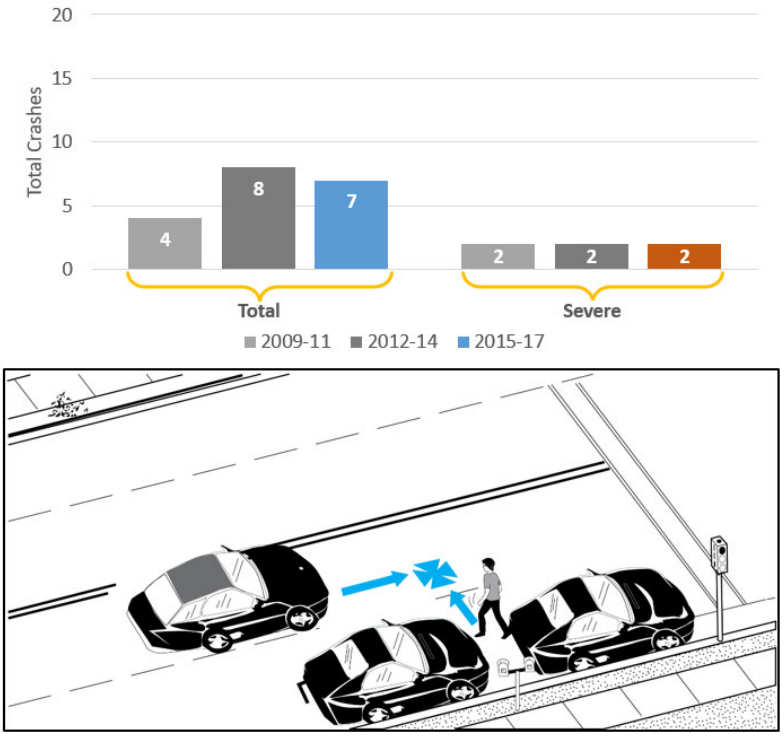
Motorists failing to yield to a pedestrian accounted for 10% of all pedestrian crashes, and, of those, one out of six resulted in a severe injury (Figure 23).

Figure 23: Crossing Roadway – Vehicle Not Turning – Motorist Failed to Yield (3-year totals)



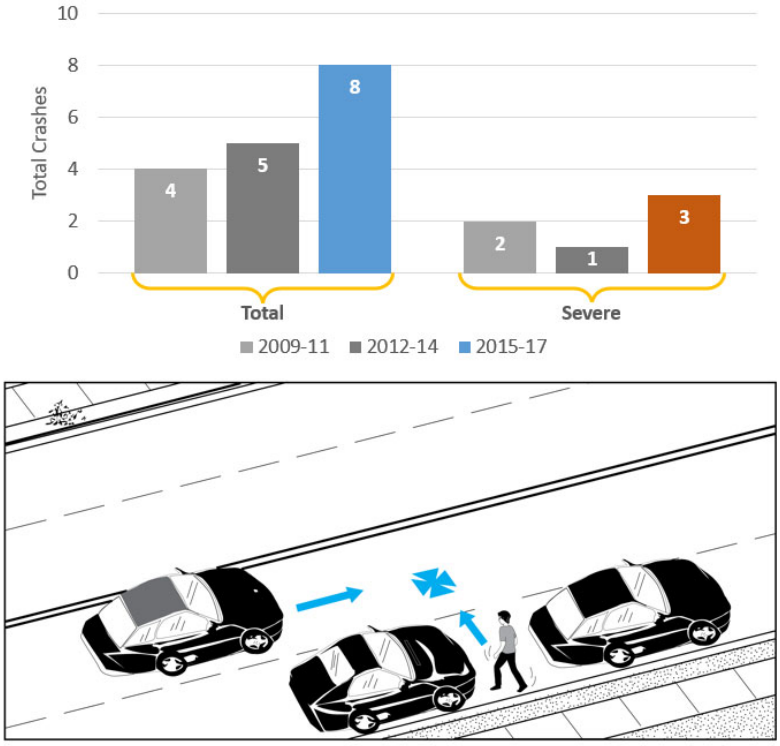
Pedestrian dart-outs accounted for 4% of all pedestrian crashes, and, of those, one out of three-and-a-half resulted in a severe injury (Figure 24).

Figure 24: Pedestrian Dart-Out (3-year totals)



Multiple threat accounted for 4% of all pedestrian crashes, and, of those, one out of three resulted in a severe injury (Figure 25). A multiple threat is similar to a dart-out; however, a multiple threat occurs when a pedestrian enters the travel lane in front of stopped or slowing traffic (rather than parked vehicles) and is struck by a vehicle traveling in the same direction as the stopped or slowing traffic.

Figure 25: Multiple Threat (3-year totals)



People Bicycling

Figure 26 shows total bicycle crashes per year between 2009 and 2017, and Figure 27 shows bicycle crashes as a 3-year rolling annual average. Between 2015 and 2017, there were a total of 61 serious injury crashes and one fatal crash involving bicyclists. Overall, bicycle crashes accounted for 6% of total crashes and 39% of severe crashes. Based on the variance of this data, the presence of an overall upward or downward trend in crashes involving a person riding a bicycle cannot be concluded.

Figure 26: Bicycle Crashes by Year (2009-2017)

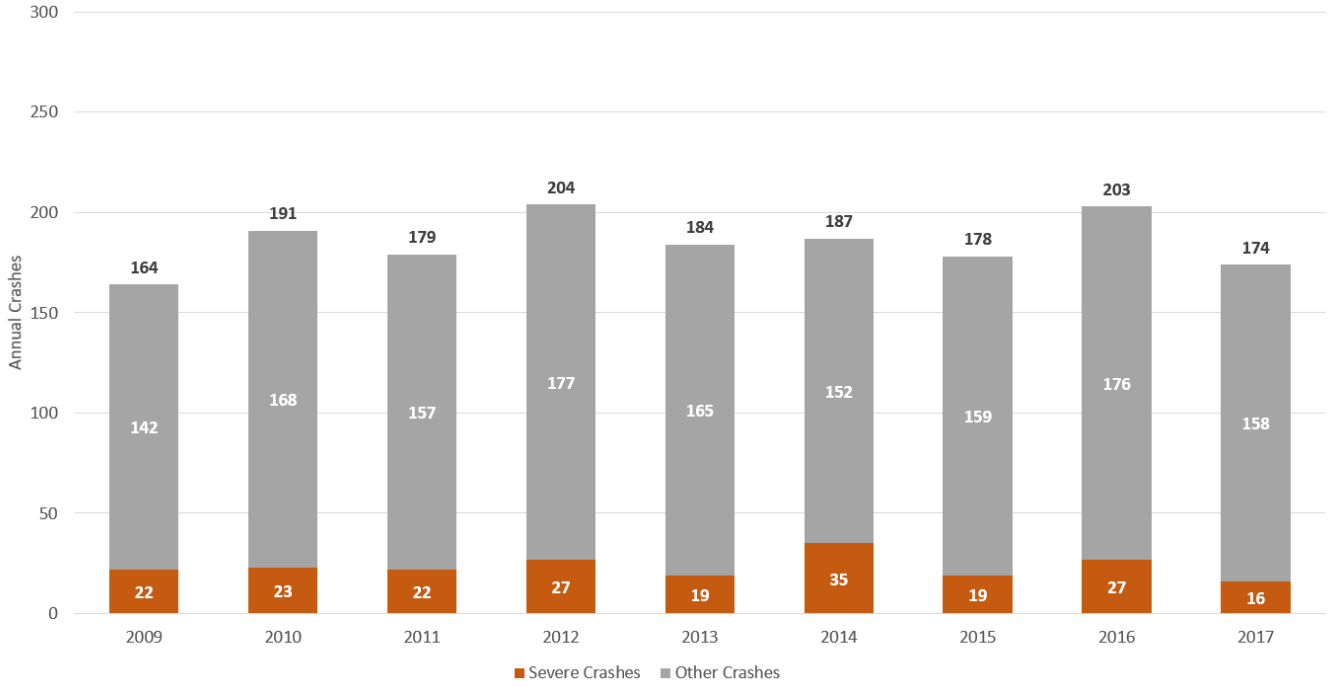


Figure 27: Bicycle Crashes (3-year annual average)

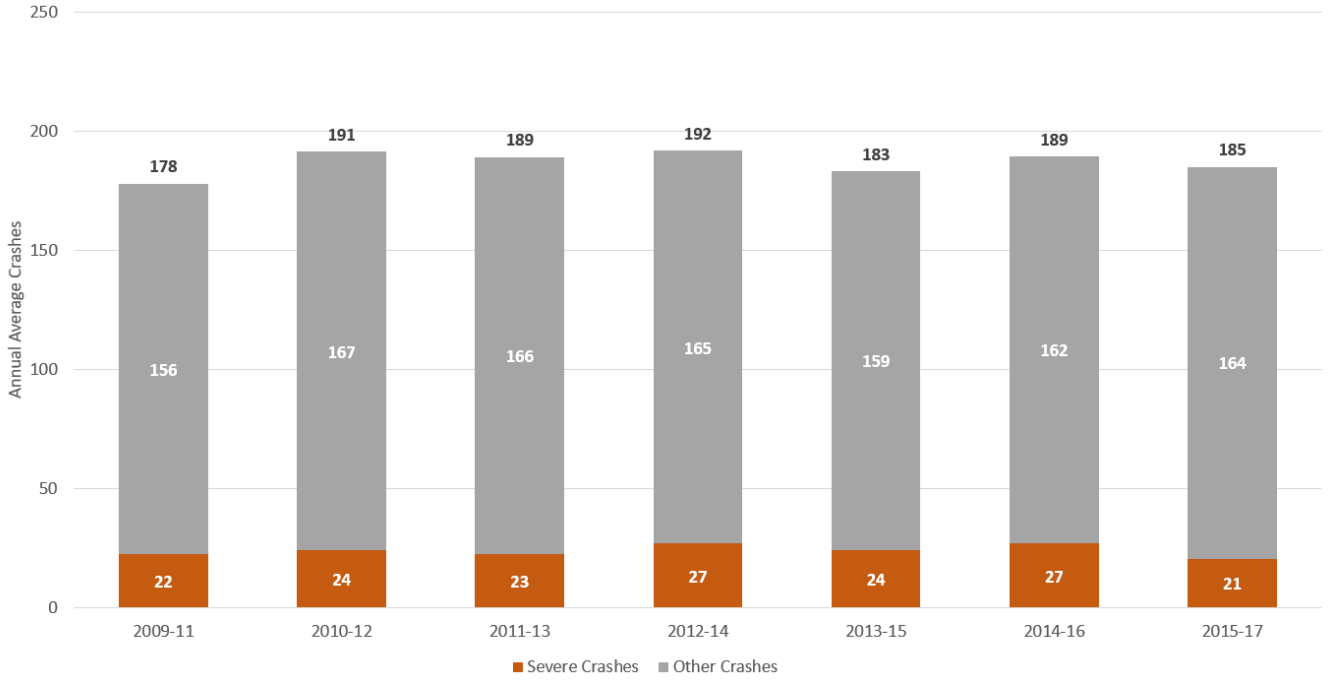
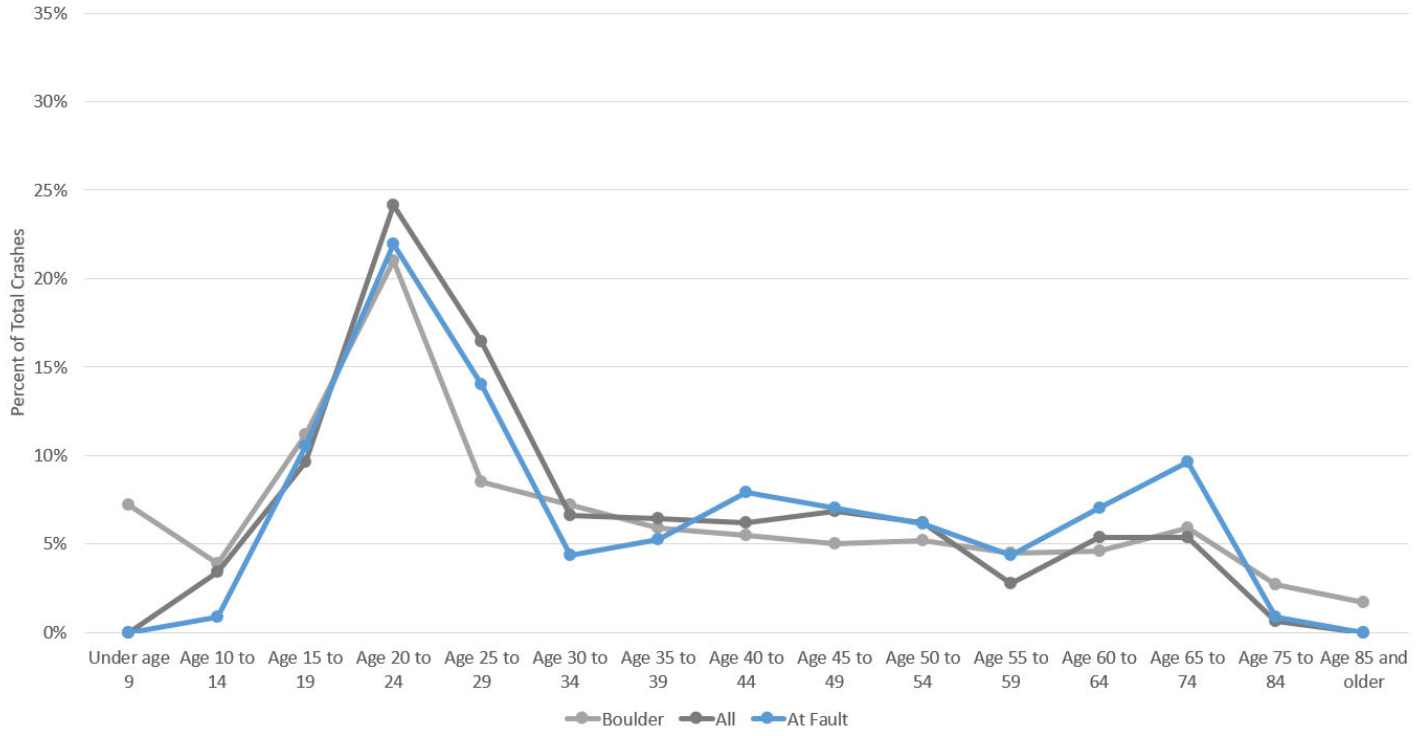


Figure 28 shows the ages of people riding a bicycle who were involved in crashes compared to the Boulder population. The dark grey line represents all bicyclists involved in crashes and the blue line represents the ages of bicyclists involved in crashes when the bicyclist is at-fault or given a citation by the responding police officer. It should be noted that when people biking are severely injured in a crash, they are often not given a citation even when they are at-fault.

Bicyclists ages 15-29, 40-54, and 60-74 were overrepresented in crashes involving an at-fault bicyclist.

Figure 28: Age of Bicyclist Involved in a Crash (2015-2017)



BICYCLE CRASH LOCATIONS

Between 2015 and 2017, 44% of all bicycle crashes occurred within roadway travel lanes, bike lanes or shoulders, and 31% of bicycle crashes occurred along multi-use paths (MUPs). Figure 29 shows the location of all crashes between 2015 and 2017 involving bicyclists. The number of bicycle crashes in these locations has been increasing, and bicycle crashes along sidewalks has been decreasing (Figure 30). Between 2015 and 2017, 66% of all bicycle severe crashes occurred within a travel lane, bike lane or shoulder and 24% occurred on an MUP (Figure 31).

Figure 29: Locations of Total Crashes Involving Bicyclists (2015-2017)

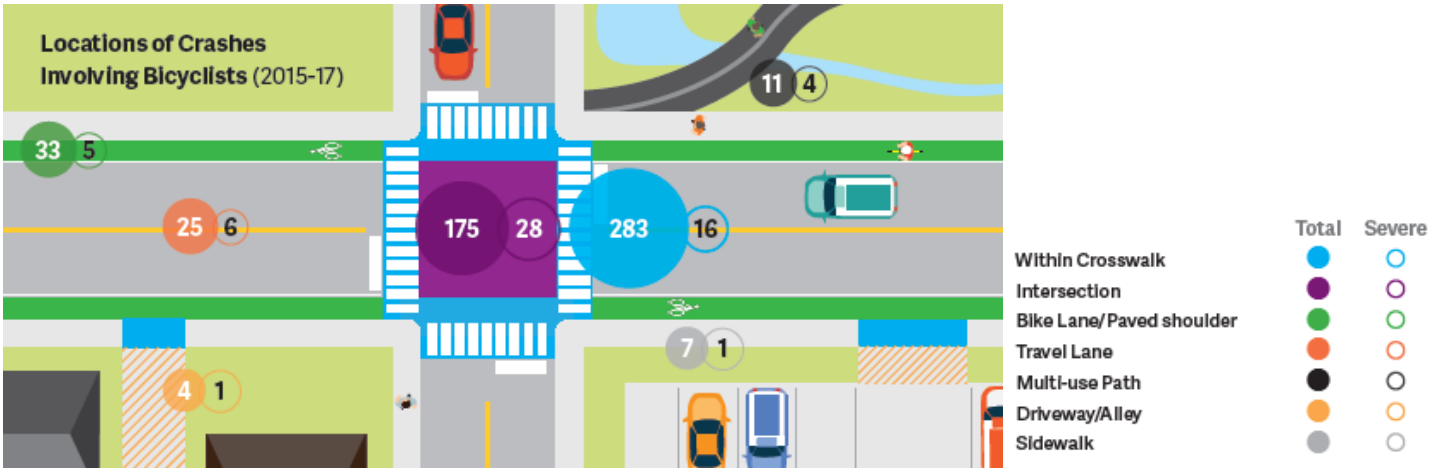


Figure 30: Facility Type Where Bicyclist Crash Occurred (3-year annual average)

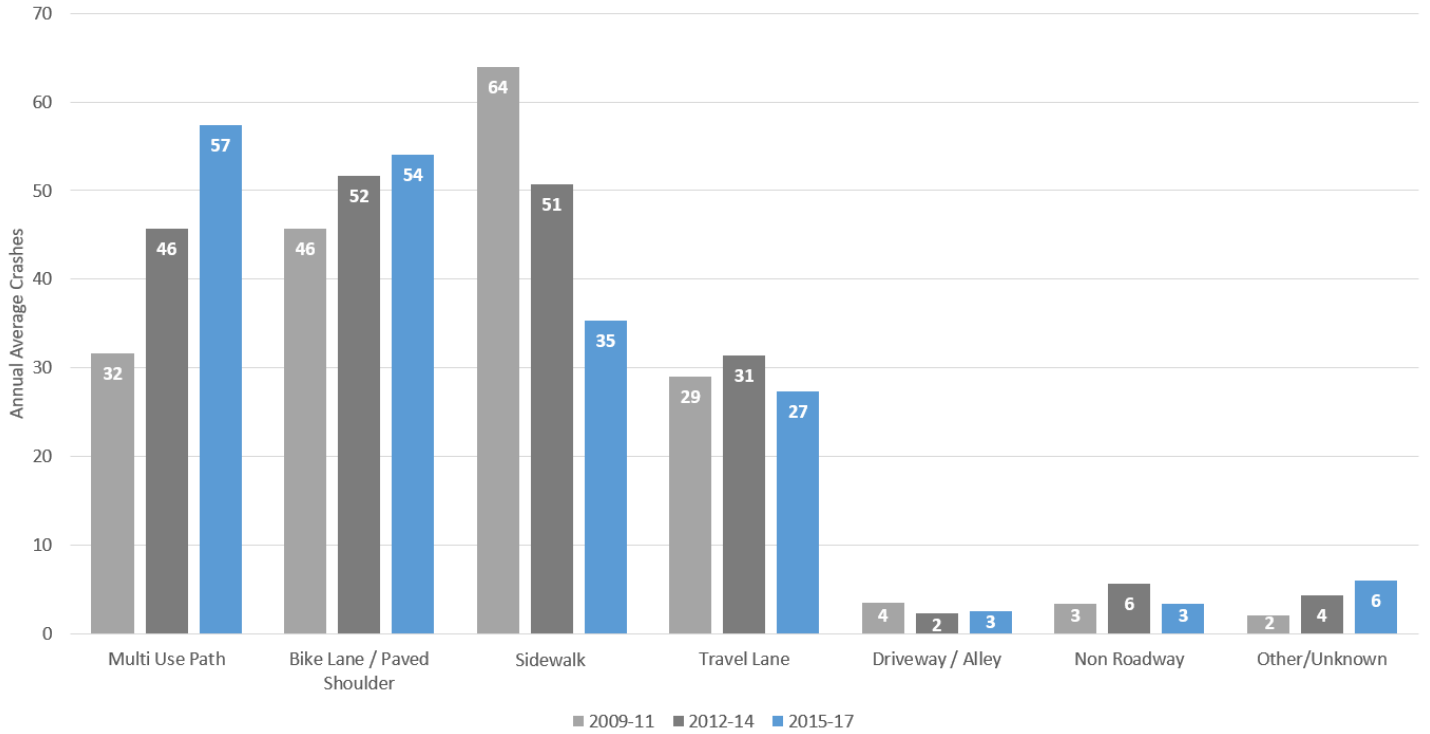


Figure 31: Facility Type Where Bicyclist Severe Crash Occurred (3-year annual average)

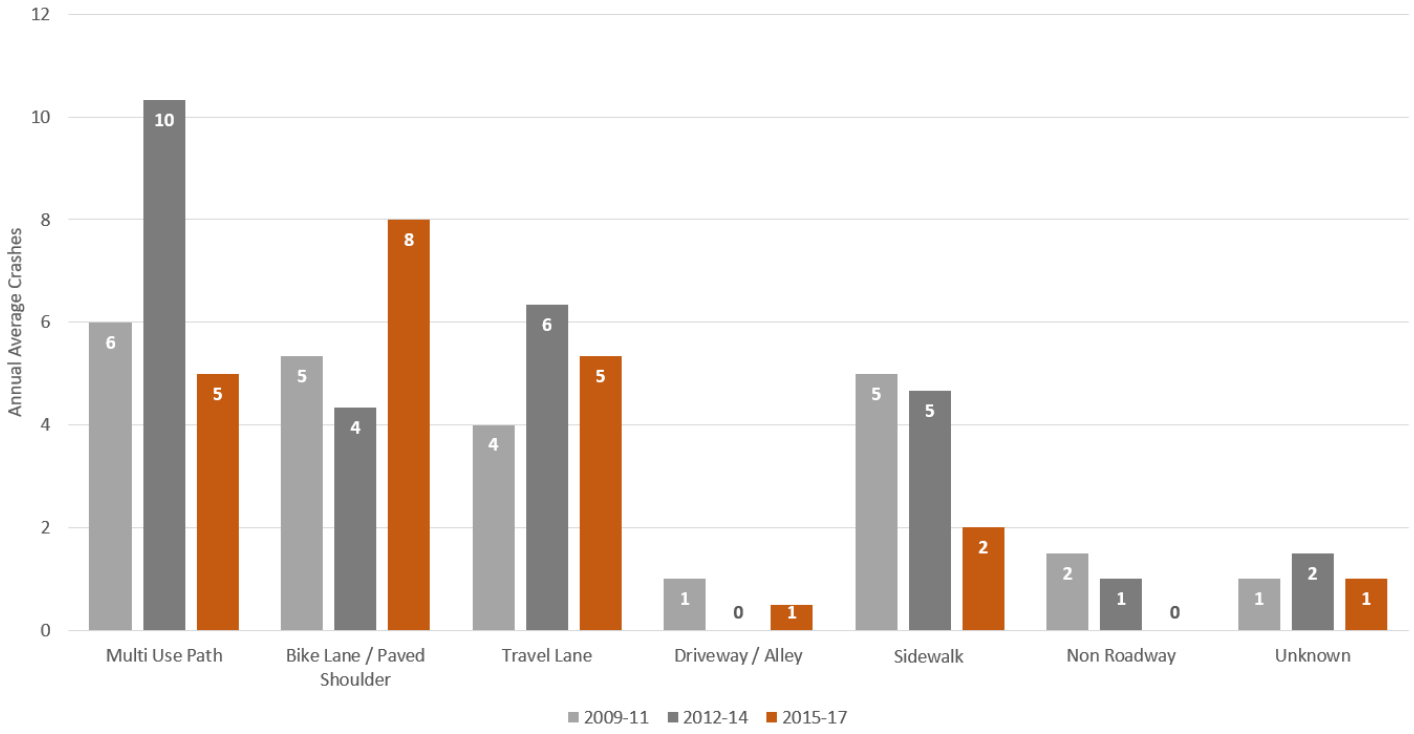


Figure 32 and Figure 33 show that between 2015 and 2017, 79% of all bicycle crashes and 61% of all severe bicycle crashes occurred at an intersection within a crosswalk, bike lane, shoulder or travel lane.

Figure 32: Bicycle Crash Location (3-year annual average)

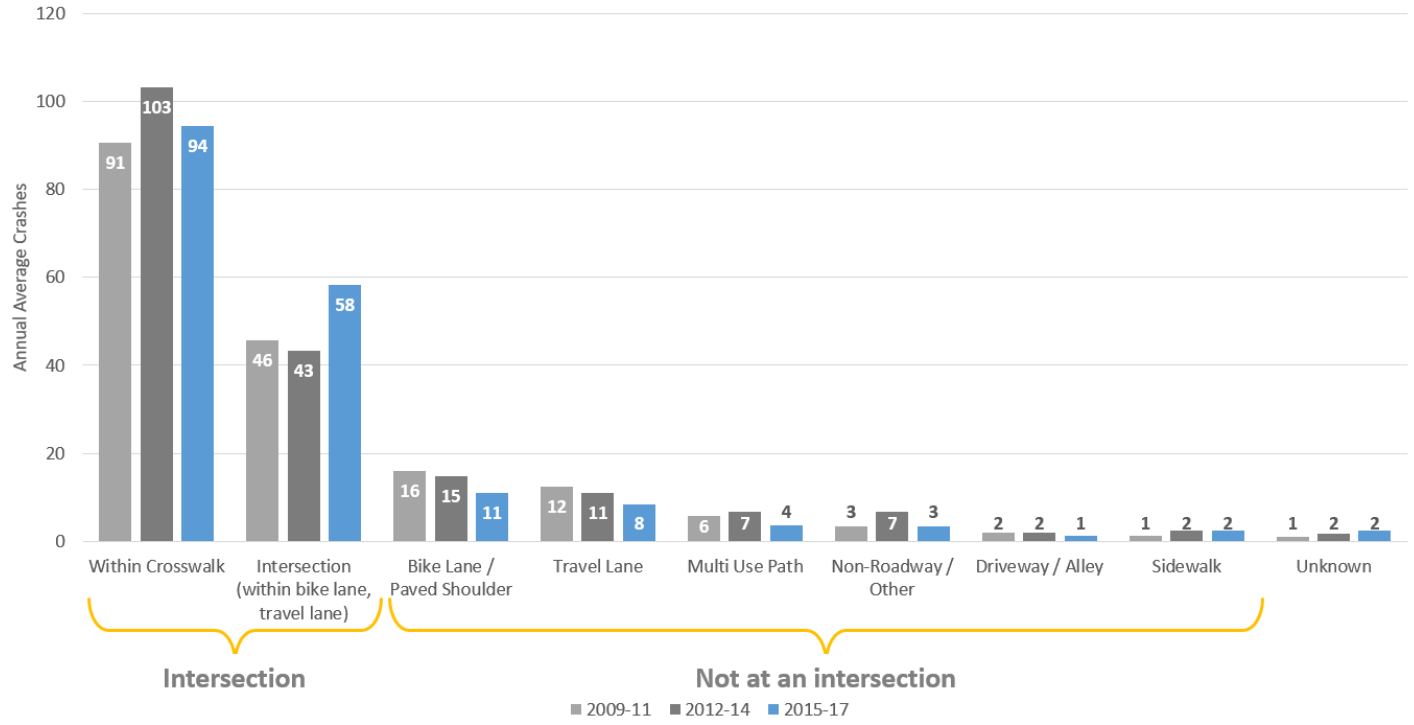


Figure 33: Severe Bicycle Crash Location (3-year annual average)

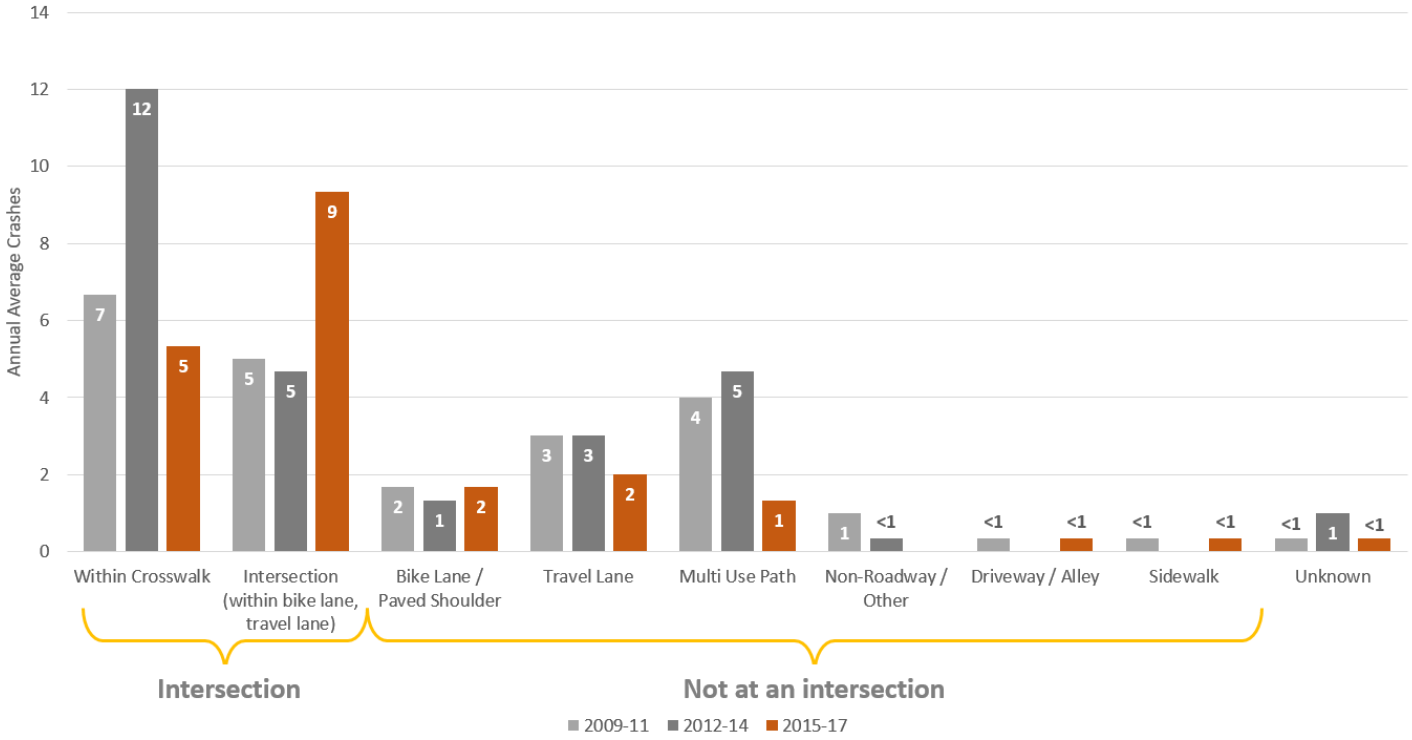


Figure 34 shows bicycle crashes at an intersection (including within a crosswalk and not within a crosswalk, as well as within a bike lane or travel lane) by the type of traffic control. Almost 70% of all bicycle crashes at intersections occurred at signalized (40%) or stop-controlled (28%) intersections between 2015 and 2017, while 19% occurred at uncontrolled intersections.

