Accelerating Roundabout Implementation in the United States – Volume IV of VII

A Review of Fatal and Severe Injury Crashes at Roundabouts

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SEPTEMBER 2015

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

FOREWORD

Since the Federal Highway Administration (FHWA) published the first *Roundabouts Informational Guide* in 2000, the estimated number of roundabouts in the United States has grown from fewer than one hundred to several thousand. Roundabouts remain a high priority for FHWA due to their proven ability to reduce severe crashes by an average of 80 percent. They are featured as one of the Office of Safety *Proven Safety Countermeasures* and were included in the *Every Day Counts 2* campaign for Intersection & Interchange Geometrics.

As roundabouts became more common across a wide range of traffic conditions, specific questions emerged on how to further tailor certain aspects of their design to better meet the needs of a growing number and diversity of stakeholders. The substantial work performed for this project – *Accelerating Roundabout Implementation in the United States* – sought to address several of the most pressing issues of National significance, including enhancing safety, improving operational efficiency, considering environmental effects, accommodating freight movement and providing pedestrian accessibility. This work represents yet another notable step forward in advancing roundabouts in the United States.

The electronic versions of each of the seven report volumes that document this project are available on the Office of Safety website at http://safety.fhwa.dot.gov/.

Michael S. Griffith
Director
Office of Safety Technologies

NOTICE

QUALITY ASSURANCE STATEMENT

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16. Abstract
This volume is fourth in a series of seven. The other volumes in the series are: Volume I - Evaluation of Rectangular Rapid-Flashing Beacons (RRFB) at Multilane Roundabouts, Volume II – Assessment of Roundabout Capacity Models for the Highway Capacity Manual, Volume III – Assessment of the Environmental Characteristics of Roundabouts, Volume V – Evaluation of Geometric Parameters that Affect Truck Maneuvering and Stability, Volume VI – Investigation of Crosswalk Design and Driver Behaviors, and Volume VII – Human Factor Assessment of Traffic Control Device Effectiveness. These reports document a Federal Highway Administration (FHWA) project to investigate and evaluate several important aspects of roundabout design and operation for the purpose of providing practitioners with better information, leading to more widespread and routine implementation of higher quality roundabouts.

This report summarizes the review of fatal crashes at roundabouts in the United States known to the team through December 2013, along with a sample of injury crashes from the States of Washington and Wisconsin. The information summarized in this report focuses on crash characteristics and harmful events to determine whether there are elements of roundabout design practice that can be modified to reduce the likelihood of a fatality or severe injury even further. Crash types found to be overrepresented include motorcycle crashes, fixed object crashes, and crashes involving impaired driving. Attention to curb design, particularly at the interior edge of the truck apron and the splitter island; increased visibility of the intersection; and attention to the placement and protection of fixed objects have the potential to reduce fatal and severe injury crashes. Continued emphasis on driver education and enforcement is also recommended to address the large number of crashes involving impaired drivers.

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CHAPTER 1. INTRODUCTION

This report summarizes the review of fatal and injury crashes at roundabouts in the United States. A roundabout is a form of circular intersection in which traffic travels counterclockwise in the United States around a central island and in which entering traffic must yield to circulating traffic. Figure 1 illustrates the key characteristics of a modern roundabout in the United States which include a generally circular shape, yield control of entering traffic, and geometric curvature and features to induce desirable traffic speeds.[1] Splitter islands have multiple roles, which include separating entering and exiting traffic, deflecting and slowing entering traffic, and providing a pedestrian refuge. (Figure 1)

The use of roundabouts as an intersection form has grown substantially over the past 15 to 20 years. As of 2005, there were 1,035 known roundabouts in the United States. By 2013, that number had been estimated to increase to over 3,200.[2]

Past research has demonstrated a very low frequency of fatalities at roundabouts, but the research has not focused on the contributing factors of these fatalities and injuries. The information summarized in this report focuses on crash characteristics and first harmful event, as cited in available crash reports, to determine whether there are elements of roundabout design practice that can be modified to reduce the likelihood of a fatality or severe injury even further. This report covers the analysis of fatal crashes known to the team through December 2013.

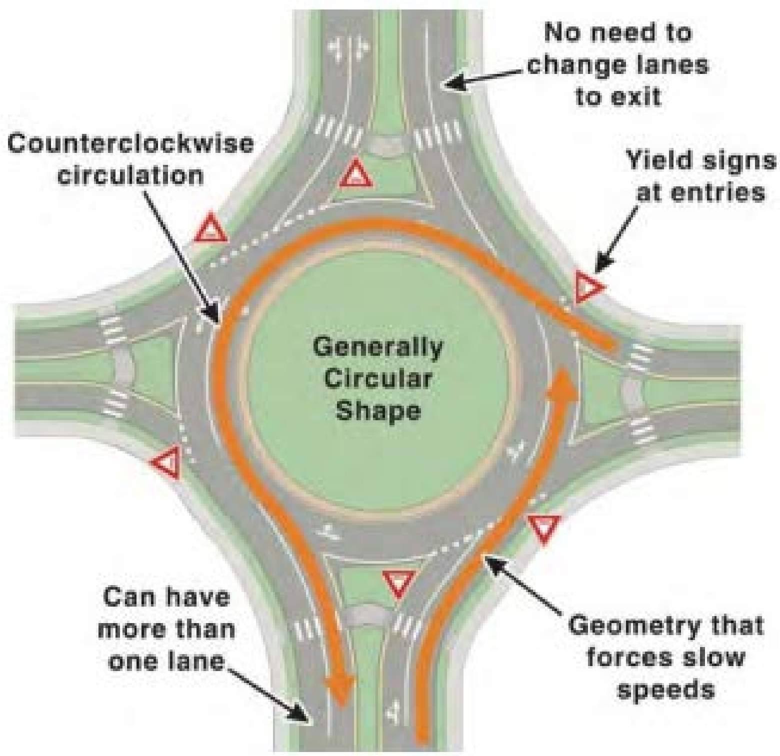

Figure 1. Diagram. Key characteristics of modern roundabouts.

The report addresses the following:

- Provides an overview of crash trends from fatal crashes at all types of intersections across the United States and corresponding crash trends from the Washington and Wisconsin Strategic Highway Safety Plans to provide potential benchmarks for comparing crashes at roundabouts.
- Summarizes the fatal crash review across the U.S.
- Summarizes injury crashes at roundabouts in the States of Wisconsin and Washington.
- Identifies key trends discovered in the analysis.
- Recommends potential strategies to address fatal and injury crash characteristics.

CHAPTER 2. NATIONAL AND STATE CRASH BENCHMARKS

National and state level benchmarks are useful points of reference to contrast the crash experience at roundabouts to other intersections and gauge whether or not there is a significant difference that could reveal an opportunity to improve safety through design modifications of roundabouts.

The research team obtained crash history statistics and information from the Fatality Analysis Reporting System (FARS) maintained by the National Highway Traffic Safety Administration (NHTSA) and Strategic Highway Safety Plans (SHSPs) produced by the States of Washington and Wisconsin. These States have been recognized for many years as leaders in roundabout implementation and have large numbers of roundabouts as compared to most other States. With this information, the research team examined the prevalence of the following crash factors or characteristics at the national and statewide levels: intersections, alcohol-involved, speed-related, time of day, fixed object involved, motorcycle-involved, bicycle-involved and pedestrian-involved.

FATAL CRASH BENCHMARKS

Fatal crash benchmarks were summarized for all fatal crashes in the United States as well as for the States of Washington and Wisconsin using the Fatality Analysis Reporting System (FARS) 2012 data.[(3)] Table 1 summarizes the number of fatalities in the United States as well as the States of Washington and Wisconsin in 2012. Table 1 also summarizes the number of fatalities that occurred at intersections in each location. Twenty-six percent of all fatalities in the United States occurred at intersections. In Washington and Wisconsin, 23 percent and 27 percent of all fatal crashes, respectively, occurred at intersections.

Table 1. Number of Fatalities in the United States in 2012.

Total Number of Fatalities in the U.S.	Number of Fatalities at Intersections in the U.S. (Percent of All Fatalities)	Total Number of Fatalities in the State of Washington	Number of Fatalities at Intersections in the State of Washington (Percent of All Fatalities)	Total Number of Fatalities in the State of Wisconsin	Number of Fatalities at Intersections in the State of Wisconsin (Percent of All Fatalities)
33,782	8,851 (26)	438	101 (23)	615	169 (27)

Table 2 summarizes the characteristics of all fatal crashes as well as fatal crashes at intersections. The summary of characteristics of fatal crashes at intersections serves as a benchmark for comparisons with characteristics of fatal crashes at roundabouts. The data summarized in Table 2 are comprehensive of all fatal crashes and includes fatal crashes that occurred at roundabouts. However, the number of fatal crashes at non-roundabout intersections is much larger than the number of fatal crashes at roundabouts, allowing this data to serve as a useful comparison.

Table 2. Summary of fatal crash characteristics.[3]

Crash Characteristic	Number of Fatal Crashes in the U.S. (Percent of All Fatal Crashes with Characteristic)	Number of Fatal Crashes at Intersections in the U.S. (Percent of All Fatal Intersection Crashes with Characteristic)	Number of Fatal Crashes in Washington (Percent of All Fatal Crashes with Characteristic)	Number of Fatal Crashes at Intersections in Washington (Percent of All Fatal Intersection Crashes with Characteristic)	Number of Fatal Crashes in Wisconsin (Percent of All Fatal Crashes with Characteristic)	Number of Fatal Crashes at Intersections in Wisconsin (Percent of All Fatal Intersection Crashes with Characteristic)
Alcohol-involved (Police Reported and/or BAC≥0.01)	10,553 (31)	1,900 (21)	158 (36)	28 (28)	229 (37)	44 (26)
Speeding-related (Non-Interstate)	8,689 (26)	1,789 (20)	137 (31)	28 (28)	192 (31)	38 (22)
Light Condition (Non-Daylight)	17,443 (52)	3,792 (43)	228 (52)	38 (38)	275 (45)	63 (37)
Fixed Objects*	10,995 (33)	937 (11)	132 (30)	17 (17)	225 (37)	28 (17)

Crash Characteristic	Number of Fatal Crashes in the U.S. (Percent of All Fatal Crashes with Characteristic)	Number of Fatal Crashes at Intersections in the U.S. (Percent of All Fatal Intersection Crashes with Characteristic)	Number of Fatal Crashes in Washington (Percent of All Fatal Crashes with Characteristic)	Number of Fatal Crashes at Intersections in Washington (Percent of All Fatal Intersection Crashes with Characteristic)	Number of Fatal Crashes in Wisconsin (Percent of All Fatal Crashes with Characteristic)	Number of Fatal Crashes at Intersections in Wisconsin (Percent of All Fatal Intersection Crashes with Characteristic)
Pedestrian	4,679 (14)	1,416 (16)	70 (16)	22 (22)	39 (6)	13 (8)
Bicyclist	736 (2)	310 (4)	14 (3)	8 (8)	10 (2)	4 (2)
Motorcycle	4,986 (15)	2,017 (23)	83 (19)	22 (22)	117 (19)	37 (22)

*Includes Pole/Post, Culvert/Curb/Ditch, Shrubbery/Tree, Guardrail/Barrier/Cushion/End, Embankment, Bridge, and Other/Unknown.

As Table 2 shows, the fatal crash statistics in Washington and Wisconsin are similar to the overall fatal crash statistics nationally with the exception of fatal crashes involving pedestrians. Fatal crashes in Wisconsin involving pedestrians accounted for only eight percent of all fatalities, while those for the state of Washington and the entire United States accounted for 22 percent and 16 percent of all fatalities respectively.

The research team conducted further review of the SHSPs for these two states to obtain additional insight on severe crashes, or those resulting in injury, in addition to the fatal crash trends.

INJURY CRASH BENCHMARKS

The Washington State and Wisconsin Strategic Highway Safety Plans were used to summarize benchmarks for all injury crashes within each state. The information summarized in this section were used as benchmarks to compare roundabout injury crash characteristics in each State.

The Washington State SHSP reviewed for this study (dated December 13, 2013)[4] identifies a number of issues related to injury and fatal crashes. The plan is based on a three-tiered prioritization system, which groups crash factors based on the number of fatalities or serious injuries that occurred between 2009 and 2011 involving that factor. Relevant Priority Level One factors include Impaired Driver(s) Involved, Run-Off-the Road Involved, Speed Involved, and Intersection Related. Priority Level Two factors include Motorcyclists and Pedestrians involved. Priority Level Three factors include Bicyclists involved. With the exception of Run-Off-Road instead of the more specific Fixed Object Involved category, these are the same crash factors noted in the fatal crash characteristics summarized in Table 2. Washington State has chosen a goal of “Target Zero” and is tracking progress toward zero fatalities by 2030.

The Wisconsin SHSP (dated September 2014)[5] identifies many of the same issues cited above. The Wisconsin SHSP identifies the state’s 10 Highest Priority Areas, which include Improve Design and Operation of Intersections, Reduce Speed-Related Crashes, Prevent/Mitigate Roadway Departure Crashes, Provide Safe Pedestrian and Bicycle Travel, Reduce Alcohol/Drug Impaired Driving, and Improve Motorcycle Safety, among others. In the SHSP, Wisconsin sets a goal to reduce the number of fatal and incapacitating injury intersection crashes by 5 percent by 2016.

Table 3 summarizes the percentage of serious injuries associated with different crash characteristics. These statistics reflect the percentage of injuries rather than the percentage of crashes. Therefore, the statistics may not be used as a direct comparison with the number of crashes since a single crash may result in multiple injuries. The statistics show similar trends in both states among injury crashes. The percentage of serious injuries resulting from intersection crashes ranged from 34 percent in Washington to 39 percent in Wisconsin. The remainder of the trends shown in the table reflects trends from all serious injuries in the State, including those that occurred at both intersections and on roadway segments. Motorcycles were involved in 16 to 17 percent of serious injuries, and impaired driving was involved in 17 to 21 percent of serious injuries. High speeds were involved in 27 to 29 percent of serious injuries, but it is unknown what percentage of these occurred at intersections. The largest difference in the trends between the two States was seen in the pedestrian and bicycle crashes. Seventeen percent of serious injuries in Washington were associated with pedestrian and bicycle crashes, while only nine percent were pedestrian- or bicycle-related in Wisconsin.

Table 3. Percentage of serious injuries by State by crash factor.

Serious Injury Crash Factors	Washington (2009 – 2011)	Wisconsin (2008 – 2012)
Intersections	34	39
Motorcycles	17	16
Impaired Driving	21	17
Speeding & Speed-related	29	27
Pedestrians & Bicycles	17	9

The information summarized in Table 2 and Table 3 was used in Chapter 3 as benchmarks to compare the crash experience at roundabouts to national and statewide trends.

CHAPTER 3. CRASH HISTORY REVIEW

This chapter presents a review of all known fatal crashes and a sample of injury crashes that occurred at roundabouts in the United States. The review of all known fatal crashes was supplemented with a review of a sample of injury crashes to increase the sample size and identify more robust trends in crash history.

FATAL CRASH REVIEW

Fatal Crash Data

The research team identified fatal crashes at roundabouts by searching through crash history data from the late 1990s to 2013. Methods of identifying crashes included FARS queries, soliciting and collecting information from the Roundabouts Listserv hosted by Kansas State University, internet search engines, professional contacts, personal experience and word of mouth. The first documented instance of a fatal crash at a roundabout in the United States occurred in the year 2001. During the early 2000s, when roundabouts were relatively new in the United States, consistent terminology regarding roundabouts was not established. Crash reports and media coverage used the terms roundabouts, traffic circles, rotaries, circular intersections, "go-arounds", and others interchangeably, despite the differences in each intersection type. The essential characteristics of roundabouts (circulating priority, entry yield control, deflection at entry, low speed, etc.) were not fully understood by those completing the reports. These discrepancies in reporting still occur, although at a smaller scale, today.

In addition to inconsistent reporting, the relative infrequency of fatal crashes at roundabouts makes capturing a comprehensive and verified list of all fatalities at roundabouts challenging. While the research team believes the effort to identify and verify the conditions and circumstances of crashes was thorough and appropriate, it is possible that other roundabout fatal crashes went unidentified because of the stated difficulties. If any fatal crashes were not identified, the number is expected to be small. The challenges of developing an accurate and comprehensive dataset of crashes at roundabouts demonstrates the need to improve crash reporting related to roundabouts to make this information more readily identifiable.

Beginning with the first known and documented roundabout fatality in 2001, the research team verified 47 fatal crashes at roundabouts through 2013, with no fatal crashes found in years 2002, 2003 and 2004. Roundabouts were relatively new in the United States prior to 2005; only 391 known roundabouts existed in the United States in 2001. By 2005, the number of known roundabouts had reached 1035, and by 2013, over 3,200 roundabouts are believed to exist in the United States. [(2)] Therefore, the analysis time period for this study was limited to 2005 through 2013, when roundabouts had become a well-established practice in several states and were increasing in numbers across the Country. Within the 2005 through 2013 study period, a total of 46 fatal crashes were known to have occurred at roundabouts and are presented for analysis in this chapter.

Characteristics of Fatal Crashes at Roundabouts

The crash reports and other information collected for the identified fatal crashes were reviewed and analyzed by the research team. The 46 fatal crashes at roundabouts occurred in 19 different States. As shown in Figure 2, there has been a general increasing trend in the number of fatal crashes at roundabouts per year starting in 2009, with the exception of 2013. Although the number of roundabouts in the United States has been increasing each year as shown in

Figure 3, there has been a general increasing trend in the rate of fatal crashes per number of roundabouts in the United States over the past five years, as shown in Figure 4.

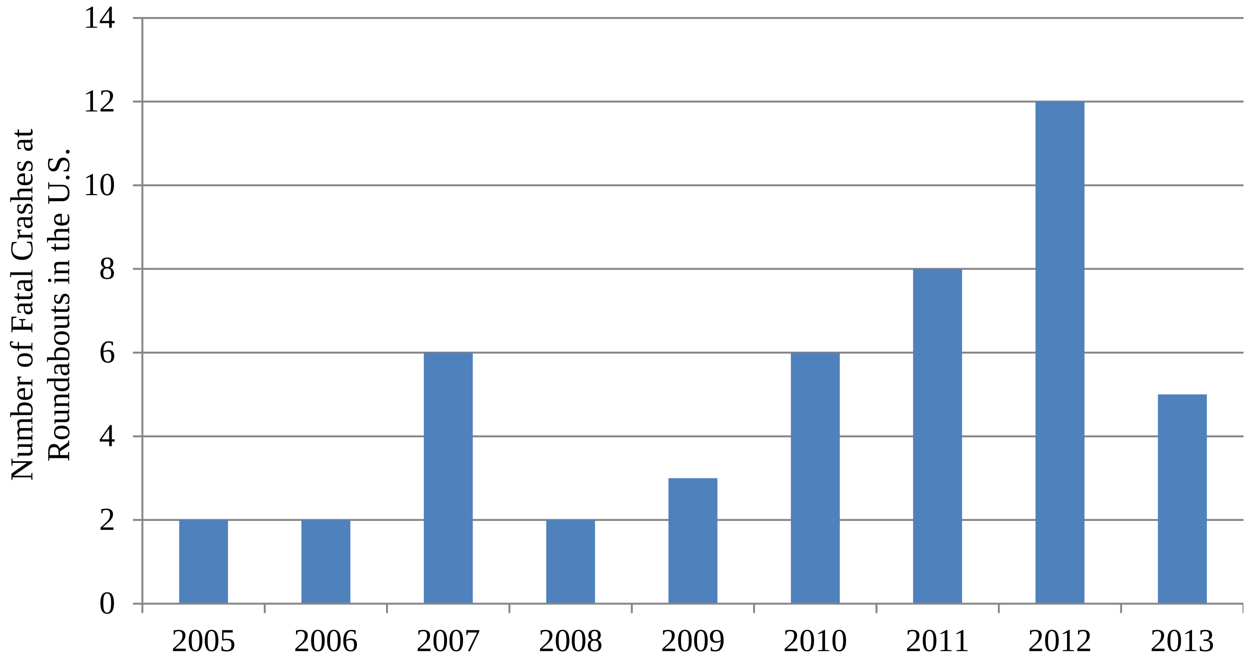

Figure 2. Chart. Number of Fatal Crashes at Roundabouts in the U.S. by Year.

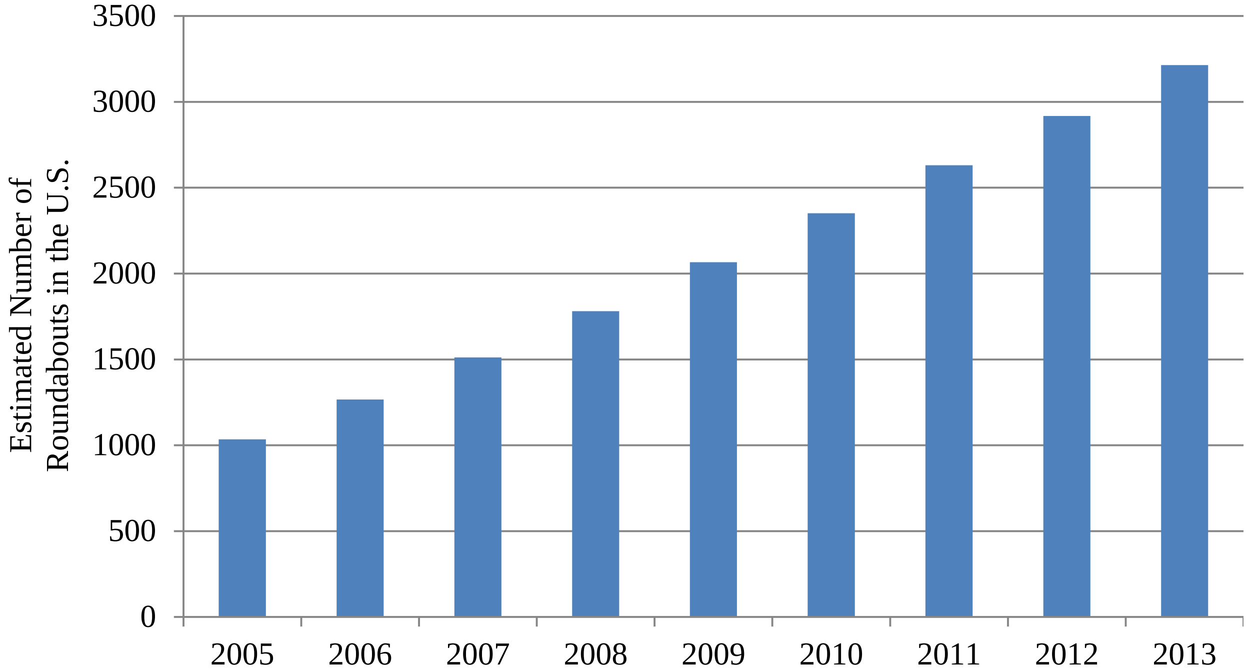

Figure 3. Chart. Estimated Number of Roundabouts in the U.S. by Year.

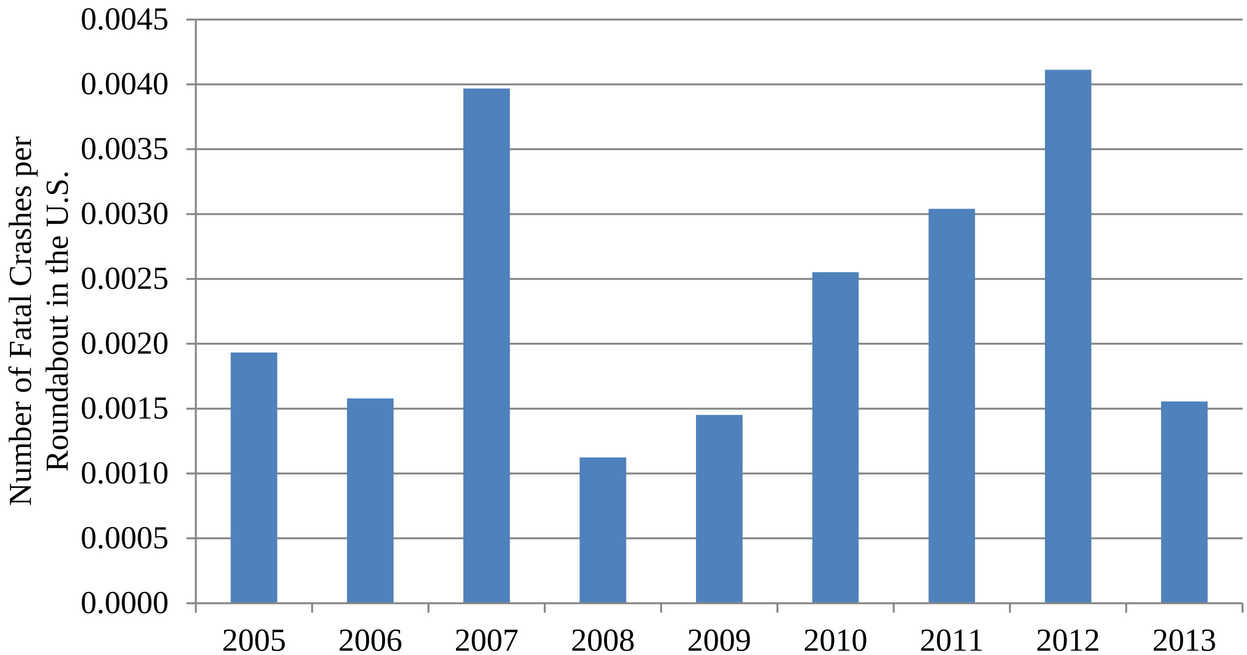

Figure 4. Chart. Estimated Number of Fatal Crashes per Roundabout in the U.S. by Year.

