

FINAL REPORT



WY-2202F

Wyoming Department of Transportation, State of Wyoming

ENHANCING CRASH DATA REPORTING TO HIGHWAY SAFETY PARTNERS IN WYOMING BY UTILIZING BIG DATA ANALYSIS AND SURVEY TECHNIQUES

By:

Department of Civil & Architectural Engineering
Wyoming Technology Transfer Center
University of Wyoming
1000 E. University Avenue, Dept. 3295
Laramie, Wyoming 82071

March, 2022

DISCLAIMER

Notice

This document is disseminated under the sponsorship of the Wyoming Department of Transportation (WYDOT) in the interest of information exchange. WYDOT assumes no liability for the use of the information contained in this document.

WYDOT does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

Quality Assurance Statement

The Wyoming Department of Transportation (WYDOT) provides high-quality information to serve Government, industry and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility and integrity of its information. WYDOT periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

Copyright

No copyrighted material, except that which falls under the "fair use" clause, may be incorporated into a report without permission from the copyright owner, if the copyright owner requires such. Prior use of the material in a WYDOT or governmental publication does not necessarily constitute permission to use it in a later publication.

- **Courtesy** — Acknowledgment or credit will be given by footnote, bibliographic reference, or a statement in the text for use of material contributed or assistance provided even when a copyright notice is not applicable.
- **Caveat for Unpublished Work** — Some material may be protected under common law or equity even though no copyright notice is displayed on the material. Credit will be given and permission will be obtained as appropriate.
- **Proprietary Information** — To avoid restrictions on the availability of reports, proprietary information will not be included in reports unless it is critical to the understanding of a report and prior approval is received from WYDOT. Reports containing such proprietary information will contain a statement on the Technical Report Documentation Page restricting availability of the report.

Creative Commons:

The report is covered under a Creative Commons, CC-BY-SA license. When drafting an adaptive report or when using information from this report, ensure you adhere to the following:

- **Attribution** — You must give appropriate credit, provide a link to the license and indicate if changes were made. You may do so in any reasonable manner but not in any way that suggests the licensor endorses you or your use.
- **ShareAlike** — If you remix, transform or build upon the material, you must distribute your contributions under the same license as the original.
- **No additional restrictions** — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.

You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation.

No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy or moral rights may limit how you use the material.

Technical Report Documentation Page

1. Report No. WY-2202F		2. Governmental Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Enhancing Crash Data Reporting to Highway Safety Partners in Wyoming by Utilizing Big Data Analysis and Survey Techniques				5. Report Date March 2022	
				6. Performing Organization Code	
7. Author(s) Ahmed Farid (0000-0002-5101-3237), Sahima Nazneen (0000-0001-7424-3089), Khaled Ksaibati (0000-0002-9241-1792), Mohammad Mahdi Rezapour (0000-0002-722X)				8. Performing Organization Report No.	
9. Performing Organization Name and Address Department of Civil & Architectural Engineering Wyoming Technology Transfer Center University of Wyoming 1000 E. University Avenue, Dept. 3295 Laramie, Wyoming 82071				10. Work Unit No. ()	
				11. Contract or Grant No. RS02220	
12. Sponsoring Agency Name and Address Wyoming Department of Transportation 5300 Bishop Blvd. Cheyenne, WY 82009-3340 WYDOT Research Center (307) 777-4182				13. Type of Report and Period Covered Final Report	
				14. Sponsoring Agency Code	
15. Supplementary Notes Project Champion: Matt Carlson, P.E., State Highway Safety Engineer					
16. Abstract: Road safety is a crucial topic of transportation engineering. The Wyoming Department of Transportation (WYDOT) collects such data from police crash reports and roadway inventories. WYDOT also provides those data to its partner groups in the form of data records or summary statistics documented in periodical reports. The groups include the Wyoming Seat Belt Coalition, the Wyoming Highway Patrol, the Wyoming Association of Sheriffs and Chiefs of Police, the Wyoming Transportation Safety Coalition, the Governor's Council on Impaired Driving, Wyoming's counties, the Wyoming Bicycle and Pedestrian System Task Force and motorcycle groups. In this research, surveys were prepared, distributed to and collected from those groups asking about the quality of the data they receive from WYDOT, particularly when it comes to data provision frequencies and unreported data that would be beneficial to those groups. In addition, big data analyses were conducted to evaluate human factors influencing crash occurrences and data provision frequencies. This research's efforts culminated in lists of recommendations to WYDOT regarding the provision of higher quality data at appropriate frequencies to its partners.					
17. Key Words Crash Data, Road Safety Groups, Surveys, Big Data Analytics			18. Distribution Statement This document is available through the National Transportation Library and the Wyoming State Library. Copyright © 2020. All rights reserved State of Wyoming, Wyoming Department of Transportation, and the University of Wyoming.		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 127	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION.....	1
Objectives	2
Report Organization.....	2
CHAPTER 2: BACKGROUND AND LITERATURE REVIEW	3
Background.....	3
Overview of the Wyoming Department of Transportation’s Safety Partners.....	3
Literature Review.....	5
Wyoming Electronic Crash Reporting System.....	5
Human Factors	6
Assessment of Crash Reporting Systems.....	7
CHAPTER 3: DISSEMINATING SURVEYS TO THE WYOMING DEPARTMENT OF TRANSPORTATION’S SAFETY PARTNERS.....	9
Summary of the Wyoming Seat Belt Coalition Survey Responses’ Results.....	9
Recommendations for the Wyoming Department of Transportation Regarding the Wyoming Seat Belt Coalition	13
Summary of the Wyoming Highway Patrol Survey Responses’ Results	29
Summary of the Wyoming Association of Sheriffs and Chiefs of Police Survey Responses’ Results.....	34
Recommendations for the Wyoming Department of Transportation Regarding the Wyoming Highway Patrol and the Wyoming Association of Sheriffs and Chiefs of Police	37
Summary of the Wyoming Transportation Safety Coalition Survey Responses’ Results.....	61
Recommendations for the Wyoming Department of Transportation Regarding the Wyoming Transportation Safety Coalition.....	64
Summary of the Governor’s Council on Impaired Driving Survey Responses’ Results.....	71
Recommendations for the Wyoming Department of Transportation Regarding the Governor’s Council on Impaired Driving.....	75
Summary of Wyoming’s Counties Survey Responses’ Results	88
Recommendations for the Wyoming Department of Transportation Regarding Wyoming’s Counties	91
Summary of the Wyoming Bicycle and Pedestrian System Task Force Survey Responses’ Results.....	92
Recommendations for the Wyoming Department of Transportation Regarding the Wyoming Bicycle and Pedestrian System Task Force	95
Summary of the Results of the Motorcycle Groups’ Survey.....	100

Recommendations for the Wyoming Department of Transportation Regarding the Motorcycle Groups.....	101
CHAPTER 4: IDENTIFYING CRITICAL HUMAN FACTORS AND APPROPRIATE CRASH DATA REPORTING TIME FRAMES	108
Identifying the Critical Human Factors	108
Identifying Appropriate Crash Reporting Time Frames.....	114
CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS.....	121
REFERENCES	123

LIST OF FIGURES

Figure 1: 2019 fatality counts of improperly belted or unbelted occupants.	14
Figure 2: 2019 counts of killed and injured improperly belted or unbelted distracted drivers.....	15
Figure 3: 2019 counts of killed and injured improperly belted or unbelted impaired drivers.	15
Figure 4: 2019 counts of killed and injured improperly belted or unbelted drivers.	15
Figure 5: 2019 counts of killed and injured improperly belted or unbelted front-seat passengers.	16
Figure 6: 2019 counts of killed and injured improperly belted or unbelted rear-seat passengers.	16
Figure 7: 2019 counts of killed and injured improperly restrained or unrestrained children 9 years or younger.	17
Figure 8: 2019 counts of killed and injured improperly belted or unbelted unlicensed drivers. ..	17
Figure 9: 2019 counts of killed and injured improperly belted or unbelted drivers with restricted licenses.	17
Figure 10: 2019 counts of killed and injured improperly belted or unbelted drivers by age.....	18
Figure 11: 2019 counts of killed and injured improperly belted or unbelted drivers by gender. .	18
Figure 12: 2019 fatal counts of improperly belted or unbelted drivers for in/out of state.....	18
Figure 13: 2019 serious injury counts of improperly belted or unbelted drivers for in/out of state.	19
Figure 14: 2019 minor injury counts of improperly belted or unbelted drivers for in/out of state.	19
Figure 15: 2019 possible injury counts of improperly belted or unbelted drivers for in/out of state.	20
Figure 16: Crash Counts of improperly belted or unbelted drivers by year.	20
Figure 17: 2019 counts of speed related crashes involving improper use or non-use of restraints.	20
Figure 18: 2019 counts of killed and injured improperly belted or unbelted occupants in crashes where air bags were not deployed.....	26
Figure 19: 2019 counts of killed and injured improperly belted or unbelted ejected/partially ejected occupants.	26
Figure 20: 2019 counts of killed and injured improperly belted or unbelted trapped occupants.	26
Figure 21: 2017 heat map of crashes involving improper use or non-use of restraints.	27
Figure 22: 2017 heat map of fatal, suspected serious injury and suspected minor injury crashes involving improper use or non-use of restraints.	27
Figure 23: 2019 distribution of unbelted occupants to vehicles.	28
Figure 24: 2019 restraint non-use proportions by day of the week.	28
Figure 25: 2019 restraint non-use proportions by weather condition.	29
Figure 26: 2019 counts of cited drivers at the crash scenes by age.	39
Figure 27: 2019 counts of cited drivers at the crash scenes by gender.	39
Figure 28: 2019 counts of hit-and-run crashes.	39
Figure 29: 2019 counts of crashes by time of day.	40
Figure 30: 2019 counts of crashes by number of vehicles involved.	41
Figure 31: 2019 counts of bicycle crashes.	42
Figure 32: 2019 counts of crashes resulting in fires.	43
Figure 33: 2019 counts of crashes involving mechanical failures.	43
Figure 34: 2019 counts of weekend driving under the influence crashes.	44
Figure 35: 2019 counts of drivers by detestable condition.	45

Figure 36: 2019 counts of ejected, partially ejected and trapped occupants.	45
Figure 37: 2019 special occasion crashes.	45
Figure 38: 2019 counts of killed and injured male drivers.	46
Figure 39: 2019 counts of killed and injured female drivers.	46
Figure 40: 2019 counts of killed and injured male passengers.	46
Figure 41: 2019 counts of killed and injured female passengers.	47
Figure 42: 2019 counts of killed and injured drivers by age in the first quarter.	47
Figure 43: 2019 counts of killed and injured drivers by age in the second quarter.	47
Figure 44: 2019 counts of killed and injured drivers by age in the third quarter.	48
Figure 45: 2019 counts of killed and injured drivers by age in the fourth quarter.	48
Figure 46: 2019 counts of killed and injured passengers by age in the first quarter.	48
Figure 47: 2019 counts of killed and injured passengers by age in the second quarter.	49
Figure 48: 2019 counts of killed and injured passengers by age in the third quarter.	49
Figure 49: 2019 counts of killed and injured passengers by age in the fourth quarter.	49
Figure 50: 2019 counts of distracted drivers by means of distraction.	50
Figure 51: 2019 fatality counts of improperly belted or unbelted occupants.	50
Figure 52: 2019 counts of killed and injured motorcycle operators.	50
Figure 53: 2019 counts of killed and injured motorcycle operators wearing helmets.	51
Figure 54: 2019 counts of killed and injured motorcycle operators not wearing helmets.	51
Figure 55: 2019 counts of killed and injured motorcycle passengers.	51
Figure 56: 2019 counts of killed and injured motorcycle passengers wearing helmets.	52
Figure 57: 2019 counts of killed and injured motorcycle passengers not wearing helmets.	52
Figure 58: 2019 counts of crashes by lighting condition in the first quarter.	53
Figure 59: 2019 counts of crashes by lighting condition in the second quarter.	53
Figure 60: 2019 counts of crashes by lighting condition in the third quarter.	54
Figure 61: 2019 counts of crashes by lighting condition in the fourth quarter.	54
Figure 62: 2019 counts of crashes by road surface condition in the first quarter.	55
Figure 63: 2019 counts of crashes by road surface condition in the second quarter.	55
Figure 64: 2019 counts of crashes by road surface condition in the third quarter.	56
Figure 65: 2019 counts of crashes by road surface condition in the fourth quarter.	56
Figure 66: 2017 heat map of fatal, suspected serious injury and suspected minor injury crashes.	57
Figure 67: 2017 heat map of speed related crashes.	57
Figure 68: 2017 heat map of speed related fatal, suspected serious injury and suspected minor injury crashes.	58
Figure 69: 2017 heat map of wild animal crashes.	58
Figure 70: 2017 heat map of adverse weather related crashes.	59
Figure 71: 2017 heat map of fatal, suspected serious injury and suspected minor injury adverse weather related crashes.	59
Figure 72: 2017 heat map of driving under the influence crashes.	60
Figure 73: 2017 heat map of driving under the influence fatal, suspected serious injury and suspected minor injury crashes.	60
Figure 74: 2019 counts of commercial vehicle drivers cited at the crash scenes.	65
Figure 75: 2019 counts of commercial vehicle drivers cited at the crash scenes by age.	65
Figure 76: 2019 counts of commercial vehicle drivers cited at the crash scenes by gender.	66
Figure 77: 2019 counts of distracted commercial vehicle drivers by means of distraction.	66

Figure 78: 2019 counts of commercial vehicle drivers driving under the influence.	66
Figure 79: 2019 counts of improperly belted or unbelted commercial vehicle drivers.	67
Figure 80: 2019 counts of cited commercial vehicle drivers at the crash scenes by state.	67
Figure 81: 2019 counts of speeding commercial vehicle drivers.	67
Figure 82: 2019 counts of commercial vehicle crashes by lighting condition.	68
Figure 83: 2019 counts of killed and injured commercial vehicle drivers.	68
Figure 84: 2019 counts of killed and injured commercial vehicle passengers.	68
Figure 85: 2019 counts of upgrade and downgrade conditions facing commercial vehicle drivers.	69
Figure 86: 2017 heat map of commercial vehicle crashes.	70
Figure 87: 2017 heat map of fatal, suspected serious injury and suspected minor injury commercial vehicle crashes.	70
Figure 88: 2019 counts of alcohol impaired drivers.	76
Figure 89: 2019 counts of drug impaired drivers.	76
Figure 90: 2019 counts of alcohol related fatalities and injuries.	76
Figure 91: 2019 counts of drug related fatalities and injuries.	77
Figure 92: 2019 counts of alcohol related crashes.	77
Figure 93: 2019 counts of drug related crashes.	77
Figure 94: 2019 counts of male drivers driving under the influence of alcohol by age.	78
Figure 95: 2019 counts of female drivers driving under the influence of alcohol by age.	78
Figure 96: 2019 counts of male drivers driving under the influence of drugs by age.	78
Figure 97: 2019 counts of female drivers driving under the influence of drugs by age.	79
Figure 98: 2019 counts of driving under the influence crashes involving pedestrians and/or bicyclists.	79
Figure 99: 2019 counts of driving under the influence crashes involving speeding.	79
Figure 100: 2019 counts of improperly belted or unbelted impaired drivers.	80
Figure 101: 2019 counts of driving under the influence related crashes during special occasions.	81
Figure 102: 2019 counts of driving under the influence related crashes by day of the week.	81
Figure 103: 2017 heat map of driving under the influence crashes.	87
Figure 104: 2017 heat map of driving under the influence fatal, suspected serious injury and suspected minor injury crashes.	87
Figure 105: 2019 counts of killed and injured pedestrians.	92
Figure 106: 2019 counts of pedestrian and bicycle crashes.	96
Figure 107: 2019 counts of killed and injured pedestrians.	96
Figure 108: 2019 counts of killed and injured bicyclists.	96
Figure 109: 2019 counts of distracted drivers involved in pedestrian and/or bicycle crashes.	97
Figure 110: 2019 counts of impaired drivers involved in pedestrian and/or bicycle crashes.	98
Figure 111: 2019 counts of pedestrian and bicycle crashes by first harmful event location.	98
Figure 112: 2019 counts of pedestrian and bicycle crashes for segments and junctions.	98
Figure 113: 2019 counts of pedestrian and bicycle crashes by weather condition.	99
Figure 114: 2019 counts of pedestrian and bicycle crashes by road surface condition.	99
Figure 115: 2019 counts of pedestrian and bicycle crashes by lighting condition.	99
Figure 116: 2017 heat map of pedestrian and bicycle crashes.	100
Figure 117: 2019 counts of killed and injured motorcycle operators.	101
Figure 118: 2019 counts of killed and injured motorcycle operators wearing helmets.	101

Figure 119: 2019 counts of killed and injured motorcycle operators not wearing helmets.....	102
Figure 120: 2019 counts of killed and injured motorcycle passengers.....	102
Figure 121: 2019 counts of killed and injured motorcycle passengers wearing helmets.	102
Figure 122: 2019 counts of killed and injured motorcycle passengers not wearing helmets.	103
Figure 123: 2019 counts of killed and injured motorcycle operators by age in the first quarter.	103
Figure 124: 2019 counts of killed and injured motorcycle operators by age in the second quarter.	103
Figure 125: 2019 counts of killed and injured motorcycle operators by age in the third quarter.	104
Figure 126: 2019 counts of killed and injured motorcycle operators by age in the fourth quarter.	104
Figure 127: 2019 counts of impaired motorcycle operators.	106
Figure 128: 2019 counts of motorcycle crashes by first harmful event location.....	106
Figure 129: 2019 counts of motorcycles involved in horizontal curve related crashes.....	106
Figure 130: 2017 heat map of motorcycle crashes.	107
Figure 131: Random forest model’s variable importance chart.....	112
Figure 132: Estimated probabilities of observing fluctuations in crash counts throughout 2019.	115
Figure 133: Estimated probabilities of observing fluctuations in counts of fatal, suspected serious injury and suspected minor injury crashes throughout 2019.	115
Figure 134: Estimated probabilities of observing fluctuations in counts of crashes involving improper or non-use of safety restraints throughout 2019.....	116
Figure 135: Estimated probabilities of observing fluctuations in counts of speed related crashes throughout 2019.....	116
Figure 136: Estimated probabilities of observing fluctuations in counts of adverse weather related crashes throughout 2019.	117
Figure 137: Estimated probabilities of observing fluctuations in counts of animal crashes throughout 2019.....	117
Figure 138: Estimated probabilities of observing fluctuations in counts of driving under the influence crashes throughout 2019.	118
Figure 139: Estimated probabilities of observing fluctuations in counts of non-motorist crashes throughout 2019.....	118
Figure 140: Estimated probabilities of observing fluctuations in counts of motorcycle crashes throughout 2019.....	119

LIST OF TABLES

Table 1: 2019 Counts of Killed and Injured Improperly Restrained or Unrestrained Occupants by Manner of Collision in the First Quarter.....	21
Table 2: 2019 Counts of Killed and Injured Improperly Restrained or Unrestrained Occupants by Manner of Collision in the Second Quarter	22
Table 3: 2019 Counts of Killed and Injured Improperly Restrained or Unrestrained Occupants by Manner of Collision in the Third Quarter	23
Table 4: 2019 Counts of Killed and Injured Improperly Restrained or Unrestrained Occupants by Manner of Collision in the Fourth Quarter	24
Table 5: 2019 Counts of Killed and Injured Improperly Belted or Unbelted Occupants by Manner of Collision.....	25
Table 6: 2019 Counts of Drivers' Actions Preceding the Crashes	38
Table 7: 2019 Counts of Crashes by First Harmful Event Location.....	40
Table 8: 2019 Counts of Crashes by Weather Condition	41
Table 9: 2019 Animal Crashes by Type of Animal Struck.....	42
Table 10: 2019 Counts of Crashes by Manner of Collision.....	44
Table 11: 2019 Counts of Commercial Vehicle Crashes by Manner of Collision	69
Table 12: 2019 Counts of Impaired Drivers' Citations Issued at the Crash Scenes	80
Table 13: 2019 Counts of Driving under the Influence Crashes by Manner of Collision in the First Quarter	82
Table 14: 2019 Counts of Driving under the Influence Crashes by Manner of Collision in the Second Quarter.....	83
Table 15: 2019 Counts of Driving under the Influence Crashes by Manner of Collision in the Third Quarter	84
Table 16: 2019 Counts of Driving under the Influence Crashes by Manner of Collision in the Fourth Quarter.....	85
Table 17: 2019 Counts of Driving under the Influence Crashes by Manner of Collision	86
Table 18: 2019 Counts of Pedestrian and Bicycle Crashes by Manner of Collision	97
Table 19: 2019 Counts of Motorcycle Crashes by Manner of Collision	105
Table 20: 2019 Counts of Citations Issued to Motorcycle Operators at the Crash Scenes	105
Table 21: Descriptive Statistics of the 2018 and 2019 Crash Records' Sample.....	108
Table 22: Results of the Driver's Status-Injury Severity Contingency Table Test	109
Table 23: Logistic Regression Model's Results	110
Table 24: Logistic Regression Model's Odds Ratios	111

LIST OF ABBREVIATIONS

ABATE	A Brotherhood against Totalitarian Enactments
ADAS	Advanced Driver Assistance Systems
BAC	Blood Alcohol Concentration
CMV	Commercial Motor Vehicle
DUI	Driving under the Influence
GCID	Governor's Council on Impaired Driving
GIS	Geographic Information System
HSO	Highway Safety Office
IIHS	Insurance Institute for Highway Safety
PDO	Property-Damage-Only
ROC	Receiver Operating Characteristic
WASCOP	Wyoming Association of Sheriffs and Chiefs of Police
WBPSTF	Wyoming Bicycle and Pedestrian System Task Force
WECRS	Wyoming Electronic Crash Reporting System
WHP	Wyoming Highway Patrol
WSBC	Wyoming Seat Belt Coalition
WTSC	Wyoming Transportation Safety Coalition
WYDOT	Wyoming Department of Transportation

CHAPTER 1: INTRODUCTION

Road safety is a crucial area that should to be addressed by transportation agencies. As per the Insurance Institute for Highway Safety (IIHS), in 2019, Wyoming's roadway death toll was estimated as 1.44 fatalities per 100 million vehicle-miles traveled (Insurance Institute for Highway Safety, 2021a). Evaluating road safety is essential to reduce crash counts, particularly those of severe crashes, by recommending appropriate safety countermeasures. This may involve redesigning roadway facilities, enhancing enforcement practices or promoting drivers' education campaigns. The fundamental component of road safety assessments is the data collection. The data, which are primarily those of police crash reports, should be accurate and collected in a timely fashion. The data are then processed to pinpoint the precursors that give rise to crashes, identify crash trends, establish definitive objectives, such as reducing the number of road fatalities per 100 million vehicle-miles traveled to 1, and reassess road safety conditions to ascertain whether or not the objectives were achieved.

The Wyoming Department of Transportation (WYDOT) is the main agency that collects and maintains Wyoming's road safety data. WYDOT provides such data to its partner groups on a regular basis such that they have a clear understanding of the safety of the state's roads, can set their objectives, and can implement road safety countermeasures to achieve those objectives. The data are provided either as database files or in the form of summary statistics documented in reports available in the WYDOT Highway Safety Office (HSO). The groups are the following:

- Wyoming Seat Belt Coalition (WSBC)
- Wyoming Highway Patrol (WHP)
- Wyoming Association of Sheriffs and Chiefs of Police (WASCOP)
- Wyoming Transportation Safety Coalition (WTSC)
- Governor's Council on Impaired Driving (GCID)
- Wyoming's counties
- Wyoming Bicycle and Pedestrian System Task Force (WBPSTF)
- Motorcycle groups

Providing the appropriate data to each group is an efficient means of addressing road safety. Yet, it should be noted that gaps in road safety data reporting exist. The appropriateness of the frequency at which road safety data are provided to the partner groups should to be evaluated as well. For this project, evaluating the data needs of the partner groups and the appropriateness of the data provision frequency was achieved by disseminating a tailored survey to each group. In addition, more profound insights on the human factors that lead to crashes in the state were obtained to better address road safety. This was achieved by using big data analytical techniques conducted on WYDOT's crash data. This project culminated in a series of recommendations for WYDOT regarding specific road safety data reporting requirements to the partner groups.

Objectives

The main objective of this project was to investigate the data needs of WYDOT's partner groups, pinpoint the gaps in road safety data reporting, and suggest appropriate guidelines for WYDOT on the reporting of the data to the groups. This was achieved via the circulation of questionnaires to those groups. The second objective was to examine the human factors that contribute to crashes in Wyoming via big data analyses.

WYDOT's partner groups would then have access to enhanced data in the form of database files or summary statistics in a timely fashion. Thus, they would have a more comprehensive understanding of the road safety conditions, especially the human factors that contribute to crashes. This would enable the groups to propose effective measures to address road safety.

Report Organization

Chapter 2 comprises background information and a review of previous studies related to this project. The subsequent chapter, Chapter 3, entails the summarized results of the responses to the surveys, which were distributed to WYDOT's safety partners. Chapter 4 presents results of discussions of big data analyses that were conducted to evaluate the human factors influencing Wyoming's crashes and ascertain appropriate periods for reporting crashes to WYDOT's partners. Finally, Chapter 5 is composed of the conclusions of this research and recommendations for future work.

CHAPTER 2: BACKGROUND AND LITERATURE REVIEW

Background

WYDOT employs the Wyoming Electronic Crash Reporting System (WECRS), an online system that is used to log crash reports. The data format and quality of the data from the system has not been found to be completely satisfactory to WYDOT's partner groups. This introduces an issue in assessing and addressing road safety efficiently.

Another area of concern is human factors, which is one of the principal crash precursors. As per Insurance Institute for Highway Safety (IIHS), the proportion of unbelted vehicle occupants in Wyoming who died in traffic crashes was estimated at 45 percent, in 2019 (Insurance Institute for Highway Safety, 2021b). Improper use or non-use of safety restraints is an issue that is addressed by the WSBC. Other human factors include, but are not limited to, inexperienced teenage drivers, who recently obtained their drivers' licenses, reckless driving, distracted driving, and driving under the influence (DUI) of drugs/alcohol. WHP and WASCOP both strive to combat the aforementioned factors. This emphasizes the importance of the timely provision of comprehensive high-quality data to WYDOT's partner groups when it comes to the evaluation of road safety and the implementation of safety improvement strategies.

Overview of the Wyoming Department of Transportation's Safety Partners

This subsection comprises an introduction to WYDOT's safety partner groups, which are: WSBC, WHP, WASCOP, WTSC, GCID, WBPSTF, Wyoming Counties, and the motorcycle groups.

The Wyoming Seat Belt Coalition endeavors to educate the public through the use of the media, seminars, and other outreach programs about the importance of properly buckling up since the seat belt use rate in the state is below that of the nation on average (Gordon et al., 2021). Also, the group holds assemblies to discuss research and strategies regarding increasing the rate of proper restraint use in order to reduce traffic injuries, including fatal injuries.

The WHP enforces traffic polices and other laws by patrolling the major highways in the state. It also supports emergency services and engages in other activities. The WHP duties include running dispatch stations, completing crash reports, conducting criminal procedures, conducting vehicle inspections, managing road closures, controlling traffic in special situations, and other activities. WHP officers also contribute to safety outreach programs across the state since one of their motives is to improve road safety. WHP manages multiple road safety-oriented programs, such as the Alive-at-25 and Report Every Drunk Driver Immediately (REDDI) programs, among others (Wyoming Highway Patrol, 2019).

The Wyoming Association of Sheriffs and Chiefs of Police is a union of federal and state officials (Wyoming Association of Sheriffs and Chiefs of Police, 2021a). On behalf of the WASCOP's members, several entities represent the association, including commissions/boards

of the Wyoming State Legislature and charity groups. The association promotes efficient law enforcement practices within the policing community. Its goal is to address issues related to Wyoming's law enforcement agencies. It also provides advice to the legislative body regarding law enforcement and public safety laws. The association is engaged in several road safety projects, including targeting alcohol use and crime. This entails the sponsoring of data collection efforts (Wyoming Association of Sheriffs and Chiefs of Police, 2021b).

The Wyoming Transportation Safety Coalition is supported by the Wyoming Trucking Association. Members of the coalition are diverse and represent freight firms transporting various types of merchandises (Wyoming Transportation Safety Coalition, 2021). Other members include those of power generation firms, WYDOT, WHP, the Department of Homeland Security (DHS), and other members. The coalition's objective is to improve the safety of truck drivers via educational campaigns.

The Governor's Council on Impaired Driving (2019) is aimed at addressing DUI drivers. This is performed by means of educational/outreach campaigns. The campaigns are run to educate the public about the disastrous consequences of DUI. Programs include the chemical testing program and the 24/7 sobriety program, to name a few. The council collects its DUI related data from WYDOT and WASCOP.

Wyoming's counties comprise multiple departments including the clerks of courts, local sheriffs' offices, planning, public health, and emergency management, among other agencies (Albany County Wyoming, 2021). In the context of this project, the local sheriffs' offices enforce the traffic laws while the health departments strive to upkeep the health and wellbeing of society, especially when it comes to treating victims of traffic crashes. The clerk of courts prosecutes the at-fault drivers involved in traffic crashes and those who received citations for committing traffic violations. Wyoming's counties collaborate with WYDOT and a proportion of its partners, as well as contributing to coordinated efforts addressing road safety.

The Wyoming Bicycle and Pedestrian System Task Force is a coalition of members from WYDOT, the City of Cheyenne, the Wyoming Office of Tourism, the Bicycle Station shop, Wyoming Pathways, Platte River Trails, the Wyoming Business Council, the Wyoming Department of Health, and Wyoming State Parks, among other critical entities. The task force was established to provide advice to Wyoming's legislature/local governments regarding insights gained from assessing the state's bicycle and pedestrian trails. The insights are those of financial gains, feasibilities, safety concerns and the fostering of travelers' health (Carlson et al., 2018).

Other than Wyoming's counties, there are several motorcycle groups and clubs in Wyoming. They include, but are not limited to, the Wyoming Central A Brotherhood against Totalitarian Enactments (ABATE), and the Harley-Davidson motorcycle groups. The Wyoming Central ABATE provides training for their neophyte motorcyclists, raises motorcycle safety awareness, and fosters rider sobriety. The group also hosts fundraising events to uphold motorcycle riders'

legal rights. The Harley-Davidson groups are dealerships that sell and service Harley-Davidson motorcycles. They are also involved in motorcycle events.

Literature Review

Road safety improvement is a result of a confluence of efforts from transportation agencies and groups. Their ultimate objectives are to reduce the counts of crashes and their unfavorable consequences, namely fatalities and severe injuries. They also aim to prevent specific behaviors, such as seat belt non-use and/or DUI. Extensive high-quality data should be available and well maintained in order to assess road safety. It is also essential that the data be processed to gain a better understanding of the various crash contributing factors, including human factors, traffic patterns, geometric conditions, and weather conditions. The influence of enforcement policies and comprehensive crash costs should to be incorporated in the data analyses. Comprehensive crash costs quantify the damages to property, medical expenses, coroner's expenses, and any costs to society incurred because of the crashes (American Association of State Highway and Transportation Officials, 2010; Australian Transport Council, 2008).

Road safety management systems comprise the personnel, tasks, hardware and software needed to perform multiple essential tasks. They include gathering, analyzing and maintaining roadway crash data, as per the World Health Organization (WHO) (2010). An essential component of any road safety management system is its stored crash records. Crash reporting is conducted by police officers manually on hard copy forms, yet, reporting on digital forms and web-based forms is gaining momentum among multiple jurisdictions. Reporting crashes on web-based forms diminishes errors in data coding and transfer leading to the compilation of accurate data (Khattak and Iranitalab, 2016). In addition, web-based crash reports are accessible instantly after being uploaded online.

Wyoming Electronic Crash Reporting System

The WECRS implements the ReportBeam digital crash reporting tool. The ReportBeam is an online system operable via Microsoft Windows platforms. It is interfaced with the Smart Roads drawing software that enables quick and detailed sketching in the reports.

The ReportBeam entails two components, namely the client system and the server. In the client system, the details are entered into the reports and stored in a manner similar to that of emails. A report manager with an inbox folder, drafts folder, and a folder for new reports is consulted to maintain the reports. The new folder contains the templates for the reports to be filled out. Any reports with missing records are saved in the drafts folder and those that are completed, submitted, yet rejected, are transferred to the inbox folder. The server is an online system that grants access to database management professionals who approve or deny the reports. The server also features tools that are utilized for the analysis of and circulation of the reports.

The ReportBeam performs four tasks that enter information into the reports, maintaining the reports, evaluating the data, and disseminating the reports. Police officers complete crash reports

promptly and submit them. An advantage of the ReportBeam is that it may be used to complete crash reporting forms offline. It also features a tool that records the driver's license information by scanning the license. Police officers may also create their profiles such that every time they fill out a new report, they need not re-enter their personal information.

Uploaded crash reports that are approved by the database managers are transferred to another database for inspection. Incomplete reports, or those that are judged to contain faulty information, are returned to the officers who uploaded them with comments. Every activity or person, including the officers who inputted the information in the reporting forms, the database management professionals who inspected the reports, comments provided, and changes made to the reports, are audited in a log. Once the reports are approved, they are assigned referencing codes and their data are logged into a dataset.

The crash data are available once uploaded online. The database management professionals can inspect the locations of the crashes, depicted summary statistics, and locations of police officers via maps. The mapping tool has a special feature that allows the user to visualize all crashes, hot spots, which are locations that are likely to experience an abnormally large number of crashes, and other crash trends. The hot spots are identified by computations built in the system and facilitate the prioritization of crash sites that are targeted for safety countermeasure implementation. The system also includes a data analysis tool used for generating charts describing specific crash summary statistics. Such statistics may be obtained for both roadway segments and intersections.

Human Factors

The WECRS contains three classifications of road safety data, vehicle characteristics data, environmental characteristics data, and drivers' characteristics data, or simply human factors data. Human factors constitute the main contributing factors that result in crashes. It is estimated that 94 percent of crash precursors are attributed to the drivers (National Highway Traffic Safety Administration, 2018). Dingus et al. (2016) examined multiple sub classifications of human factors, which are DUI/tiredness, driving blunders (e.g. encroaching on an adjacent lane while turning), judgement errors (e.g. tailgating) and identifiable distractions (e.g. use of electronic device). DUI/tiredness was estimated to raise the odds of being involved in a crash by 5.2 times, while driving blunders were estimated to raise such odds by 18.2 times assuming all else was unchanged.

The preponderance of large amounts of data collected from not only crash reports but also the social media, mobile phones, and hospital records, among others, has motivated the proposition of employing big data analysis techniques. They are utilized for processing gigantic datasets that otherwise cannot be processed using conventional data analysis methods to uncover data patterns and relationships among variables. When it comes to road safety data analyses, big data methods, which are data mining/machine learning algorithms, are widely implemented (Stylianou et al., 2019).

Multiple big data methods categorize crash injury severity by detecting trends and implementing models to organize crash data points into severity categories, such as property-damage-only (PDO), injury, or fatality (Kashani and Mohaymany, 2011). This type of analysis reveals insights regarding the conditions that lead to both severe and non-severe crashes. Typical crash injury severity models employed include decision trees (Abellán et al., 2013; Chang and Chien 2013; Kashani and Mohaymany, 2011), support vector machines (Chen et al., 2016; Li et al., 2008; Yu and Abdel-Aty, 2014), and artificial neural networks (Delen et al., 2006; Zeng and Huang, 2014).

Decision tree methods and their variants (James et al., 2013b) are non-parametric methods that do not specify any relationship between the outcome being modeled, whether it be the counts or severities of the crashes, and the crash precursors, which are the human factors, roadway geometric conditions, and environmental conditions, among others. Decision trees subset the data to facilitate the interpretation of the crash precursors' effects on the outcome and present the results in the form of branches/leaves. For instance, a decision tree model's output diagram may illustrate two branches, one being roadway segments with shoulders that are wider than six feet and the other representing those with shoulders that are six feet or narrower. By visually inspecting the diagram, the user may simply infer that the segments with the wider shoulders are likely to experience fewer lane departure crashes.

The support vector machine technique is another viable machine learning method that is mainly used for modeling outcomes that are not continuous (e.g. crash severity). It has been shown to perform well among the variety of machine learning methods (James et al., 2013a).

Artificial neural networks are methods that are used to estimate non-linear relationships between the outcome modeled (e.g. crash count) and the variables influencing it (e.g. crash precursors), unlike traditional statistical methods, as per Moghaddam et al. (2011). Artificial neural networks function as a trend recognition tool similar to that of the human brain and are shown to exhibit better predictive power than those of multiple statistical methods (Abdel-Aty and Abdelwahab, 2004).

Assessment of Crash Reporting Systems

As per the United States Government Accountability Office (2004), crash data quality are evaluated based on six criteria, timeliness, consistency, completeness, accuracy, accessibility, and data integration. Timeliness is the prompt provision of crash data for evaluation purposes, preferably within ninety days of the crashes' occurrences. Consistency refers to the concept that crash data ought to be reported in a format that closely resembles those of the other jurisdictions in the state and is satisfactory according to national standards. Completeness refers to the premise that detailed data be collated for each reported crash and should not omit any critical information. Accuracy is the absence of data errors. Accessibility is the ease of obtaining the crash data by the primary analysts. Data integration refers to the ability to merge the crash dataset with other relevant data (United States Government Accountability Office, 2004).

Timeliness is a fundamental criterion for transportation safety professionals since obtaining outdated crash data may result in the misidentification of crash sites targeted as priorities for the deployment of safety countermeasures (Scopatz et al., 2017). Logan and McShane (2006) noted that using data of five crash years disguises the significances of traffic safety problems motivating the prompt collection of crash data. Instead, the immediate diagnosis of hazardous crash sites is desired. Mitchell et al. (2009) categorized the timeliness of collecting and storing crash data by time frame. The authors ranked data made available within a month, those made available between one and two years and those made available after two years as “very high,” “high” and “low,” respectively.

The United States Government Accountability Office assessed data management programs in nine states and, as per the results, crash data were not disseminated for a month to a year and a half in the majority of the states. In addition, in a proportion of states, the data were circulated after the suggested ninety-day period (United States Government Accountability Office, 2004).

Delucia and Scopatz (2005) evaluated the performances of twenty-six state roadway agencies. The authors interpreted that twenty-two states reported all crashes that incurred damages exceeding the reporting thresholds. The reporting threshold is the minimum quantified damage to property sustained to warrant the reporting of a crash. It was also inferred that the minority of the states (20 percent) inputted the crash data into their statewide database between 91 to 364 days from the crashes’ occurrences. Furthermore, data quality should be assessed promptly so as not to compromise the timeliness of submitting the crash reports to database managers who approve them for entry into the statewide database after corresponding with the officers who completed those reports (Scopatz et al., 2017).

CHAPTER 3: DISSEMINATING SURVEYS TO THE WYOMING DEPARTMENT OF TRANSPORTATION'S SAFETY PARTNERS

The initial task of this research project involved evaluating the data needs of WYDOT's partner groups. This was conducted by drafting and disseminating a tailored survey questionnaire to each group. The survey questions asked about data timeliness, metrics interpreted from analyses of crash data (e.g. seat belt use statistics, DUI statistics, etc.), statistics describing crash consequences (i.e. severities), reports documenting road safety statistics, citation statistics, and relevant topics that might be of interest to those partner groups. Once the surveys were distributed and responses were received back, the responses were evaluated in order to interpret the groups' data needs. From the survey, WYDOT received suggestions regarding not only the data needs of its partners but also the data formats, crash reporting time periods, data quality, and topics for future research. This might include upgrading WECS.

Summary of the Wyoming Seat Belt Coalition Survey Responses' Results

A survey was disseminated to members of the Wyoming Seat Belt Coalition and thirteen responses were received. The common question asked in all surveys was how often did the respondents receive/secure road safety data/reports from the WYDOT Highway Safety Office? Less than half (40 percent) of the respondents claimed that they often obtained crash data from WYDOT once a month, while a third checked the option, "other," and specified the following:

- "Never."
- "I do not receive any."
- "Upon request."
- "Sporadically."
- "Have not received."

When it comes to data transfer protocols, 80 percent stated that they received the data via email. Also, the respondents were asked whether the current safety data provided to them from the WYDOT HSO fulfilled their needs on a scale of one (not at all) to five (absolutely). Almost half of the respondents declared that the current crash data being provided to them were either of no benefit or were absolutely not beneficial (provided a rating of three), while over a quarter claimed that the data were beneficial (provided ratings of four and five). More importantly, the respondents were asked about the ideal period during which they preferred to receive the crash data from the dates the crashes occurred. Roughly a third stated that they preferred that the crash data be delivered to them within a week of the crashes occurrences, and another similar proportion stated that the desired time frames was a week to two weeks from the dates the crashes occurred.

Regarding the data format preferred, over 90 percent of the respondents favored summary statistics tables, over 50 percent preferred figures, and about 20 percent preferred pie charts.

Note that each respondent was provided the option of specifying multiple data formats from a list (i.e. checkboxes).

The respondents were further asked about the preferred method of portraying locations of crashes involving improper use or non-use of safety restraints. They included the following:

- Narrative descriptions of the locations
- Photos
- Color-coded maps
- Road and milepost information
- Geographic information system (GIS) coordinates
- A combination of the above
- Other (please specify)

Remarkably, more than half of the respondents claimed that they were interested in a combination of methods of depicting the crash locations. The answer choices were provided in the form of checkboxes such that each respondent might have selected multiple options. The respondents also selected the options, “narrative descriptions of the locations,” “color-coded maps” and “road and milepost information.”

In the following section of the survey, respondents were asked about road safety reports pertaining to the use of restraints. The reports, most of which are available in the WYDOT HSO website, are the following:

- Wyoming Occupant Seat Belt Usage by Year
- Wyoming Drivers Survey, 2016
- 2019 Seat Belt Survey Analysis
- Wyoming Statewide Crashes by Year
- 2019 Highway Safety Crash Data Survey Final Report
- Wyoming Highway Safety Behavioral Program FY2020 Highway Safety Plan
- Wyoming Report on Traffic Crashes 2019

On a scale of one (not at all) to five (absolutely) describing whether the respondents were familiar with these reports and whether they frequently utilized them, roughly 35 percent provided a rating of three while another roughly 35 percent provided a rating of five. In the following question, members of the Wyoming Seat Belt Coalition were asked about the importance of the dissemination of road safety data, presented in those reports, in real-time. More than half of the respondents stated that the prompt circulation of such data was critical. Also, 80 percent of the coalition’s members maintained that they were satisfied with the frequency at which the reports were released. Furthermore, more than half of the respondents preferred addressing the issue of records showing seat belt use habits designated as “unknown” and receiving reports describing the influence of seat belt use fine amounts on seat belt use habits. In addition, almost half of the respondents favored receiving data on the socio-

demographics and aggression levels of drivers who fail to properly buckle up. A proportion of the members of WSBC also stated that they were concerned about distracted improperly belted or unbelted drivers. Such data might be collected from reports of crashes involving improper use or non-use of restraints. Other respondents declared that they were interested in sharing the aforementioned reports among policy makers, the media and other concerned parties. Such reports are already available to the public via the WYDOT HSO website and may be disseminated as needed.

In the subsequent section of the survey, members of the coalition were asked specific questions about crash data. At least 50 percent of them indicated that they were interested in the following data collected from crash records:

- Whether the driver was properly wearing the seat belt.
- Whether the passenger in the front seat was properly wearing the seat belt.
- Whether the passengers in the rear seats were properly secured.
- Whether children were properly secured in their appropriate car seats.
- Whether children with special needs were properly secured.
- Whether the pregnant women were properly wearing their seat belts.
- Whether persons with physical disabilities were properly secured.
- Whether the driver was injured and the injury severity level.
- Whether the passenger in the front seat was injured and the injury severity level.
- Whether the passengers in the rear seats were injured and the injury severity level of each passenger.
- Whether children requiring car seats were injured and the injury severity level.
- Whether children with special needs were injured and the injury severity level.
- Whether persons with physical disabilities were injured and the injury severity level.
- Whether the driver was licensed.
- Driver license level (restricted learner's permit, regular learner's permit, intermediate permit or regular driving license).
- Whether the young driver was accompanied by a passenger eighteen years or older if the license required.
- Driver's age.
- Driver's gender.
- Driver's state.
- Driver's race.
- Driver's income category.
- Driver's seat belt policy violations history.
- Driver's other policy violations history.
- Makes, models and years of each vehicle involved in the crashes.
- Travel speeds of the vehicles involved in the crashes.

- Crash types (rear-end, sideswipe, etc.).
- Impact point information (struck from the side, struck from the front, etc.).
- Airbag deployment information at the times of the crashes.
- Seat belt condition (good, poor) at the times of the crashes.
- Whether any vehicle occupant was ejected from the vehicle.
- Whether any vehicle occupant was trapped in the vehicle.
- Length of the trip planned.