Figure 34: Bicycle Crashes at an Intersection* by Type of Traffic Control (3-year annual average)

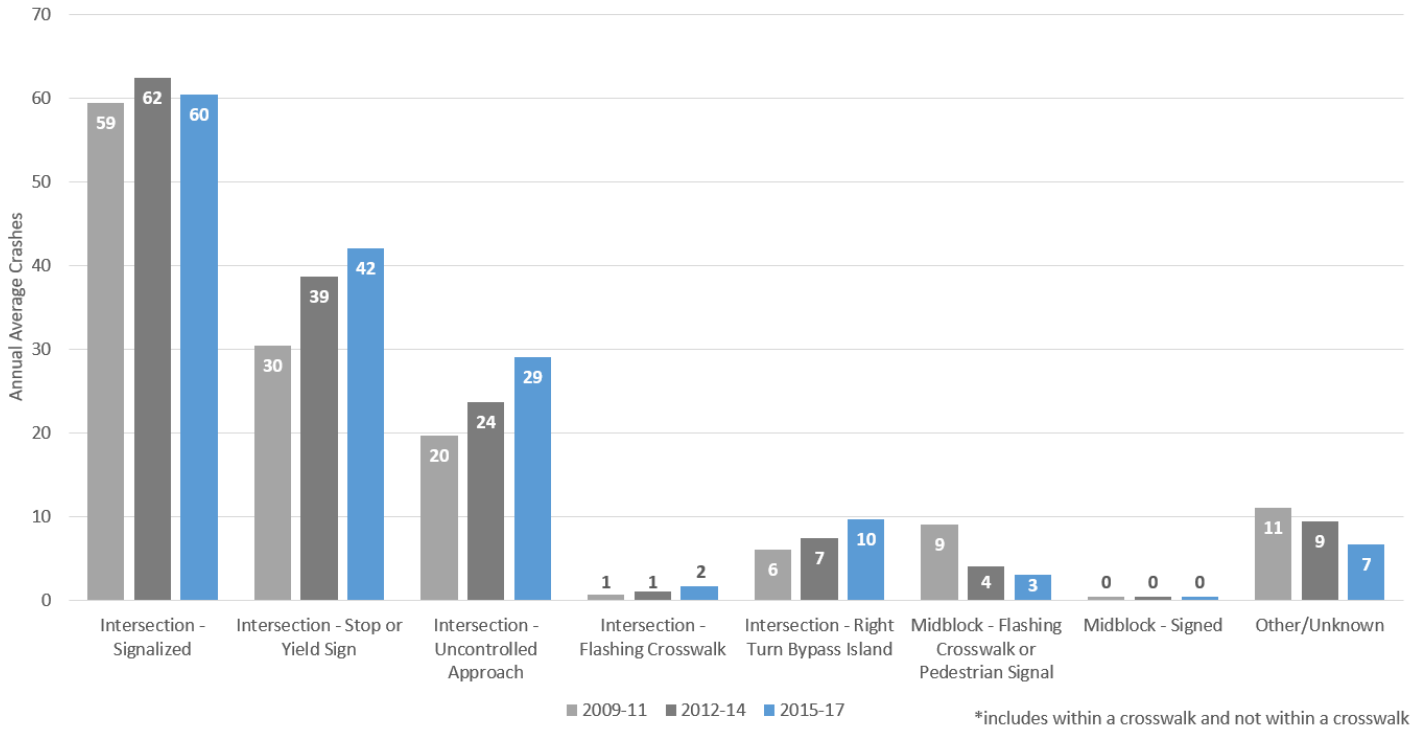
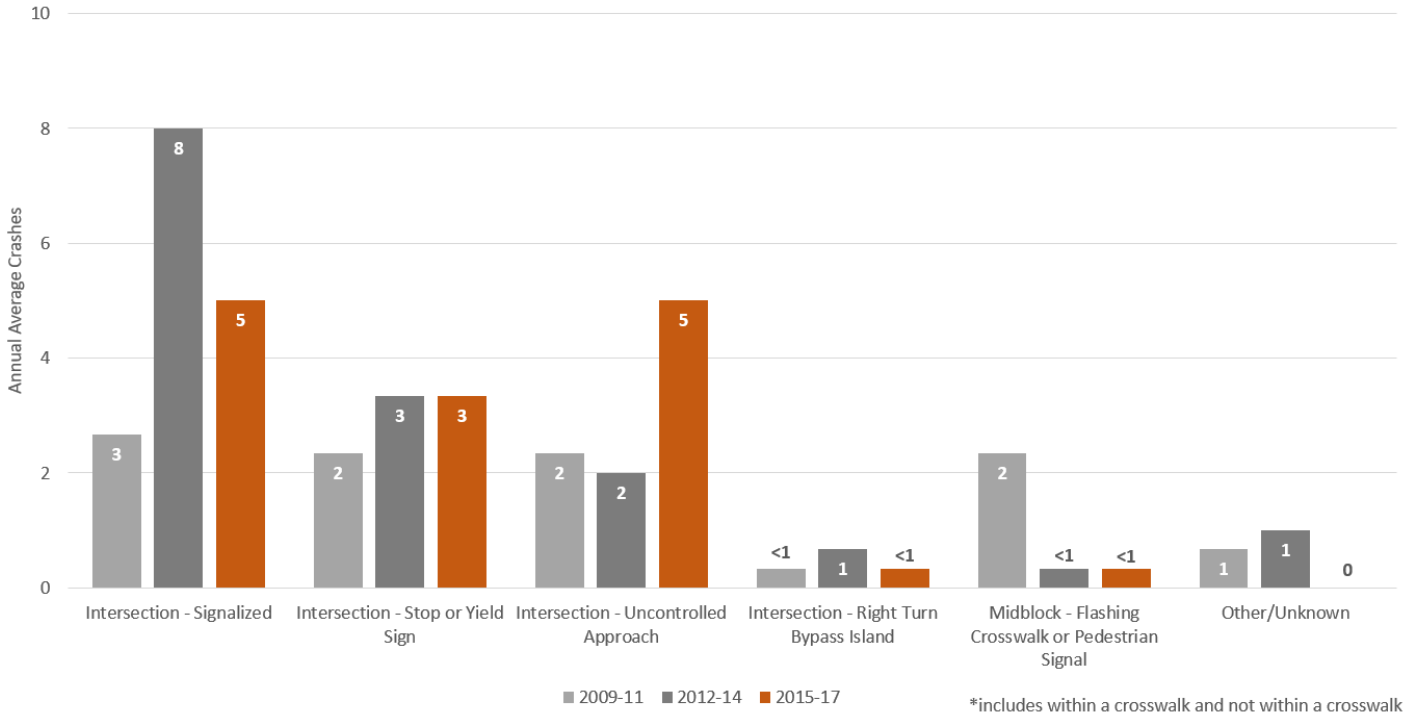


Figure 35 shows that between 2015 and 2017, 36% of all severe bicycle crashes occurred at signalized intersections, 24% at signed intersections and 36% at uncontrolled intersection approaches.

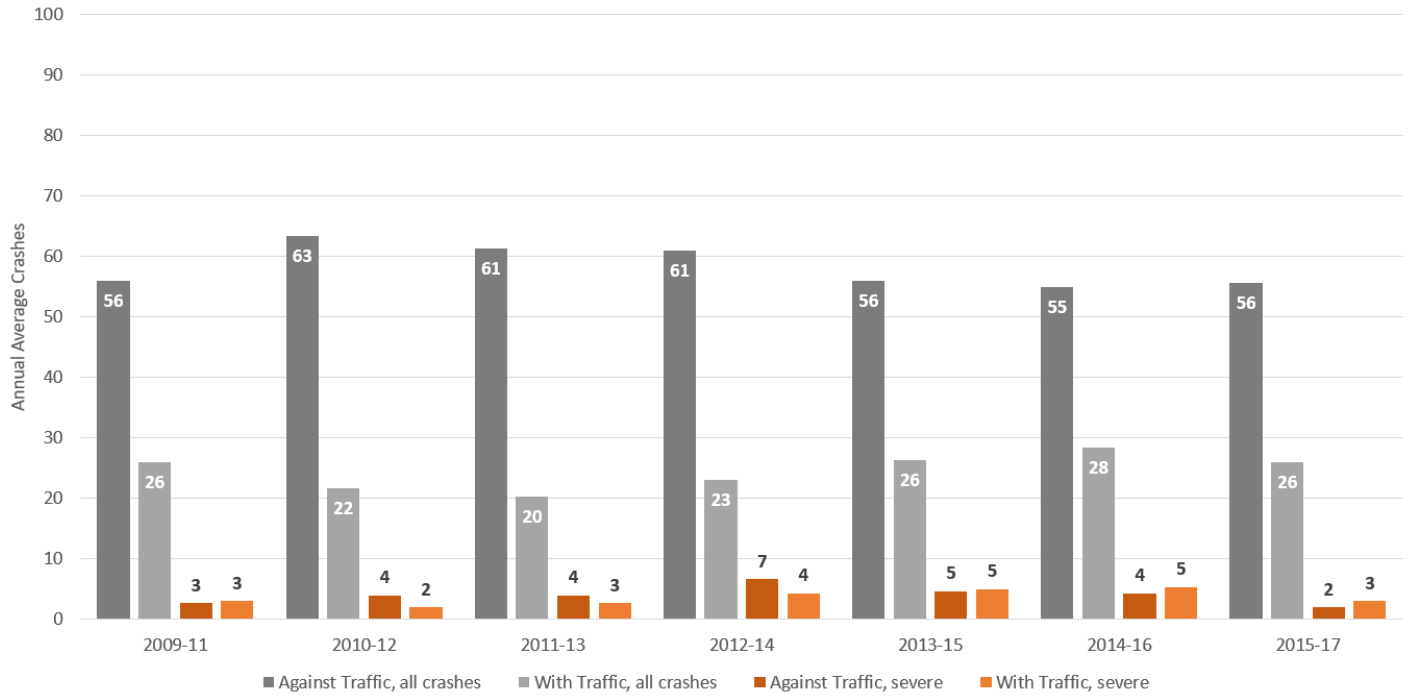
Figure 35: Severe Bicycle Crashes at an Intersection* by Type of Traffic Control (3-year annual average)



BICYCLIST DIRECTION IN TRAVEL CRASHES

On average, a bicyclist was riding against traffic in 70% of all crashes that occurred on an MUP or sidewalk. There is not a clear trend in the direction of bicyclist travel in severe crashes.

Figure 36: Bicyclist Direction of Travel Compared to Closest Travel Lane When Bicyclist Is Riding on a MUP or Sidewalk (3-year annual average)



BICYCLE CRASH TYPES

Motorists failing to yield for bicyclists at sign-controlled intersections, motorists turning right and hitting bicyclists traveling in the same direction, and motorists turning left and hitting bicyclists traveling in the opposite direction are the most common crash types (Figure 37). A motorist turning left or merging was the most common severe crash type between 2015 and 2017, accounting for 27% of severe bicycle crashes during that time frame (Figure 38).

Figure 37: Most Common Bicycle Crash Type (3-year annual average)

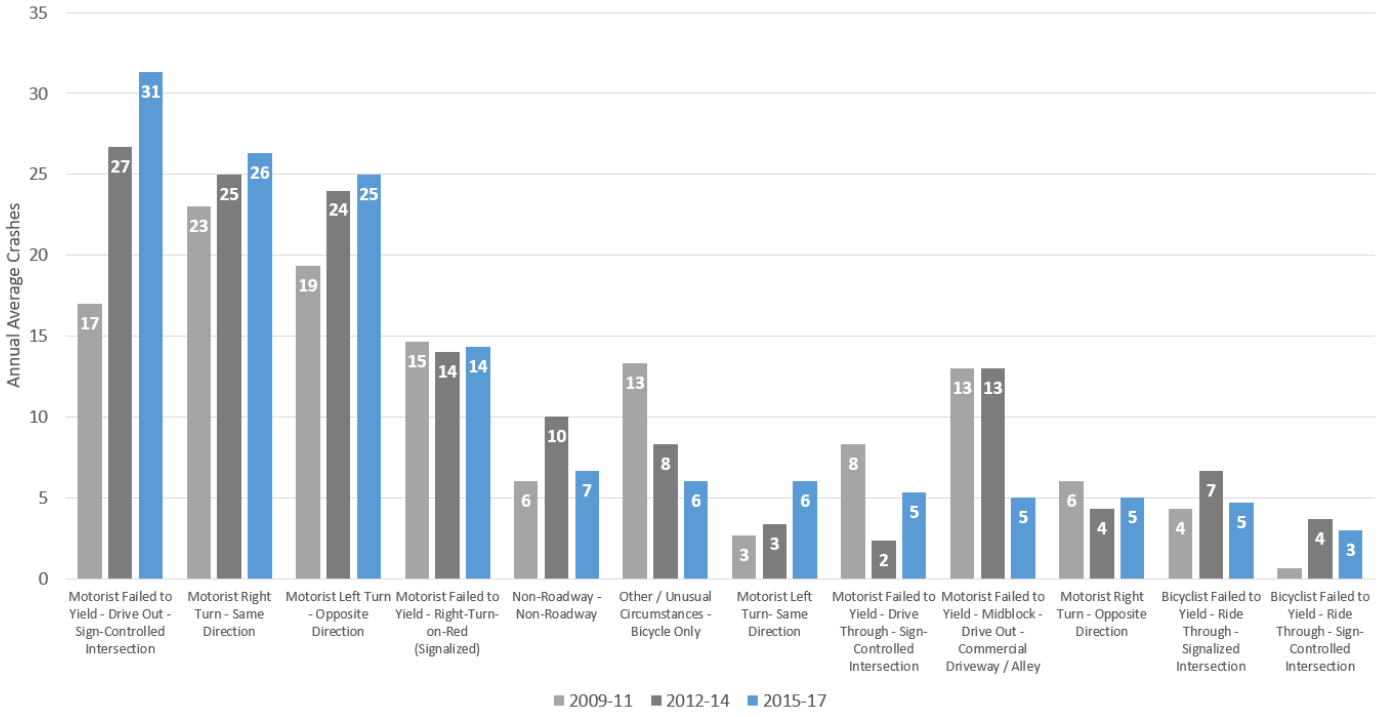


Figure 38: Most Common Severe Bicycle Crash Type (3-year annual average)

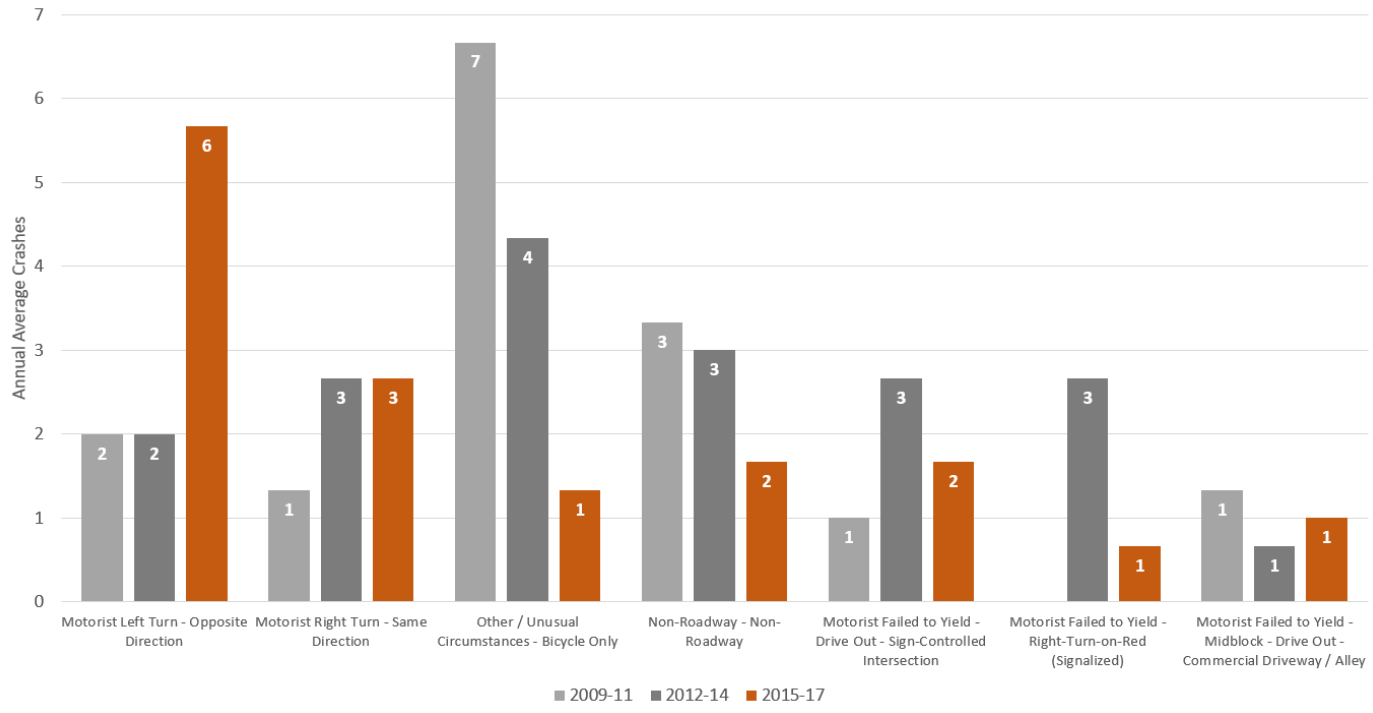
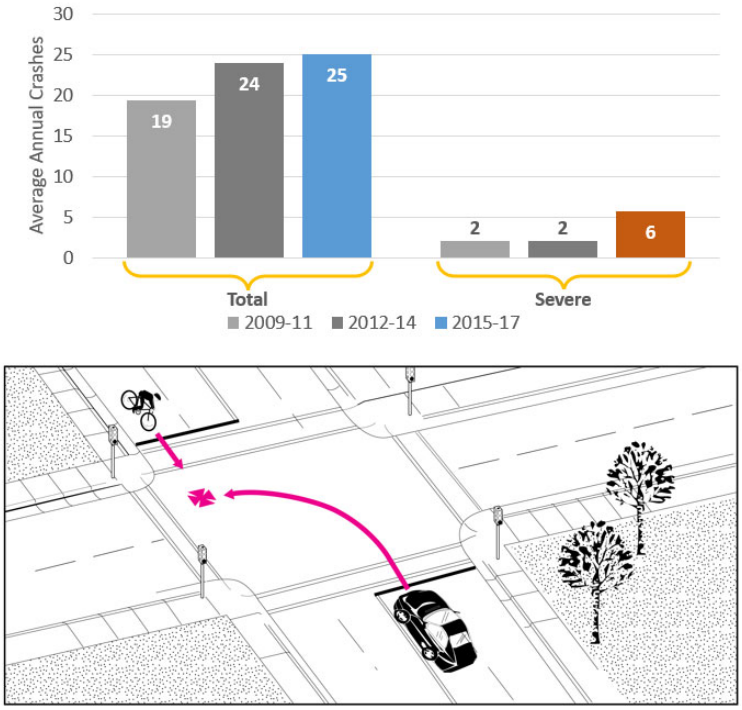


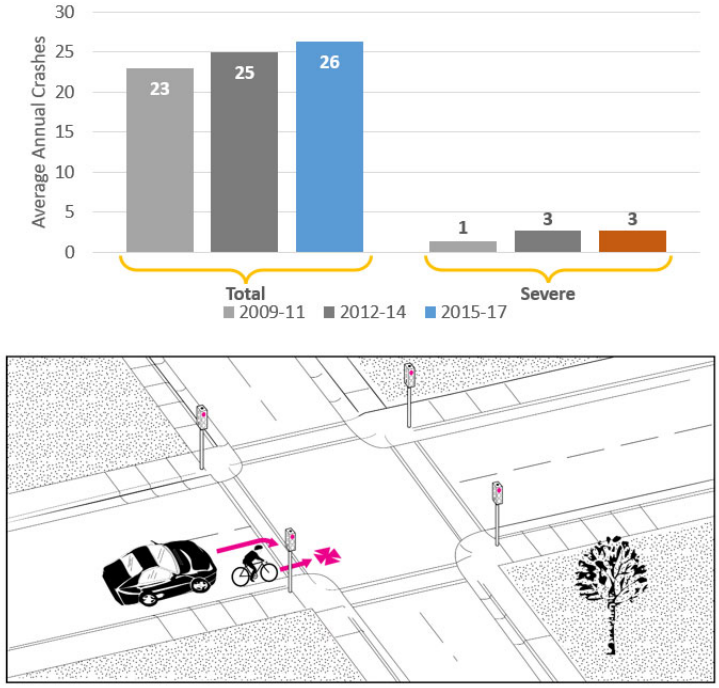
Figure 39 through Figure 44 show additional details on the most common bicycle crash types along with a diagram to explain how these types of crashes occur. Motorists turning left and hitting bicyclists traveling in the opposite direction accounted for 14% of all bicycle crashes and one out of four resulted in a severe injury.

Figure 39: Motorist Left Turn – Opposite Direction (3-year annual average)



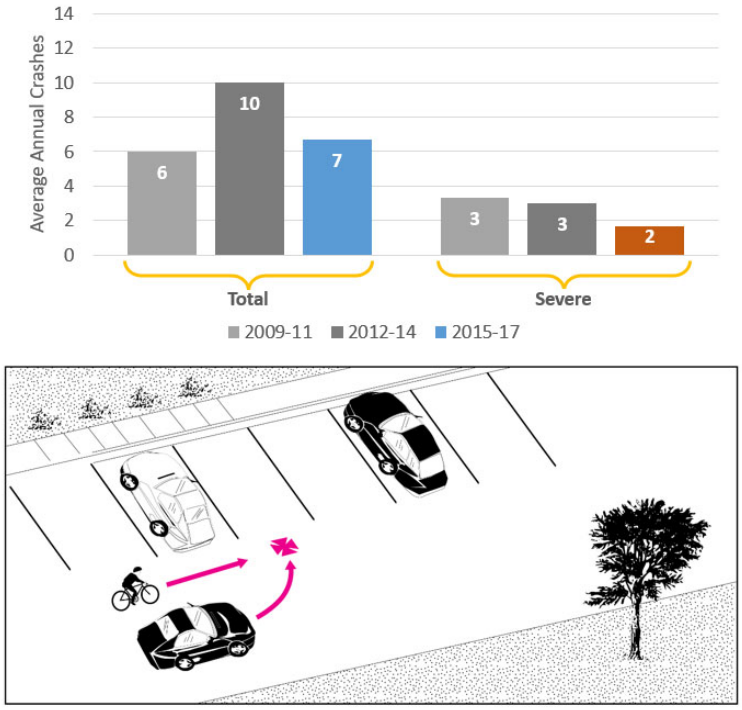
Motorists turning right and hitting a bicyclist traveling in the same direction accounted for 14% of all bicycle crashes, and, of those, one out of 10 resulted in a severe injury.

Figure 40: Motorist Right Turn – Same Direction (3-year annual average)



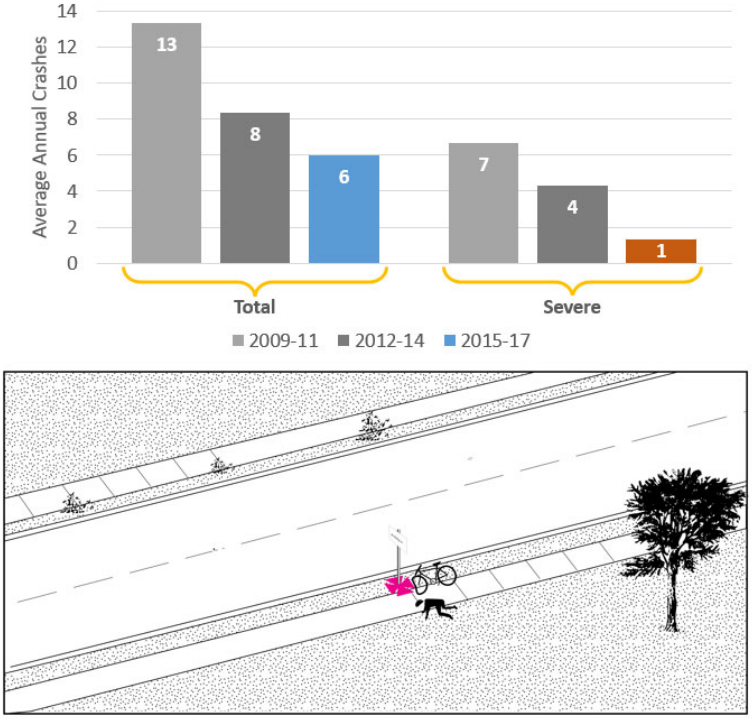
Non-roadway crashes accounted for 4% of all bicycle crashes, and, of those, one out of four resulted in a severe injury.

Figure 41: Non-Roadway (3-year annual average)



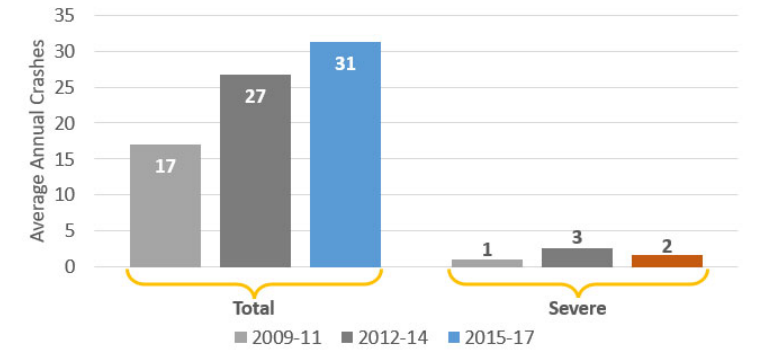
Bicycle-only crashes with unusual circumstances accounted for 3% of all bicycle crashes, and one out of every four-and-a-half crashes resulted in a severe injury.

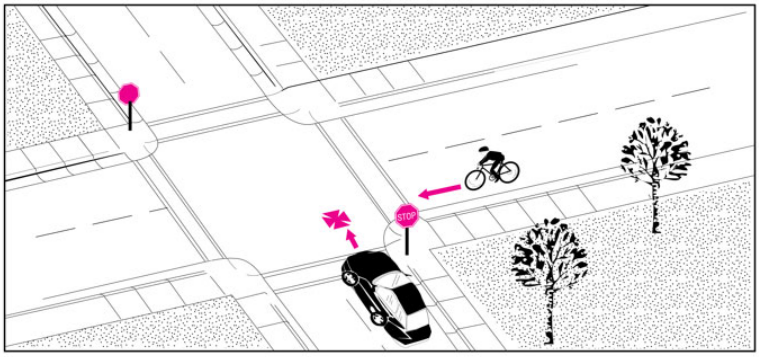
Figure 42: Other / Unusual Circumstances – Bicycle-Only (3-year annual average)



Crashes at signed intersections where drivers failed to yield to bicyclists accounted for 17% of overall bike crashes and have been increasing since 2009.

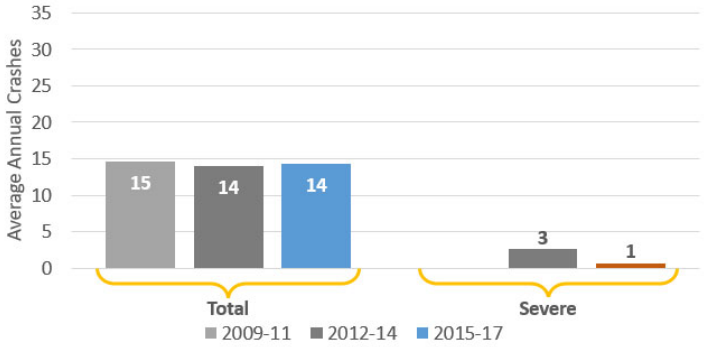
Figure 43: Motorist Failed to Yield – Drive Out – Sign-Controlled Intersection (3-year annual average)

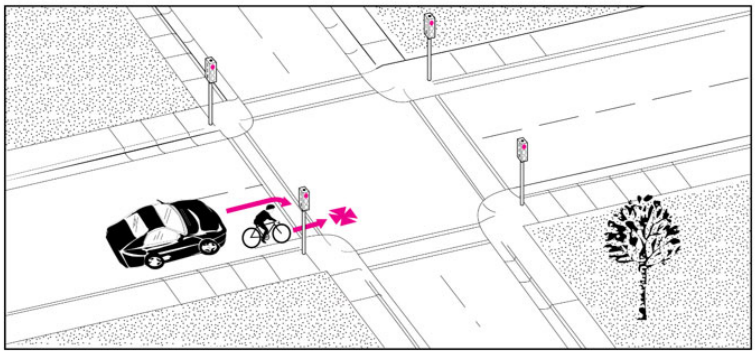




Crashes at signalized intersections where a driver failed to yield while turning right accounted for 8% of overall crashes and have remained constant since 2009.

Figure 44: Motorist Failed to Yield - Right-Turn-on-Red (Signalized) (3-year annual average)





People Traveling Under the Influence of Alcohol or Drugs

From 2009 to 2013, the annual number of impaired crashes, or crashes involving a person suspected of or charged with driving under the influence of alcohol or drugs (DUI), was steady (Figure 45). Figure 46 shows impaired crashes as a 3-year rolling annual average. From 2014 to 2017, the total number of annual crashes involving impairment has increased at approximately 11 crashes per year, or 10%. Overall, impaired crashes accounted for 4% of total and 13% of severe crashes between 2015 and 2017.

Figure 45: Impaired Crashes by Year (2009-2017)

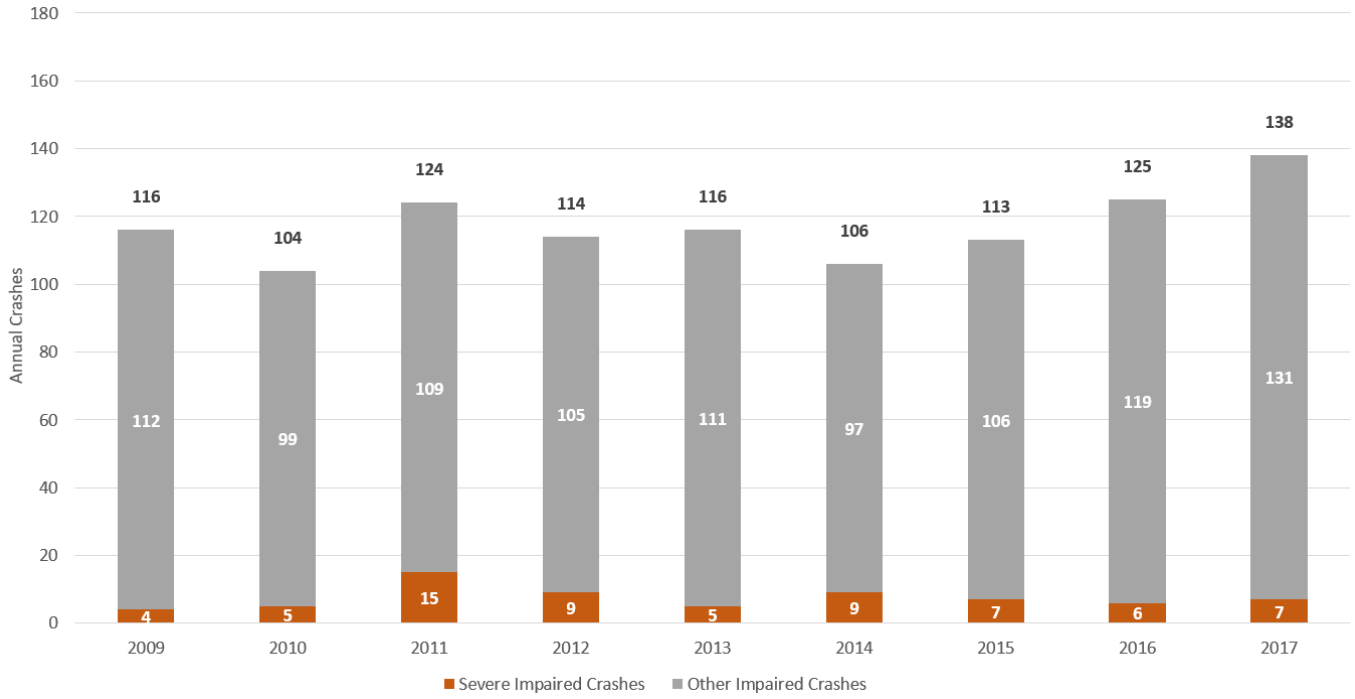
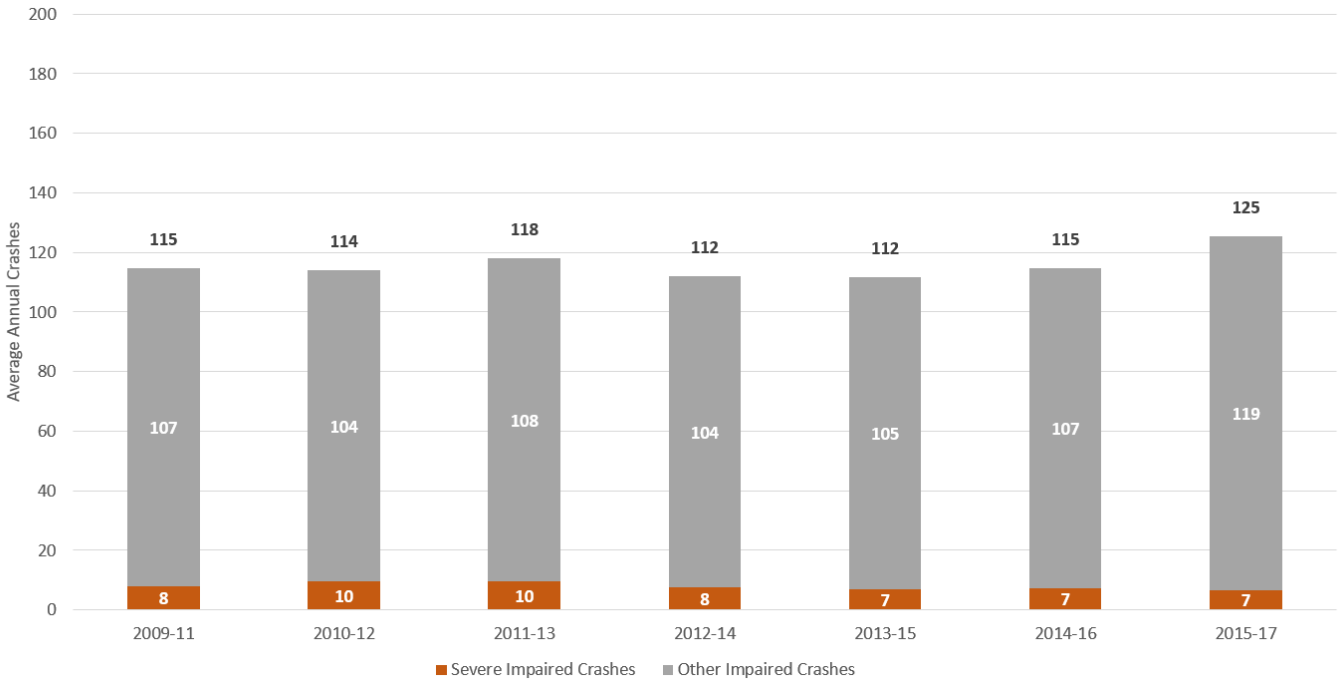


Figure 46: Impaired Crashes (3-year annual average)



DUI AND SUSPECTED DUI CRASHES

Figure 47 and Figure 48 show the number of crashes involving a person charged with and suspected of a DUI. On average between 2015 and 2017, there were 76 crashes annually involving a person charged with a DUI and 49 involving a person suspected of a DUI. While there were less suspected DUI crashes overall (40% of impaired crashes), they accounted for a greater number of the severe impaired crashes (65% of severe impaired crashes).