The statistics summarized in Table 2 in Chapter 2 were specifically examined to compare the overall experience in the roundabout fatal crashes to national and statewide levels. Table 4 summarizes the characteristics of the fatal crashes at roundabouts and compares them to the statistics of characteristics at all fatal crashes at intersections. Compared to fatal crashes at all intersections, fatal crashes at roundabouts had higher percentages of crashes that occurred during dark light conditions and crashes that involved motorcycles, speeding, impaired driving, and fixed objects. A high percentage (83 percent) of fatal roundabout crashes were single-vehicle crashes.

Of the 24 impaired driving crashes, the majority (21 crashes) were associated with alcohol impairment, with the remainder due to medical or drug impairment. Of the 26 speed-involved crashes, at least two involved vehicles exceeding 100 miles per hour (mph). Many of the motorcycle crashes at roundabouts involved loss of control and motorcycles striking curbs. Many of the fixed object crashes involved vehicles striking the splitter and central islands of roundabouts, striking curbs and sometimes other fixed objects such as sign posts, light poles, landscaping walls, boulders, and trees. At least 35 of the 39 fixed object crashes involved vehicles striking a curb. Fatal roundabout crashes were less likely to involve pedestrians or bicyclists when compared to fatal intersection crashes.

Table 4. Summary of characteristics of fatal crashes at roundabouts in the United States.

Characteristics cited in Crash Reports	Number of Crashes with Characteristic (Percent of all fatal roundabout crashes)	Number of Crashes without Characteristic or where Information Not Reported (Percent of all fatal roundabout crashes)	Percent of Fatal Crashes at All Intersections in the U.S. with Characteristic
Multiple Vehicles Involved	8 (17)	38 (83)	67
Vehicle Struck Fixed Object(s)	39 (85)	7 (15)	11
Motorcycle Involved	21 (46)	25 (54)	23
Speed Cited	26 (57)	20 (43)	20
Impaired Driving Cited	24 (52)	22 (48)	21
Bicyclist Involved	1 (2)	45 (98)	4
Pedestrian Involved	0 (0)	46 (100)	16
Light Conditions (Daylight)	20 (43)	26 (57)	57
Multilane Roundabout	13 (28)	33 (72)	N/A

Due to the relatively small number of fatal crashes, the crash review was expanded to include an analysis of injury crashes in two states. The following section explains the trends identified among these crashes.

INJURY CRASH REVIEW

The review of injury crashes was limited to reviewing crash data available from two states: Washington and Wisconsin, two states that are widely recognized as leaders in terms of the number of roundabouts. With higher numbers of roundabouts, these states' experiences are valuable in identifying injury crash trends related to roundabouts to build upon information learned from the fatal crash review.

The data analyzed includes injury crashes of all severity levels with a focus on serious injury crashes, which include those coded as A (incapacitating) and B (non-incapacitating) on the KABCO scale. Fatal crashes were excluded from the analysis. The states provided their crash data in the form of Excel databases to FHWA with permission to share the data with the research team. Crashes reviewed include crashes at roundabouts between 2001 and 2013, although the number of years included varies for each intersection based upon the opening date of the roundabout.

Due to the larger datasets for injury data in each state, data review was limited to the crash records in Excel format. Without the crash report narratives, news stories, and physical information for each site, the detailed events of each crash could not be readily ascertained. Therefore, the data summarized in this section provides insight into common trends but cannot be used to provide details of crash causes and design elements that were identified in the fatal crash review. Some of these relationships may be inferred from the trends identified.

Injury Crash Data

Washington

The database provided by the State of Washington included crashes occurring at neighborhood traffic circles in addition to roundabouts. To efficiently verify the validity of the data, crashes were geocoded using the intersection street names, highway names, and mileposts. After geocoding the crashes, each crash was given a control type to indicate whether the crash occurred at a roundabout that was included in an online database of roundabouts. Crashes that could not be verified as having occurred at a roundabout were excluded from analysis to avoid the inclusion of neighborhood traffic circles.

The original dataset included 3,990 crash records, which included all levels of severity ranging from property-damage only to fatal crashes. The research team was unable to geocode 326 crash locations. In addition, 597 of the crash locations were at locations that were not identified as roundabouts. The majority of these locations were neighborhood traffic circles. Therefore, the analysis presented in this section is based on a dataset of 3,067 crashes of all severity levels at roundabouts.

Wisconsin

Wisconsin data for the injury analysis were from data used by the Traffic Operations and Safety (TOPS) Laboratory at the University of Wisconsin-Madison in a report completed in 2011. The data include information on crashes that occurred at 34 roundabouts in Wisconsin and do not include crashes from all roundabouts in the state. Data were provided in the format of one Excel file for each intersection. These files were used in a previous study that reviewed differences in crash patterns before and after construction of the roundabout. Each file included, at a minimum, a summary table indicating the number of crashes that occurred in the three years prior to the roundabout opening and the years immediately after the roundabout opening. The year that the roundabout opened was excluded from the data to account for change in conditions during and immediately after construction.

Characteristics of Injury Crashes at Roundabouts

Similar to the fatal crash analysis, injury crash data were reviewed for the two states to further examine crash trends that may lead to opportunities to modify design practices and potentially improve roundabout safety. Because crash records differ between states, slightly different data are recorded (and in different formats) for each state. Appendix B shows the graphs that support the trends discussed in this section, as well as other trends reviewed. Comparable graphs for each state are presented consecutively to reveal similar trends for both states. In some cases, comparable data were not available for both states, or the two datasets provided similar categories, although not exactly the same.

In addition, the benchmarks summarized for each state in Chapter 2 cannot be used as a direct comparison to the crash statistics summarized in this section for two reasons: the benchmarks presented in Chapter 2 reflect the percentage of injuries rather than the percentage of crashes associated with a characteristic, and the benchmarks reflect percentages of all severe injuries in the state associated with a characteristic rather than only those injuries that occurred at intersections.

The crash data for Washington included a total of 3,067 crashes. Of these, 2,465 (80 percent) did not result in an injury and were categorized as property-damage-only, as shown in figure 9. Of the 744 crashes in the roundabout database for Wisconsin, 599 (81 percent) were property-damage only crashes, as shown in figure 10. For the purpose of this study, only crashes that resulted in an injury were included, with a focus on injury A (incapacitating injury) and B (non-incapacitating injury) crashes. Fatal crashes were excluded from the analysis because they were reviewed in the fatal crash analysis.

For many trends, one figure is presented in Appendix B to show the trend among all injury crashes, and another figure is used to show the trend among the more severe crashes, those characterized as injury A and injury B. Characteristics among severe crashes sometimes differ from those of overall crashes. For the purpose of improving safety, highest priority will be given to addressing the most severe crashes.

Table 5 summarizes the most common crash types among injury crashes at roundabouts in Washington and Wisconsin. In both states, rear-end crashes were the most common crash types among all injury crashes at roundabouts, but fixed object crashes were the most common crash types among the Injury A and B roundabout crashes. The most common objects struck at roundabouts were curbs, raised traffic islands, and raised median curbs. Crashes involving curbs were nearly 50 percent likely to involve impaired driving as a factor.

Table 5. Summary of crash type trends in injury crashes at roundabouts in Washington and Wisconsin.

Crash Type	Percentage of Injury A & B Crashes in Washington	Percentage of All Injury Crashes in Washington	Percentage of Injury A & B Crashes in Wisconsin	Percentage of All Injury Crashes in Wisconsin	Figures Illustrating Trend in Appendix B
Fixed object crashes	41	25	59	31	Figure 9 Figure 10
Rear-end Crashes	10	29	11	36	Figure 9 Figure 10

Table 6 shows that single-vehicle crashes and motorcycle crashes were common trends among the roundabout injury crashes. Single-vehicle crashes made up a higher proportion of the severe crashes as compared to all injury crashes. Impaired driving was more commonly reported in single-vehicle crashes than multiple vehicle crashes. Motorcycles were commonly involved in injury crashes at roundabouts and more likely to be severe crashes. Both motorcycles and non-motorcycles were most likely to crash upon entering the roundabout, but motorcycles were more likely to crash while circulating the roundabout than non-motorcycles. At least half of severe motorcycle crashes were single-vehicle crashes.

Pedestrians and bicyclists were involved in a small percentage of crashes, but they were more likely to be severe crashes, as shown in Table 6. Bicycles were more commonly involved in injury crashes at roundabouts than pedestrians.

Table 6. Summary of vehicle and participant type trends in injury crashes at roundabouts in Washington and Wisconsin.

Vehicle or Participant Characteristic	Percentage of Injury A & B Crashes in Washington	Percentage of All Injury Crashes in Washington	Percentage of Injury A & B Crashes in Wisconsin	Percentage of All Injury Crashes in Wisconsin	Figures Illustrating Trend in Appendix B
Motorcycles	29	17	28	13	Figure 23 Figure 24 Figure 25 Figure 26
Single-Vehicle	66	37	54	28	Figure 31 Figure 32 Figure 33 Figure 34
Pedestrians Involved	3	2	0	0	Figure 53 Figure 54 Figure 55 Figure 56
Bicyclists Involved	13	6	9	5	Figure 53 Figure 54 Figure 55 Figure 56

Table 7 shows that impaired driving was more likely to be a factor in the severe crashes, accounting for 21 percent of severe crashes at roundabouts in Washington and 13 percent of severe crashes at roundabouts in Wisconsin.

Table 7. Summary of injury crashes involving impaired driving at roundabouts in Washington and Wisconsin.

Crash Factor	Percentage of Injury A & B Crashes in Washington	Percentage of All Injury Crashes in Washington	Percentage of Injury A & B Crashes in Wisconsin	Percentage of All Injury Crashes in Wisconsin	Figures Illustrating Trend in Appendix B
Impaired Driving Involved	21	13	13	7	Figure 27 Figure 28 Figure 29 Figure 30

Light conditions and inclement weather did not appear to be key factors in the injury crashes at roundabouts, as shown in Table 8 and Table 9. The majority of injury crashes occurred in daylight. Those crashes that did occur at night commonly occurred in locations with street lights, which are common design elements with roundabouts. Inclement weather did not appear to be a factor in the majority of crashes.

Table 8. Summary of light conditions in injury crashes at roundabouts in Washington and Wisconsin.

Light Condition	Percentage of Injury A & B Crashes in Washington	Percentage of All Injury Crashes in Washington	Percentage of Injury A & B Crashes in Wisconsin	Percentage of All Injury Crashes in Wisconsin	Figures Illustrating Trend in Appendix B
Dark, With Lights	31	35	15	21	Figure 19 Figure 20 Figure 21 Figure 22
Dark, No Lights	2	2	4	2	Figure 19 Figure 20 Figure 21 Figure 22

Table 9. Summary of weather conditions in injury crashes at roundabouts in Washington and Wisconsin.

Weather Condition	Percentage of Injury A & B Crashes in Washington	Percentage of All Injury Crashes in Washington	Percentage of Injury A & B Crashes in Wisconsin	Percentage of All Injury Crashes in Wisconsin	Figures Illustrating Trend in Appendix B
Clear or partly cloudy	71	69	54	57	Figure 15 Figure 16 Figure 17 Figure 18
Overcast	16	15	30	31	Figure 15 Figure 16 Figure 17 Figure 18
Rain, snow, or other	14	16	17	12	Figure 15 Figure 16 Figure 17 Figure 18

SUMMARY OF CRASH TRENDS

This review of fatal and injury crashes revealed several similar trends. Many of these were similar to general trends seen at the state and national level, implying that they may not be specific to roundabouts. Other trends indicate factors at roundabouts that may be considered for modifications to current design practices.

Major Trends

As shown in Figure 5, the majority of fatal roundabout crashes were single-vehicle crashes. For severe injury crashes at roundabouts in Washington and Wisconsin, multiple vehicle crashes were more common, but single-vehicle crashes still accounted for over half of all roundabout crashes in each state.

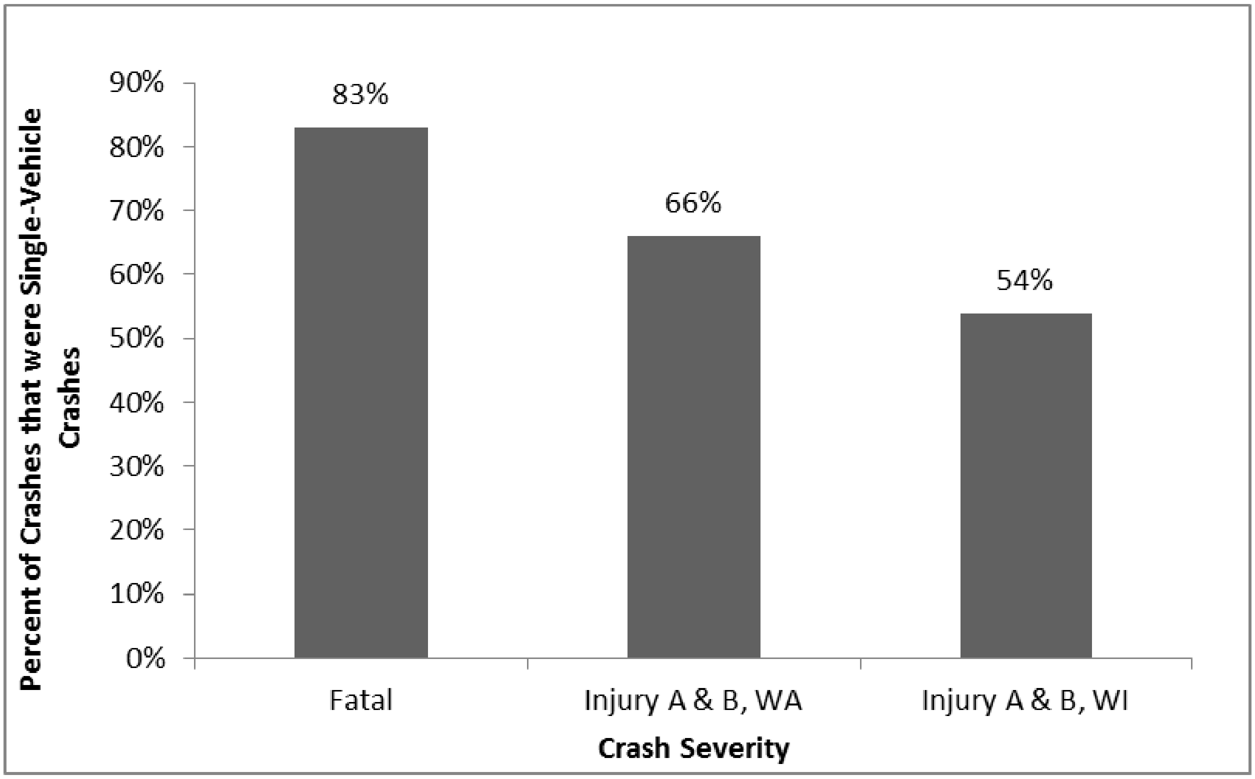

Figure 5. Chart. Percent of crashes that were single-vehicle crashes.

A relatively high percentage of crashes at roundabouts involved motorcycles. Nationally, the number of crashes involving motorcycles has been increasing in recent years. In 2012, motorcycles were involved in 23 percent of all traffic fatalities at intersections nationally. Figure 6 shows that the percentage of injury A and B crashes in Washington and Wisconsin that involved motorcycles was 29 percent and 28 percent, respectively, and 46 percent of fatal crashes involved motorcycles.

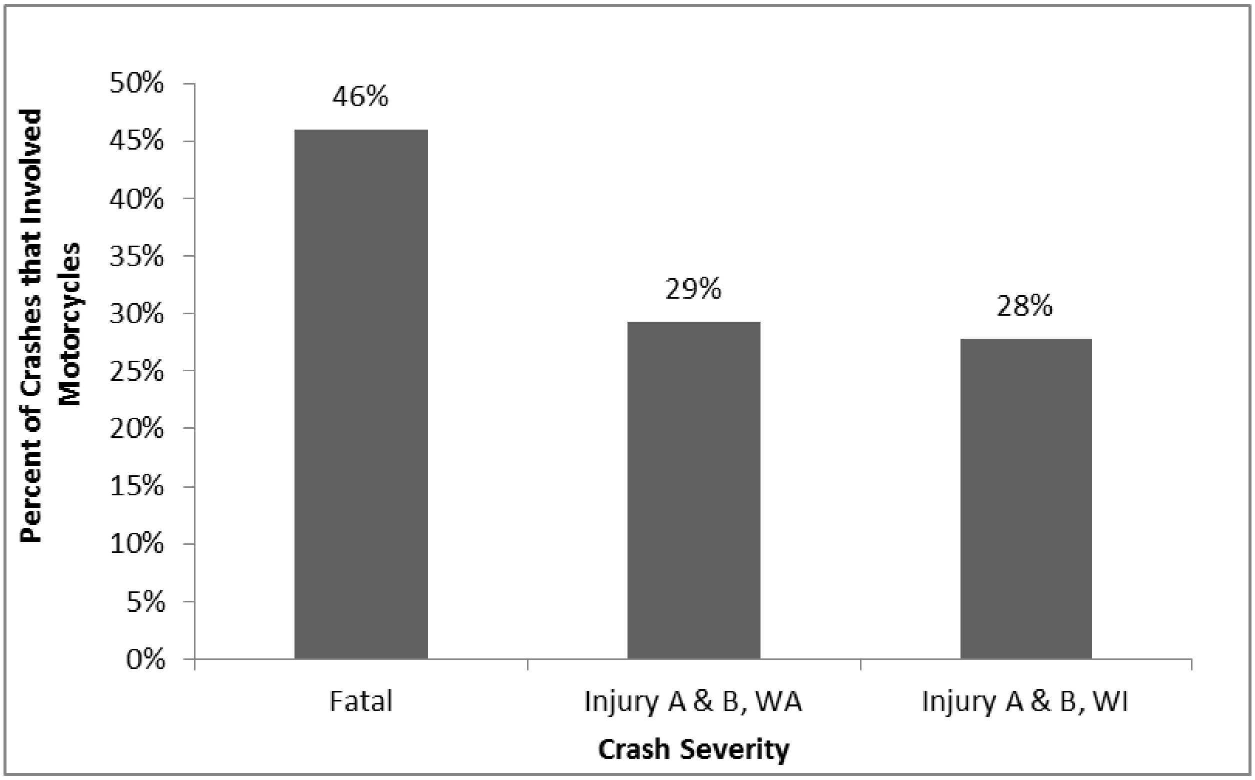

Figure 6. Chart. Percent of crashes involving motorcycles.

Many injury and fatal crashes at roundabouts involved impaired driving, as shown in Figure 7. This is a common trend nationally, as 21 percent of all traffic fatalities at intersections in 2012 involved an alcohol-impaired driver. However, this statistic is even higher for roundabouts, where alcohol-impaired drivers were involved in percent of all fatal crashes.

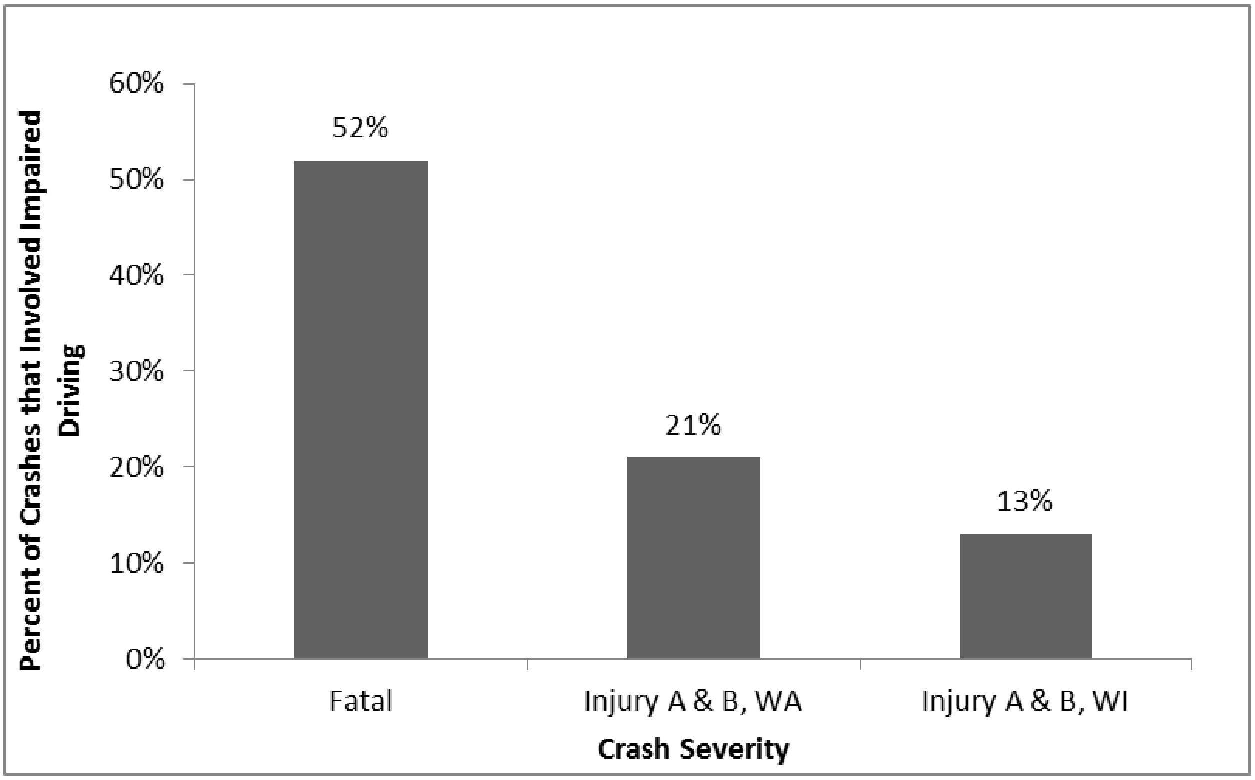

Figure 7. Chart. Percent of crashes involving impaired driving.

Fixed-object crashes, including crashes involving vehicles that hit the curb, were the most common fatal and severe injury crash type. As shown in Figure 8, many crashes involved vehicles losing control after hitting the curb, especially the back edge of the truck apron. Curbs are an important element in roundabout design. However, the design of the back edge of the truck apron may benefit from modification to reduce the likelihood of roll-overs after vehicles strike the curb.

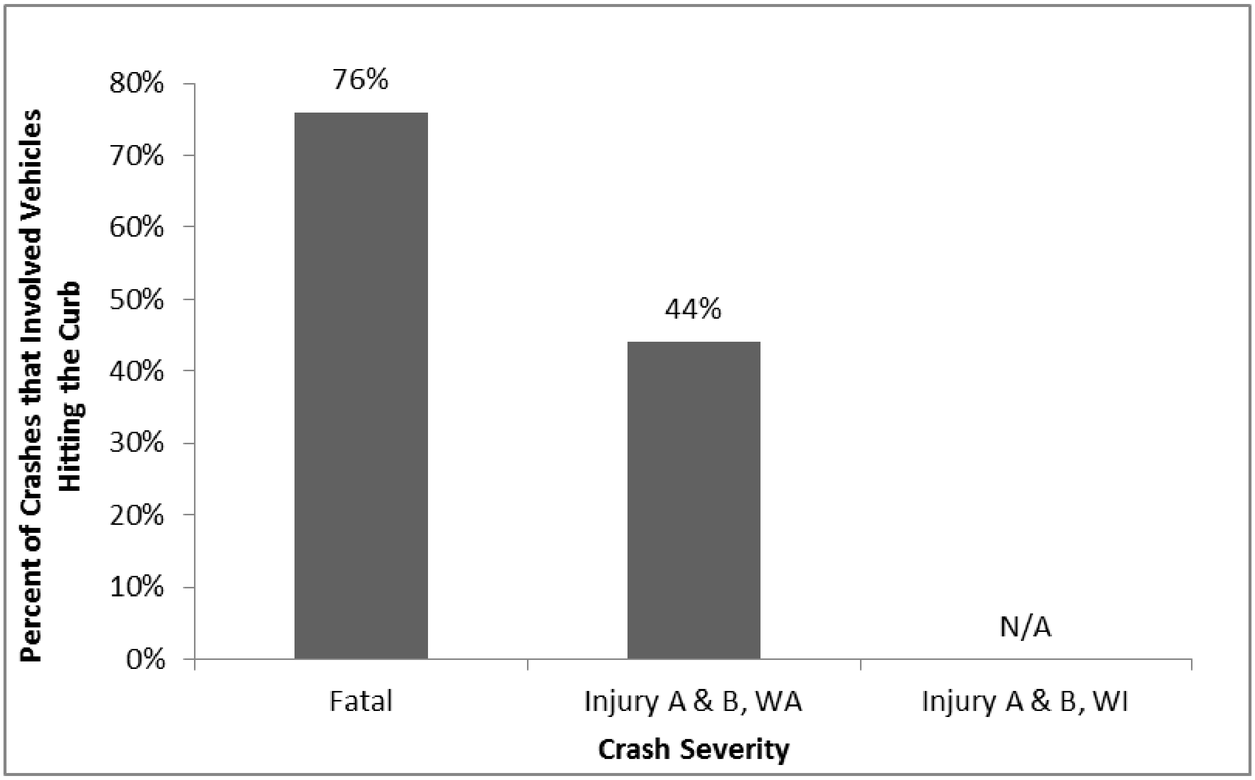

Figure 8. Chart. Percent of crashes involving vehicles hitting the curb.

Traveling at high speeds was a common contributing factor in the fatal crash reports. Speed was cited in 20 percent of fatal crashes at intersections in the U.S. in 2012, but speed was involved in at least 57 percent of fatal roundabout crashes.