In addition, the coalition's members were asked whether they were interested in summary statistics, in the form of charts, tables, or color-coded maps depicting certain trends. At least half of the respondents indicated that they were interested in summary statistics depicting the following:

- The association between seat belt use policy violations and counts of injuries/fatalities that were sustained due to crashes.
- The difference in fatality and injury counts of belted versus unbelted occupants.
- Locations characterized by risks of encountering high severity (fatal, suspected serious injury and suspected minor injury) crashes involving improper use or non-use of safety restraints.
- Locations characterized by risks of encountering high severity crashes involving proper use of safety restraints.
- Locations characterized by risks of encountering PDO crashes involving improper use or non-use of safety restraints.
- Locations characterized by risks of encountering PDO crashes involving proper use of safety restraints.

The respondents were then directed to another section asking about whether they were interested in specific data of restraint use habits and other related data. Note that, throughout the survey, some questions were about citation statistics and that the WYDOT HSO does not maintain such data. Instead, independent studies would have to be conducted to collect and evaluate citation data. At least half of the respondents maintained that they preferred the following data:

- Whether the seat belt fitted appropriately.
- Whether occupants, cited for previous seat belt use violations, attended driver's education sessions.
- The influence of the driver's seat belt use habits on the passengers.
- Seat belt use habits by day of week (weekday versus weekend).
- Counts of occupants (properly belted versus improperly belted or unbelted) by state. (Wyoming residents versus out-of-state residents).
- The influence of weather conditions on seat belt use habits.
- Seat belt use habits by driver type. (passenger car driver, bus driver, or truck driver)

- Whether parents ensured that their children were properly secured.
- Whether drivers, previously cited for impaired driving, were likely or not to buckle up.
- Seat belt use citation statistics excluding those of which data were collected from crash records.
- Whether occupants, previously cited for improper use or non-use of safety restraints were likely to buckle up.
- How changes in seat belt use policies in other states influenced the number of injuries and fatalities incurred as a result of crashes.
- Data collected from a survey disseminated to young drivers, who've recently obtained their driver's licenses, asking about their seat belt use habits.
- Statistics depicting the association between the number of outreach campaigns and seat belt use habits by county or district.
- Seat belt use habits of occupants riding in vehicles with advanced driver assistance systems (ADAS), such as forward collision warning systems.
- Seat belt use habits of occupants riding in vehicles with side airbags in addition to the ones in the front.

Furthermore, the respondents were asked to provide any additional information of interest. Following are notable responses:

- “If the finalized data can include roadway fatalities that include reservation areas, private roads, etc. Possibly an annual report that includes information from the Wyoming Coroners offices to be sure every fatality that is unbuckled, impaired, or distracted is within the annual information.”
- “An interactive map would be a great idea.”
- “Separation of Wyoming resident behaviors and out-of-state is imperative.”
- “Much of the data in this section would help support or disprove many of the assumptions used in outreach concerning occupant protection.”

The respondent who requested fatality count data by area type, and the one who suggested the provision of an interactive map were not definitive. Hence, it was inferred that the former was concerned about fatality statistics pertaining to crashes involving improper use or non-use of safety restraints by area type while the latter was interested in an interactive map depicting the locations that were characterized by risks of encountering such crashes by severity level (fatality, suspected serious injury, suspected minor injury, possible injury and PDO).

Recommendations for the Wyoming Department of Transportation Regarding the Wyoming Seat Belt Coalition

Based on the interpretations of the Wyoming Seat Belt Coalition's survey results, recommendations were made to WYDOT concerning the data that would be provided to WSBC. First, it is suggested that the data belonging to crashes involving improper use or non-use of

restraints be provided to WSBC at the earliest convenience. It is also recommended that WYDOT provide quarterly summary statistics of restraint use habits, similar to the ones illustrated in Figures 1 through 20, and Tables 1 through 5. Such statistics were extracted from the WYDOT HSO 2019 crash data. In addition, heat maps, which are maps of high risk crash locations or simply hot spots, are presented in Figures 21 and 22. They were developed using 2017 crash data since this was the latest year of which precise coordinates of the crash records were provided by the WYDOT HSO. The maps were generated using the GIS software, ArcMap 10.4 (Environmental Systems Research Institute, 2016). In particular, the optimized hot spot and inverse distance weighted (IDW) interpolation features of the software were implemented. Also, the Z's (the standard normal distribution values that correspond to the crash risks), presented in the heat maps, are the standard normal distribution values that correspond to the crash risks. For the other safety groups, WHP, WASCOP, GCID, WTSC, Wyoming's counties, WBPST and motorcycle groups, heat maps were generated via the same procedure as that implemented to generate the maps for WSBC.

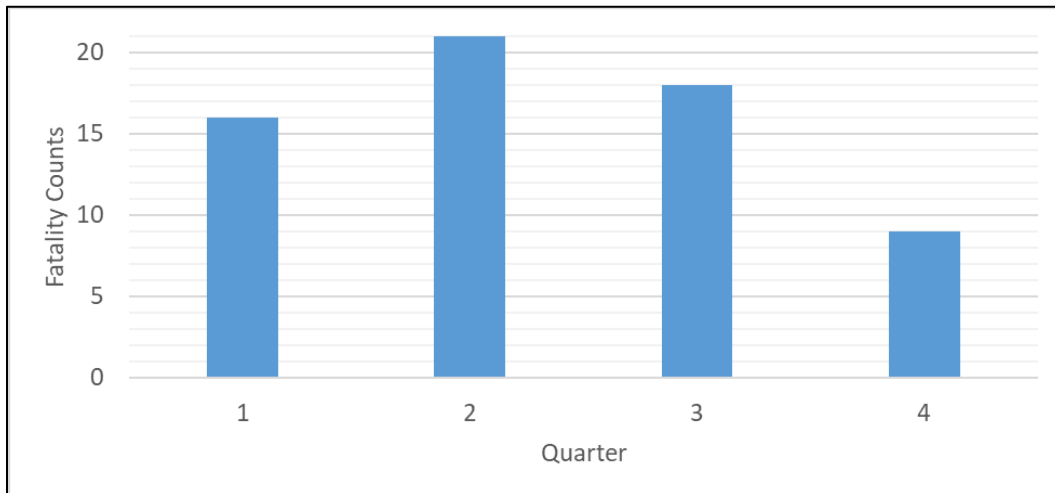


Figure 1: 2019 fatality counts of improperly belted or unbelted occupants.

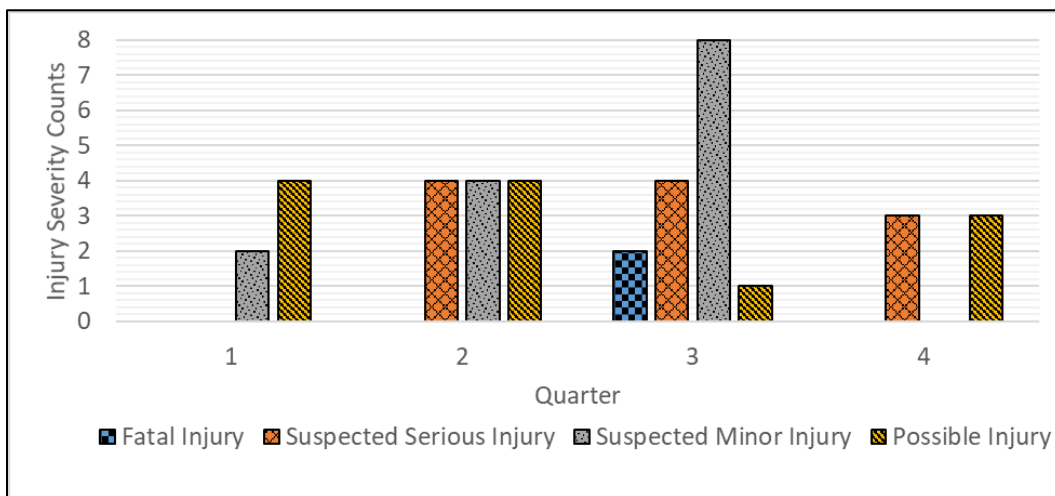


Figure 2: 2019 counts of killed and injured improperly belted or unbelted distracted drivers.

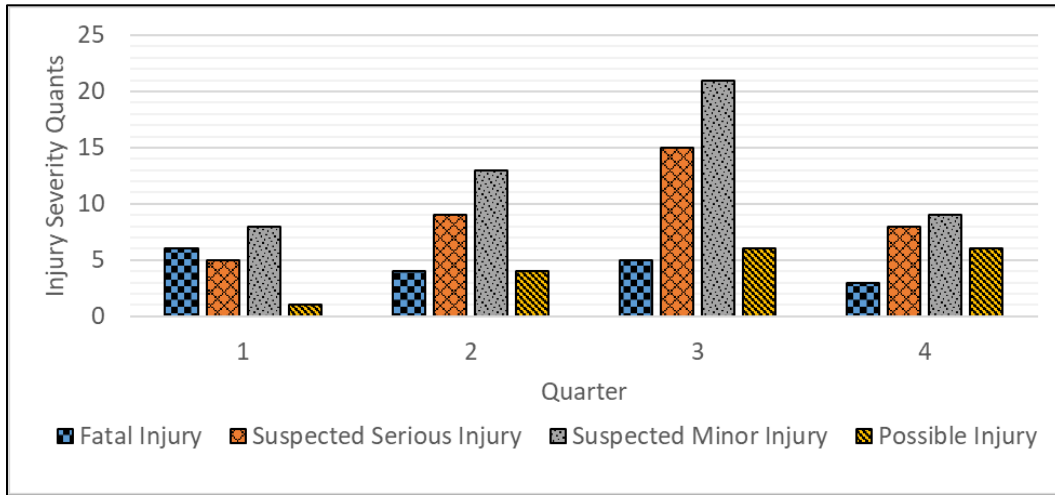


Figure 3: 2019 counts of killed and injured improperly belted or unbelted impaired drivers.

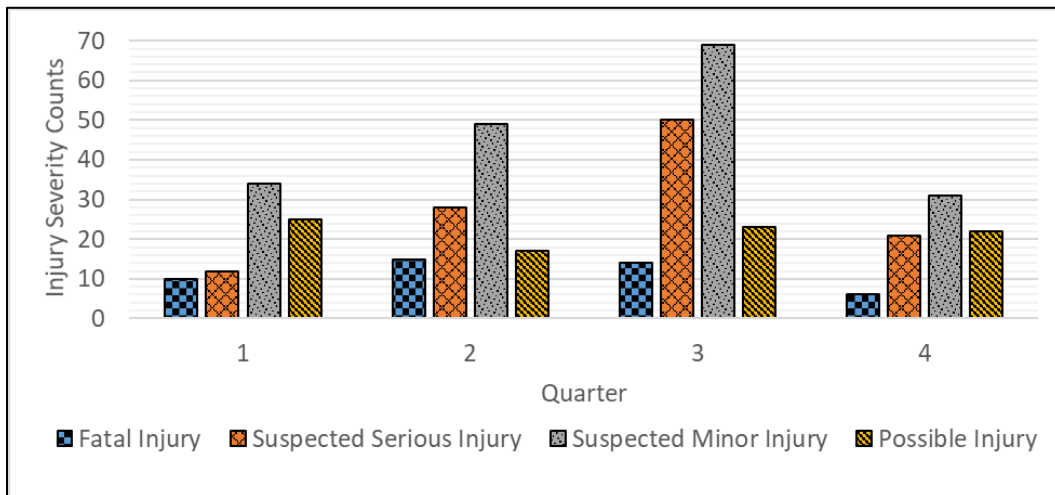


Figure 4: 2019 counts of killed and injured improperly belted or unbelted drivers.

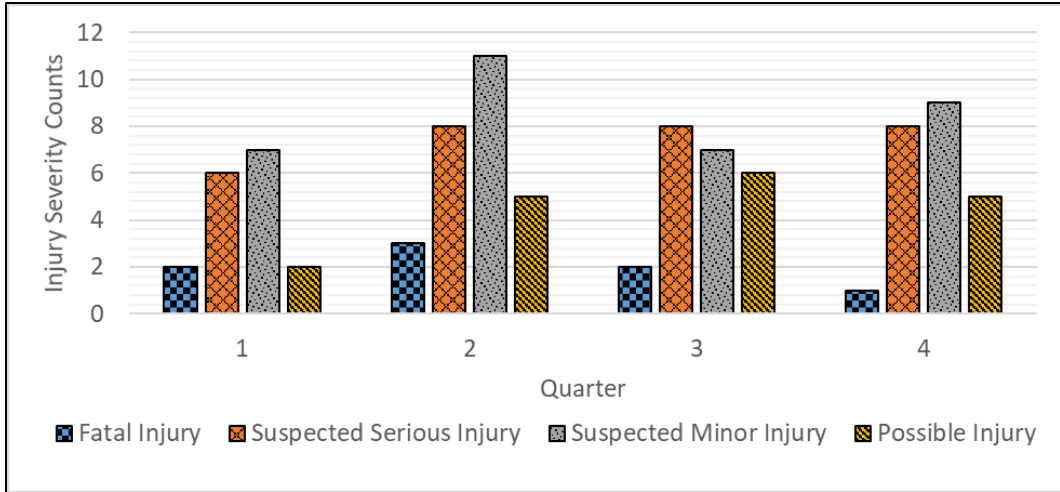


Figure 5: 2019 counts of killed and injured improperly belted or unbelted front-seat passengers.

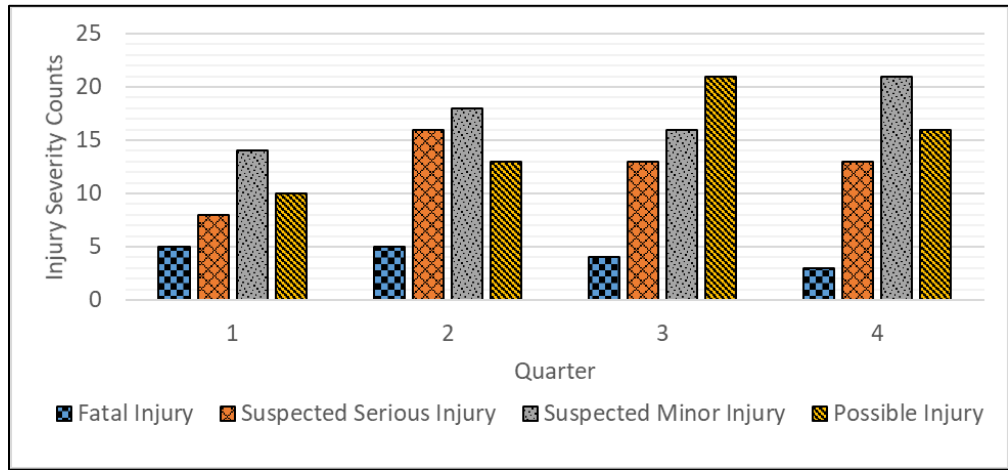


Figure 6: 2019 counts of killed and injured improperly belted or unbelted rear-seat passengers.

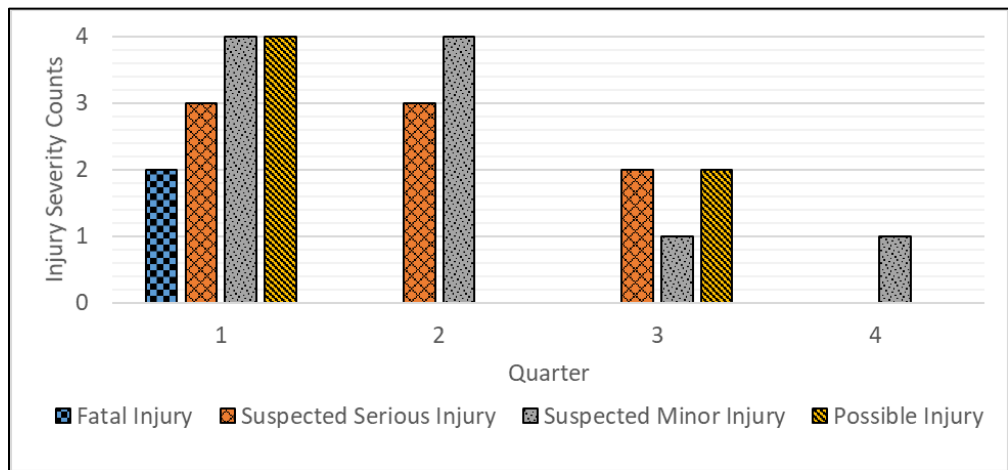


Figure 7: 2019 counts of killed and injured improperly restrained or unrestrained children 9 years or younger.

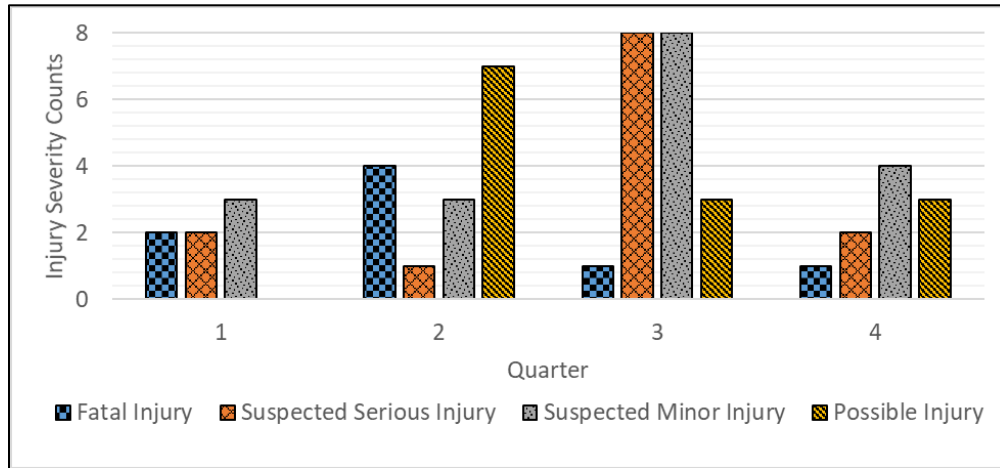


Figure 8: 2019 counts of killed and injured improperly belted or unbelted unlicensed drivers.

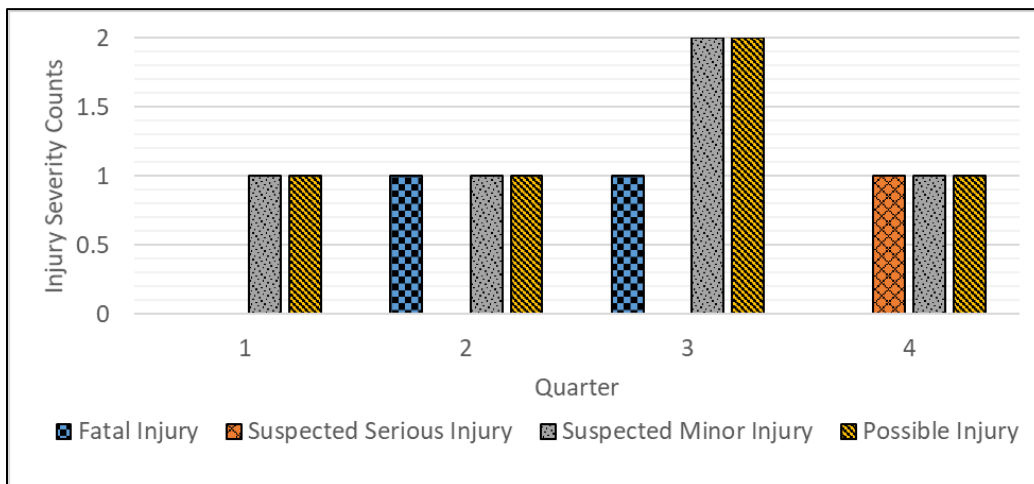


Figure 9: 2019 counts of killed and injured improperly belted or unbelted drivers with restricted licenses.

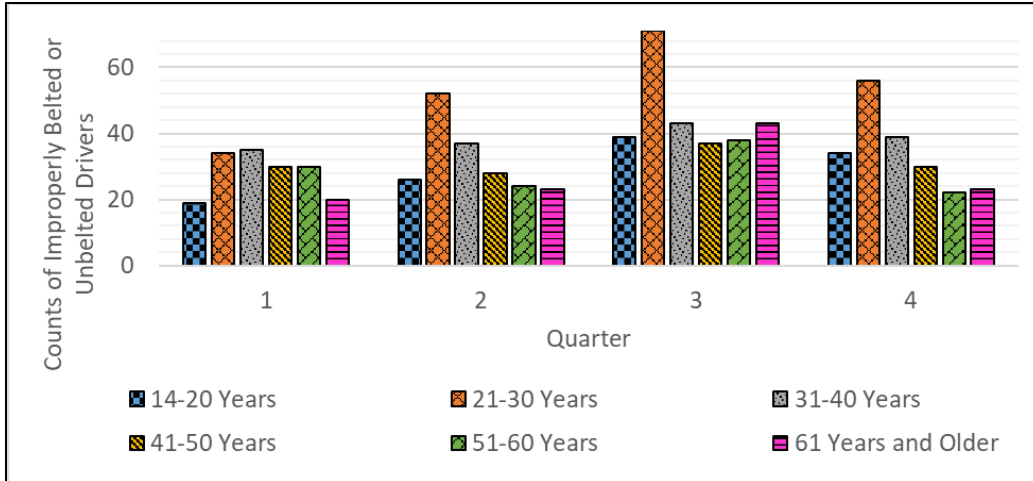


Figure 10: 2019 counts of killed and injured improperly belted or unbelted drivers by age.

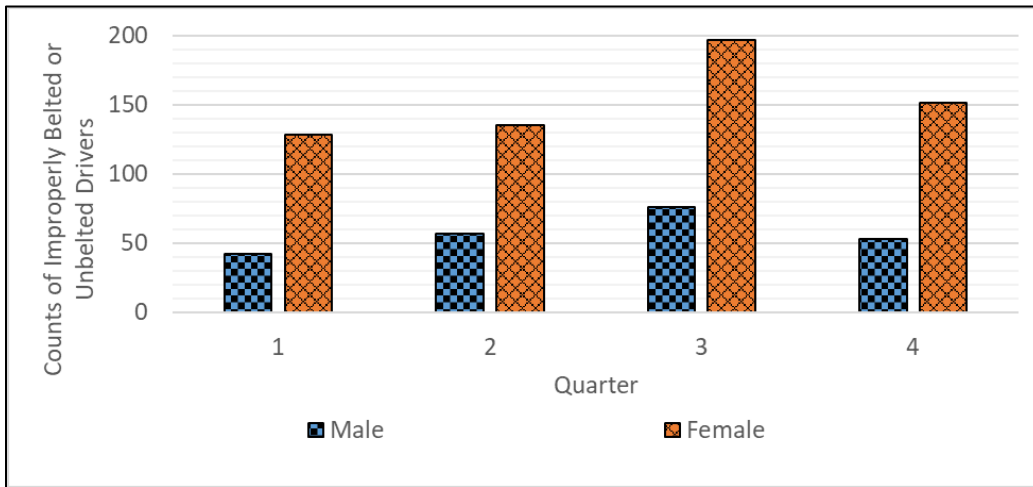


Figure 11: 2019 counts of killed and injured improperly belted or unbelted drivers by gender.

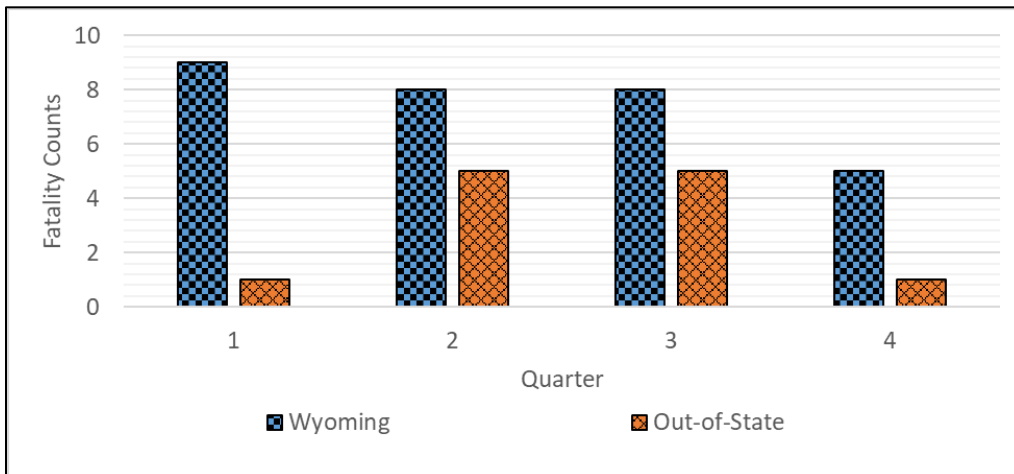


Figure 12: 2019 fatal counts of improperly belted or unbelted drivers for in/out of state.

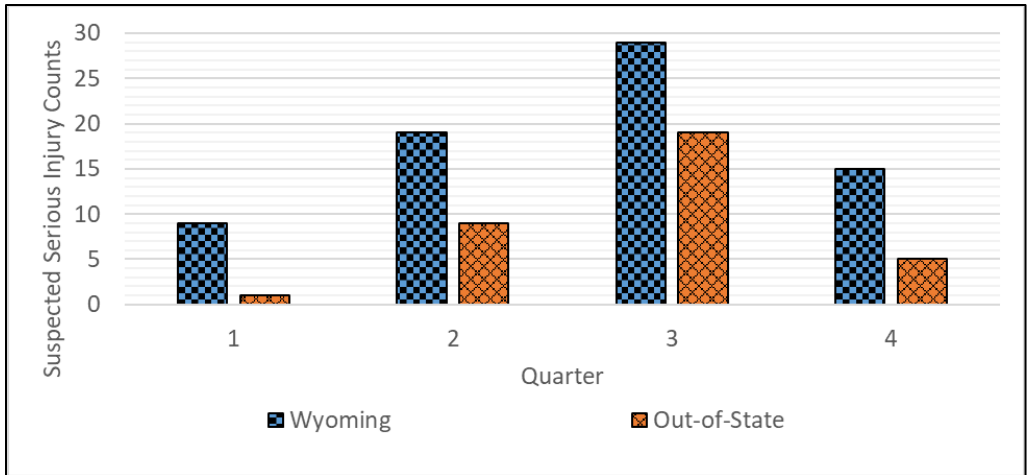


Figure 13: 2019 serious injury counts of improperly belted or unbelted drivers for in/out of state.

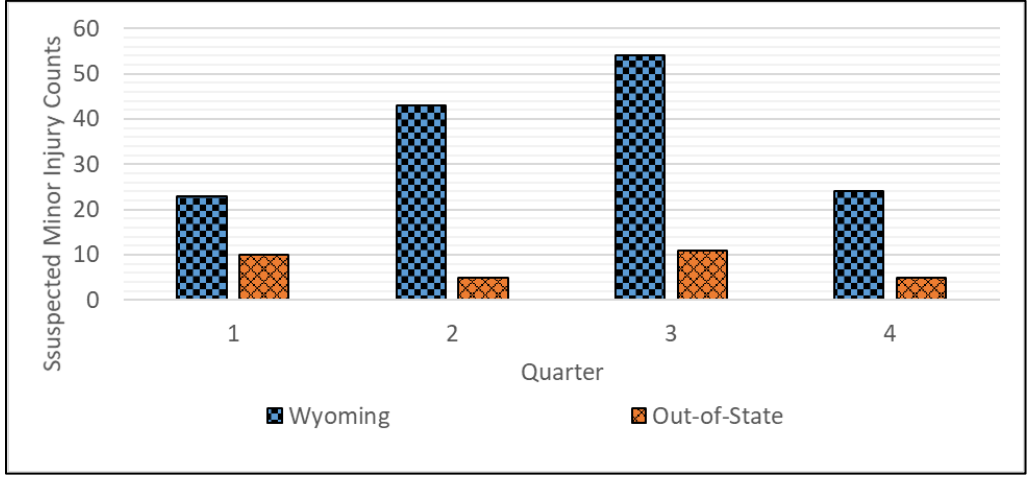


Figure 14: 2019 minor injury counts of improperly belted or unbelted drivers for in/out of state.

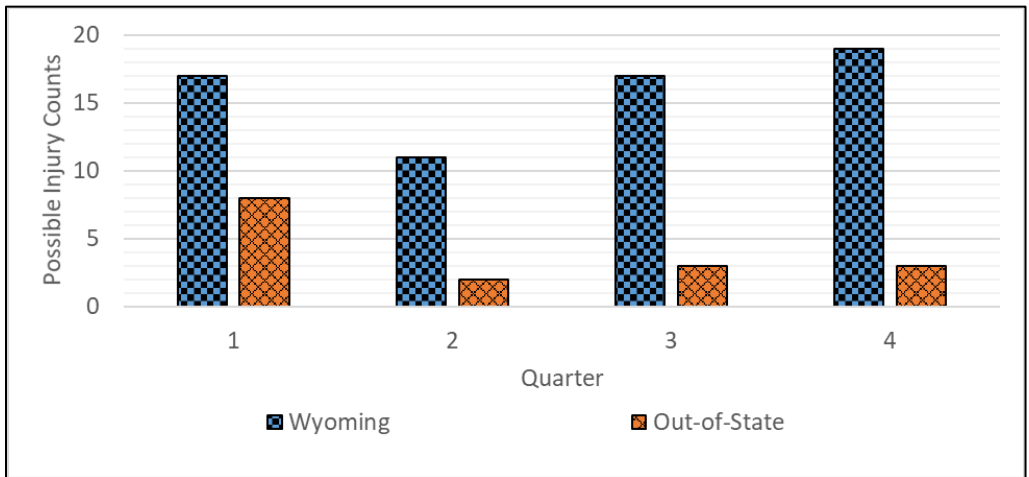


Figure 15: 2019 possible injury counts of improperly belted or unbelted drivers for in/out of state.

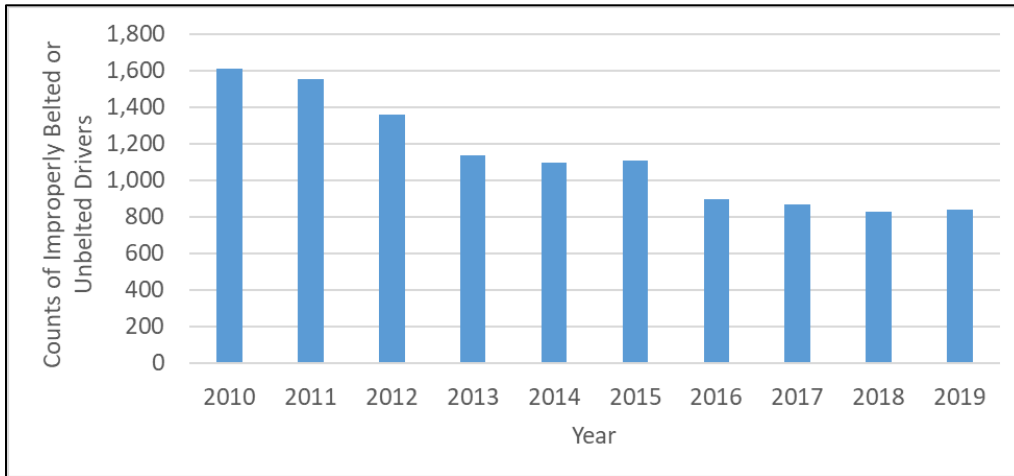


Figure 16: Crash Counts of improperly belted or unbelted drivers by year.

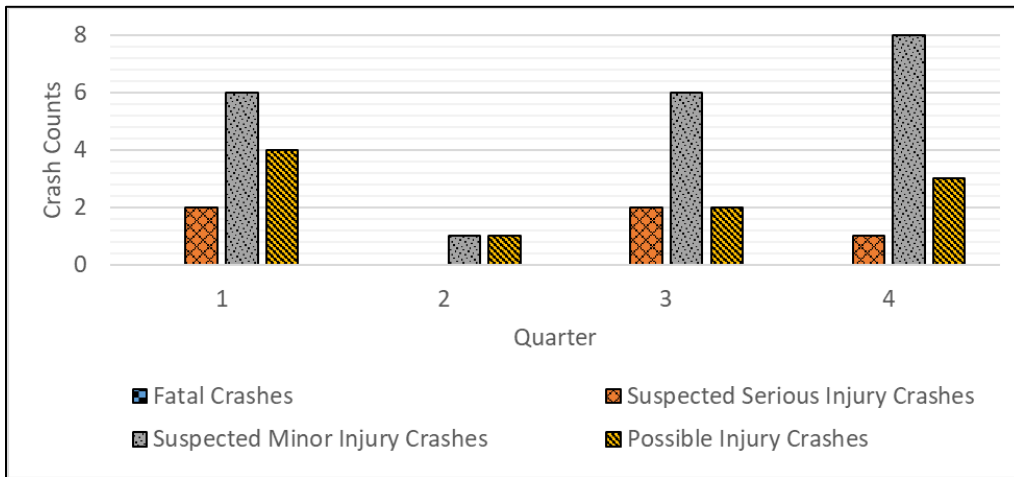


Figure 17: 2019 counts of speed related crashes involving improper use or non-use of restraints.

Table 1: 2019 Counts of Killed and Injured Improperly Restrained or Unrestrained Occupants by Manner of Collision in the First Quarter

Manner of Collision	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	Total
Angle (Front to Side), Opposing Direction	7	0	55	49	111
Angle, Direction Not Specified	0	0	0	0	0
Angle, Right (Front to Side, Includes Broadside)	5	22	70	94	191
Angle, Same Direction (Front to Side)	2	5	43	32	82
Head-On (Front to Front)	16	13	21	38	88
Not a Collision with Two Vehicles in Transport	14	44	366	219	643
Other	0	0	3	0	3
Rear-End (Front to Rear)	2	19	92	136	249
Rear to Front (Normally Backing)	0	0	0	5	5
Rear to Rear (Normally Backing)	0	0	0	0	0
Rear to Side (Normally Backing)	0	0	3	1	4
Sideswipe, Opposite-Direction (Meeting)	1	2	8	9	20
Sideswipe, Same-Direction (Passing)	0	1	11	13	25
Unknown	0	0	0	0	0
Total	47	106	672	596	1,421

Table 2: 2019 Counts of Killed and Injured Improperly Restrained or Unrestrained Occupants by Manner of Collision in the Second Quarter

Manner of Collision	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	Total
Angle (Front to Side), Opposing Direction	3	20	34	47	104
Angle, Direction Not Specified	0	0	0	0	0
Angle, Right (Front to Side, Includes Broadside)	5	15	68	82	170
Angle, Same Direction (Front to Side)	0	2	28	17	47
Head-On (Front to Front)	16	19	78	11	124
Not a Collision with Two Vehicles in Transport	69	143	536	229	977
Other	4	1	4	2	11
Rear-End (Front to Rear)	1	23	77	112	213
Rear to Front (Normally Backing)	0	0	0	0	0
Rear to Rear (Normally Backing)	0	0	0	0	0
Rear to Side (Normally Backing)	0	0	1	2	3
Sideswipe, Opposite-Direction (Meeting)	0	0	54	7	61
Sideswipe, Same-Direction (Passing)	1	3	13	5	22
Unknown	0	0	0	0	0
Total	99	226	893	514	1,732

Table 3: 2019 Counts of Killed and Injured Improperly Restrained or Unrestrained Occupants by Manner of Collision in the Third Quarter

Manner of Collision	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	Total
Angle (Front to Side), Opposing Direction	0	13	56	38	107
Angle, Direction Not Specified	0	2	0	0	2
Angle, Right (Front to Side, Includes Broadside)	3	25	101	98	227
Angle, Same Direction (Front to Side)	0	2	22	17	41
Head-On (Front to Front)	21	29	51	14	115
Not a Collision with Two Vehicles in Transport	104	287	571	150	1,112
Other	0	1	7	2	10
Rear-End (Front to Rear)	8	14	99	135	256
Rear to Front (Normally Backing)	0	0	1	2	3
Rear to Rear (Normally Backing)	0	0	0	0	0
Rear to Side (Normally Backing)	0	0	0	1	1
Sideswipe, Opposite-Direction (Meeting)	1	1	1	2	5
Sideswipe, Same-Direction (Passing)	1	2	13	5	21
Unknown	0	0	0	1	1
Total	138	376	922	465	1,901

Table 4: 2019 Counts of Killed and Injured Improperly Restrained or Unrestrained Occupants by Manner of Collision in the Fourth Quarter

Manner of Collision	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	Total
Angle (Front to Side), Opposing Direction	5	28	30	52	115
Angle, Direction Not Specified	0	0	0	0	0
Angle, Right (Front to Side, Includes Broadside)	6	13	56	118	193
Angle, Same Direction (Front to Side)	0	4	30	22	56
Head-On (Front to Front)	11	7	22	19	59
Not a Collision with Two Vehicles in Transport	18	190	379	273	860
Other	0	0	1	3	4
Rear-End (Front to Rear)	2	13	108	154	277
Rear to Front (Normally Backing)	0	0	0	2	2
Rear to Rear (Normally Backing)	0	0	0	0	0
Rear to Side (Normally Backing)	0	0	2	1	3
Sideswipe, Opposite-Direction (Meeting)	0	0	3	5	8
Sideswipe, Same-Direction (Passing)	4	0	9	11	24
Unknown	0	0	0	0	0
Total	46	255	640	660	1,601

Table 5: 2019 Counts of Killed and Injured Improperly Belted or Unbelted Occupants by Manner of Collision

Manner of Collision	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	Total
Angle (Front to Side), Opposing Direction	15	61	175	186	437
Angle, Direction Not Specified	0	2	0	0	2
Angle, Right (Front to Side, Includes Broadside)	19	75	295	392	781
Angle, Same Direction (Front to Side)	2	13	123	88	226
Head-On (Front to Front)	64	68	172	82	386
Not a Collision with Two Vehicles in Transport	205	664	1852	871	3,592
Other	4	2	15	7	28
Rear-End (Front to Rear)	13	69	376	537	995
Rear to Front (Normally Backing)	0	0	1	9	10
Rear to Rear (Normally Backing)	0	0	0	0	0
Rear to Side (Normally Backing)	0	0	6	5	11
Sideswipe, Opposite-Direction (Meeting)	2	3	66	23	94
Sideswipe, Same-Direction (Passing)	6	6	46	34	92
Unknown	0	0	0	1	1
Total	330	963	3,127	2,235	6,655

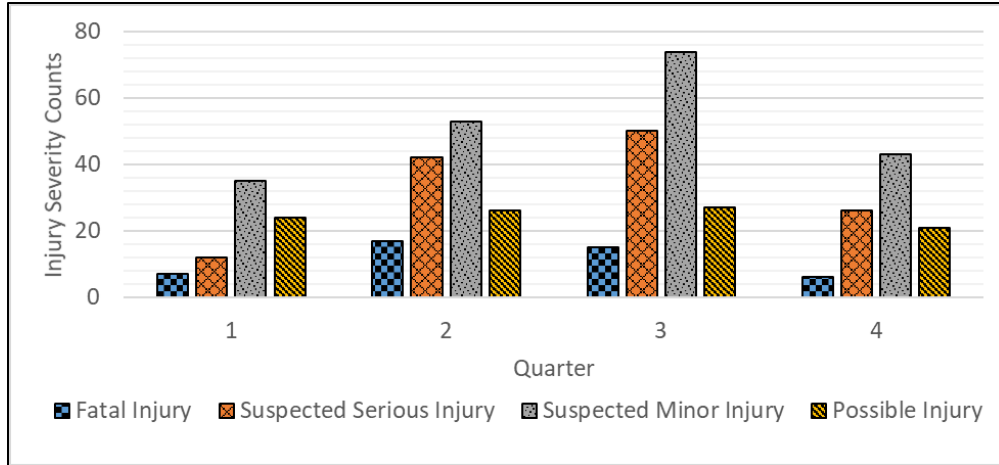


Figure 18: 2019 counts of killed and injured improperly belted or unbelted occupants in crashes where air bags were not deployed.

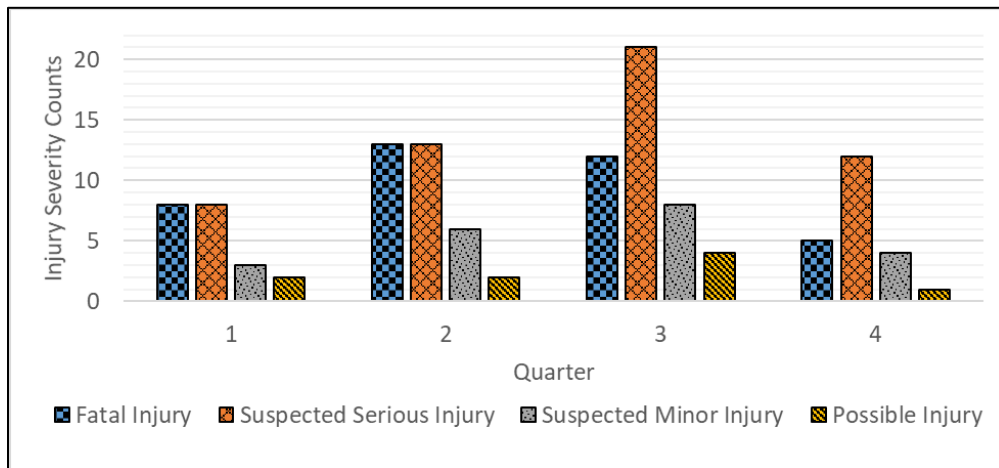


Figure 19: 2019 counts of killed and injured improperly belted or unbelted ejected/partially ejected occupants.

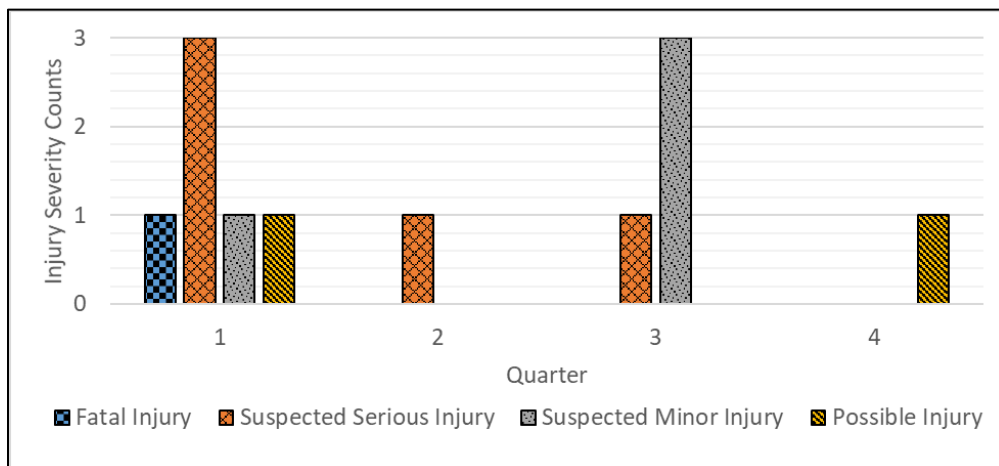


Figure 20: 2019 counts of killed and injured improperly belted or unbelted trapped occupants.

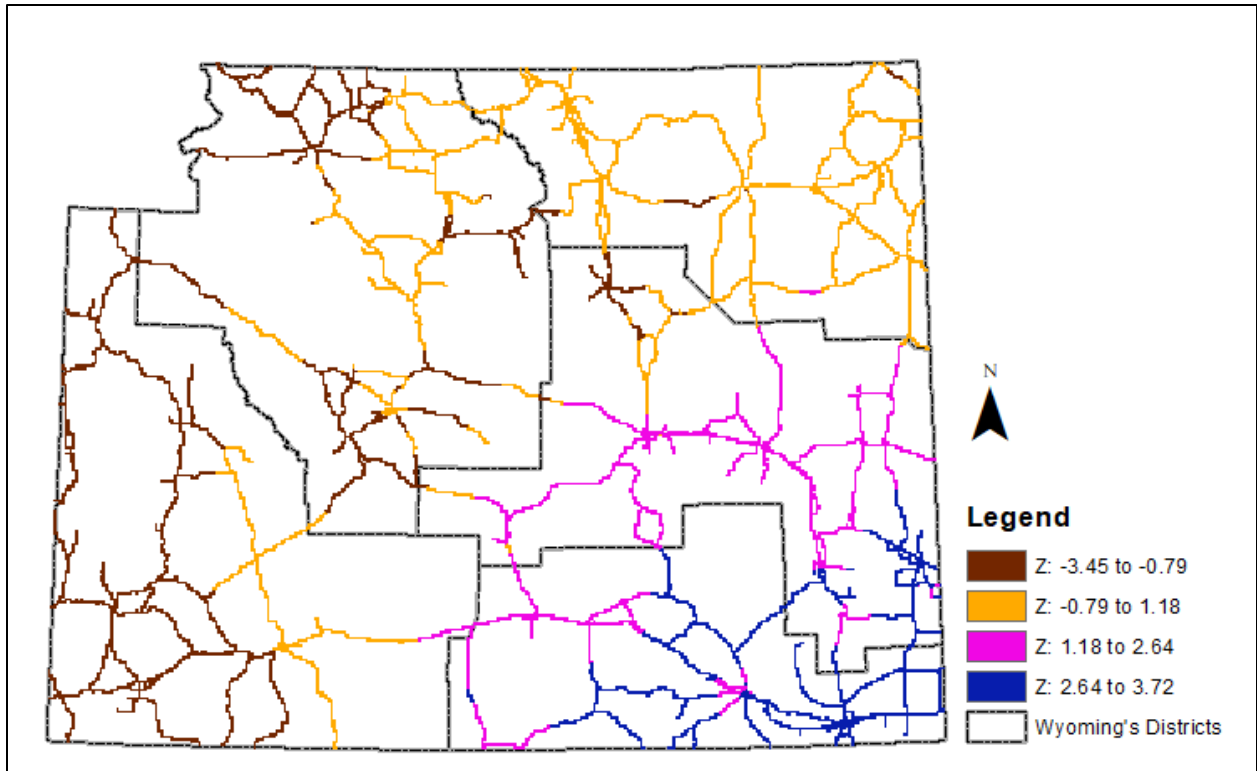


Figure 21: 2017 heat map of crashes involving improper use or non-use of restraints.