Figure 47: DUI Crashes by Year (2009-2017)

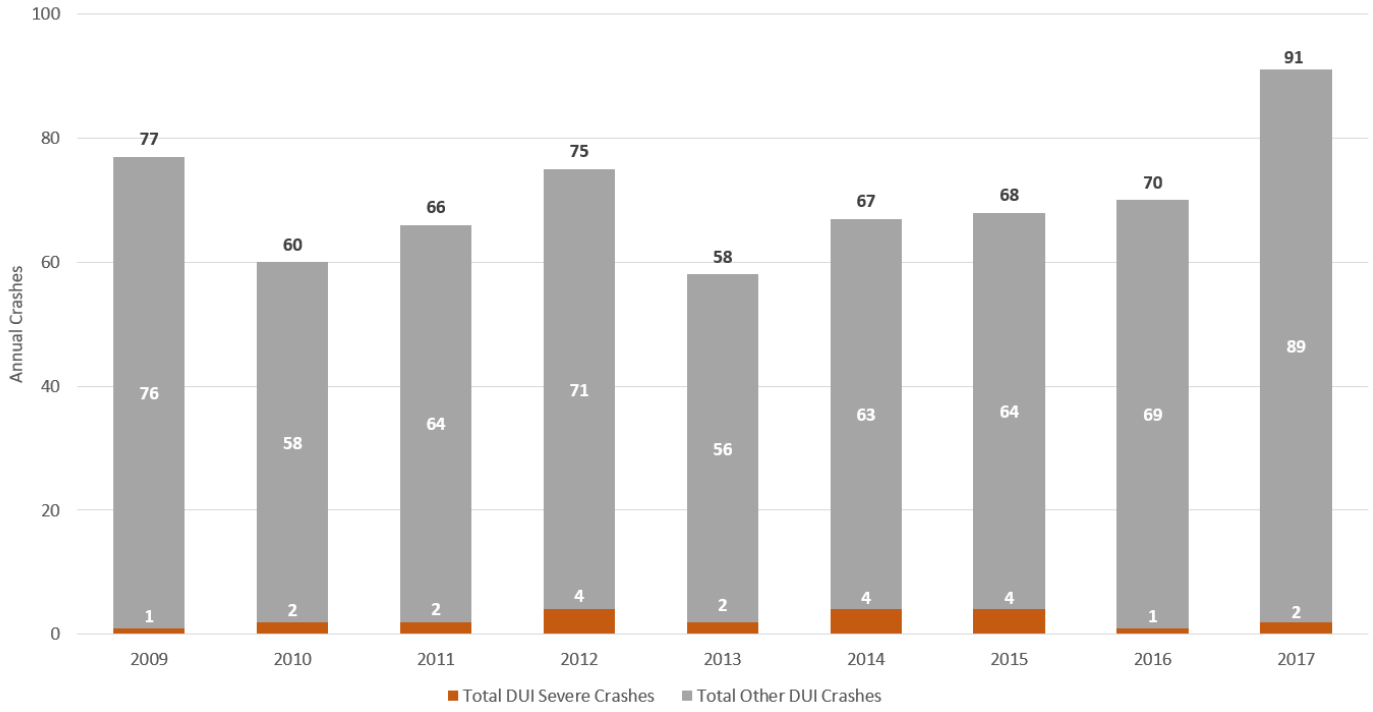
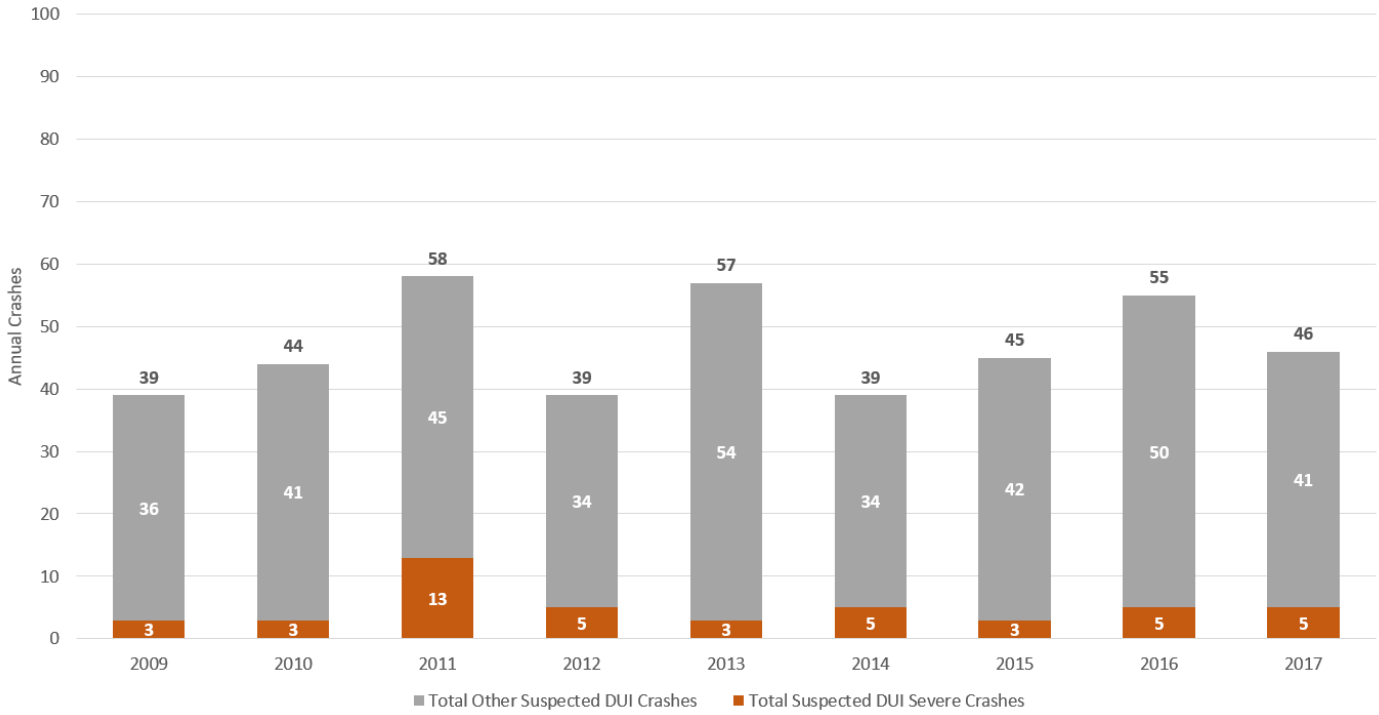


Figure 48: Suspected DUI Crashes by Year (2009-2017)



TYPE OF IMPAIRMENT

Between 2015 and 2017, 87% of impaired crashes involved alcohol impairment (Figure 49), and 70% of severe crashes involved alcohol impairment (Figure 50). Since 2015, the number of impaired crashes involving alcohol and drugs has increased.

Figure 49: Impaired Crashes by Type of Impairment (2009-2017)

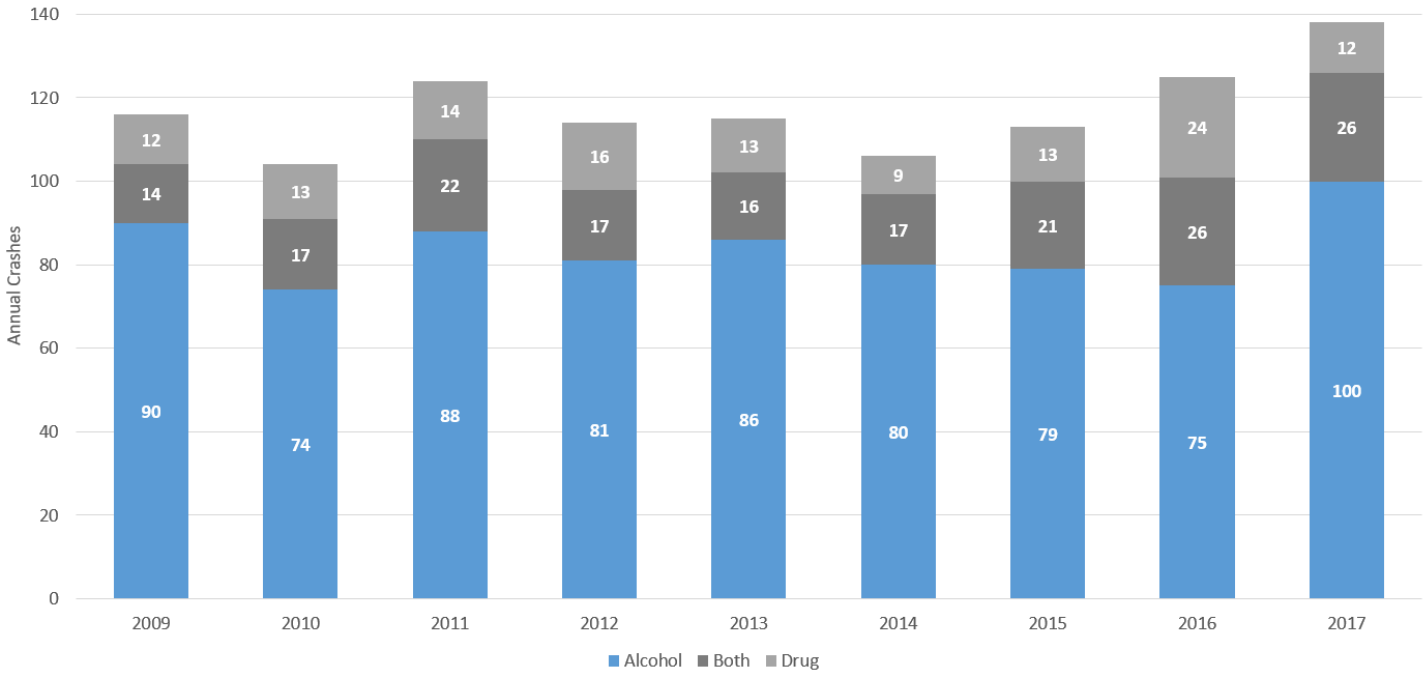
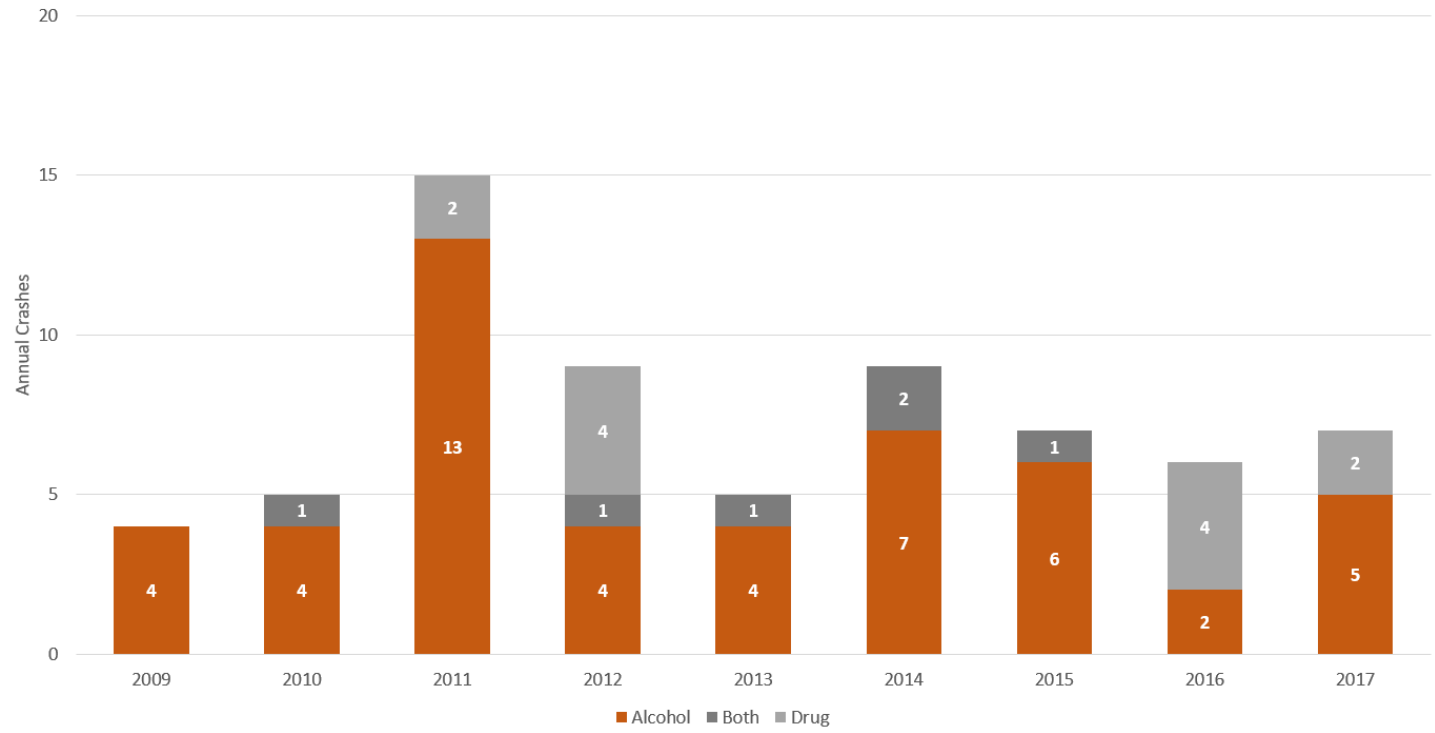


Figure 50: Severe Impaired Crashes by Type of Impairment (2009-2017)



IMPAIRED CRASH TYPES

Fixed-object, rear-end, and parked-vehicle are the most common crash types among all impaired crashes (Figure 51). The most common severe impaired crashes types are fixed-object, pedestrian, and rear-end (Figure 52).

Figure 51: Impaired Crashes by Crash Type (3-year annual average)

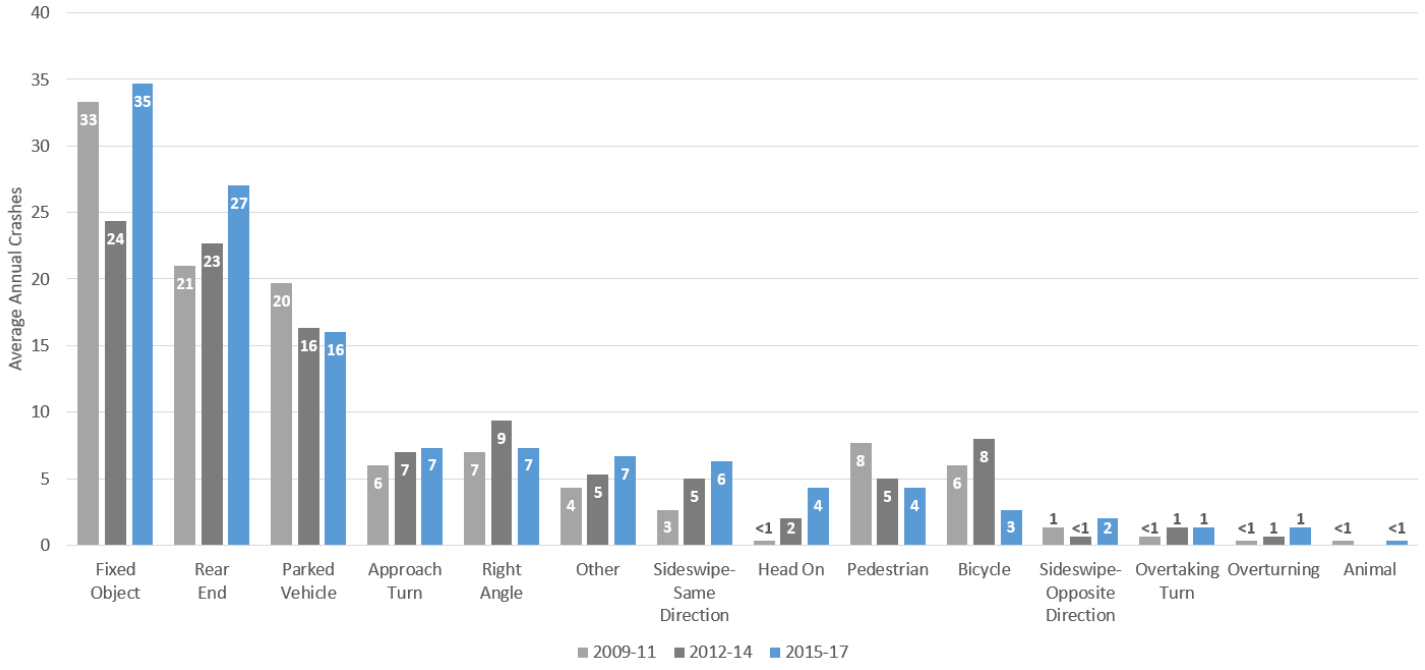
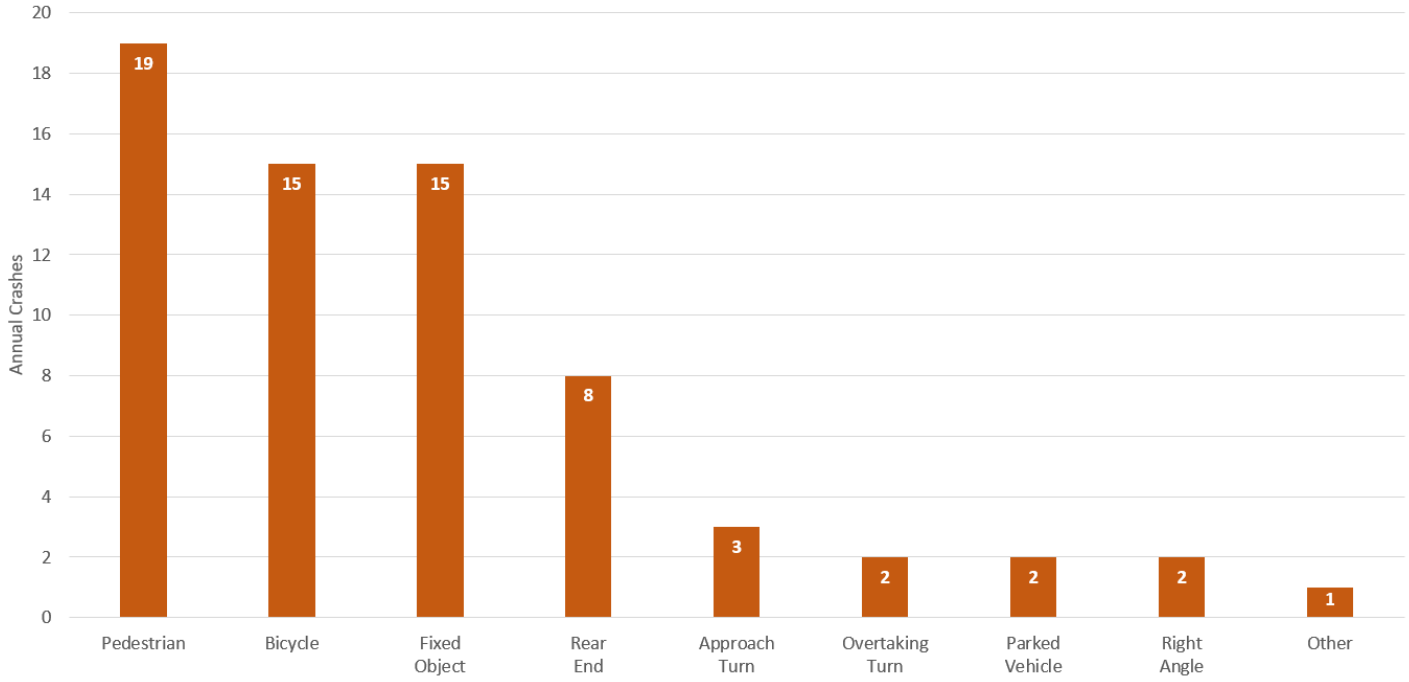


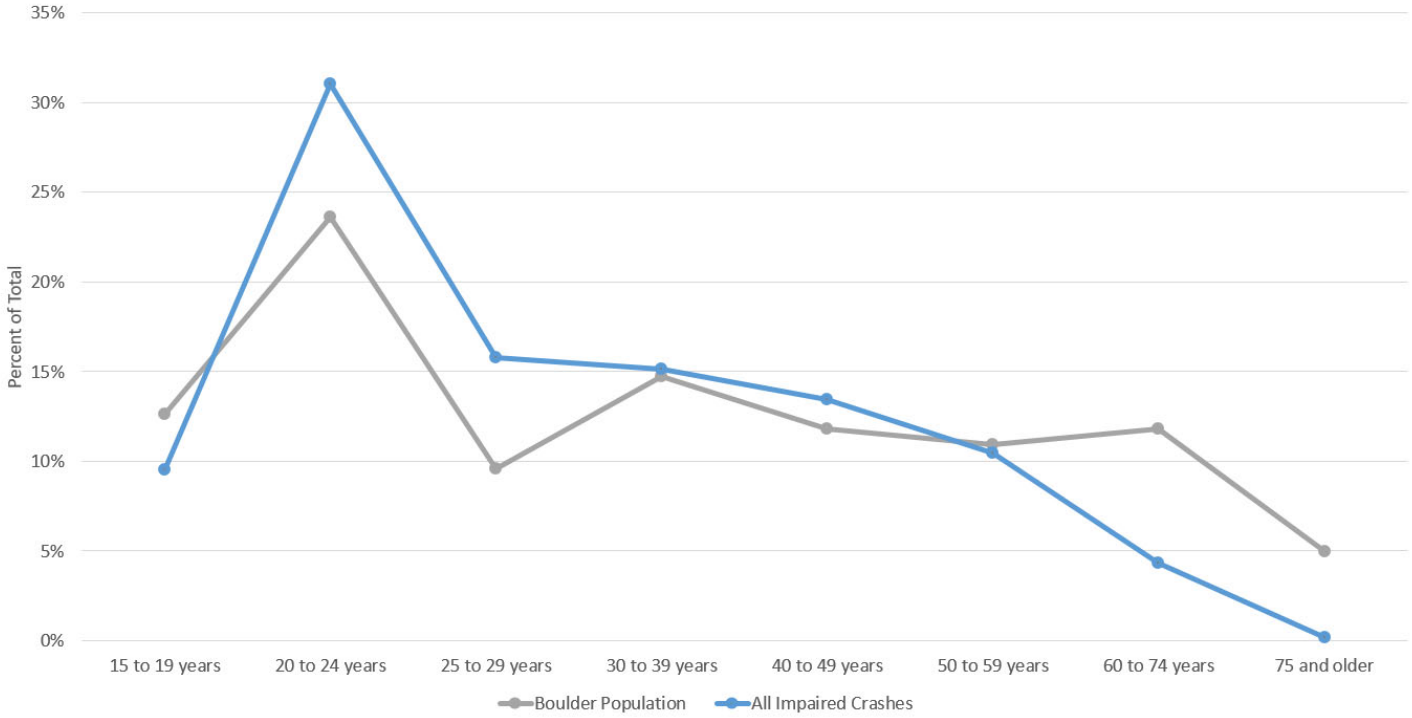
Figure 52: Severe Impaired Crashes by Crash Type (2009-2017)



IMPAIRED DRIVER AGE, GENDER AND TRAVEL MODE

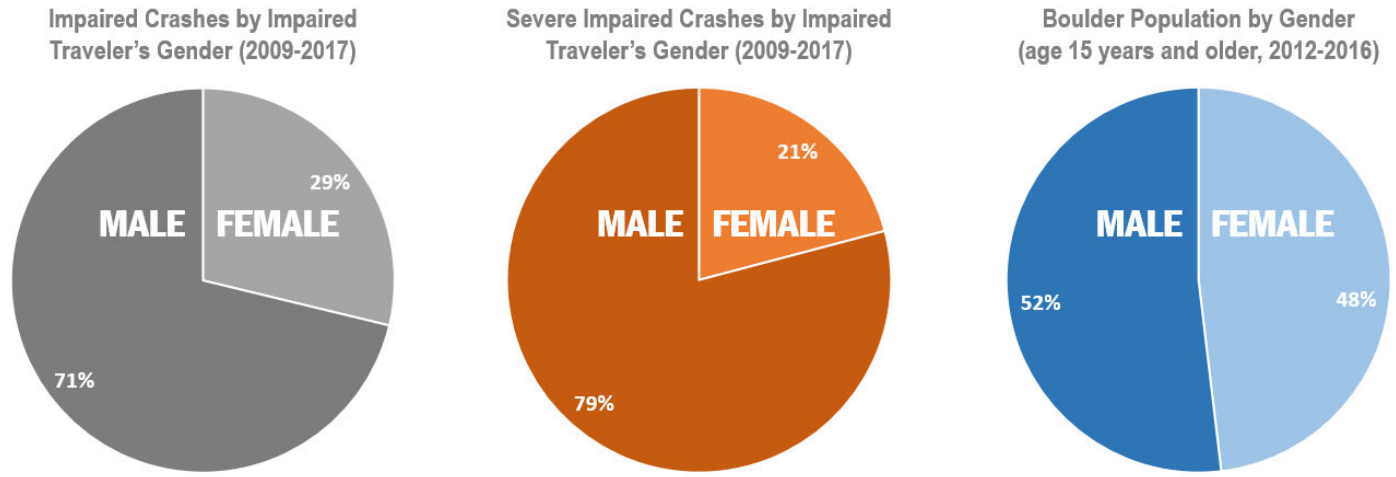
Over half of all impaired drivers are under the age of 30. Impaired drivers between 15 and 49 years old are overrepresented in severe crashes, with this most pronounced between ages 20 and 29 (Figure 53).

Figure 53: Age Distribution of Impaired Drivers by Year (2009-2017)



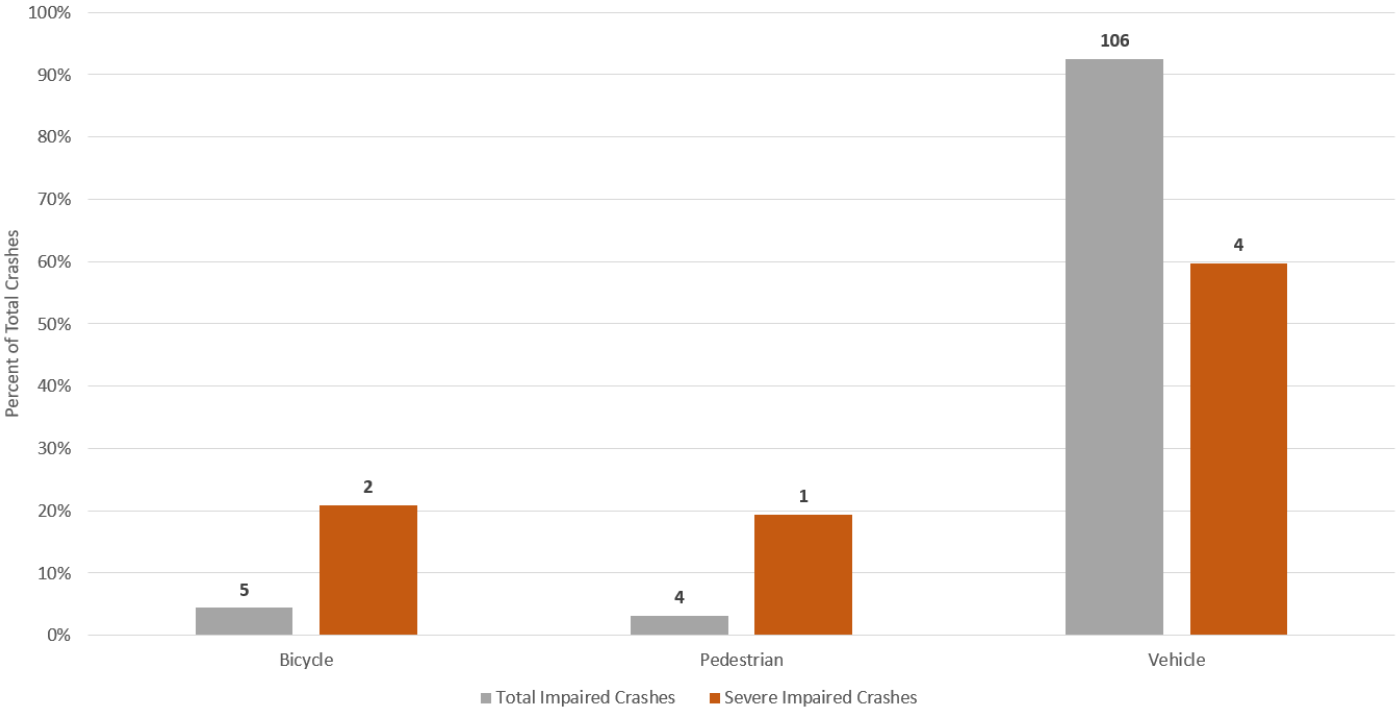
Between 2009 and 2017, 71% percent of impaired drivers involved in crashes were male, and 79% of impaired drivers involved in severe impaired crashes were male (Figure 54).

Figure 54: Impaired Crashes by Impaired Traveler's Gender



Impaired bicyclists and pedestrians were a small share of the total impaired travelers (4% and 3%); however, 21% of severe impaired crashes involved an impaired bicyclist, and 19% involved an impaired pedestrian (Figure 55).

Figure 55: Travel Mode of Person Impaired (annual average 2009-2017)



People Speeding

Speeding crashes were identified by selecting all crashes where an officer noted:

1. The estimated speed of a traveler was greater than the speed limit (majority of speeding crashes).
2. Traveler "exceeded safe/posted speed" only in good weather (smaller subset of the speeding crashes).

Speeding crashes have increased since 2014. There was an average of 186 speeding crashes and 10 severe speeding crashes annually between 2015 and 2017. During this period, speeding crashes accounted for 6% of total and 19% of severe crashes.

Figure 56: Speeding Crashes by Injury Severity (2009-2017)

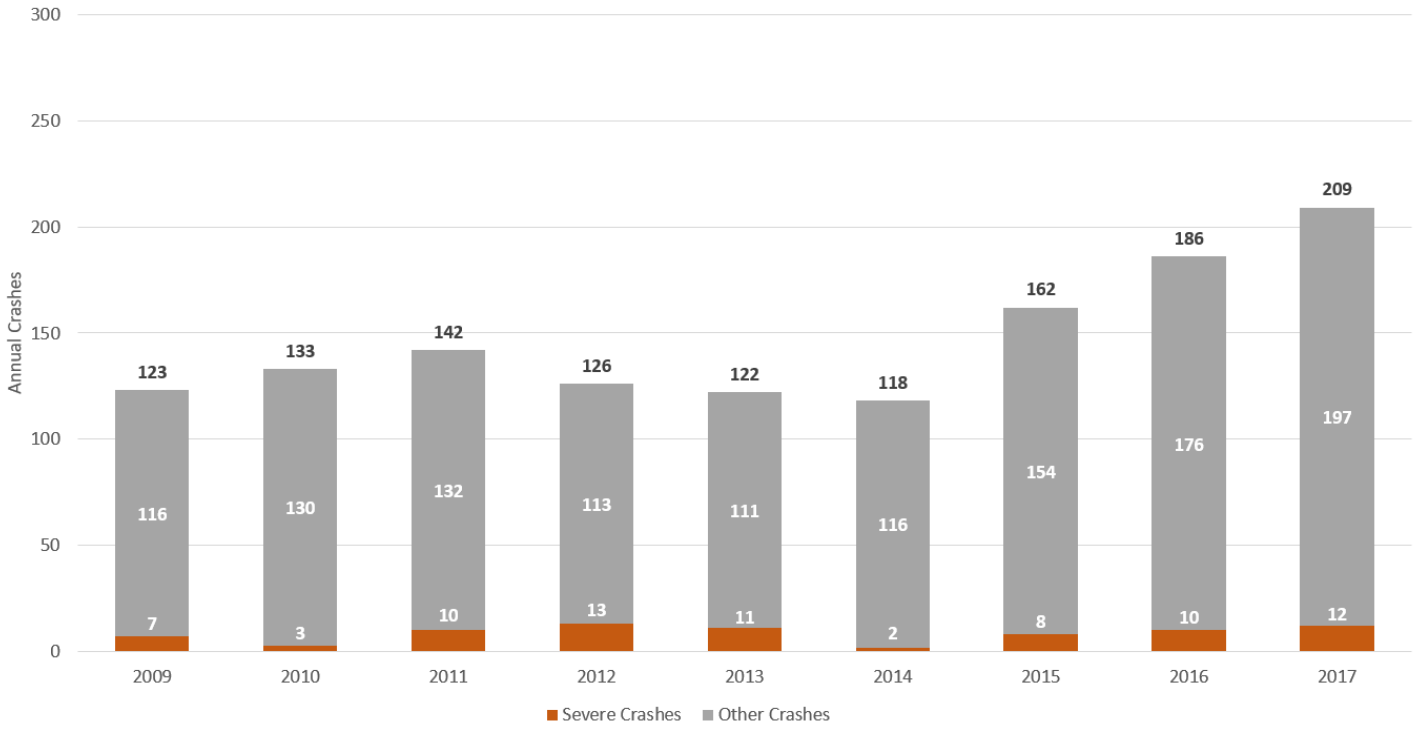
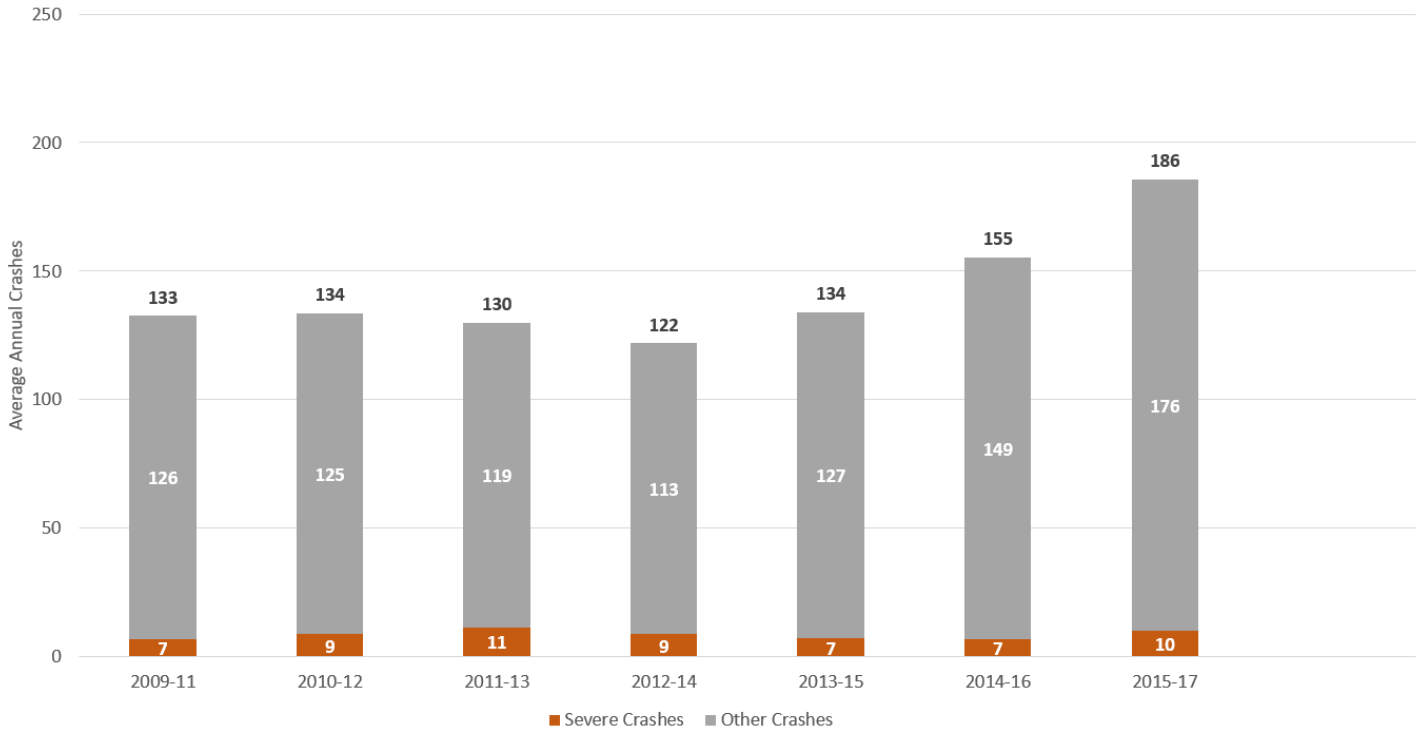


Figure 57: Speeding Crashes by Injury Severity (3-year annual average)



Rear-end, fixed-object and bicycle (when the bicyclist is speeding) are the most common speeding crash types. There were 48 speeding crashes involving a bicyclist speeding in 2017, four of which resulted in severe injuries (Figure 58).