Summary

Based on the trends identified in the fatal and injury crash review, several potential opportunities to improve safety at roundabouts were identified. The factors identified related to roundabout design, including curb design and placement of fixed objects, factors related to motorcycle crashes, and factors related to intersection awareness and driver education and enforcement.

Engineering, which includes roadway design, is one component that may impact safety at roundabouts. Curbs are important at roundabouts to control speeds, but the frequency of fatal crashes involving the back edge of the truck apron may indicate the need for a central island curbing design modification. Consideration of the placement of fixed objects relative to roundabouts may also reduce risk. However, some fixed objects are necessary: curbs to manage entry speed; sign posts to provide regulatory and wayfinding guidance; and street light poles to provide lighting at the roundabout.

Another common factor was motorcycle crashes. Research pertaining to roadway design to improve the safety for motorcyclists is limited. Some international research suggests that pavement treatments, entry radius at roundabouts, roadway barrier design, and fixed object placement may be considerations for accommodating motorcyclists. However, these have not been adequately tested through in-depth research studies to date.

The high number of crashes involving dark conditions, speeding, and single-vehicle crashes may indicate that drivers were unaware of approaching the roundabouts, making intersection awareness another factor, similar to other types of intersection control. A review and consideration of intersection awareness at roundabouts may be needed to determine whether opportunities exist to improve intersection awareness at roundabouts.

Many of these crashes also involved impaired drivers, and driver education and enforcement could be another factor to help reduce crashes.

Chapter 4 summarizes the recommendations that result from the findings of this study.

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

Prior research has confirmed that severe crashes, defined as crashes that result in injury or fatality, are less frequent at roundabouts than at conventional signalized and stop-controlled intersections. However, as this study has documented, some fatal and injury crashes have occurred at roundabouts. Crash characteristics and trends identified from fatal roundabout crashes throughout the United States over an extended time period, and multiple years of injury crashes from roundabouts in the states of Washington and Wisconsin, provide useful insights for both the road design and traffic safety communities. These insights have informed four categories of recommendations based on overarching themes, as follows: recommendations addressing fixed object crashes at roundabouts; recommendations addressing motorcycle crashes at roundabouts; recommendations addressing intersection visibility and conspicuity at roundabouts, and education and enforcement strategies to complement engineering recommendations. These categories capture concepts from the first three of the "Four E's" of traffic safety: engineering, enforcement, education, and emergency response.

FIXED OBJECTS

Fixed-object crash types were the most common crash types among the Injury A and B crashes at roundabouts in Washington and Wisconsin and were involved in 85 percent of fatal crashes at roundabouts. Of the 39 fatal fixed object crashes at roundabouts, 35 involved vehicles striking the curb. In some cases, multiple fixed objects were involved in a single crash. For example, a vehicle may have struck the curb first and a sign post second.

Given that roundabouts rely on effective channelization using raised features such as splitter islands and central islands, as well as on signing to communicate legal movements and right-of-way to users, some fixed objects are inherent in the design of roundabouts and must be present in the design. Other objects that were hit, such as boulders, retaining walls, trees, and landscaping, may be optional at many roundabout locations. Based on these observations, the following sections summarize recommendations made about fixed objects.

Curbs

Curbs were frequently involved in the roundabout injury and fatal crashes, and in some cases, were related to subsequent harmful events. Past research on curbs and their relationship to roadside safety hardware (NCHRP Report 537) demonstrates how varying curb characteristics produce different vehicle responses, including temporary loss of control and even overturn at higher speeds.[6] Since curbs are an essential component of roundabouts for the channelization features and functional delineation features, it is not practical to omit curbs as a roundabout design component. Splitter islands' function is to provide refuge for pedestrians, help control entry speeds, guide vehicles into the roundabout, and provide physical separation for entering and existing vehicles. Raised central islands are provided to enhance driver awareness of the approaching roundabout. [1]

Agencies and designers should review what curb types are presently used at roundabouts in their jurisdictions and consider if other curb types are available or if modifications may be made that would retain the basic advantages and functions, while reducing the potential for adverse effects.

Generally, types of curbs that feature milder sloping faces and/or less vertical height or reveal can still provide a raised channelization or delineation effect, with less potential for inducing vehicle instability. Curbs with milder sloping faces and less vertical height or reveal have also been shown to be more accommodating to a wider range of truck/freight combinations (i.e., low-clearance and/or oversize).

Rigid Fixed Objects

Thoughtful placement of fixed objects is a basic principle of proper roadside design. In 2011, the American Association of State Highway and Transportation Officials (AASHTO) published an updated Roadside Design Guide (RDG), and the revisions to Chapter 10 on Roadside Safety in Urban or Restricted Environments represented a new perspective on roadside design in lower speed and urban contexts.(7) Roundabouts share many of the characteristics discussed in this chapter of the RDG, and hence the updated guidance may be of value for roundabout design as well. In particular, as described in the RDG, it could be worthwhile to consider what may be "high risk" locations for fixed objects unique to roundabouts, given the movements of traffic approaching, circulating, and leaving the vicinity of a roundabout.

MOTORCYCLES

Motorcycles are overrepresented in severe crashes at roundabouts as compared to national and statewide trends for intersections. Addressing curbs as indicated above would likely have a positive effect for motorcycles because milder sloped curbs could reduce the adverse effects of a motorcycle impact. In addition, the evaluation of fixed object placement to minimize potential points of impact would be beneficial to motorcycles.

While wet pavement was not a significant factor identified by this analysis, it is possible that pavement-tire friction could play a role in some motorcycle crashes. Therefore, another possible mitigation strategy to consider for motorcycles and other vehicles is the documented practice from the United Kingdom to apply high friction surface treatments to roundabouts. Federal Highways Administration research has shown that high-friction surfaces have been successful in reducing crashes at intersections with curvature, frequent wet pavement, and steep grades.(8) These results indicate that high-friction surfaces may have applications at roundabouts. Further tests may be needed to determine how motorcycles perform on these surfaces before widespread implementation.

VISIBILITY AND CONSPICUITY

Dark lighting conditions, high speeds, and single-vehicle crashes were also common themes in the fatal and injury roundabout crashes. These trends may suggest that the drivers who were approaching the roundabout were unaware of the upcoming roundabout. Therefore, intersection visibility and conspicuity is another design factor that should be considered at roundabouts, particularly those in more rural locations.

As discussed in NCHRP Report 672, additional advanced illumination and changes to the roadway environment such as extending the length of splitter islands on approaches may better inform the driver of the approaching roundabout. Pavement markings and adequate advanced warning signage may also be used to inform drivers of the upcoming roundabout.

EDUCATION AND ENFORCEMENT

Many of the fatal and injury crashes at roundabouts involved impaired drivers and excessive speeds. Although roadway design is an important role in roadway safety, education and enforcement should be used in conjunction with engineering to obtain the most effective use of resources. Enhanced enforcement may be used to encourage drivers to follow the posted speed limit. Enforcement may also help keep impaired drivers off the road. Educating drivers of the proper method of driving roundabouts and the proper design speed of roundabouts may encourage them to slow down when approaching a roundabout.

ADDITIONAL RECOMMENDATIONS

The findings of this study were based on crash data from crashes that occurred at roundabouts. One of the challenges documented in Chapter 3 was the difficulty in verifying that crashes occurred at modern roundabouts rather than traffic circles or other intersection forms. Programs to educate all law enforcement staff and others who are responsible for completing crash reports about the unique characteristics of modern roundabouts would also help lead to a more accurate and comprehensive dataset of crashes at roundabouts to make information more readily identifiable in the future. Readily available data will enable future analysis and monitoring of safety trends at roundabouts to determine if design changes have impacts on safety trends.

REFERENCES

1. Rodegerdts, L., J. Bansen, C. Tiesler, J. Knudsen, E. Myers, M. Johnson, M. Moule, B. Persaud, C. Lyon, S. Hallmark, H. Isebrands, R. B. Crown, B. Guichet, and A. O'Brien. *NCHRP Report 672: Roundabouts: An Informational Guide, 2nd ed*. Transportation Research Board of the National Academies, Washington, D.C., 2010.

2. Rodegerdts, L. "Status of Roundabouts in North America." Presented at TRB 4th International Conference on Roundabouts, Seattle, Washington, April 2014.

3. *Fatality Analysis Reporting System (FARS)*. National Highway Traffic Safety Administration.

4. Washington Traffic Safety Commission. *Washington State Strategic Highway Safety Plan 2013*. http://www.wsdot.wa.gov/NR/rdonlyres/5FC5452D-8217-4F20-B2A9-080593625C99/0/TargetZeroPlan.pdf.

5. Wisconsin Department of Transportation. *Wisconsin Strategic Highway Safety Plan 2014 – 2016.* September 2014. http://www.dot.wisconsin.gov/library/publications/topic/safety/hwy-strategic-safety-plan.pdf.

6. Plaxico, C. A., M. H. Ray, J. A. Weir, F. Orengo, P. Tiso, H. McGee, F. Council, and K. Eccles. *NCHRP Report 537: Recommended Guidelines for Curb and Curb-Barrier Installations*. Transportation Research Board. Washington, DC, 2005.

7. American Association of State Highway and Transportation Officials (AASHTO). *Roadside Design Guide*. AASHTO, Washington, D.C., 2011.

8. Julian, F. and S. Moler. "Gaining Traction in Roadway Safety." *Public Roads*. Federal Highway Administration. http://www.fhwa.dot.gov/publications/publicroads/08july/05.cfm

APPENDIX A. FATAL CRASH DATA

Table 10. Fatal crash data.

#	Year	Month	Date	Time	State	City	Intersection	Type	Conditions	Lighting	Vehicles	Vehicle Type(s)	Speed Cited	Impaired Cited	Fixed Object(s) Cited
1	2005	Jan	28	1:34	FL	Del Ray Beach	Lake Ida Rd./Via Flora	Single	Clear, Dry	Dark-Lighted	1	Motorcycle	Yes	No	Curb
2	2005	Oct	30	1:52	WI	Howard	Lineville Rd./Yelp Ave.	Single	Clear, Dry	Dark-Lighted	1	Motorcycle	NR	Yes	Curb, Sign
3	2006	Apr	2	7:43	KS	Wichita	Sycamore St./ Douglas Ave.	Single	Clear, Dry	Daylight	1	Car	No	No	Curb, Object in Central Island
4	2006	Aug	12	1:37	WA	Tacoma	S. Tyler St./S. 66th St.	Single	Clear, Dry	Dark-Lighted	2	Motorcycle, Car	Yes	No	NR
5	2007	Feb	22	0:44	CO	Avon	US 6/Post Blvd.	Multi	Clear, Dry	Dark-Lighted	1	Car	Yes	Yes	Curb, Light Pole
6	2007	Mar	4	17:40	KS	Lawrence	Clinton Pkwy./Lake Pointe Dr.	Single	Clear, Debris	Daylight	1	Motorcycle	NR	No	Curb
7	2007	Jun	5	15:20	NC	Waynesville	US 23B/ Ratcliffe Cove Rd./Zemery Ln.	Single	Clear, Dry	Daylight	1	Car	No	No	Tree
8	2007	Oct	1	3:10	IN	Carmel	N. Westfield Blvd./E. 96th St.	Single	Clear, Dry	Dark-Lighted	1	Car	Yes	No	Curb, Wall in Central Island
9	2007	Oct	7	2:30	CA	Encinitas	Santa Fe Dr./ Rubenstein Ave./Devonshire Rd.	Single	Clear, Dry	Dark-Lighted	1	Pickup	Yes	Yes	Curb, Light Pole
10	2007	Oct	14	17:18	MD	Burtonsville	US 29 SB Ramps/Dustin Rd./Columbia Pike	Single	Clear, Dry	Daylight	1	Car	Yes	Yes	Curb, Roadside Wall
11	2008	Mar	13	1:30	FL	Punta Gorda	Beach Rd./Gulf Blvd.	Single	Clear, Dry	Dark-Lighted	1	Car	Yes	Yes	Curb, Fence, Tree

#	Year	Month	Date	Time	State	City	Intersection	Type	Conditions	Lighting	Vehicles	Vehicle Type(s)	Speed Cited	Impaired Cited	Fixed Object(s) Cited
12	2008	May	14	23:16	NC	Charlotte	Moore Chapel Rd./I-485 NB Ramps	Single	Clear, Dry	Dark-Not Lighted	1	Car	Yes	Yes	Curb
13	2009	Jul	23	16:23	KS	Manhattan	SR 18/Scenic Dr.	Single	Clear, Dry	Daylight	2	Motorcycle, SUV	No	No	None
14	2009	Sep	15	2:11	CA	Oxnard	N. Ventura Rd./ Forest Park Blvd.	Multi	Clear, Dry	Dark-Lighted	1	Motorcycle	NR	Yes	Curb
15	2009	Oct	15	15:26	CA	Santa Maria	McCoy Ln./South College Dr.	Single	Clear, Dry	Daylight	1	SUV	Yes	Yes	Curb, Fence
16	2010	Jan	20	21:05	KS	Macpherson	N. Centennial Dr./E. First St.	Single	Cloudy/Fog, Dry	Dark-Lighted	1	Car	Yes	Yes	Curb, Wall
17	2010	Jan	31	12:28	KS	Manhattan	Kimball Ave./Grand Mere Pkwy.	Single	Cloudy, Dry	Daylight	1	Car	No	No	Curb, Wall
18	2010	Feb	21	1:25	FL	Orlando	Yucatan Dr./Oxalis Dr.	Mini	Clear, Dry	Dark-Lighted	1	Motorcycle	Yes	No	Curb, Parked Car
19	2010	Apr	4	3:04	TN	Chattanooga	SR 153/Access Rd.	Multi	Clear, Dry	Dark-Lighted	2	Motorcycle, Car	Yes	Yes	None
20	2010	Jul	10	20:33	WI	Delton	Moon Rd./Timothy Ln.	Multi	Clear, Dry	Daylight	1	Motorcycle	Yes	Yes	Curb, Central Island, Sign Post
21	2010	Oct	28	3:25	NV	Summerlin	W. Flamingo Rd./Granite Ridge Dr.	Multi	Clear, Dry	Dark-Lighted	1	Motorcycle	Yes	Yes	Curb
22	2011	May	10	12:37	MN	New Prague	TH 19/11th Ave.	Single	Windy, Cloudy, Dry	Daylight	1	Motorcycle	No	No	Curb, Sign, Tree
23	2011	Jun	5	19:27	WI	Howard	Woodale Ave./Velp Ave.	Single	Clear, Dry	Daylight	1	Motorcycle	No	Yes	Curb

#	Year	Month	Date	Time	State	City	Intersection	Type	Conditions	Lighting	Vehicles	Vehicle Type(s)	Speed Cited	Impaired Cited	Fixed Object(s) Cited
24	2011	Jun	16	21:03	FL	Wildwood	Buena Vista Blvd./Pinellas Pl.	Multi	Clear, Dry	Dark-Lighted	2	Car, Golf Cart	No	No	None
25	2011	Jun	28	21:20	NC	Charlotte	Moore Chapel Rd./I-485 NB Ramps	Single	Rain, Wet	Dark-Not Lighted	1	Car	No	No	Guardrail
26	2011	Jun	29	16:57	IN	South Bend	US 20/Lexington Ave.	Multi	Clear, Dry	Daylight	1	Car	Yes	No	Curb, Pole
27	2011	Oct	28	1:32	NY	Hamburg	US 62/Big Tree Rd.	Single	Clear, Dry	Dark-Lighted	1	Car	Yes	Yes	Curb, Boulders
28	2011	Nov	24	19:45	GA	Douglasville	SR 5/SR 166	Single	Clear, Dry	Dark-Not Lighted	1	Minivan	NR	NR	Curb, Wall
29	2011	Dec	22	21:00	WA	Mount Vernon	SR 538/SR 9	Single	NR	Dark	2	Car (both)	No	Yes*	Curb, Light Pole, Parked Car
30	2012	Jan	1	16:33	AZ	Clarkdale	SR 89A/Valley View Rd.	Multi	Cloudy, Dry	Daylight	1	Motorcycle	Yes	Yes	Curb
31	2012	Jan	8	23:40	WI	Appleton	US 10/CH N	Single	Clear, Dry	Dark-Lighted	1	Car	Yes	Yes	Curb
32	2012	Jan	22	18:10	FL	Land O'Lakes	Connerton Blvd./Park Bench Ct.	Multi	Clear, Dry	Dark-Lighted	1	Motorcycle	No	Yes	Curb
33	2012	Jun	4	10:26	MT	Billings	Shiloh Rd./Grand Ave.	Multi	Clear, Dry	Daylight	2	Car, SUV	No	Yes*	None
34	2012	Jun	10	0:35	WI	Marinette	SR 64/CH T	Single	Clear, Dry	Dark-Lighted	1	Car	Yes	Yes	Boulder, Tree
35	2012	Jun	10	19:56	CA	Ripon	N. Ripon Rd./River Rd.	Single	Clear, Dry	Daylight	1	Motorcycle	Yes	Yes	Curb, Pole
36	2012	Jun	20	20:41	MI	Clinton	Cass Ave./Romeo Plank Rd.	Multi	Clear, Dry	Daylight	1	Motorcycle	No	Yes*	Curb

#	Year	Month	Date	Time	State	City	Intersection	Type	Conditions	Lighting	Vehicles	Vehicle Type(s)	Speed Cited	Impaired Cited	Fixed Object(s) Cited
37	2012	Jun	30	2:12	FL	Fleming Island	Town Center Blvd./East-West Pkwy.	Single	Clear, Dry	Dark-Not Lighted	1	Car	Yes	Yes	Sign, Tree, Utility Pole
38	2012	Aug	23	6:09	FL	Jacksonville	Huffman Blvd./Walle Dr.	Single	Clear, Dry	Daylight	1	Motorcycle	No	No	None
39	2012	Nov	21	23:15	LA	Lafayette	SR 93/SR 98	Single	Clear, Dry	Dark-Not Lighted	1	Motorcycle	Yes	NR	Curb
40	2012	Nov	24	14:55	CA	Truckee	Donner Pass Rd./McIver Crossing/ Lincoln Hwy	Single	Clear, Dry	Daylight	2	Bicycle, Car	No	No	None
41	2012	Dec	1	0:42	AZ	Chino Valley	SR 89/Outer Loop Rd.	Multi	Clear, Dry	Dark-Lighted	1	Pickup	Yes	Yes	Curb
42	2013	May	1	12:13	AZ	Salome	US 60/ Vicksburg Rd.	Single	Clear, Dry	Daylight	2	Pickup, Semi-Truck	No	No	Curb, Sign, Vehicle
43	2013	Aug	11	2:09	NY	Hamburg	US 62/Big Tree Rd.	Single	Clear, Dry	Dark-Lighted	1	Motorcycle	Yes	Yes	Curb
44	2013	Aug	29	18:22	WI	New Berlin	I-43 NB Ramps/CH Y	Multi	Clear, Dry	Daylight	1	Motorcycle	No	Yes	Curb
45	2013	Sep	1	13:43	OR	Newberg	N.Springbrook Rd./ E.Crestview Dr.	Single	Clear, Dry	Daylight	1	Motorcycle	Yes	No	Curb
46	2013	Dec	10	1:16	FL	Gainesville	SW 24th Ave./SW 38th Terr.	Single	Cloudy, Dry	Dark-Lighted	1	Car	Yes	Yes	Curb, Sign, Tree

APPENDIX B: INJURY CRASH DATA TRENDS

INJURY SEVERITY

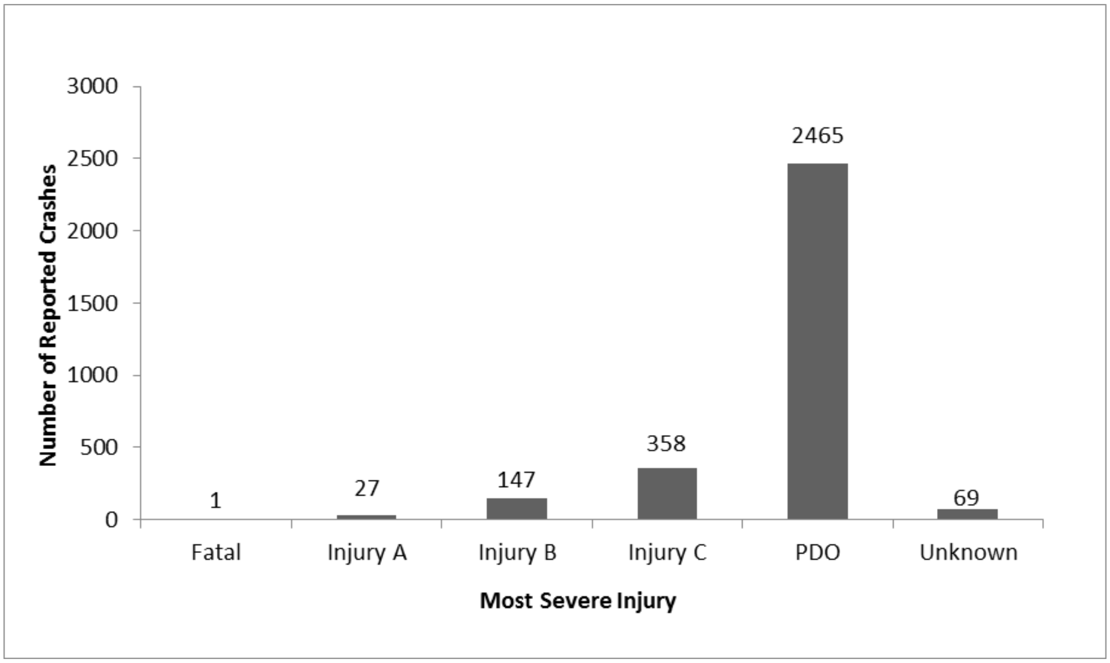

Figure 9. Chart. Number of crashes by injury severity, Washington; "PDO" stands for "property damage only."

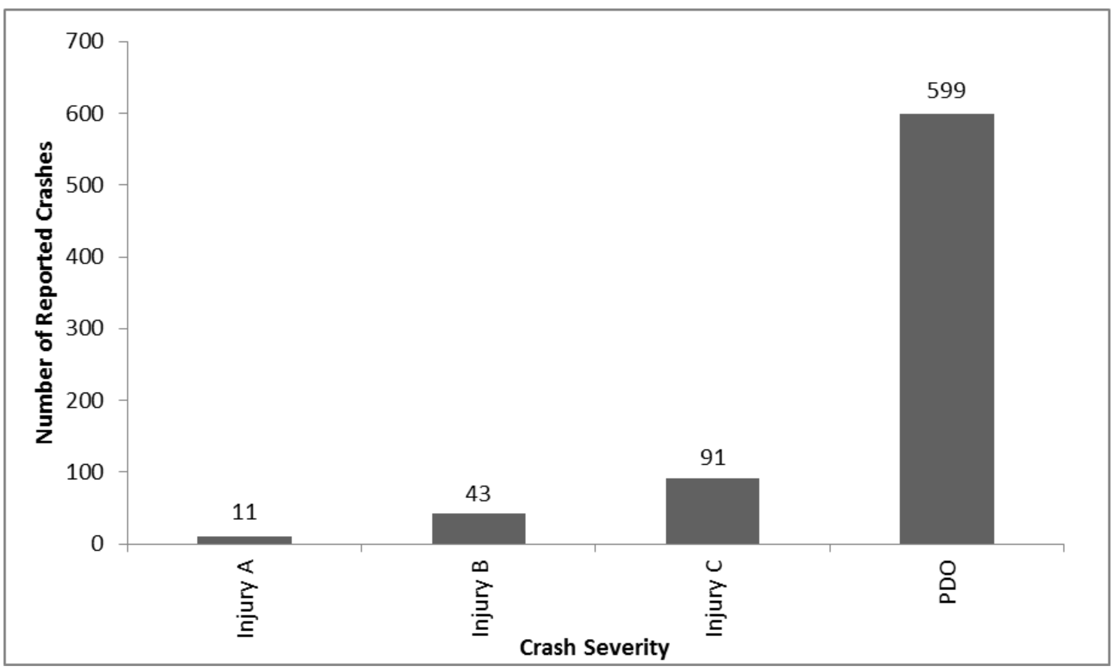

Figure 10. Chart. Number of crashes by injury severity, Wisconsin. "PDO" stands for "property damage only."