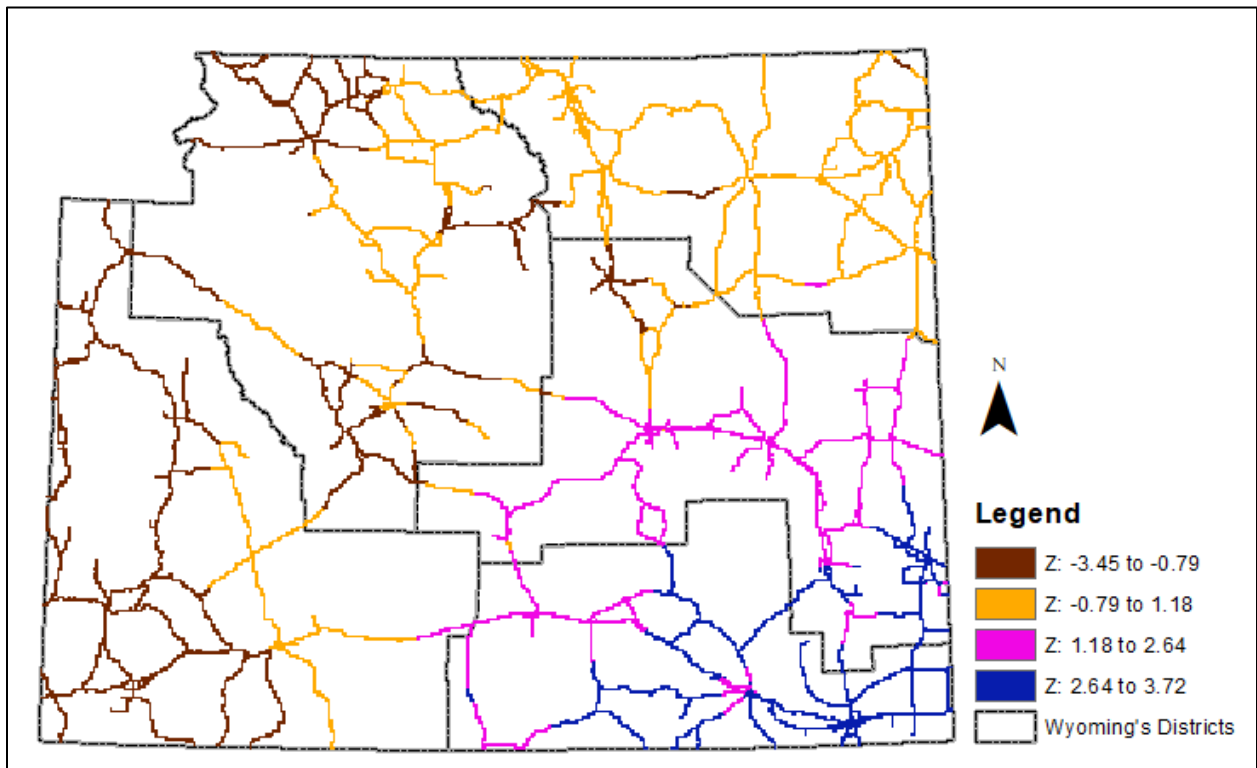


Figure 22: 2017 heat map of fatal, suspected serious injury and suspected minor injury crashes involving improper use or non-use of restraints.

In addition to statistics obtained from crash data, it is suggested to provide other summary statistics data collected from periodical state seat belt surveys (Fernsler, 2019) similar to the ones presented in Figures 23 through 25. They are descriptive of seat belt use habits by vehicle type, day of week, and weather condition.

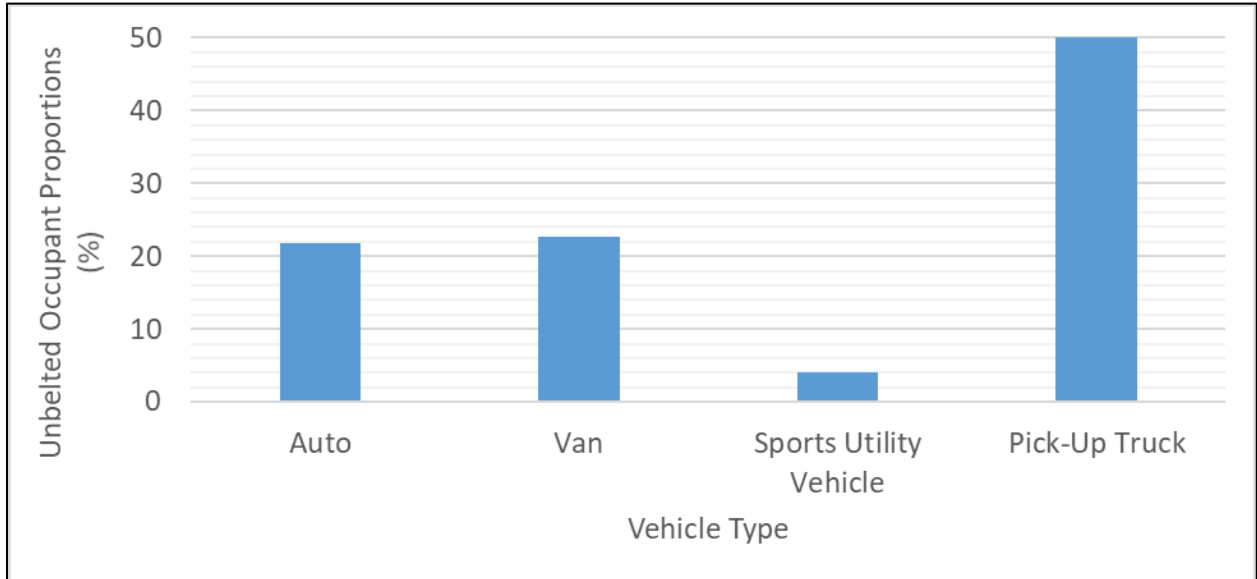


Figure 23: 2019 distribution of unbelted occupants to vehicles.

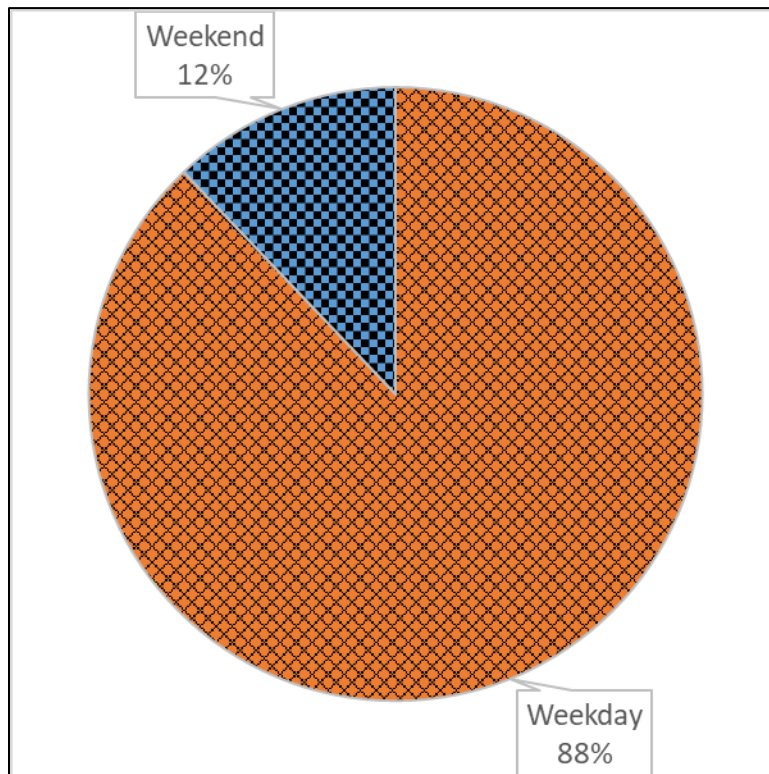


Figure 24: 2019 restraint non-use proportions by day of the week.

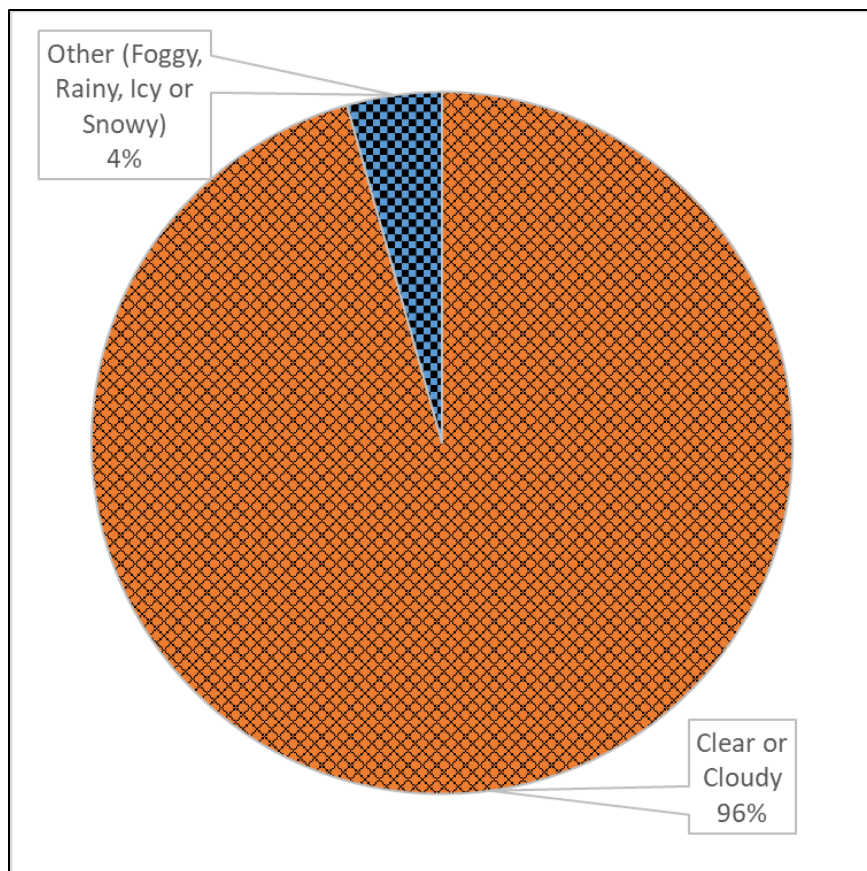


Figure 25: 2019 restraint non-use proportions by weather condition.

It is also recommended that future studies be conducted to assess the following:

- Effectiveness of traffic education sessions in promoting proper safety restraint use.
- The influence of drivers’ seat belt use habits on those of the passengers and vice versa.
- Seat belt use habits of occupants riding in vehicles with ADAS technologies.

Summary of the Wyoming Highway Patrol Survey Responses’ Results

A survey was disseminated to members of the Wyoming Highway Patrol and four responses were received. The common question asked in all surveys was how often did the respondents receive/secure road safety data/reports from the WYDOT HSO? It was found that 50 percent of the respondents often obtained crash data from the office once a month while some checked the option, “other,” and specified the following:

- “Unknown”
- “N/A”

When it comes to data transfer protocols, the respondents declared that they received the data mostly via email and online databases. Also, the survey results indicated that this was their preferred method of data acquisition. Other than that, the respondents were asked whether the

current safety data provided to them from the WYDOT HSO fulfilled their needs on a scale of one (not at all) to five (absolutely). Twenty five percent of the respondents declared that the current crash data being provided to them were neither of no benefit nor beneficial (selected three) while 50 percent claimed that the data were indeed beneficial (selected four and five). More importantly, the respondents were asked about the ideal period during which they preferred to receive the crash data from the dates the crashes occurred. One respondent stated that he or she preferred that the data be delivered within a month of the crash's occurrences and that this would be the desired period. Another declared that he or she secured the data within a day of the crash occurrences and that this would be the preferred period.

Regarding the preferred data format, half of the respondents favored summary statistics tables, a quarter preferred figures and half-preferred pie charts. One respondent checked the option, "other," and stated, "as simple as possible." Note that each respondent was provided the option of specifying multiple data formats from a list (i.e. checkboxes).

The respondents were further asked about the preferred method of portraying crash sites. They included the following:

- Narrative descriptions of the locations
- Photos
- Color-coded maps
- Road and milepost information
- GIS coordinates
- A combination of the above

Remarkably, 75 percent of the respondents claimed that they were interested in a combination of methods of depicting the crash locations. The answer choices were provided in the form of checkboxes such that the respondents might have selected multiple options. The respondents also selected the options, "narrative descriptions of the locations," "color-coded maps" and "road and milepost information." One respondent selected the option, "other," and stated, "pinpointed on a digital map that you can zoom in and out on."

In the following section of the survey, respondents were asked about road safety reports pertaining to crash data. The reports, most of which are available in the WYDOT HSO website, are the following:

- 2019 Highway Safety Crash Data Survey Final Report
- Wyoming Department of Transportation Highway Safety Behavioral Grants Office 2019 Annual Report
- Wyoming Highway Safety Behavioral Program FY2020 Highway Safety Plan
- Wyoming Report on Traffic Crashes 2019
- Wyoming Drivers Survey 2016
- 2019 Seat Belt Survey Analysis

- Wyoming Statewide Crashes by Year
- Wyoming Statewide Speed Related Crashes by Year
- Wyoming Statewide Crashes Involving a Wild Animal by Year
- Wyoming Statewide Occupant Seat Belt Usage by Year
- Wyoming Statewide Crashes Involving a Pedestrian by Year
- Wyoming Statewide Crashes Involving Alcohol or Drugs by Year
- Wyoming Statewide Crashes Involving Commercial Motor Vehicles by Year
- Wyoming Statewide Distracted Driving Crashes by Year
- Wyoming Strategic Highway Safety Plan 2017

On a scale of one (not at all) to five (absolutely) describing whether the respondents were familiar with these reports and whether they frequently used them, roughly half provided a rating of four while a quarter provided a rating of five. Also, all declared that they were satisfied with the frequency at which the reports were released. Members of WHP were then asked about the importance of incorporating specific summary statistics safety data in the listed reports. At least half of them indicated that they were interested in the following:

- Drivers' improper actions/error information preceding the crashes (e.g. driving too fast, improper passing, following too closely, etc.)
- Aggressiveness of drivers who were at-fault in the crashes
- Whether the passengers in the rear seats were properly secured
- Socio-demographics of drivers who were at-fault in the crashes
- Truck safety and truck policy violations at the times of the crashes (exceeded weight limit, improperly secured hazardous materials, etc.)
- Animal crash hot spots
- Hit-and-run crashes
- The effectiveness of media outreach campaigns in raising traffic safety awareness (traffic safety slogans and/or relevant content disseminated via the social media, television, radio, billboards)

In the subsequent section of the survey, WHP officers were asked specific questions about processed crash data. At least half of them declared that they were interested in the following:

- Crash locations (on the road, on the shoulder, off the road, etc.)
- Crash times (morning, afternoon, etc.)
- Weather conditions at the times of the crashes
- Vehicle travel speeds preceding the crashes (i.e. too slow for the conditions, reasonable or too fast for the conditions)
- Number of vehicles involved in the crashes
- Number of pedestrians and/or bicyclists involved in the crashes
- Types of animals involved in the crashes

- Whether the drivers were properly wearing their seat belts at the times of the crashes
- Whether the passengers were properly wearing their seat belts at the times of the crashes
- Whether children were properly secured in their appropriate car seats at the times of the crashes
- Whether the drivers were driving under the influence of alcohol/drugs at the times of the crashes
- Whether the drivers were tired at the times of the crashes
- Hit-and-run crashes
- Crashes resulting in fires
- Crashes resulting in jackknifed vehicles
- Crashes resulting in ejected occupants
- Crashes in which trucks were overturned by severe winds
- Motorcycle crashes
- Whether the motorcyclists were wearing helmets at the times of the crashes
- Whether the motorcyclists were wearing the appropriate gear (riders' jackets, boots, etc.) at the times of the crashes
- Whether the motorcycle passengers were wearing helmets at the times of the crashes
- Whether the motorcyclists were riding in motorcycle groups at the times of the crashes
- Whether work zone plans were implemented according to the standards when the crashes occurred at or near the work zones
- Whether workers were present when the crashes occurred at or near the work zones
- Shoulder and lane closure information when the crashes occurred at or near the work zones
- Whether drivers violated work zone regulations giving rise to the crashes (i.e. exceeded the work zones' speed limits, failed to obey the traffic guards' signals, etc.)
- Vehicle parts' conditions (tires, brakes, engine, etc.) at the times of the crashes

Furthermore, the officers stated that information regarding the number of injured drivers, passengers, motorcyclists, pedestrians and their injury severity levels were important. The officers were also asked whether they were interested in summary statistics, in the form of charts and tables, depicting certain crash patterns. At least half of the respondents indicated that they were interested in summary statistics depicting the following:

- Crash types (rear-end, sideswipe, etc.)
- Impact point information of vehicles involved in the crashes (struck from the side, struck from the front, etc.)
- Crashes that occurred during special holidays/events (Fourth of July, Labor Day weekend, Thanksgiving, Christmas, etc.)
- DUI related crashes by day of the week (i.e. weekdays versus weekends)

- Injury severity levels of DUI related crashes by blood alcohol concentration (BAC) of the impaired drivers
- Comparison of the injury severity levels among properly buckled and improperly buckled or unbuckled vehicle occupants
- Injury severity levels by drivers' age group and gender
- Crashes on roads with challenging geometric conditions (steep upgrades, steep downgrades, tight horizontal curves, etc.)
- Crashes involving distractions by distraction method (use of electronic device, picking up an object from the vehicle's floor, etc.)
- Crash locations by injury severity level and lighting conditions (daylight, dawn, dark with street lighting, etc.) at the times of the crashes
- Crash locations by injury severity level and road surface conditions (dry, wet, icy, snowy, etc.) at the times of the crashes

The respondents were also asked about the importance of color-coded maps presenting locations characterized by risks of encountering the following types of crashes on a scale of one (not important) to five (crucial). At least half declared scores of four or five for those crashes.

- High severity (fatal, suspected serious injury and suspected minor injury) crashes
- Possible injury and PDO crashes
- High severity crashes that occurred in the presence of adverse weather conditions (snow, fog, rain, etc.)
- High severity crashes where visual obstructions (vegetation, hill crests, sun glare, headlight glare, other vehicles, animals, fog, snow showers, etc.) posed hazards
- High severity crashes involving improperly buckled or unbuckled occupants
- High severity DUI related crashes
- High severity speed related crashes

The respondents were then directed to another section asking about whether they were interested in specific citation information. As was the case of the WSBC survey, the WYDOT HSO would not maintain such data. Hence, a disclaimer was provided stating this fact and that independent studies would have to be conducted to process citation data. At least half of the respondents declared that they preferred the following data:

- Citation counts of unlicensed drivers
- Citation counts of drivers not wearing their prescription glasses/contact lenses if their licenses required so
- Citation counts of young drivers who were not accompanied by passengers eighteen years or older if their licenses required so
- Citation counts by violation type and driver's age
- Citation counts by violation type and driver's gender

- Citation counts of seat belt use policy violations by county and year
- Whether vehicle occupants, cited for previous seat belt use violations, attended traffic education sessions
- Citation counts of child restraint policy violations by county and year
- Citation counts of aggressive/reckless drivers by county and year
- Citation counts of tired drivers by county and year
- Speeding citation counts by county and year
- Locations characterized by a considerable number of citations issued

Finally, the officers were asked to select topics they might be interested in for further investigation (i.e., data analyses, interpretation and documentation of results in reports). At least three quarters of them declared that they were interested in the following topics:

- Effectiveness of DUI enforcement policies
- Effectiveness of speed enforcement policies
- Effectiveness of seat belt use policies
- Response times of emergency services, particularly for severe crashes
- Effectiveness of traffic safety educational campaigns
- Effectiveness of other traffic violation enforcement policies (i.e. improper lane change, red light running, etc.)
- Effective methods of capturing motorcyclists committing traffic violations
- Safety benefits of vehicles equipped with ADAS
- Safety benefits of mandatory periodic vehicle inspections in other states
- Fluctuations in traffic fatality rates in Wyoming throughout the years

Summary of the Wyoming Association of Sheriffs and Chiefs of Police Survey Responses' Results

A survey was prepared and distributed to members of the Wyoming Association of Sheriffs and Chiefs of Police (WASCOP) asking about road safety data they needed in addition to those already provided in statewide road safety reports and database files they would retrieve from the WYDOT HSO. Three responses were obtained. In the first section of the survey, the respondents indicated that they received road safety data and/or reports once a month via email, which was the preferred means of data acquisition. Note that one of the officers stated that he or she did not receive such data. The respondents also maintained that the data provided fulfilled their needs. Furthermore, one respondent stated that they received crash data 12 to 15 days from the dates the crashes occurred and that, ideally, this duration ought to be shortened to a week. The other claimed that WASCOP received the crash data a day after the crashes occurred and that this was the ideal time interval. Also, the respondents indicated that they preferred crash data be summarized in the form of pie charts/bar charts, summary statistics tables and figures. Furthermore, two of the three respondents concurred that color-coded maps would be considered efficient means of illustrating crash locations.

In the second section of the survey, members of WASCOP were provided a list of reports available in the WYDOT HSO website, which are the following:

- 2019 Highway Safety Crash Data Survey Final Report
- Wyoming Department of Transportation Highway Safety Behavioral Grants Office 2019 Annual Report
- Wyoming Highway Safety Behavioral Program FY2020 Highway Safety Plan
- Wyoming Report on Traffic Crashes 2019
- Wyoming Drivers Survey 2016
- 2019 Seat Belt Survey Analysis
- Impaired Driver-Involved Crash Statistics
- Wyoming Statewide Crashes by Year
- Wyoming Statewide Speed Related Crashes by Year
- Wyoming Statewide Occupant Seat Belt Usage by Year
- Wyoming Statewide Crashes Involving a Wild Animal by Year
- Wyoming Statewide Crashes Involving Alcohol or Drugs by Year
- Wyoming Statewide Crashes Involving Commercial Motor Vehicles by Year
- Wyoming Statewide Distracted Driving Crashes by Year
- Wyoming Strategic Highway Safety Plan 2017

When asked about how familiar the respondents were with the reports listed, on a scale of one (not at all) to five (absolutely), one provided a rating of one while another provided a rating of two, and the third provided a rating of three. In particular, one respondent stated that he or she was familiar with three of the aforementioned reports, which are:

- Wyoming Department of Transportation Highway Safety Behavioral Grants Office 2019 Annual Report
- Wyoming Report on Traffic Crashes 2019
- Wyoming Statewide Crashes by Year

Remarkably, one respondent declared that the reports listed in the survey would be considered beneficial to WASCOP, and two respondents indicated that they were satisfied with the frequency at which those reports were released. Also, none suggested any additional reports to include in the list. Furthermore, two respondents claimed that they would like to be presented summary statistics describing drivers' improper actions/error information preceding the crashes in those reports.

After answering questions about the road safety reports, the respondents were asked about particular crash data that would be of interest to them. At least two indicated that they were interested in the following crash data variables presented in the form of summary statistics:

- Crash locations (on the road, on the shoulder, off the road, etc.)

- Crash times (morning, afternoon, etc.)
- Weather conditions at the times of the crashes
- Number of vehicles involved in the crashes
- Vehicle travel speeds at the times of the crashes (too slow, reasonable or too fast for the conditions)
- Whether the passengers were properly wearing their seat belts at the times of the crashes
- Whether the drivers were driving under the influence of drugs or alcohol
- Motorcycle crashes
- Number of injured drivers/motorcyclists and their injury severity levels
- Crash types (rear-end, sideswipe, etc.)
- Impact point information (struck from the side, etc.)
- Crashes that occurred during special holidays/events (Fourth of July, Labor Day weekend, Thanksgiving, Christmas, etc.)
- DUI related crashes by day of the week (weekdays versus weekends)
- Injury severity levels of DUI related crashes by blood alcohol concentration (BAC) level of impaired drivers
- Comparison of the injury severity levels among properly buckled and improperly buckled or unbuckled vehicle occupants
- Injury severity levels by drivers' age group and gender
- Crashes on roads with challenging geometric conditions (steep upgrades, steep downgrades, tight horizontal curves, etc.)
- Crashes involving distractions by distraction method (use of electronic device, picking up an object from the vehicle's floor, etc.)
- Crash locations by injury severity level and lighting conditions (daylight, dark with street lighting, etc.)
- Crash locations by injury severity level and road surface conditions (dry, wet, icy, snowy, etc.)

Furthermore, two of the three respondents indicated that they were interested in color-coded maps describing specific crash categories, which are the following:

- High severity (fatal, suspected serious injury and suspected minor injury) crashes
- High severity crashes that occurred in the presence of adverse weather conditions (snow, rain, etc.)
- High severity DUI related crashes
- High severity speed related crashes

Other than crash information related questions, members of WASCOP were also asked about citation data. Similar to the WHP survey, a disclaimer was included to inform the respondents that the WYDOT HSO would not maintain citation data and that independent studies would have

to be conducted on such data, if needed. From the survey results, only one respondent claimed interest in data of citation counts of aggressive/reckless drivers by county and year. Similarly, one respondent stated that he or she was willing to receive data on citation counts of tired drivers by county and year. Finally, a question was asked about specific research topics that would be of interest to WASCOP. Two respondents suggested that studies be conducted on the following topics:

- Effectiveness of DUI enforcement policies
- Effectiveness of speed enforcement policies

Recommendations for the Wyoming Department of Transportation Regarding the Wyoming Highway Patrol and the Wyoming Association of Sheriffs and Chiefs of Police

The results of the WHP and WASCOP surveys were similar and, hence, recommendations made regarding the data WYDOT should provide to those groups were combined in one section. The first recommendation was to provide crash records to WHP and WASCOP at the shortest possible time. It is also suggested WYDOT should provide quarterly summary statistics similar to the ones illustrated in Figures 26 through 65, and Tables 6 through 10. Similar to the recommendations regarding heat maps to be provided to WSBC, other heat maps are suggested for both WHP and WASCOP. The suggested heat maps would be comparable to the ones presented in Figures 66 through 73.

Table 6: 2019 Counts of Drivers' Actions Preceding the Crashes

Drivers' Actions Prior to the Crashes	Quarter				Total
	1	2	3	4	
Avoiding Animal	22	30	49	33	134
Avoiding Motor Vehicle	85	53	70	83	291
Avoiding Non-Motorist	2	0	11	4	17
Avoiding an Object on Road	4	9	14	14	41
Disregarded Other Road Marking	11	33	21	68	133
Disregarded Traffic Signs	135	123	152	170	580
Drove too Fast for Conditions	1,216	322	160	1,401	3,099
Erratic/Reckless/Careless/Aggressive	229	366	363	350	1,308
Evading Law Enforcement	15	35	18	17	85
Failed to Keep Proper Lane	848	657	691	963	3,159
Failed to Yield Right-of-Way	477	444	512	477	1,910
Following Too Closely	378	371	455	424	1,628
Improper Backing	167	189	180	184	720
Improper Parking	16	9	23	10	58
Improper Passing	57	65	75	53	250
Improper Turn or No Signal	136	146	183	153	618
Over Corrected/Over Steered	160	163	195	189	707
Ran Off the Road	950	749	732	1,074	3,505
Ran Red Light	120	91	110	121	442
Speeding	91	162	214	133	600
Swerve Due to Wind/Slippery Surface	246	65	8	205	524
Wrong Side/Wrong Way	49	59	43	33	184
Other Improper Action	230	253	327	329	1,139
No Improper Driving	2,557	2,299	2,663	3,232	10,751
Unknown	253	196	290	286	1,025
Total	8,454	6,889	7,559	10,006	32,908

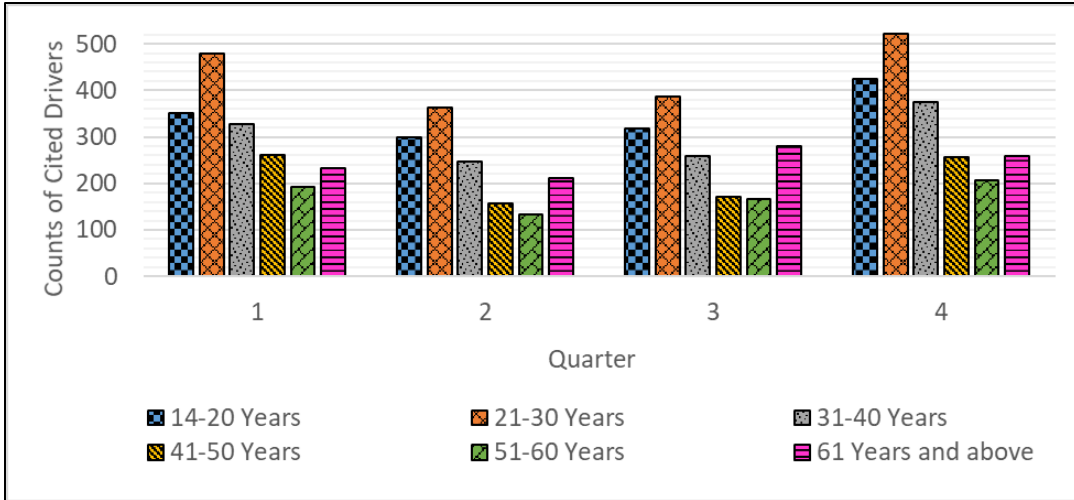


Figure 26: 2019 counts of cited drivers at the crash scenes by age.

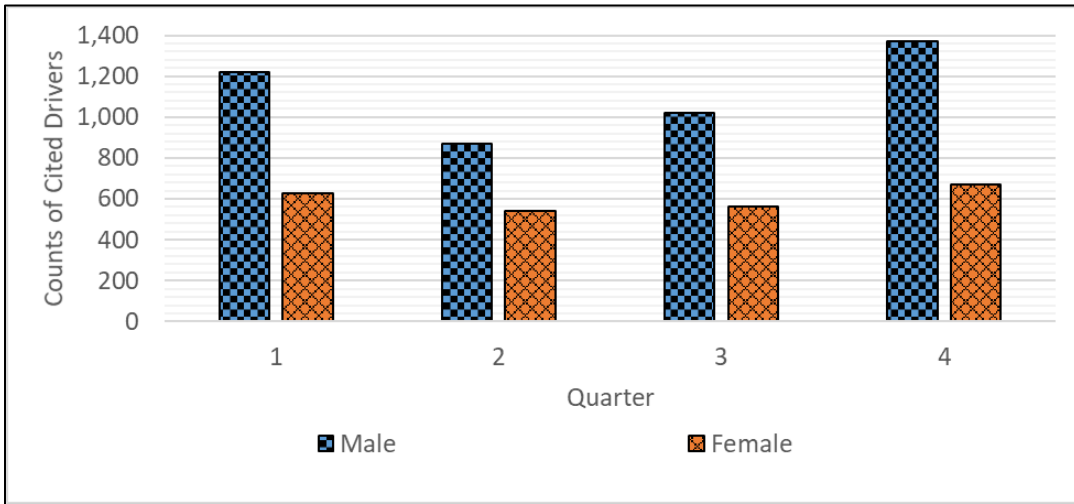


Figure 27: 2019 counts of cited drivers at the crash scenes by gender.

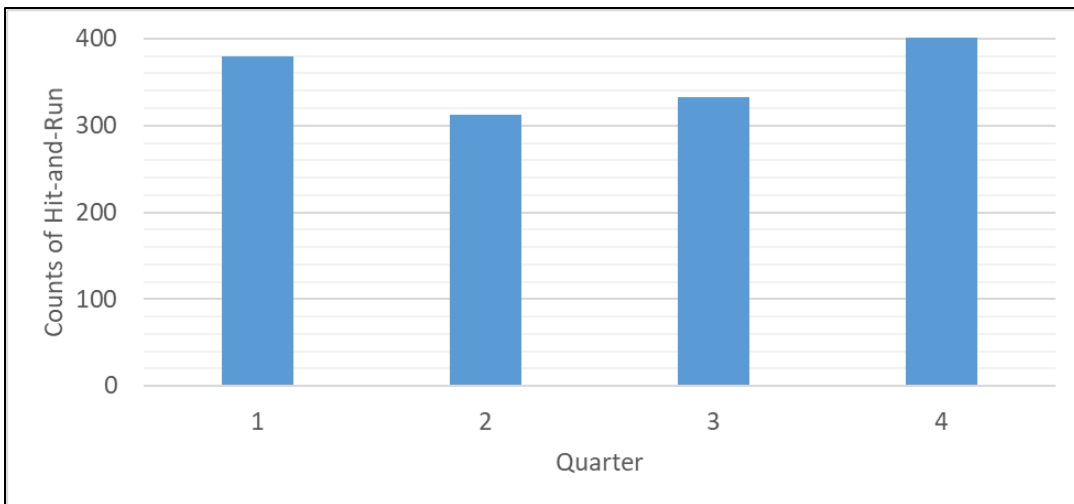


Figure 28: 2019 counts of hit-and-run crashes.

Table 7: 2019 Counts of Crashes by First Harmful Event Location

First Harmful Event Location	Quarter				Total
	1	2	3	4	
Bridge	2	0	1	1	4
Gore	5	4	5	8	22
In Parking Lane/Zone	223	179	204	269	875
Median	198	131	70	240	639
Off Roadway	858	599	525	1,063	3,045
On Other Roadway	3	0	3	1	7
On Roadway	2,254	2,007	2,475	2,914	9,650
Outside of Right-of-Way	7	5	7	9	28
Port of Entry	1	3	0	0	4
Rest Area	0	0	1	1	2
Separator	3	4	1	3	11
Shoulder	154	107	137	193	591
Tunnel	9	3	0	6	18
Unknown	0	1	2	1	4
Total	3,717	3,043	3,431	4,709	14,900

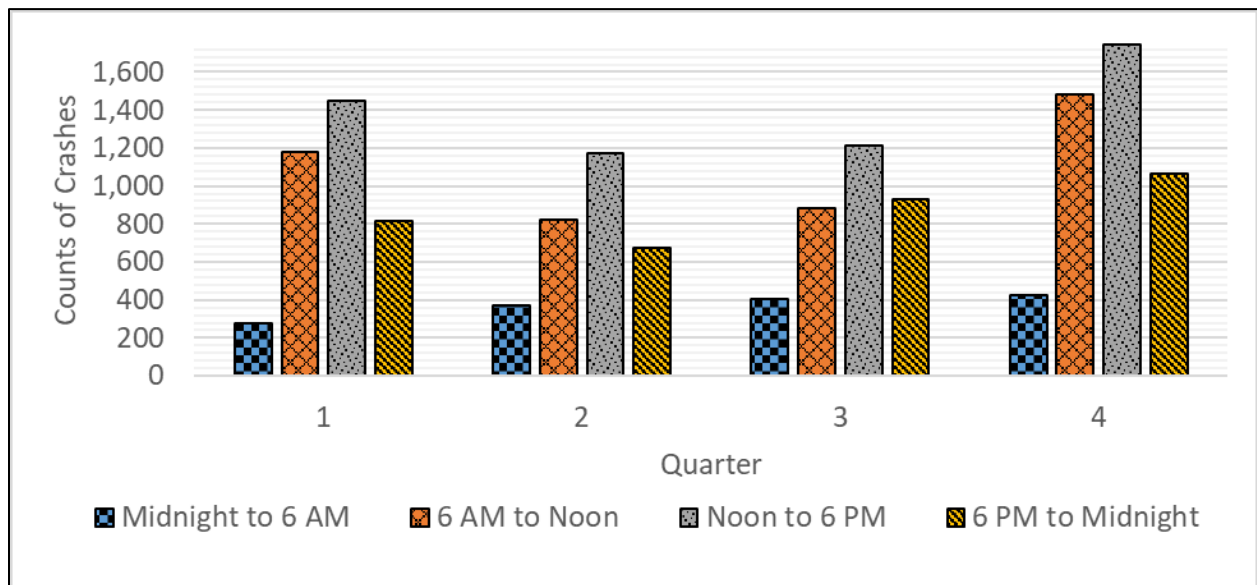


Figure 29: 2019 counts of crashes by time of day.

Table 8: 2019 Counts of Crashes by Weather Condition

Weather Condition	Quarter				Total
	1	2	3	4	
Blizzard	34	7	0	39	80
Blowing Dust/Sand/Dirt	7	0	0	4	11
Blowing Snow	285	24	0	244	553
Clear	2,394	2,312	3,187	3,168	11,061
Cloudy, Overcast	138	171	61	183	553
Fog	41	26	15	40	122
Raining	18	217	121	42	398
Severe Wind Only	107	9	5	65	186
Sleet/Hail/Freezing Rain	12	28	3	53	96
Smoke	0	2	0	0	2
Snowing	623	199	1	794	1,617
Other	3	0	0	7	10
Unknown	55	48	38	70	211
Total	3,717	3,043	3,431	4,709	14,900

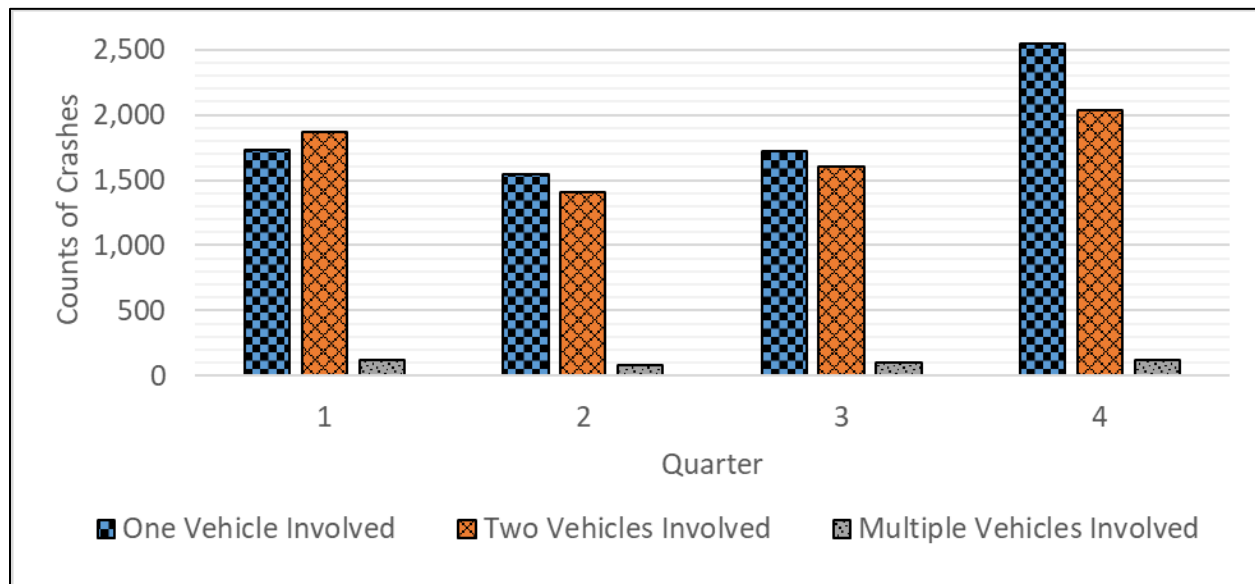


Figure 30: 2019 counts of crashes by number of vehicles involved.

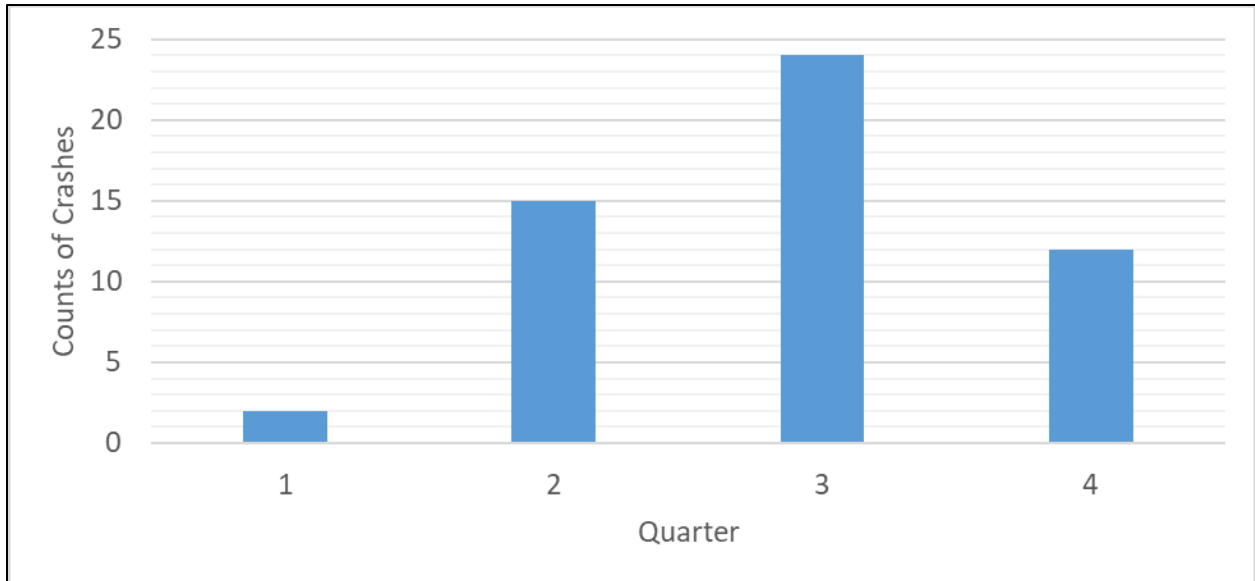


Figure 31: 2019 counts of bicycle crashes.

Table 9: 2019 Animal Crashes by Type of Animal Struck

Animal	Quarter				Total
	1	2	3	4	
Deer	336	457	613	795	2,201
Antelope	31	65	84	62	242
Elk	17	27	62	36	142
Buffalo	1	1	0	0	2
Moose	7	9	16	9	41
Other Wild	4	8	12	11	35
Cow	13	26	56	46	141
Horse	4	6	4	7	21
Sheep	4	1	3	4	12
Pig	0	1	0	0	1
Other Domestic (Dog, Lama, etc.)	6	7	9	13	35
Total	423	608	859	983	2,873

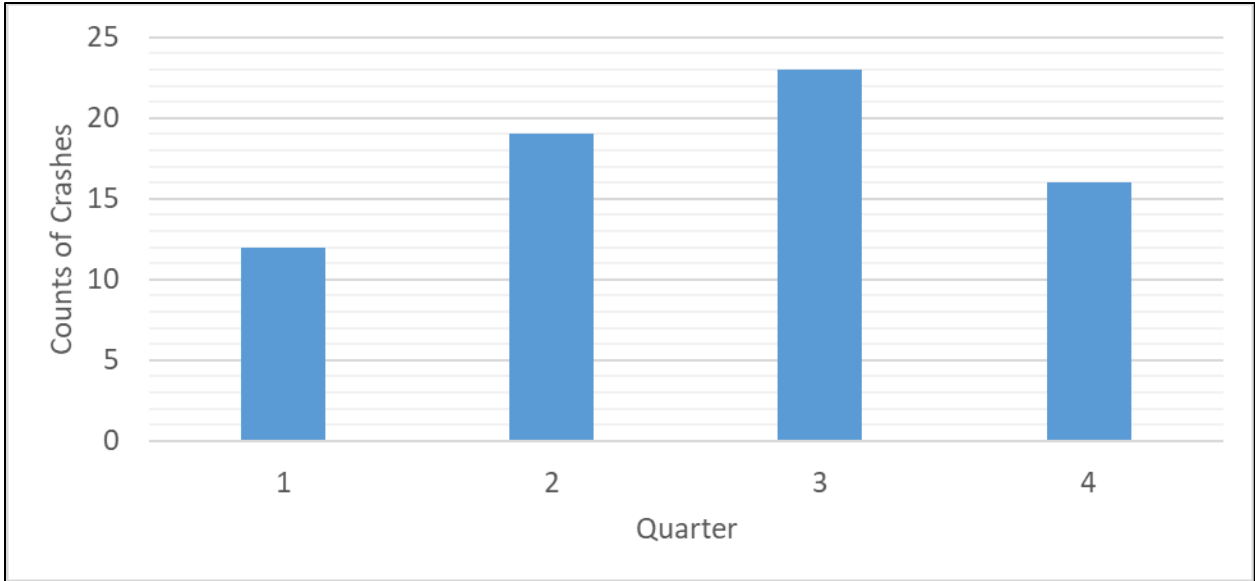


Figure 32: 2019 counts of crashes resulting in fires.