Figure 58: Speeding-related Crashes by Crash Type (3-year annual average)

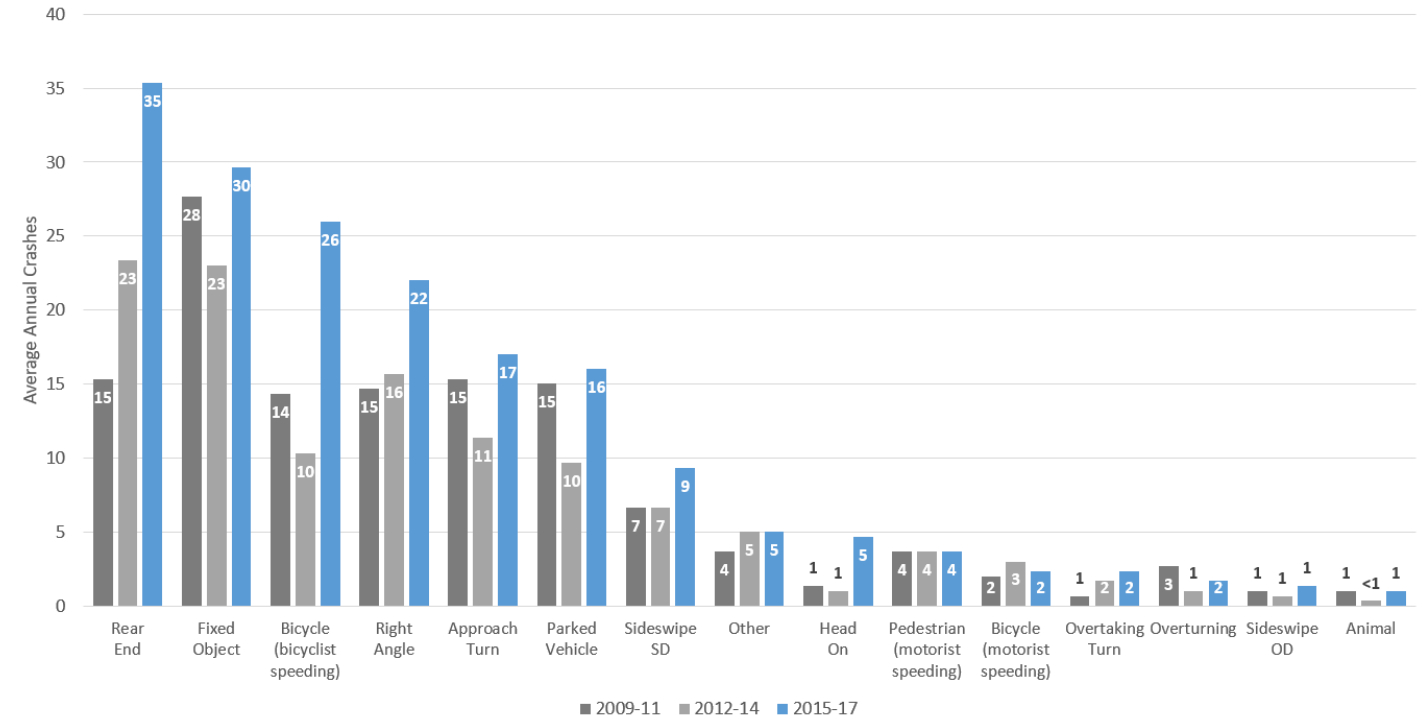
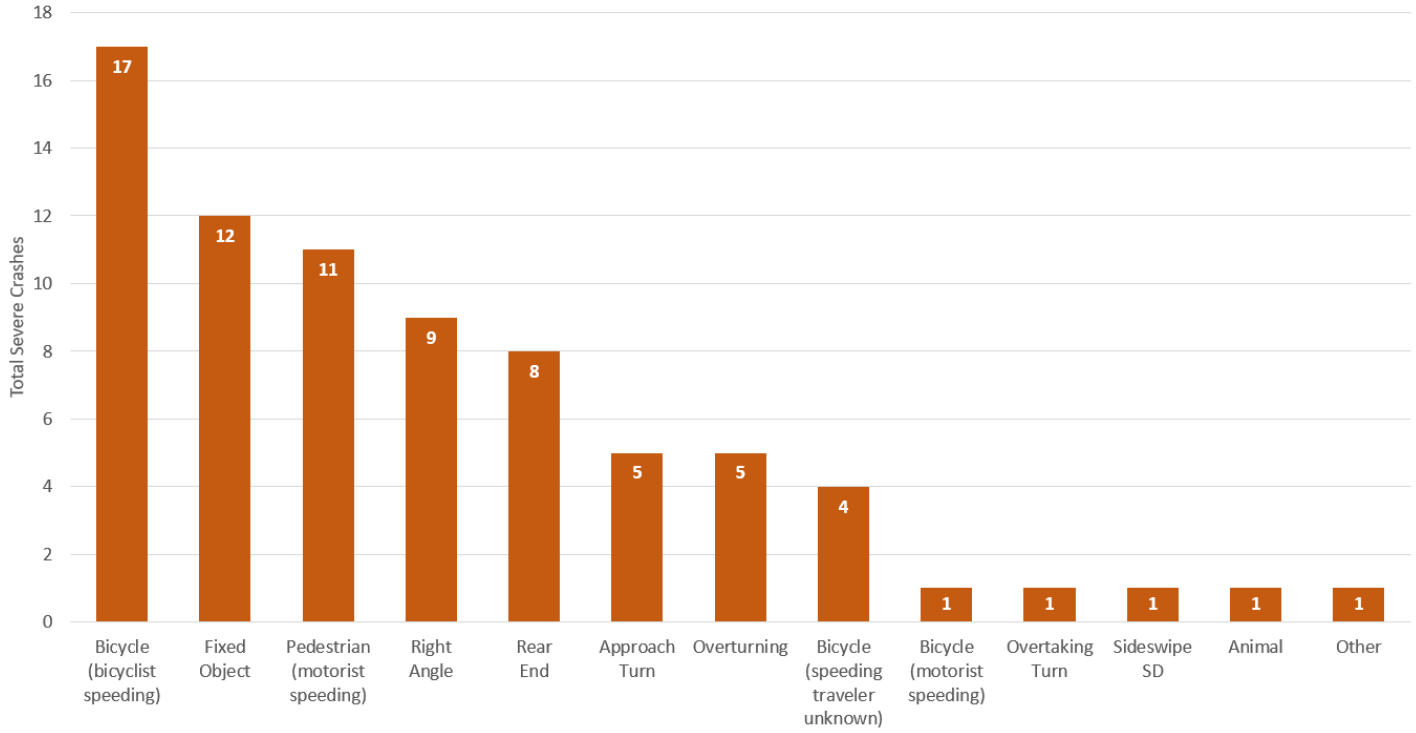


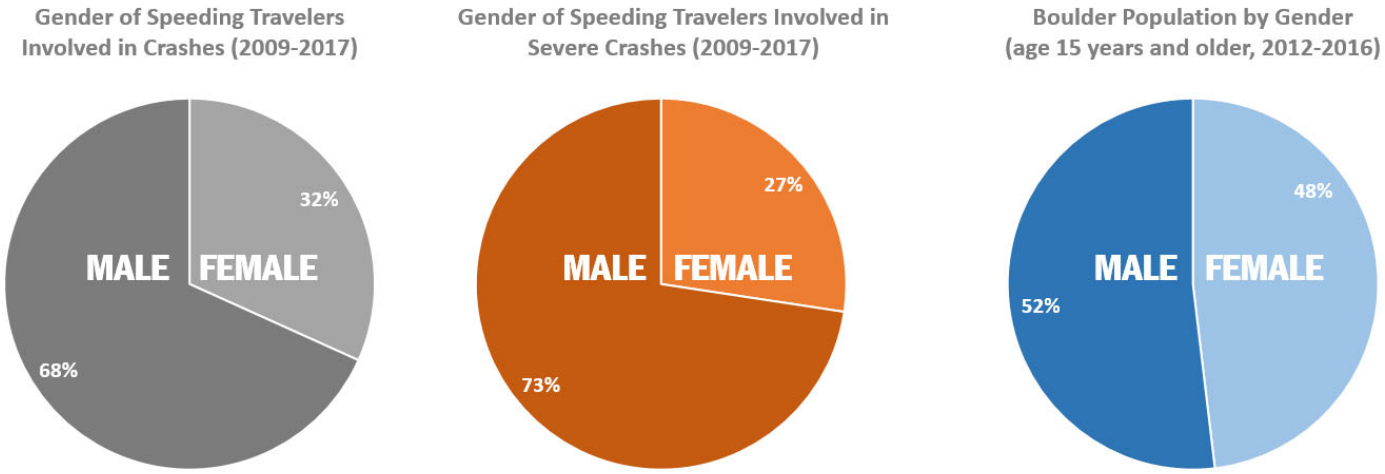
Figure 59 shows the total severe crashes by type between 2009 and 2017. Bicycle crashes where the bicyclist was speeding was the most common speeding severe crash type.

Figure 59: Severe Speeding Crashes by Crash Type (2009-2017)



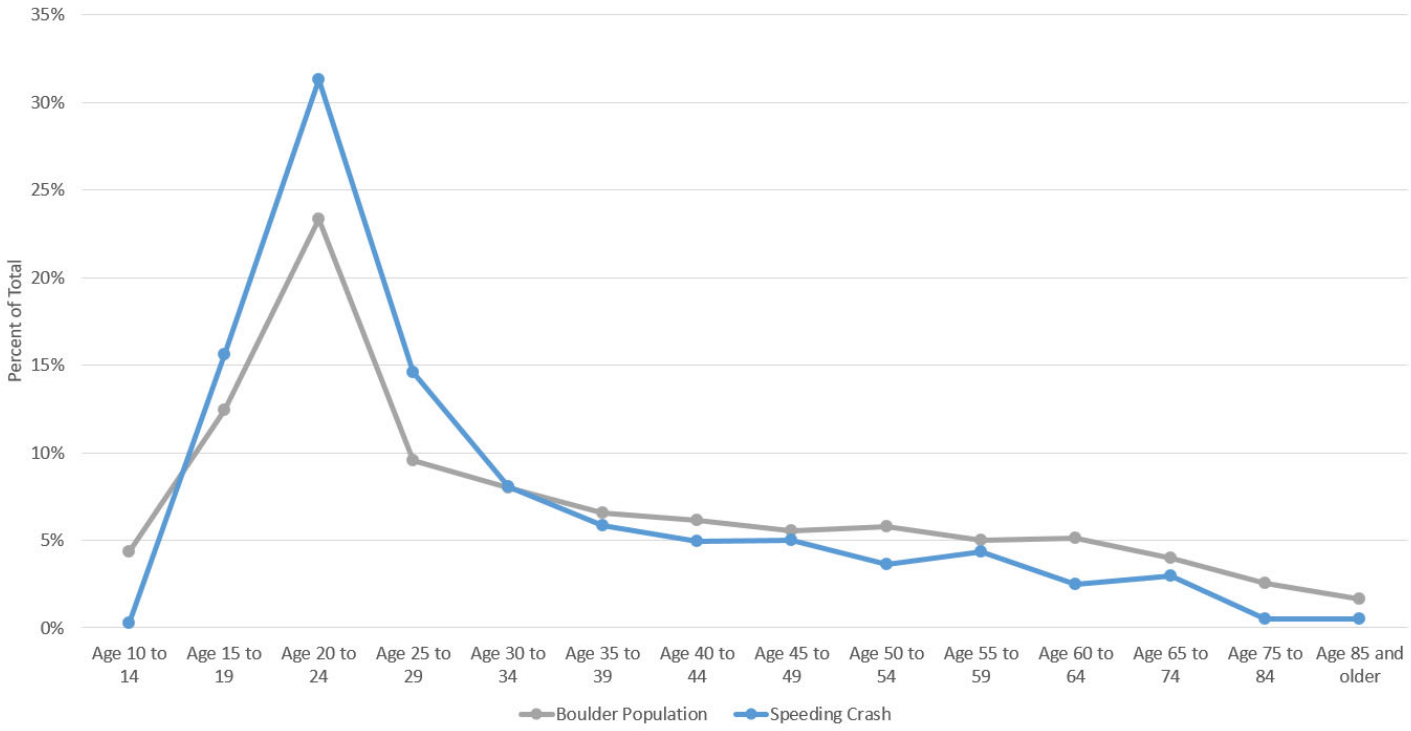
Approximately 68% of speeding travelers involved in a speeding crash are male, and 73% of speeding travelers involved in speeding severe crashes are male.

Figure 60: Gender of Speeding Travelers



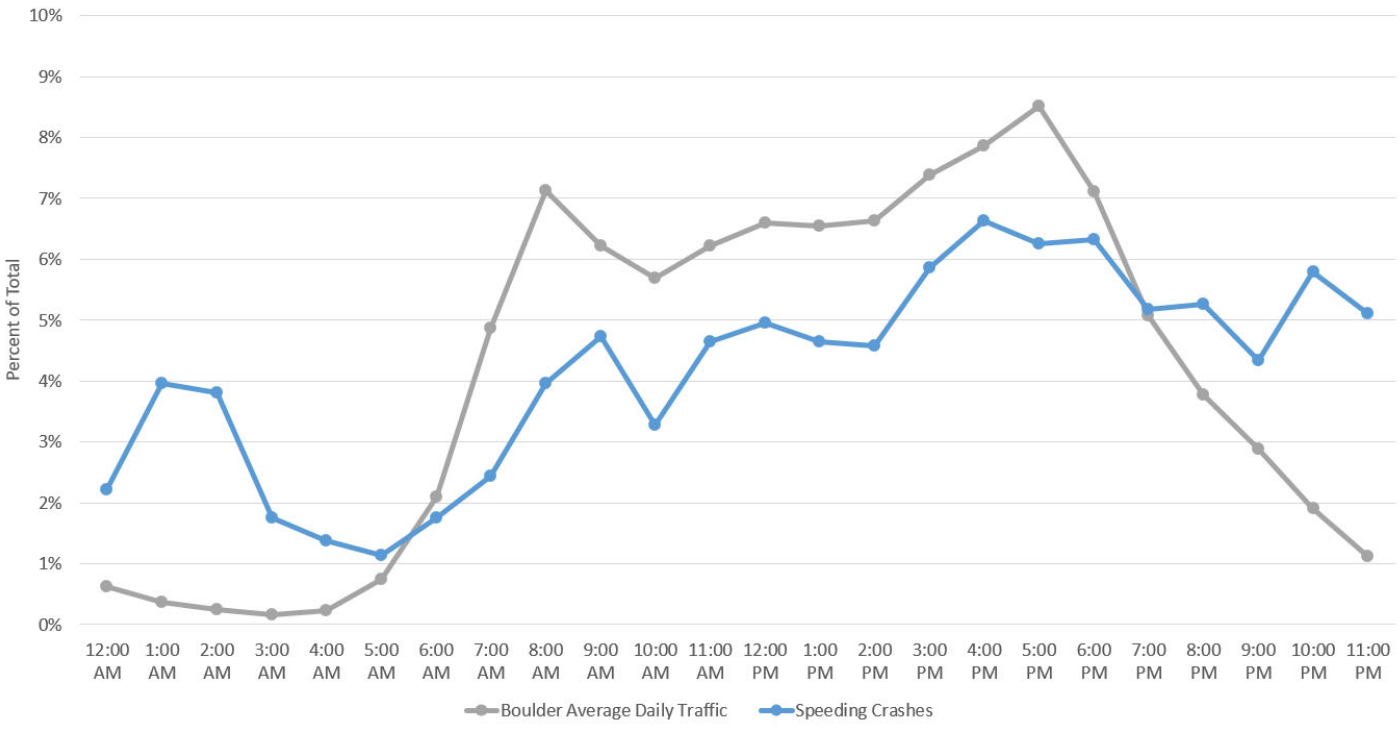
Speeding travelers between 20 and 29 years old are overrepresented in speeding crashes (Figure 61).

Figure 61: Speeding Crashes and Age of Speeding Traveler (2009-2017)



Speeding crashes are most frequent between 3 and 6 p.m. and 10 and 11 p.m. When compared to average daily traffic, they are overrepresented between 8 p.m. and 5 a.m., particularly between 1 and 3 a.m.

Figure 62: Speeding Crashes by Time of Day (2009-2017)



HOW DOES SPEED INFLUENCE THE SEVERITY OF CRASHES?

In addition to the analysis of the crash reports, an evaluation of all severe crashes (those in which a person was seriously injured or killed) that occurred between January 2015 and December 2017 (three years) was completed. The effect of speed on severe crashes during this period was evaluated and then categorized by crashes that occur on local, residential collector and arterial roadways. If the crash may have been prevented with the elimination of the speeding behavior, speeding is considered a casual factor in the crash. If the speeding behavior likely increased the severity of the injury or injuries sustained, speeding is considered a significant factor in the severity of the crash.

Local Roadways (generally 25 mph speed limits)

Of the 21 severe crashes that occurred on local roadways, only one crash involved speeding as a causal factor. In this crash, the driver was also noted as impaired and distracted. This was also the only crash on a local roadway in which the speed of a motor vehicle was a significant factor in the crash. However, the speed of a bicycle was a significant factor in the case of six of the severe crashes that occurred on local roadways.

Residential Collector Roadways (generally 25 to 30 mph speed limits)

Of the 17 severe crashes that occurred on residential collectors, three crashes involved speeding as a causal factor. Two were motor vehicle crashes that were DUI-related and the third involved a speeding bicyclist traveling downhill. The speed of a motor vehicle was a significant factor in two crashes, while the speed of a bicyclist was a significant factor in four crashes.

Arterial Roadways (generally 35 mph and higher speed limits)

Of the 115 severe crashes that occurred on arterial roadways, 14 involved speeding as a causal factor. Five of those crashes were DUI- or distracted-driving-related and three involved speeding on a motorcycle. One crash involved a speeding bicyclist traveling downhill. The speed of a motor vehicle was a significant factor in 47 of these severe crashes on arterial roadways, and the speed of a bicyclist was a significant factor in another six of these crashes (all riding downhill).

People Making Left Turns

Between January 2015 and December 2017, there were 980 crashes (11% of total) and 48 severe crashes (30% of total) involving a person making a left turn. Left turns were the most common type of severe crash in Boulder during this time period. A number of crashes involving a person walking or riding a bicycle are also crashes involving a left turn. The people walking and biking analysis sections contain more details about these types of crashes.

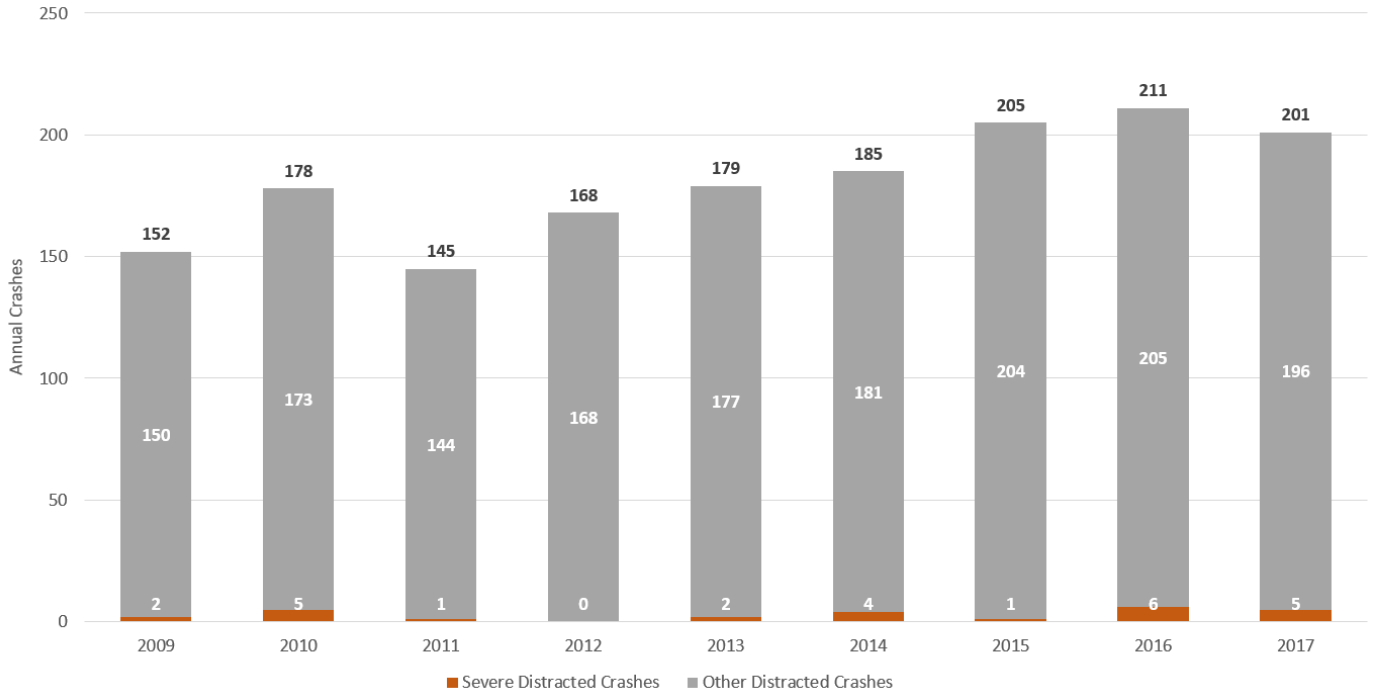
The following list includes details of severe crashes involving left turns:

- Permitted left turns made at signalized intersection were the most common type of severe crash. Thirty of the severe crashes (19% of total) involved vehicles making a permitted left turn at a signalized intersection.
- Another 15 of severe crashes (9% of total) occurred at unsignalized intersections, while the remaining three crashes were at signalized intersections with protected phasing where a vehicle ran a red light.
- Fourteen of the severe crashes (47%) that involved vehicles making a permitted left turn involved a crash with another motor vehicle. Nine (30%) involved a crash with a pedestrian and seven involved a crash with a bicyclist (23%).
- Of the 15 severe crashes that involved a left turn at an unsignalized intersection, 11 (73%) involved a crash with a bicyclist, three (20%) involved a crash with another motor vehicle and one (7%) involved a crash with a pedestrian.
- Fifty-nine (37%) of the severe crashes occurred at an intersection with a traffic signal, 37 (23%) occurred at an unsignalized intersection, and 61 (38%) of the severe crashes were not intersection-related (generally occurring midblock away from an intersection). The final three crashes were either at unsignalized right-turn bypass islands at intersections or the location was unknown.

People Distracted While Driving

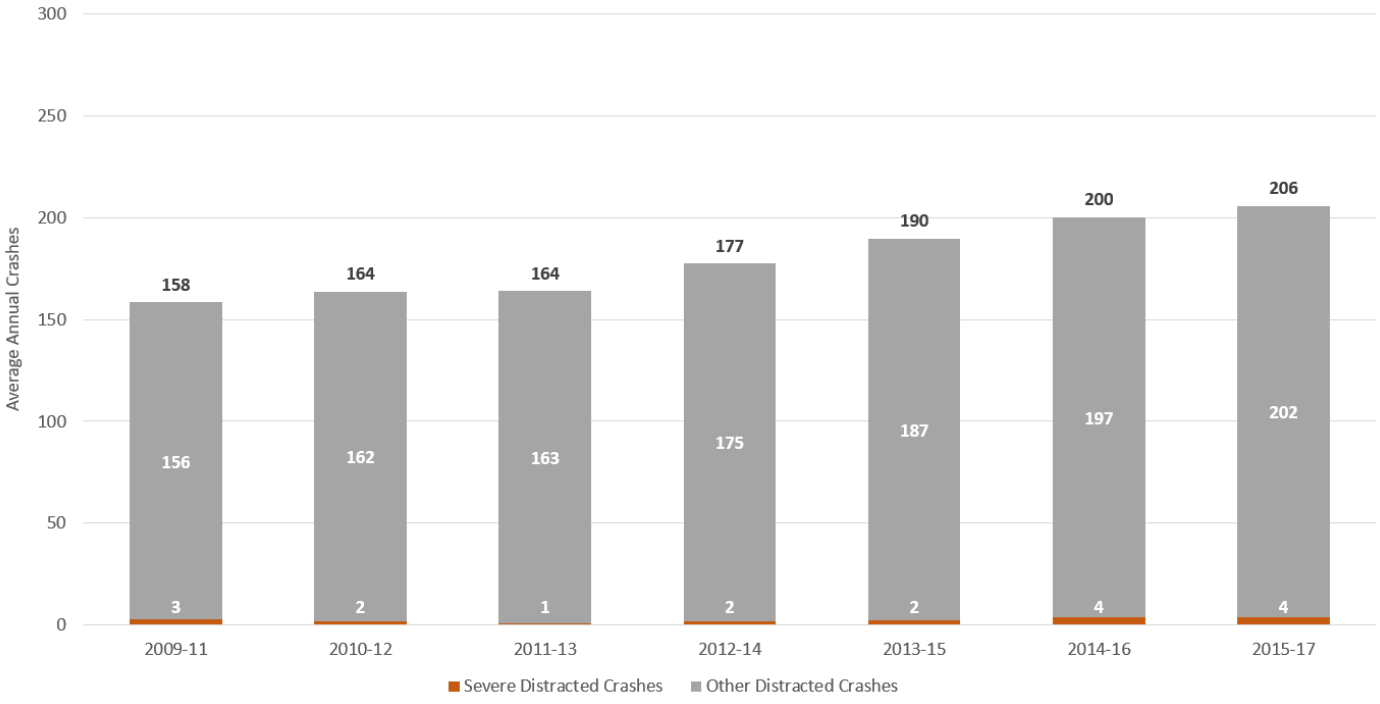
Between 2015 and 2017, about 200 distracted crashes occurred annually, and about five of those crashes resulted in a serious injury. Overall, distracted crashes accounted for 7% of all crashes and 8% of severe crashes (Figure 63).

Figure 63: Total and Severe Distracted Crashes by Year (2009-2017)



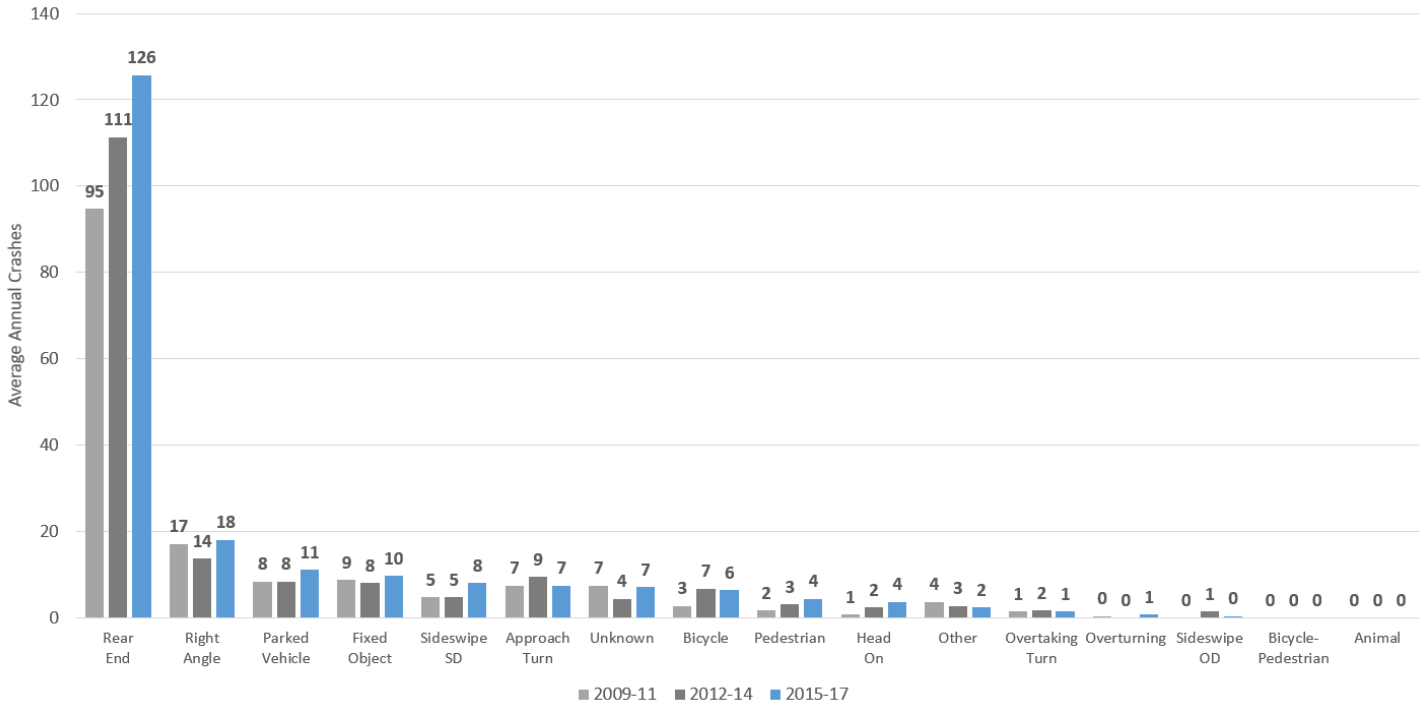
The number of distracted crashes has been increasing since 2009 (Figure 64). Police code the following as distractions: passenger, cell phone, radio, other (e.g., food, objects, pet, etc.).

Figure 64: Total and Severe Distracted Crashes (3-year annual average)



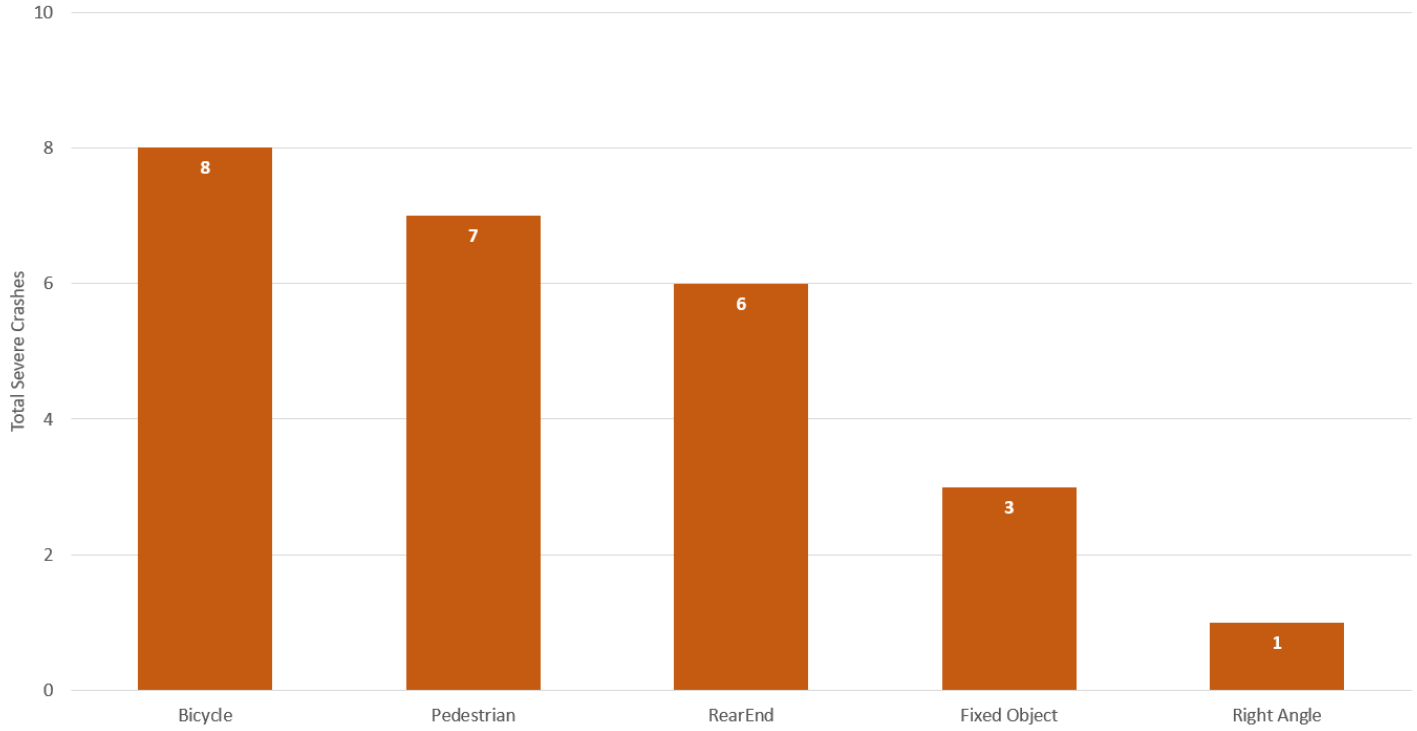
The most common distracted crash type is rear-end, which accounts for about 65% of all distracted crashes (Figure 65).

Figure 65: Distracted Crashes by Crash Type (3-year annual average)



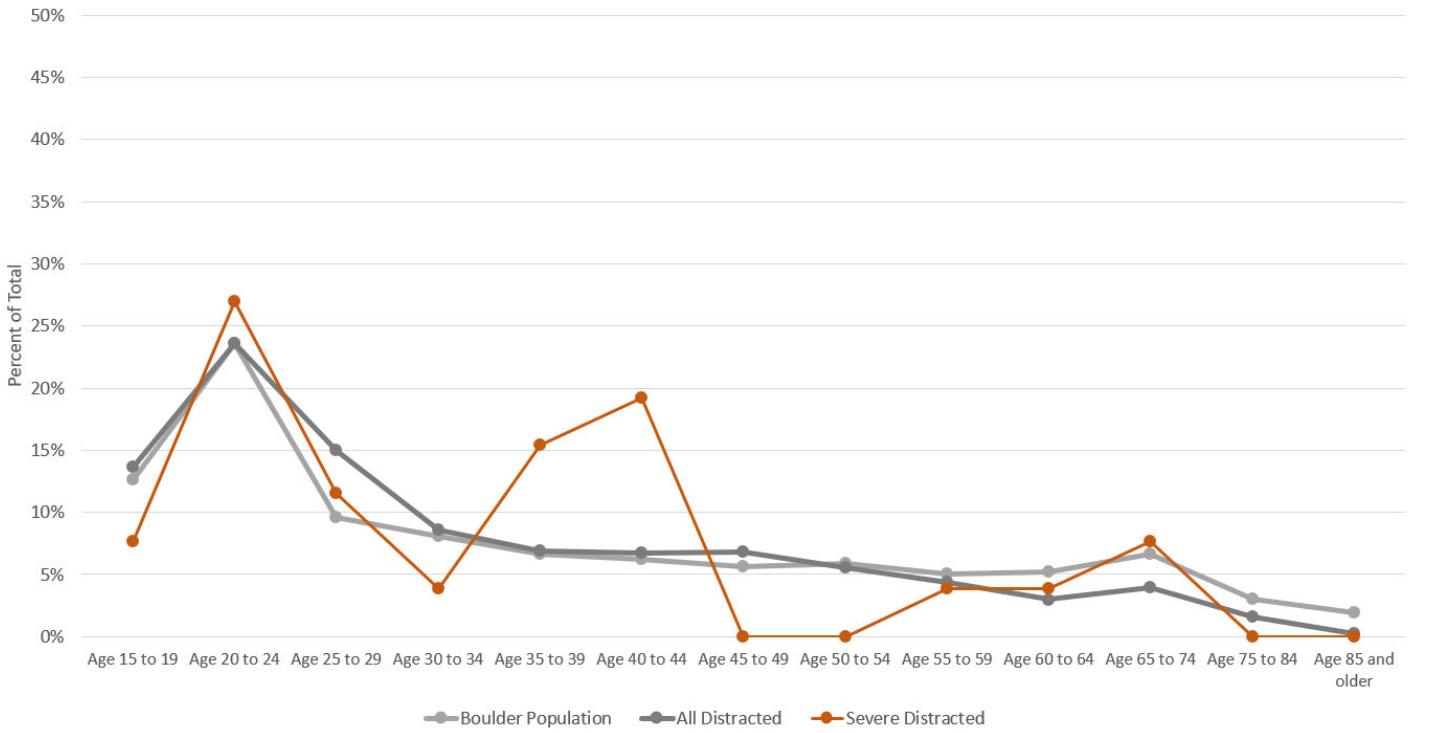
The most common distracted severe crash types are bicycle and pedestrian crashes. Between 2009 and 2017, there were a total of 15 severe bicycle and pedestrian crashes resulting from a distracted traveler (60%).