TIME OF DAY

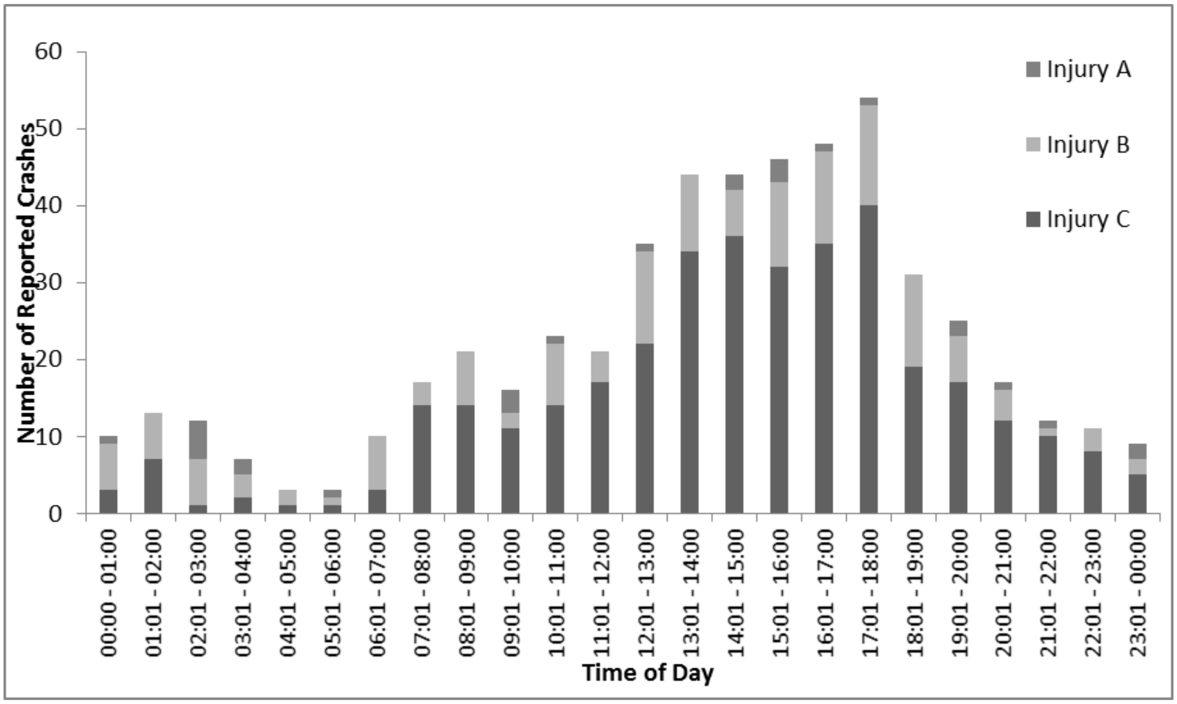

Figure 11. Chart. Time of day for all injury crashes, Washington.

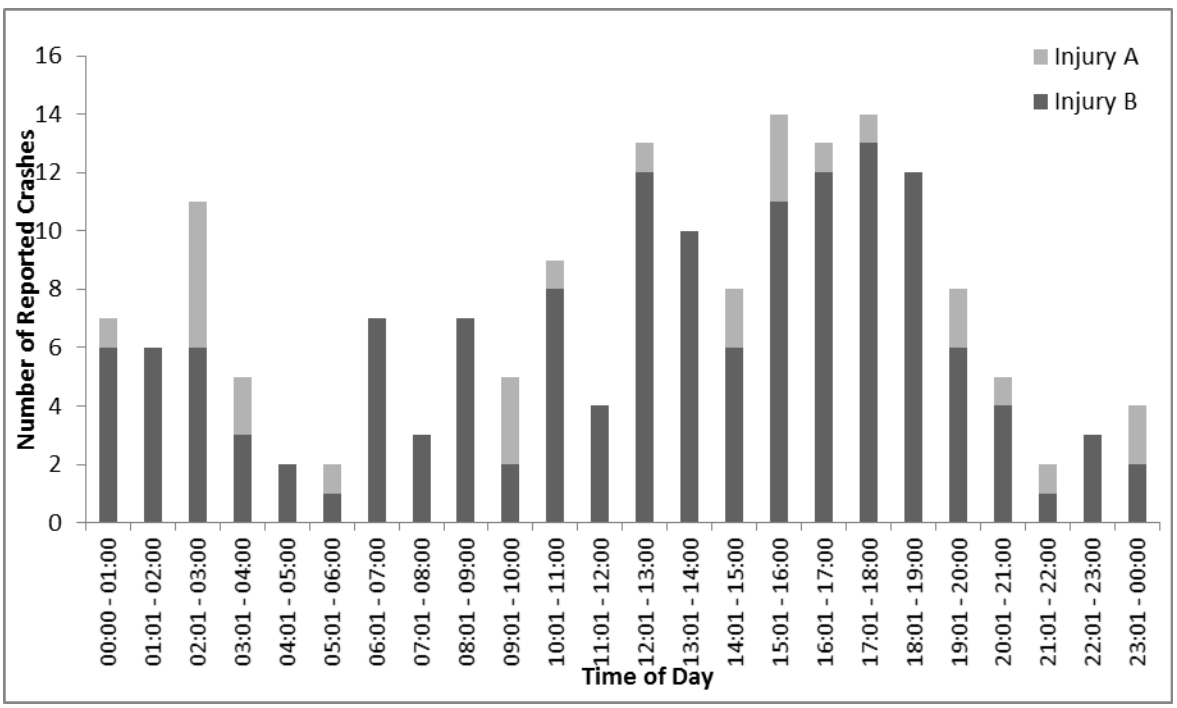

Figure 12. Chart. Time of day for injury A and B crashes, Washington.

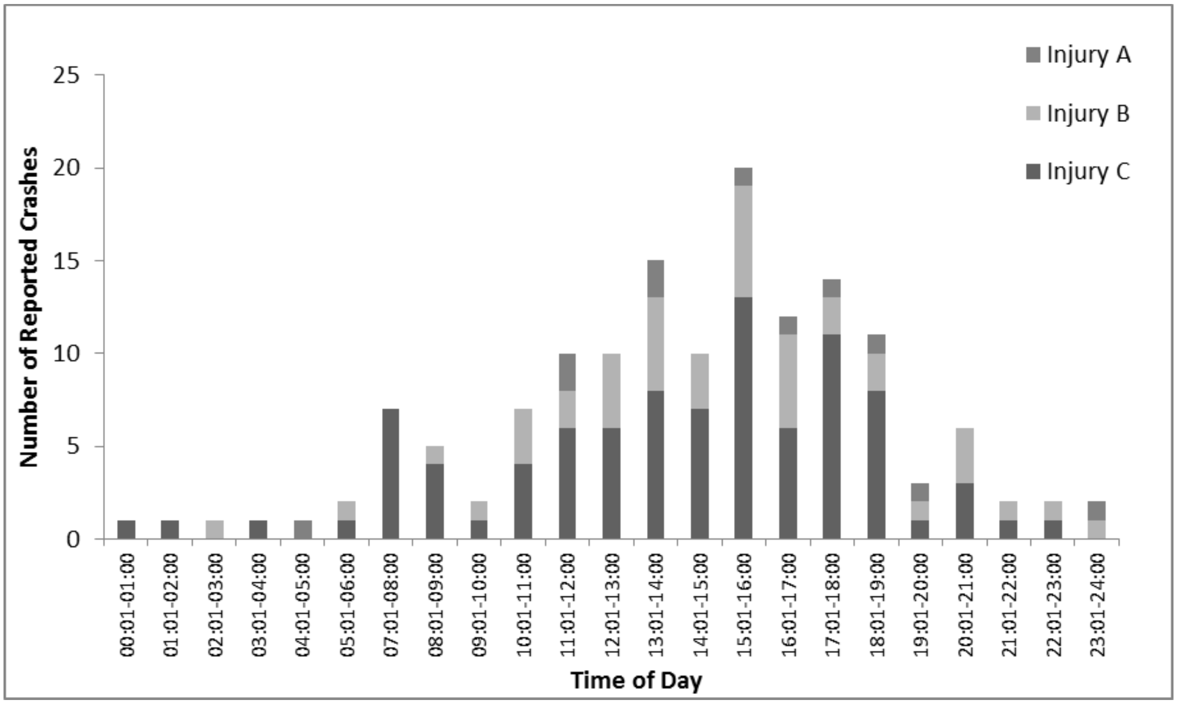

Figure 13. Chart. Time of day for all injury crashes, Wisconsin.

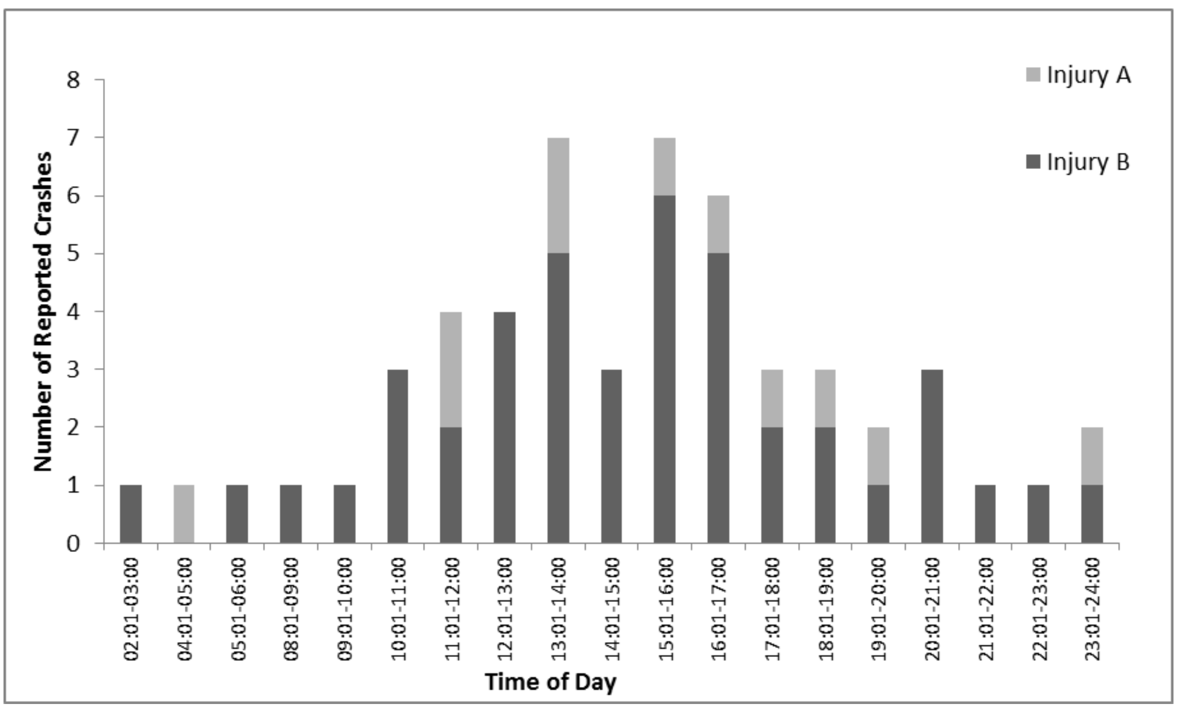

Figure 14. Chart. Time of day for injury A and B crashes, Wisconsin.

WEATHER

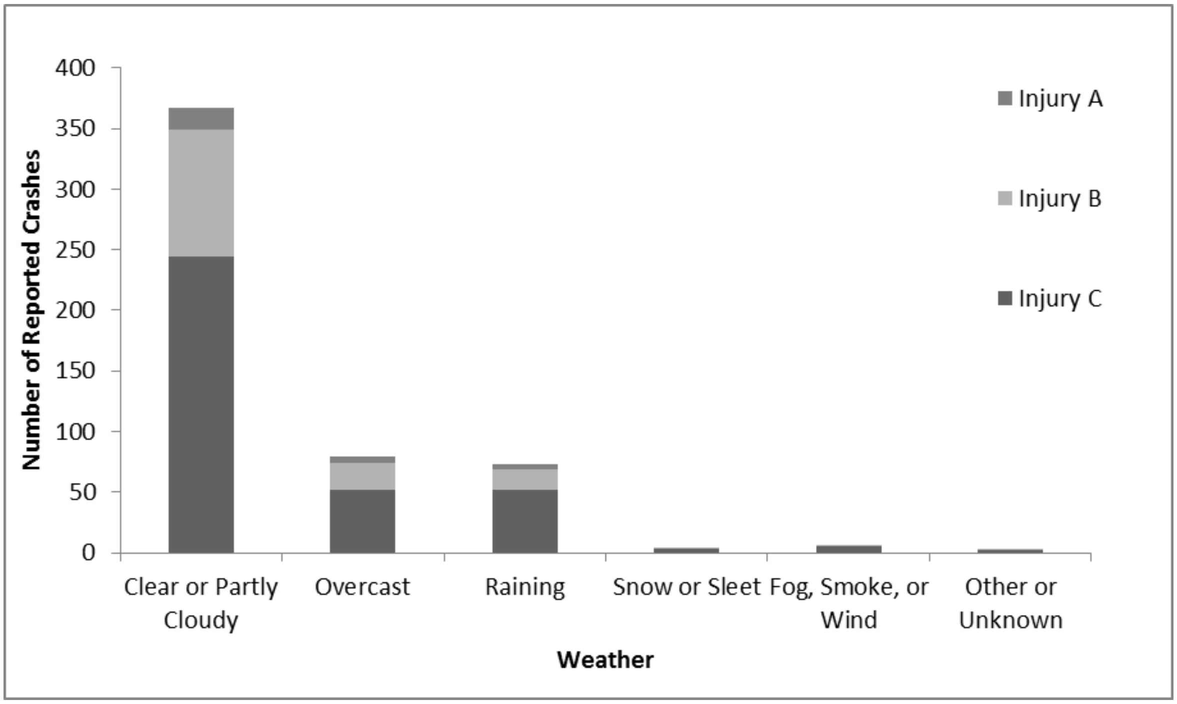

Figure 15. Chart. Weather, all injury crashes, Washington.

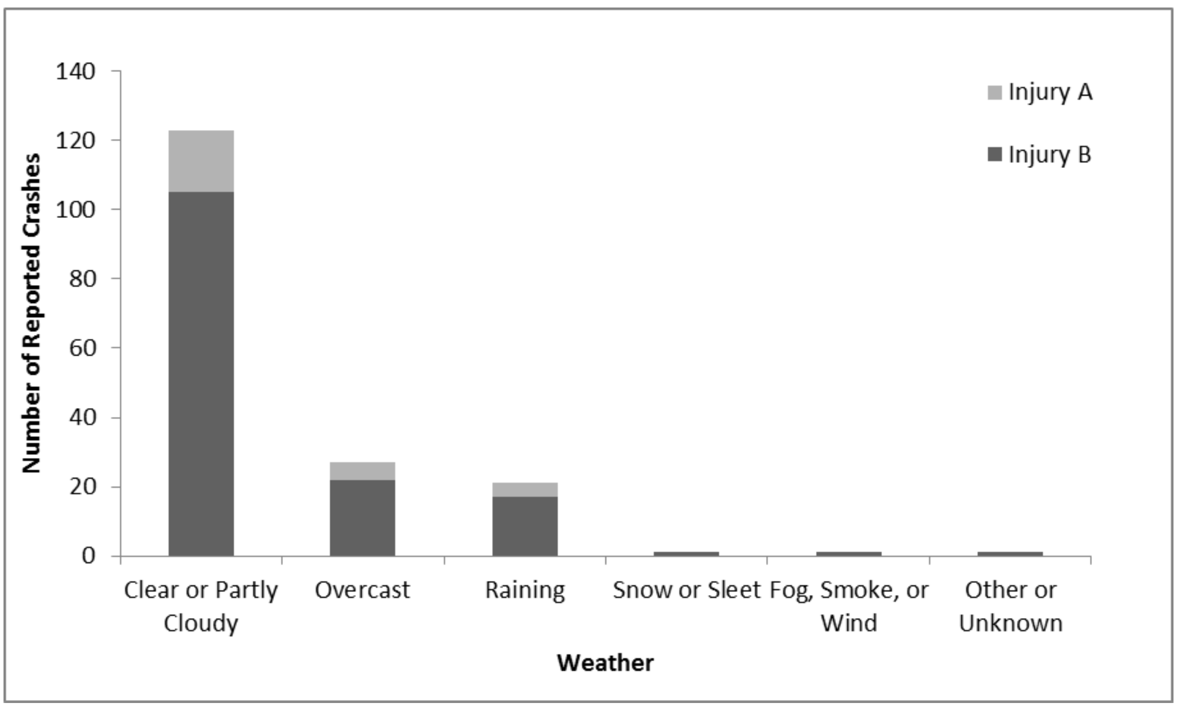

Figure 16. Chart. Weather, for injury A and B crashes, Washington.

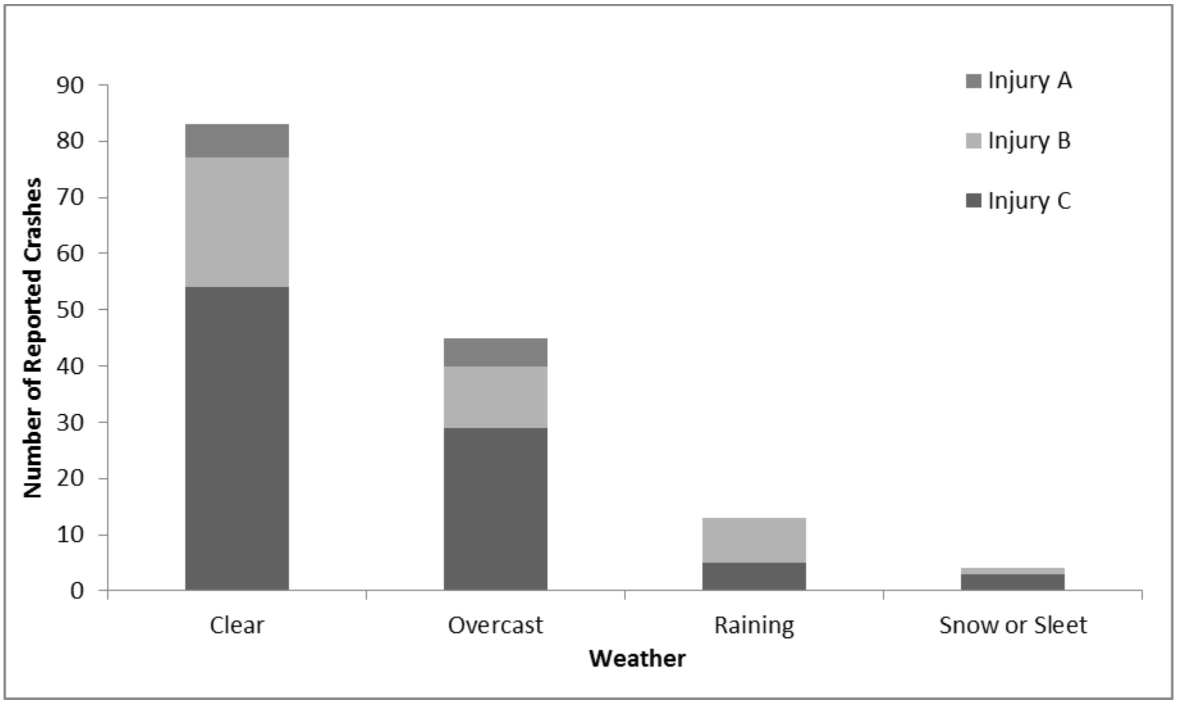

Figure 17. Chart. Weather, for all injury crashes, Wisconsin.

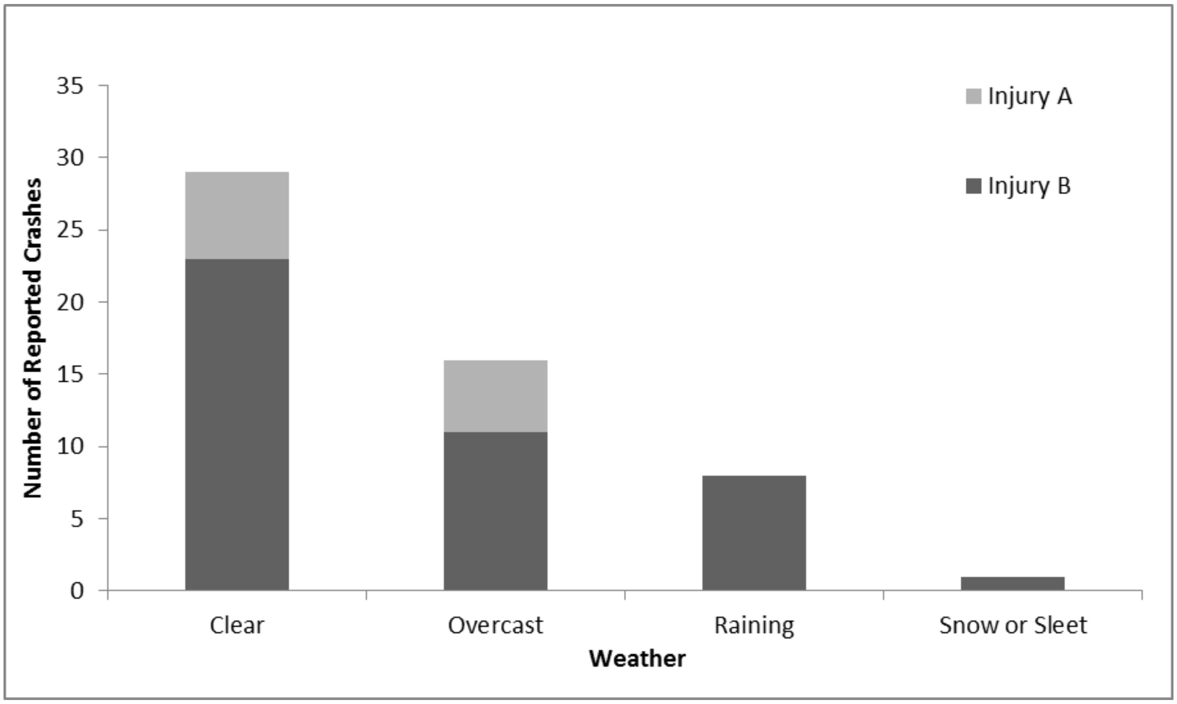

Figure 18. Chart. Weather, for injury A and B crashes, Wisconsin.

LIGHT CONDITIONS

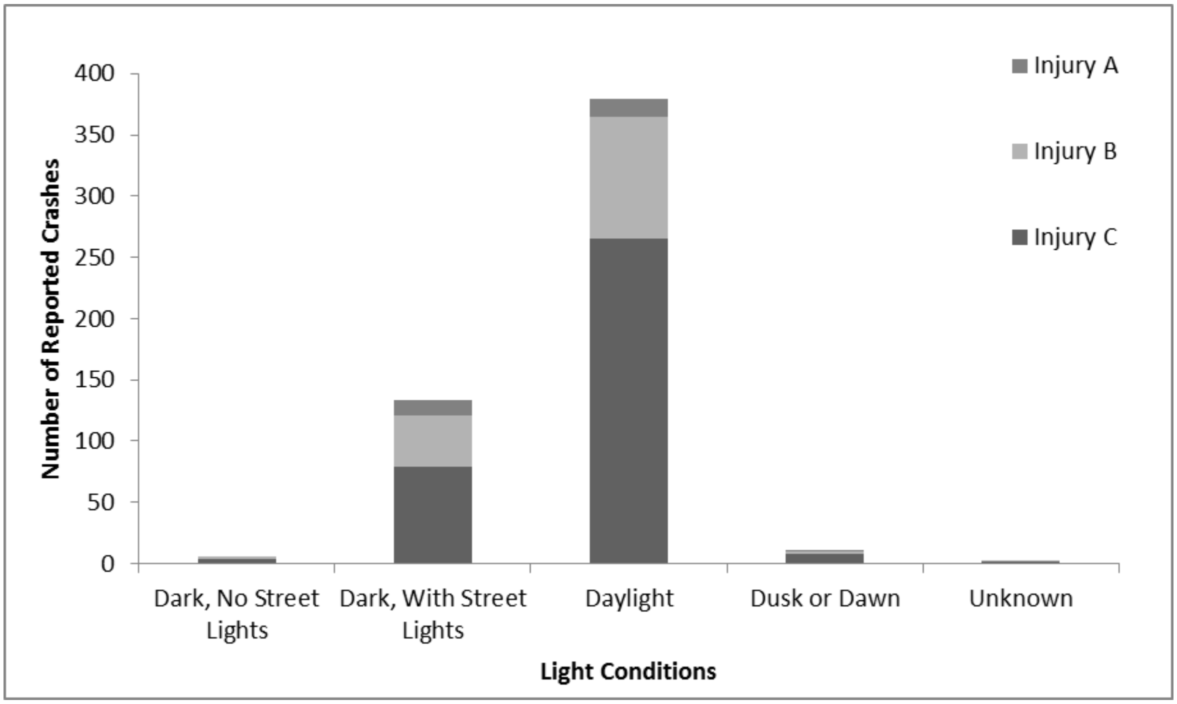

Figure 19. Chart. Light conditions for all injury crashes, Washington.

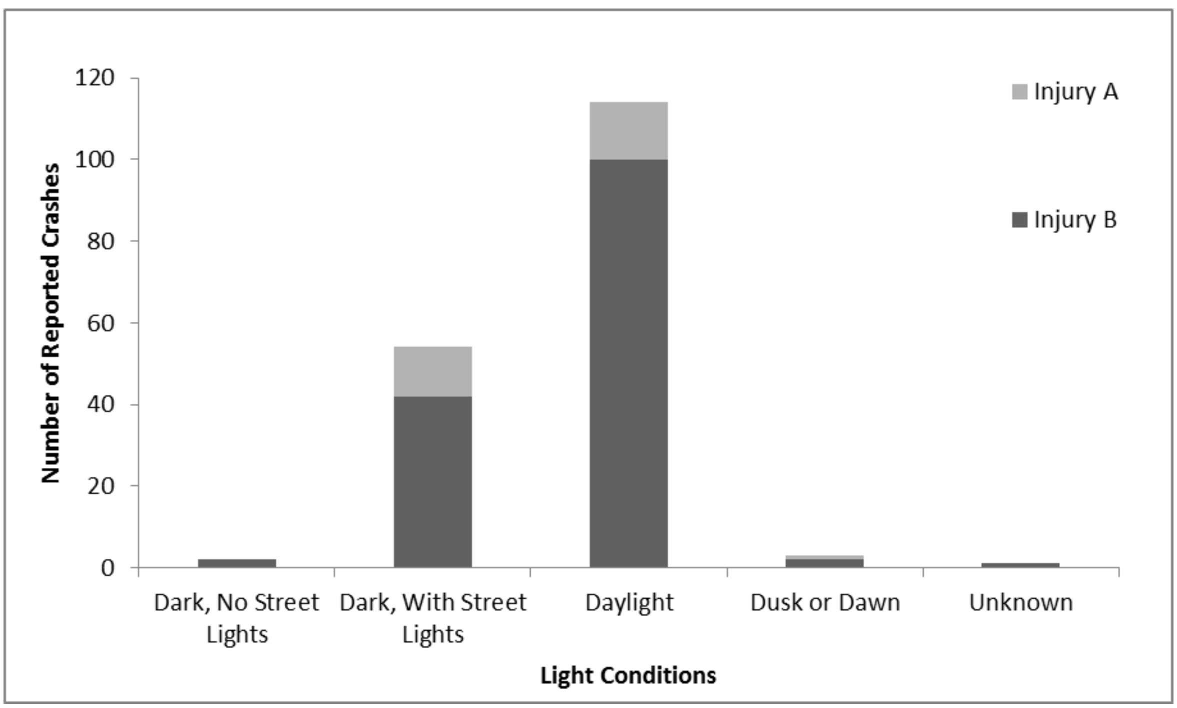

Figure 20. Chart. Light conditions for injury A and B crashes, Washington.