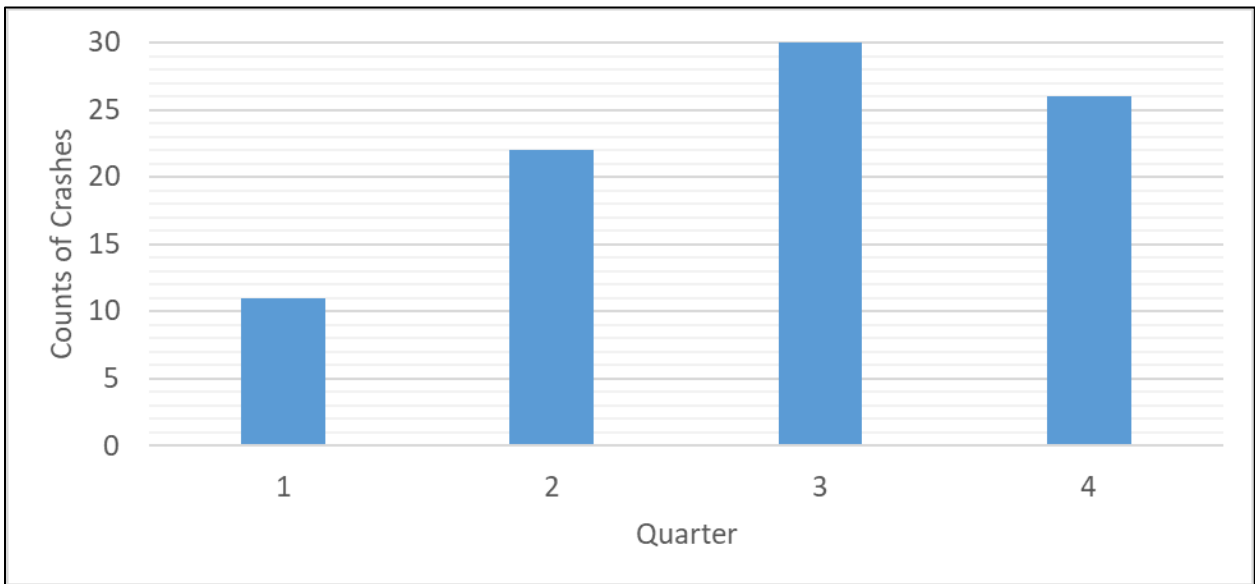


Figure 33: 2019 counts of crashes involving mechanical failures.

Table 10: 2019 Counts of Crashes by Manner of Collision

Manner of Collision	Quarter				Total
	1	2	3	4	
Head On (Front to Front)	82	52	70	94	298
Angle (Front to Side), Opposing Direction	248	165	176	294	883
Angle Right (Front to Side, Includes Broadside)	424	268	334	405	1,431
Angle Same Direction (Front to Side)	196	138	162	198	694
Angle Direction Not Specified	7	1	3	3	14
Rear End (Front to Rear)	567	450	496	652	2,165
Rear to Front (Normally Backing)	59	50	55	63	227
Rear to Rear (Normally Backing)	12	16	12	20	60
Rear to Side (Normally Backing)	73	79	83	80	315
Sideswipe Opposite Direction (Meeting)	51	32	31	56	170
Sideswipe Same Direction (Passing)	216	184	219	237	856
Other	17	35	30	31	113
Not a Collision with Two Vehicles in Transport	1,321	962	909	1,607	4,799
Unknown or Not Stated	444	611	851	969	2,875
Total	3,717	3,043	3,431	4,709	14,900

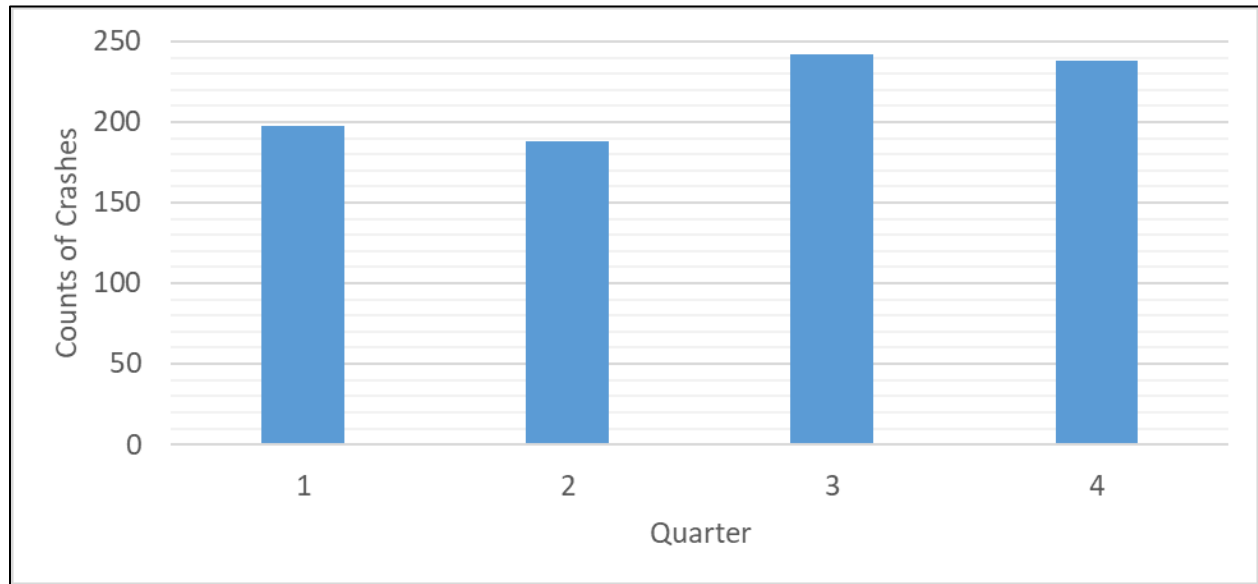


Figure 34: 2019 counts of weekend driving under the influence crashes.

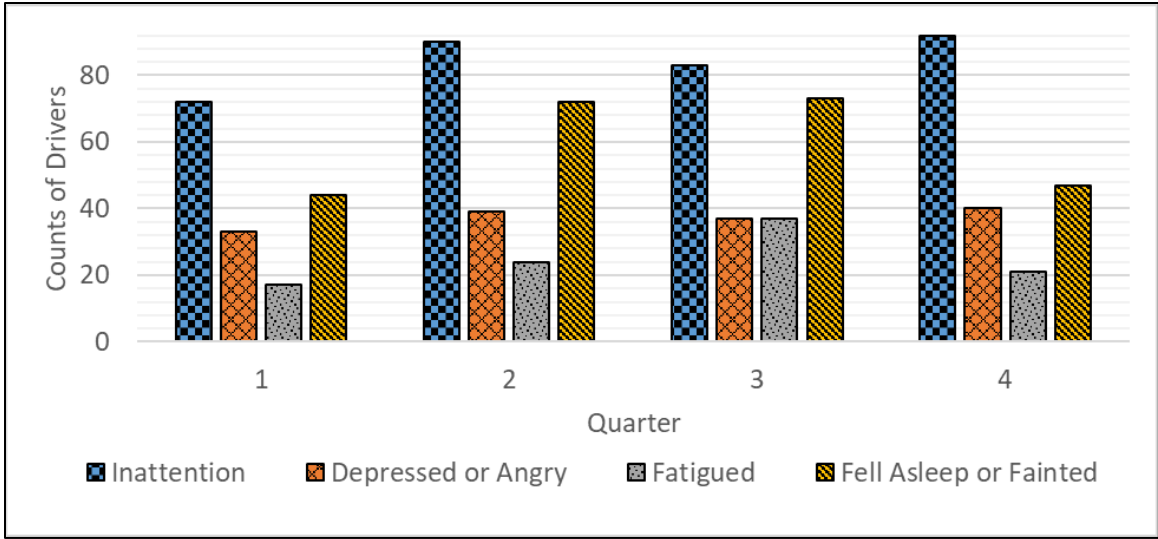


Figure 35: 2019 counts of drivers by detestable condition.

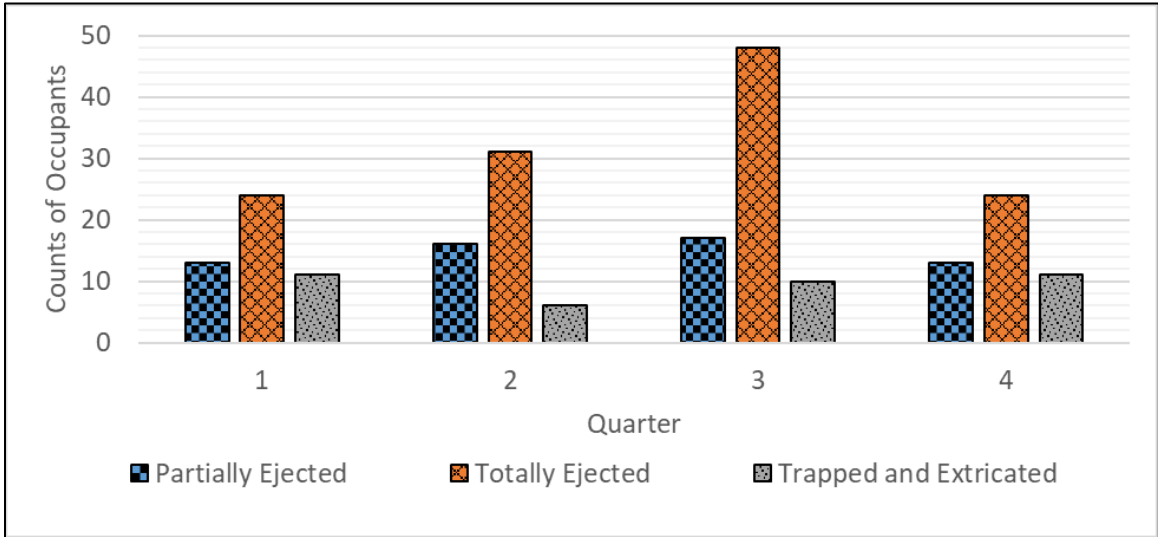


Figure 36: 2019 counts of ejected, partially ejected and trapped occupants.

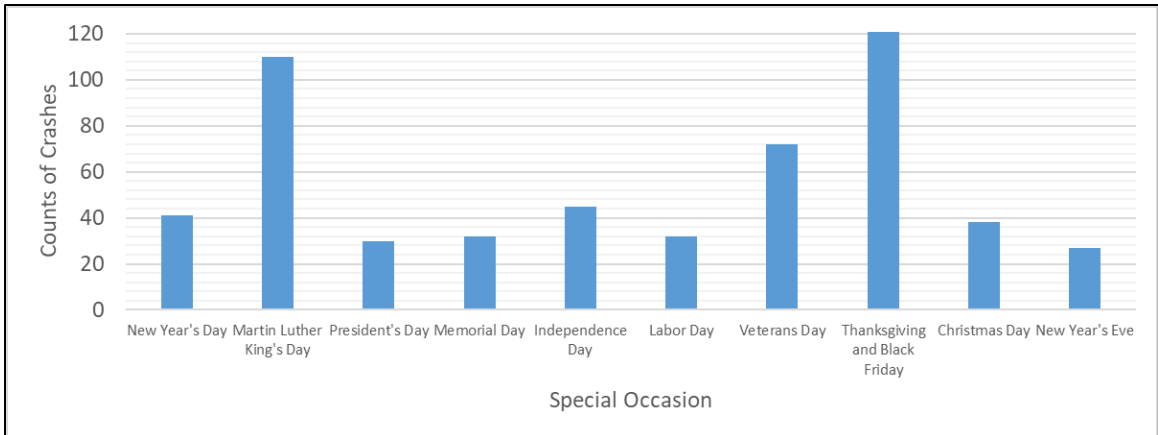


Figure 37: 2019 special occasion crashes.

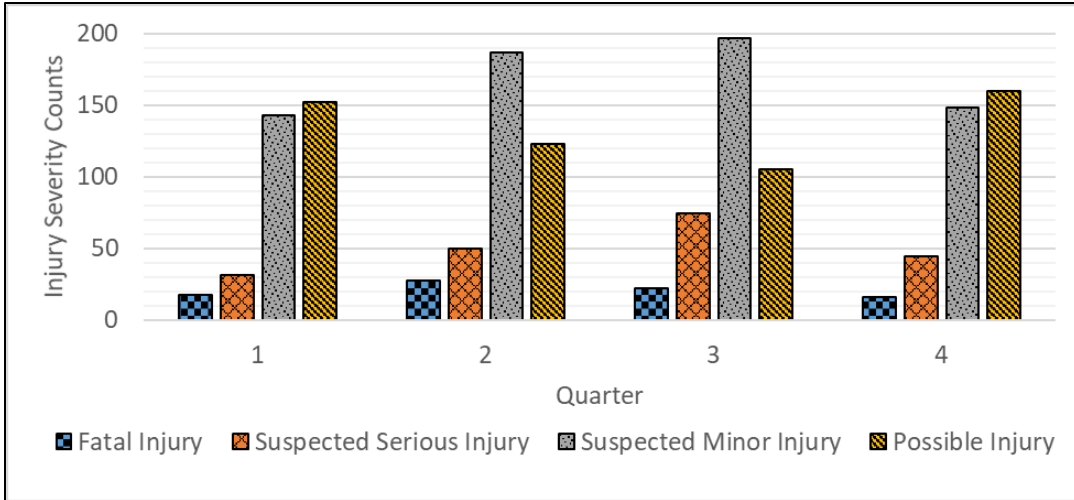


Figure 38: 2019 counts of killed and injured male drivers.

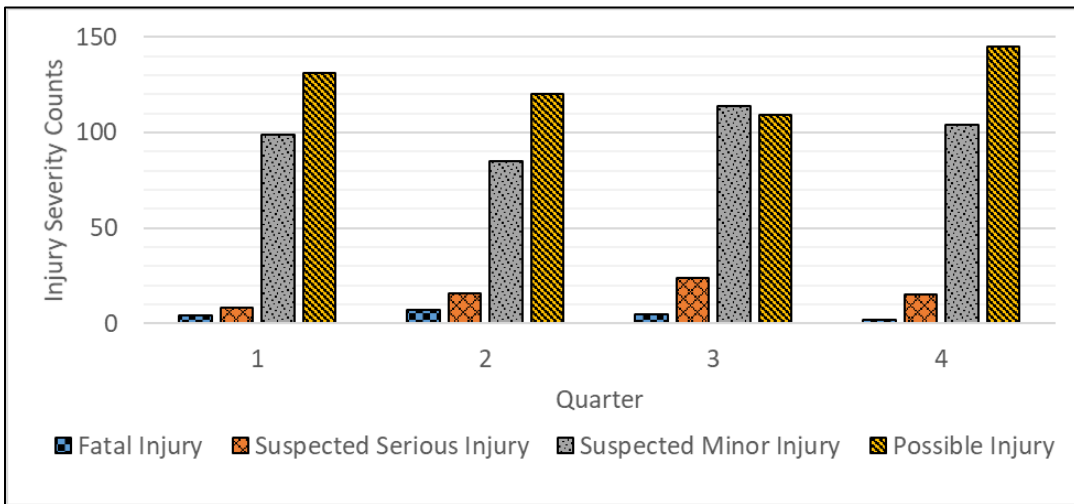


Figure 39: 2019 counts of killed and injured female drivers.

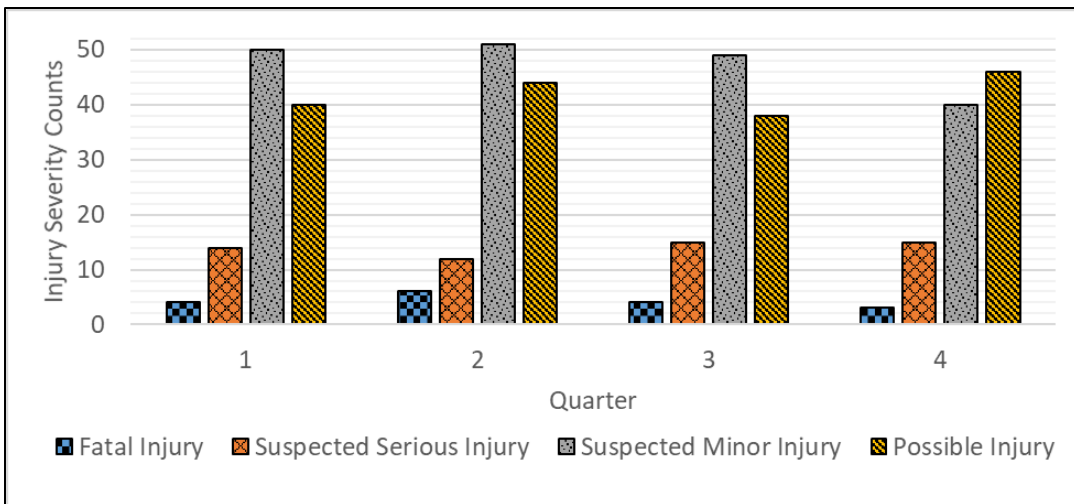


Figure 40: 2019 counts of killed and injured male passengers.

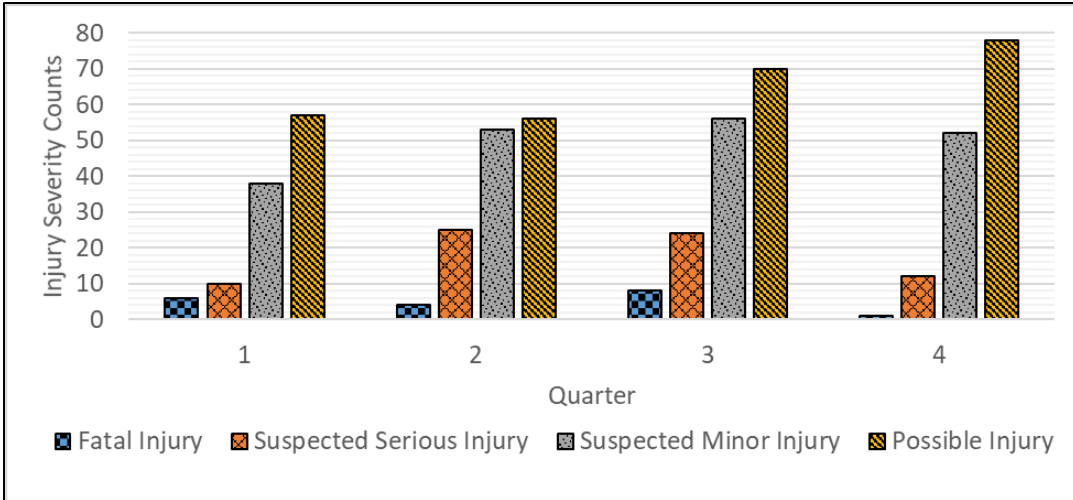


Figure 41: 2019 counts of killed and injured female passengers.

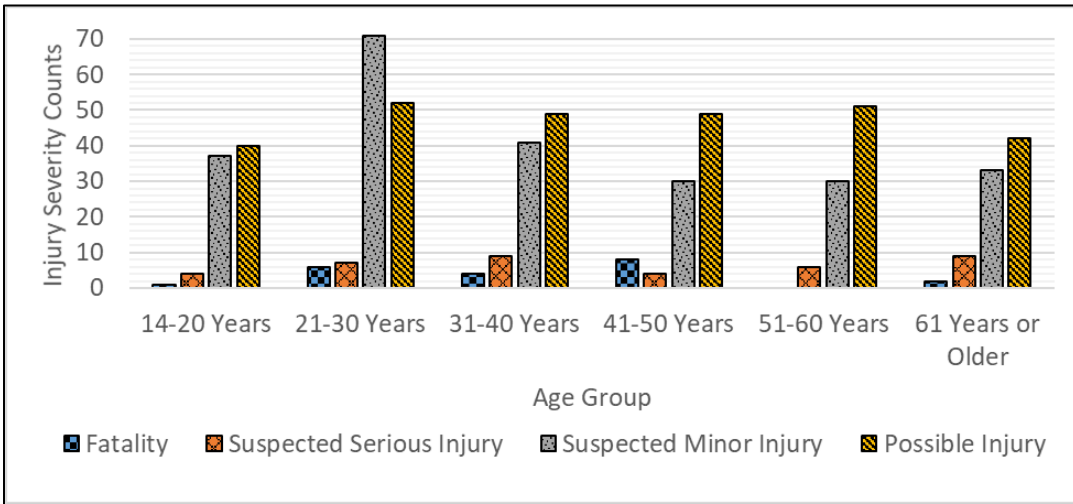


Figure 42: 2019 counts of killed and injured drivers by age in the first quarter.

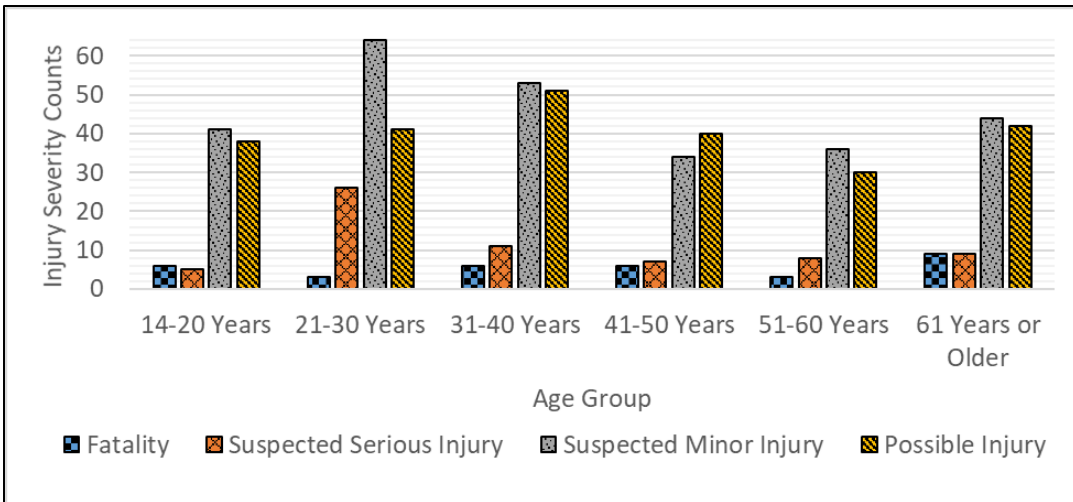


Figure 43: 2019 counts of killed and injured drivers by age in the second quarter.

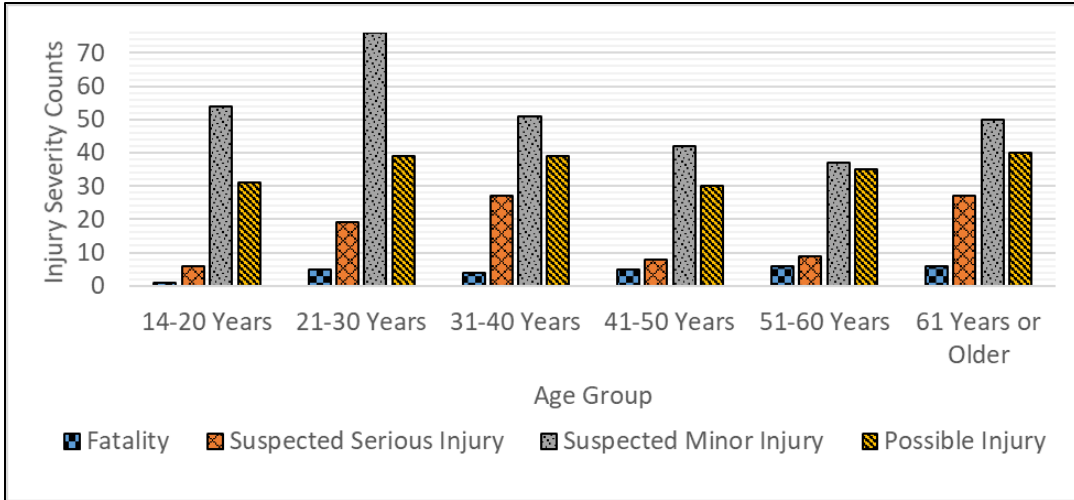


Figure 44: 2019 counts of killed and injured drivers by age in the third quarter.

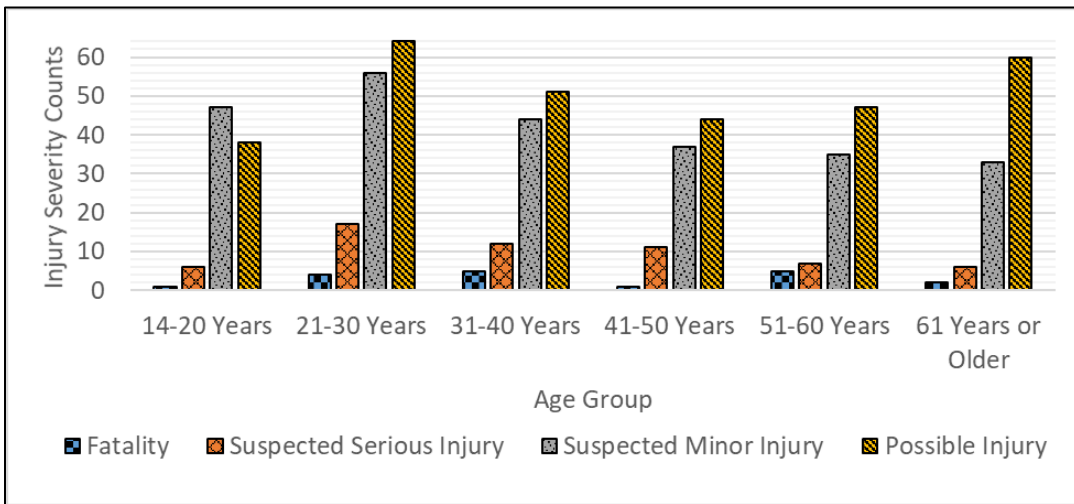


Figure 45: 2019 counts of killed and injured drivers by age in the fourth quarter.



Figure 46: 2019 counts of killed and injured passengers by age in the first quarter.

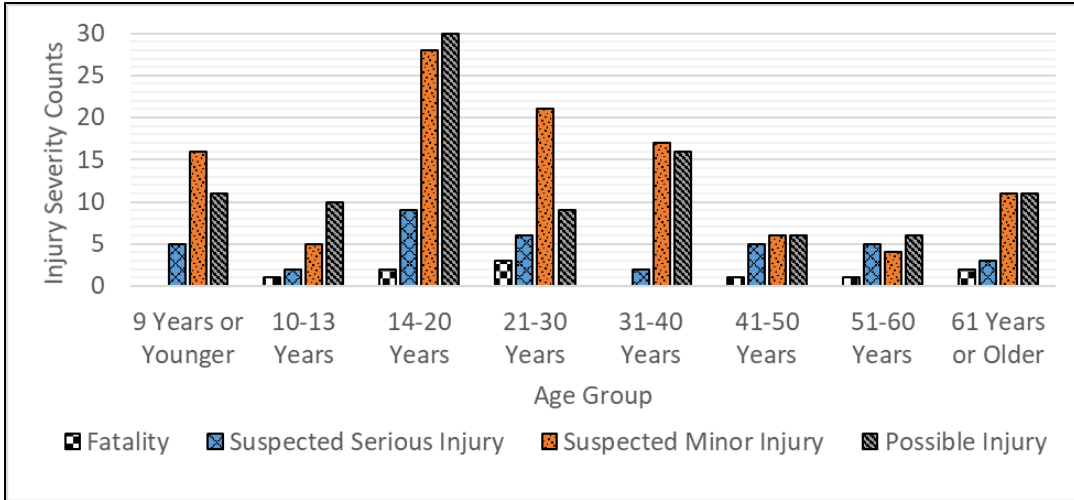


Figure 47: 2019 counts of killed and injured passengers by age in the second quarter.



Figure 48: 2019 counts of killed and injured passengers by age in the third quarter.

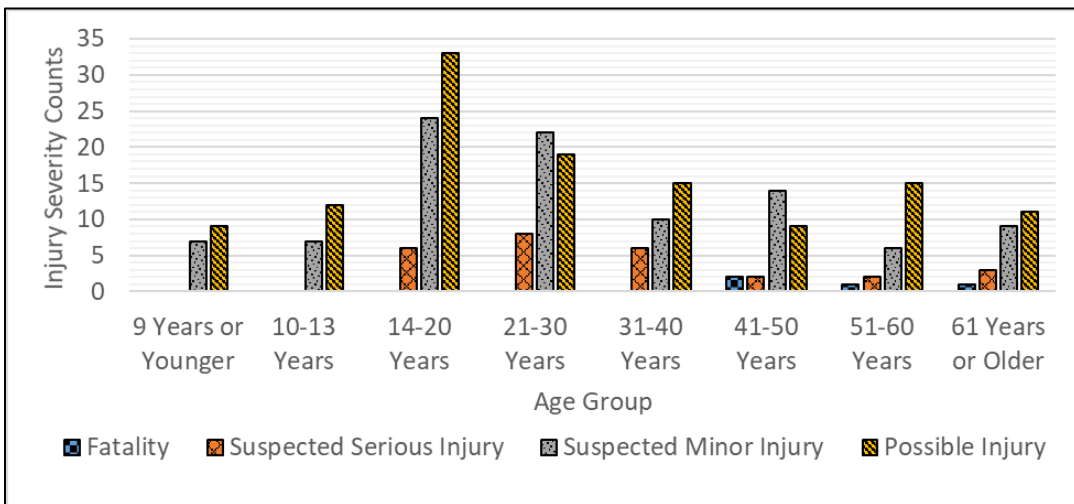


Figure 49: 2019 counts of killed and injured passengers by age in the fourth quarter.

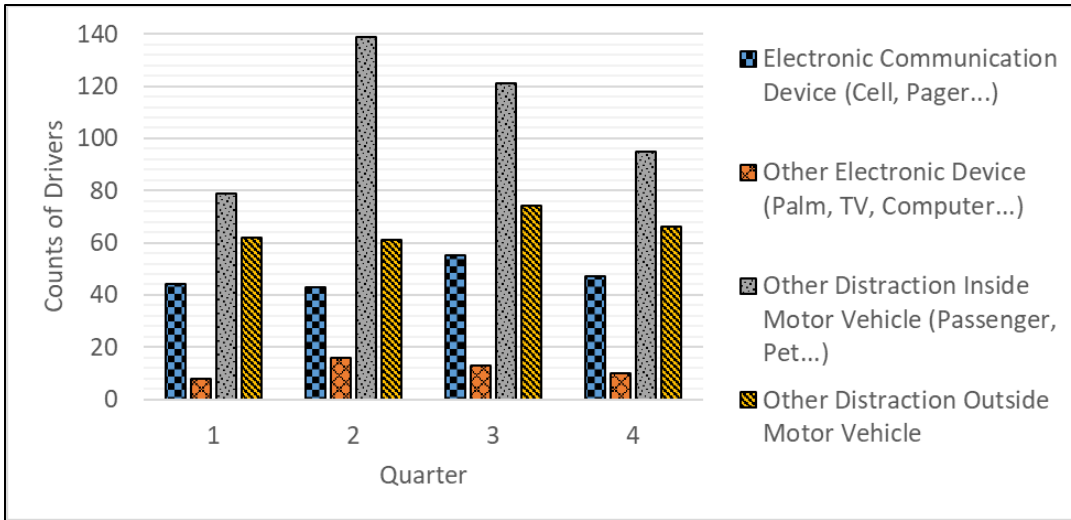


Figure 50: 2019 counts of distracted drivers by means of distraction.

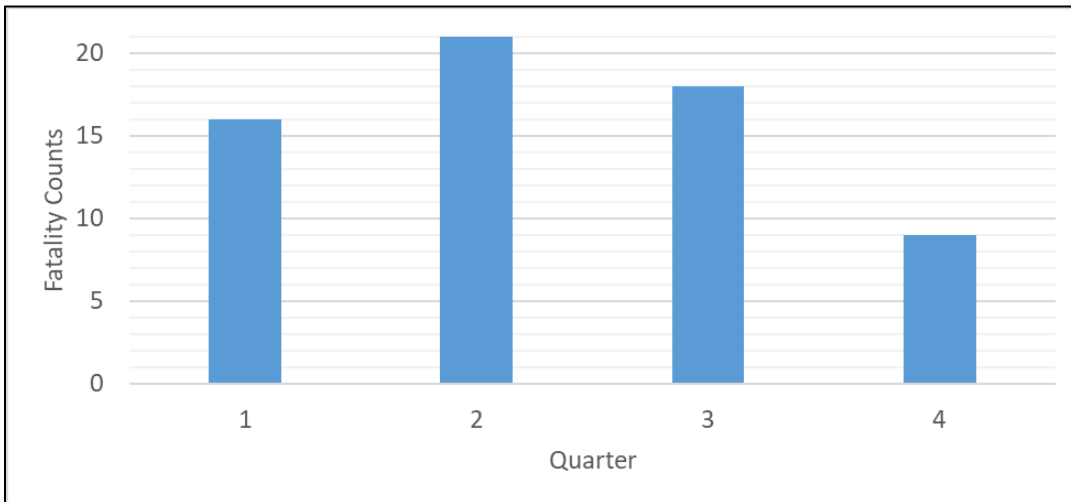


Figure 51: 2019 fatality counts of improperly belted or unbelted occupants.

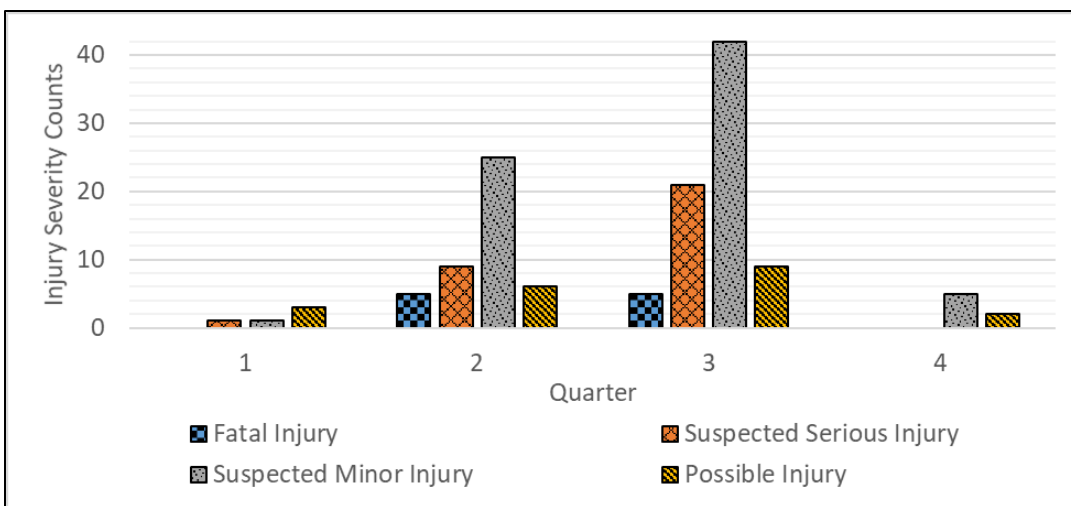


Figure 52: 2019 counts of killed and injured motorcycle operators.

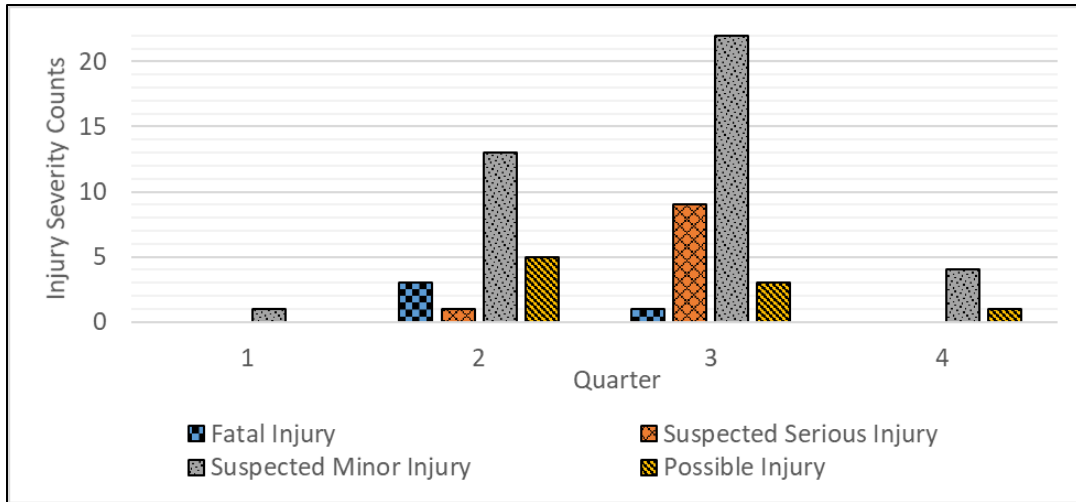


Figure 53: 2019 counts of killed and injured motorcycle operators wearing helmets.

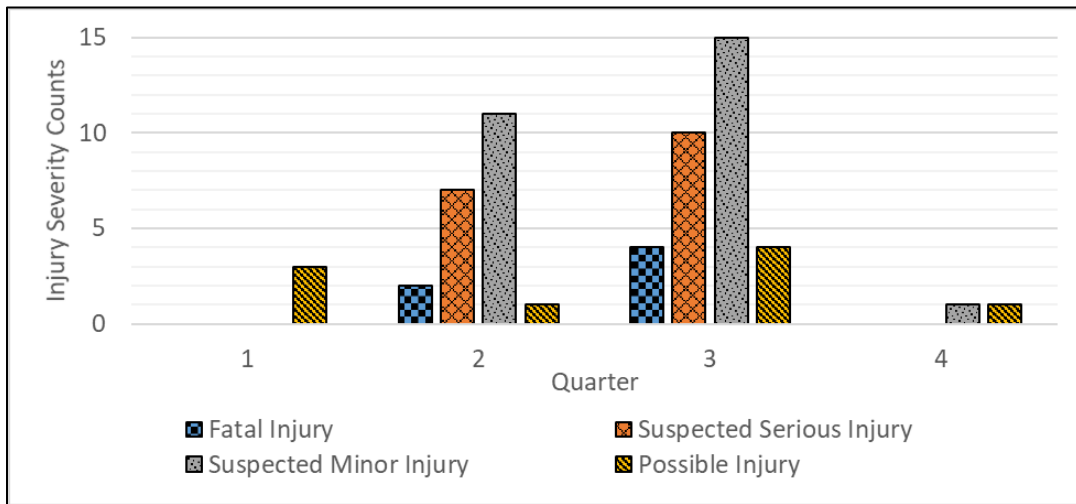


Figure 54: 2019 counts of killed and injured motorcycle operators not wearing helmets.

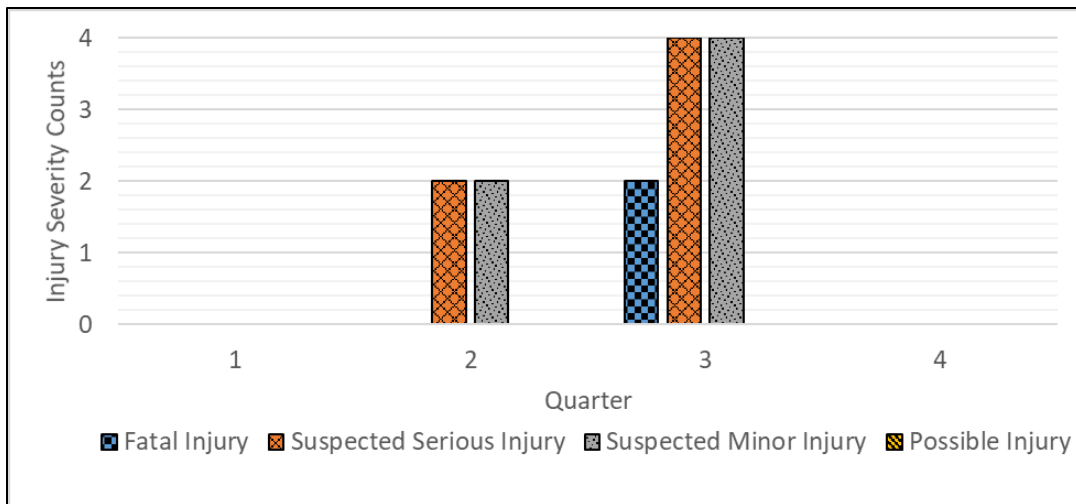


Figure 55: 2019 counts of killed and injured motorcycle passengers.

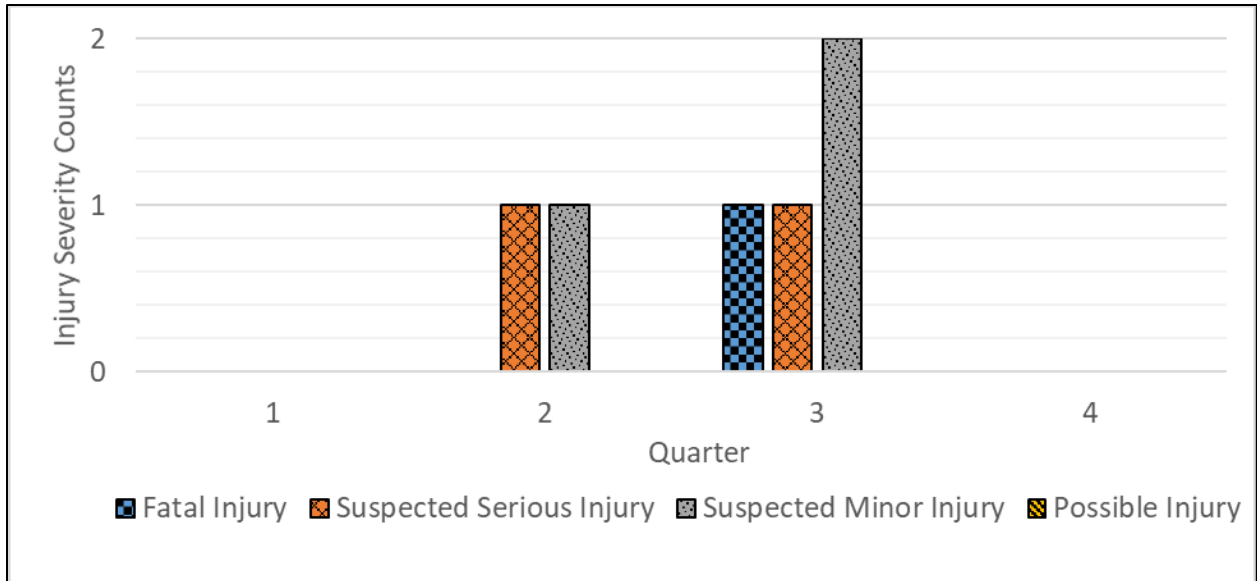


Figure 56: 2019 counts of killed and injured motorcycle passengers wearing helmets.

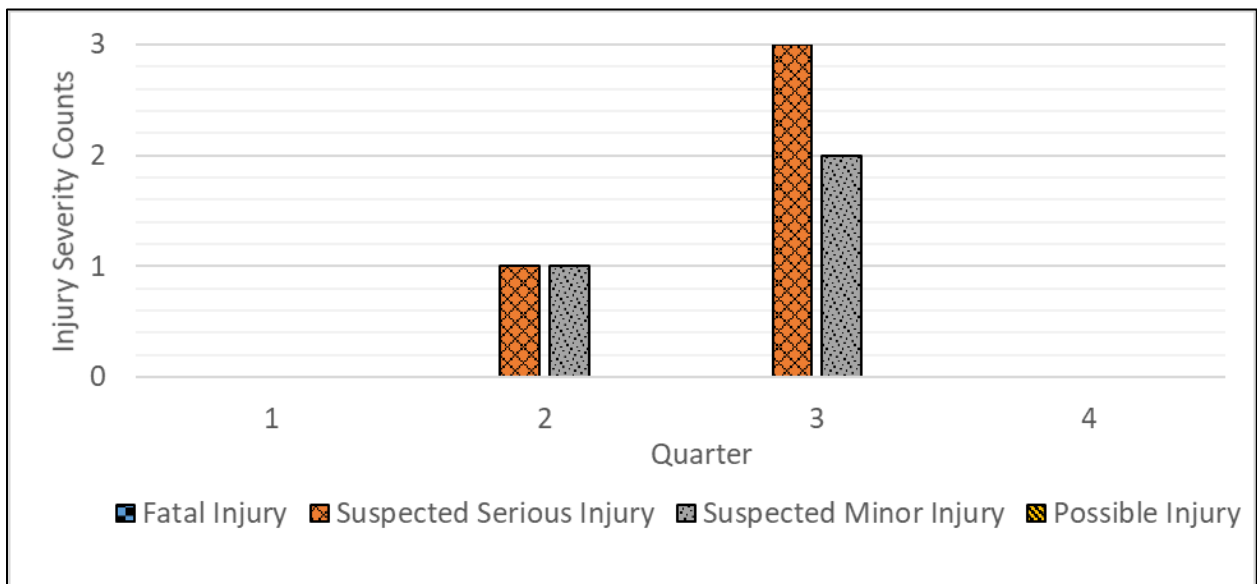


Figure 57: 2019 counts of killed and injured motorcycle passengers not wearing helmets.