Figure 66: Severe Distracted Crashes by Crash Type (annual total 2009-2017)



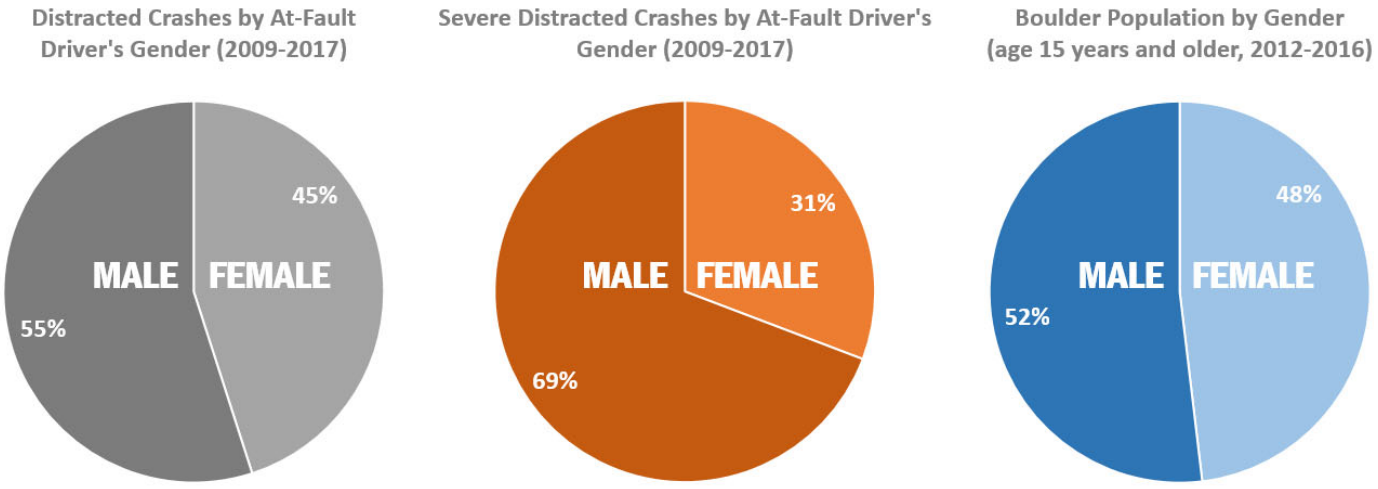
Distracted drivers between 35 and 44 years old are overrepresented in distracted severe crashes, and this overrepresentation is most pronounced between ages 40 and 44 (Figure 67).

Figure 67: Distracted Crashes by Age (2009-2017)



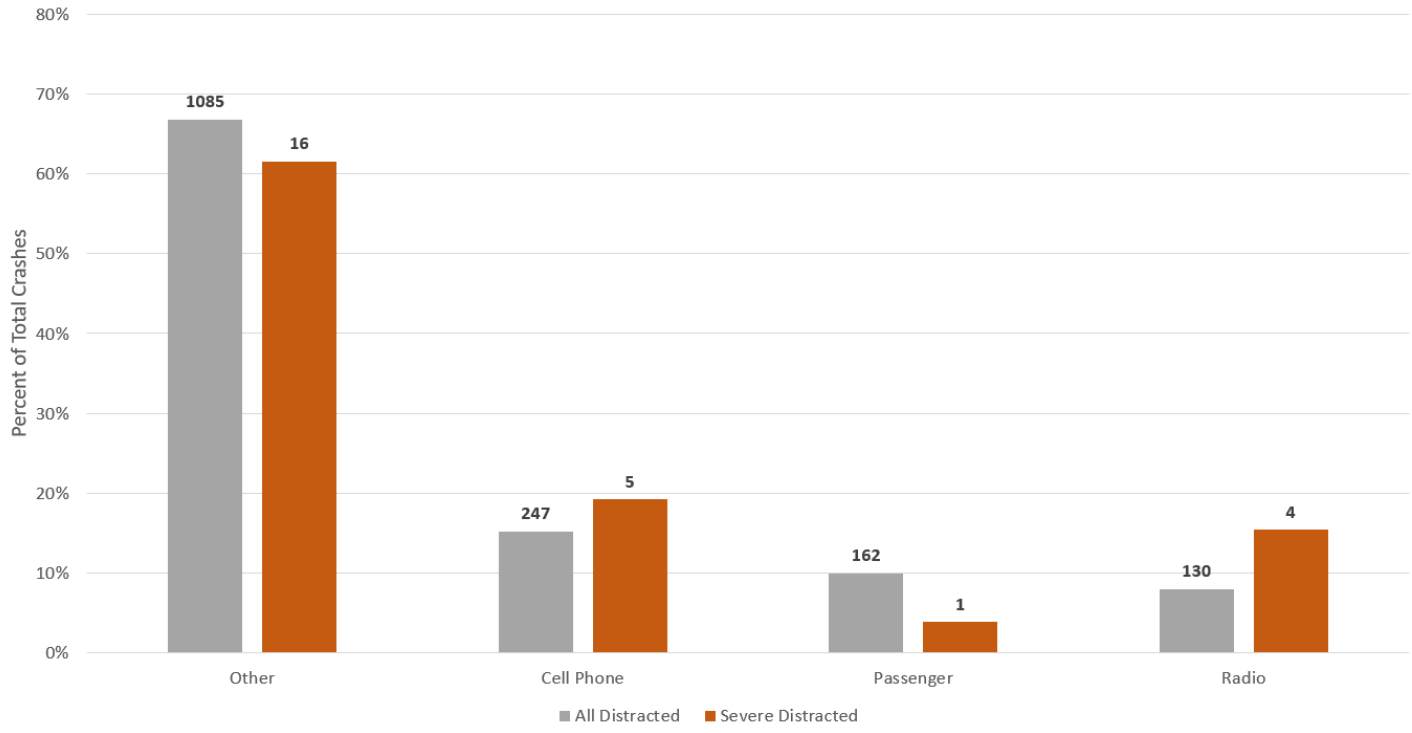
Between 2009 and 2017, 69% of at-fault drivers involved in severe distracted crashes were male (Figure 68).

Figure 68: Gender of Distracted Driver



Most distraction types fall under the “other” category which includes eating food, applying makeup, using objects, engaging with a pet, etc. (Figure 69).

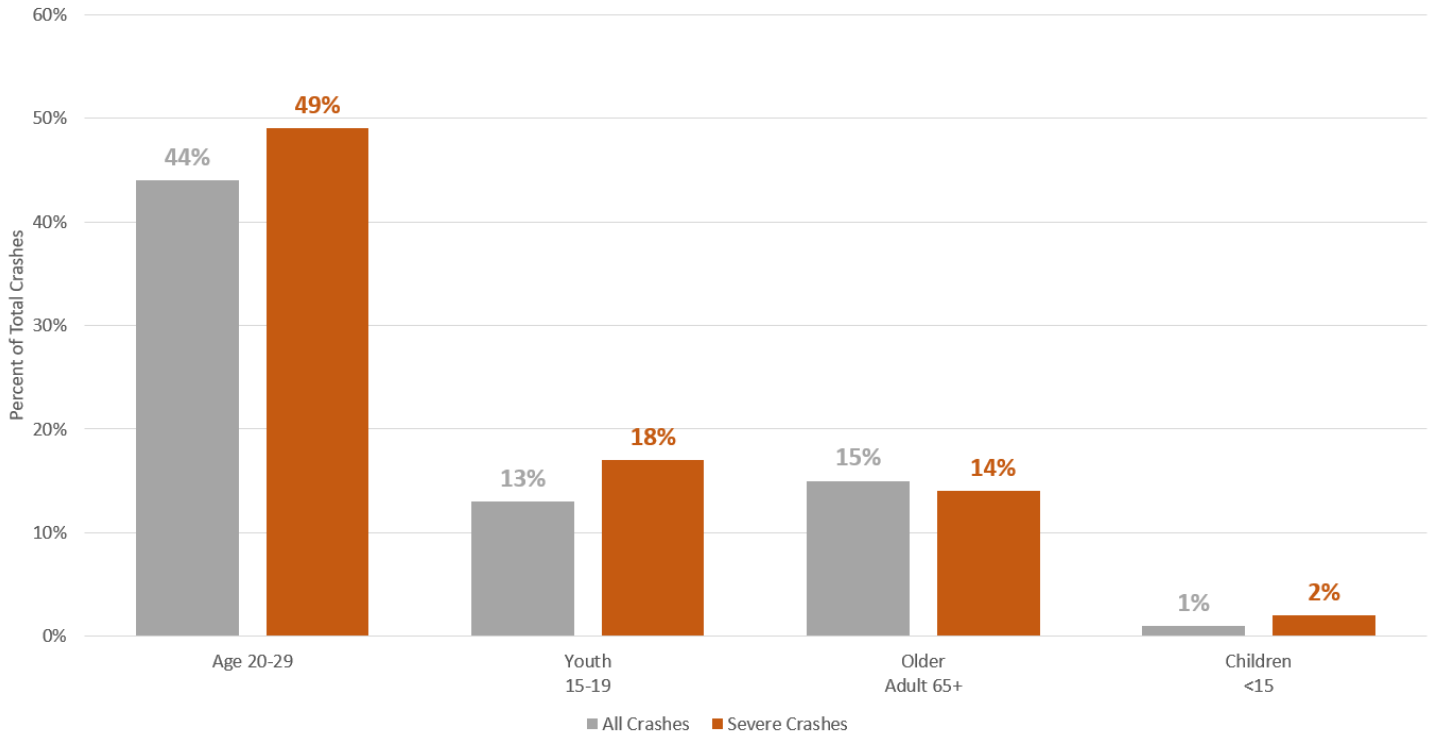
Figure 69: Distracted Crashes by Type of Distraction (2009-2017)



People of Different Ages

Figure 70 shows age categories of people involved in a crash that are considered vulnerable populations and/or overrepresented in severe crashes. More details about the age categories 15 to 19, 20 to 29 and over 65 years old are included in this section. While children under the age of 15 are overrepresented in severe crashes, they are involved as a pedestrian or bicyclist in only 1% of all crashes and 2% of severe crashes. Additional analysis of these crashes was not completed at this time to allow for focus on the most common severe crash types.

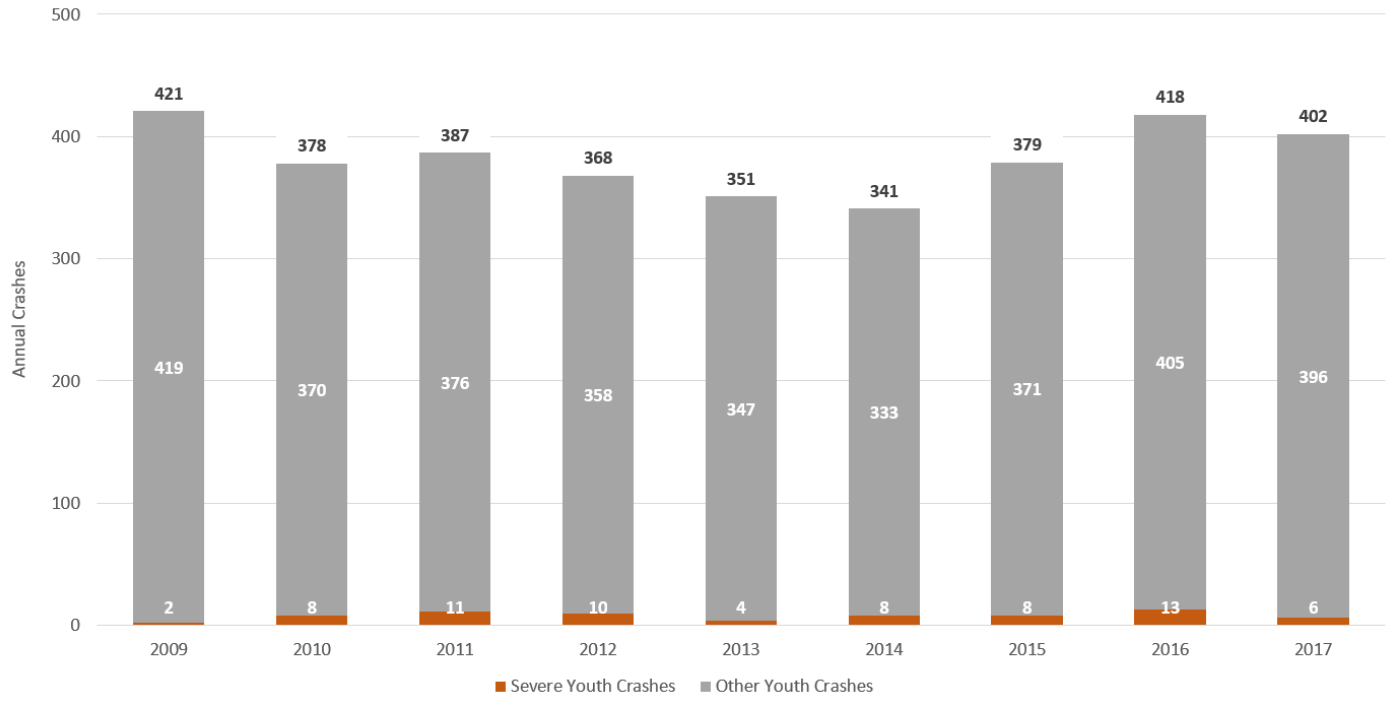
Figure 70: Total and Severe Crashes Involving People of Different Ages (2015-2017)



CRASHES INVOLVING YOUTH

From 2015 to 2017, there was an annual average of 390 crashes and nine severe crashes involving a youth ages 15 to 19. Youth crashes decreased between 2009 and 2014 but increased in 2015 and 2016 (Figure 71).

Figure 71: Crashes Involving a Youth, Age 15-19 (2009-2017)



Rear-end, right-angle and approach-turn crashes are the most common crash types (Figure 72). Bicycle and pedestrian crashes are the most common severe crash types (Figure 73).

Figure 72: Crash Type Involving a Youth, Age 15-19 (2009-2017)

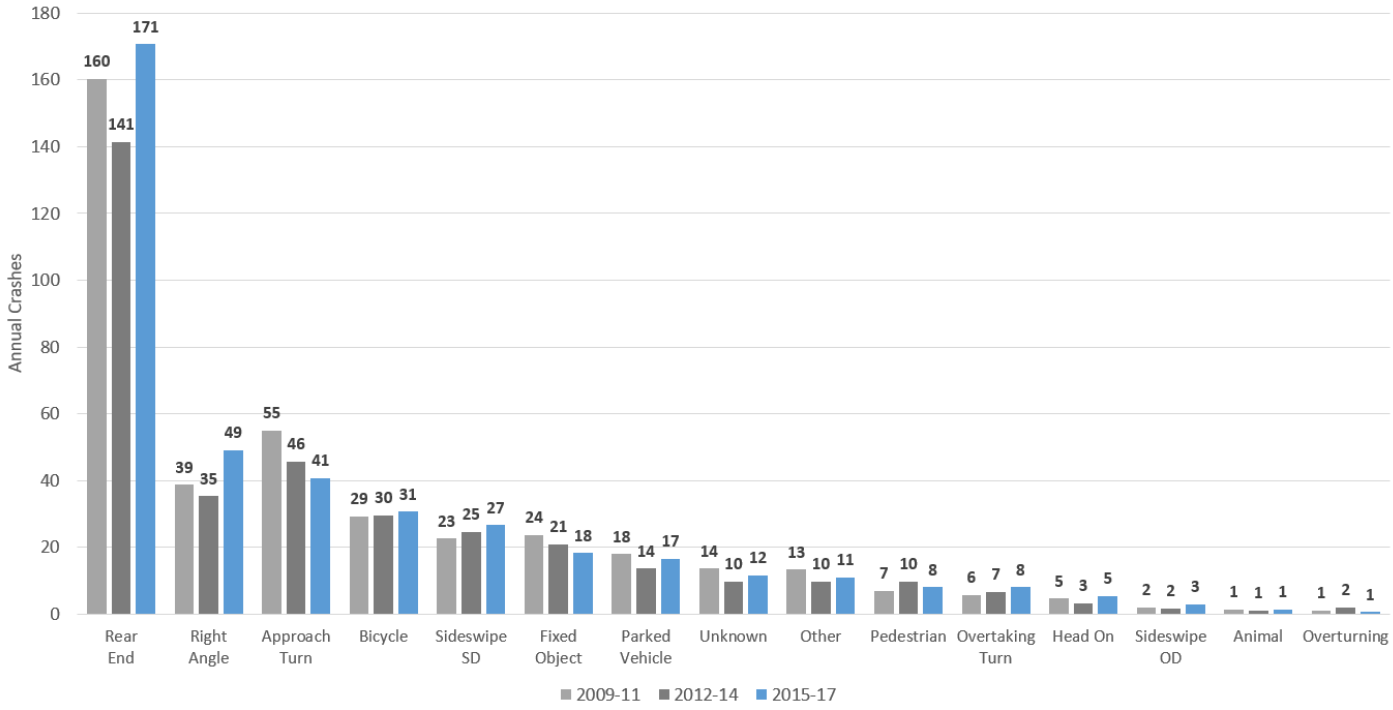
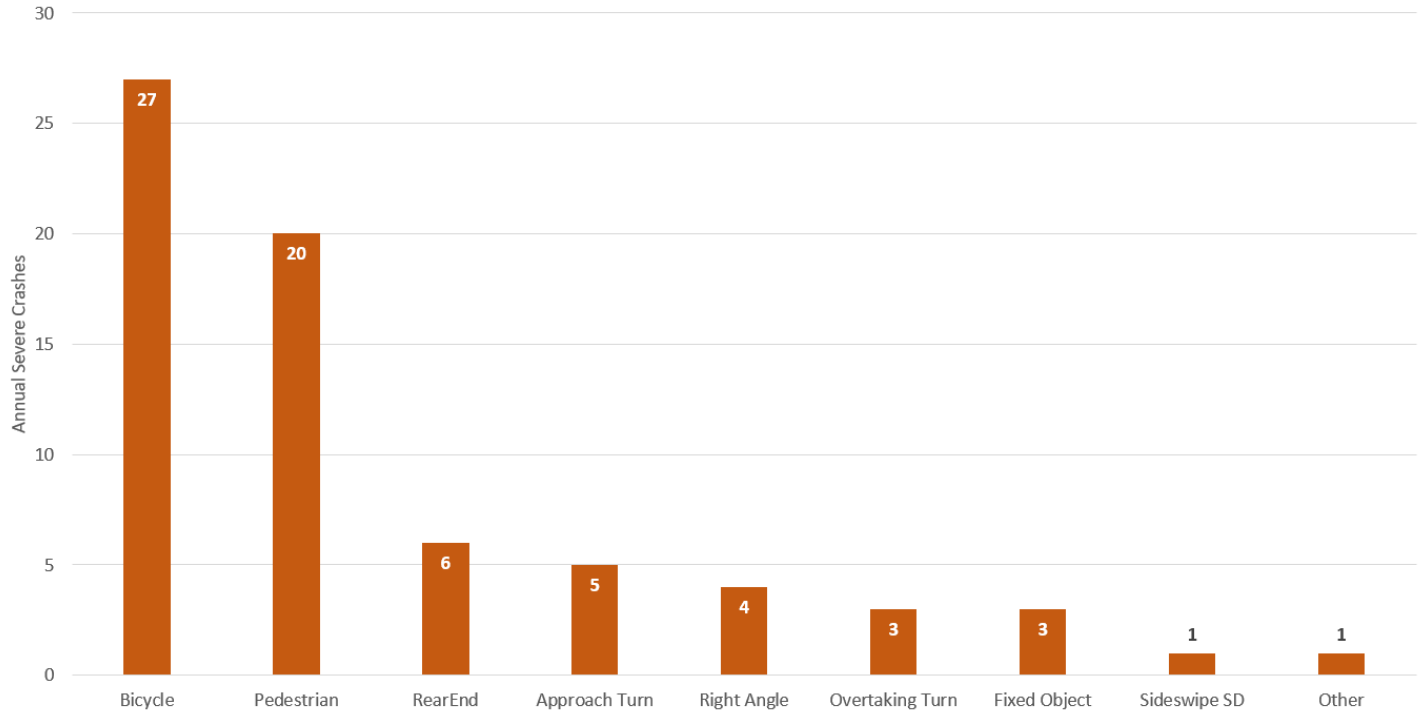


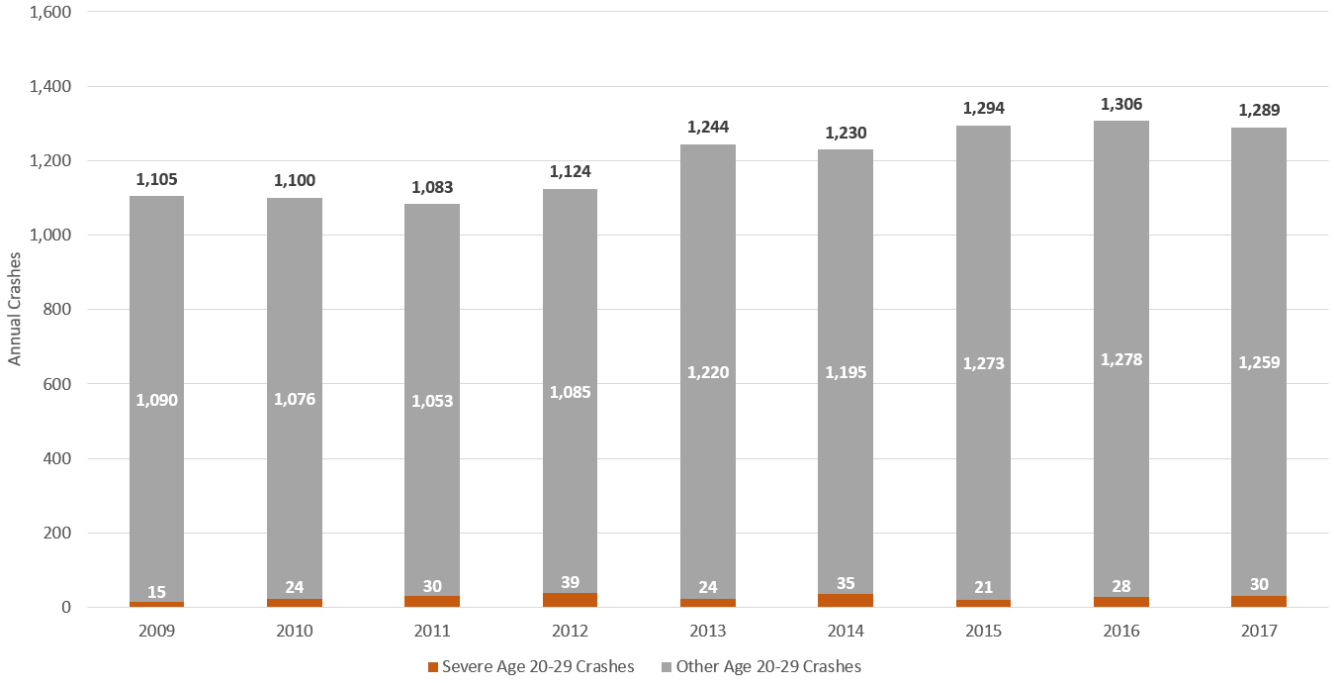
Figure 73: Severe Crashes by Crash Type Involving a Youth, Ages 15-19 (2009-2017)



CRASHES INVOLVING PEOPLE AGES 20 TO 29

Between 2015 and 2017, there was an annual average of 1,276 crashes and 27 severe crashes involving people ages 20 to 29. People these ages were involved in 44% of overall crashes and almost half (49%) of severe crashes (Figure 74).

Figure 74: Crashes Involving a Person Age 20-29 (2009-2017)



Rear-end, right-angle and approach-turn are the most common crash types (Figure 75). Bicycle and pedestrian crashes are the most common severe crash types (Figure 76).

Figure 75: Crash Type Involving a Person Age 20-29 (2009-2017)

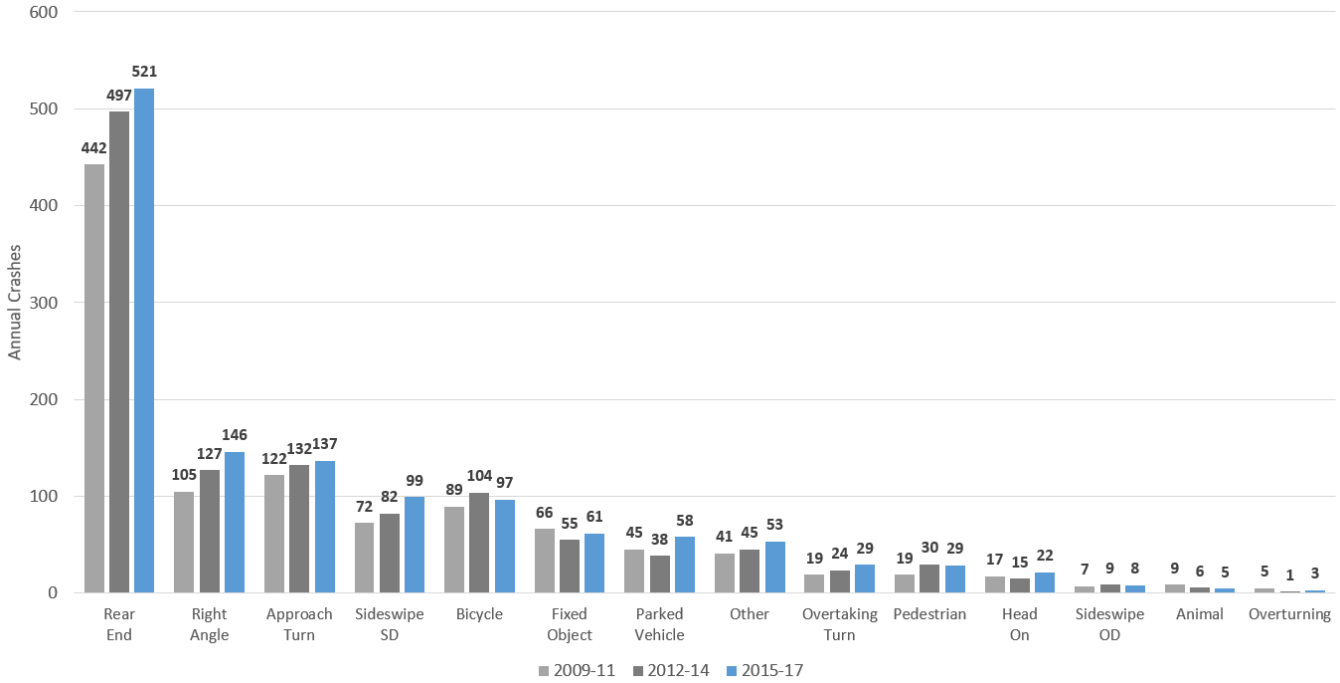
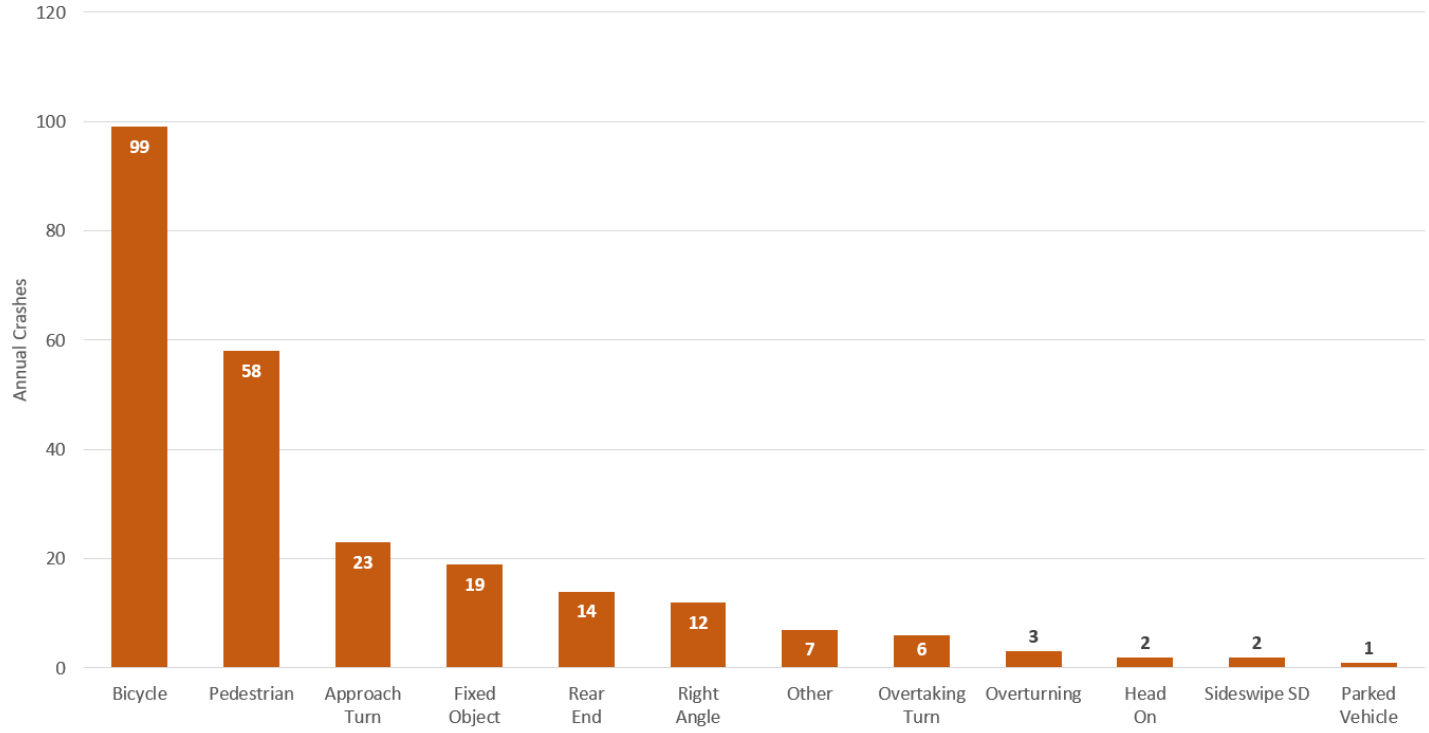


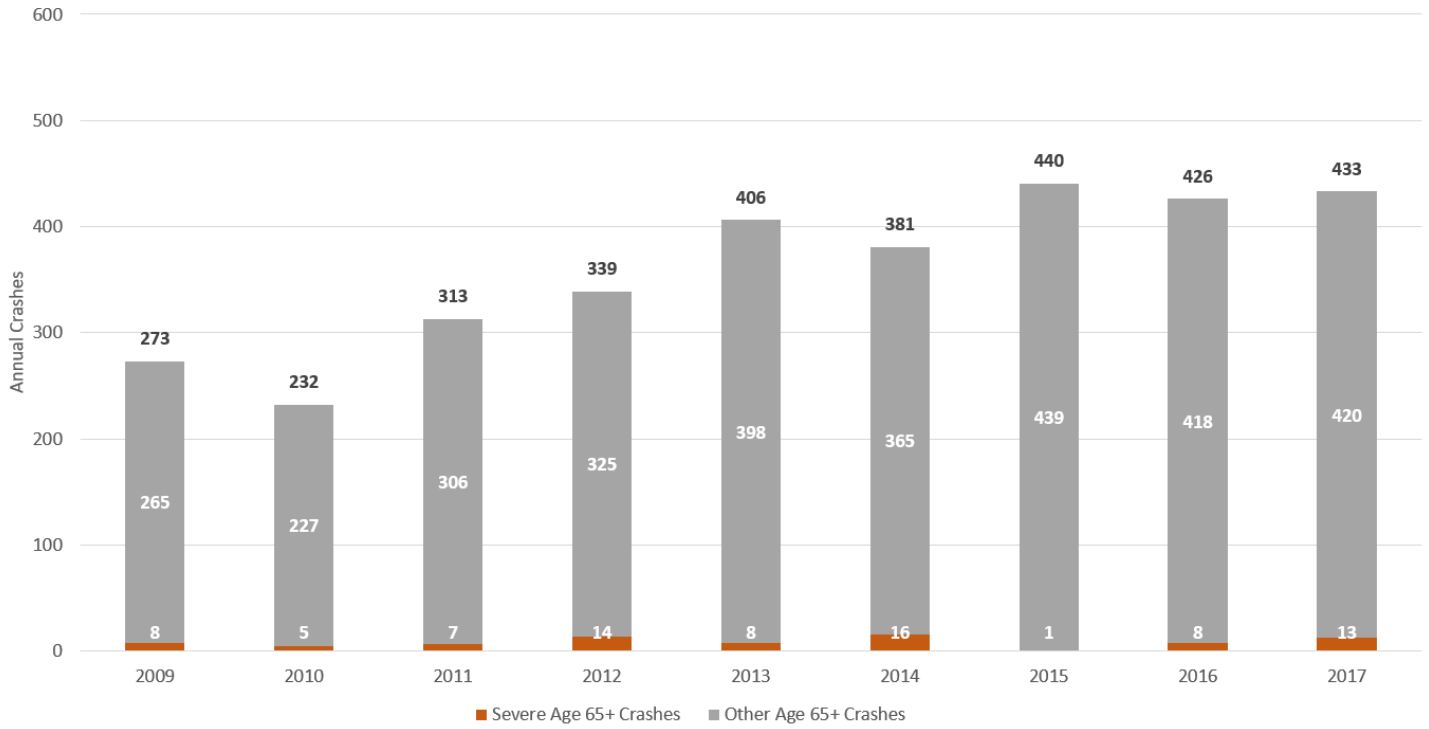
Figure 76: Severe Crashes by Crash Type Involving a Person Age 20-29 (2009-2017)



CRASHES INVOLVING OLDER ADULTS

From 2015 to 2017, there was an annual average of 433 crashes and seven severe crashes involving a person 65 years or older, representing 15% of overall crashes and 13% of severe crashes. Since 2009, crashes involving an older adult have increased by 59%, while the older adult population has increased by 29% (Figure 77 and Figure 78).