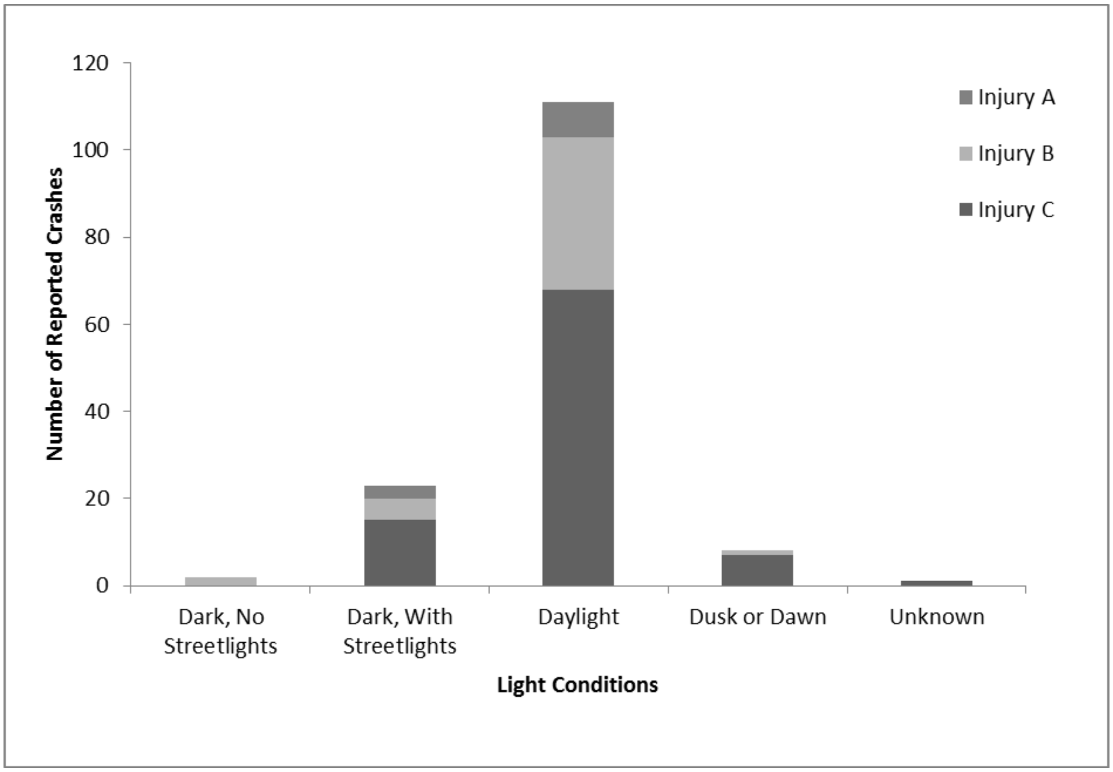

Figure 21. Chart. Light conditions for all injury crashes, Wisconsin.

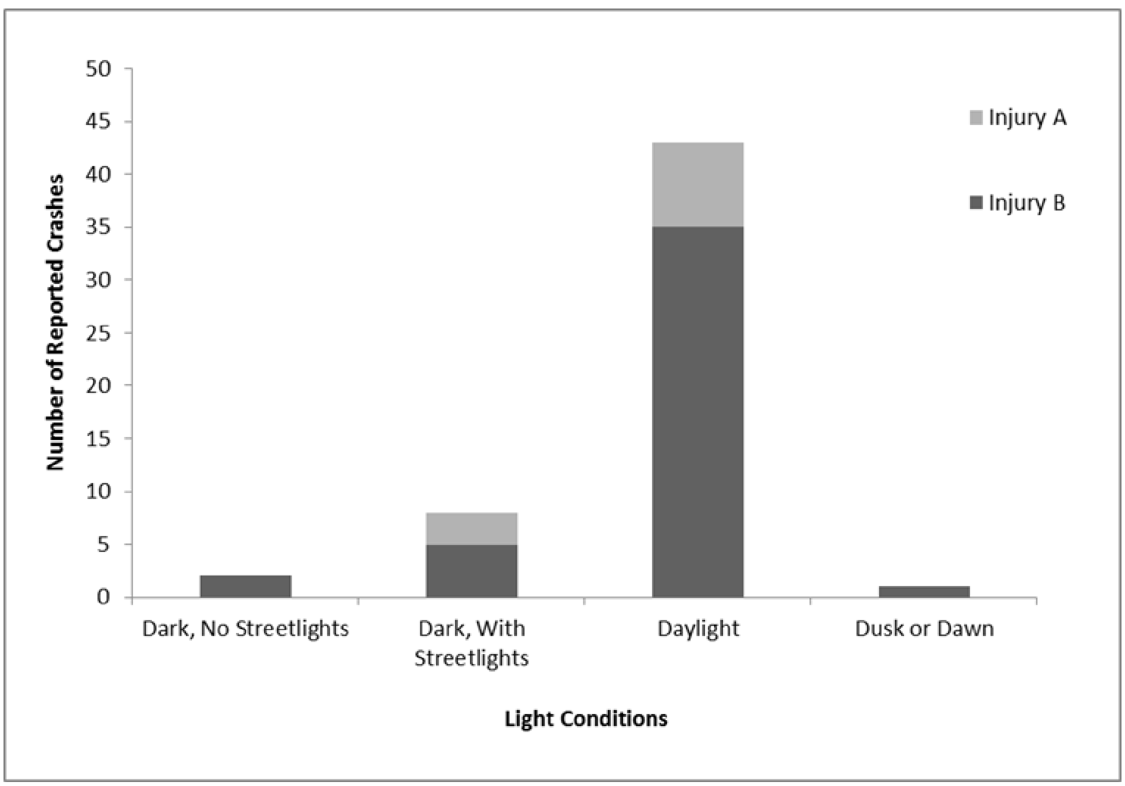

Figure 22. Chart. Light conditions for injury A and B crashes, Wisconsin.

VEHICLE TYPE

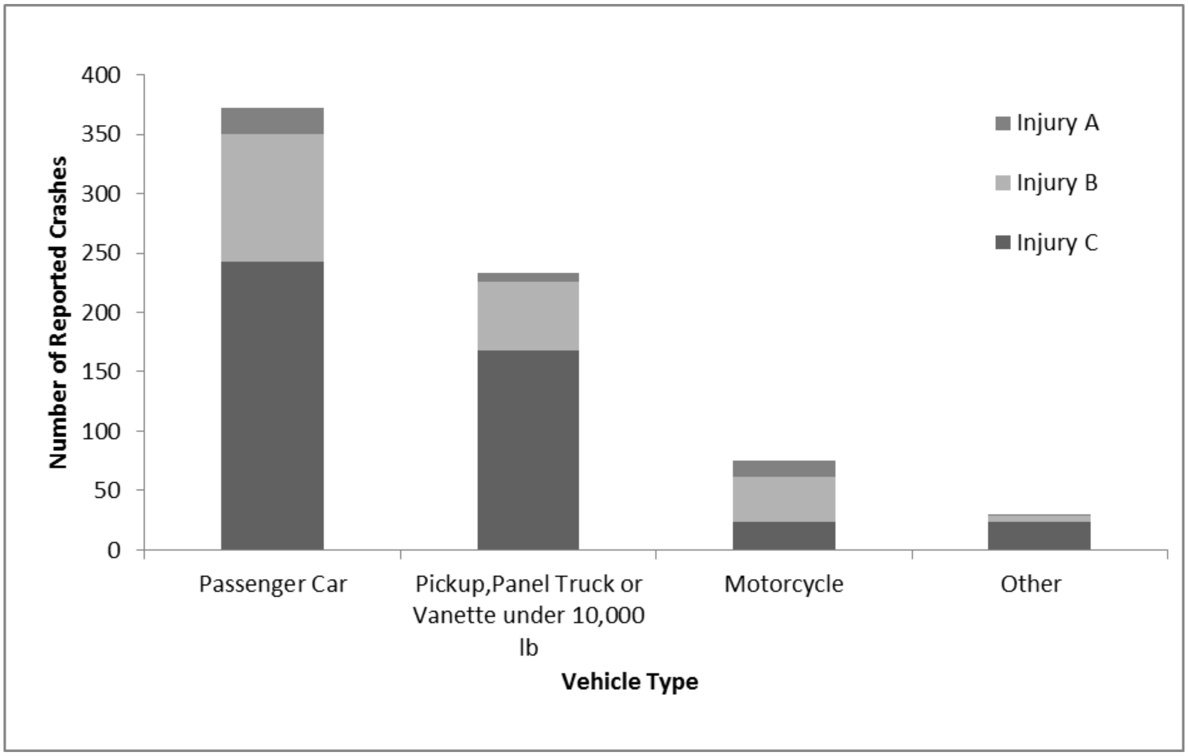

Figure 23. Chart. Vehicle type for all injury crashes, Washington.

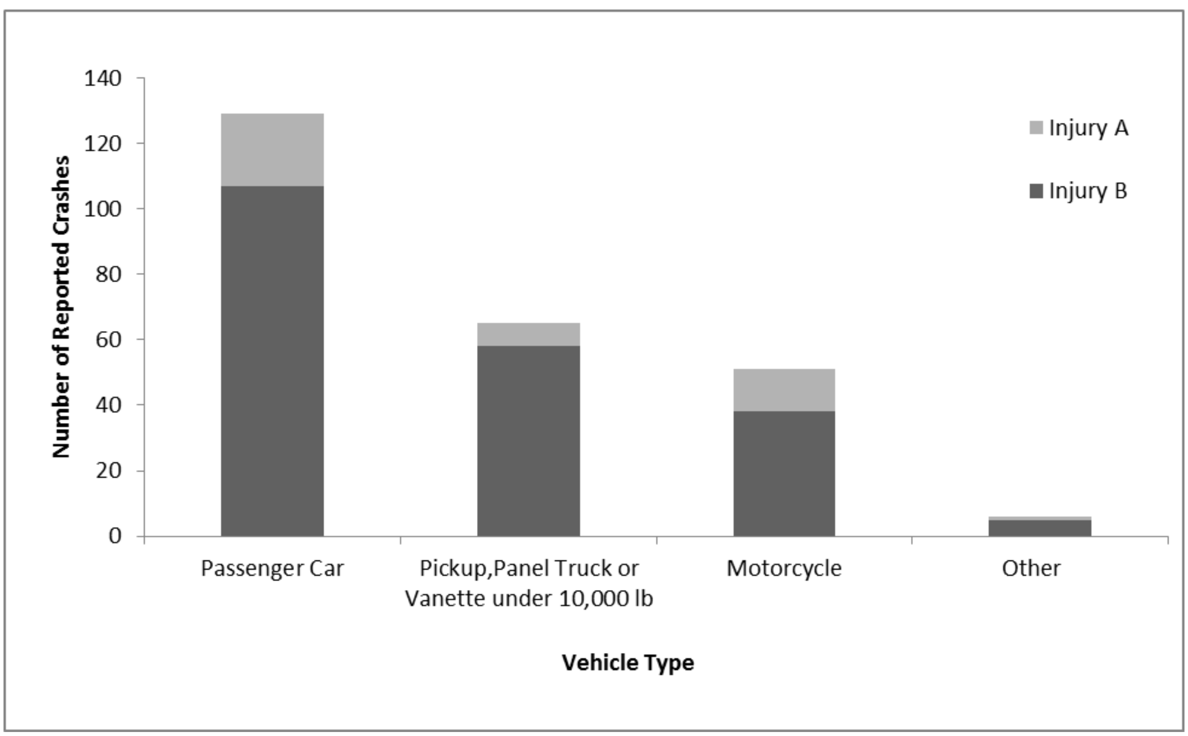

Figure 24. Chart. Vehicle type for all injury A and B crashes, Washington.

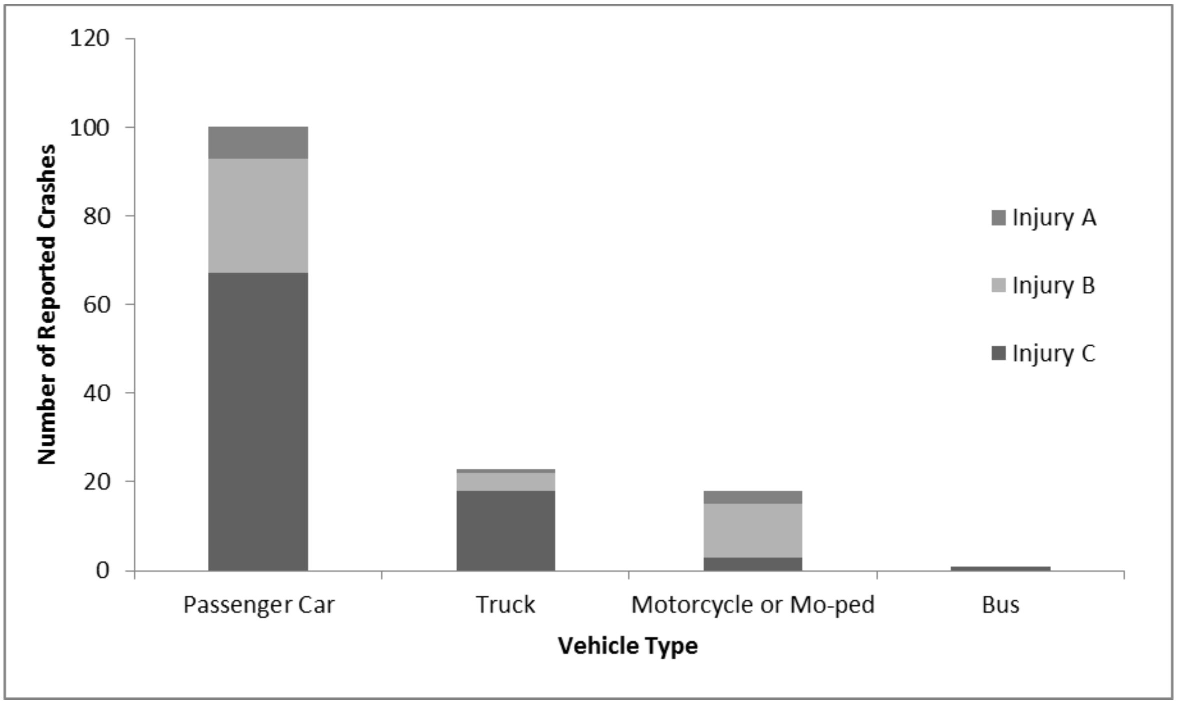

Figure 25. Chart. Vehicle type for all injury crashes, Wisconsin.

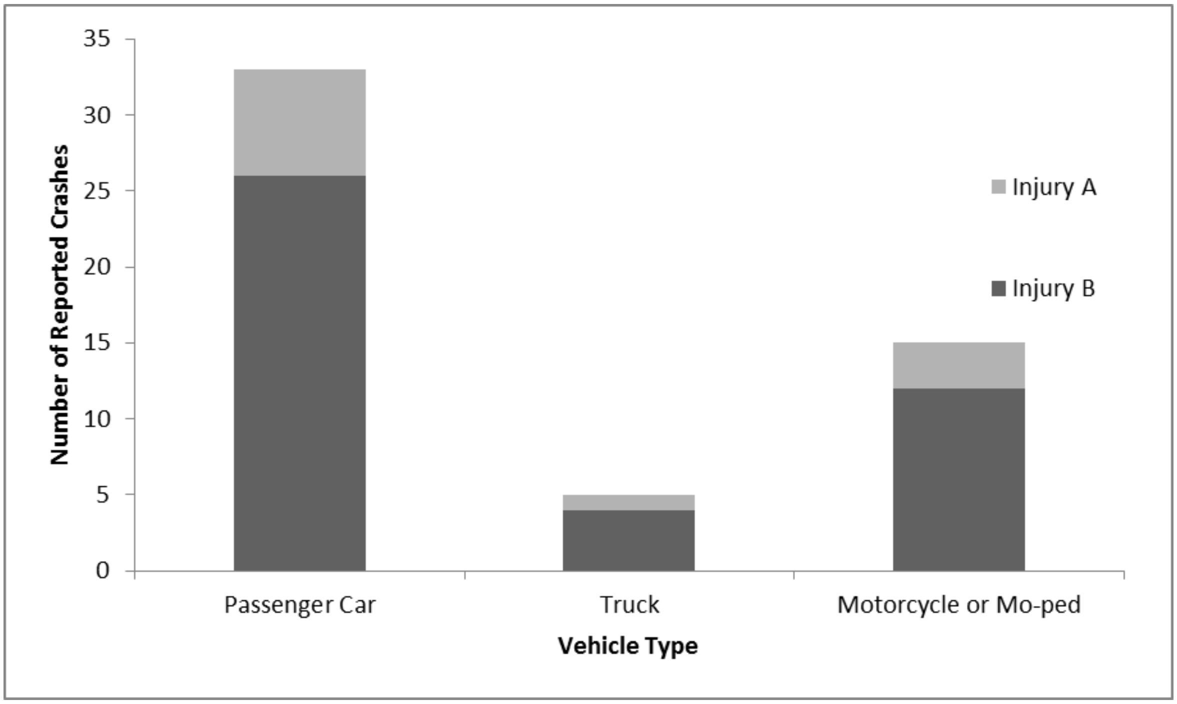

Figure 26. Chart. Vehicle type for injury A and B crashes, Wisconsin.

ALCOHOL INVOLVEMENT

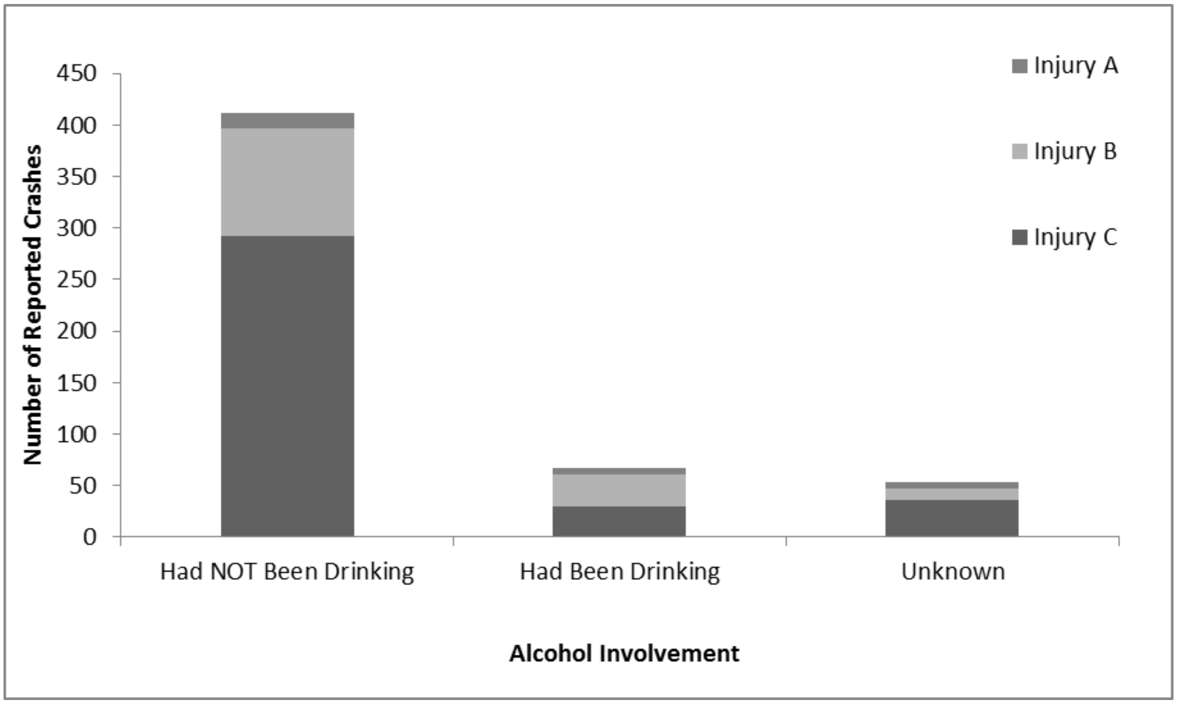

Figure 27. Chart. Alcohol involvement for all injury crashes, Washington.

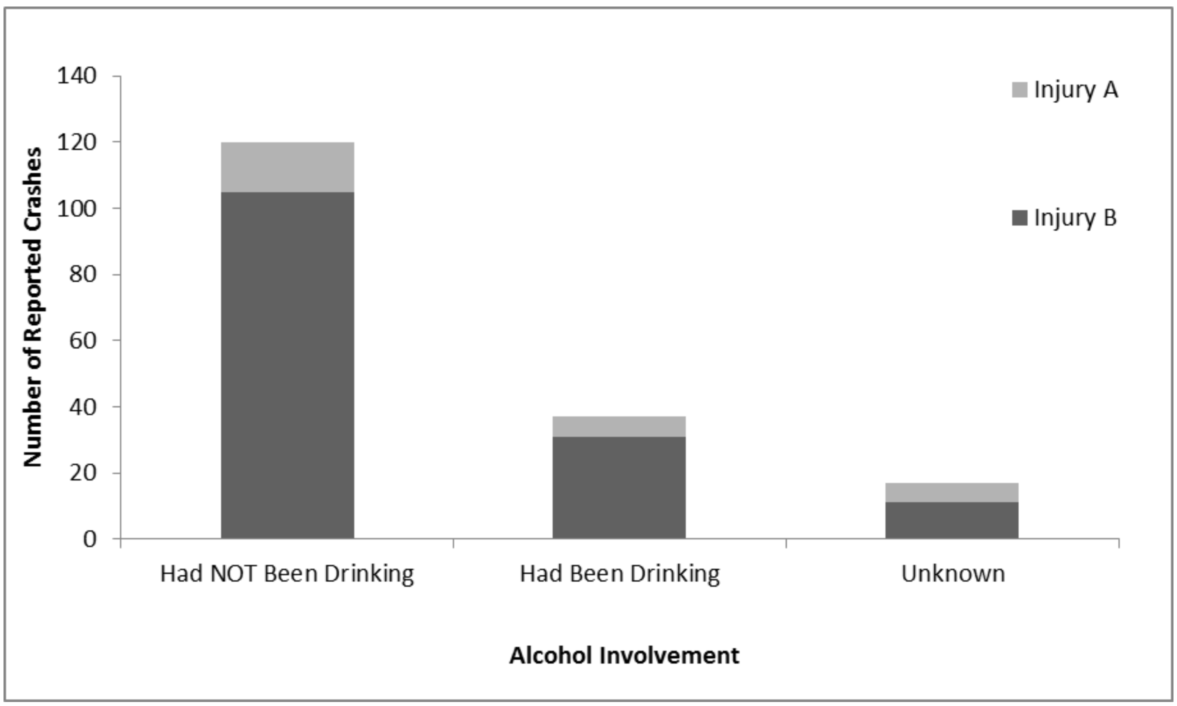

Figure 28. Chart. Alcohol involvement in injury A and B crashes, Washington.

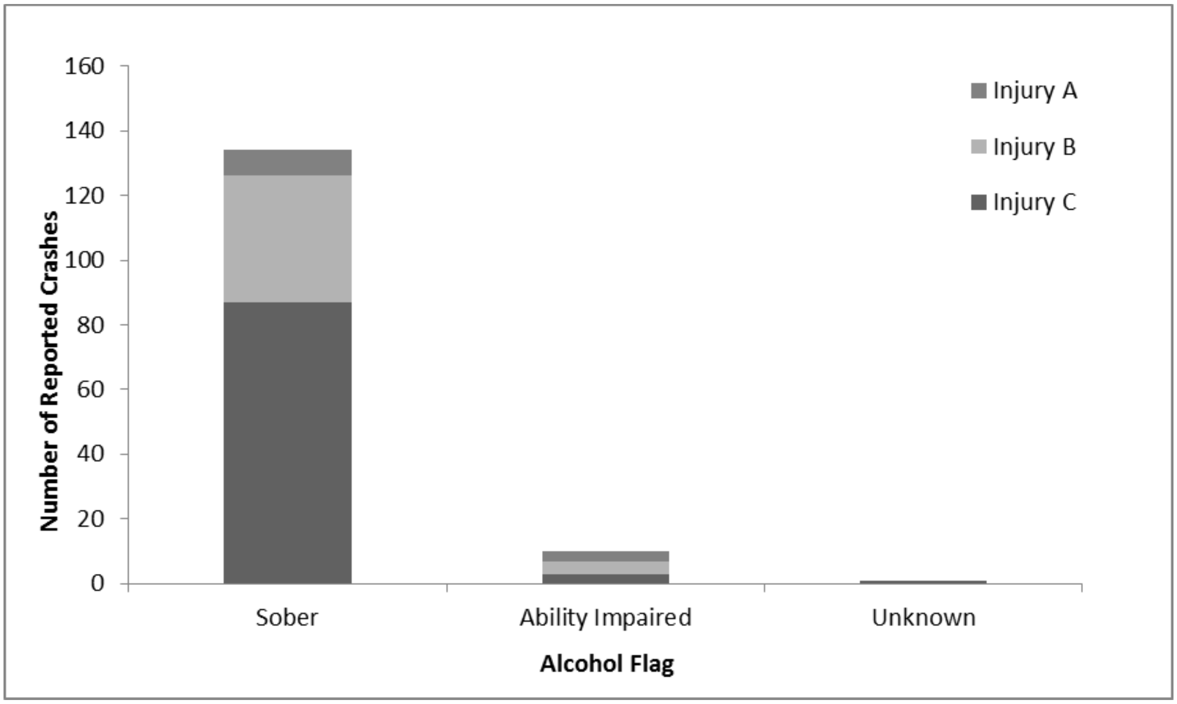

Figure 29. Chart. Alcohol involvement in all injury crashes, Wisconsin.