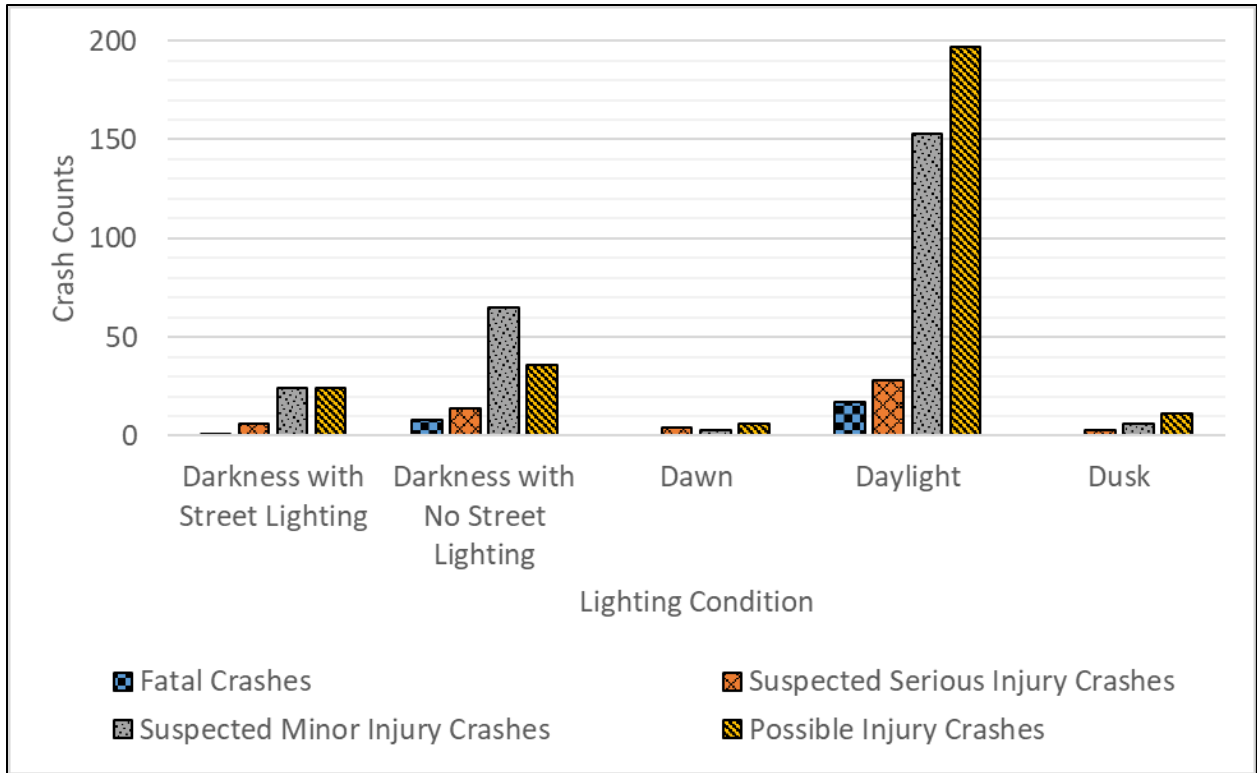


Figure 58: 2019 counts of crashes by lighting condition in the first quarter.

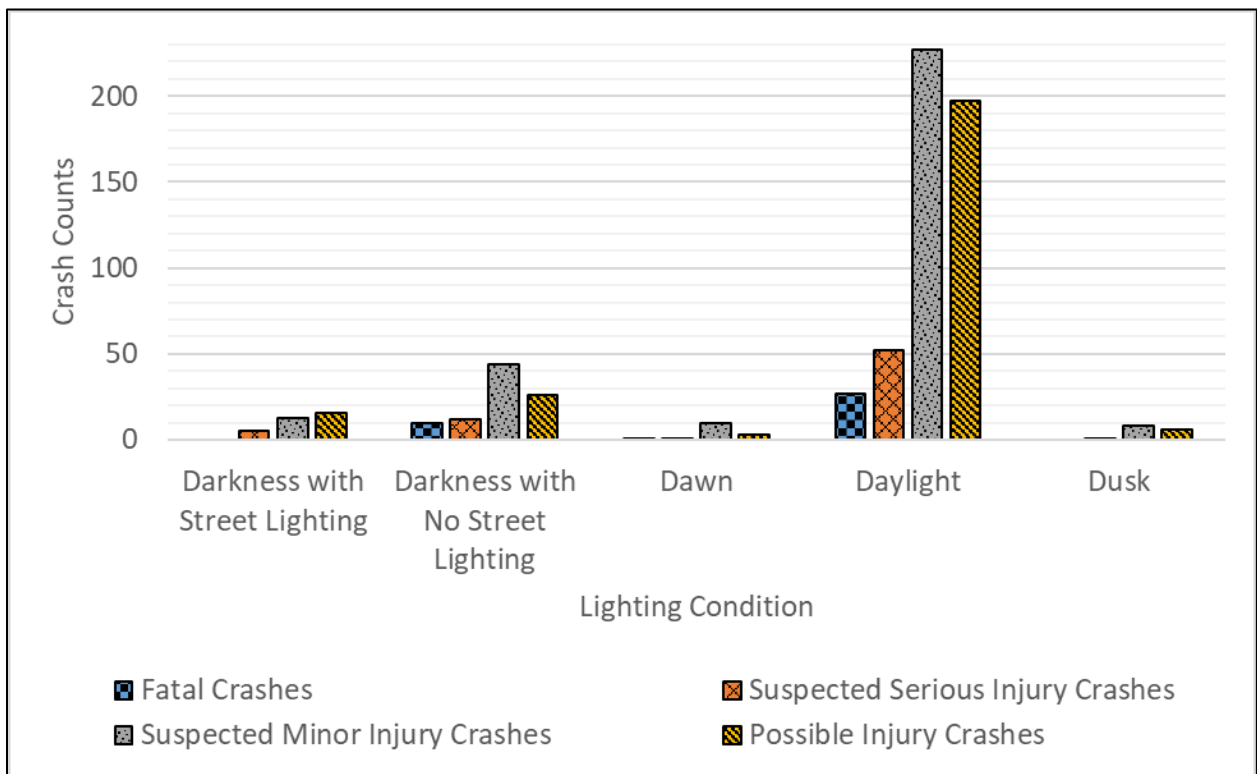


Figure 59: 2019 counts of crashes by lighting condition in the second quarter.

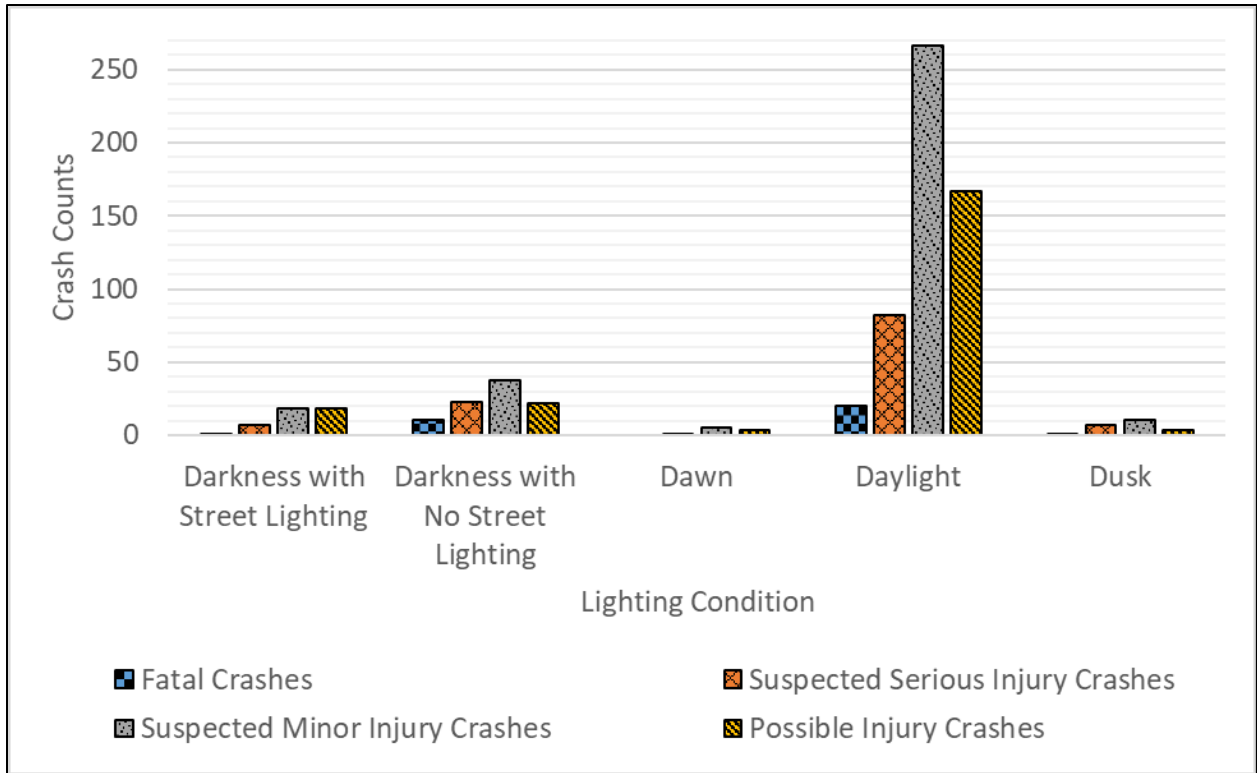


Figure 60: 2019 counts of crashes by lighting condition in the third quarter.

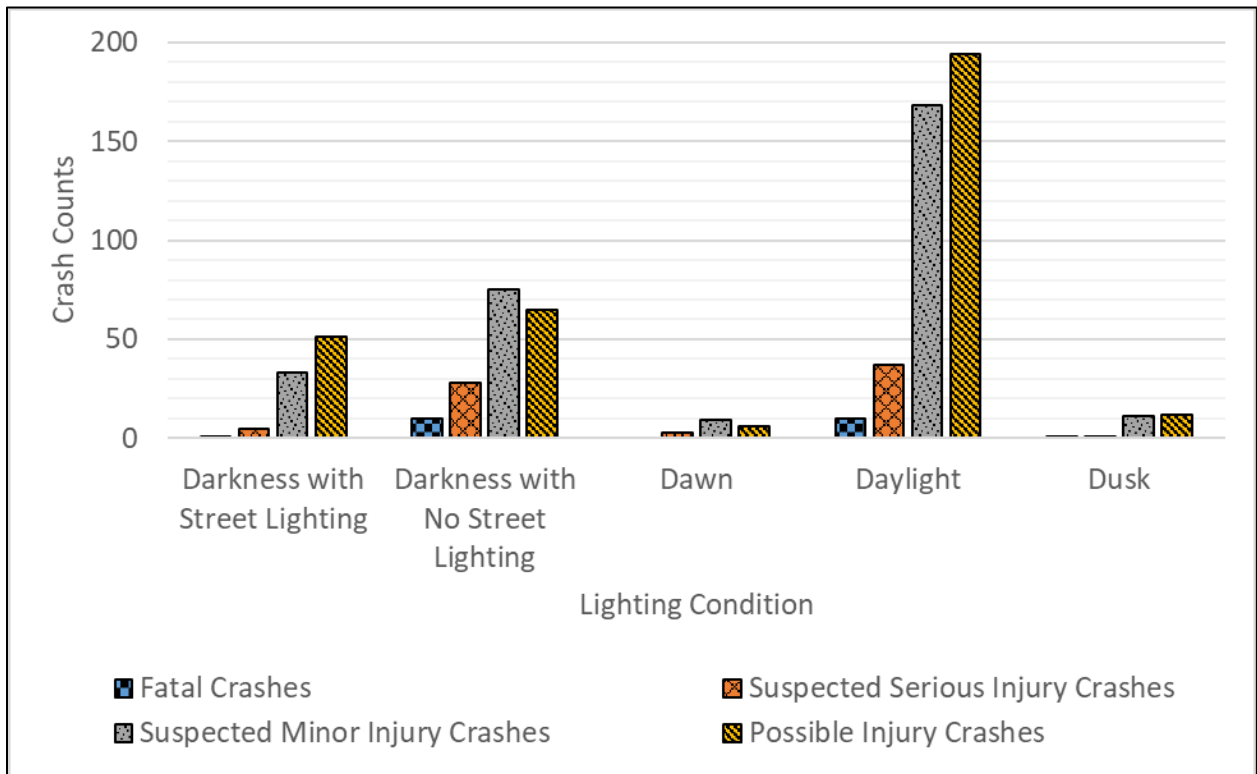


Figure 61: 2019 counts of crashes by lighting condition in the fourth quarter.

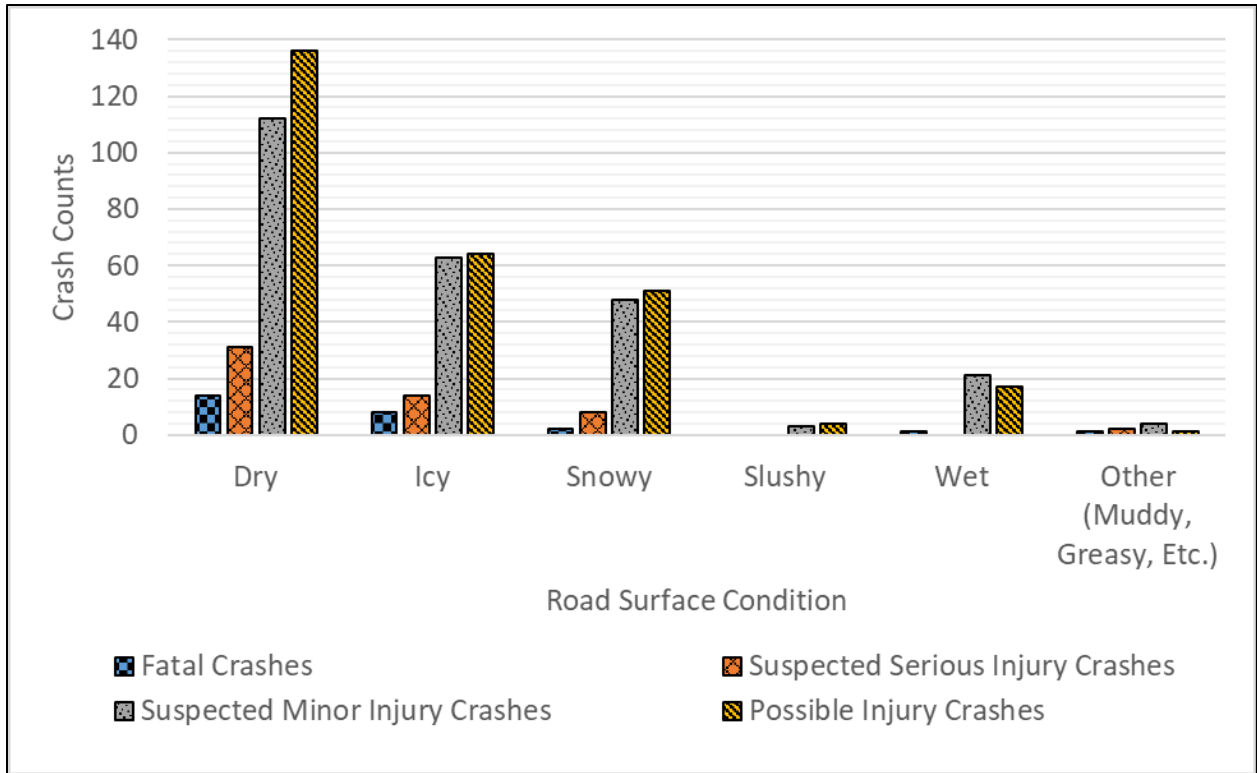


Figure 62: 2019 counts of crashes by road surface condition in the first quarter.

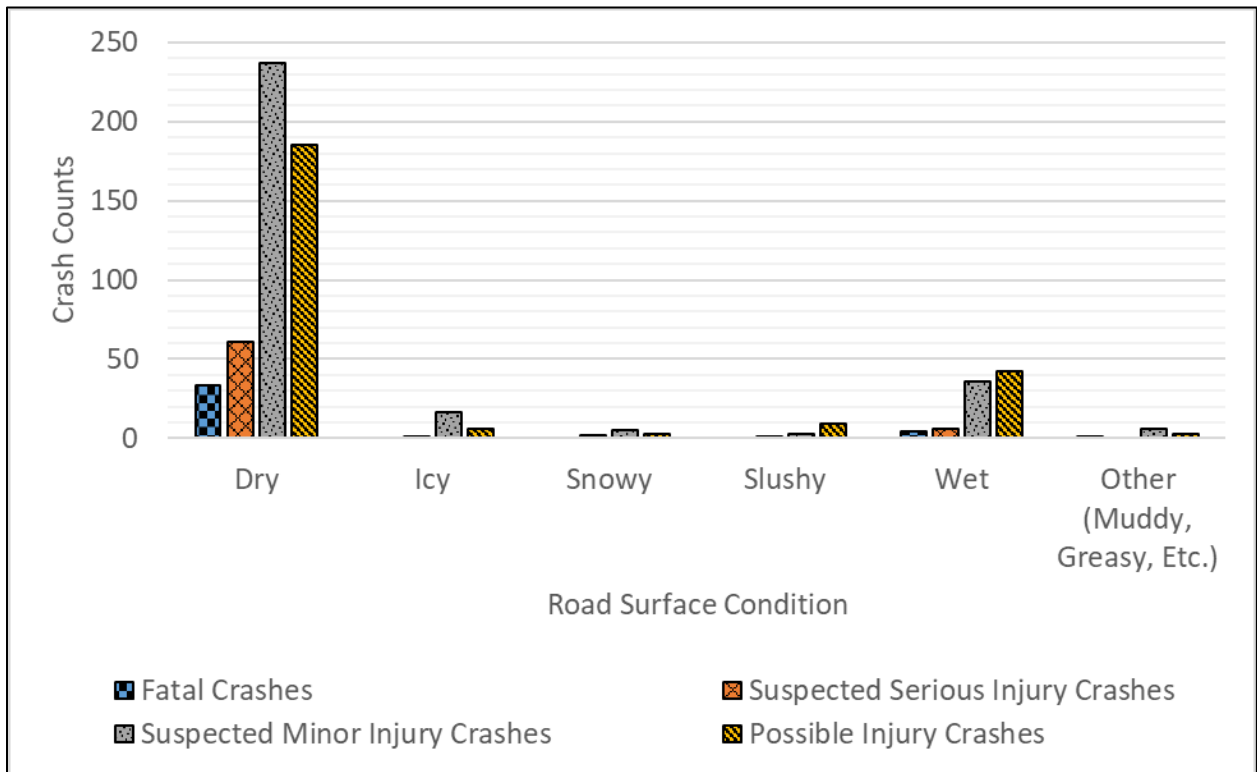


Figure 63: 2019 counts of crashes by road surface condition in the second quarter.

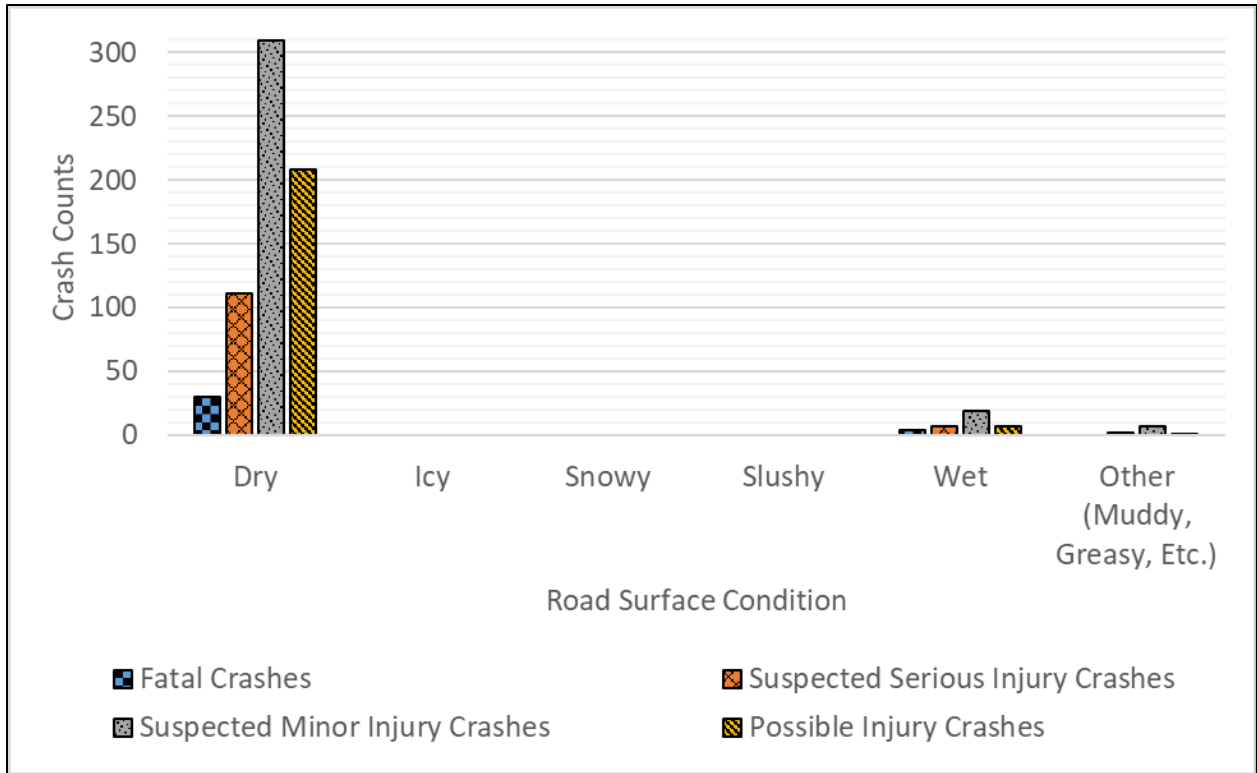


Figure 64: 2019 counts of crashes by road surface condition in the third quarter.

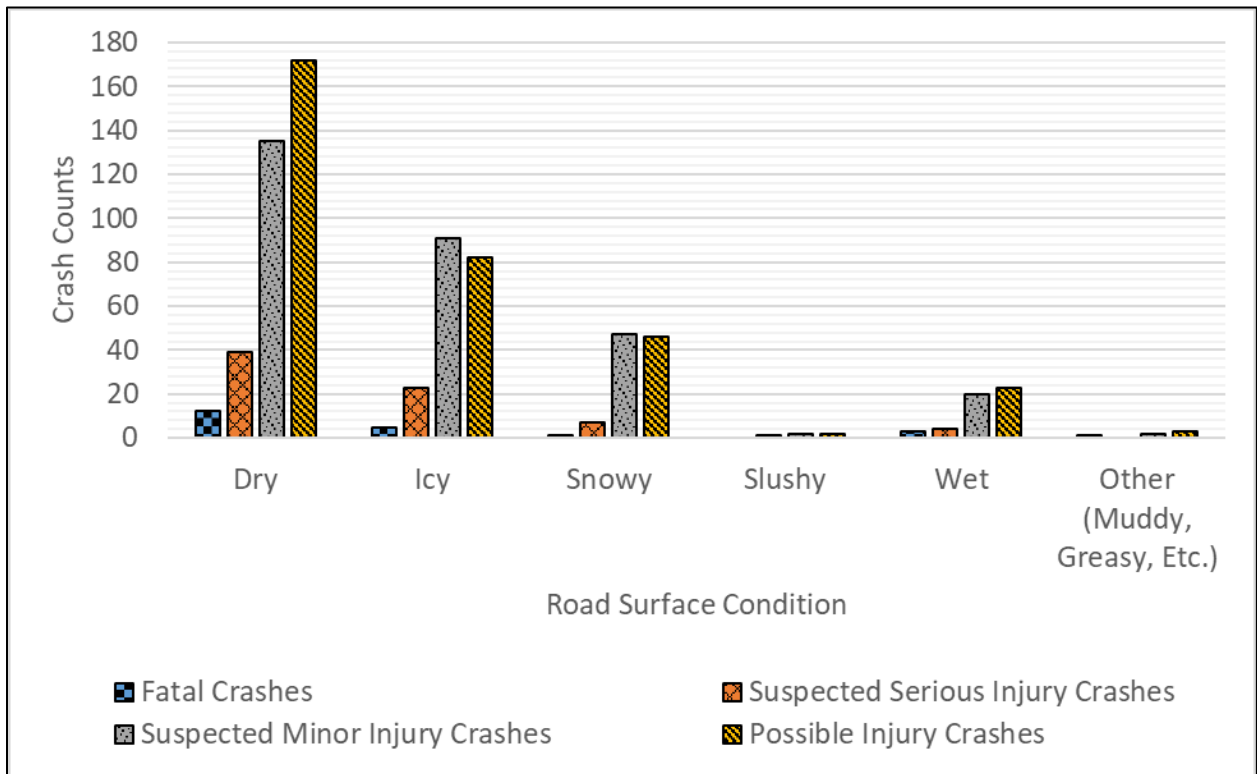


Figure 65: 2019 counts of crashes by road surface condition in the fourth quarter.

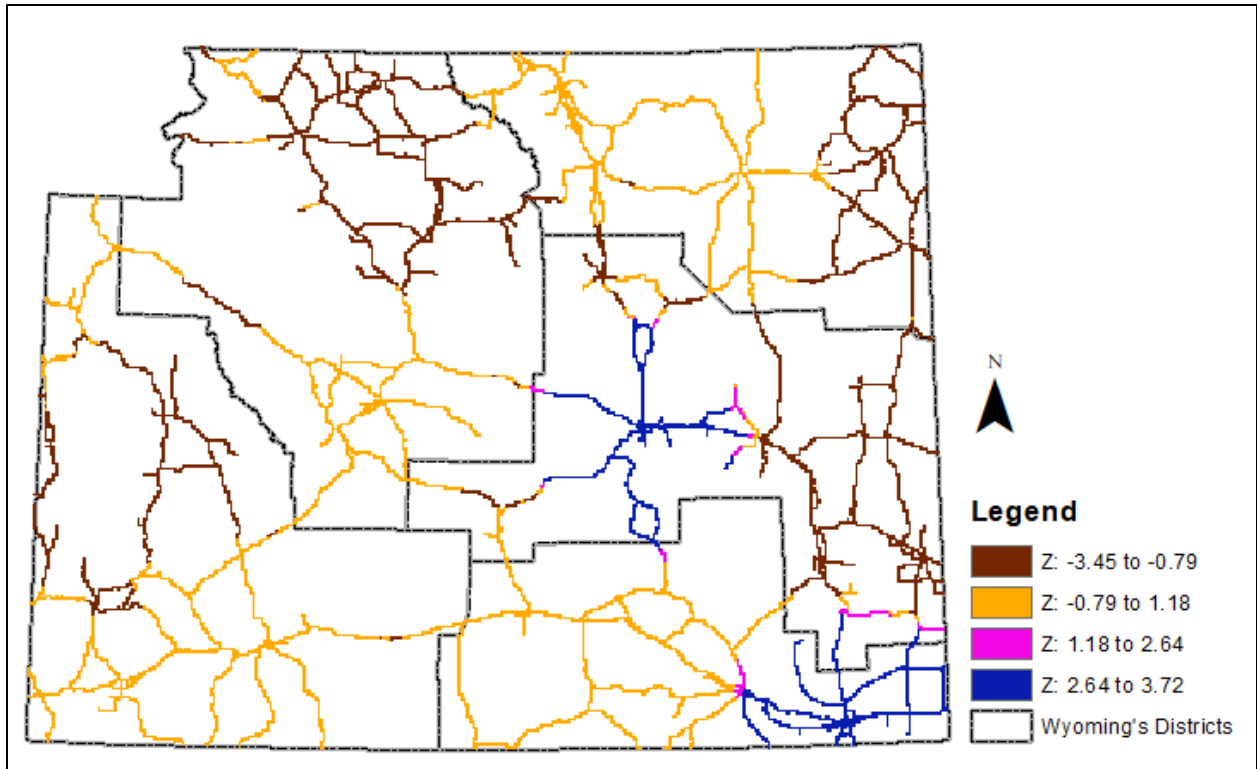


Figure 66: 2017 heat map of fatal, suspected serious injury and suspected minor injury crashes.

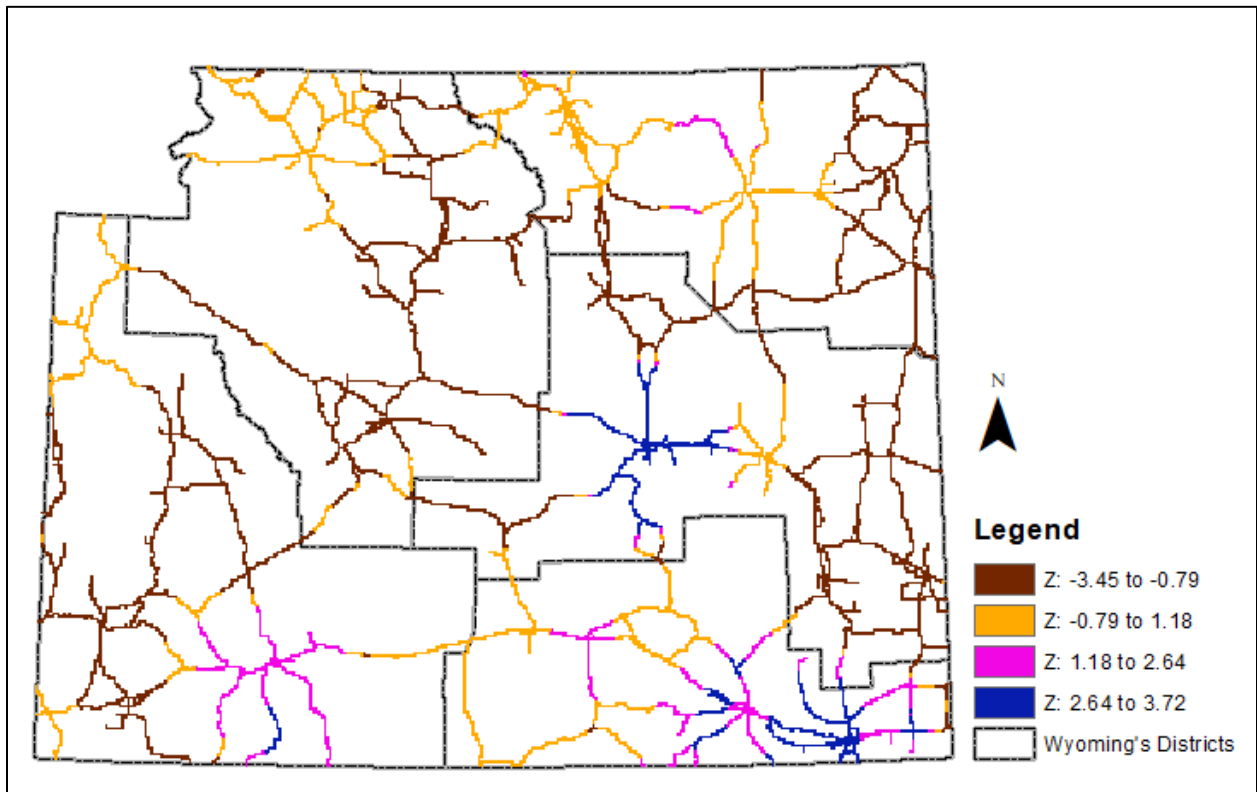


Figure 67: 2017 heat map of speed related crashes.

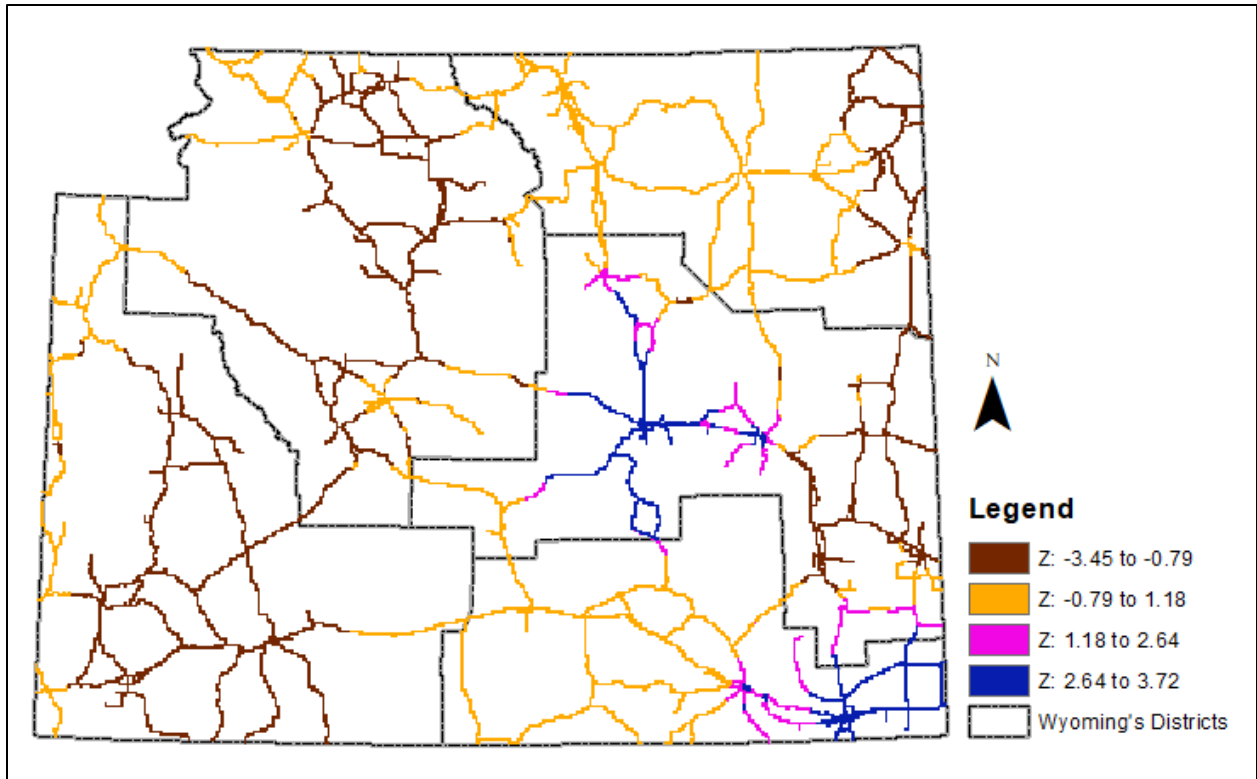


Figure 68: 2017 heat map of speed related fatal, suspected serious injury and suspected minor injury crashes.

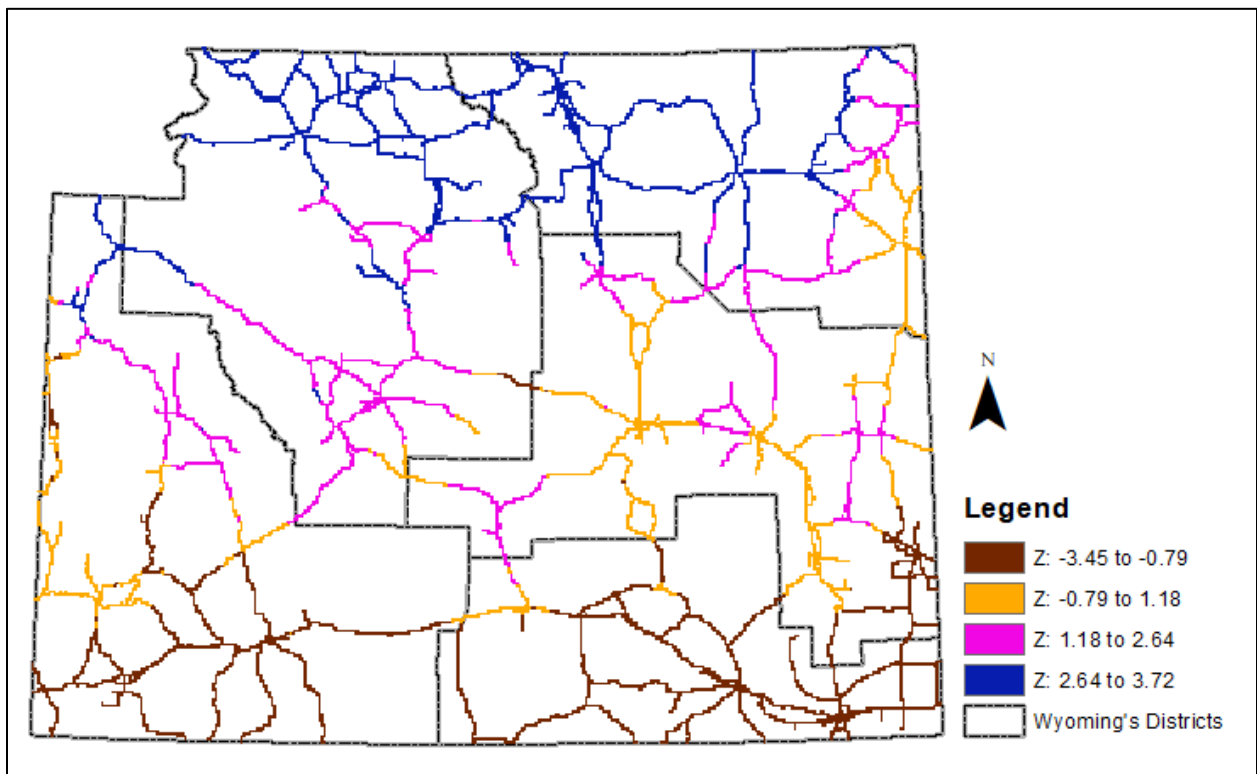


Figure 69: 2017 heat map of wild animal crashes.

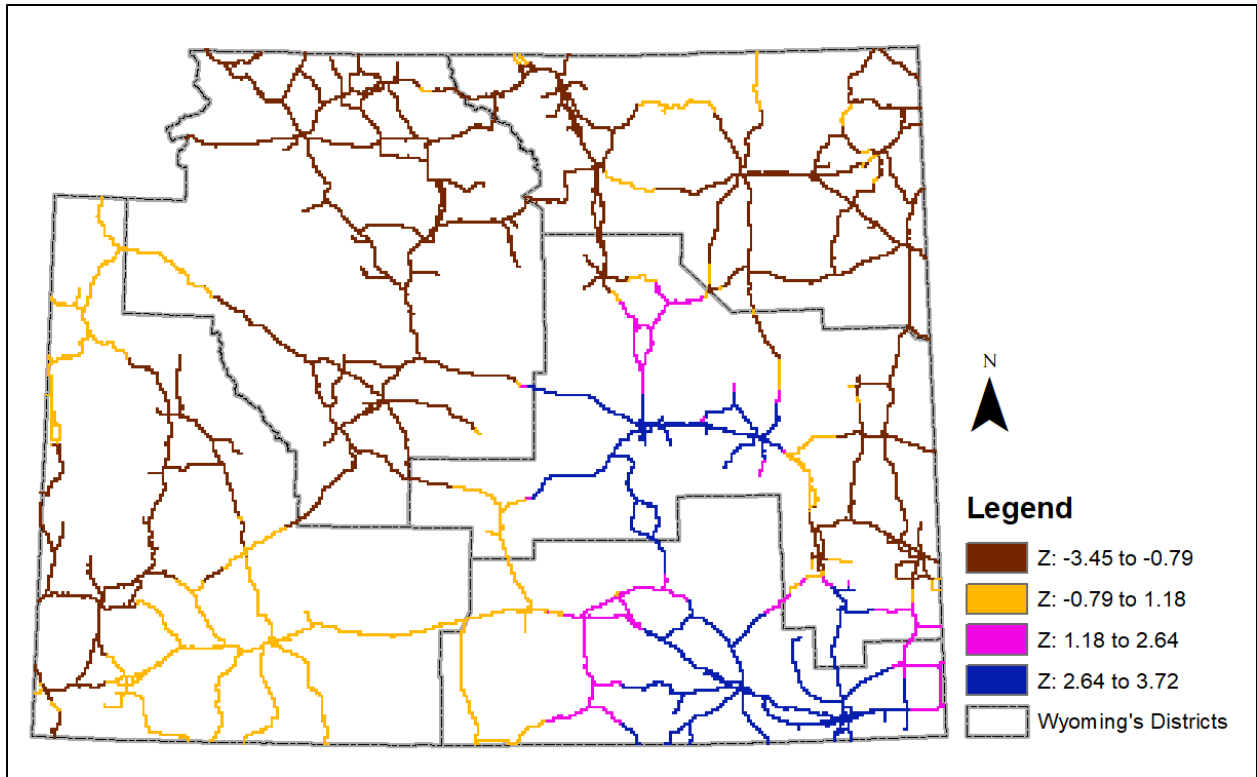


Figure 70: 2017 heat map of adverse weather related crashes.

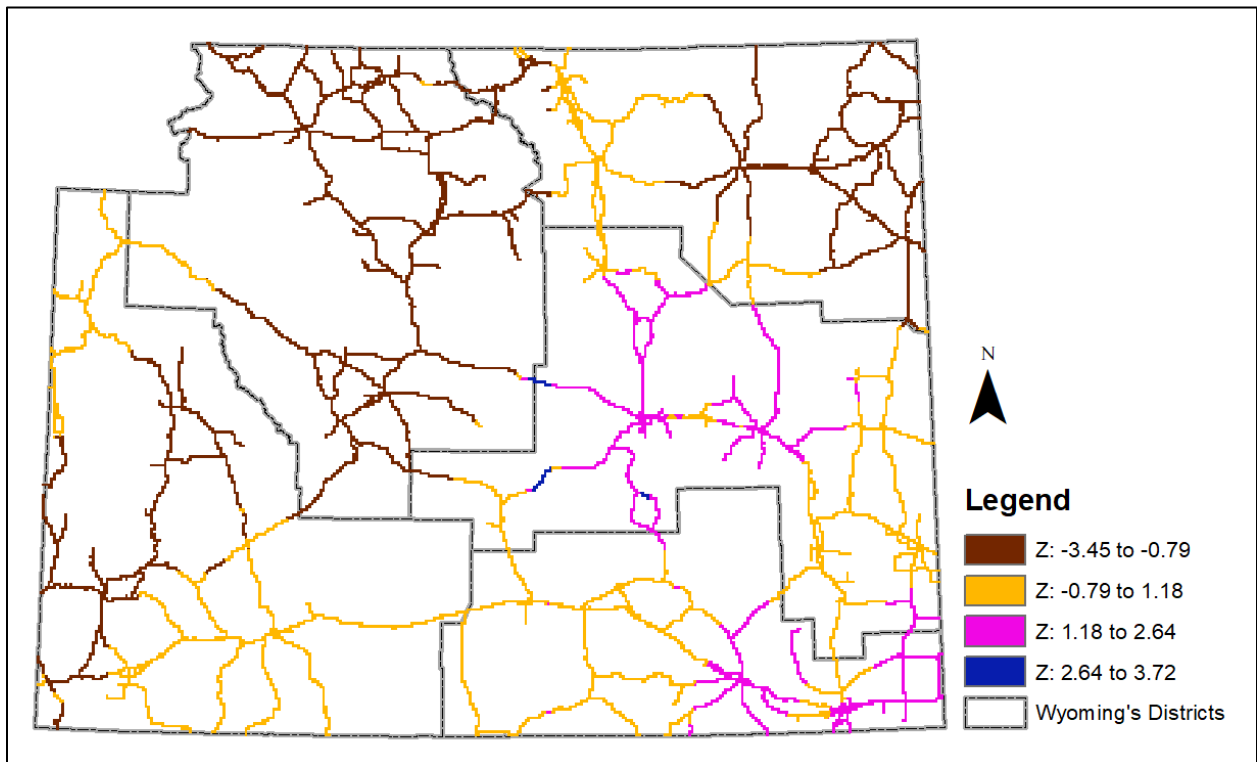


Figure 71: 2017 heat map of fatal, suspected serious injury and suspected minor injury adverse weather related crashes.