Figure 77: Crashes Involving an Older Adult Driver, Age 65+, by Year (2009-2017)



Rear-end, right-angle, sideswipe-same-direction, and approach-turn are the most common crash types and have been increasing for crashes involving an older adult. Bicycle, pedestrian, right-angle, and approach-turn make up the majority of severe crash types (Figure 78 and Figure 79).

Figure 78: Crash Types with Older Adult (65+) Driver Involved (3-year annual average)

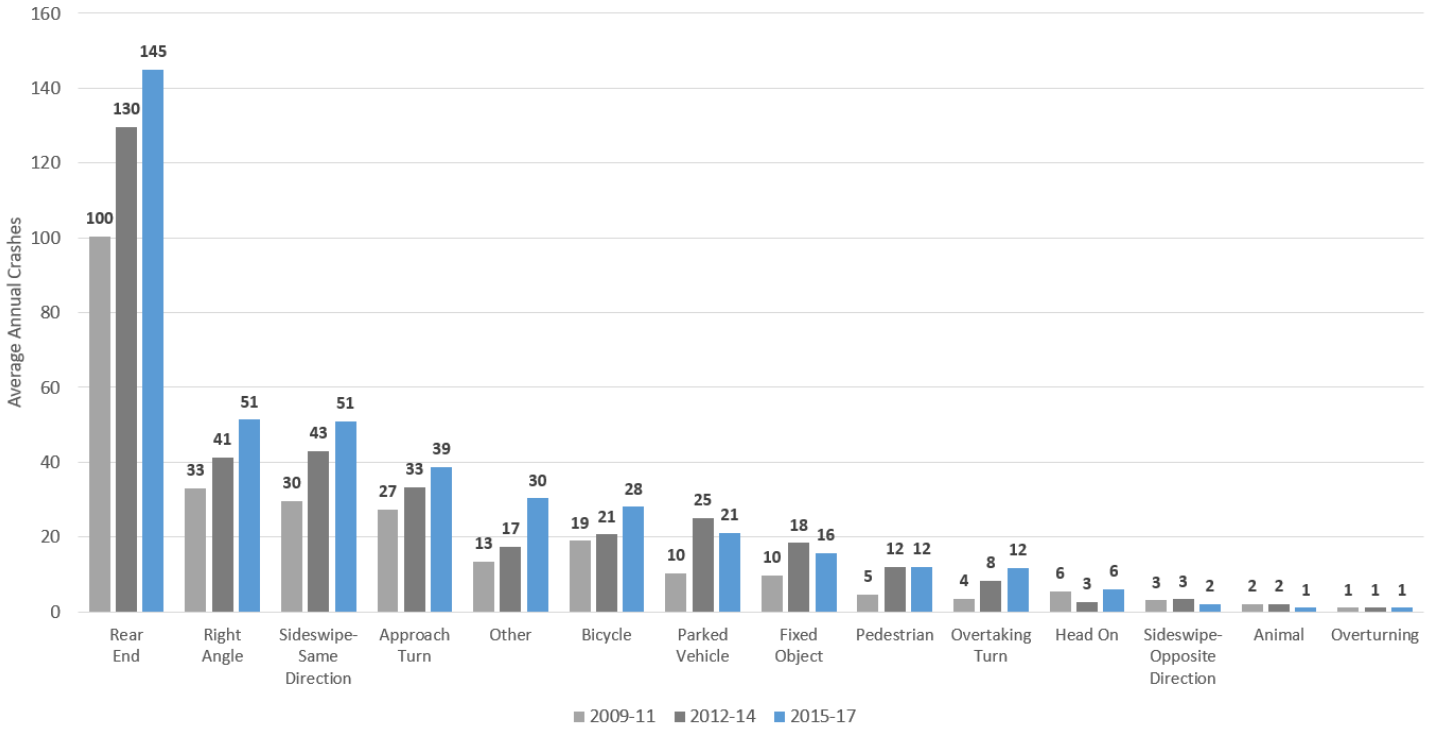
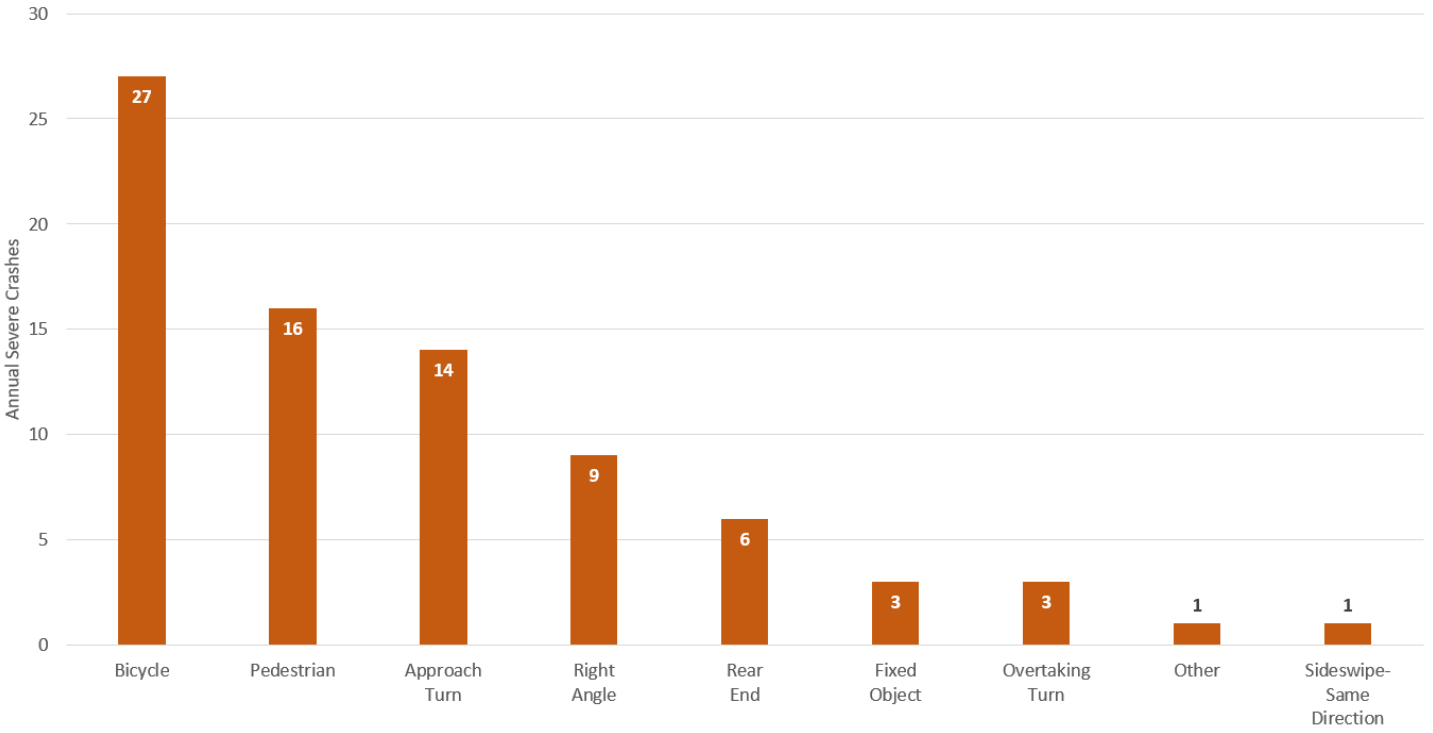


Figure 79: Severe Crash Types with Older Adult (65+) Driver Involved (2009-2017)



People on Motorcycles

Between 2015 and 2017, there were 46 motorcycle crashes and eight severe crashes on average annually. There was no clear upward or downward trend in overall or severe motorcycle crashes. Motorcycle crashes accounted for 2% of total and 14% of severe crashes between 2015 and 2017.

Figure 80: Motorcycle Crashes by Year (2009-2017)

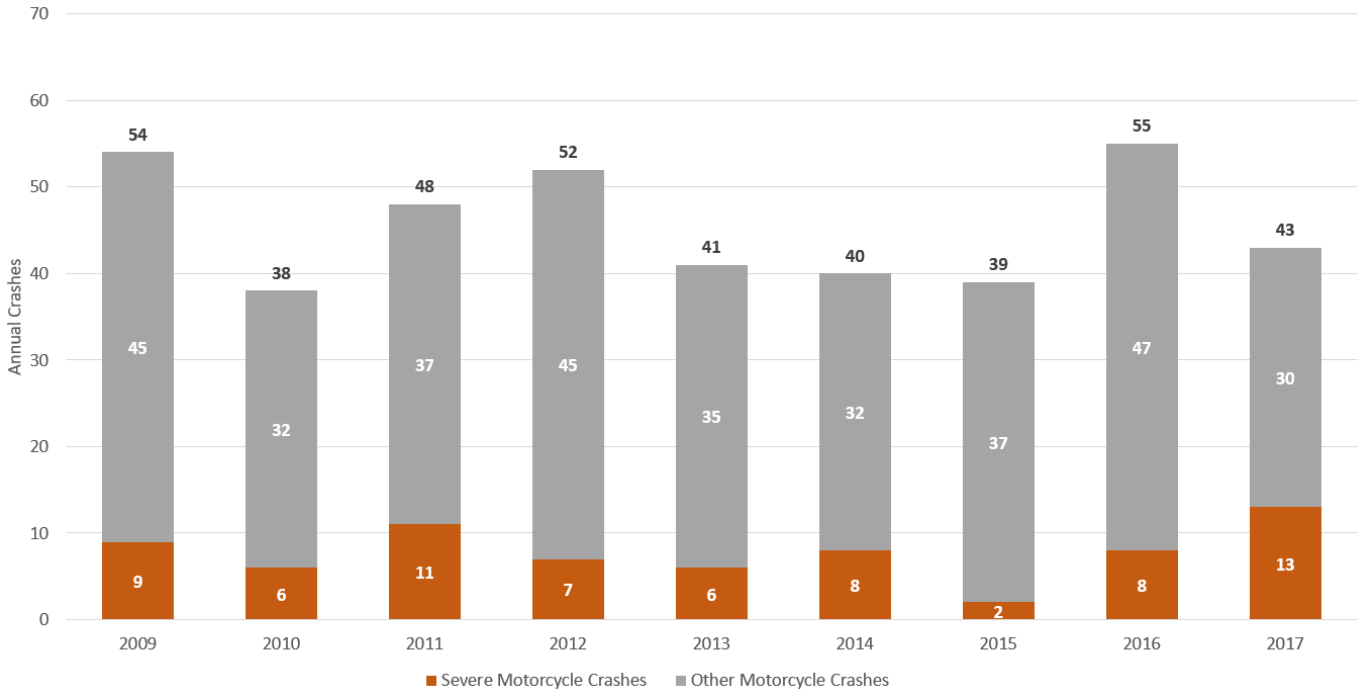


Figure 81: Motorcycle Crashes (rolling 3-year annual average)

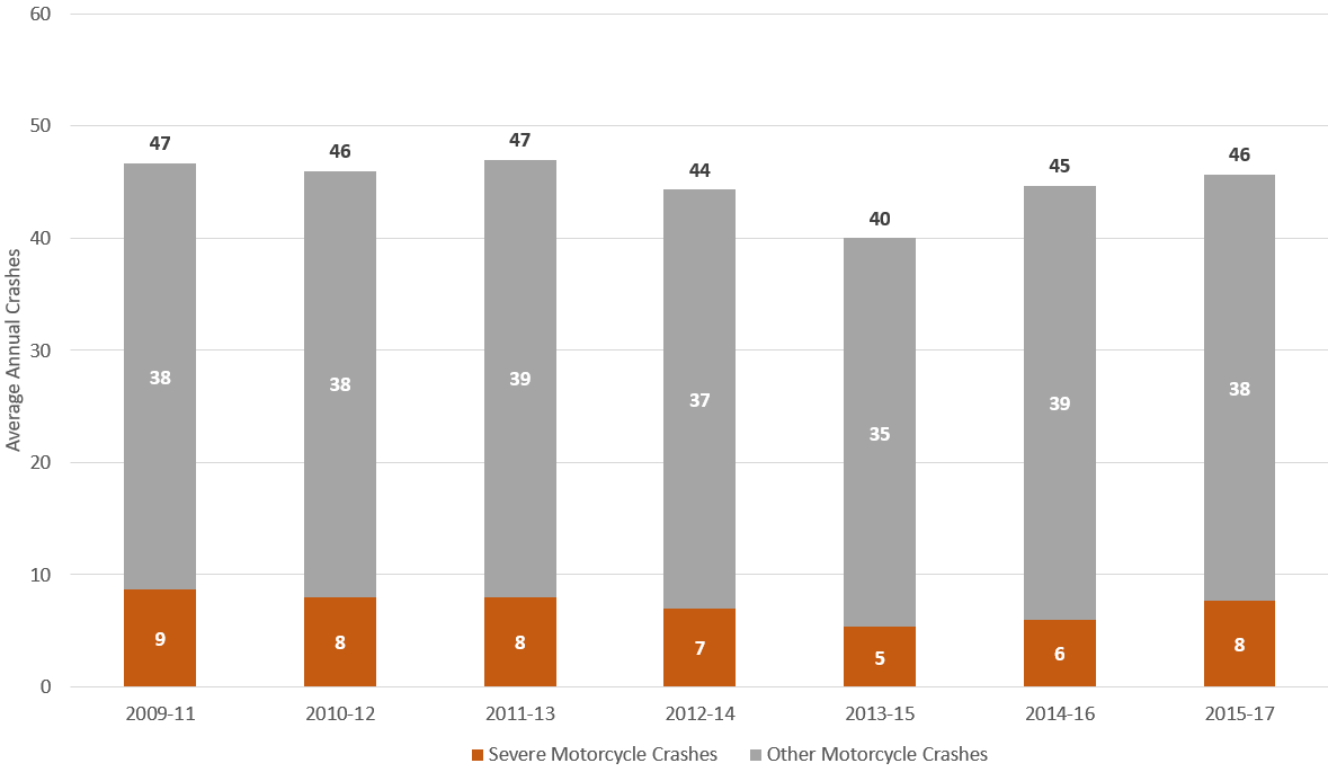


Figure 82 and Figure 83 show that rear-end, approach-turn, and right-angle are the most common crash types and are also the most likely to be severe crashes. A number of motorcycle crashes do not fall within the defined crash type categories and are categorized as "other."

Figure 82: Motorcycle Crashes by Crash Type (3-year annual average)

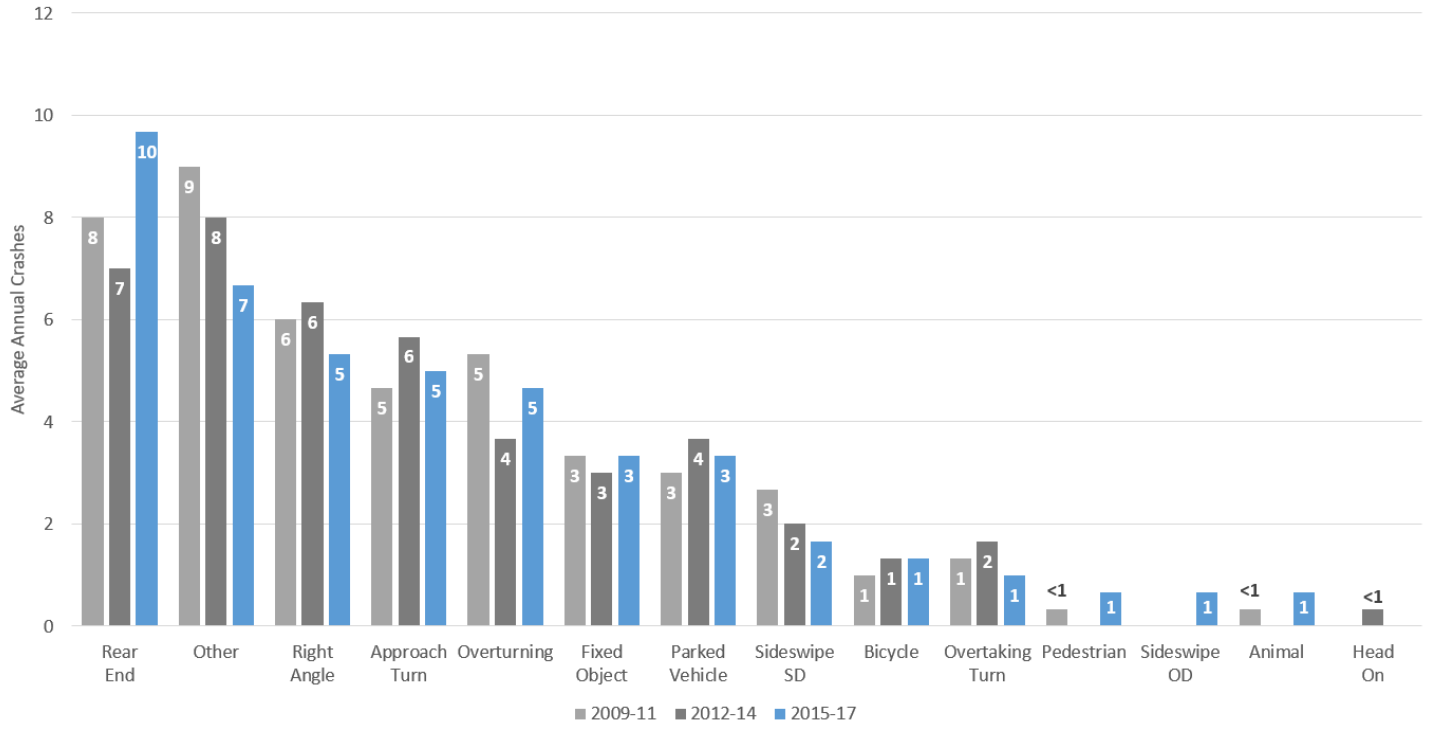
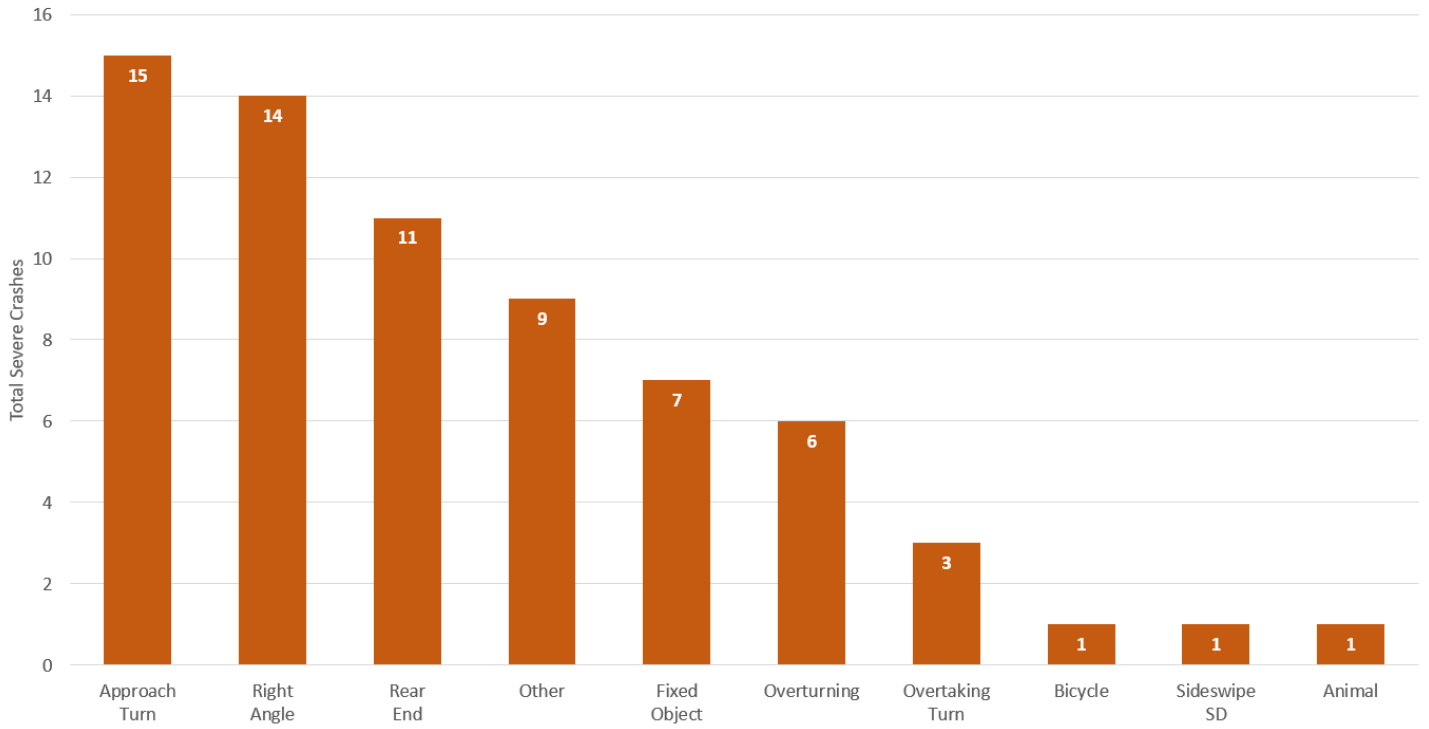
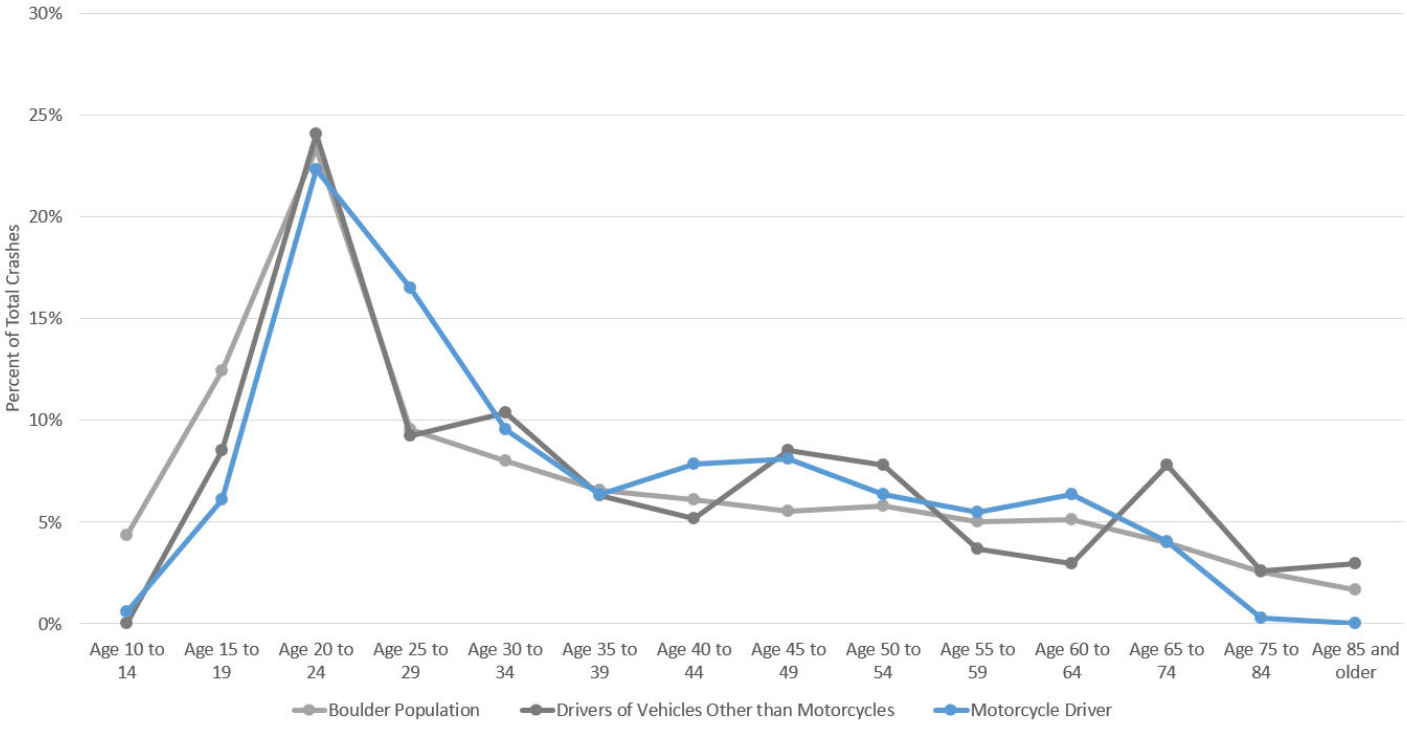


Figure 83: Severe Motorcycle Crashes by Crash Type (2009-2017)



Motorcycle drivers ages 25-34 and 40-64 are overrepresented in crashes. Drivers of non-motorcycle vehicles ages 30-34, 45-54, and 65-74 are overrepresented in motorcycle crashes (Figure 84).

Figure 84: Age of Drivers Involved in Motorcycle Crashes and Boulder Demographics (2009-2017)



B. Severe Crash Analysis

These findings are from an evaluation of all severe crashes (those in which a person was seriously injured or killed) in Boulder between January 2015 and December 2017.

SEVERE CRASH TYPES AND LOCATIONS

Between January 2015 and December 2017, there were a total of 160 severe crashes in Boulder. This included 154 crashes that involved a person being seriously injured and six crashes in which seven people were killed.

Of the total 160 severe crashes, 62 (39%) involved a bicyclist, 38 (24%) involved a pedestrian, and the remaining 60 (37%) involved only one or more motor vehicles.

Forty-eight of the severe crashes (30%) involved a left-turning vehicle. Thirty of these crashes (19%) involved vehicles making a permitted left turn at a signalized intersection. Another 15 of these crashes (9%) involved vehicles making a left turn at an unsignalized intersection, while the remaining three crashes were at signalized intersections with protected left-turn phasing. **Crashes involving left turns and specifically permitted left turns at signalized intersections are the most common types of severe crashes in Boulder**.

Fourteen of the severe crashes (47%) involving vehicles making a permitted left-turn at a signalized intersection involved a crash with another motor vehicle. Nine of the crashes (30%) involved a crash with a pedestrian and seven of the crashes involved a crash with a bicycle (23%).

Of the 15 severe crashes involving a left turn at an unsignalized intersection, 11 (73%) involved a bicycle, three (20%) another motor vehicle, and one (7%) involved a pedestrian.

Fifty-nine (37%) of the severe crashes occurred at signalized intersections, 37 (23%) occurred at an unsignalized intersection, and 61 (38%) of the severe crashes were not intersection-related (generally occurring mid-block away from an intersection). The final three crashes were either at unsignalized right-turn bypass islands at signalized intersections or are location-unknown.

One hundred and fifteen (72% of total) of the severe crashes occurred on arterial roadways, 17 (11%) occurred on residential collectors, and 21 (13%) occurred on local roadways. The remaining seven severe crashes occurred on the city's multi-use path system, on private roads or in parking lots.

EFFECT OF SPEED ON CRASHES

Of the 21 severe crashes that occurred on local roadways, only one crash involved speeding (defined as traveling above the posted speed limit) as a significant factor. The primary causes of this crash were driving under the influence (DUI) and driving while distracted; however, these factors contributed to the speed of the vehicle.

The speed of a bicycle was a significant factor in the case of six of the severe crashes that occurred on local roadways – while the bicycle was not traveling above the posted speed limit in these crashes, the speed they were traveling contributed to the crash.

Of the 17 severe crashes that occurred on residential collectors, three crashes involved speeding as a significant factor. Two were motor vehicle crashes that were DUI-related and the third involved a speeding bicyclist traveling downhill.

The speed of a motor vehicle was a significant factor in two crashes that occurred on residential collectors, while the speed of a bicyclist was a significant factor in four crashes. In these instances, the individuals were not traveling above the posted speed limit, but their speed was a factor in the crashes.

Of the 115 severe crashes that occurred on arterial roadways, 14 involved speeding as a factor. Five of those crashes also involved DUI or distracted driving and three involved speeding on a motorcycle.

One crash on an arterial roadway involved a speeding bicyclist traveling downhill.

The speed of a motor vehicle was a significant factor in 47 of the severe crashes on arterial roadways and the speed of a bicyclist was a significant factor in another six of these crashes (all bicyclists were riding downhill). These individuals were not traveling above the posted speed limit, but their speed was a factor in the crashes.

MITIGATION POTENTIAL

Sixty-two (39%) of the total severe crashes were crashes that could potentially be mitigated by some type of currently known engineering treatment (such as a traffic control or change to the street design).

Almost half of these crashes (30) were left-turn crashes that occurred during permitted phasing and could potentially be mitigated by protected left-turn signal phasing.

Five crashes could potentially be mitigated by green pavement markings or other right-turn mitigation to reduce right-turn conflicts with bicyclists and pedestrians.

Three crashes could be mitigated by green pavement markings at unsignalized intersections to reduce left-turn conflicts with bikes.

Four crashes could be mitigated by an enhanced pedestrian-crossing treatment.

Of the remaining severe crashes that potentially could be mitigated by an engineering strategy, there were no more than two crashes that could be mitigated by the same strategy. The remaining crashes could be mitigated by these various engineering strategies:

- Pedestrian head-start traffic signal phasing (also called a Leading Pedestrian Interval, or LPI).
- Right-turn-on-red restrictions.
- Adding signing and striping to address conflicts with pedestrians and cyclists at right-turn bypass islands.
- Striping a bike lane where none was present.
- Constructing a protected or buffered bike lane where a standard bike lane was present.
- Addressing sight distance issues such as landscape vegetation trimming.
- Enhancing multi-use path signing and striping.
- Establishing better roadway maintenance.
- Lowering vehicle speeds.

One hundred and ten (69% of total) of the severe crashes were crashes that could potentially be mitigated by some type of education and outreach to encourage a change in behavior. Of these 110 severe crashes:

- 28 (26%) involved a need to watch for bikes or peds when turning left (both at signalized and unsignalized intersections).
- 16 (15%) were related to driving under the influence of alcohol or drugs.
- 15 (14%) involved pedestrians jaywalking near traffic signals or entering a roadway where they did not have the right-of-way.
- Eight (7%) involved a vehicle both driving while districted and traveling in congested conditions at or under the posted speed limit but at a speed faster than what would have allowed for safe stopping distances.
- Six (6%) involved a need to watch for motorcycles or scooters on the roadway.
- Three (3%) involved speeding or driving recklessly on a motorcycle or scooter.
- Four (4%) involved a bicycle traveling fast downhill and hitting a turning or parked car.
- Four (4%) involved conflict on a multi-use path system between two bicycles.

Of the remaining severe crashes that potentially could be mitigated by some type of education or outreach, there were no more than two crashes that could be mitigated by the same strategy. The remaining crashes could be mitigated by various education and outreach campaigns focused on encouraging these behaviors:

- Obeying stop signs, right-turn-on-red restrictions and other traffic-control devices.
- Turning right from a bicycle lane instead of adjacent to it.
- Yielding to pedestrians and cyclists when turning right across a multi-use path.
- Wearing sunglasses to avoid glare.
- Yielding to pedestrians in crosswalks.
- Yielding when exiting alleys or driveways.
- Pushing the button at crosswalks with flashing beacons.
- Refraining from driving when you have an impairing medical condition.
- Avoiding parking in a bike lane.
- Refraining from changing a tire on a high-speed roadway.
- Cycling in the correct direction on the roadway.
- Safely making a left turn on a bicycle from a bike lane.
- Avoiding distractions while driving.

Fifty-one (32% of total) of the severe crashes were crashes that could potentially be mitigated by enforcement efforts. Note that several of these crashes presented multiple enforcement opportunities, such as DUI and speeding. Of these 51 crashes:

- 17 (33%) involved speeding.
- 16 (31%) involved DUI.
    - 7 (nearly half) of the 16 crashes that involved DUI also involved speeding.
- Six (12%) involved drivers running red lights.
- Four (8%) involved drivers not yielding or people not entering the crosswalk appropriately.
- Three (6%) involved cyclists running red lights.
- Three (6%) involved cyclists speeding or riding recklessly downhill.
- Three (6%) involved pedestrians jaywalking at or near a traffic signal.

Of the remaining severe crashes that could potentially be mitigated by some type of enforcement effort, there were no more than two crashes that could be mitigated by the same strategy. The remaining crashes could be mitigated by enforcement strategies focused on these behaviors:

- Cyclists must stop at stop signs.
- Motor vehicle drivers must stop at stop signs.
- Skateboarder must stop at stop signs.
- Parking is not permitted in a bike lane.
- Bikes must ride in the correct direction on the roadway.

CONCLUSIONS

From an engineering perspective, the highest leverage improvements will be to replace green ball signal indications with flashing yellow arrows for permitted left turns and to install protected left-turn phasing consistent with the city's Traffic Signal Practices.

Other potentially valuable improvements include:

- Implementing strategies to prevent crashes between left-turning vehicles and cyclists at unsignalized intersections, such as green pavement markings and/or warning signs. Consider changes in right-of-way control where appropriate.
- Implementing strategies to avoid crashes between right-turning vehicles and cyclists in adjacent bike lanes, such as green pavement markings and/or warning signs.

From an enforcement perspective, the highest leverage improvement is increased DUI enforcement and the placement of additional photo red-light cameras at intersections, of which the city will be installing an additional two locations in 2019. The other significant enforcement strategy is to direct limited police officer resources at high-value speed-enforcement locations (typically arterial roadways) and other locations with a high number of violations (such as locations where there are existing right-turn-on-red restrictions). Time would also be well spent doing additional "Heads Up" enforcement at targeted crosswalk locations (for all modes) and enforcing bicycle speeds at several key downhill locations.

From an educational standpoint, the highest leverage action would be increased education around watching for bicycles and pedestrians when making left turns at both signalized and unsignalized intersections. Other high-leverage educational efforts include campaigns and messaging around:

- Never drive or bicycle while impaired.
- Cross the road legally as a pedestrian or bicyclist. Do not jaywalk at traffic signals and wait for appropriate gaps in traffic when crossing a roadway away from crosswalks.
- Do not speed, and be especially careful in congested conditions where there are high volumes of traffic repeatedly slowing and speeding back up.
- As a driver, watch for pedestrians, bicyclists, motorcycles and scooters. They are on the roadway with you but more difficult to see.

C. Green Pavement Markings Analysis and Recommendations

METHODOLOGY

Common bicycle crash types that are susceptible to correction by the installation of green pavement markings (GPM) were reviewed through two separate analyses:

Analysis 1: By mapping these crash types and looking for locations with crash frequencies greater than one.

Analysis 2: Reviewed bicycle crashes along 13 major corridors that have bicycle crash trends mitigatable by GPM but have bicycle crash frequencies at specific locations of less than one.