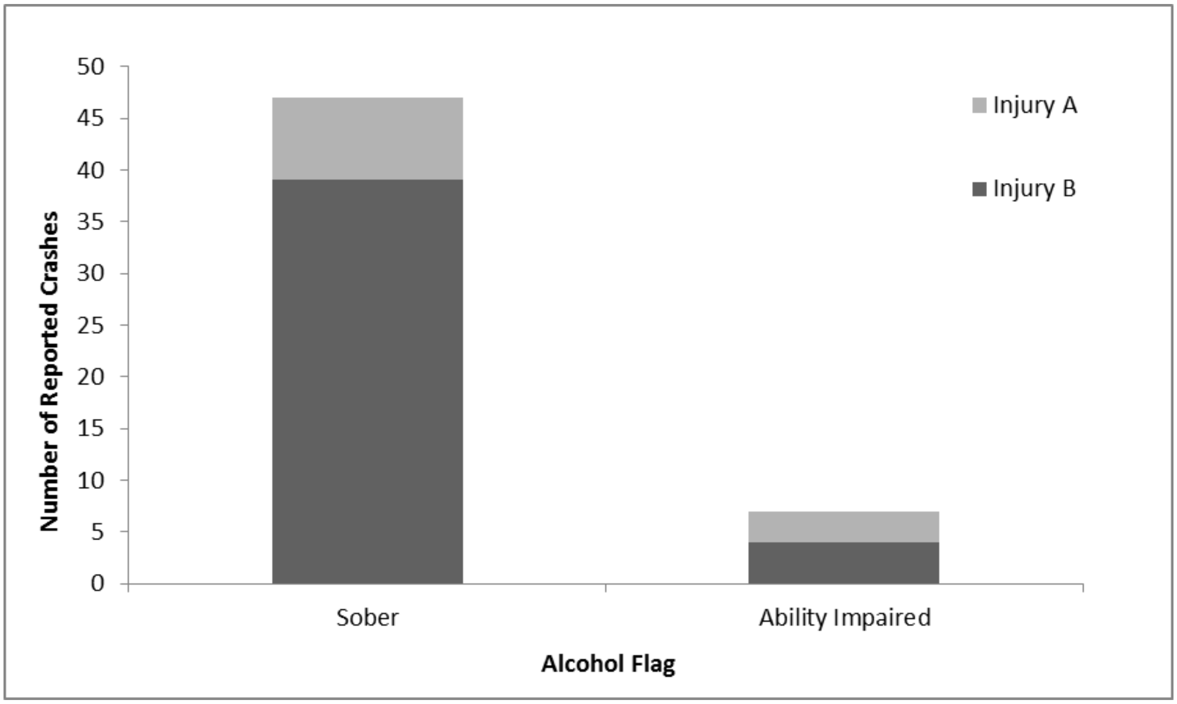

Figure 30. Chart. Alcohol involvement in injury A and B crashes, Wisconsin.

NUMBER OF VEHICLES INVOLVED

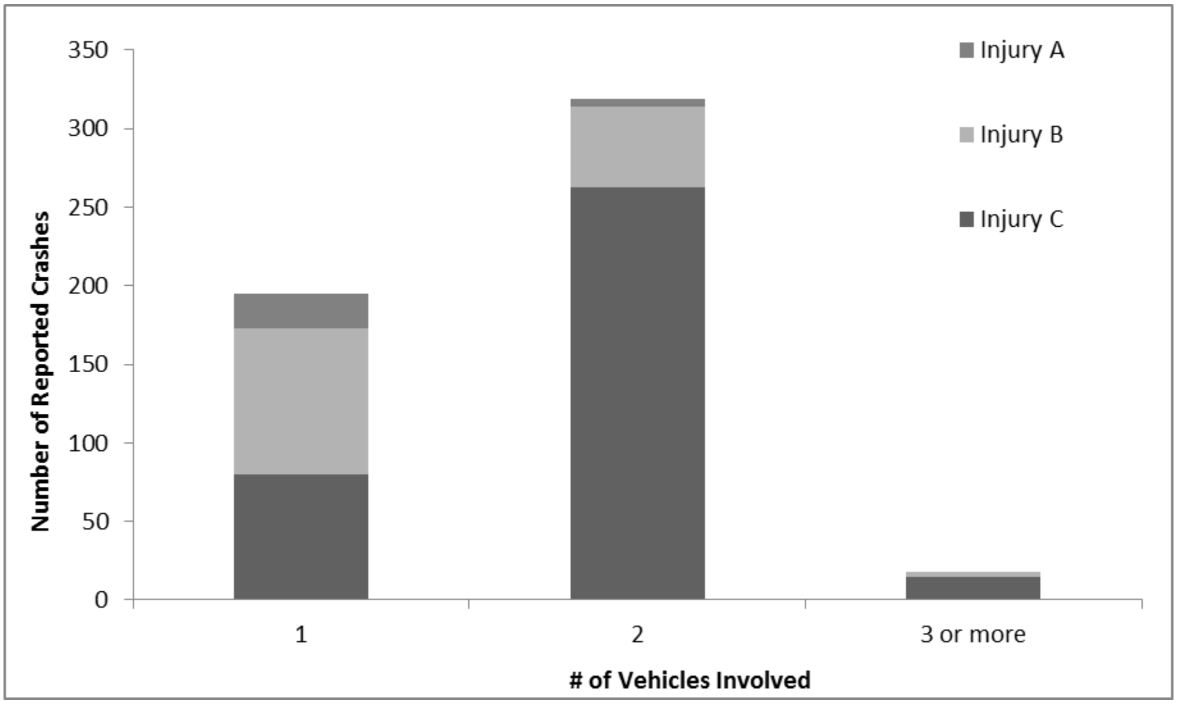

Figure 31. Chart. Number of vehicles involved, all injury crashes, Washington.

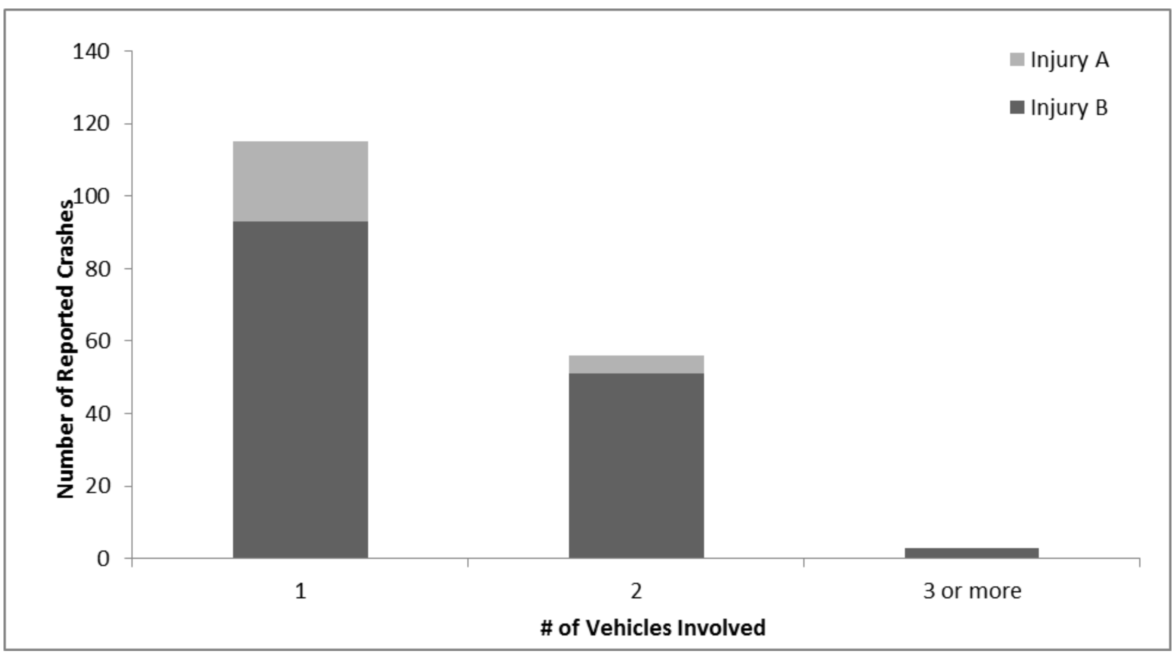

Figure 32. Chart. Number of vehicles involved, injury A and B crashes, Washington.

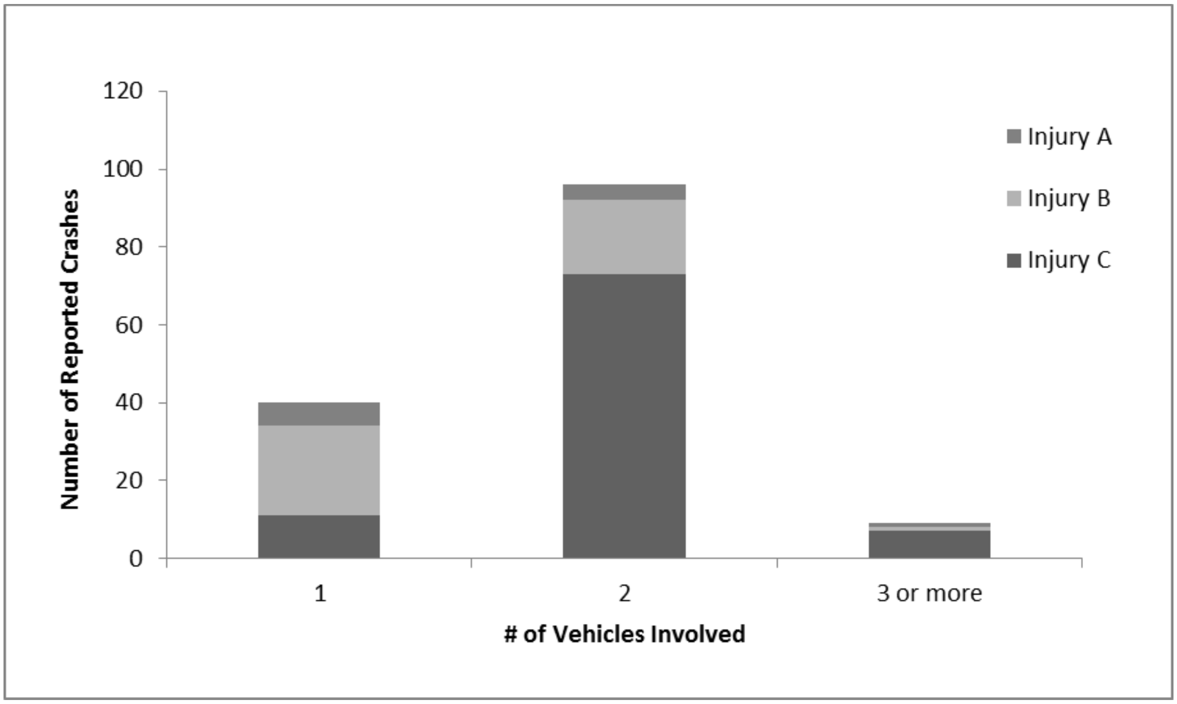

Figure 33. Chart. Number of vehicles involved, all injury crashes, Wisconsin.

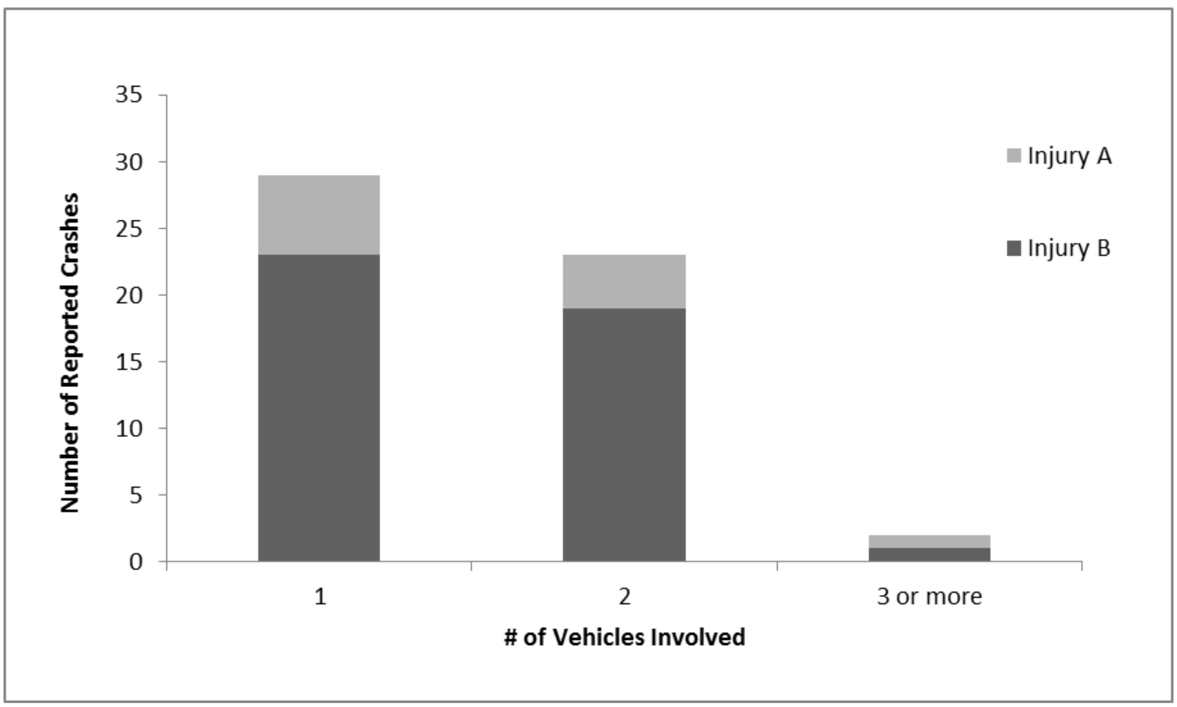

Figure 34. Chart. Number of vehicles involved, injury A and B crashes, Wisconsin.

ALCOHOL INVOLVEMENT AND NUMBER OF VEHICLES INVOLVED

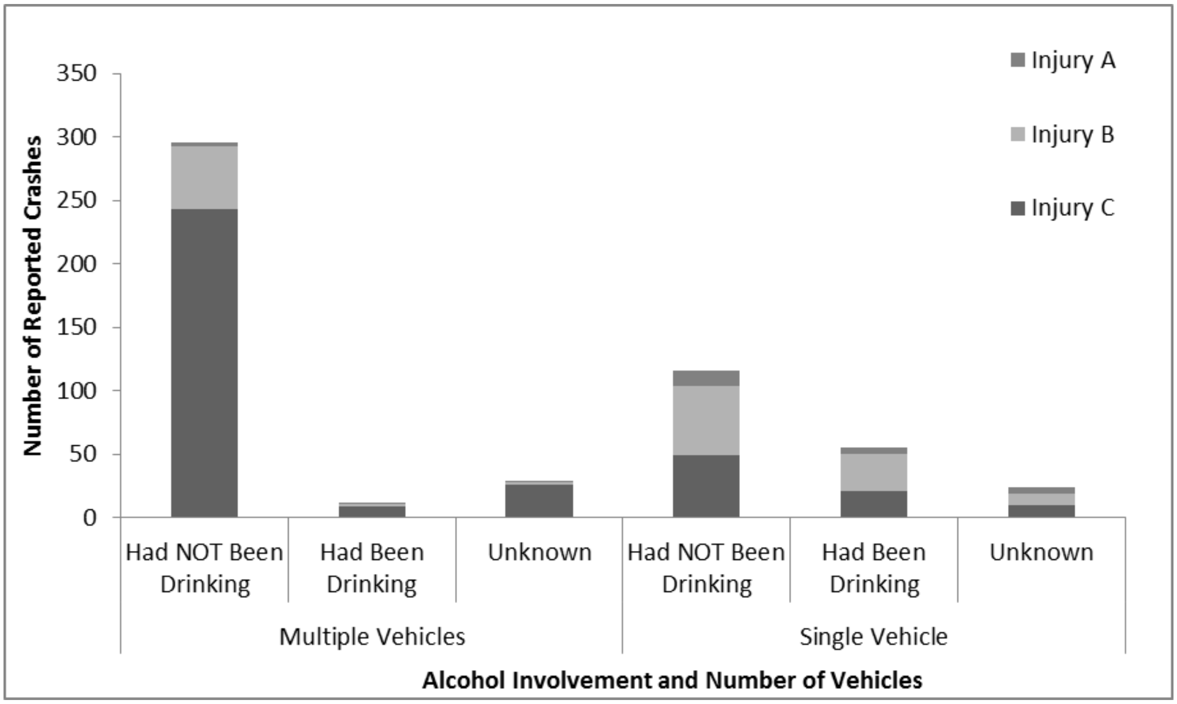

Figure 35. Chart. Alcohol involvement and number of vehicles involved, all injury crashes, Washington.

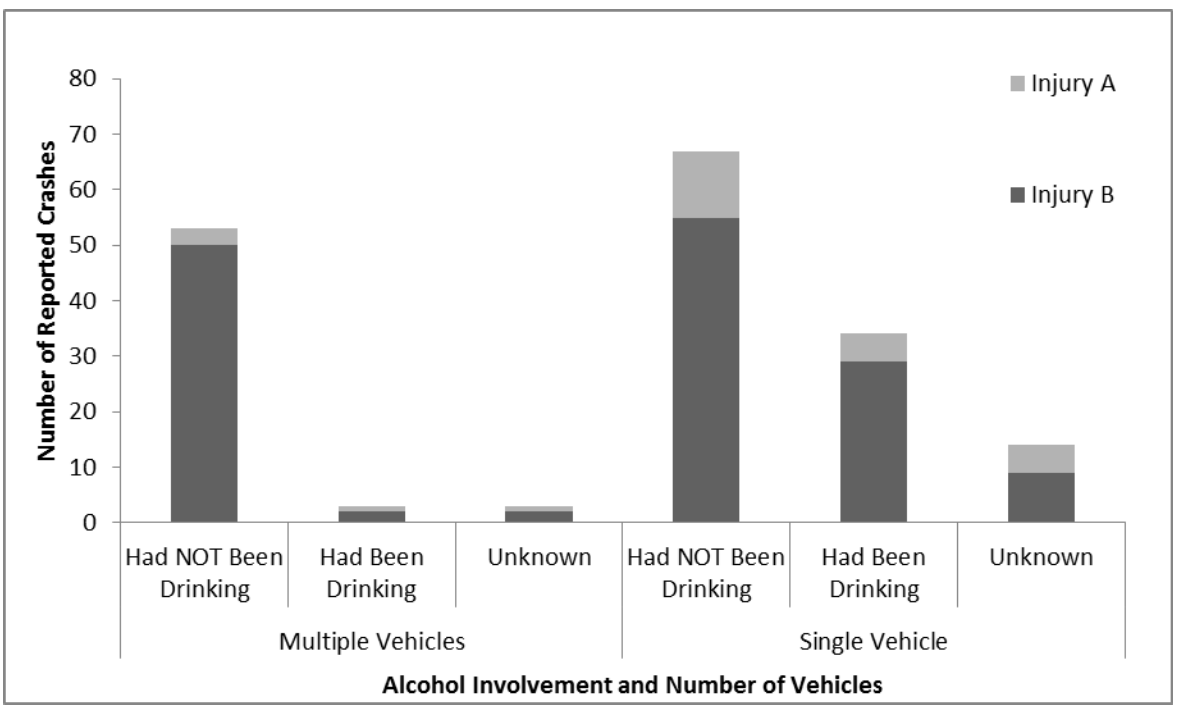

Figure 36. Chart. Alcohol involvement and number of vehicles involved, injury A and B crashes, Washington.

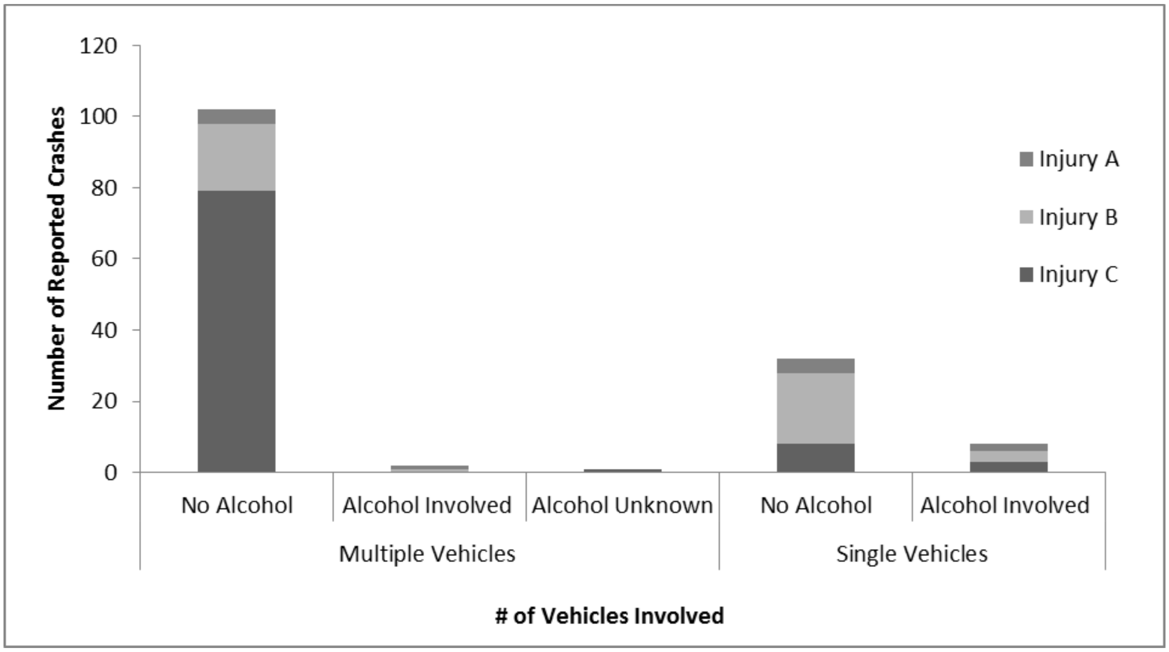

Figure 37. Chart. Alcohol involvement and number of vehicles involved, all injury crashes, Wisconsin.

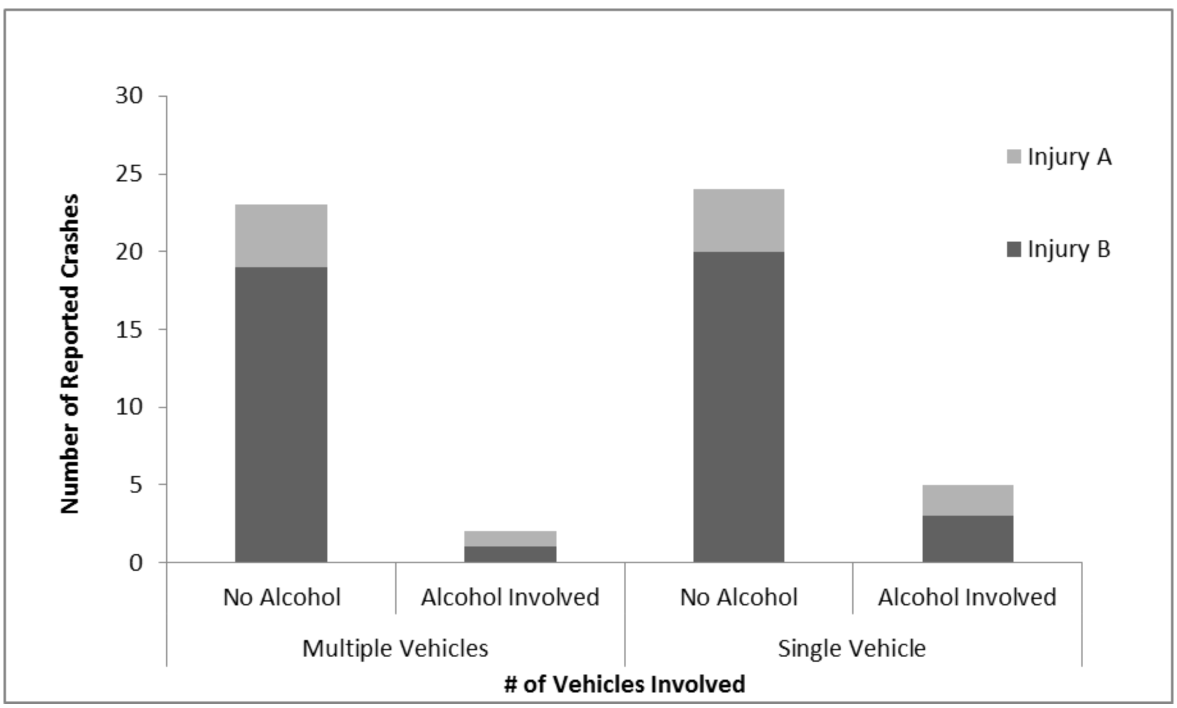

Figure 38. Chart. Alcohol involvement and number of vehicles involved, injury A and B crashes, Wisconsin.