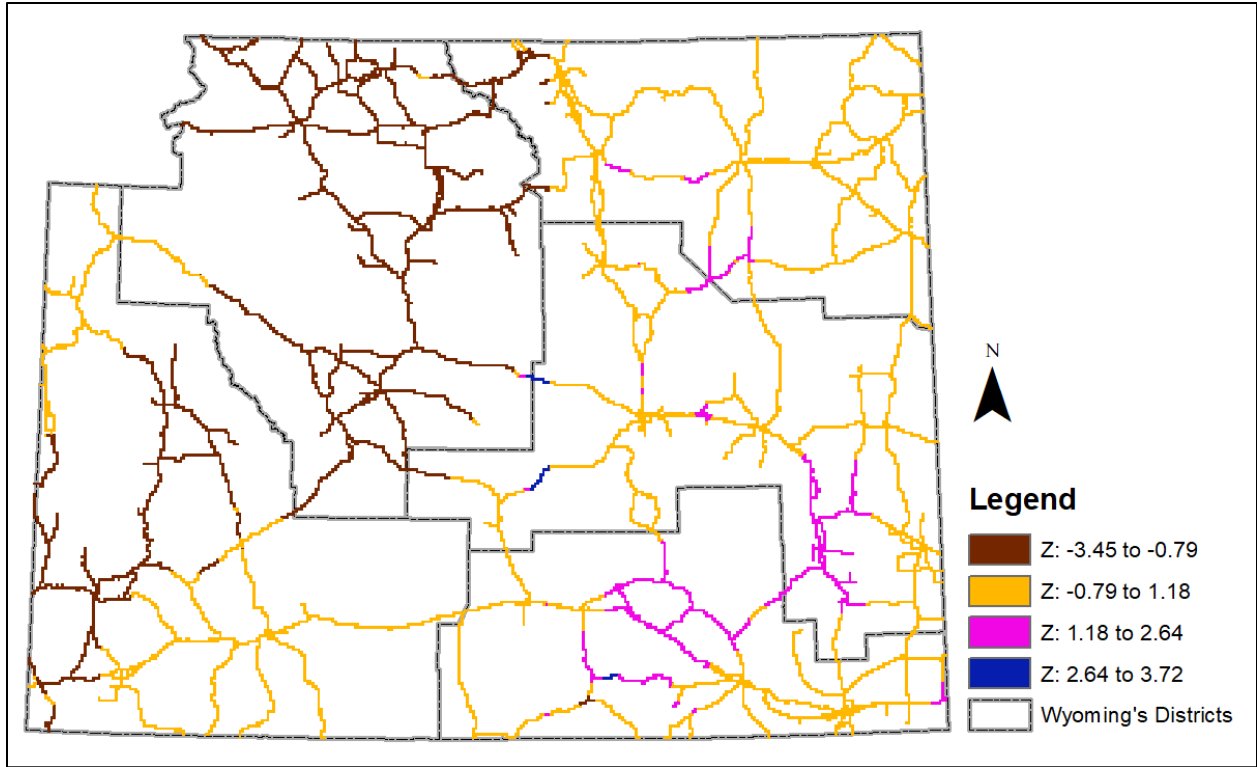


Figure 72: 2017 heat map of driving under the influence crashes.

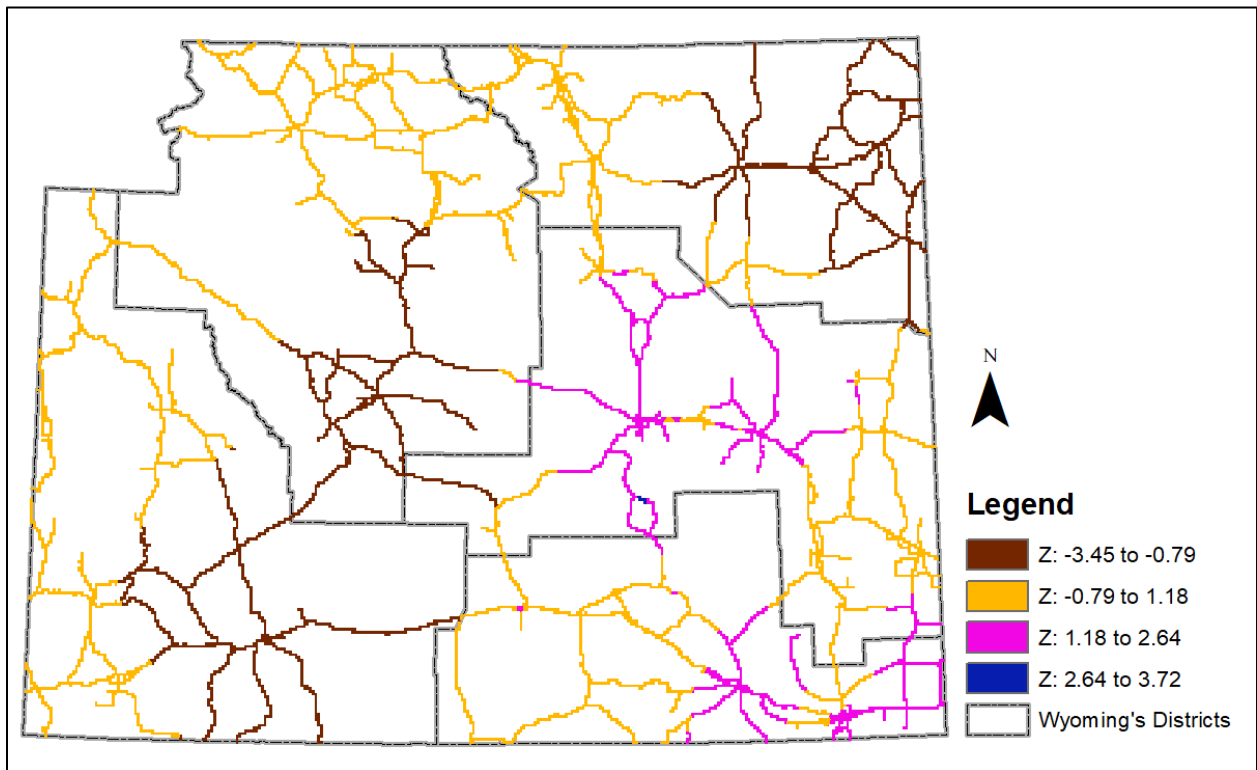


Figure 73: 2017 heat map of driving under the influence fatal, suspected serious injury and suspected minor injury crashes.

Other than disseminated the crash summary statistics, it is recommended that WYDOT plan for future independent studies on citation records, particularly to obtain the following:

- Citation counts of unlicensed drivers
- Citation counts of drivers not wearing their prescription lenses if their licenses require so
- Citation counts of young drivers with licenses that are of lower rank than regular licenses (e.g. learner's permits, etc.)
- Citation counts by drivers' age groups
- Citation counts by gender
- Citation counts of seat belt use policy violations by county and year
- Citation counts of child restraint policy violations by county and year
- Citation counts of reckless drivers by county and year
- Citation counts of impaired drivers by county and year
- Speeding citation counts by county and year
- Information on locations that are characterized by considerable citation counts

It is also suggested that WYDOT plan for research activities on the following list of topics and document the results in reports.

- Effectiveness of DUI enforcement policies
- Effectiveness of speed enforcement policies
- Effectiveness of seat belt use enforcement policies
- Response times of emergency services, especially for fatal, suspected serious injury and suspected minor injury crashes
- Effectiveness of traffic safety educational campaigns
- Effectiveness of other traffic violation enforcement policies (i.e. improper lane change, red light running, etc.)
- Effective methods of capturing motorcyclists committing traffic violations

Summary of the Wyoming Transportation Safety Coalition Survey Responses' Results

Similar to the cases of the previously discussed groups, a survey was drafted and disseminated to members of the Wyoming Transportation Safety Coalition. The survey targeted topics related to large commercial motor vehicles (CMVs). In the first section of the survey, the participants were asked generic questions related to the road safety data they received. When asked how often members of WTSC obtained crash summary reports/data from the WYDOT HSO, 40 percent claimed that they obtained them once a month while another 40 percent indicated that they did not obtain them in any respect. In addition, 60 percent stated that they received the reports/data via email and 20 percent stated that they received them via online databases. With that, 80 percent of the respondents indicated that they preferred receiving the reports/data by means of email in the future. The majority of the respondents indicated that the information received fulfilled their needs. The respondents were also asked about the number of days it would take to

receive relevant crash data of interest from the dates the crashes occurred and the ideal number of days preferred. One respondent claimed that he or she had not received reports previously and preferred that crash data be provided five days after the occurrences of the crashes. Another indicated that he or she received the data two days after the occurrences of the crashes and that this would be the ideal number of days preferred. The third claimed that the crash reporting period was not applicable. The fourth respondent indicated that it would take ten days to obtain such data and that this would be the ideal number of days. The fifth respondent skipped this question. Furthermore, the majority of the respondents declared that they were interested in road safety data in the form of pie charts/bar charts and summary statistics tables. In the following question, the participants were asked about the preferred method of portraying locations of commercial motor vehicle (CMV) crashes. The answer choices were provided in the form of checkboxes to allow each participant to select multiple choices. From the survey results, 80 percent of the respondents favored narrative descriptions of the locations while 60 percent favored road and milepost information.

In the subsequent section of the survey, the participants were provided a list of road safety reports, most of which are available in the WYDOT HSO website. They are the following:

- Wyoming Statewide Crashes by Year
- Wyoming Statewide Crashes Involving Commercial Motor Vehicles by Year
- 2019 Highway Safety Crash Data Survey Final Report
- Wyoming Highway Safety Behavioral Program FY2020 Highway Safety Plan
- Wyoming Report on Traffic Crashes 2019
- Wyoming Occupant Seat Belt Usage by Year
- Wyoming Governor’s Council on Impaired Driving – Strategic Plan to Reduce Impaired Driving in Wyoming
- Wyoming Drivers Survey, 2016
- Truck Driver Safety Investigation – A Survey of Truck Drivers: Cheyenne, Wyoming
- 2019 Pocket Guide to Large Truck and Bus Statistics
- Fatality Facts 2018 – Large Trucks

When asked about the familiarity of those reports and how often members of WTSC utilized them, only two respondents claimed that they frequently did so. In the following question, the respondents were specifically asked which of the listed reports they regularly used. The responses were as follows:

- “Wyoming Report on Traffic Crashes 2019”
- “We use custom reports and track fatalities yearly.”
- “Highway Safety Plan and crash reports”
- “I would use all reports [listed].”

Also, three respondents indicated that the reports listed were useful to WTSC. With that, the majority of the respondents maintained that they were satisfied with the frequency at which those reports were released. None of the respondents suggested any additional reports to include in the list. A question was asked regarding whether surveys should be disseminated to CMV drivers and only two respondents agreed. This question was posed because the Wyoming Drivers Survey, 2016 report shows that, even though CMV crashes are severe, CMV drivers represent a small proportion of the driving population and that such drivers might have been underrepresented. In the end of this section of the survey, the participants were asked to include any additional information they would like to see in the reports. One respondent stated, “Seat belt use/non-use and distracted driving.”

In the following section of the survey, members of WTSC were asked specific questions about CMV crash data in the form of charts, summary statistics tables or color-coded maps if applicable. More than half of the respondents indicated that they were interested in the following data:

- Whether the at-fault drivers were the CMV drivers
- At-fault drivers’ ages
- At-fault drivers’ genders
- At-fault drivers’ states
- Travel speeds of the CMVs at the times of the crashes (i.e. too slow for the conditions, reasonable or too fast for the conditions)
- Whether the CMV drivers were driving under the influence of alcohol/drugs
- Whether any vehicle occupant was ejected from the vehicle
- Traffic violations leading to the crashes (e.g. failure to yield the right-of-way, etc.)
- Times of the crashes
- Number of injured drivers and their injury severity levels
- Number of injured passengers and their injury severity levels
- Crash types (rear-end, sideswipe, etc.)
- Impact point information of each vehicle involved in the crash (hit from the side, hit from the front, etc.)
- Seat belt condition (good versus bad) information at the times of the crashes
- Difference in fatality/injury counts of victims involved in CMV crashes versus those of victims involved in non-CMV crashes
- Locations characterized by risks of encountering high severity (fatal, suspected serious injury or suspected minor injury) CMV related crashes in which the CMV drivers were at-fault
- Locations characterized by risks of encountering high severity CMV related crashes in which the CMV drivers were not at fault

- Locations characterized by risks of encountering possible injury or PDO CMV related crashes in which the CMV drivers were at-fault
- Locations characterized by risks of encountering possible injury and PDO CMV related crashes in which the CMV drivers were not at-fault

The participants were then asked questions related to citation record data of CMV drivers. Similar to the surveys that were distributed to the other groups, a disclaimer was provided stating that the WYDOT HSO would not maintain citation data and, therefore, independent studies would have to be conducted on such data if required. Regarding the citation related questions, the respondents maintained that they were interested in the following summary statistics:

- Association between the citations of CMV drivers and the counts of injuries, including fatal injuries, that were sustained due to CMV crashes
- CMV drivers' citations by type (i.e. failed to yield right of way, drove too fast for the conditions, DUI, driving while tired, violation of storage policies, etc.)
- Whether CMV drivers, cited for previous violations, attended drivers' education sessions

Finally, the respondents were asked to select research topics related to CMVs for detailed investigation involving data analyses, interpretation and documentation of results in reports. The answer choices were provided in the form of checkboxes to allow for the selection of multiple choices. More than half of the respondents indicated that they were interested in the following topics:

- Effectiveness of CMV drivers' DUI enforcement policies
- Effectiveness of CMV speed enforcement policies
- Effectiveness of CMV driver's seat belt use enforcement policies
- Effectiveness of other traffic violation enforcement policies related to CMVs (i.e. improper lane change, red light running, etc.)
- Response times of emergency services particularly for severe (fatal, suspected serious injury and suspected minor injury) CMV crashes

Recommendations for the Wyoming Department of Transportation Regarding the Wyoming Transportation Safety Coalition

The results of the WTSC survey were examined and interpreted. Based on the survey's findings, it is recommended that WYDOT establish an email list to provide truck related crash records data to a wider audience within WTSC. It is also suggested that surveys be disseminated to truck drivers asking about their driving habits and their perception of road safety. The survey results would be documented in a report, which would be made available in the WYDOT HSO website. In addition, it is recommended that summary statistics, similar to those illustrated in Figures 74 to 87, and Table 11, be provided to WTSC. It should be noted that Figures 86 and 87 depict heat maps of CMV crashes and severe (fatal, suspected serious injury and suspected minor injury)

crashes, respectively. The maps were generated using the same procedure implemented to obtain the ones for WSBC, WHP and WASCOP.

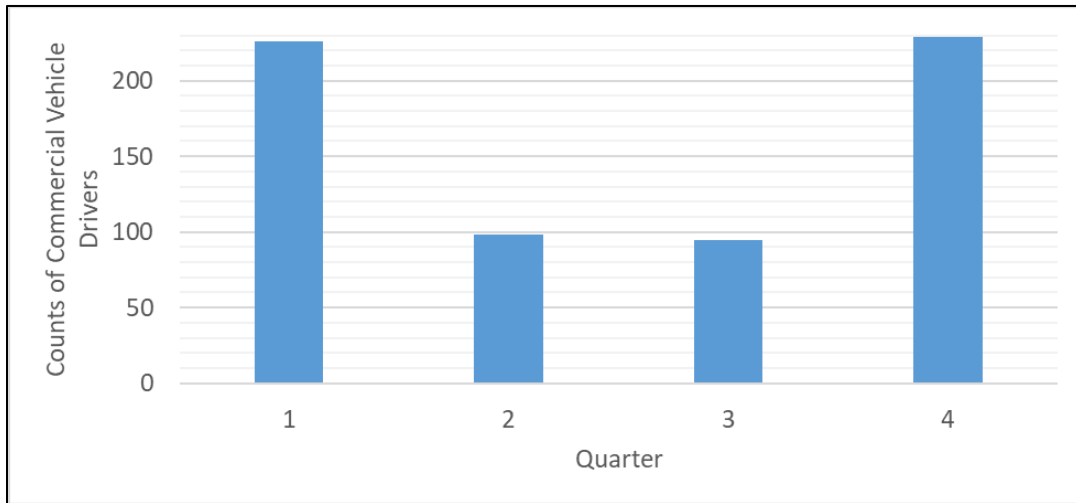


Figure 74: 2019 counts of commercial vehicle drivers cited at the crash scenes.

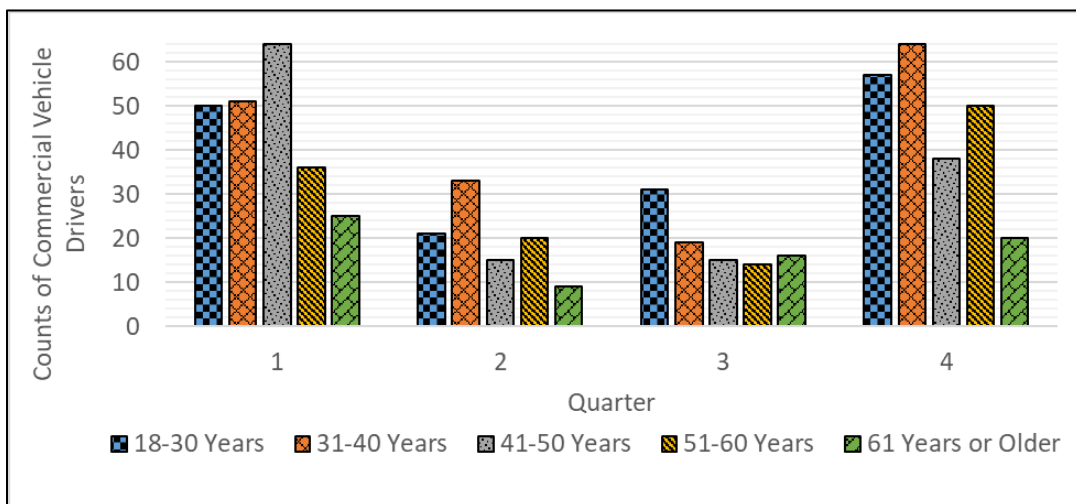


Figure 75: 2019 counts of commercial vehicle drivers cited at the crash scenes by age.

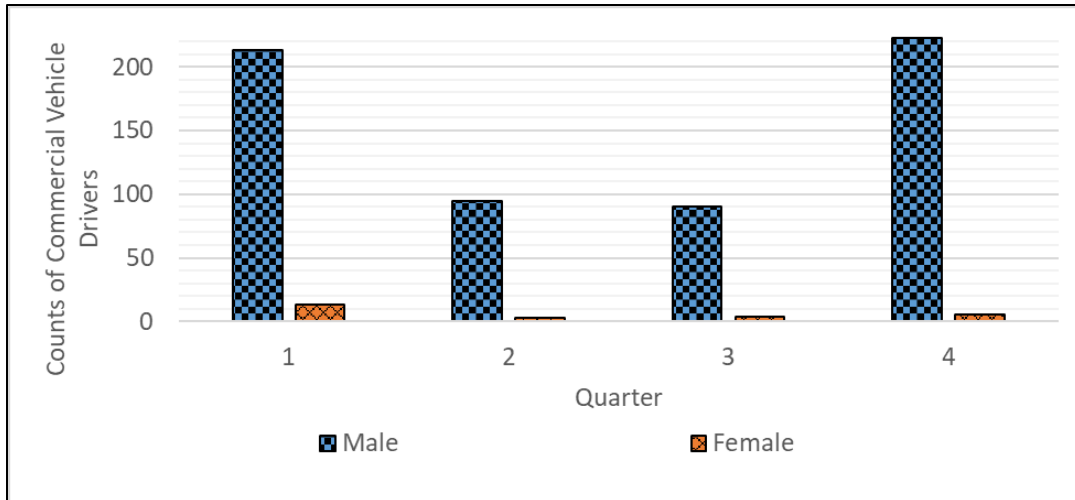


Figure 76: 2019 counts of commercial vehicle drivers cited at the crash scenes by gender.

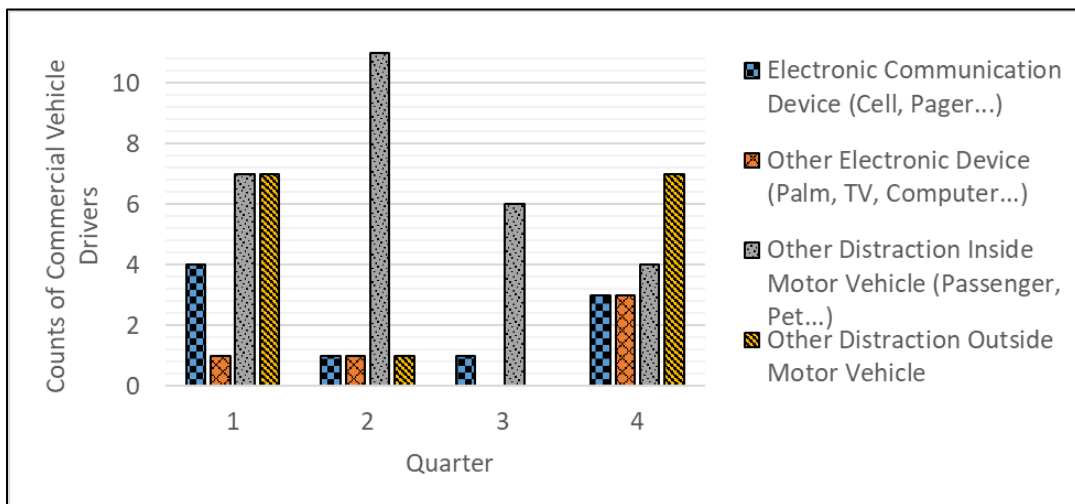


Figure 77: 2019 counts of distracted commercial vehicle drivers by means of distraction.

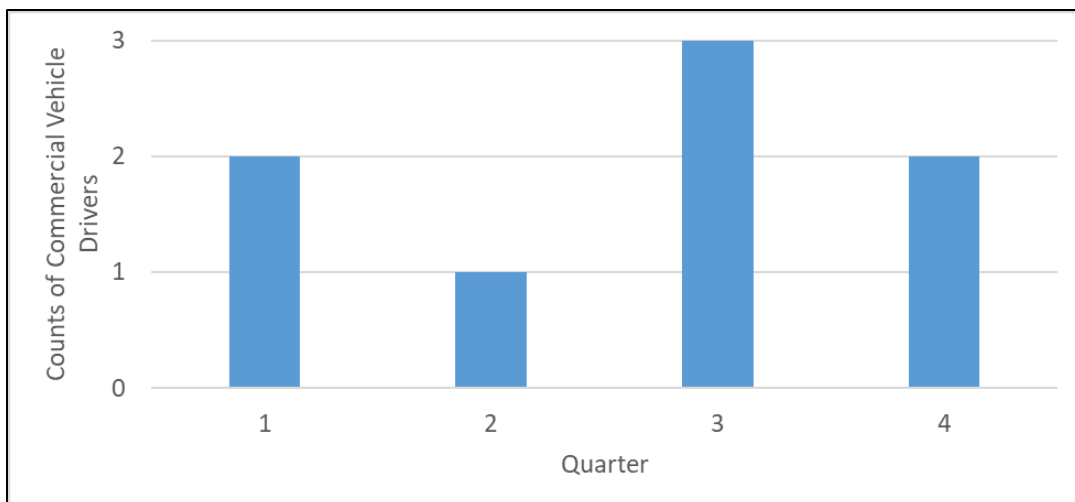


Figure 78: 2019 counts of commercial vehicle drivers driving under the influence.

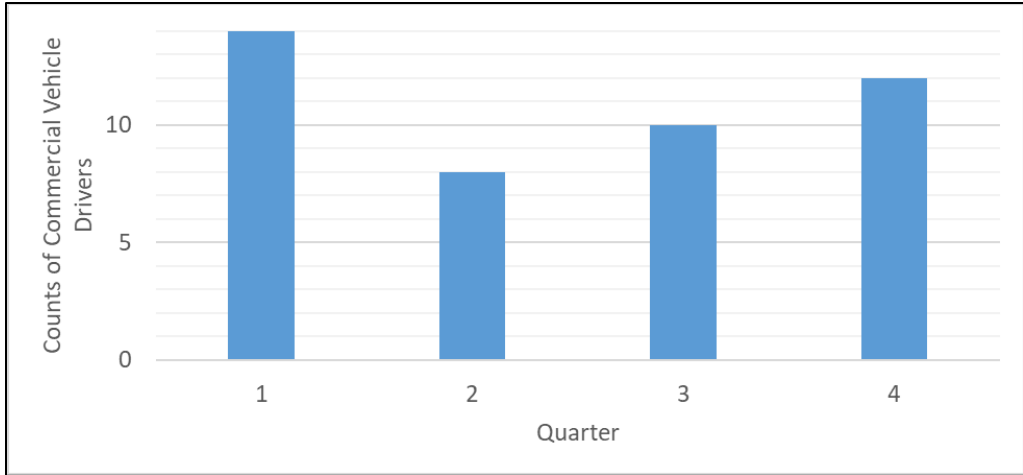


Figure 79: 2019 counts of improperly belted or unbelted commercial vehicle drivers.

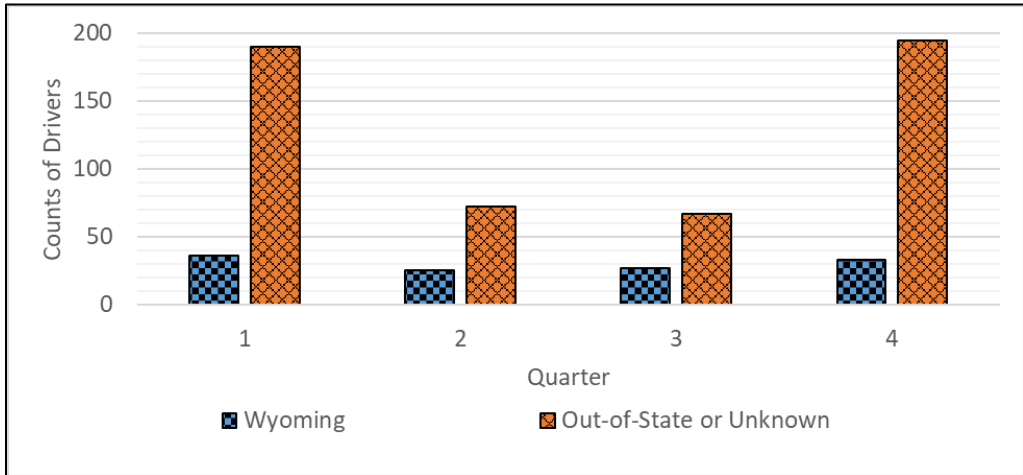


Figure 80: 2019 counts of cited commercial vehicle drivers at the crash scenes by state.

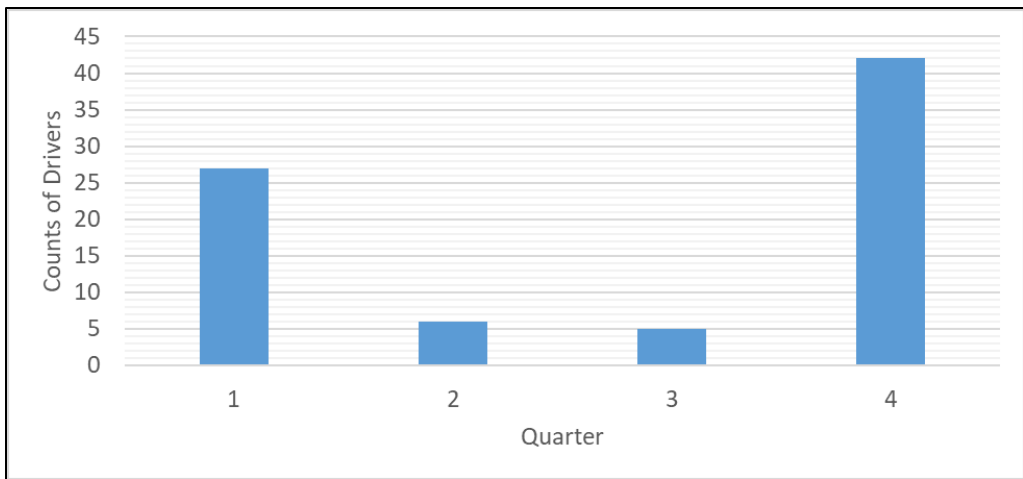


Figure 81: 2019 counts of speeding commercial vehicle drivers.

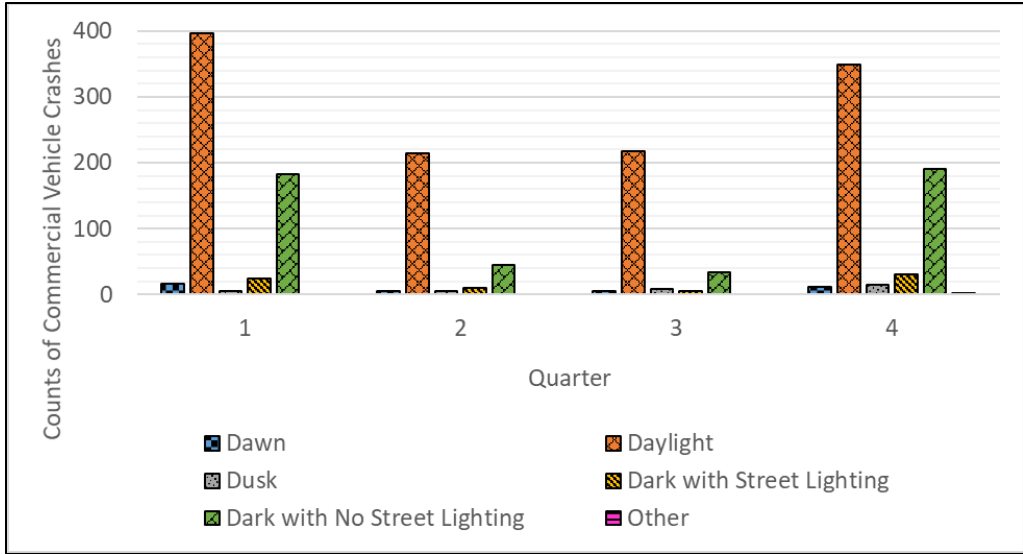


Figure 82: 2019 counts of commercial vehicle crashes by lighting condition.

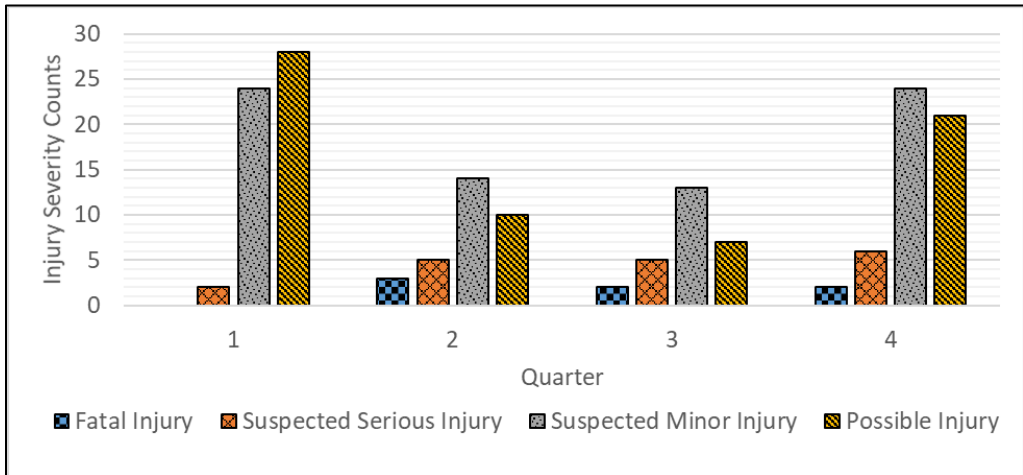


Figure 83: 2019 counts of killed and injured commercial vehicle drivers.

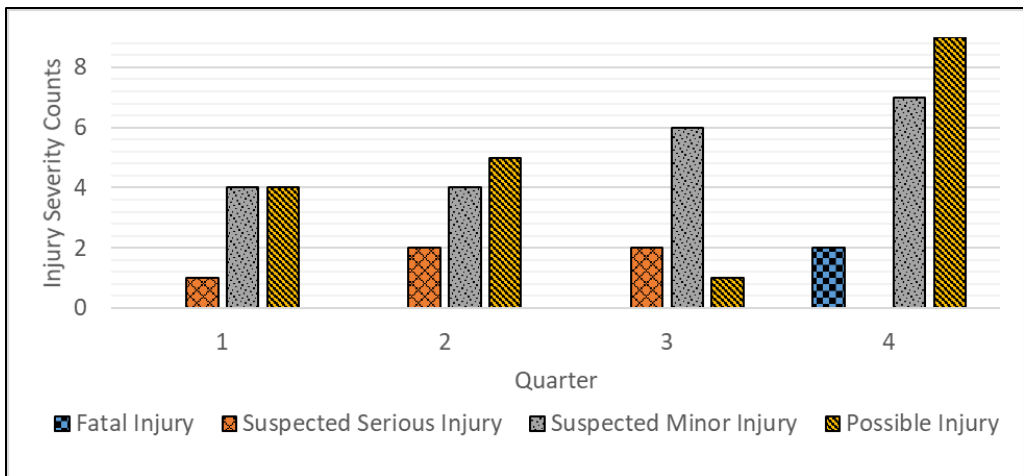


Figure 84: 2019 counts of killed and injured commercial vehicle passengers.

Table 11: 2019 Counts of Commercial Vehicle Crashes by Manner of Collision

Manner of Collision	Quarter				
	1	2	3	4	Total
Angle (Front to Side), Opposing Direction	20	18	9	17	64
Angle Direction Not Specified	1	0	0	2	3
Angle Right (Front to Side, includes Broadside)	28	10	12	22	72
Angle Same Direction (Front to Side)	36	21	17	45	119
Head On (Front to Front)	5	4	4	10	23
Rear End (Front to Rear)	343	113	106	291	853
Rear to Front (Normally Backing)	91	39	46	84	260
Rear to Rear (Normally Backing)	5	2	5	8	20
Rear to Side (Normally Backing)	0	1	1	0	2
Sideswipe Opposite Direction (Meeting)	2	6	7	6	21
Sideswipe Same Direction (Passing)	14	9	6	11	40
Not a Collision with Two Vehicles in Transport	70	42	47	87	246
Other	11	14	11	14	50
Unknown	0	0	1	0	1
Total	626	279	272	597	1,774

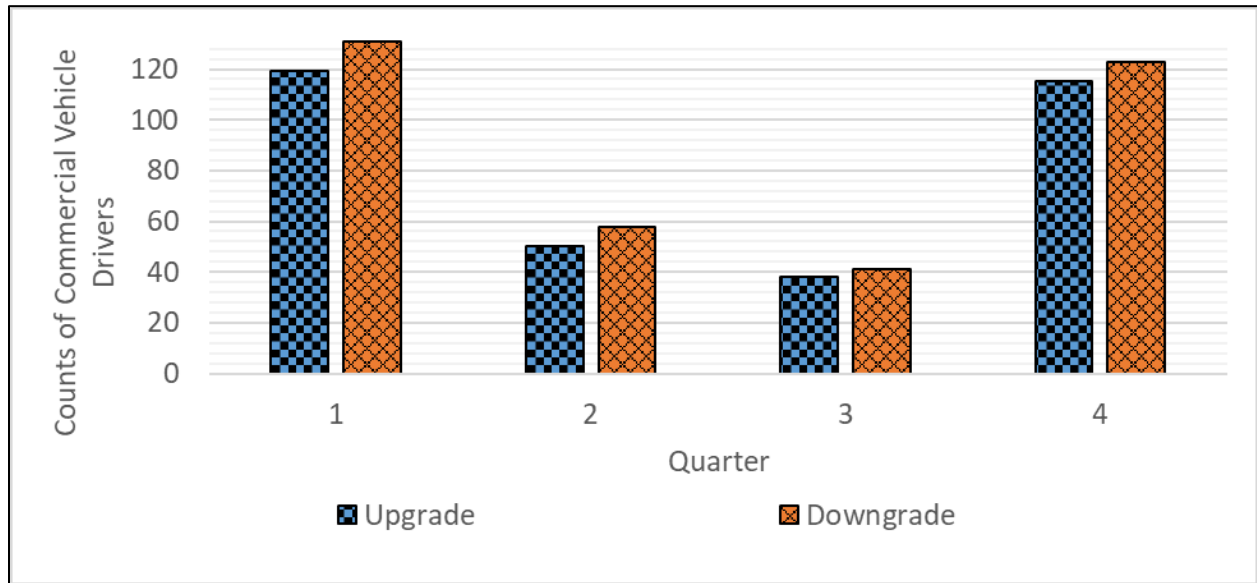


Figure 85: 2019 counts of upgrade and downgrade conditions facing commercial vehicle drivers.

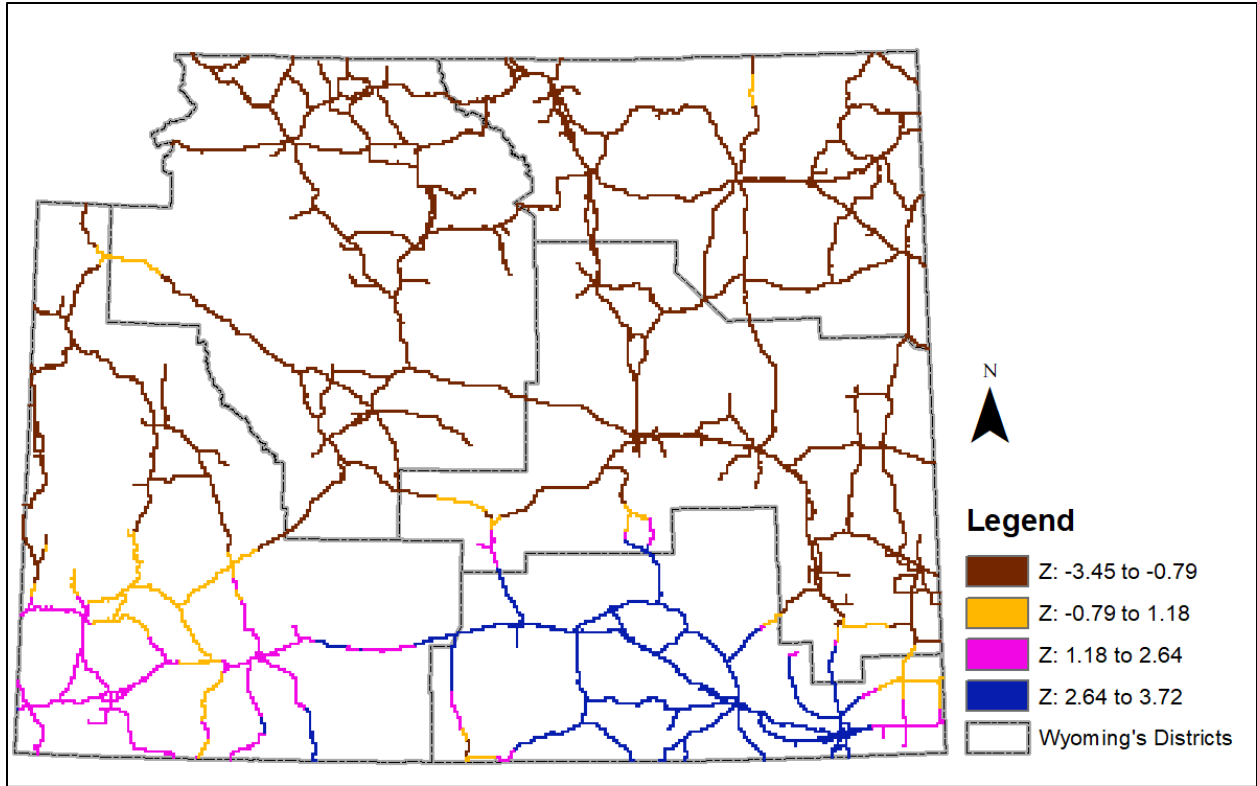


Figure 86: 2017 heat map of commercial vehicle crashes.

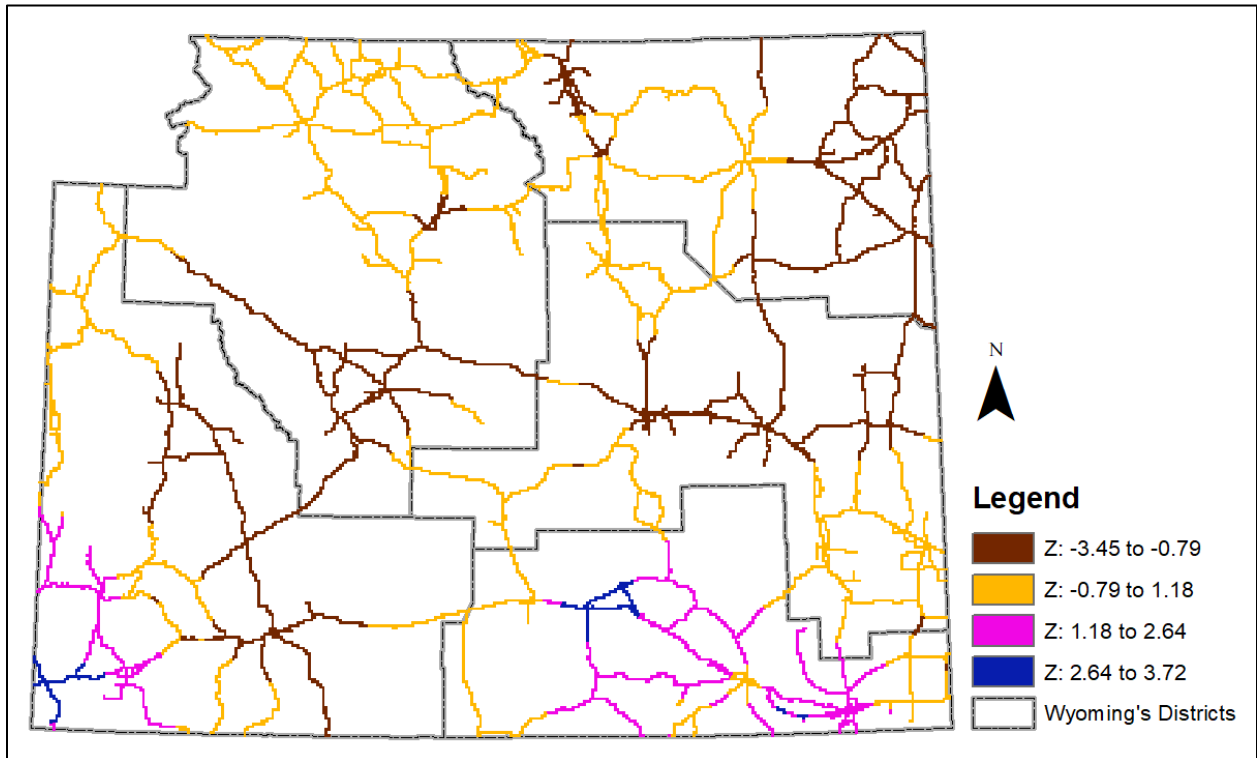


Figure 87: 2017 heat map of fatal, suspected serious injury and suspected minor injury commercial vehicle crashes.

Other than the previously presented summary statistics, it is suggested that WYDOT conduct independent studies involving the collection and provision of statistics on the following CMV drivers' citation data to WTSC:

- Counts of CMV drivers' citations by type (i.e. failed to yield the right of way, drove too fast for the conditions, DUI, driving while tired, violation of storage policies, etc.) in the form of bar charts
- Proportions of CMV drivers, cited for previous violations, attending drivers' education sessions

Finally, the results of the WTSC survey indicated that this group's members were interested in research regarding specific CMV related topics. As per the survey's results, it is suggested that WYDOT plan for research studies on the following topics:

- Effectiveness of CMV drivers' DUI enforcement policies
- Effectiveness of CMV speed enforcement policies
- Effectiveness of CMV drivers' seat belt use enforcement policies
- Effectiveness of other traffic violation enforcement policies related to CMVs (i.e. improper lane change, red light running, etc.)
- Response times of emergency services particularly for severe (fatal, suspected serious injury and suspected minor injury) CMV crashes

Summary of the Governor's Council on Impaired Driving Survey Responses' Results

A survey was disseminated to members of the Governor's Council on Impaired Driving and 10 responses were received. The common question asked in all surveys was how often did the respondents receive/secure road safety data/reports from the WYDOT Highway Safety Office? More than half of the respondents declared that they often obtained the relevant data from the WYDOT HSO once a year while some checked the option, "other," and specified the following:

- "I don't receive them but would like to."
- "When requested."
- "We don't."