Primary bicycle crash types reviewed were:

- Motorist Right-Turn – Same Direction (Right-Hook)
- Motorist Left-Turn
- Motorist/Bicycle Merge

KEY FINDINGS

1. The city has identified high frequency bicycle crash locations and is actively planning, designing, and constructing improvements. For larger capital projects where funding may be several years away, it is recommended that the city establish a short-term GPM solution before a long-term permanent solution can be implemented. These locations include:
    - 30th and Colorado Underpass
    - Colorado and Regent
    - 29th and Baseline
    - Table Mesa and Stanford
    - 30th and Arapahoe
    - Folsom and Taft
    - 30th St. Corridor
    - Colorado Ave. Corridor

2. For those bicycle crashes that were not at locations listed above, but susceptible to mitigation by using GPM, the 2015-2017 crash data suggests that the city has already addressed most high frequency bicycle crash locations appropriate for GPM implementation. In accordance with the city's efforts to take a proactive Safe Systems approach to travel safety, it is recommended that GPM be installed at a corridor level at specific locations that are susceptible to common bicycle crash types that may be mitigated using GPM.

3. Investigate changes in right-turn bypass signing/marking standards, especially those right-turn bypasses that are connected to multi-use paths and are at ramp locations. It is recommended to perform a system wide analysis focused on right-turn bypass characteristics.

Analysis 1: Recommended Green Pavement Marking Locations - Crash Frequency Based

- 30th and Marine, 250 feet south at private driveway on east: Left-Turn GPM across east approach with signing
- 30th and Pearl, Barnes and Noble driveway on west side of 30th: Green bike lane and green bordered crosswalk with signing
- Broadway and Juniper: Left -Turn/Right-Turn GPM across eastbound approach
- Broadway and Union: Right-Hook GPM southbound approach
- Baseline and 20th: Left-Turn/Right-Turn GPM on northbound approach

- Folsom and Pine: Left-Turn/Right-Turn northbound and southbound approaches
- 13th and Pine: Left-Turn/Right-Turn eastbound and westbound approaches
- 13th and Balsam: Left-Turn/Right-Turn eastbound and westbound approaches

Analysis 2: Recommended Green Pavement Marking Locations - Proactive Safe Systems Approach

Common bicycle crash types and locations where GPM is appropriate:

Bicycle Lanes

Intersection

- Motorist Left-Turn
- Motorist Right-Turn

Non-Intersection

- Motorist Left-Turn
- Motorist Right-Turn

Multi-Use Paths

Intersection

- Motorist Left-Turn
- Motorist Right-Turn

Non-Intersection

- Motorist Left-Turn
- Motorist Right-Turn

Sidewalks

(Relatively low numbers compared to the above.)

The following corridors were identified as being candidates for GPM to be used as a proactive approach on a corridor level:

- 13th: Arapahoe to Balsam
- 28th: Colorado to Violet
- 30th: Baseline to Diagonal Hwy.
- Arapahoe: Broadway to 55th
- Baseline: Flagstaff to 30th
- Broadway: Baseline to Canyon
- Canyon: Broadway to 30th
- Colorado: Folsom to Foothills Pkwy.
- Folsom: Colorado to Iris
- Broadway: Balsam to Lee Hill
- Pearl: Folsom to Foothills Pkwy.
- Table Mesa: Lehigh to Foothills Pkwy.

The city is currently in the process of establishing the criteria to prioritize the implementation of GPM on a corridor level. Based on an initial screening and other transportation projects, the following two corridors have been selected for the implementation of GPM:

1. 30th between Baseline and Valmont;
    - This corridor has been selected due to several reasons, including higher bicycle crash numbers, significant bicycle trips and key connections to places like the University of Colorado. The installation of GPM is a near-term improvement for the 30th corridor prior to the construction of the 30th Corridor Project.
2. 13th between Arapahoe and Iris
    - This corridor will be Boulder's first Neighborhood Greenway and will be implemented summer 2019 through the Low-Stress Walk and Bike Network Plan. Neighborhood Greenways are streets with low vehicle volumes/speeds and are designed to prioritize and improve conditions for walking and biking.

D. Mitigation Effectiveness

BACKGROUND

The city is currently updating its Safe Streets Report, which provides an overview of the city's efforts to continuously improve safety and comfort for people using all modes of travel. Travel safety is the top priority for the city, and the Safe Streets Report is an important tool to track crash trends by type and location and identify safety improvements to be included in the Vision Zero Action Plan that will reduce the number of crashes, especially those that are severe.

EVALUATION PURPOSE

The purpose of this study is to evaluate the effectiveness of safety improvements deployed by the city. If a specific safety improvement has been identified as effective, it can be used at other locations that have the same (or similar) physical/operational characteristics and that may or may not be experiencing a crash trend (demonstrating a reactive and proactive safety approach). If a safety improvement has been identified as ineffective, city staff can re-evaluate the engineering strategies available to mitigate those specific crash trends. This study will also help inform the city as to which travel safety improvements are effective at mitigating crashes as well as which improvements enhance travel comfort and security.

Travel Safety Improvements and Crash Data Sources

The Transportation Division of Public Works documents and tracks a comprehensive list of travel safety improvements it implements across the city's transportation network.

Crash data is provided by the City of Boulder Police Department and is stored in the Transportation Division's crash database and analytics software program.

Travel Safety Improvement Evaluation Requirements

For a specific travel safety improvement to be included in this evaluation, the improvement needed to have at least nine months of "after data." Meaning, the improvement needed to have been installed and operating for at least nine months. It's important to note that industry best practices for after data is typically three years. The city is aligning an initial effectiveness evaluation with the 2019 Safe Streets Report and will be continually monitoring the effectiveness these improvements.

Crash data included in this study is from Jan. 1, 2012, through Aug. 31, 2018.

Travel Safety Evaluation Data Limitations

It is important to note that this evaluation is based on a rather coarse scoring criterion. Limited engineering improvement records, relatively low crash numbers in Boulder and short study periods make it difficult to evaluate the effectiveness of the engineering changes that have been implemented since 2012. For instance, some engineering strategies have only been implemented at a single location in the city, presenting limited data from which to draw conclusions.

In addition, there are locations where several safety improvements were implemented at the same time, making it difficult to identify a single improvement type that was effective. There are also locations where safety improvements were implemented in a staged approached over time, making it difficult to establish if a single safety improvement was effective, especially within short study periods.

As the city continues to develop operational best practices, while continuing to track safety improvements over time, the evaluation component of the Vision Zero program will evolve to become more structured and will provide a clearer overall understanding of the effectiveness of safety improvements.

Effectiveness Scoring Guide

VERY effective – eliminated crash trend
Effective – reduced but did not eliminate crash trend
NOT effective – did not reduce crash trend
INCONCLUSIVE – insufficient data to make a determination (tracking)

Safety Improvement Effectiveness Results and Recommendations

TRAFFIC SIGNALS (54 LOCATIONS)

Conversion of Green Ball Signal to Left-Turn Flashing Yellow Arrow (FYA) Signal for Permitted Left Turns (44 Left-Turn Directions)

- Effective at some locations and NOT effective at other locations

Left-Turn FYA Protected-Permitted Operation (Four Left-Turn Movements)

- Effective

Left-Turn Protected-Only Operation (Four Left-Turn Movements)

- Effective

Pedestrian Head-Start or Leading Pedestrian Interval (LPI) (One Location)

- VERY effective
  Note: The very limited number of locations, one, doesn't demonstrate the effectiveness of deploying pedestrian head-starts, but rather deploying a pedestrian head-start at this specific location. The city is currently deploying more pedestrian head-starts and will be reviewing their effectiveness in a systemwide study.

Other (includes timing parameters, e.g. extending green time) (One Location)

- Effective

Recommendations

The Transportation Division recommends continuing to convert green ball left-turn signals to FYA signals to meet current Manual on Uniform Traffic Control Devices (MUTCD) national safety standards and to reduce left-turn crashes. (For more information on why the city is installing FYAs, see the note below.) Transportation also recommends continuing to follow the city's Traffic Signal Practices guidance for left-turn phasing.

At locations where crash trends are identified and the left-turn phasing is changed, the recommendation is to monitor crashes in six-month time periods to determine the effectiveness of the phasing change. If a specific location is not effective, the left-turn phasing at this location will be provided additional protection, e.g. converting an FYA-only phasing to protected-permitted phasing. Left-turn phasing operation will be provided based on the city's Traffic Signal Practices.

Additionally, as data on LPIs is limited to a single location, Transportation recommends exploring the installation of LPIs at additional intersections to support further data collection and evaluation of safety improvement effectiveness. The city continues to research national best practices for the use of LPIs.

Note on the city's left-turn phasing standards: Flashing yellow arrows are the new national standard from the MUTCD for permitted left-turn phasing and signify that vehicles may turn when there is a break in oncoming traffic and in the crosswalk. Previously, drivers would see a green circle to indicate that they could turn left when safe to do so. These two signals mean the same thing, but national research has found that the flashing yellow arrow better and more safely indicates to drivers that they must wait for a break in traffic to proceed, as the green ball is occasionally mistaken as a protected left turn. Where permitted left turns are allowed, the city is installing flashing yellow arrows when new signals are installed and when existing signals are being reconstructed.

GREEN PAVEMENT MARKINGS (24 LOCATIONS)

Note: Green pavement markings are typically used to mitigate bicycle crashes; however, the use of green bordered crosswalks may also be used to mitigate pedestrian crashes.

Green Pavement Markings at Locations with High Risk of Right-Hook Conflicts (Six Locations)

- Effective

Green Pavement Markings at Locations with High Risk of Right- or Left-Turn Conflicts (Eight Locations)

- Effective

Green Boarded Crosswalks (10 Locations)

- Effective

Systemwide

- Effective

Recommendation

Historically, the city has installed green pavement markings for both travel safety and travel comfort. It is challenging to evaluate specific bicycle crash trends that have statistical relevance as the bicycle crash numbers in the studied time period are relatively low. After addressing high bicycle crash locations that would be mitigatable by using green pavement markings, the Transportation Division recommends increasing the installation of green pavement marking improvements on corridors where overrepresented bicycle crash types are occurring (proactive approach). Systemwide, there has been a significant decrease in bicycle crashes where green pavement markings have been installed.

RIGHT-TURN BYPASSES (SIX LOCATIONS)

State Law Signs and Yield Signs/Markings (Four Locations)

- Vehicle
    - Effective
- Bicycle/Pedestrian
    - Effective

Stop Sign and Yield Signs/Markings (One Location)

- Vehicle
    - Effective
- Bicycle/Pedestrian
    - Effective

Merge Sign and Yield Signs/Markings (One Location)

- Vehicle
    - Effective
- Bicycle/Pedestrian
    - NOT APPLICABLE

Recommendation

As part of the safety improvement recommendations identified in the 2016 Safe Streets Report, changes to signing and markings were made at several right-turn bypass locations. The purpose of these changes was to better inform drivers that they needed to first yield to pedestrians and bicyclist in the crosswalk and then to through-traffic. The intent of the above changes was to evaluate the effectiveness of these signs/markings and possibly establish a new signing/marking standard for right-turn bypasses that would be implemented citywide.

The city found that crashes occurring in right-turn bypasses happen mainly because the at-fault drivers are looking to their left to find a gap in through-traffic and are either striking a pedestrian or bicyclist in the crosswalk or rear-ending the vehicle in front of them that has stopped for through-traffic. Almost all rear-end crashes are occurring between a vehicle stopped past the crosswalk waiting to merge and a vehicle entering the right-turn bypass looking to their left. In addition to enhancements in signing and markings, the Transportation Division also recommends developing an educational campaign focused on the proper and safe use and operation of right-turn bypasses for all users.

Given the small sample size of right-turn bypass locations, staff recommends that the city perform a more robust crash analysis of its right-turn bypasses and develop a series of standardized signing and markings to accommodate specific crash trends at locations with similar physical characteristics.

SIGNING (THREE LOCATIONS)

No Right-Turn-on-Red (One Location)

- INCONCLUSIVE – insufficient data to make a determination (tracking)

Turning Vehicles Yield to Peds/Bikes (Two Locations)

Note: These signs are used for both right- and left-turning vehicles.

- INCONCLUSIVE – primarily installed in combination with right-/left-hook green pavement marking improvements.

Recommendation

The Transportation Division recommends continuing to install "No Right-Turn-on-Red" signing based on the city's Traffic Signal Practice's guidance and monitoring their effectiveness on a six-month recurring study period.

Continue to install "Turning Vehicles Yield to Pedestrians/Bikes" signs at locations identified as having crash trends that involve turning vehicles. Further investigation should be completed for locations that have a large opposing through volume compared to the number of left-turning vehicles and crossing pedestrians/bikes (representing a proactive effort).

Tracking Effectiveness of Travel Safety Improvements

The city continues to implement numerous safety improvements that are focused on its commitment to achieving its Vision Zero goals. The city employs a Safe Systems approach that calls for being both reactive to current crash trends at specific locations and proactive by installing best practices in locations that have not yet exhibited a crash trend but have similar roadway characteristics and conditions. The continued development of best practices, for example the Traffic Signal Practices, will better inform staff and the public about how to operate and manage the transportation system to achieve Vision Zero.

Recommendation

The city should continue to allocate significant resources to achieving its Vision Zero goals. To accurately describe the effectiveness of the variety of engineering improvements, targeted enforcement, and educational outreach campaigns, it is crucial that the city continue to strengthen the evaluation component of its 4 E's approach (Engineering, Education, Enforcement, and Evaluation).

It's important to document safety improvements for the following reasons:

1. To monitor established crash trends that are overrepresented in severe injuries and non-incapacitating injuries
2. To act proactively to potential crash trends that are overrepresented in severe injuries and non-incapacitating injuries
3. To monitor established non-injury crash trends
4. To act proactively to potential non-injury crash trends
5. To improve travel comfort and security
6. To refine operational practices

It's important that these individual improvements and programs be documented in a database that has the capability to be shared with the public both within a document and geographically through GIS mapping. Creating a tracking database will be a robust effort but critical when informing city staff and policy makers of the progress and effectiveness of the city's work to implement Vision Zero.

E. High Crash Locations

The following intersections were identified as having high numbers of crashes in one or more of the following categories:

- High number of crashes
- High percentage of crashes with severe outcome
- High percentage of crashes with a crash type that lends itself to severe injury (pedestrian, bicycle, bicycle-pedestrian, approach-turn, etc.)
- Number of bicycle crashes
- Number of pedestrian crashes
- Number of approach-turn crashes
- Number of fixed-object crashes
- Number of rear-end crashes
- Number of right-angle crashes

For each intersection, there is a description of the intersection; details about the type of significant crash trends identified; and a summary of the specific engineering, education and/or enforcement mitigation that is recommended for that location. If a category of mitigation is not listed for a particular intersection, then no mitigation for that category was recommended.

LOCATION: 30TH AND ARAPAHOE

Description: Signalized intersection of two arterial, four-lane roadways with bike lanes

Crash Trends: Between 2015 and 2017, there were 37 approach-turn crashes associated with permitted left-turn phasing. There were two crashes involving northbound bikes running the red light, two crashes involving eastbound motor vehicles running the red light, and one bike being hit by an eastbound right-turning vehicle in the bypass island crosswalk. All left-turn movements were converted to FYA displays on 9/6/2016.

Mitigation: Engineering: Change the eastbound, westbound and northbound left-turn operation in the evening off-peak plan from protected/permitted to protected-only phasing; change all approaches from permitted-only to protected/permitted phasing during low-volume free-operation. Change the start of protected-only left-turn phasing on all approaches on Sundays from 11 a.m. to 10 p.m. Upgrade all right-turn bypass islands to new signing and striping.

Enforcement: Existing red-light camera for eastbound direction. Police enforcement for northbound red-light-running (bikes were the violator in both crashes).

LOCATION: 28TH AND VALMONT

Description: Signalized intersection of a four-lane and a six-lane arterial roadway. Valmont has bike lanes and the outside lane of 28th has a shared bus/bike/right-turn lane.

Crash Trends: Between 2015 and 2017, there were 14 approach-turn crashes associated with permitted left-turn phasing, of which six were southbound left-turning and five were westbound left-turning. They are spread across all time periods with the greatest concentration in the mid-day plan. There were two red-light-running crashes, both of which likely involved westbound violations. There were also nine westbound right-turn rear-end crashes, but seven of these occurred within a small time period in one year and were most likely associated with construction in that area. All left-turn movements were converted to FYA displays in 2012.

Mitigation: Engineering: Change the southbound left-turn and westbound left-turn operation in the mid-day plan from protected/permitted to protected-only phasing.

Enforcement: Police enforcement for westbound red-light running.

LOCATION: BASELINE AND BROADWAY

Description: Signalized intersection of a six-lane arterial roadway with a second roadway which is a four-lane arterial on the east side and a two-lane collector roadway on the west side. Bike lanes are present on Baseline east of Broadway and a climbing lane is in place on Baseline west of Broadway. A multi-use path runs along the west side of Broadway and on the north and south sides of Baseline, east of Broadway.

Crash Trends: Between 2015 and 2017, there were five approach-turn crashes associated with permissive left-turn phasing. They were either eastbound or westbound left-turn crashes, and there was not a significant trend in direction or time period. There were seven red-light running crashes including three for the eastbound through movement, two for the northbound through movement and two for the southbound left-turn movement. There were 23 westbound right-turn rear-end crashes occurring in or near the right-turn bypass island. There were also several crashes involving people being hit by vehicles, including a violation of the existing eastbound right-turn-on-red restriction, a southbound right-turn-on-red conflict with a bike on the multi-use path, a bicycle illegally jaywalking in the south crosswalk, and a pedestrian being hit by a eastbound right-turn-on-green.

Mitigation: Engineering: Convert the eastbound left-turn and westbound left-turn movements from three-sections to FYA displays (which will require reconstruction of the mast arms to support the new signal heads). Provide mitigation for right-turn rear-end crashes (new signing and striping but also potential experimentation with signalization of the westbound right-turn approach). Upgrade all right-turn bypass islands to new signing and striping.

Enforcement: Police enforcement for red-light running in several directions. Consideration for future photo red-light camera deployment.

LOCATION: ARAPAHOE AND FOOTHILLS PARKWAY

Description: Signalized intersection of one four-lane arterial roadway and one six-lane arterial roadway. Multi-use paths exist on the north and south sides of Arapahoe and on the east side of Foothills Parkway. There is an underpass crossing Foothills Parkway north of Arapahoe and additional underpasses crossing Arapahoe east and west of Foothills Parkway.

Crash Trends: Between 2015 and 2017, there were 25 red-light-running crashes with the most involving a westbound-through or left-turn violator. There were also 12 northbound right-turn rear-end crashes. There was one crash involving a bicycle being hit by a right-turning vehicle in the right-turn bypass island crosswalk by a southbound right-turn vehicle. There were also 36 northbound- and southbound-through vehicle rear-end crashes that may be associated with high speeds and congestion on Foothills Parkway. There was one westbound rear-end crash that involved a DUI and had a fatal result.

Mitigation: Engineering: Upgrade all right-turn bypass islands to new signing and striping. There is a future planning project for this intersection, associated with the East Arapahoe Plan and all crash trends should be reconsidered as part of that project.

Enforcement: Police enforcement for red-light-running in all directions. Consider all directions for red-light-camera deployment. Also, both DUI and speed enforcement on Foothills Parkway to reduce severity of rear-end crashes.

LOCATION: 28TH AND JAY

Description: Signalized intersection of a two-lane arterial (28th) with another two-lane roadway (Jay), which is a minor arterial east of the intersection and a residential collector west of the intersection. Jay has bike lanes and 28th has bikeable shoulders.

Crash Trends: Between 2015 and 2017, there were 13 approach-turn crashes associated with permitted left-turn phasing, with eight of those involving a southbound left-turning vehicle. There was one crash involving a northbound motor vehicle sideswiping a bicycle in the shoulder. There was also one crash involving an eastbound left-turning vehicle sideswiping a westbound right-turning bicycle. The northbound and southbound movements were converted to FYA displays on 10/26/2017.

Mitigation: Engineering: Change the southbound left-turn operation in the mid-day and p.m.-peak plans from protected/permitted to protected-only phasing, and the a.m.-peak and evening off-peak plans from permitted-only to protected/permitted phasing.

LOCATION: 30TH AND THE DIAGONAL HIGHWAY

Description: Signalized T-intersection between a four-lane arterial roadway (Diagonal Highway) and another four-lane arterial roadway which creates a T at the intersection. The Diagonal Highway has bike lanes, and these were recently upgraded to protected bike lanes. 30th Street has bike lanes. There is also an underpass which connects the north side of the intersection to the south-east corner of the intersection. A multi-use path (Wonderland Creek) runs NE/SW through the intersection using this underpass.

Crash Trends: Between 2015 and 2017, there were seven approach-turn crashes associated with permitted left-turn phasing. All involved westbound left-turning vehicles and six of these crashes occurred during the mid-day plan.

Mitigation: Engineering: Change the westbound left-turn operation in the mid-day plan from protected/permitted to protected-only operation.

LOCATION: BASELINE AND CANYON CREEK

Description: Unsignalized T-intersection of a four-lane arterial roadway and a local roadway. Baseline has bike lanes. There is a rectangular rapid flash beacon crossing treatment on the west leg of the intersection.

Crash Trends: Between 2015 and 2017, there were five crashes in which a person was hit by a vehicle in the crosswalk and 12 crashes in which eastbound or westbound vehicles had a rear-end crash because of a vehicle stopping to yield at the crosswalk.

Mitigation: Engineering: In the short term, eliminate vegetation that may be causing sight-distance issues. In the long term, modify the crossing treatment to one less prone to crashes.

Education: "Heads Up" campaign for crosswalk safety.

Enforcement: Police enforcement for all "Heads Up" campaign violations.

LOCATION: FOLSOM AND PINE

Description: Signalized intersection of a two-lane minor arterial and a two-lane residential collector roadway. Folsom has protected bike lanes and Pine Street has bike lanes west of Folsom.

Crash Trends: Between 2015 and 2017, there were four approach-turn crashes associated with permitted left-turn phasing (one in each direction). Two of these crashes involved bikes and resulted in serious injury. There were three crashes involving red-light running. There was one eastbound and one westbound right-turn-on-red crash with a person in a crosswalk. There was also one southbound right-turn crash in which the vehicle right-hooked the southbound bike in the bike lane.

Mitigation: Engineering: In the long term, rebuild the traffic signal so that the mast arms can support FYA displays (which will also allow the use of protected/permitted and/or protected-only left-turn phasing). Reconstruct the Folsom bike lanes so that they have more traditional concrete separated protected bike lanes.

Enforcement: Police enforcement for red-light running.

LOCATION: BROADWAY AND MARINE

Description: Unsignalized intersection between a four-lane arterial roadway and a two-lane local roadway. There is a bicycle climbing lane on Broadway south of Marine. There is a multi-use path significantly east of Broadway

Crash Trends: Between 2015 and 2017, there were two northbound left-turn crashes, including one that hit a pedestrian in the west crosswalk. There were three crashes involving northbound bicycles illegally riding on the east sidewalk and being hit by vehicles. There was also one crash involving a northbound bike on the west sidewalk hitting a southbound bike turning right onto Marine.

Mitigation: Enforcement: Police enforcement of bikes riding illegally on the east sidewalk.

LOCATION: FOLSOM AND SPRUCE

Description: Unsignalized intersection of a two-lane minor arterial and a two-lane residential collector roadway. Both directions of Spruce are right-in/right-out only. Spruce has buffered bike lanes west of Folsom and Folsom has protected bike lanes. There is a rectangular rapid flash beacon crossing which connects the north and south sides of Spruce, east and west of Folsom.

Crash Trends: Between 2015 and 2017, there was one crash involving a southbound right-turning vehicle right-hooking a bicycle which caused the bicycle to lose control and hit a pole.

Mitigation: Engineering: In the long term, reconstruct the Folsom bike lanes so that they have more traditional concrete separated protected bike lanes.

LOCATION: TABLE MESA AND S. 46TH

Description: Unsignalized intersection between a four-lane arterial roadway and an unstriped local roadway. Table Mesa has bike lanes and a multi-use path on both sides of the roadway.

Crash Trends: Between 2015 and 2017, there were four rear-end crashes involving westbound left-turning and westbound-through vehicles. There is no turn lane so vehicles turning left on Table Mesa stop in the through lane. There was also one crash involving a northbound right-turning vehicle hitting a bike in the south crosswalk and one crash involving a northbound bicycle crossing Table Mesa in the roadway and being hit by a southbound left-turning motor vehicle.

Mitigation: Engineering: Because of this intersection's proximity to a nearby school, westbound left-turn movements will continue to occur here. In the short term, no action should be taken, but the crash history should be monitored, and, if crashes continue, then either the construction of a left-turn lane or a change in traffic control should be considered.

LOCATION: PEARL PARKWAY AND FRONTIER

Description: Unsignalized intersection between a four-lane arterial roadway and an unstriped local roadway. Pearl Parkway has a multi-use path on both sides of the roadway.

Crash Trends: Between 2015 and 2017, there were three crashes involving bikes being hit by turning vehicles: two in the north crosswalk and one in the south crosswalk.

Mitigation: Education: "Heads Up" campaign for crosswalk safety.

LOCATION: BROADWAY AND TABLE MESA

Description: Signalized intersection of a four-lane arterial roadway and a six-lane arterial roadway. Broadway has multi-use paths on both sides of the roadway. There is a bike climbing lane on the north side of Table Mesa, west of Broadway. Table Mesa has a multi-use path on both sides of the roadway, east of Broadway.

Crash Trends: Between 2015 and 2017, there were nine crashes associated with permitted left-turn phasing and another two crashes that may have been associated with permitted left-turn phasing (conflicting stories in the police report). All of these crashes involved southbound left-turning vehicles. There were also 22 rear-end crashes involving southbound right-turning vehicles in the right-turn bypass island. There was one crash involving a southbound right-turning vehicle hitting a bicycle in the right-turn bypass island crosswalk and one crash involving a westbound right-turning vehicle hitting a bicycle in the right-turn bypass island. There was also one crash involving an eastbound right-turning vehicle hitting a pedestrian in the south crosswalk.

Mitigation: Engineering: Change the southbound left-turn operation in the a.m.-peak, mid-day, p.m.-peak, and evening off-peak plans from protected/permitted to protected-only phasing and in the low volume free period from permitted-only to protected/permitted phasing. The southbound right-turn bypass island already has upgraded signing and striping but upgrade the signing and striping on the westbound approach to match. In the long term, potential experimentation with signalization of the right-turn approach.

LOCATION: 15TH AND BALSAM

Description: Unsignalized intersection between a two-lane residential collector and an unmarked local roadway. There is a traffic circle (speed mitigation) in the center of the intersection. Balsam has bike lanes.

Crash Trends: Between 2015 and 2017, there were four crashes involving a vehicle on Balsam running into the traffic circle. One was DUI related and the other two had to do with limited visibility for the driver (sun glare and window condensation).

Mitigation: Education: Importance of wearing sunglasses in Colorado and making sure you have good visibility in all windows before driving.

Enforcement: DUI enforcement from police on Balsam.

LOCATION: FOLSOM AND WALNUT

Description: Unsignalized intersection of a two-lane minor arterial and a two-lane residential collector roadway. Both directions of Walnut are right-in/right-out only. Both roadways have bike lanes. There is a rectangular rapid flash beacon crossing which connects the north and south sides of Walnut, east and west of Folsom.

Crash Trends: Between 2015 and 2017, there were three crashes involving a person being hit in the crosswalk by southbound-through vehicles. There was also one crash involving a bike being hit by a right-turning vehicle when riding counter-flow on the west sidewalk.

Mitigation: Education: “Heads Up” campaign for crosswalk safety.

Enforcement: Police enforcement for all “Heads Up” campaign violations.

LOCATION: 13TH AND PINE

Description: Signalized intersection of a two-lane residential collector and a two-lane local roadway. Pine has bike lanes in both directions while 13th has bike lanes north of Pine and is designated as a bike route south of Pine.

Crash Trends: Between 2015 and 2017, there was one crash associated with permitted left-turn phasing involving a southbound bike and a northbound left-turning vehicle. There was also one crash involving a southbound bike running the red light and one crash involving an eastbound right-turning vehicle right-hooking an eastbound bicycle in the bike lane.

Mitigation: Engineering: As part of the development of the 13th Neighborhood Greenway, use green pavement markings to highlight potential conflict areas.

LOCATION: 13TH AND BALSAM

Description: Four-way stop controlled intersection of a pair of two-lane local roadways. Both roadways have bike lanes.

Crash Trends: Between 2015 and 2017, there were five crashes involving bikes on 13th crossing Balsam being hit by vehicles on Balsam crossing 13th. In one case, the bike ran the stop sign. In the other four instances, all parties stopped but the vehicle failed to yield to the bicycle. There was also one crash involving a westbound motor vehicle running the stop sign and hitting a southbound motor vehicle.

Mitigation: Engineering: As part of the development of the 13th Neighborhood Greenway, use green pavement markings to highlight potential conflict areas.

LOCATION: FOLSOM AND CANYON

Description: Signalized intersection of a pair of two-lane arterial roadways. Folsom has bike lanes while Canyon has no bicycle facilities.

Crash Trends: Between 2015 and 2017, there were 10 left-turn crashes involving permitted phasing. The majority were for northbound and southbound left-turn movements, and prior changes in phasing are mitigating those crashes. There were three left-turn crashes involving eastbound or westbound left-turn movements. There were two crashes involving southbound right-turning vehicles hitting a person (one ped and one bike) in the crosswalk and one crash involving an eastbound right-turning vehicle hitting a bicycle in the crosswalk. There was also one crash involving a northbound right-turning vehicle right-hooking a northbound-through bicycle in the bike lane.

Mitigation: Engineering: Changes to protected-only left-turn phasing during peak periods for the northbound and southbound left-turn movements have already been implemented to address crash trends on those movements. No other changes in signal timing are proposed. There are existing green pavement markings intended to mitigate right-hook crashes on Folsom. Coordinate any changes in green pavement markings to ensure installation at this location.

LOCATION: 30TH AND COLORADO

Description: Signalized intersection of a pair of two-lane arterials. Both roadways have bike lanes and there is a multi-use path on the north side.

Crash Trends: Between 2015 and 2017, there were seven left-turn crashes associated with permitted phasing, including three southbound left-turn crashes which occurred during the mid-day plan. There were five crashes involving right-turning vehicles right-hooking bicycles in the bike lanes. There was one in each direction except for northbound which had two.

Mitigation: Engineering: Change the southbound left-turn operation in the mid-day plan from permitted-only to protected/permitted phasing. There are existing green pavement markings intended to mitigate the right-turn-hook crash trend. Additional mitigation for right-hook crashes should occur when this intersection is reconstructed as a protected intersection in 2020.

LOCATION: BROADWAY AND UNIVERSITY

Description: Signalized intersection of a four-lane arterial roadway and a two-lane collector roadway. University has bike lanes while Broadway has a multi-use path on the east side of the roadway.

Crash Trends: Between 2015 and 2017, there were eight left-turn crashes involving permitted phasing, with five of the crashes occurring in the northbound direction and three of those crashes occurring during the p.m.-peak plan. There were also three crashes involving a northbound right-turning vehicle hitting a bicycle in the right-turn bypass island crosswalk.

Mitigation: Engineering: Convert the northbound and southbound movements from five-section displays to FYA displays. Upgrade the northbound right-turn bypass island to new signing and striping.

LOCATION: 28TH AND COLORADO

Description: Signalized intersection of a pair of four-lane arterial roadways. Colorado has bike lanes while 28th has a frontage road on the east side which includes bicycle lanes and a transit queue jump facility for northbound buses.

Crash Trends: Between 2015 and 2017, there were five eastbound left-turn crashes associated with permitted phasing, with the majority during the p.m.-peak period. There were seven westbound left-turn crashes associated with permitted phasing, with the majority of those during the mid-day and p.m.-peak periods. There were also five crashes involving eastbound right-turning vehicles right-hooking bikes in the bike lane as they turned onto the 28th Street frontage road.

Mitigation: Engineering: Change the eastbound left-turn operation in the p.m.-peak plan from protected/permitted to protected-only phasing and change the westbound left-turn operation in the mid-day and p.m.-peak plans from protected/permitted to protected-only phasing. These changes will require the conversion of the eastbound and westbound movements from five sections to FYA displays, which will necessitate a rewiring of this complex intersection. Previous green pavement markings placed at the right turn onto the 28th Street frontage road have helped mitigate that crash trend, but additional improvement is expected from concrete separation that is being constructed in a future 28th and Colorado capital project (Colorado Corridor Study).

LOCATION: PEARL PARKWAY AND FOOTHILLS PARKWAY (WEST RAMP)

Description: Signalized intersection of a four-lane arterial roadway and the on- and off-ramps of a perpendicular four-lane arterial roadway. Pearl Parkway has multi-use paths on both sides of the roadway.

Crash Trends: Between 2015 and 2017, there were 28 southbound right-turn rear-end crashes with the majority associated with vehicles stopping in a short acceleration lane as they seek to merge into traffic and being rear-ended by another vehicle seeking to do the same. There were also nine westbound left-turn crashes associated with permitted phasing, with the majority during the mid-day and p.m.-peak periods.

Mitigation: Engineering: Change the westbound left-turn operation in the mid-day and p.m.-peak plans from protected/permitted to protected-only phasing, which will require converting the westbound movement from five-section displays to FYA displays. Experiment with signalizing the southbound right-turn approach (may need to remove the raised crossing on the right-turn bypass island).

LOCATION: PEARL PARKWAY AND FOOTHILLS PARKWAY (EAST RAMP)

Description: Signalized intersection of a four-lane arterial roadway and the on- and off-ramps of a perpendicular four-lane arterial roadway. Pearl Parkway has multi-use paths on both sides of the roadway.

Crash Trends: Between 2015 and 2017, there were six eastbound left-turn crashes associated with permitted phasing, with the majority during the mid-day and p.m.-peak periods.

Mitigation: Engineering: Change the eastbound left-turn operation in the mid-day and p.m.-peak plans from protected/permitted to protected-only phasing, which will require converting the eastbound movement from five-section displays to FYA displays.

LOCATION: 30TH AND BASELINE

Description: Signalized intersection of a four-lane arterial roadway (Baseline) with another roadway which is a four-lane arterial north of the intersection and a two-lane local roadway south of the intersection (30th). Baseline has bike lanes and 30th has bike lanes north of the intersection only.

Crash Trends: Between 2015 and 2017, there were 20 eastbound left-turning crashes associated with permitted phasing with relatively high numbers in all time periods except the a.m.-peak. There were also three northbound left-turning crashes and four southbound left-turning crashes associated with permitted phasing. There were two crashes involving right-turning vehicles hitting persons in the parallel crosswalk (one northbound and one southbound). There was also one crash involving a northbound right-turn-on-red hitting a person in the perpendicular crosswalk.