NUMBER OF VEHICLES INVOLVED AND VEHICLE TYPE

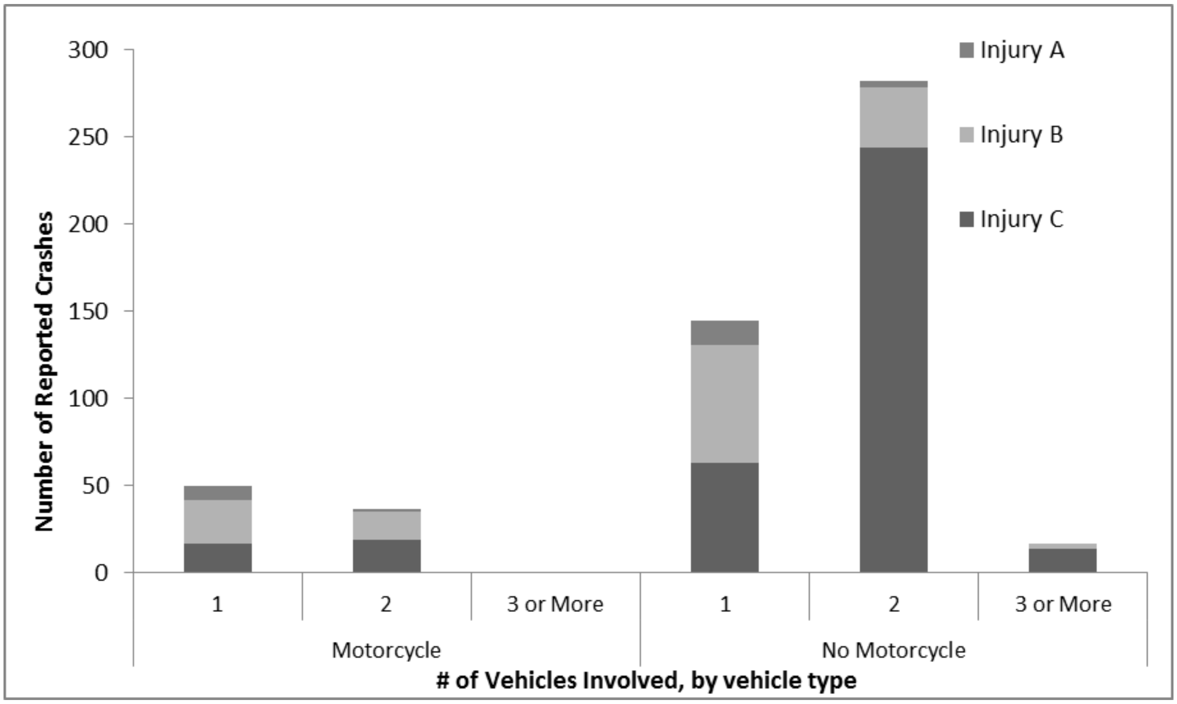

Figure 39. Chart. Number of vehicles involved and vehicle type, all injury crashes, Washington.

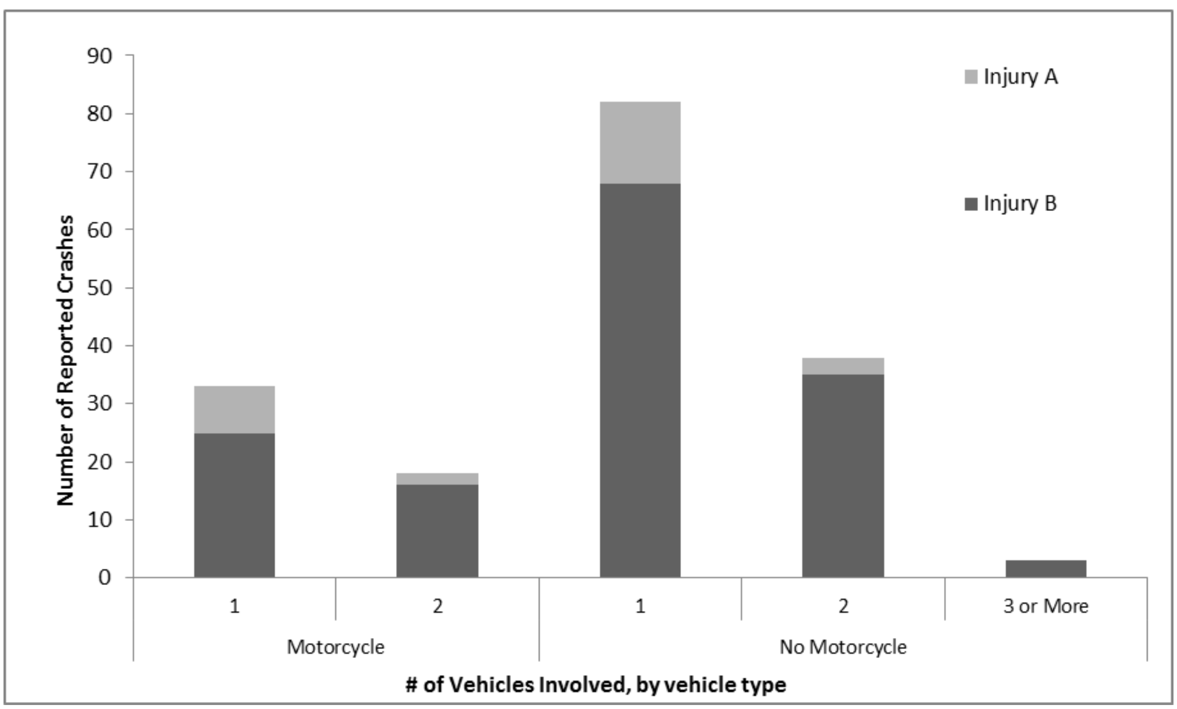

Figure 40. Chart. Number of vehicles involved and vehicle type, injury A and B crashes, Washington.

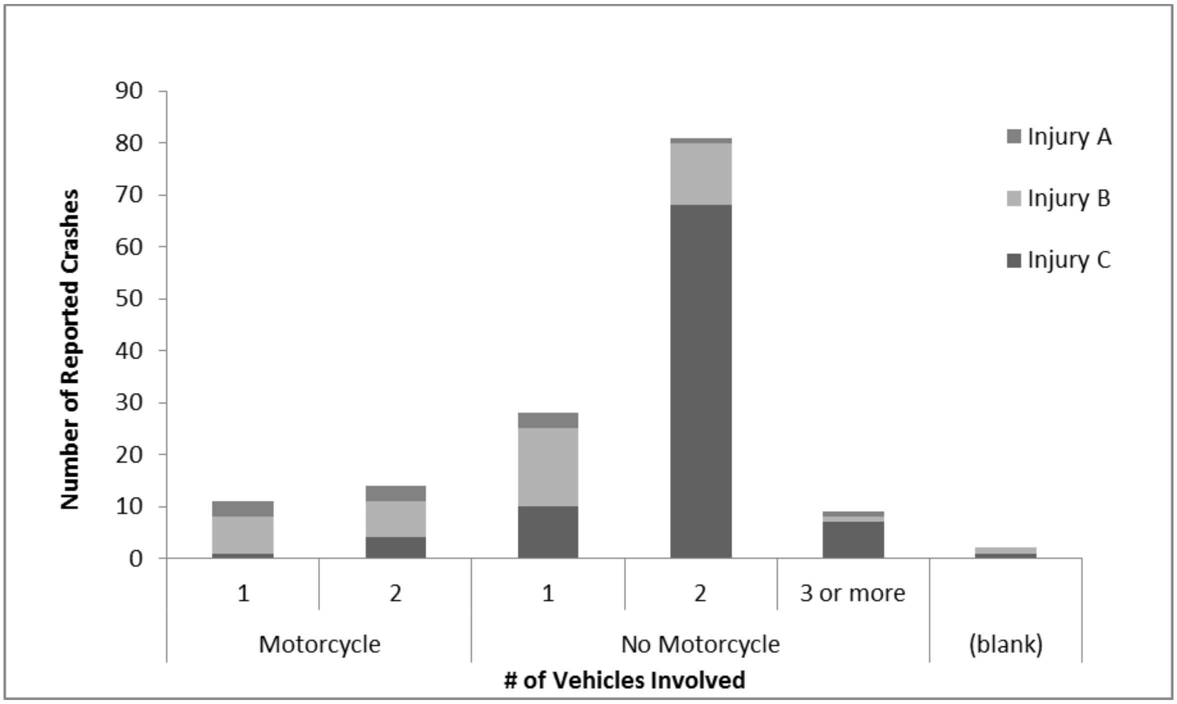

Figure 41. Chart. Number of vehicles involved and vehicle type, all injury crashes, Wisconsin.

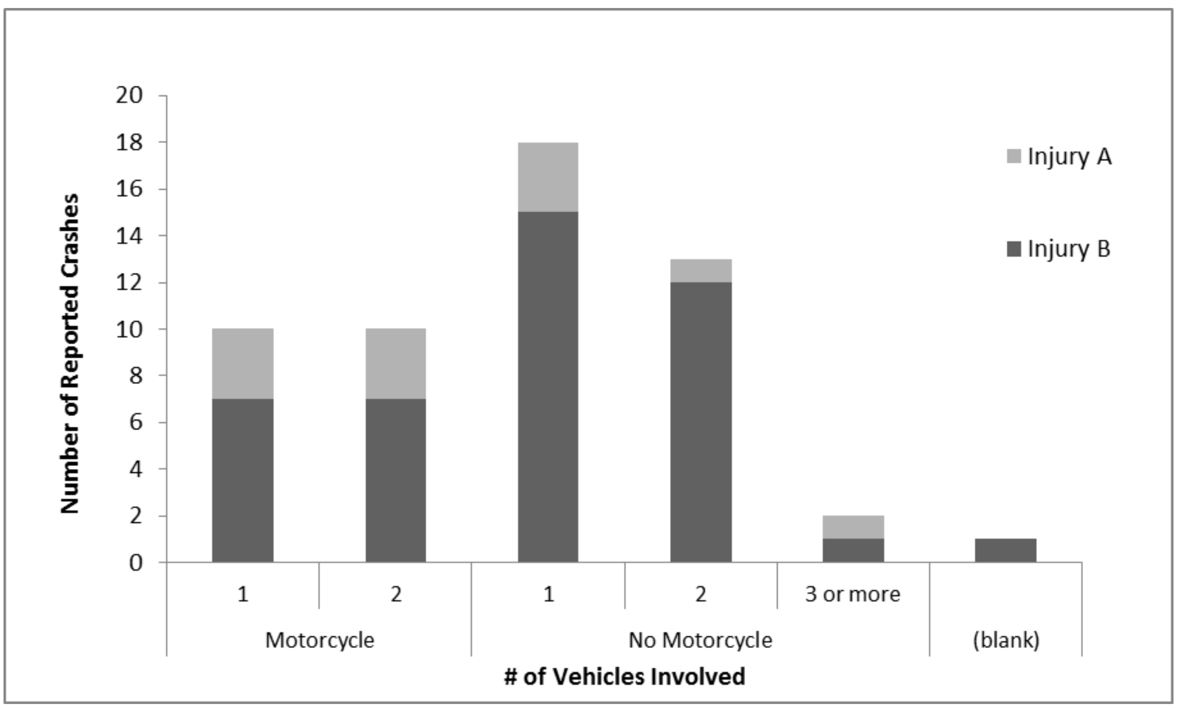

Figure 42. Chart. Number of vehicles involved and vehicle type, Injury A and B crashes, Wisconsin.

CRASH TYPE

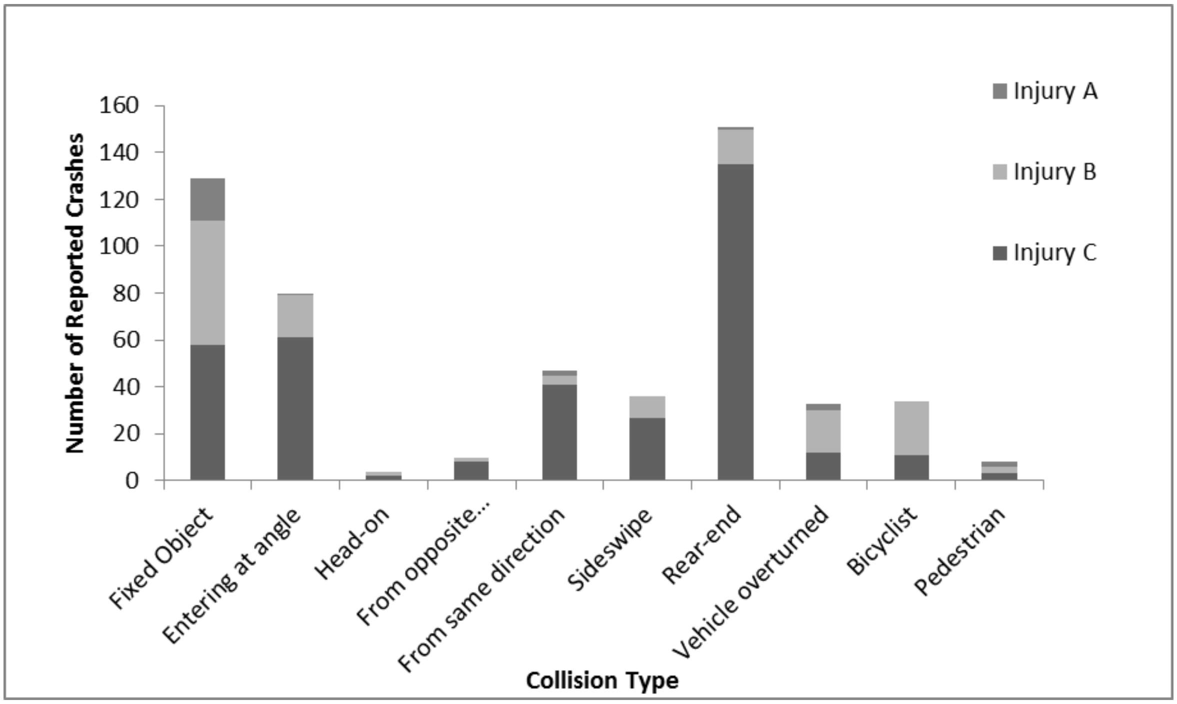

Figure 43. Chart. Crash type for all injury crashes, Washington.

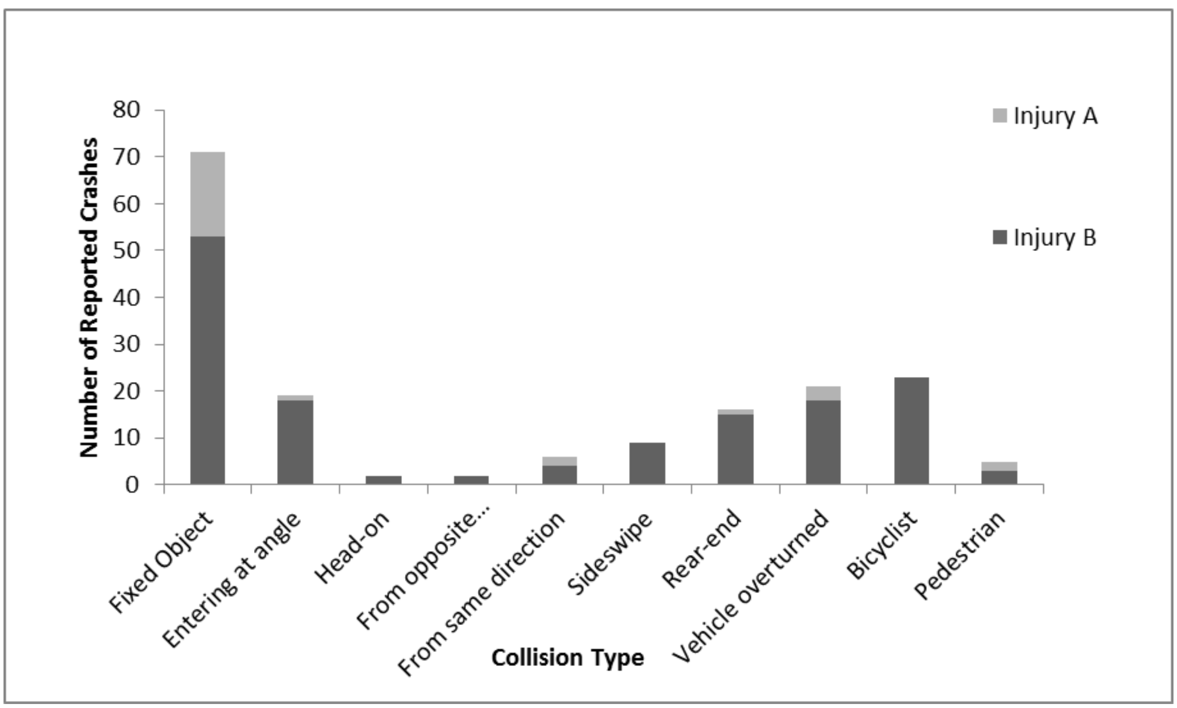

Figure 44. Chart. Crash type for all Injury A and B crashes, Washington.

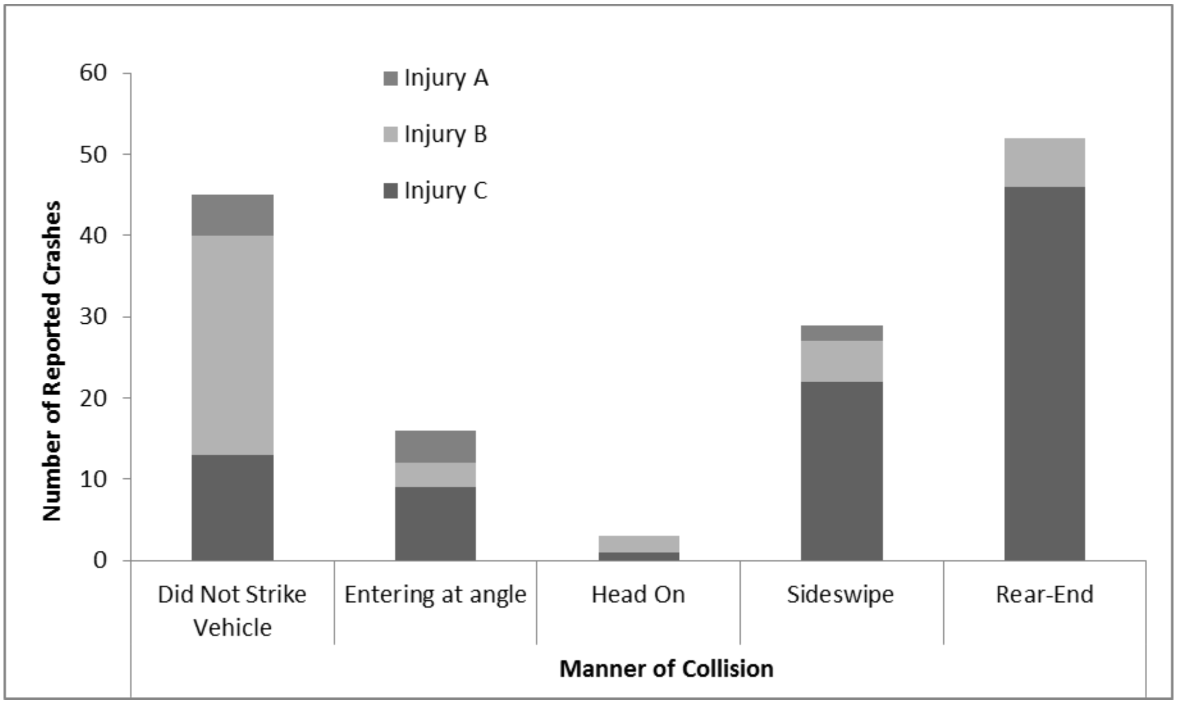

Figure 45. Chart. Crash type for all injury crashes, Wisconsin.

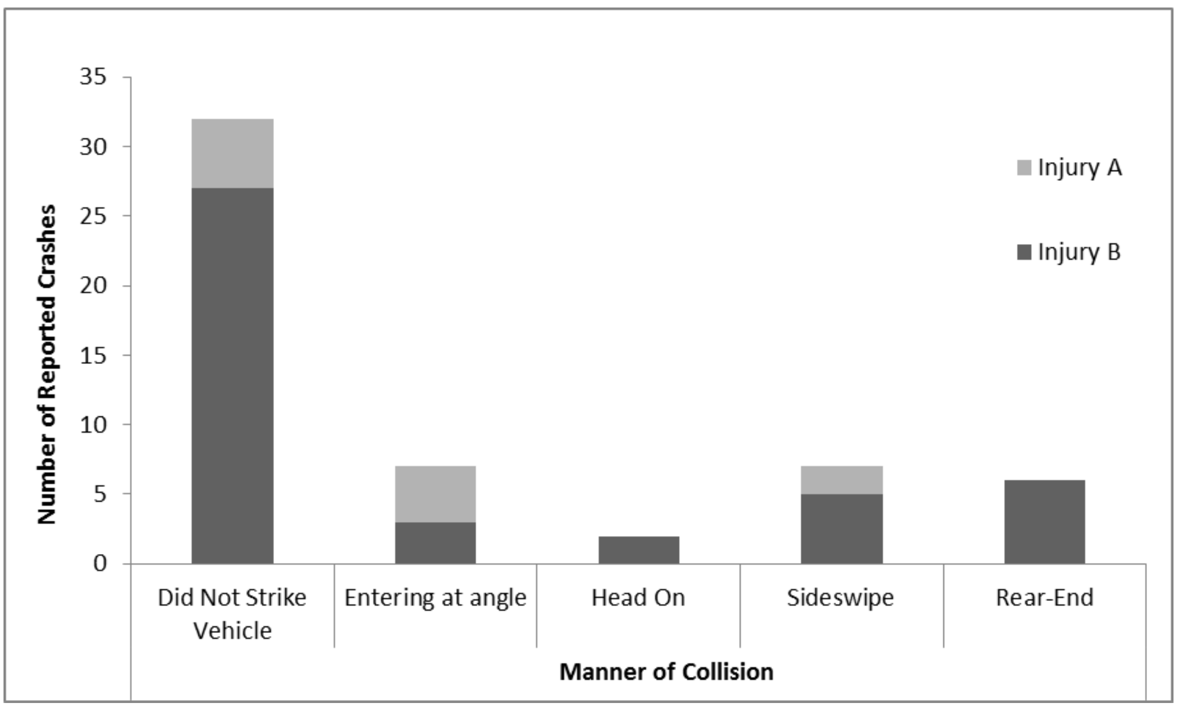

Figure 46. Chart. Crash type for injury A and B crashes, Wisconsin.

OBJECTS STRUCK

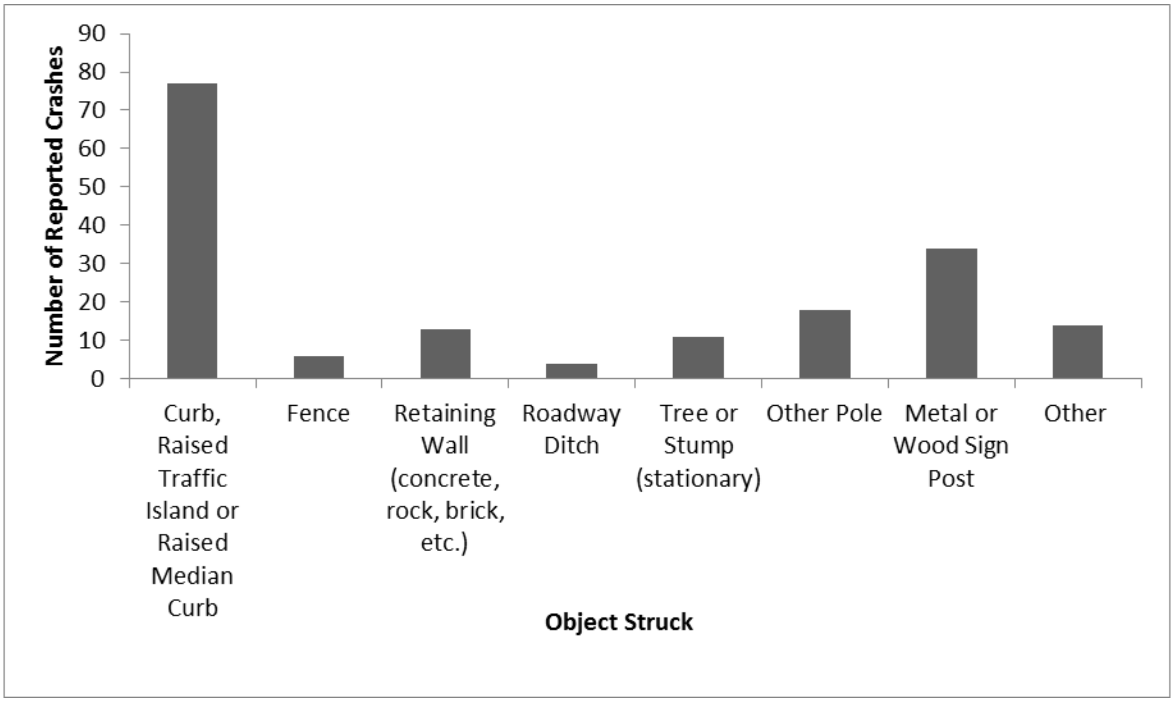

Figure 47. Chart. First and second objects struck, all injury crashes, Washington.