When it comes to data transfer protocols, the respondents indicated that they received the data mostly via email and online databases (55 percent and 33 percent, respectively). In the follow-up question, almost 80 percent indicated that they preferred to receive such data via email. Also, the respondents were asked whether the current safety data provided to them from the WYDOT HSO fulfilled their needs on a scale of one (not at all) to five (absolutely). Two thirds claimed that the data were indeed beneficial (selected four and five). More importantly, the respondents were asked about the ideal period during which they preferred to receive the crash data from the dates the crashes occurred. Almost half of the GCID members omitted this question while the other half provided the following responses:

- “Monthly would be fine.”
- “Five [days].”
- “Quarterly.”
- “Two [days].”
- “Fourteen days.”

Regarding the preferred data format, almost 90 percent of the respondents indicated that they were interested in summary statistics tables, while over 40 percent indicated that they were interested in figures and another 40 percent indicated that they were interested in pie charts. Note that each respondent was provided the option of specifying multiple data formats from a list (i.e. checkboxes). The respondents were further asked about the preferred method of portraying the locations of DUI related crashes. They included the following:

- Narrative descriptions of the locations
- Photos
- Color-coded maps
- Road and milepost information
- GIS coordinates
- Other (please specify)

More than three quarters claimed that they were interested in color-coded maps while two thirds claimed that they were interested in road and milepost information. The answer choices were provided in the form of checkboxes such that the respondents might have selected multiple options. Some respondents also selected the options, “narrative descriptions of the locations” and “photos.” The respondents were then asked whether they would like to provide any suggestions regarding the data they would receive. One recommended data on the location of which the impaired driver drank his or her liquor (home, bar, etc.). Another suggested the delivery of maps illustrating the locations of driving under the influence busts, crashes, mortalities and other relevant information without specifying details.

In the following section of the survey, the respondents were asked about road safety reports pertaining to DUI related crash data. The reports, most of which are available in the WYDOT HSO website, are the following:

- 2019 Highway Safety Crash Data Survey Final Report
- Wyoming Department of Transportation Highway Safety Behavioral Grants Office 2019 Annual Report
- Wyoming Highway Safety Behavioral Program FY2020 Highway Safety Plan
- Wyoming Report on Traffic Crashes 2019
- Wyoming Statewide Crashes by Year
- Wyoming Statewide Crashes Involving Alcohol or Drugs by Year
- Wyoming Strategic Highway Safety Plan 2017

- Wyoming Drivers Survey 2016
- Alcohol and Crime in Wyoming 2019

On a scale of one (not at all) to five (absolutely) describing whether the respondents were familiar with these reports and whether they frequently utilized them, 40 percent provided ratings of four and five. Remarkably, more than half declared that the listed reports were beneficial to GCID even though only 40 percent stated that they used them frequently. Perhaps after being informed about the reports, members of GCID briefly scanned them and became intrigued about them. In another question, more than half of the respondents declared that they were satisfied with the frequency at which the reports were released. Roughly, 40 percent of the respondents stated that they either did not receive them or would like to receive them on a more frequent basis. One suggested that the reports be publicized quarterly and another suggested that they be publicized semi-annually. The respondents were also asked to recommend any reports they would like to receive in addition to the ones listed. One recommended a report on the statistics of the locations (bars, etc.) at which drunken drivers consumed their liquor prior to being involved in DUI related crashes. This would aid members of GCID in targeting such bars in their outreach campaigns. Another respondent suggested a report with statistics on DUI busts, BAC levels and locations of parties or concerts involving drinking. Members of GCID were also asked about the importance of certain summary statistics to be included in the reports. More than half selected the following:

- Effectiveness of DUI offender rehabilitation campaigns
- Effectiveness of implementing ignition interlocks in vehicles of DUI offenders in improving road safety
- Effectiveness of media outreach campaigns in raising awareness about DUI (impact and consequences of impaired driving slogans and/or relevant content disseminated via the social media, television, radio, billboards)

In the subsequent section of the survey, the respondents were asked specific questions about DUI related crash data in the form of summary statistics. More than half of them indicated that they were interested in the following elements collected from crash records:

- Types of substances involved in DUI related crashes (alcohol, marijuana, etc.).
- BACs of impaired at-fault drivers by age and gender.
- Injury severity levels of DUI related crashes by BACs of impaired drivers.
- Whether passengers were impaired at the times of the crashes.
- BACs of the passengers if impaired at the times of the crashes.
- Number of pedestrians and/or bicyclists involved in the DUI related crashes.
- Whether the pedestrians and/or bicyclists were impaired if found to be at-fault.
- BACs of the impaired pedestrians and/or bicyclists at the times of the crashes.
- Whether motorcycles were involved and the riders were impaired at the times of the crashes.

- BACs of the impaired motorcycle riders at the times of the crashes.
- Crash locations (on the road, on the shoulder, off the road, etc.).
- Crash times (morning, afternoon, etc.).
- Vehicle travel speeds preceding the crashes (i.e. too slow for the conditions, reasonable or too fast for the conditions).
- Makes, models and years of each vehicle involved in the DUI related crashes.
- Number of vehicles involved in the DUI related crashes.
- Whether the impaired at-fault drivers were properly wearing their seat belts at the times of the crashes.
- Whether the passengers were properly wearing their seat belts at the times of the crashes.
- Whether children were properly secured in their appropriate car seats at the times of the crashes.
- DUI related crashes resulting in ejected occupants.
- Whether impaired drivers violated work zone regulations (i.e. exceeded the work zones' speed limits, failed to obey the traffic guards' signals, etc.).
- Driving errors leading to the DUI related crashes that are not previously listed.
- Number of injured drivers/motorcyclists and their injury severity levels.
- Number of injured passengers and their injury severity levels.
- Number of injured non-motorists and their injury severity levels.
- DUI related crashes that occurred at or near bars and liquor stores.
- DUI related crashes that occurred at or near concerts, sports events or other special events.
- DUI related crashes that occurred during special holidays/events (4th of July, Labor Day weekend, Thanksgiving, Christmas, etc.).
- DUI related crashes by day of the week (i.e. weekdays versus weekends).
- Types of DUI related crashes (rear-end, sideswipe, etc.).
- Impact point information of vehicles involved in the DUI related crashes (e.g. hit from the side, hit from the front, etc.).
- Comparisons of fatality/injury counts of victims involved in DUI related crashes versus those of victims involved in non-DUI related crashes.
- Weather conditions (clear, cloudy, rainy, foggy, snowy) at the times of the DUI related crashes.
- Road surface conditions (dry, wet, icy, etc.) at the times of the DUI related crashes.

Furthermore, members of GCID were asked about the importance of color-coded maps presenting locations characterized by risks of encountering DUI related crashes by category. More than 50 percent of the respondents indicated that they were interested in color-coded maps illustrating the following DUI related crashes:

- High severity (fatal, suspected serious injury and suspected minor injury) crashes

- Possible injury and PDO crashes
- High severity crashes involving improperly buckled or unbuckled occupants
- High severity speed related crashes

The respondents were then directed to another section asking about whether they were interested in specific information regarding DUI citation and other related data. Similar to the previous surveys, a disclaimer was presented to inform the respondents that independent studies would have to be conducted to collect and evaluate citation data since the WYDOT HSO would not maintain such data. At least half of the respondents maintained that they preferred the following summary statistics data:

- Citation counts of impaired (DUI, tired or not wearing prescription glasses/contact lenses) drivers by county
- Citation counts of impaired drivers by age
- Citation counts of impaired drivers by gender
- Number of impaired drivers who persistently violated impairment related policies even after being subjected to disciplinary action
- Association between impairment related offences and speeding
- Association between impairment related offences and other policy violation types except speeding (e.g. failure to yield, improper passing, etc.)
- Locations characterized by a considerable number of impairment related citations issued

Finally, the GCID members were asked to select topics they might be interested in for further investigation (i.e., data analyses, interpretation and documentation of results in reports). At least three quarters of them were interested in the following topics:

- Effectiveness of DUI enforcement policies
- Effectiveness of impaired drivers' rehabilitation campaigns
- Effectiveness of other impairment enforcement policies (e.g. tired, not wearing prescription glasses/contact lenses)
- Effectiveness of educational campaigns addressing impaired driving
- Association between alcohol/drug use and crime

Recommendations for the Wyoming Department of Transportation Regarding the Governor's Council on Impaired Driving

Based on the interpretations of the Governors' Council on Impaired Driving's survey results, suggestions were made for WYDOT with regards to the data to be provided to GCID. One is to disseminate DUI related crash data as soon as they are made available. Another is to provide processed quarterly DUI crash related data in the form of tables and charts, similar to the ones presented in Figures 88 to 104, and Tables 12 to 17.

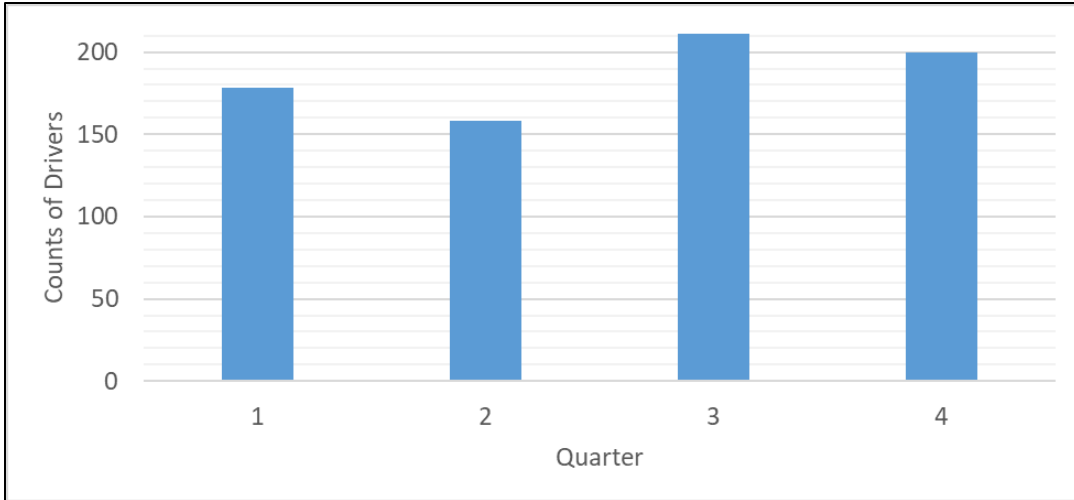


Figure 88: 2019 counts of alcohol impaired drivers.

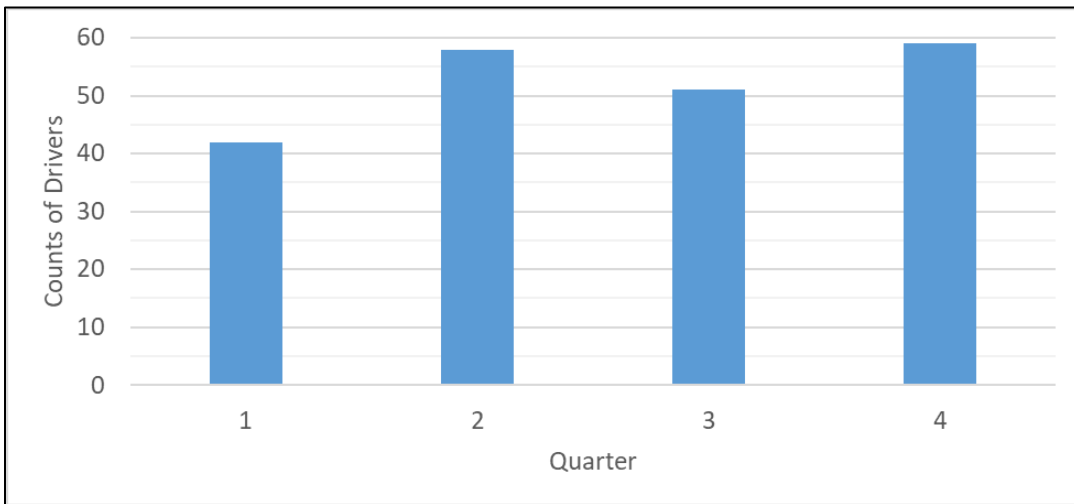


Figure 89: 2019 counts of drug impaired drivers.

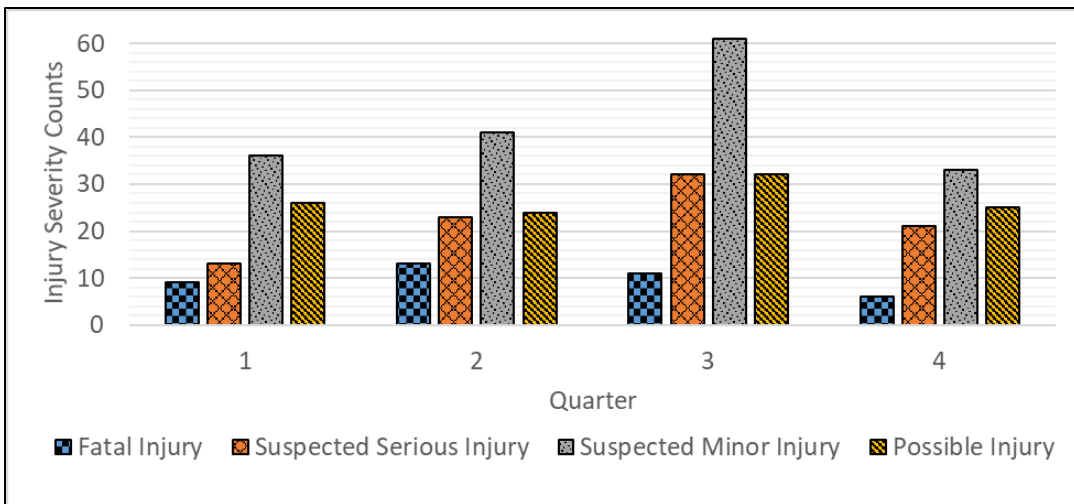


Figure 90: 2019 counts of alcohol related fatalities and injuries.

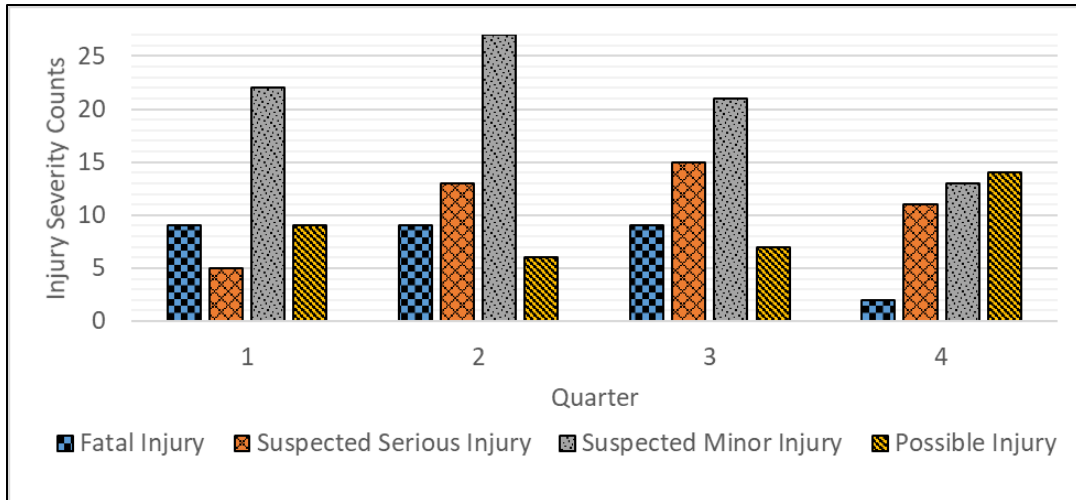


Figure 91: 2019 counts of drug related fatalities and injuries.

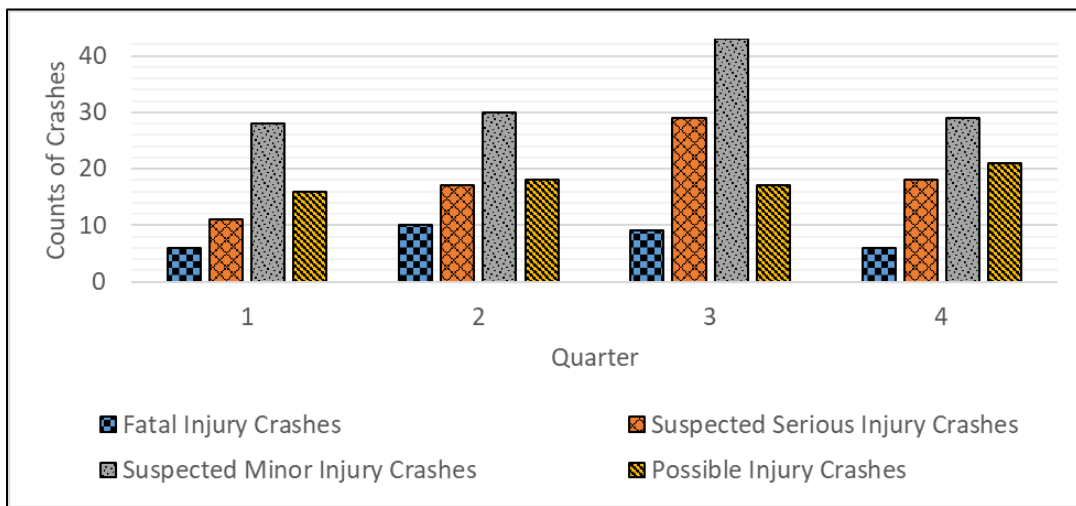


Figure 92: 2019 counts of alcohol related crashes.

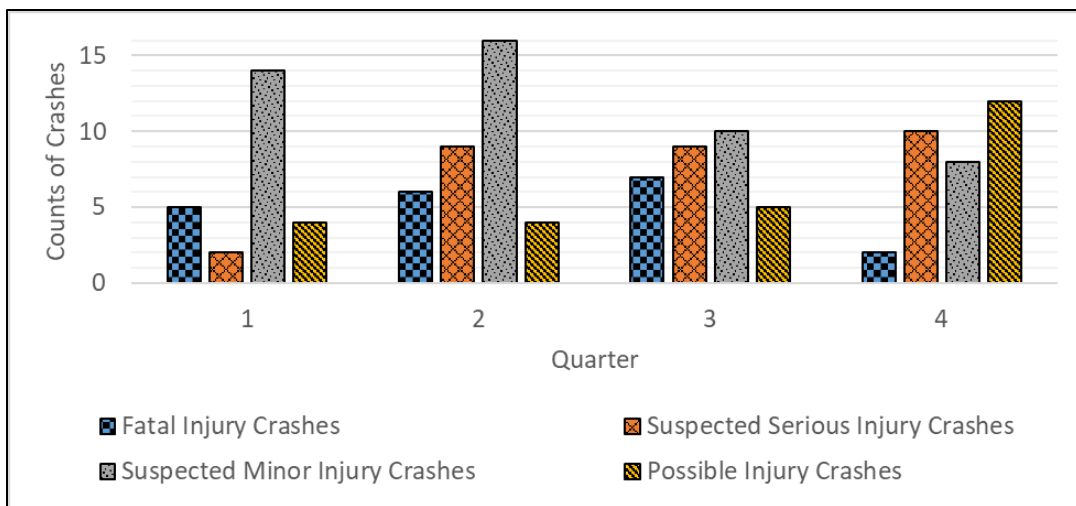


Figure 93: 2019 counts of drug related crashes.

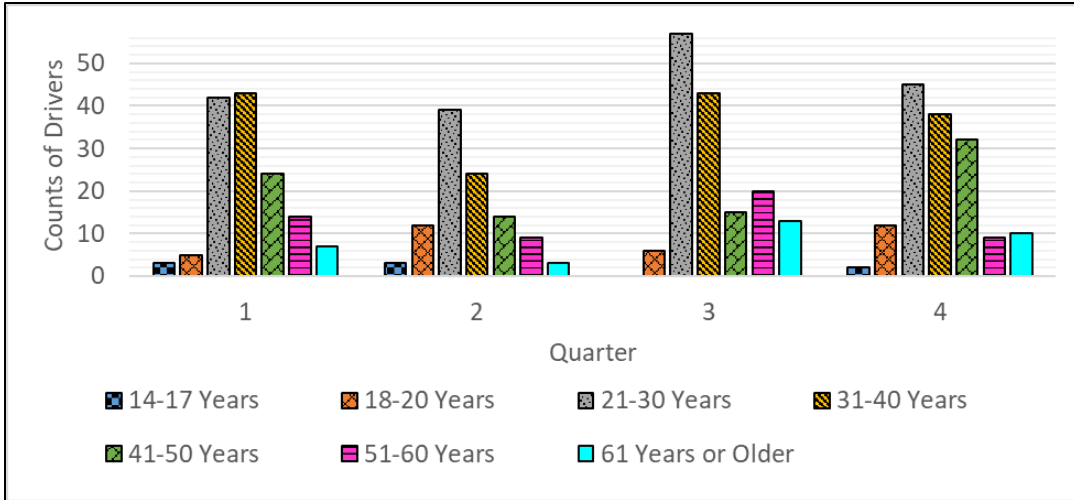


Figure 94: 2019 counts of male drivers driving under the influence of alcohol by age.

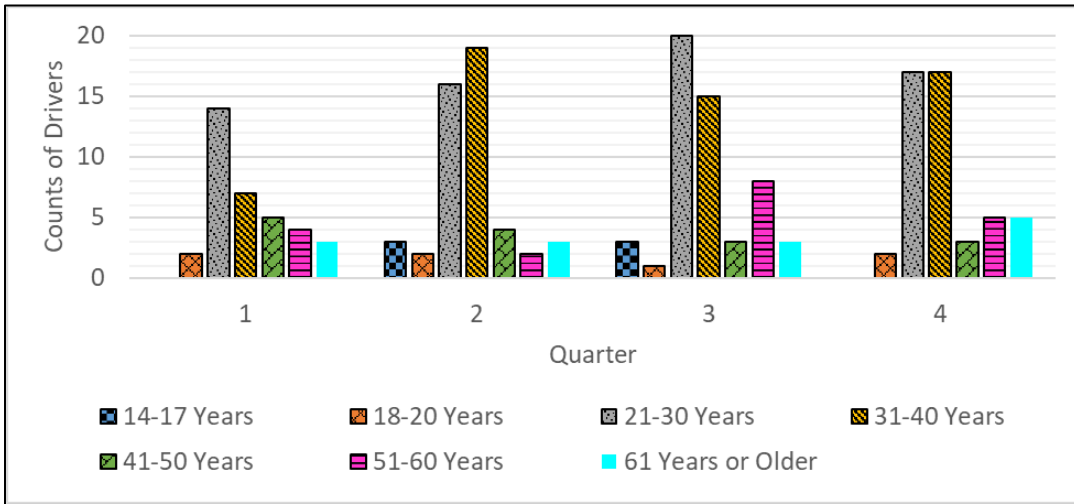


Figure 95: 2019 counts of female drivers driving under the influence of alcohol by age.

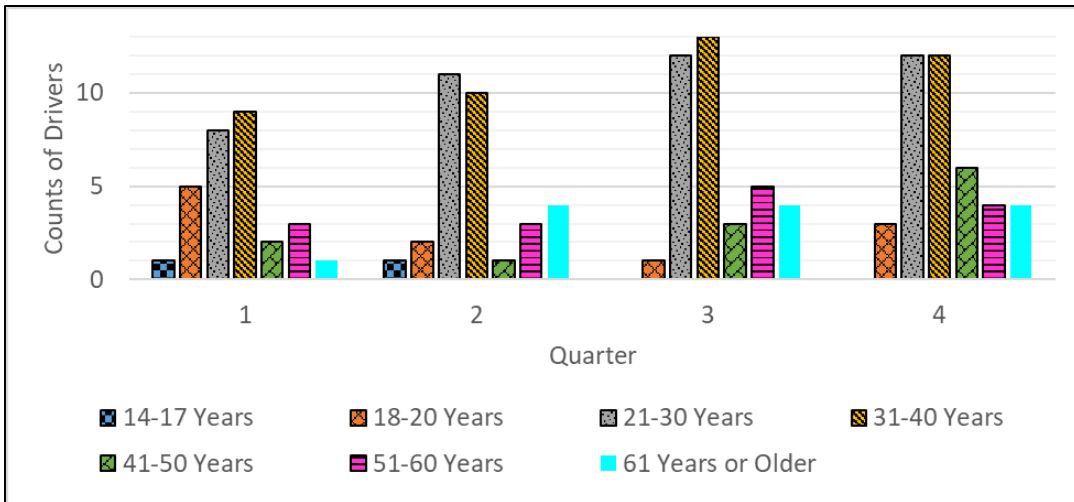


Figure 96: 2019 counts of male drivers driving under the influence of drugs by age.

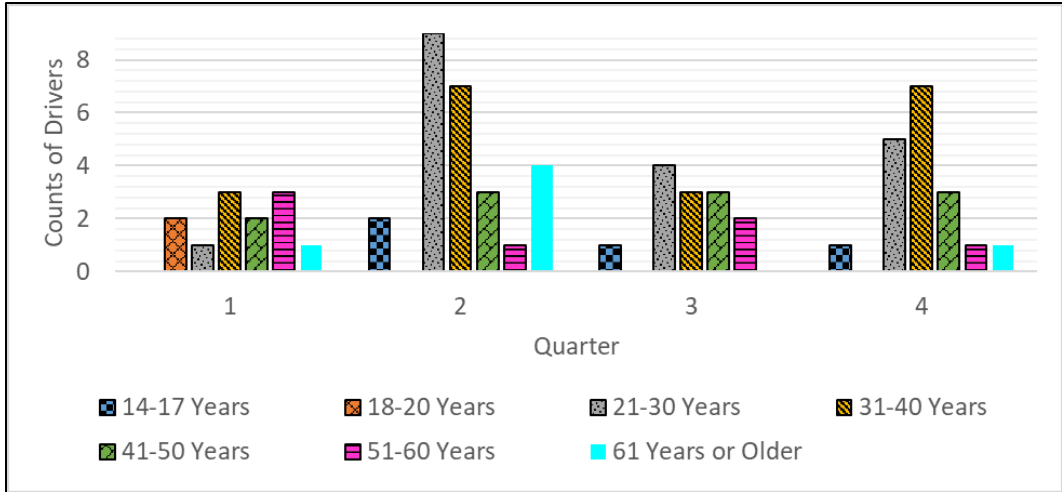


Figure 97: 2019 counts of female drivers driving under the influence of drugs by age.

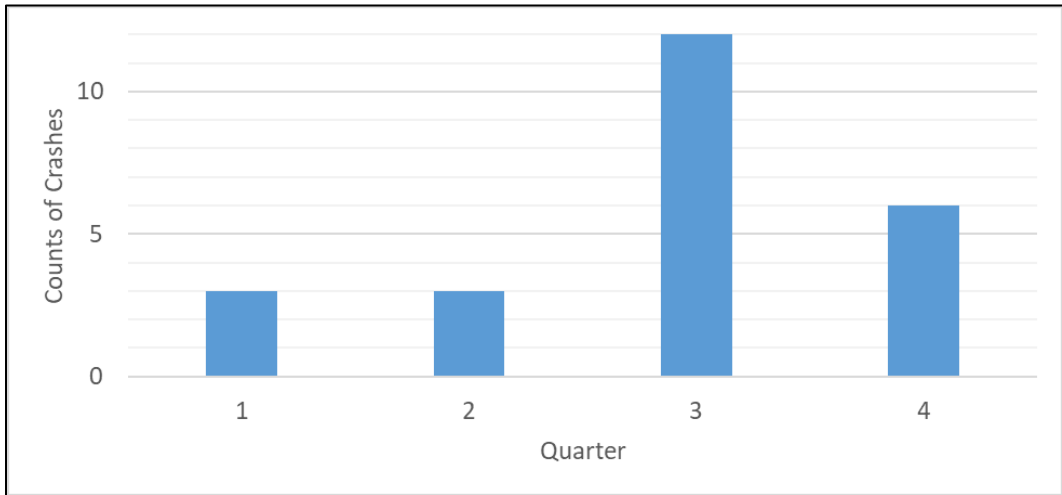


Figure 98: 2019 counts of driving under the influence crashes involving pedestrians and/or bicyclists.

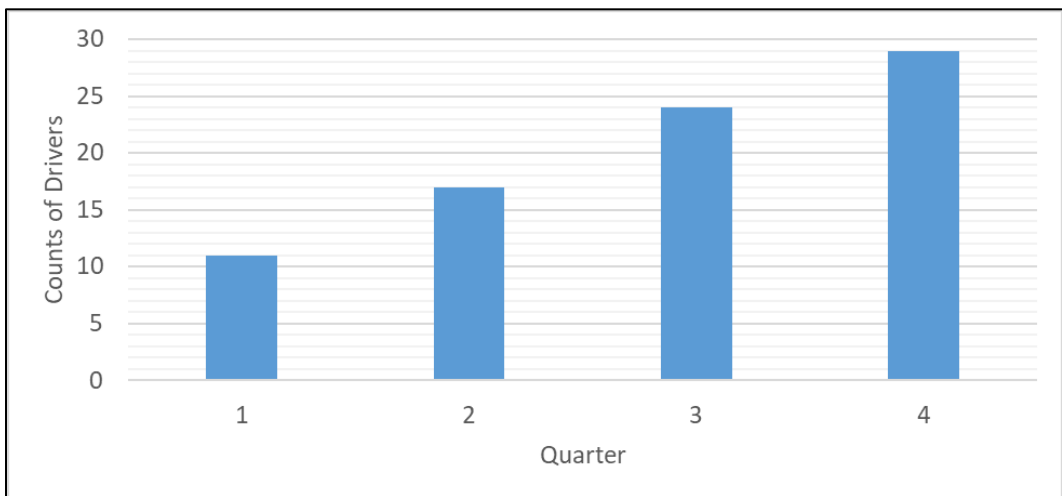


Figure 99: 2019 counts of driving under the influence crashes involving speeding.

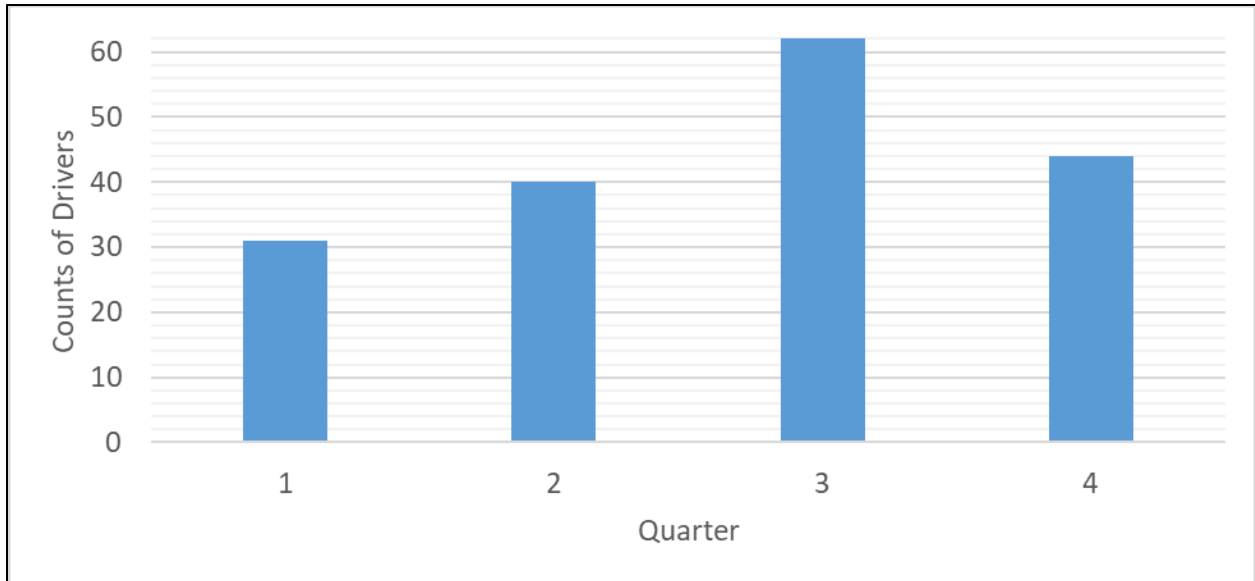


Figure 100: 2019 counts of improperly belted or unbelted impaired drivers.

Table 12: 2019 Counts of Impaired Drivers’ Citations Issued at the Crash Scenes

Citation	Quarter				Total
	1	2	3	4	
Careless Driving	20	31	65	55	171
Disregarding the Officer	2	3	4	5	14
Disregarding the Stop Light	5	8	8	1	22
Disregarding Stop Sign	9	6	13	4	32
Disregard Other	0	0	6	0	6
Drinking - (i.e. Open Container)	30	32	40	52	154
Failed to Grant the Right-of-Way to Other Motor Vehicle	6	10	4	19	39
Following Too Closely	16	13	15	16	60
Hitting-and-Running	62	71	79	103	315
Improper Backing	1	2	4	3	10
Improper Lane Use	83	92	150	120	445
Improper Turn	2	0	0	12	14
Improper or No Signal	0	0	0	2	2
Reckless Driving	13	26	16	42	97
No Insurance	44	94	104	60	302
Driver’s License Violation	31	41	56	37	165
Vehicle Registration Violation	10	5	35	9	59
Vehicular Homicide	0	2	6	1	9
Wrong Side of Road	1	0	1	4	6
Other	64	80	150	100	394
Total	399	516	756	645	2,316

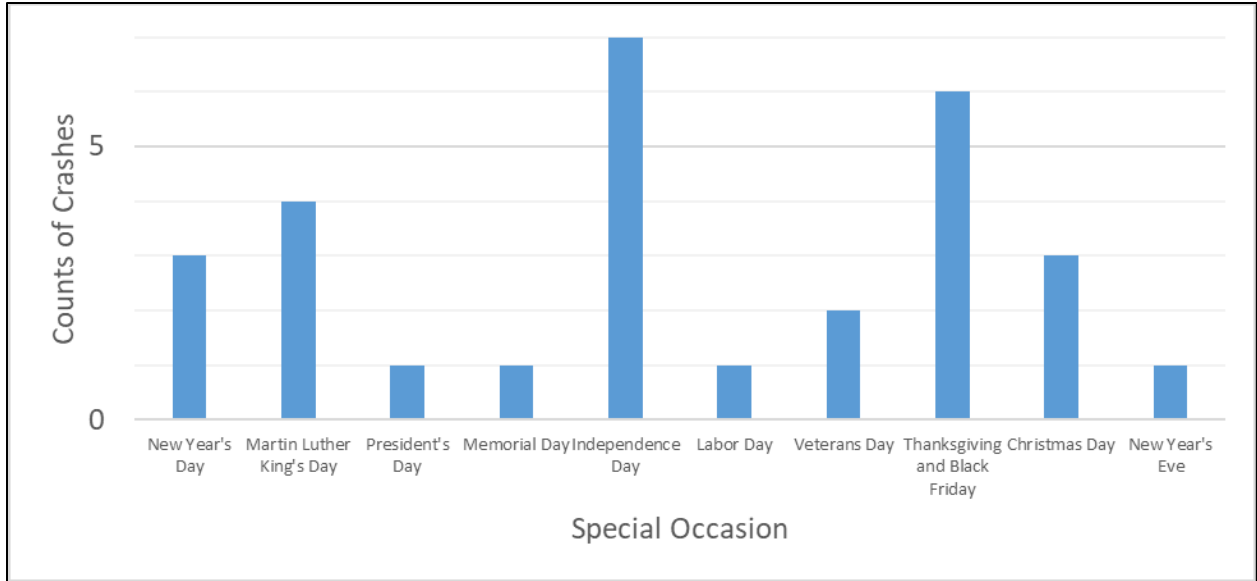


Figure 101: 2019 counts of driving under the influence related crashes during special occasions.

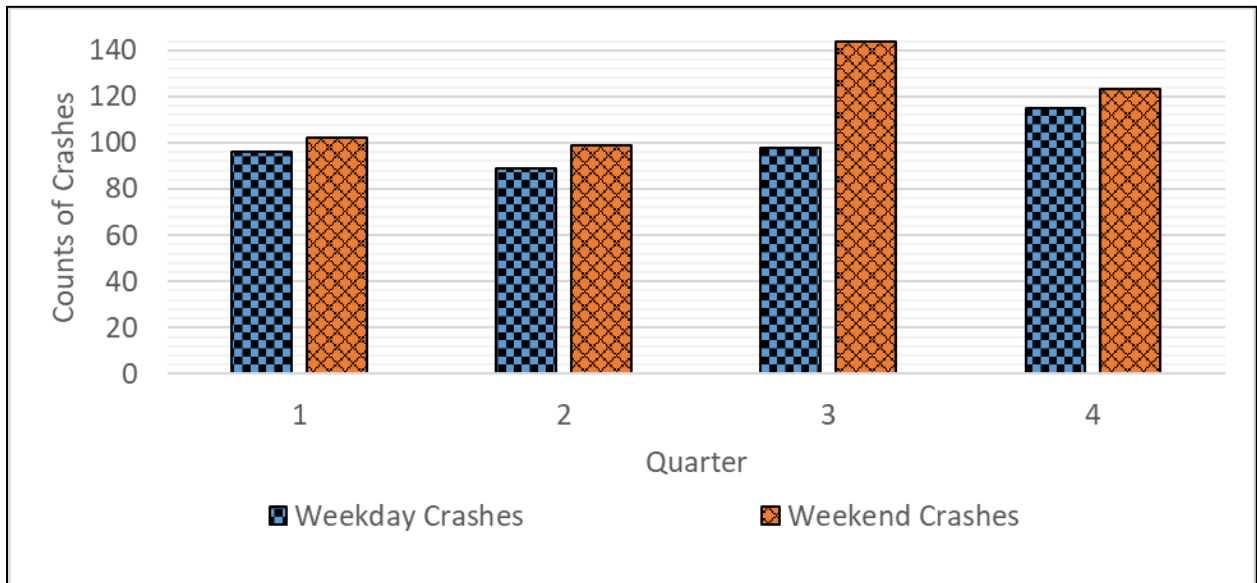


Figure 102: 2019 counts of driving under the influence related crashes by day of the week.

Table 13: 2019 Counts of Driving under the Influence Crashes by Manner of Collision in the First Quarter

Manner of Collision	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	Total
Angle (Front to Side), Opposing Direction	2	0	2	3	7
Angle, Right (Front to Side, includes Broadside)	2	1	3	3	9
Angle, Same Direction (Front to Side)	0	0	3	1	4
Head-On (Front to Front)	2	2	1	1	6
Not a Collision with Two Vehicles in Transport	2	7	18	2	29
Rear-End (Front to Rear)	0	1	9	10	20
Rear to Front (Normally Backing)	0	0	0	0	0
Rear to Rear (Normally Backing)	0	0	0	0	0
Rear to Side (Normally Backing)	0	0	0	0	0
Sideswipe Opposite Direction (Meeting)	0	0	0	0	0
Sideswipe Same Direction (Passing)	0	0	1	0	1
Other	0	0	0	0	0
Total	8	11	37	20	76

Table 14: 2019 Counts of Driving under the Influence Crashes by Manner of Collision in the Second Quarter

Manner of Collision	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	Total
Angle (Front to Side), Opposing Direction	1	2	1	2	6
Angle, Right (Front to Side, includes Broadside)	0	1	2	2	5
Angle, Same Direction (Front to Side)	0	0	0	1	1
Head-On (Front to Front)	2	1	2	0	5
Not a Collision with Two Vehicles in Transport	8	14	32	12	66
Rear-End (Front to Rear)	0	2	4	2	8
Rear to Front (Normally Backing)	0	0	0	0	0
Rear to Rear (Normally Backing)	0	0	1	0	1
Rear to Side (Normally Backing)	0	0	0	0	0
Sideswipe Opposite Direction (Meeting)	0	0	2	0	2
Sideswipe Same Direction (Passing)	0	0	0	0	0
Other	0	1	0	0	1
Total	11	21	44	19	95

Table 15: 2019 Counts of Driving under the Influence Crashes by Manner of Collision in the Third Quarter

Manner of Collision	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	Total
Angle (Front to Side), Opposing Direction	0	2	2	2	6
Angle, Right (Front to Side, includes Broadside)	0	4	5	1	10
Angle, Same Direction (Front to Side)	0	0	1	0	1
Head-On (Front to Front)	4	1	2	1	8
Not a Collision with Two Vehicles in Transport	7	24	33	10	74
Rear-End (Front to Rear)	1	0	5	6	12
Rear to Front (Normally Backing)	0	0	0	0	0
Rear to Rear (Normally Backing)	0	0	0	0	0
Rear to Side (Normally Backing)	0	0	0	0	0
Sideswipe Opposite Direction (Meeting)	0	1	1	0	2
Sideswipe Same Direction (Passing)	0	0	0	1	1
Other	0	0	0	0	0
Total	12	32	49	21	114

Table 16: 2019 Counts of Driving under the Influence Crashes by Manner of Collision in the Fourth Quarter

Manner of Collision	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	Total
Angle (Front to Side), Opposing Direction	0	3	2	6	11
Angle, Right (Front to Side, includes Broadside)	1	2	3	4	10
Angle, Same Direction (Front to Side)	0	0	1	0	1
Head-On (Front to Front)	1	0	3	1	5
Not a Collision with Two Vehicles in Transport	4	15	20	12	51
Rear-End (Front to Rear)	0	1	2	5	8
Rear to Front (Normally Backing)	0	0	0	0	0
Rear to Rear (Normally Backing)	0	0	0	0	0
Rear to Side (Normally Backing)	0	0	0	0	0
Sideswipe Opposite Direction (Meeting)	0	0	0	1	1
Sideswipe Same Direction (Passing)	1	0	1	0	2
Other	0	0	0	0	0
Total	7	21	32	29	89

Table 17: 2019 Counts of Driving under the Influence Crashes by Manner of Collision

Manner of Collision	Fatal Injury	Suspected Serious Injury	Suspected Minor Injury	Possible Injury	Total
Angle (Front to Side), Opposing Direction	3	7	7	13	30
Angle, Right (Front to Side, includes Broadside)	3	8	13	10	34
Angle, Same Direction (Front to Side)	0	0	5	2	7
Head-On (Front to Front)	9	4	8	3	24
Not a Collision with Two Vehicles in Transport	21	60	103	36	220
Rear-End (Front to Rear)	1	4	20	23	48
Rear to Front (Normally Backing)	0	0	0	0	0
Rear to Rear (Normally Backing)	0	0	1	0	1
Rear to Side (Normally Backing)	0	0	0	0	0
Sideswipe Opposite Direction (Meeting)	0	1	3	1	5
Sideswipe Same Direction (Passing)	1	0	2	1	4
Other	0	1	0	0	1
Total	38	85	162	89	374

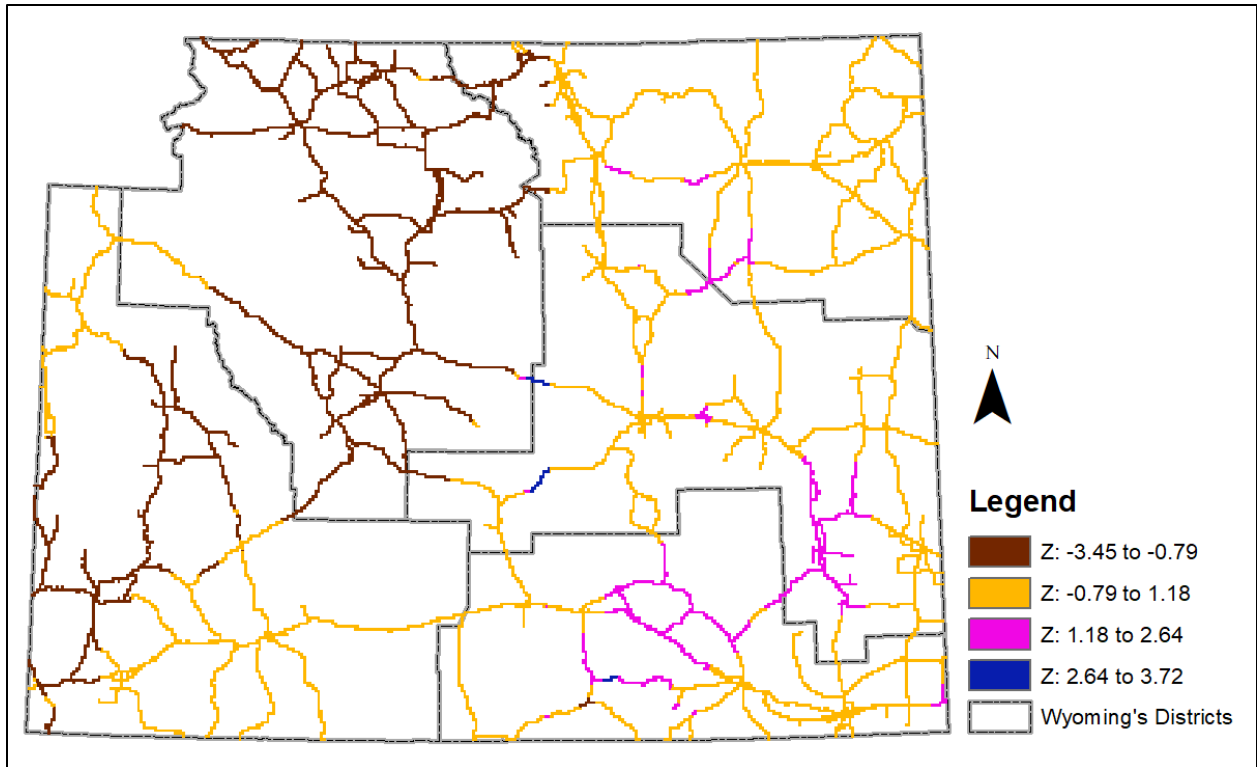


Figure 103: 2017 heat map of driving under the influence crashes.