Mitigation: Engineering: Several changes to signal timing at this intersection have already been made to mitigate crash trends, including changing the operation of the eastbound and southbound left-turn movements in the p.m.-peak plan from protected/permitted to protected-only phasing in 2016, changing the operation of the eastbound and southbound left-turn movements in the mid-day plan from protected/permitted to protected-only phasing in 2018, and installing a leading pedestrian interval for the northbound/southbound pedestrian movements in 2018. In addition, change the operation of the eastbound left-turn movement in the evening off-peak plan from protected/permitted to protected-only phasing, and during low volume free operation from permitted-only to protected/permitted phasing, and change the operation of the northbound left-turn movement in the p.m.-peak and evening off-peak plans from protected/permitted to protected-only phasing.

LOCATION: BROADWAY AND NORTH

Description: Signalized intersection of a four-lane arterial roadway and a two-lane local roadway. No bicycle facilities on either roadway.

Crash Trends: Between 2015 and 2017, there were six westbound left-turning crashes associated with permitted phasing, including five crashes in which a pedestrian was hit. Most of these crashes occurred during the mid-day plan.

Mitigation: Engineering: Implement a five-second leading pedestrian interval (pedestrian head-start) for the crosswalks on the north and south legs of the intersection.

LOCATION: BASELINE AND 29TH

Description: Unsignalized T-intersection of a four-lane principal arterial with a two-lane local street. Baseline has on-street bike lanes and detached/attached multi-use paths on both sides.

Crash Trends: Between 2015 and 2017, there were 17 crashes. Of the 17 crashes, the significant trend was eight crashes involving cyclists on the north multi-use path. Of the eight crashes, five were southbound right-turning vehicles colliding with an eastbound cyclist, two were southbound right-turning vehicles colliding with a westbound cyclist, and one was an eastbound left-turn vehicle colliding with an eastbound cyclist. Of the 17 crashes, five were severe. Of the five severe crashes, three involved cyclists on the north multi-use path.

Mitigation: Engineering: Standard multi-use path/unsignalized intersection crossing warning signs are currently in place. Consider narrowing 29th to reduce crossing distance and raising the crosswalk to sidewalk height to emphasize the multi-use path crossing for motorists. Review site conditions and address any sight obstructions for southbound motorists looking for eastbound cyclists. This location is currently under design as part of the city's Capital Improvement Program.

Education: Consider an educational campaign to address driver attention to cyclists on multi-use paths approaching from the right.

LOCATION: ARAPAHOE AND CONESTOGA

Description: Signalized intersection of a six-lane arterial roadway and another roadway which is an unmarked two-lane roadway to the north and a driveway to a commercial center to the south. Arapahoe has bike lanes east of the intersection and a multi-use path that runs along the north side of the roadway.

Crash Trends: Between 2015 and 2017, there were 10 left-turn crashes associated with permitted phasing, with the majority involving westbound left-turns. There was one crash involving a southbound right-turn-on-red hitting a bike in the multi-use path and two crashes involving northbound right-turn-on-red, with one hitting a pedestrian and another hitting a bicyclist illegally riding on the commercial sidewalk. There was also noted conflict between eastbound U-turning movements and both westbound-through traffic and southbound traffic illegally turning right on red.

Mitigation: Engineering: Previous mitigation at this location sought to address most crash trends, including protected left-turn phasing for the westbound left-turn during peak periods, a three-second leading pedestrian interval (pedestrian head-start) for the northbound/southbound pedestrian movements, and a no-right-turn-on-red restriction for the southbound approach. New mitigation includes additional mast arm signing for the southbound no-right-turn-on-red restriction and the placement of a new right-turn-on-red restriction for the northbound approach.

Enforcement: Police enforcement of both the northbound and southbound no-right-turn-on-red restrictions.

LOCATION: 28TH AND CANYON

Description: Signalized intersection of a six-lane arterial with another roadway which is a four-lane arterial to the west and a two-lane private roadway into a commercial center to the east. 28th has a multi-use path running along the east side of the roadway and Canyon has a multi-use path on the south side of the roadway, east of 28th only.

Crash Trends: Between 2015 and 2017, there were three southbound left-turning sideswipe crashes and two eastbound left-turning sideswipe crashes. The majority of these crashes occurred during the nighttime. There were also two red-light-running crashes involving southbound left-turning vehicles. The majority of crashes in this intersection were congestion-related rear-end crashes in the northbound, southbound and westbound directions.

Mitigation: Enforcement: Determine the feasibility of modifying existing southbound red-light running camera enforcement to enforce the southbound left-turn movement as well.

LOCATION: BROADWAY AND PENNSYLVANIA

Description: Signalized T-intersection of a four-lane arterial roadway with a one-way eastbound roadway, west of Broadway. There is a heavily used pedestrian crossing on the south leg of the intersection (connecting CU campus and the University Hill district) and no pedestrian facilities on the north leg.

Crash Trends: Between 2015 and 2017, there were three crashes involving "jaywalking" including one cyclist and two pedestrians. There were also five southbound rear-end crashes that all occurred within a few days of each other. These were likely associated with a construction project in place during that time period.

Mitigation: Enforcement: Police enforcement of "Jaywalking" at this high pedestrian crossing location.

LOCATION: FOOTHILLS AND VALMONT

Description: Signalized intersection of a four-lane arterial roadway with another arterial roadway which has three southbound lanes and two northbound lanes. There are right-turn bypass islands on all four corners. There are bike lanes on Valmont and a multi-use path on both sides of Foothills Parkway.

Crash Trends: Between 2015 and 2017, there were 31 crashes between eastbound right-turning vehicles and southbound through vehicles. These are likely the result of the changes to this intersection which repurposed southbound acceleration and deceleration lanes into a 3rd southbound through lane. There were also 19 rear-end crashes involving northbound right turning vehicles.

Mitigation: Engineering: There have been several attempts to mitigate the eastbound right-turn crash trend with signing and striping, with minimal effectiveness. Implement changes to the eastbound right-turn bypass movement, which may include construction of a new acceleration lane and/or the signalization of this movement. Potential experimentation of signalization of the northbound right-turn approach.

LOCATION: CANYON AND 15TH

Description: Signalized intersection of a four-lane arterial roadway and a two-lane local roadway. 15th is a designated bicycle route.

Crash Trends: Between 2015 and 2017, there were a total of 30 crashes. There were three pedestrian crashes, two of which involved a northbound right-turning vehicle hitting a pedestrian when the walk phase was on, and the other with a southbound left-turning vehicle. There was no identifiable trend with the left turns.

Mitigation: Engineering: Install a leading pedestrian interval (pedestrian head start) for the northbound/southbound pedestrian movements.

LOCATION: 17TH AND WALNUT

Description: Signalized intersection of a pair of two-lane collector roadways. Walnut has bike lanes on both sides of the intersection, while 17th has bike lanes south of the intersection and is a bike route north of the intersection.

Crash Trends: Between 2015 and 2017, there were eight crashes. There were two pedestrian crashes and two bike crashes that all resulted in injuries, two of which were severe. There were no trends at this specific intersection, as all crashes were different movements and behaviors. There was one westbound vehicle crash due to sun glare, a pedestrian crash involving a skateboard, and a bicycle crash due to a bicycle trying to pass a school bus.

Mitigation: Engineering: No engineering mitigations are proposed at this time since no mitigatable trends were found. However, trends found in other locations (Sun glare, skateboarding safety, and school bus safety) were found in the crashes and could be a candidate location for education.

LOCATION: 28TH AND THE DIAGONAL HIGHWAY/IRIS

Description: Signalized intersection of two arterial roadways. 28th is a six-lane arterial, with the outside lanes being shared bus, bike and right-turn only lanes. The Diagonal Highway on the east side of the intersection has two approach lanes and three departure lanes, as well as a curb protected bike lane and multi-use path. Iris Avenue on the west side is a four-lane arterial with bike lanes.

Crash Trends: Between 2015 and 2017, there were 86 total crashes. A large majority of them were rear-end crashes in all directions. There were a 12 southbound left-turn crashes, some of which were already in protected-only timing plans. However, there were seven crashes in the evening off-peak plan. There were two bicycle crashes, one where a bicycle ran a red light, and one in which a motorist ran a red light. There was a small trend (three crashes) in which a motorist turned left in front of the bus. Due to the bus being allowed to go through or turn right, motorists were not able to tell what the bus was doing and turned in front of or into the side of the bus.

Mitigation: Engineering: Change the southbound left-turn operation in the weekday evening off-peak plan from protected/permitted to protected-only. Look at the operation of the bus and right-turn lane to determine efficiency and safety. Add to the list of locations for potential red-light-running enforcement.

LOCATION: 28TH AND ARAPAHOE

Description: Signalized intersection of two six lane arterial roadways. There are no bike lanes on any approaches but there are multi-use paths on both sides of both roadways.

Crash Trends: Between 2015 and 2017, there were 128 crashes at this intersection. 110 crashes were low injury crashes including sideswiping, overtaking, rear end, and fixed object. There were seven right angle crashes that all involved failure to yield, but none of them resulted in injury. There were seven bicycle crashes. One was in the right-turn bypass. All others were in the crosswalks. As far as trends seen in other locations, there were two right hooks and three crashes occurred when the bicyclist was riding against traffic.

Mitigation: Engineering: Signing and striping treatments on right-turn bypasses. Potentially look at funding to enhance the slope of the raised crosswalk to slow cars and increase awareness. Add to the list of locations for red-light running and distraction enforcement.

LOCATION: BASELINE AND 28TH FRONTAGE/US-36 (EAST RAMP)

Description: Signalized intersection of four-lane arterial and US-36 on/off ramps. Detached multi-use paths are present along Baseline with a north/south bicycle/pedestrian underpass just east of the intersection. There is a northbound right-turn bypass for vehicles exiting westbound US-36 heading eastbound Baseline Rd.

Crash Trends: Between 2015 and 2017, there were 35 rear-end crashes for northbound right-turning vehicles associated with the right-turn bypass showing a significant crash trend for this movement. There were three northbound right turning vehicles that struck a fixed object, mainly due to weather conditions. There were four eastbound improper lane change crashes, and one sideswipe same direction crash, two improper lane change crashes, and three rear-end crashes between vehicles turning eastbound left in the dual left-turn lanes. There were two DUI crashes both striking a fixed object, one traveling eastbound and one traveling eastbound left. There were three approach-turn crashes with no trend in any direction and one red-light running vehicle in the eastbound direction.

Mitigation: Engineering: Changes to signing and markings for the northbound right-turn bypass were installed in September/2016. Consider additional signing and striping upgrades and investigate the operational impacts of signalizing the northbound right-turn bypass.

Education: Create educational campaign centered around drivers paying attention to vehicles ahead of them who are yielding to traffic in right-turn bypasses.

LOCATION: BASELINE AND 27TH/US-36 (WEST RAMP)

Description: Signalized intersection of four-lane arterial, four-lane arterial and US-36 on/off ramps. Right-turn bypasses for vehicles traveling northbound 27th to eastbound Baseline and southbound US-36 off ramp to westbound Baseline. There are detached multi-use paths along Baseline with a bicycle/pedestrian underpass crossing the eastbound US-36 on-ramp.

Crash Trends: Between 2015 and 2017, there were 18 crashes involving southbound right-turning vehicles in the right-turn bypass. Three of these southbound right-turning crashes struck a bicycle crossing in the marked crosswalk. There was a total of eight red-light-running crashes, two of which were bicycles crossing against the light in the southbound and eastbound directions, three were vehicles traveling eastbound, two westbound (one severe injury), and one southbound. There were 20 rear-end crashes with vehicles primarily in the eastbound and westbound directions. There was a bicycle crash between a vehicle traveling eastbound against a red-light onto US-36 and a bicycle in the east crosswalk traveling north.

Mitigation: Engineering: Changes to signing and markings for the southbound right-turn bypass were installed in August/2016. Upgrade the right-turn bypass with new signing and striping and investigate the operational impacts of signalizing the southbound right-turn bypass.

Education: Create an educational campaign centered around: yielding to bicycles/pedestrians by right-turn drivers and drivers paying attention to vehicles ahead of them who are yielding to traffic in right-turn bypasses.

Enforcement: Police enforcement for eastbound red-light running.

LOCATION: 28TH AND PEARL

Description: Signalized intersection of a four-lane arterial and a six-lane arterial with the outside lane being a shared bus, bike and right-turn lane north of Pearl. 28th has a multi-use path on both sides of the roadway. Pearl has bike lanes and a multi-use path on the north side.

Crash Trends: Between 2015 and 2017, there were 59 crashes at the intersection. There were five crashes involving permitted left-turns late at night (after 10 p.m.). There were also a few crashes involving left-turns where the phasing was already protected-only (red-light running). There were four bike crashes, all with different directions and different movements (one right hook, one bicyclist entered on yellow, and two involved failure to yield for a motorist and vehicle.

Mitigation: Engineering: Change the operation of all left-turn movements during the low volume free period from permitted-only to protected/permitted phasing.

LOCATION: 28TH AND SPRUCE

Description: Unsignalized intersection of a four-lane arterial with a two-lane local street. 28th has auxiliary bus/right-turn lanes and an associated transit stop with RRFB street crossing on the north approach. Spruce Street west of the intersection has on-street bike-lanes. Detached multi-use paths are present along 28th.

Crash Trends: Between 2015 and 2017, there were eight crashes. Of the eight crashes, one was rear-end/ failure to avoid interfering with vehicle ahead crashes. There were zero severe crashes. Two crashes involving a motorist or a bus in bus lane/transit stop colliding with a southbound right-turn. One crash involved a southbound vehicle colliding with eastbound pedestrian on a motorized skateboard at the RRFB crossing. One crash involved an eastbound right-turn colliding with northbound cyclist on the west multi-use path.

Mitigation: No engineering mitigations are proposed at this time since no mitigatable trends were found.

LOCATION: 30TH AND PEARL

Description: Signalized intersection of two four-lane arterials. Eastbound and westbound Pearl have auxiliary right-turn lanes and associated bypass islands. Attached multi-use paths are present along both 30th Street and Pearl.

Crash Trends: Between 2015 and 2017, there were 78 crashes. Of the 78 crashes, 44 were rear-end/ failure to avoid interfering with vehicle ahead crashes. Of the 44 crashes – 10 eastbound (five eastbound right), 12 southbound, 12 northbound, nine westbound, one undefined. There were three severe crashes. Of the severe crashes two involved cyclists. All severe crashes were approach turn: one – eastbound left collides with westbound on yellow, one – eastbound right from incorrect lane (#2 thru lane) collides with eastbound cyclist in eastbound bike lane, one – westbound left turn during permissive operation collides with westbound cyclist in south crosswalk.

Of note, seven severe crashes occurred in proximity, but not related to the intersection. One was a fatality when a northbound vehicle collided with an eastbound pedestrian in the RRFB crossing north of Pearl. The other six involved motorists exiting driveways colliding with cyclists in bike-lanes four or on multi-use paths. Specifics related to these crash trends are addressed elsewhere in this report.

Mitigation: Engineering: Change the southbound left-turn operation in the mid-day and p.m. peak plan from protected/permitted to protected-only phasing. Change the westbound left-turn operation in the mid-day and p.m. peak plan from protected/permitted to protected-only phasing, and in the evening off-peak plan from permitted-only to protected/permitted phasing. Consider signing and striping upgrades for the eastbound right-turn bypass.

Education: Consider an educational campaign to address drivers paying attention to vehicles ahead of them in the queue at signalized intersections.

LOCATION: 9TH AND UNIVERSITY

Description: Unsignalized intersection of two two-lane collector roadways with four-way stop control at the intersection. University has bike lanes through the corridor while 9th has a bike climbing lane on the west side.

Crash Trends: Between 2015 and 2017, there were nine total crashes. Three involved a bicycle, and one involved a pedestrian. There were no trends in directions, placement, or factor. Of the bicyclist crashes, one was bicycle only, and two were car-on-vehicle. Of the two car-on-vehicle crashes, one was westbound and one was eastbound, one bicyclist ran the stop sign, and on the other one the car "didn't see him."

Mitigation: Engineering: None proposed at this time.

LOCATION: ARAPAHOE AND FOLSOM

Description: Signalized intersection of two four-lane arterials. Arapahoe Avenue transitions to a two-lane arterial west of the intersection. Folsom transitions to a two-lane arterial south of the intersection. Folsom has on-street bike-lanes. Attached multi-use paths are present along Arapahoe from Folsom east. University of Colorado campus is located south of the intersection. The corridor has significant cycling use.

Crash Trends: Between 2015 and 2017, there were 51 crashes. Of the 51 crashes, 30 were rear-end/failure to avoid interfering with vehicle ahead crashes. Of these 30 crashes 11 westbound, four northbound, 14 eastbound, one southbound. There were two DUI crashes. There was one severe crash. The severe crash was a northbound cyclist crash on icy roadway due to southbound left-turn across the cyclist path.

Mitigation: Education: Consider an educational campaign to address drivers paying attention to vehicles ahead of them in the queue at signalized intersections.

LOCATION: BASELINE AND MOHAWK

Description: Signalized intersection of a four-lane arterial roadway with a two-lane local roadway. Baseline has bollard protected bike lanes and a multi-use path on the south side of the street. There are no bicycle facilities on Mohawk.

Crash Trends: Between 2015 and 2017, there were 31 total crashes at this intersection. There were three bicycle crashes, all of which were in the south crosswalk, but involved different vehicle movements, one eastbound right, one northbound right, and one westbound left. There were two pedestrian crashes in the east crosswalk, and two immediately north of the intersection. There were nine westbound left-turn crashes, one with a bicycle (riding against traffic in the south crosswalk) and eight vehicular crashes, one of which involved an injury.

Mitigation: Engineering: A leading pedestrian interval (pedestrian head start) was installed in April of 2018 for the northbound/southbound pedestrian movements, and a FYA display was installed for the westbound left-turn in June of 2018. Staff will monitor the effectiveness of the FYA display on the crash trends. Additional short-term mitigation would be a longer Leading Pedestrian Interval. Providing protected left-turn phasing at this location would require a reconstruction of the traffic signal. No further mitigation is proposed at this time.

LOCATION: BROADWAY AND CANYON

Description: Signalized intersection of two four-lane arterial roadways with no bicycle facilities on either roadway.

Crash Trends: Between 2015 and 2017, there were 55 crashes at this intersection. There were eight total left-turn crashes, four pedestrian crashes, and two bicycle crashes, both of which involved illegal movements (SB bicyclists riding the sidewalk along Broadway). The eastbound and westbound left-turns each had three crashes suggesting mitigation. No vehicle movement met the criteria for a Leading Pedestrian Interval, although the installation of FYA displays for all left-turn movements may bring the driver's attention to the pedestrians on the corner.

Mitigation: Engineering: Convert all left-turn movements from five-section displays to FYA displays, which may require re-wiring the intersection.

LOCATION: COLORADO AND REGENT

Description: Signalized intersection of a four-lane arterial roadway with a roadway which is a collector roadway, entering the University of Colorado south of the intersection and a short local cul-de-sac north of the intersection. Colorado has bike lanes and a multi-use path on the south side of the roadway. Regent Drive has no bicycle facilities.

Crash Trends: Between 2015 and 2017, there were 61 crashes at this intersection. There were four bike or pedestrian crashes associated with the eastbound right-turn. 28 crashes involved the northbound right-turn, two involving a bicycle in the crosswalk. There were crashes in 2015 involving the westbound left-turn, and so a FYA display was installed. There were 11 crashes involving the westbound left-turn movement.

Mitigation: Engineering: Green pavement markings were installed in 2017 to mitigate the eastbound right, westbound left, and northbound right. A flashing yellow arrow was installed on the westbound left in 2015, and due to additional crashes, the movement was changed to protected-only left-turn phasing in May 2017. There was subsequently only one crash in 2017, but staff will continue to monitor. This intersection is also the site of a pilot protected intersection project which will build protected bike lanes on the south side of Colorado from Regent east to 28th. These improvements are being funded through the federal Highway Safety Improvement program.

LOCATION: FOLSOM AND TAFT

Description: Unsignalized three-legged intersection of an arterial roadway with a local roadway.

Crash Trends: Between 2015 and 2017, there were eight bicycle crashes involving bicyclists going downhill (northbound) and often at high speed. Cars were mostly making a southbound left or making a westbound right or left.

Mitigation: Engineering: In 2017 a bicycle lane and green pavement markings were installed. The city will be constructing a pedestrian crosswalk with a new median refuge island on the south leg of the intersection. Within the new median will be additional signing warning southbound drivers turning left to yield to bicycles coming down the hill.

LOCATION: FOOTHILLS PKWY AND TABLE MESA (RTD DWY)

Description: Signalized intersection of a four-lane arterial roadway with the Table Mesa Park-N-Ride driveway to the south, and the southbound Foothills Pkwy off-ramp with right-turn bypass that turns into a westbound trap lane for the westbound US-36 on-ramp. Bike lanes and a multi-use paths are present along Table Mesa. The Table Mesa Park-N-Ride is a regional transit hub that generates substantial bus volumes that utilizes this intersection.

Crash Trends: Between 2015 and 2017, there were 26 southbound right-turn rear-end crashes associated with the right-turn bypass and westbound merge lane showing a significant crash trend for this movement. There was one southbound right-turn crash that struck a bicyclist in the raised crosswalk traveling eastbound. There were 17 rear-end crashes without a trend in any direction. There were three red-light-running crashes, two westbound and one eastbound and one approach turn crash in the westbound left direction.

Mitigation: Engineering: Upgrade the right-turn bypass with new signing and striping and investigate the operational impacts of signalizing the southbound right-turn bypass.

Education: Create educational campaign centered around: yielding to bicycles/pedestrians in right-turn drivers and drivers paying attention to vehicles ahead of them who are yielding to traffic in right-turn bypasses.

LOCATION: TABLE MESA AND STANFORD

Description: Unsignalized intersection of a four-lane arterial roadway with a two-lane local roadway to the north and the King Sooper's shopping center driveway to the south. These roadways are separated by a stop-controlled center median area that straddles Bear Canyon Creek. There is an on-street bike lane and detached multi-use path for westbound Table Mesa. There is a shared vehicle/bike travel lane and detached sidewalk for eastbound Table Mesa. Sidewalks are located on both sides of Stanford.

Crash Trends: Between 2015 and 2017, there were a total of 29 crashes. The primary crash trend at this intersection is right-angle crashes between southbound vehicles exiting the median area and eastbound vehicles (nine crashes). There were four bicycle crashes: a hit and run, northbound cyclist in crosswalk vs. westbound vehicle, eastbound cyclist in north crosswalk vs. northbound vehicle, and westbound cyclist in south crosswalk vs. southbound vehicle. Other crash types occurring at this intersection include rear-ends, side swipes, and left turns. The center median area that separates the different directions of Table Mesa is making it challenging for motorists, cyclists, and pedestrians to navigate through this intersection, especially during peak periods.

Mitigation: Engineering: In the near future, the Transportation Division will begin the process of developing conceptual design alternatives to mitigate the crash trends stated above and will include a robust community engagement plan.

Education: Create educational campaign centered around vehicles yielding to bicycles/pedestrians.

Traffic Signal Practice Update: Critical Left-Turn Crash Count

These are locations that were identified during the development of the city's Traffic Signal Practices work. They met the left-turn crash threshold of three crashes in three years and were reviewed for changes in left-turn phasing.

LOCATION: 29TH AND ARAPAHOE

Description: Signalized intersection of a six-lane arterial roadway with a roadway which is the driveway access to the 29th Street mall on the north side and a two-lane local roadway on the south side. Arapahoe has a multi-use path on both sides of the roadway. 29th has a bike lane north of Arapahoe.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the eastbound approach. Between 2015 and 2017, there were four eastbound left-turning crashes (all on weekdays); two in the mid-day plan, one in the weekday p.m. peak plan, and one in the a.m. off-peak plan. The eastbound left-turn and westbound left-turn movements were converted to FYA displays in 2013.

Mitigation: Engineering: Change the eastbound left-turn operation in the mid-day plan and weekday p.m. peak plan from protected/permitted to protected-only phasing.

LOCATION: 55TH AND ARAPAHOE

Description: Signalized intersection of a six-lane arterial roadway with a four-lane arterial roadway. Arapahoe has a multi-use path on the north side of the roadway. 55th has bicycle lanes.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the eastbound approach. Between 2015 and 2017, there were four mitigatable eastbound left-turning crashes in three years: two in the mid-day plan and two in the p.m. peak plan. Subsequently, all left-turn movements were converted to FYA displays on 1/28/2018. Extended crash history review through 4/1/2019 showed two eastbound left-turning crashes since conversion to the FYA displays (one in the mid-day plan and one in the p.m. peak plan), and none to date in 2019.

Mitigation: Engineering: No signal operation changes; monitor intersection for additional eastbound left-turn crashes.

LOCATION: 28TH AND WALNUT

Description: Signalized intersection of a six-lane roadway with a two-lane private roadway providing access to adjacent commercial property. 28th has a multi-use path on both sides of the roadway. Walnut has bicycle lanes.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the southbound approach. Between 2015 and 2017, there were two southbound left-turning crashes in three years: one in the weekday a.m. peak plan and one in the weekend a.m. peak plan. All left-turn movements were converted to FYA displays on 11/22/2017. Extended crash history review through 4/1/2019 showed one southbound left-turning crash in the weekday a.m. peak plan since conversion to the FYA displays, and none to date in 2019.

Mitigation: Engineering: No signal operation changes; monitor intersection for additional westbound left-turn crashes.

LOCATION: 30TH AND CANYON

Description: Signalized intersection of a four-lane arterial roadway with a two-lane private roadway providing access to adjacent commercial property. 30th has a multi-use path on the west side and bicycle lanes. There are no bicycle facilities on Canyon.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the northbound approach. Between 2015 and 2017, there were five northbound left-turning crashes (all on weekdays); two in the mid-day plan, two in the weekday p.m. peak plan, and one in the evening off-peak plan.

Mitigation: Engineering: Convert the northbound (and southbound) left-turn movements from five-section to FYA displays (which will require the installation of additional through movement displays); monitor the intersection for additional northbound left-turn crashes.

LOCATION: 30TH AND VALMONT

Description: Signalized intersection of two four-lane arterial roadways. Both roadways have bicycle lanes.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the northbound and southbound approaches. Between 2015 and 2017, there were five mitigatable northbound left-turning crashes, all in the mid-day plan, and there were four southbound left-turning crashes, three in the p.m. peak plan and one in the evening off-peak plan.

Mitigation: Engineering: Convert all four left-turn movements from five-section to FYA displays (which will require the installation of additional through movement displays). Change the northbound left-turn operation in the mid-day plan from protected/permitted to protected-only phasing. Change the southbound left-turn operation in the p.m. peak plan from protected/permitted to protected-only phasing.

LOCATION: 17TH AND ARAPAHOE

Description: Signalized intersection of a two-lane minor arterial roadway and a two-lane collector roadway. 17th has bicycle lanes. There are no bicycle facilities on Arapahoe.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the westbound approach. Between 2015 and 2017, there were four westbound left-turning crashes; three in the evening off-peak plan and one in the weekday p.m. peak plan. The westbound left-turn movement was converted to FYA displays in 2014.

Mitigation: Engineering: Change the westbound left-turn operation in the evening off-peak plan from permitted-only to protected/permitted phasing.

LOCATION: BROADWAY AND IRIS

Description: Signalized three-legged intersection of a four-lane arterial roadway and a roadway that is east of Broadway and has two approach lanes but only one departure lane. Broadway has bicycle lanes and a multi-use path on the east side of the roadway. Iris has bicycle lanes.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the southbound approach. Between 2015 and 2017, there were seven southbound left-turning crashes (all on weekdays); four in the p.m. peak plan, two in the mid-day plan, and one on the a.m. peak plan. The southbound left-turn movement was converted to FYA displays in 2010.

Mitigation: Engineering: Change the southbound left-turn operation in the weekday mid-day plan and weekday p.m. peak plan from protected/permitted to protected-only phasing.

LOCATION: BROADWAY AND SPRUCE

Description: Signalized intersection of a four-lane arterial with a two-lane one-way arterial downtown loop roadway. Neither roadway has bicycle facilities.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the northbound approach. Between 2015 and 2017, there were three northbound left-turning crashes, all during the mid-day plan. Extended crash history review through 4/1/2019 showed only one additional northbound left-turning crash, in which a southbound through driver was cited for going around a stopping southbound through driver and causing the crash.

Mitigation: Engineering: Convert the northbound left-turn movement from five-section displays to FYA displays (which will require the installation of an additional through display and a signal controller cabinet replacement), and monitor intersection for additional northbound left-turn crashes.

LOCATION: FOOTHILLS AND COLORADO

Description: Signalized three-legged intersection of two four-lane arterial roadways. Colorado has bicycle lanes and Foothills Parkway has a multi-use path on the east side of the roadway.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the northbound approach. Between 2015 and 2017, there were six northbound left-turning crashes, four during the mid-day plan, and two during the p.m. peak plan.

Mitigation: Engineering: Convert the northbound left-turn movement from five-section displays to FYA displays. Change the northbound left-turn operation in the weekday mid-day plan and weekday p.m. peak plan from protected/permitted to protected-only phasing.

LOCATION: 63RD AND LOOKOUT

Description: Signalized intersection of a four-lane arterial roadway with a roadway which is a four-lane arterial roadway east of the intersection and a two-lane local roadway west of the intersection. Lookout has bicycle lanes east of the intersection, and 63rd has bicycle lanes north and south of the intersection.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the southbound approach. Between 2015 and 2017, there were four southbound left-turning crashes (all on weekdays); two in the p.m. peak plan, one in the mid-day plan (but in a construction zone), and one in free operation. The southbound left-turn movement was converted to FYA displays in 2010.

Mitigation: Engineering: Change the southbound left-turn operation in the weekday p.m. peak plan from protected/permitted to protected-only phasing.

LOCATION: 55TH AND PEARL PARKWAY

Description: Signalized intersection of a four-lane arterial roadway with a roadway which is a four-lane arterial south of the intersection and a two-lane arterial north of the intersection. 55th has bicycle lanes and there is a multi-use path segment on the south-east corner of the intersection which connects to underpasses east and south of this intersection.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the westbound approach. Between 2015 and 2017, there were five westbound left-turning crashes (all on weekdays); two in the weekday p.m. peak plan, two in the weekday mid-day plan, and one in the a.m. peak plan. All left-turn movements were converted to FYA displays on 5/5/2017.

Mitigation: Engineering: Change the westbound left-turn operation in the weekday mid-day and weekday p.m. peak plans from protected/permitted to protected-only phasing.

LOCATION: FOOTHILLS PARKWAY WEST RAMP AND DIAGONAL HIGHWAY

Description: Signalized intersection of an arterial roadway which has one westbound lane and two eastbound lanes, with a roadway which is the off ramp and the corresponding on-ramp to the Foothills Parkway. The Diagonal Highway has a buffered bike lane on the south side of the intersection and a curb protected bike lane on the north side of the intersection. There is also a multi-use path which runs along the south side of the Diagonal Highway. There are shoulders for the on and off-ramps to Foothills Parkway.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the westbound approach. Between 2015 and 2017, there were six westbound left-turning crashes, four in the evening off-peak plan, one in the weekday p.m. peak plan, and one in the weekday a.m. peak plan. However, only one of the crashes occurred after the 11/27/2017 conversion of the westbound left-turn movement to FYA displays, and extended crash history review through 4/1/2019 found no additional westbound left-turn crashes.

Mitigation: Engineering: No signal operation changes; monitor intersection for additional westbound left-turn crashes.

LOCATION: 28TH AND GLENWOOD

Description: Signalized intersection of a six-lane arterial roadway with the outside lane being a shared bus, bike and right-turn lane, with a two-lane local roadway. 28th has a multi-use path on both sides of the roadway.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the northbound and southbound approaches. Between 2015 and 2017, there were three northbound left-turning crashes; two in the mid-day plan (one of them on the weekend), and one in the p.m. peak plan. There were three southbound left-turning crashes; one in the mid-day plan, one in the p.m. peak plan, and one in the evening off-peak plan on a weekend.

Mitigation: Engineering: Convert the northbound and southbound movements from three-section to FYA displays (which will require a signal controller cabinet replacement). If possible, coordinate the conversion work with the reconstruction of the intersection which will replace the span-wire signal with mast arms.

LOCATION: 48TH AND ARAPAHOE

Description: Signalized intersection of a six-lane arterial with a two-lane local roadway. Arapahoe has a multi-use path on the north side of the roadway. 48th does not have any bicycle facilities.

Crash Trends: This location was identified through the Traffic Signal Practices evaluation to study potential changes in left-turn phasing in the eastbound approach. Between 2015 and 2017, there were seven eastbound left-turning crashes (all on weekdays); four in the weekday p.m. peak plan, two in the mid-day plan, and one in the weekday a.m. peak plan.

Mitigation: Engineering: Change the eastbound left-turn operation in the mid-day and weekday p.m. peak plans from protected/permitted to protected-only phasing.

F. Summary of Fatal Crashes

Year	Description
2015	No Fatal Crashes occurred in 2015.
2016	On 3/19/2016 at 6:44 p.m., a 29-year-old male pedestrian was crossing Pearl Street south to north at a point east of 28th Street and west of the mid-block flashing crosswalk. This pedestrian was hit by a motorist traveling westbound in the outside through-lane. The pedestrian was cited for crossing at other than a crosswalk.
2016	On 4/21/2016 at 1:47 p.m., an 85-year-old female pedestrian was crossing Canyon Boulevard south to north at Folsom Avenue in the east crosswalk. She was hit by a motorist making a southbound permitted left-turn. The driver failed to yield to the pedestrian in the crosswalk and was cited for Careless Driving – Causing Death.
2016	On 5/7/2016 at 11:52 p.m., a pair of vehicles stopped on westbound Arapahoe Avenue at the Foothills Parkway intersection were struck from behind by a drug- or alcohol-impaired motorist traveling at an estimated 50 mph. A 39-year-old male driving one of the struck vehicles and his passenger (a women of unknown age) were both killed. The motorist who hit them was cited for Reckless Driving.
2016	On 11/9/2016 at 8:50 p.m., a 50-year-old female pedestrian was struck in the mid-block flashing crosswalk (with the lights activated) across 30th crossing west to east, north of Pearl by a motorist traveling northbound. The motorist failed to yield to the pedestrian and was cited for Careless Driving – Causing Death.
2016	On 11/30/2016 at 5:20 p.m., a 65-year-old male cyclist was killed when he was traveling northbound and entered the crosswalk on the east side of the 28th Street and Arapahoe Avenue intersection and struck the side of a tractor trailer which was in the process of turning right onto Arapahoe Avenue. Neither the motorist nor the cyclist was cited.
2016	On 12/22/2016 at 2:22 p.m., a 58-year-old male was riding a motor scooter westbound on Baseline Road approaching 55th Street. He illegally passed to the right of motor vehicle traffic using the bike lane and then ran the red light at the 55th Street intersection, where he was struck by a motorist turning left onto 55th Street with a green arrow display. The rider of the motor scooter was cited for Passing on Right When Not Permitted.
2017	No Fatal Crashes occurred in 2017.