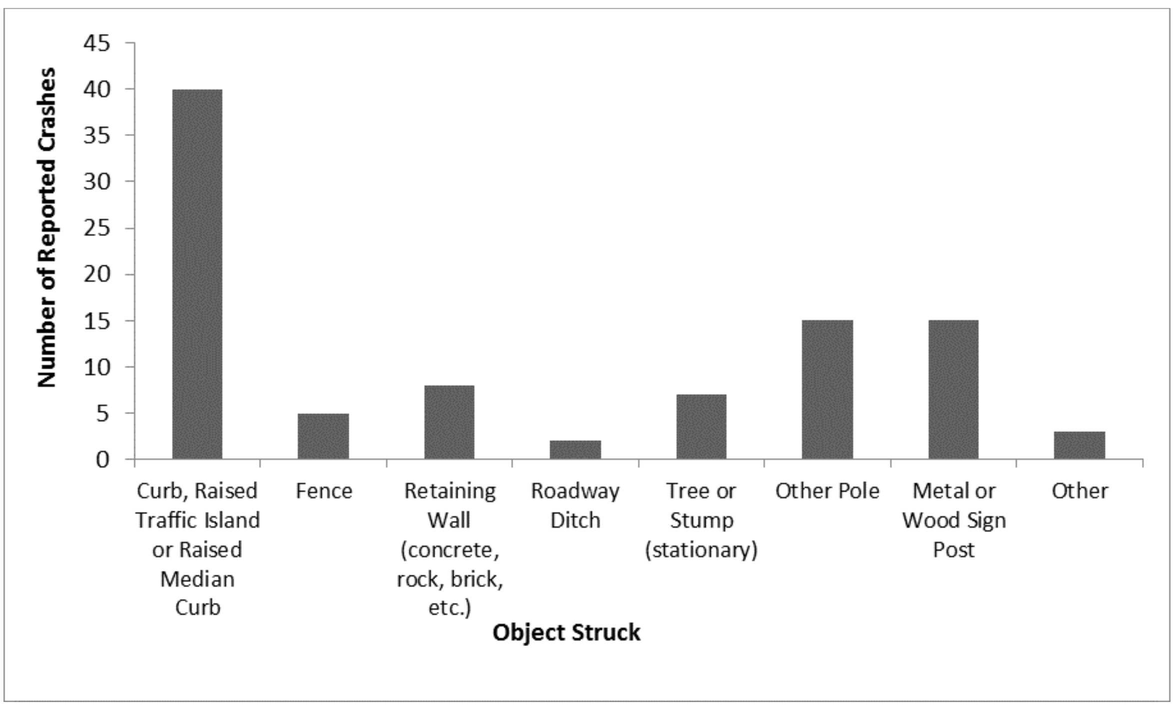

Figure 48. Chart. First and second objects struck, injury A and B crashes, Washington.

CONTRIBUTING CIRCUMSTANCES

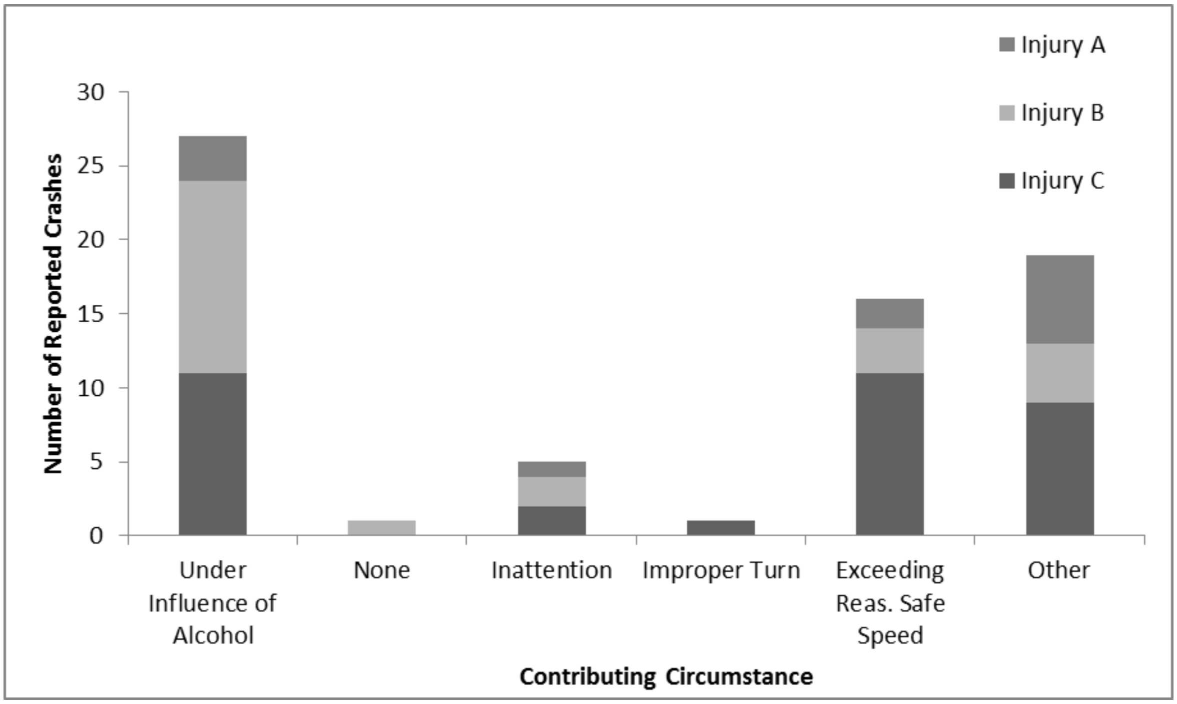

Figure 49. Chart. Contributing circumstances for all injury crashes involving vehicles hitting the curb, Washington.

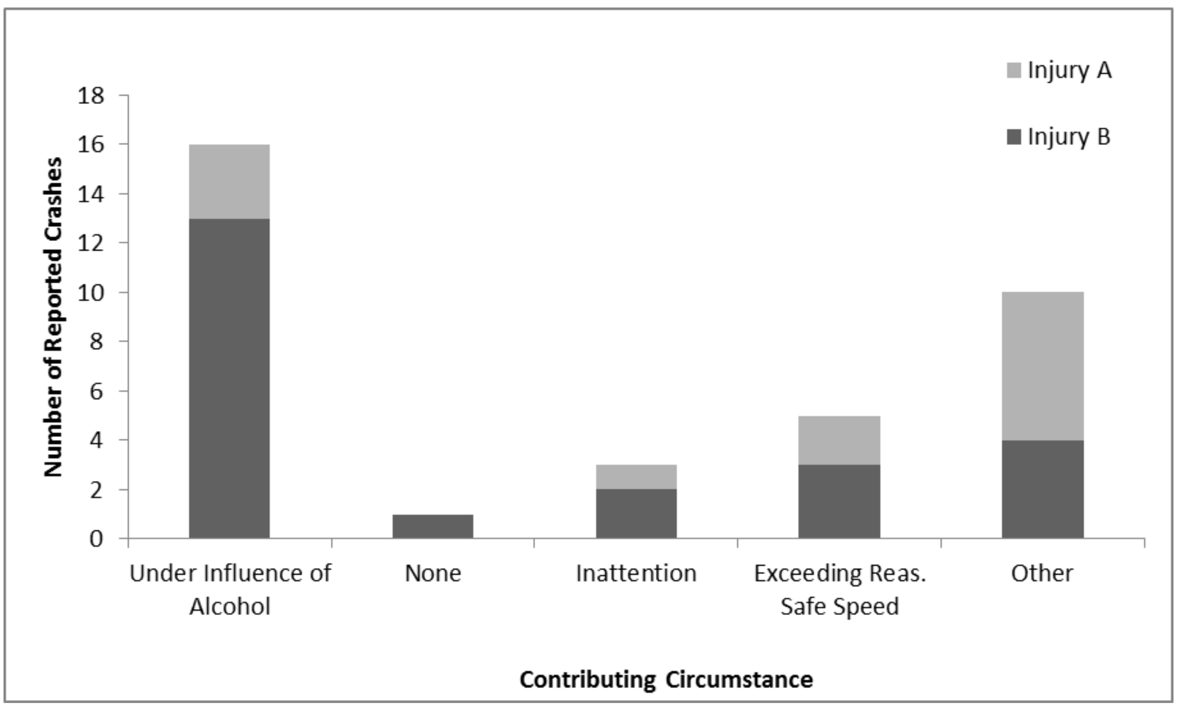

Figure 50. Chart. Contributing circumstances for all injury A and B crashes involving vehicles hitting the curb, Washington.

JUNCTION RELATION BY VEHICLE TYPE

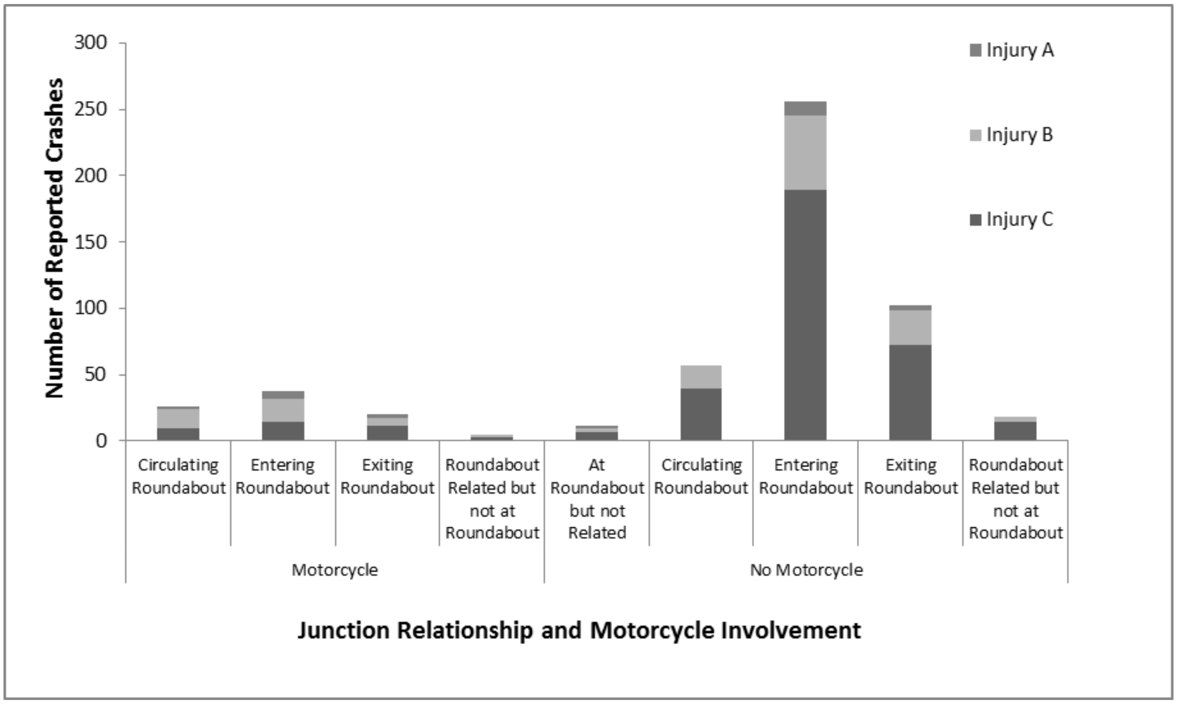

Figure 51. Chart. Junction relation by vehicle type, all injury crashes, Washington.

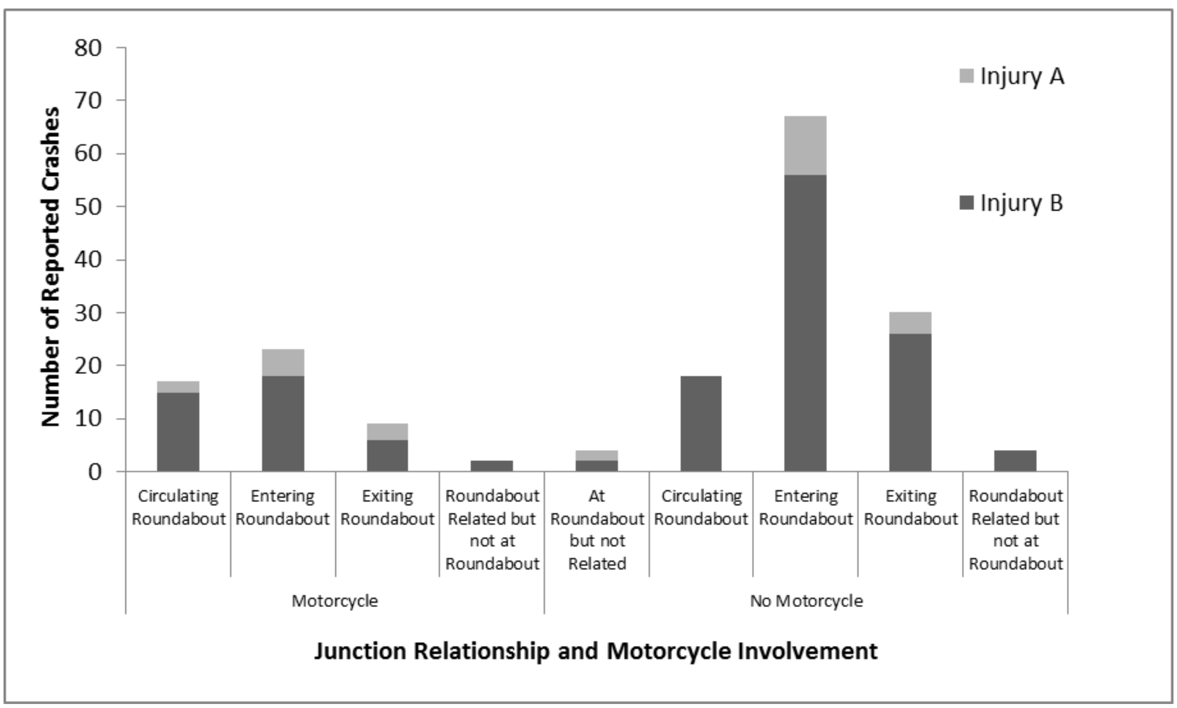

Figure 52. Chart. Junction relation by vehicle type, injury A and B crashes, Washington.

PEDESTRIAN AND BICYCLIST CRASHES

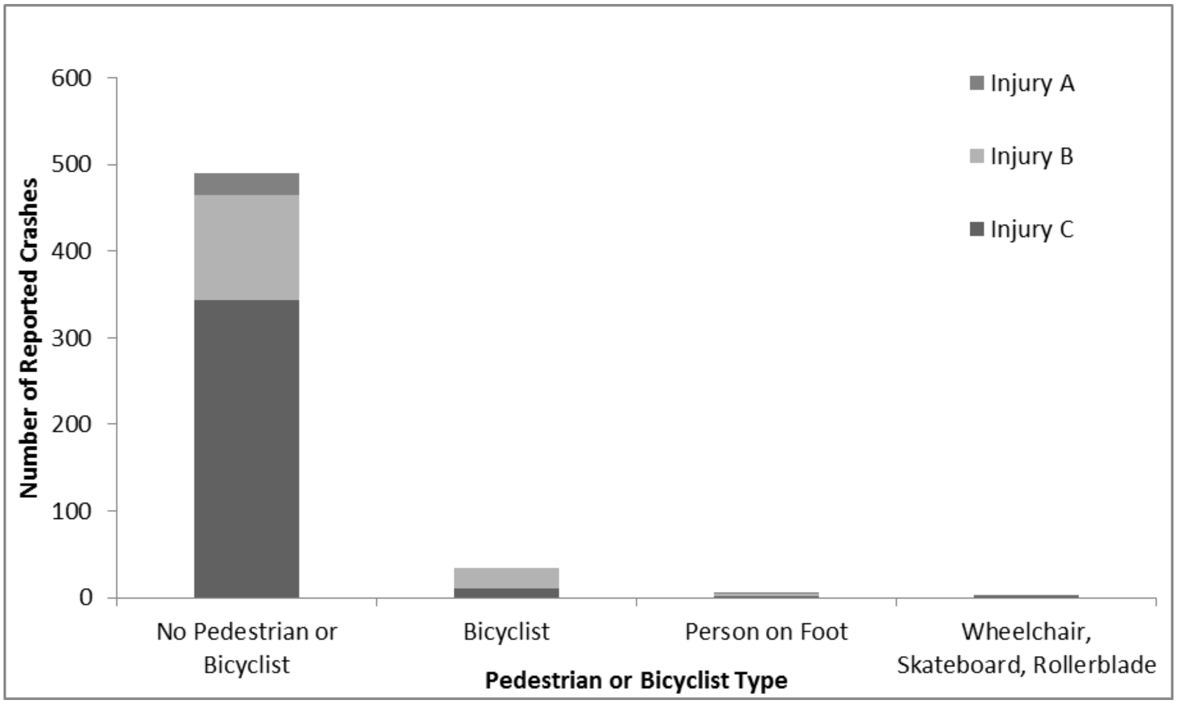

Figure 53. Chart. Pedestrian and bicyclist crashes, all injury crashes, Washington.

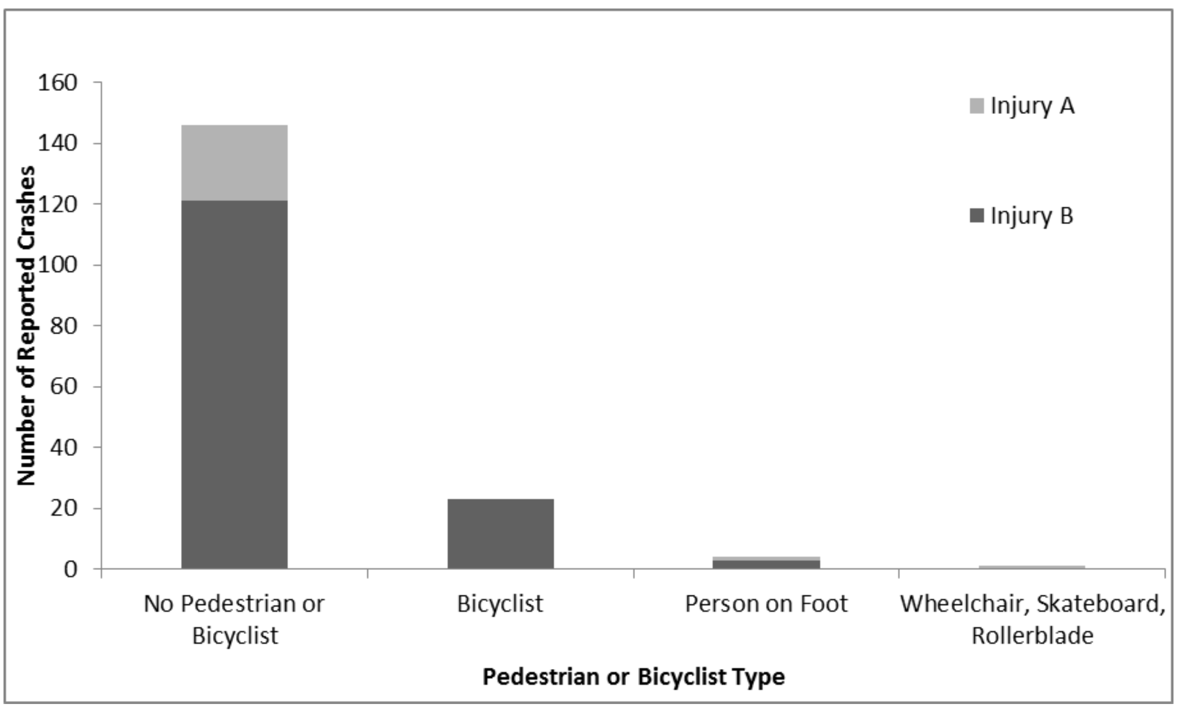

Figure 54. Chart. Pedestrian and bicyclist crashes, injury A and B crashes, Washington.

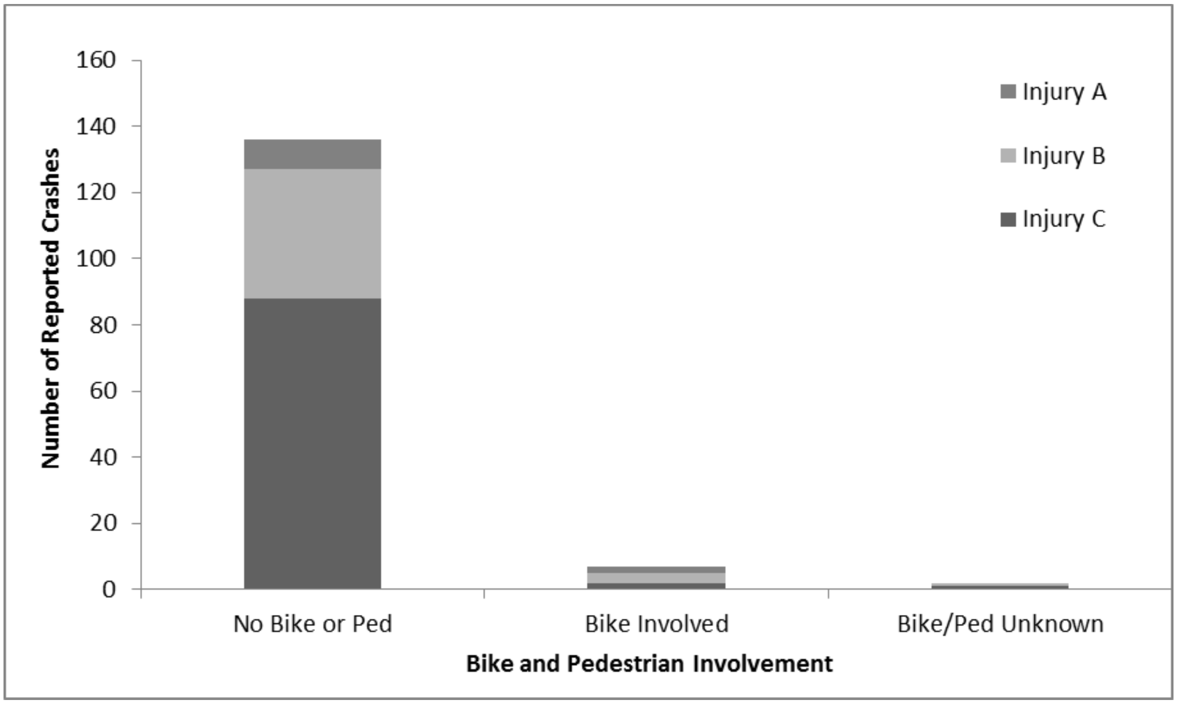

Figure 55. Chart. Pedestrian and bicyclist crashes, all injury crashes, Wisconsin.

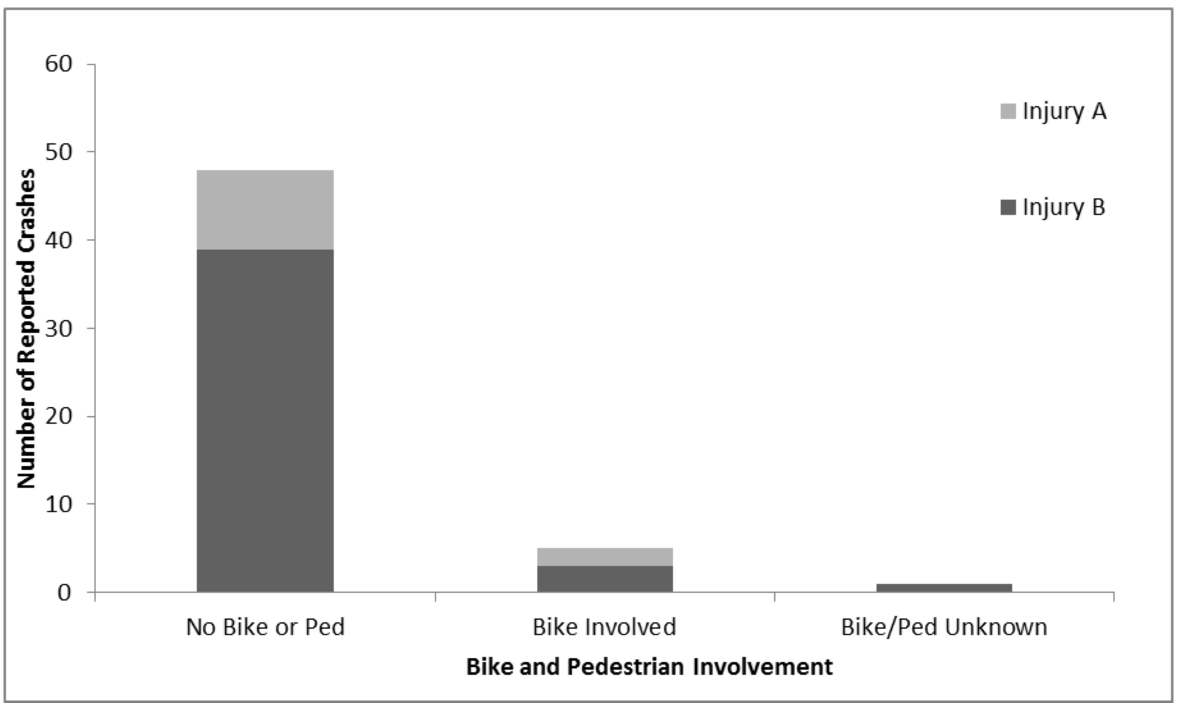

Figure 56. Chart. Pedestrian and bicyclist crashes, injury A and B crashes, Wisconsin.

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