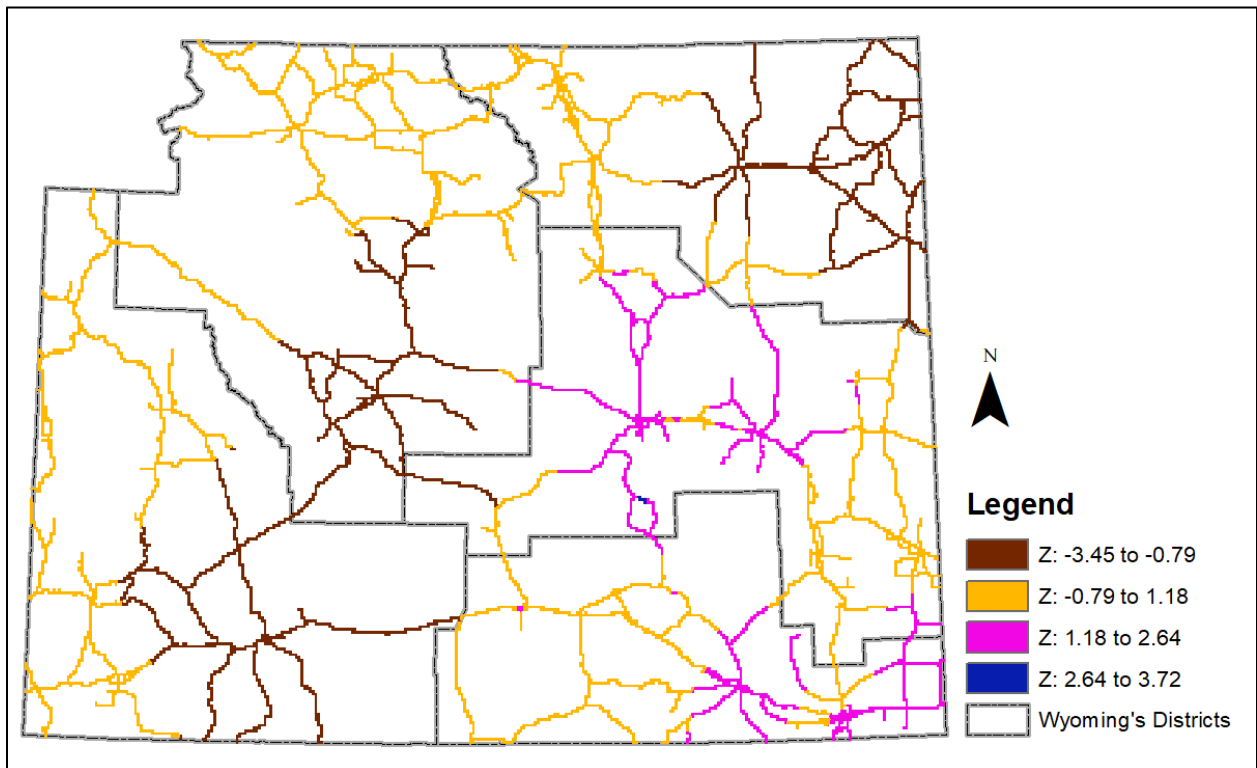


Figure 104: 2017 heat map of driving under the influence fatal, suspected serious injury and suspected minor injury crashes.

It is also recommended that WYDOT plan for the following research studies:

- Effectiveness of DUI enforcement policies
- Effectiveness of impaired drivers' rehabilitation campaigns
- Effectiveness of other impairment enforcement policies (e.g. tired, not wearing prescription glasses/contact lenses)
- Effectiveness of educational campaigns addressing impaired driving
- Association between alcohol or drug use and crime

Summary of Wyoming's Counties Survey Responses' Results

A survey was disseminated to officials in Wyoming's counties and 10 responses were received from multiple jurisdictions scattered around the state. The common question asked in all surveys was how often did the respondents receive/secure road safety data/reports from the WYDOT HSO? Ninety percent of the respondents indicated that they often obtained the relevant road safety information from the Wyoming Technology Transfer Center, which collaborates with the WYDOT HSO, once a year. The remaining 10 percent indicated that they received the data once every six months. In the follow-up question, there were mixed responses regarding the ideal reporting period. Forty percent declared that they were willing to receive the data semi-annually, 30 percent indicated that they were willing to receive the data annually through the Wyoming Technology Transfer Center, and 20 percent indicated that they were willing to receive the information once a month. One respondent, comprising the remaining 10 percent, stated that he or she was willing to receive the road safety data as soon as the crashes occurred. That is to conduct road safety evaluations and propose mitigation measures promptly.

When it comes to data transfer protocols, the respondents declared that they secured reports/data mostly via mail and email (80 percent and 60 percent, respectively). The answer choices were provided in the form of checkboxes. In the subsequent question, most respondents indicated that they preferred receiving the reports/data via email. Also, the respondents were asked whether the current safety data provided to them fulfilled their needs on a scale of one (not at all) to five (absolutely). Sixty percent selected the options four and five. Regarding the preferred data format, more than half of the respondents selected the options, "pie charts/bar charts," "summary statistics tables," "figures" and "GIS maps." Note that the answer choices were provided as checkboxes to allow the respondents to select multiple choices. Furthermore, the counties' officials were asked to provide any suggestions regarding the data or reports they would receive. One suggested that it would be beneficial to provide the data they needed in a GIS format such that the records would be efficiently incorporated into their GIS inventory and another recommended creating an email list for the prompt sharing of crash information whenever a crash would occur.

In the following section of the survey, the counties' officials were asked about road safety reports pertaining to crash data. The reports, most of which are available in the WYDOT HSO website, are the following:

- 2019 Highway Safety Crash Data Survey Final Report
- Wyoming Department of Transportation Highway Safety Behavioral Grants Office 2020 Annual Report
- Wyoming Highway Safety Behavioral Program FY2021 Highway Safety Plan
- Wyoming Report on Traffic Crashes 2019
- Wyoming Drivers Survey 2016
- 2020 Wyoming Statewide Seatbelt Survey Data Analysis
- Wyoming Statewide Crashes by Year
- Wyoming Statewide Speed Related Crashes by Year
- Wyoming Statewide Crashes Involving a Wild Animal by Year
- Wyoming Statewide Occupant Seat Belt Usage by Year
- Wyoming Statewide Crashes Involving a Pedestrian by Year
- Wyoming Statewide Crashes Involving Alcohol or Drugs by Year
- Wyoming Statewide Crashes Involving Commercial Motor Vehicles by Year
- Wyoming Statewide Distracted Driving Crashes by Year
- Wyoming Strategic Highway Safety Plan 2017

On a scale of one (not at all) to five (absolutely) describing whether the respondents were familiar with these reports and whether they frequently used them, more than half provided a rating of three, less than 15 percent provided a rating of four, and none provided a rating of five. In another question, the respondents were asked about the usefulness of the listed reports and half indicated that such reports were beneficial. Also, all respondents declared that they were satisfied with the frequency at which the reports were released.

The county officials were then asked specific questions about the importance of incorporating specific road safety summary statistics data in the listed reports. At least half of them indicated that they were interested in the following crash statistics:

- Drivers' improper actions/error information preceding the crashes (e.g. driving too fast, improper passing, following too closely, etc.)
- Aggressiveness of drivers who were at-fault in traffic crashes
- Truck safety and truck policy violations at the times of the crashes (exceeded weight limit, improperly secured hazardous materials, etc.)
- Animal crash hot spots

In the subsequent section of the survey, the county officials were asked specific questions about crash data. At least half of them indicated that they were interested in the following data collected from crash records:

- Crash locations (on the road, on the shoulder, off the road, etc.)
- Crash times (morning, afternoon, etc.)
- Weather conditions at the times of the crashes

- Vehicle travel speeds preceding the crashes (i.e. too slow for the conditions, reasonable or too fast for the conditions)
- Number of vehicles involved in the crashes
- Number of pedestrians and/or bicyclists involved in the crashes
- Types of animals involved in the crashes
- Whether the drivers were properly wearing their seat belts at the times of the crashes
- Whether the passengers were properly wearing their seat belts at the times of the crashes
- Whether children were properly secured in their appropriate car seats at the times of the crashes
- Whether the drivers were driving under the influence of alcohol/drugs at the times of the crashes
- Whether the drivers were tired at the times of the crashes
- Motorcycle crashes
- Whether work zone plans were implemented according to the standards when the crashes occurred at or near the work zones
- Whether workers were present when the crashes occurred at or near the work zones
- Shoulder and lane closure information when the crashes occurred at or near the work zones
- Whether drivers violated work zone regulations giving rise to the crashes (i.e. exceeded the work zones' speed limits, failed to obey the traffic guards' signals, etc.)
- Number of injured drivers/motorcyclists and their injury severity levels
- Number of injured passengers and their injury severity levels
- Number of injured non-motorists and their injury severity levels
- Crash types (rear-end, sideswipe, etc.)
- Impact point information of vehicles involved in the crashes (e.g. hit from the side, hit from the front, etc.)
- DUI related crashes by day of the week (i.e. weekdays versus weekends)
- Injury severity levels of DUI related crashes by BAC level of impaired drivers
- Crashes on roads with challenging geometric conditions (steep upgrades, steep downgrades, etc.)
- Crashes involving distractions by distraction method (use of electronic device, picking up an object from the vehicle's floor, etc.)
- Crash locations by injury severity level and lighting conditions (daylight, dawn, dark with street lighting, etc.) at the times during which the crashes occurred
- Crash locations by injury severity level and road surface conditions (dry, wet, icy, snowy, etc.) at the times during which the crashes occurred

In the subsequent section, the county officials were asked about the importance of color-coded maps presenting locations characterized by risks of encountering certain types of crashes. At least half of the respondents declared that they were interested in maps presenting the following:

- High severity (fatal, suspected serious injury and suspected minor injury) crashes
- High severity crashes that occurred in the presence of adverse weather conditions (snow, fog, rain, etc.)
- High severity crashes where visual obstructions (vegetation, hill crests, sun glare, headlight glare, other vehicles, animals, fog, snow showers, etc.) posed hazards
- High severity crashes involving improperly buckled or unbuckled occupants
- High severity DUI related crashes
- High severity speed related crashes

In the second to the last question, the officials of Wyoming’s counties were asked to select topics they might be interested in for research from a list. At least half selected the following topics:

- Safety of low-volume paved and unpaved roads
- Assessing and updating strategic county road safety plans
- Optimization of road safety improvement budgets
- Effectiveness of speed enforcement policies
- Changes in Wyoming’s road fatality toll rates (fatalities per hundred million vehicle-miles traveled) throughout the years

Finally, the respondents were asked whether they would like to provide any recommendation regarding the data they would receive in general. One suggested the provision of the GIS coordinates of the crash locations since he or she would typically receive narrative descriptions of the locations, which would otherwise be considered as imprecise.

Recommendations for the Wyoming Department of Transportation Regarding Wyoming’s Counties

Based on the interpretations of the Wyoming counties’ survey responses, it is suggested that WYDOT establish an email list for sharing road safety data with the counties on a quarterly basis. With that, it would also be beneficial that WYDOT communicate with the county officials regarding whether some would be willing to receive such data within a shorter period after the occurrences of crashes. The data, recommended for Wyoming’s counties in the form of plots/tables, would be similar to those which were suggested for WHP and WASCOP (Figures 26 through 73, and Tables Table 6 through 10). Furthermore, since it was inferred from the counties’ survey results that the county officials were interested in pedestrian injury and fatality statistics, it is recommended to provide such data to Wyoming’s counties. Pedestrian casualty statistics would be provided in the form similar to that depicted in Figure 105.

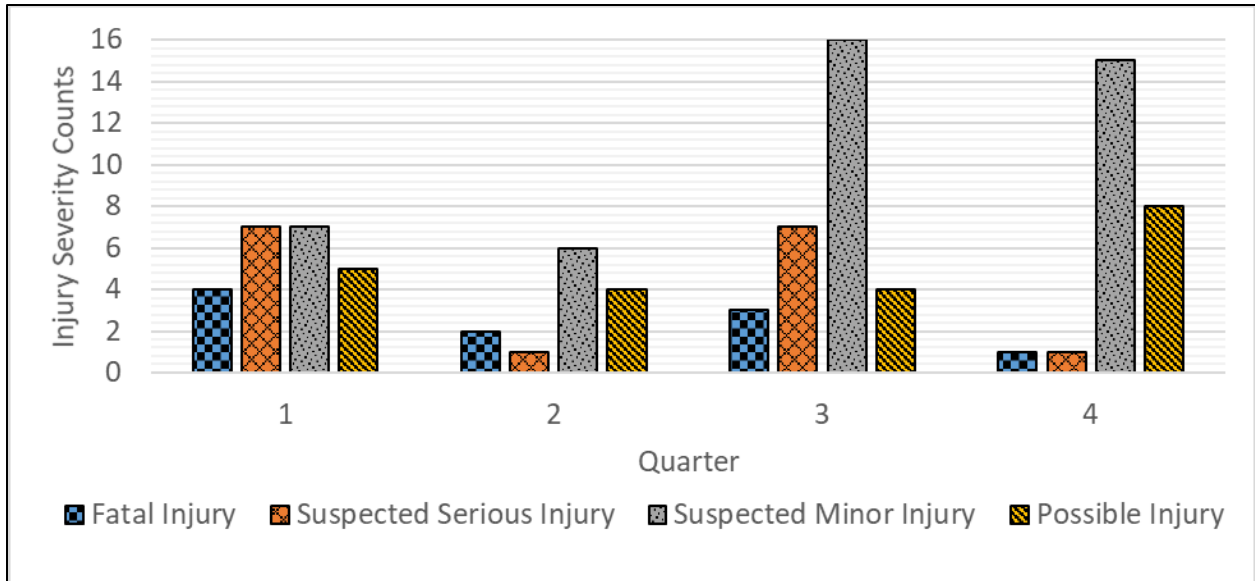


Figure 105: 2019 counts of killed and injured pedestrians.

In addition, it is suggested that WYDOT plan for conducting research on the following topics:

- Safety of low-volume paved and unpaved roads
- Assessing and updating strategic county road safety plans
- Optimization of road safety improvement budgets
- Effectiveness of speed enforcement policies
- Changes in Wyoming’s road fatality toll rates throughout the last decade

Summary of the Wyoming Bicycle and Pedestrian System Task Force Survey Responses’ Results

A survey was circulated among members of the Wyoming Bicycle and Pedestrian System Task Force and other interested parties. The survey asked about the frequency at which WBPSTF were receiving non-motorist safety data, whether members of WBPSTF were utilizing relevant safety reports available in the WYDOT HSO website, additional data needed and non-motorist safety topics WBPSTF might be interested in for research. Three responses were received.

In the first section of the survey, WBPSTF members were asked how often they received pedestrian/bicycle safety data from the WYDOT HSO. One respondent declared that he or she received them once every six months. Another indicated that her or she never received such data unless the data were requested, and the third stated that he or she never received the data. In the results of the following question, which included answer choices provided in the form of checkboxes, one respondent declared that he or she would receive non-motorist safety data via online databases or reports. The option “email,” was also selected. More importantly, one of the respondents stated that he or she would solicit non-motorist safety data and they would be provided in an Excel pdf format. The third question asked about the preferred means of data delivery and, similar to the previous question, checkboxes were provided to the respondents.

Two thirds of the respondents selected the options, “online databases and/or reports” and “email.” The subsequent question asked whether the non-motorist safety data fulfilled the needs of WBPSTF on a scale of one (not at all) to five (absolutely). Two respondents checked the option “two” and the third selected the option “four.” When it comes to the number of days it would take for the respondents to receive the safety data from the dates non-motorist crashes occurred, one respondent indicated that this duration would be a week. Another indicated one to two days, and the third preferred a duration less than a week. With that, the respondents stated that these were ideal reporting periods. The respondents also declared that they would prefer summary statistics tables and figures as means of presenting pedestrian/bicycle safety data. Furthermore, it was interpreted that the respondents would like the locations of pedestrian and bicycle crashes to be portrayed via narrative descriptions, GIS coordinates or heat maps. At the end of the first section of the survey, the respondents were asked to provide any additional feedback. One suggested the provision of non-motorist facility budget information. That is, when pedestrian and bicycle casualties become substantial, it would be beneficial to have budget reports handy in order to plan for improving non-motorist safety accordingly. Another respondent recommended the provision of more accurate GIS coordinates of the locations of pedestrian and bicycle crashes.

In the second section of the survey, the respondents were asked about the following reports:

- Wyoming Statewide Crashes Involving a Pedestrian by Year
- Wyoming Strategic Highway Safety Plan
- 2019 Wyoming Department of Transportation Highway Safety Behavioral Grants Office Annual Report
- 2019 Highway Safety Crash Data Survey Final Report
- Cyclist and Pedestrian Accident Statistics for Wyoming
- Wyoming Highway Safety Behavioral Program FY2020 Highway Safety Plan
- Wyoming Report on Traffic Crashes 2019
- Wyoming Bicycle & Pedestrian Transportation Plan
- Bicycle Friendly State Report Card Wyoming
- Wyoming Active Transportation Webinar Series
- A Resident's Guide for Creating Safer Communities for Walking and Biking
- Urban Bikeway Design Guide

The respondents were asked whether they were familiar with the aforementioned reports and frequently utilized them. Only one declared that he or she utilizes most of those reports often and that they were beneficial. Regarding the frequency at which the reports were released, one respondent indicated that he or she was satisfied with such frequency. At the end of the survey’s second section, the respondents were asked to include any additional reports that might be of benefit to them. One respondent suggested a report of pedestrian and bicycle safety budgets.

The third section of the survey was aimed at specific questions concerning non-motorist safety data in which the respondents might be interested. At least two of the three respondents were interested in the following summary statistics data collected from crash records.

- Pedestrian/bicycle crash types (sideswipe, right turn at intersection, dooring, etc.)
- Whether any road users, involved in the pedestrian/bicycle crashes, were using an electronic device or distracted by any other means
- Whether the bicyclists were wearing helmets at the times of the crashes
- Pedestrian/bicycle crash locations (intersections, mid-block locations, road shoulders or parking lots)
- Whether the drivers maintained an adequate distance between their vehicles and the bicyclists on the shoulder or bicycle lane
- Whether the pedestrian/bicycle crashes occurred within school zones
- Traffic violation details at the times of the pedestrian/bicycle crashes
- Weather conditions at the times of the pedestrian/bicycle crashes (clear, cloudy, foggy, rainy, snowy etc.)
- Road surface conditions at the times of the pedestrian/bicycle crashes (dry, wet, icy, snowy or slushy)
- Crash times

In addition, two respondents declared that they agreed that non-motorist injury severity levels (fatal, suspected serious injury, suspected minor injury and possible injury) should be further categorized. Also, one respondent indicated that he or she would be interested in color-coded maps depicting the high-risk non-motorist crash locations.

The third section of the survey comprised questions about miscellaneous topics regarding non-motorists. The respondents were asked to select the type of summary statistics citation data in which they were willing to receive. Yet, a disclaimer was incorporated stating that the WYDOT HSO would not maintain citation data and, hence, independent studies would have to be conducted on such data if needed. At least two of the three respondents indicated that they would like to receive summary statistics data on the following:

- Traffic violations posing hazards to pedestrians and bicyclists (e.g. failure to yield the right-of-way to pedestrians and bicyclists)
- Whether drivers, cited for previous violations against pedestrians and bicyclists, attended drivers' education sessions
- Whether pedestrians/bicyclists, cited for previous violations, attended traffic education sessions

Other than citation data, two of the three respondents stated that they were interested in information on projects geared towards providing pedestrian and bicyclist friendly facilities (e.g.

providing a designated bicycle lane or widening a sidewalk, etc.). Also, at least two respondents recommended that the WYDOT HSO carry out research on the following topics:

- Assessing the adequacy of the existing pedestrian and bicycle infrastructure
- Assessing the health benefits of walking and biking
- Assessing the economic impact of walking and biking; this would include special bicycle events
- Assessing the environmental impact of walking and biking

Recommendations for the Wyoming Department of Transportation Regarding the Wyoming Bicycle and Pedestrian System Task Force

Based on the Wyoming Bicycle and Pedestrian System Task Force's survey results, noteworthy recommendations are made for WYDOT. As such, it is recommended that WYDOT deliver non-motorist crash data to WBPSTF as promptly as the data become available. It is also suggested that WYDOT share information with the group regarding its bicycle and pedestrian facility budgets, especially when having a considerable rate of non-motorist crashes. Other suggestions include disseminating a survey to schools asking about school zone and school bus safety concerns from the viewpoints of non-motorists. Another survey may be circulated among bicyclists asking about their safety concerns. Both surveys' results would be documented in official reports and shared with WBPSTF. In addition, it is recommended that WYDOT provide quarterly summary statistics of non-motorist crash data, similar to the ones presented in Figures 99 through 116, and Table 18. Note that Figure 116, which is a heat map of non-motorist crashes, was produced using the 2017 data since this was the latest year during which accurate GIS coordinates of the crash locations were provided. The mapping procedure implemented was the same as that employed for generating the heat maps of the other road safety groups.

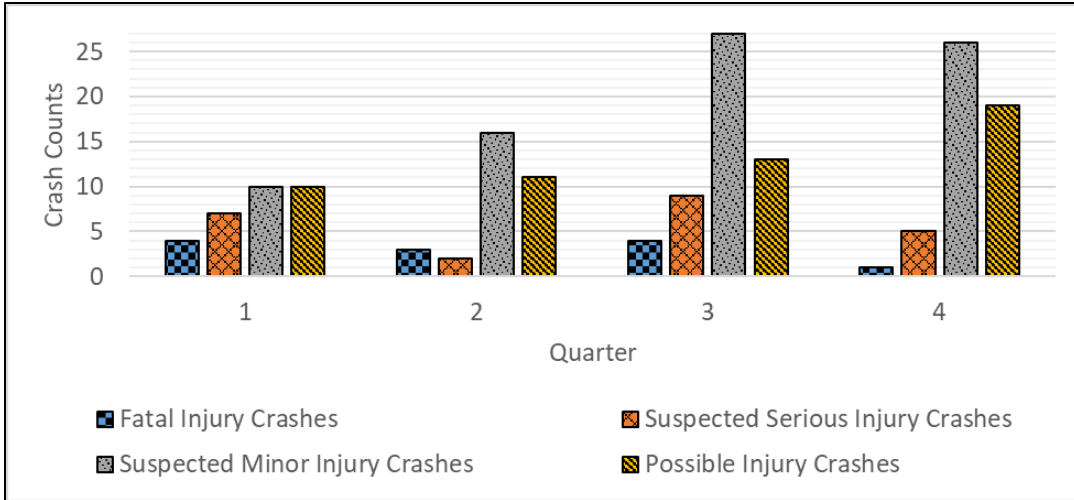


Figure 106: 2019 counts of pedestrian and bicycle crashes.

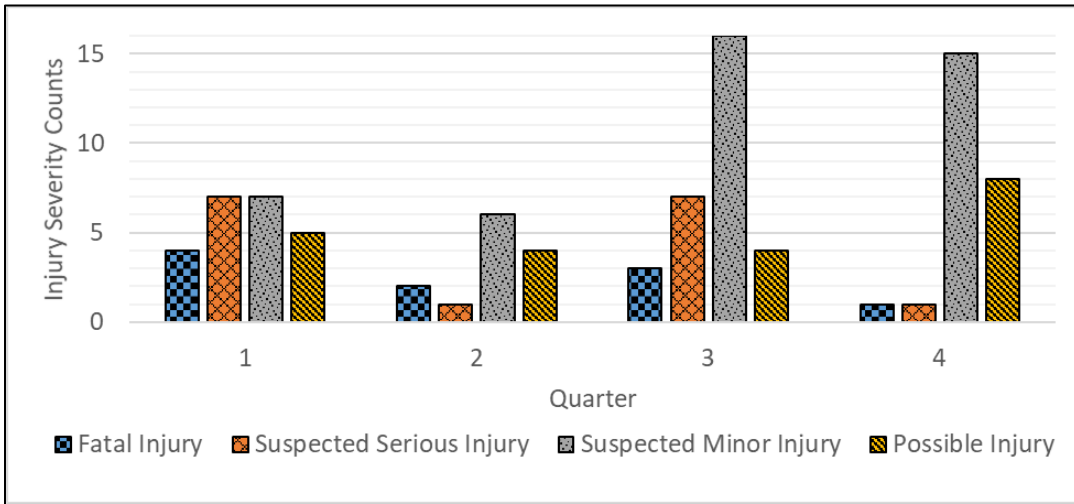


Figure 107: 2019 counts of killed and injured pedestrians.

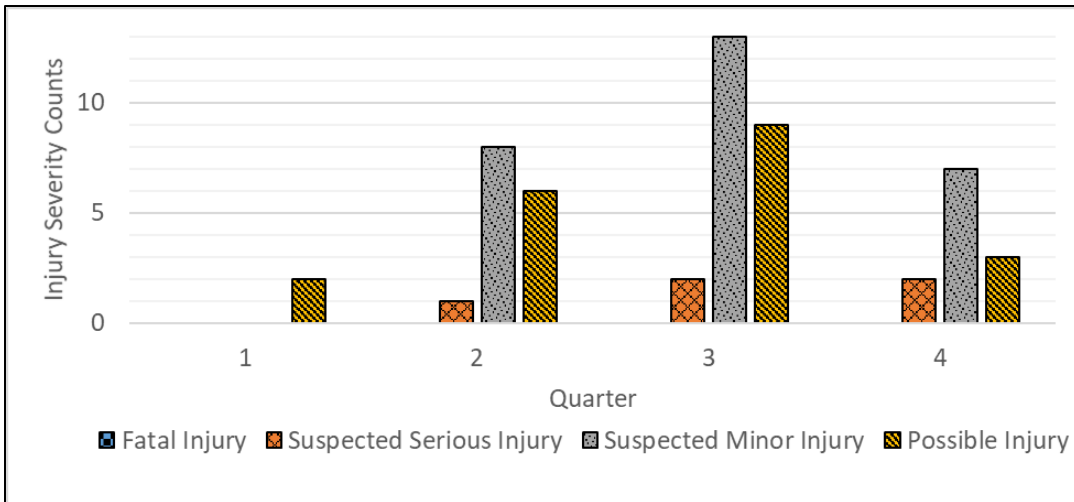


Figure 108: 2019 counts of killed and injured bicyclists.

Table 18: 2019 Counts of Pedestrian and Bicycle Crashes by Manner of Collision

Manner of Collision	Quarter				Total
	1	2	3	4	
Angle (Front to Side), Opposing Direction	1	1	1	1	4
Angle, Direction Not Specified	0	0	0	1	1
Angle, Right (Front to Side, includes Broadside)	0	0	0	1	1
Angle, Same-Direction (Front to Side)	3	4	0	2	9
Head-On (Front to Front)	0	0	0	1	1
Not a Collision with Two Vehicles in Transport	19	26	51	31	127
Rear-End (Front to Rear)	6	4	4	9	23
Rear to Front (Normally Backing)	0	1	1	4	6
Rear to Rear (Normally Backing)	1	1	0	0	2
Rear to Side (Normally Backing)	1	1	1	0	3
Sideswipe-Opposite Direction (Meeting)	0	1	2	0	3
Sideswipe-Same Direction (Passing)	7	4	7	10	28
Other	2	0	0	0	2
Total	40	43	67	60	210

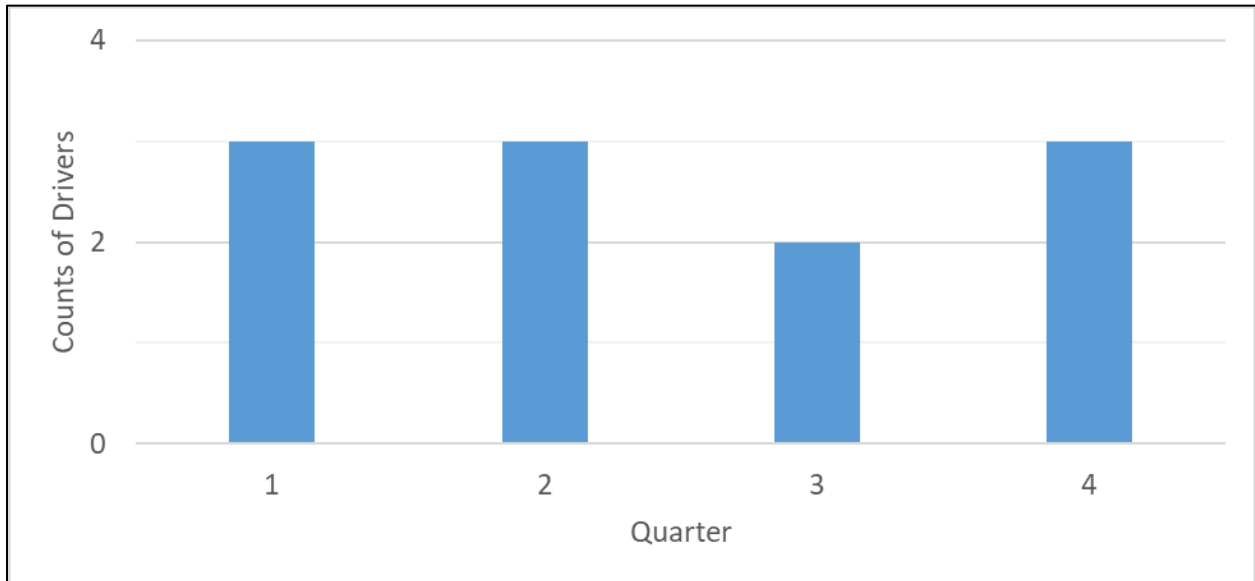


Figure 109: 2019 counts of distracted drivers involved in pedestrian and/or bicycle crashes.

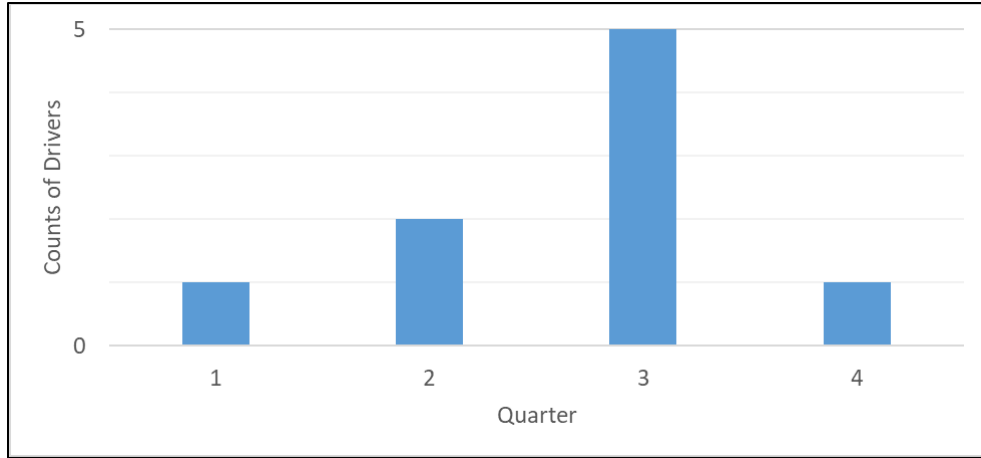


Figure 110: 2019 counts of impaired drivers involved in pedestrian and/or bicycle crashes.

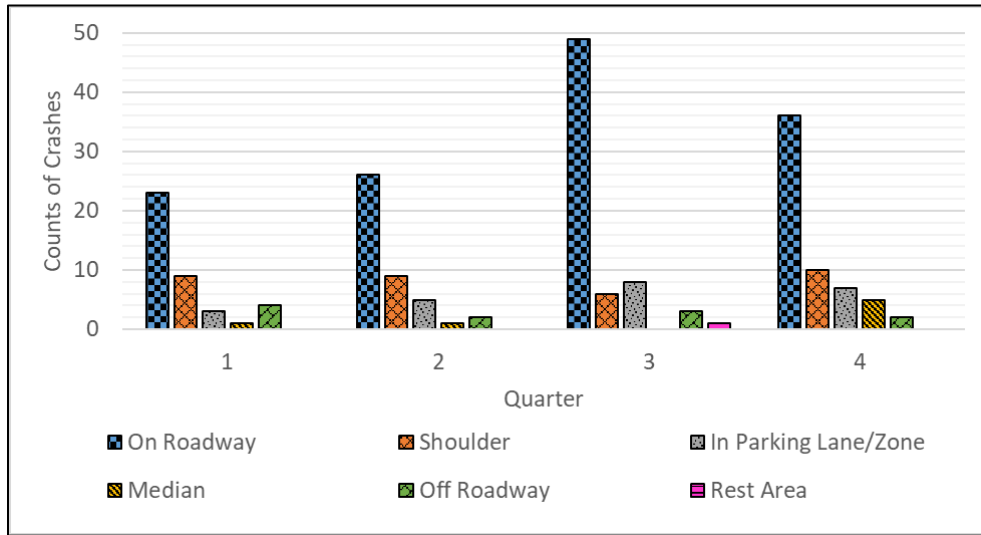


Figure 111: 2019 counts of pedestrian and bicycle crashes by first harmful event location.

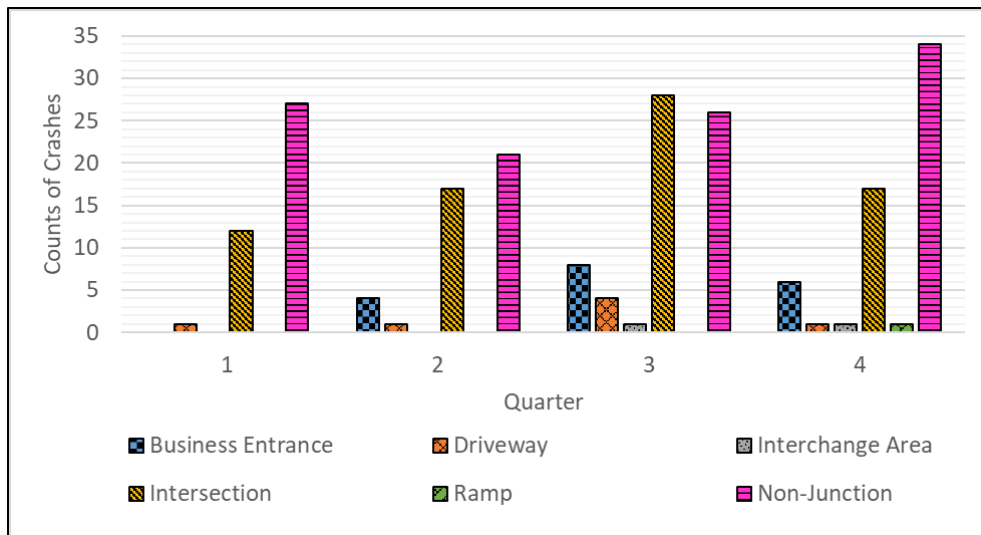


Figure 112: 2019 counts of pedestrian and bicycle crashes for segments and junctions.

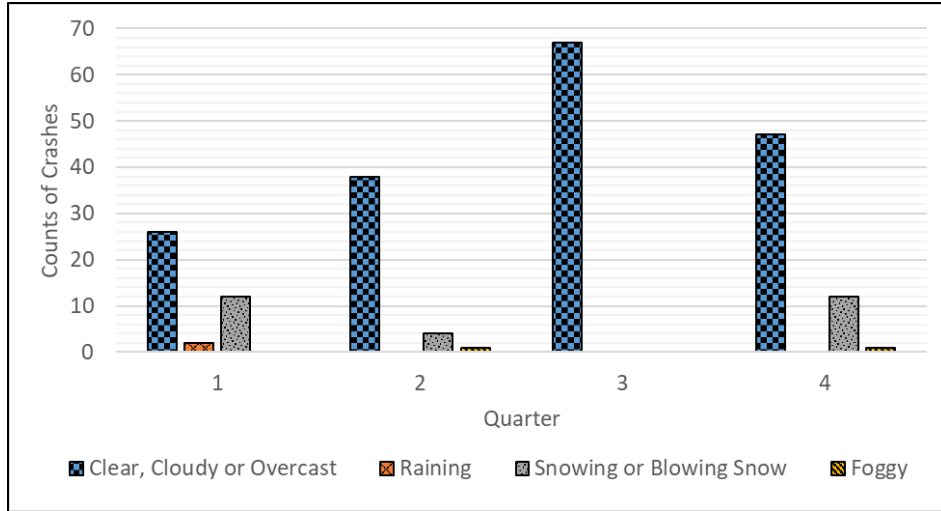


Figure 113: 2019 counts of pedestrian and bicycle crashes by weather condition.

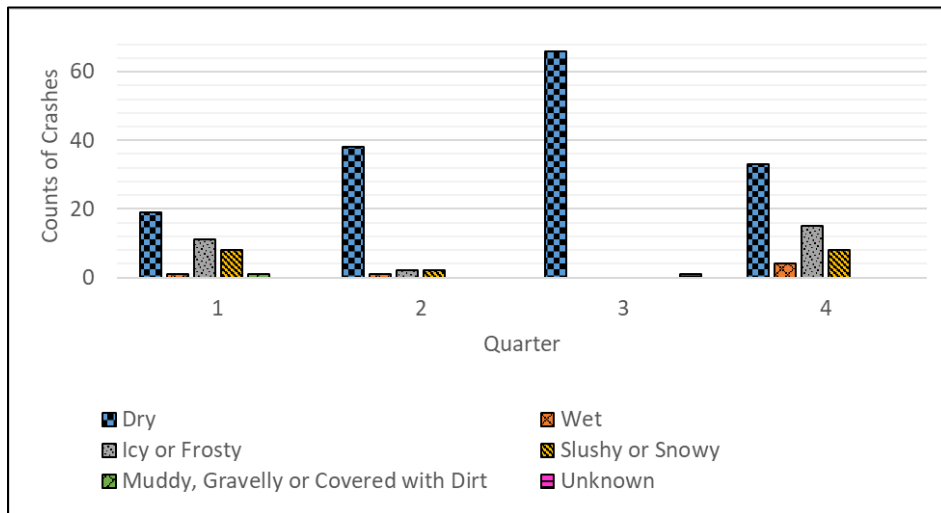


Figure 114: 2019 counts of pedestrian and bicycle crashes by road surface condition.

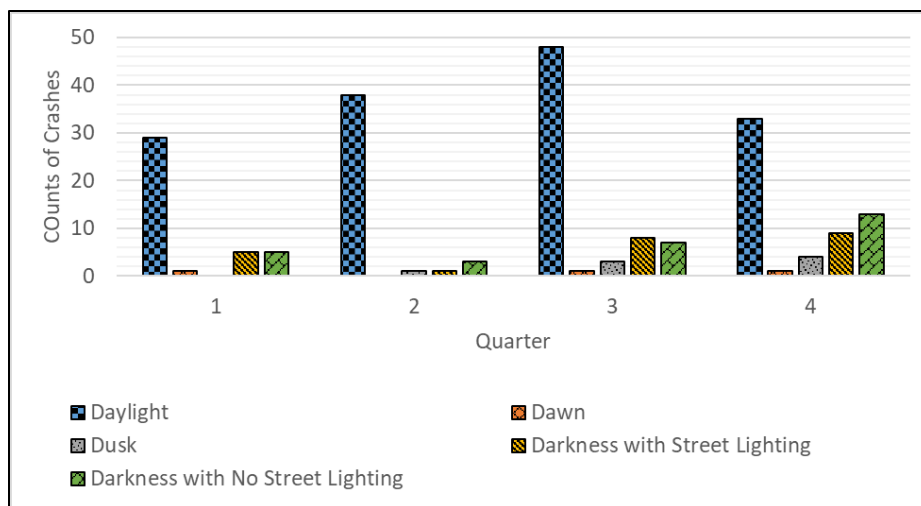


Figure 115: 2019 counts of pedestrian and bicycle crashes by lighting condition.

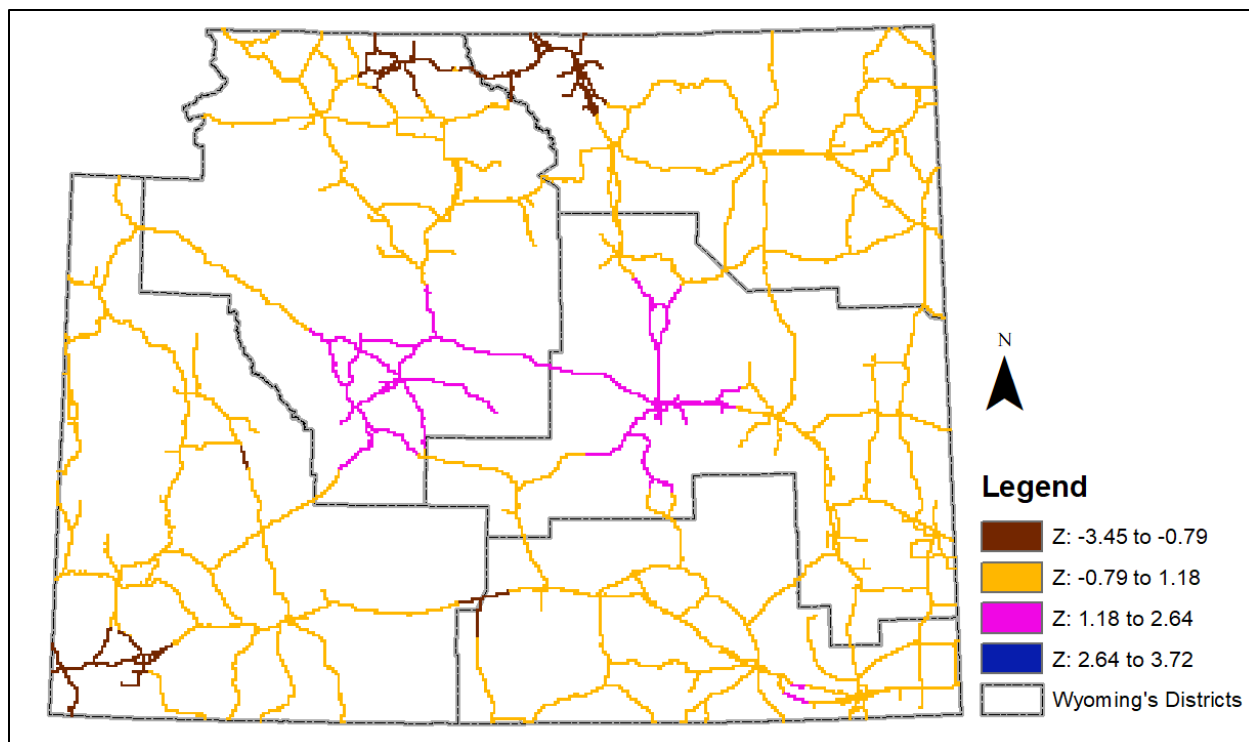


Figure 116: 2017 heat map of pedestrian and bicycle crashes.

Another suggestion is to conduct independent studies to collect, summarize and present data of the following:

- Citations issued to drivers for posing hazards to pedestrians and bicyclists (e.g. failure to yield the right-of-way to pedestrians and bicyclists)
- Whether drivers, cited for previous violations against pedestrians and bicyclists, attended drivers' education sessions
- Whether pedestrians/bicyclists, cited for previous violations, attended traffic education sessions

Other than the citation data suggestions, it would be recommended that WYDOT plan for research on the following topics:

- Assessing the adequacy of the existing pedestrian and bicycle infrastructure
- Assessing the health benefits of walking and biking
- Assessing the economic impact of walking and biking; this would include special bicycle events
- Assessing the environmental impact of walking and biking

Summary of the Results of the Motorcycle Groups' Survey

A survey was distributed to multiple motorcycle groups, including the Wyoming Central ABATE and the Harley-Davidson motorcycle groups. Yet, no responses were received after

multiple attempts to reach out to the groups. Therefore, recommendations were made to WYDOT concerning the provision of pertinent road safety data to the motorcycle groups in the state based on experiential knowledge and a prior reasoning.

Recommendations for the Wyoming Department of Transportation Regarding the Motorcycle Groups

It is recommended that WYDOT provide quarterly summary statistics data extracted from motorcycle crash records to motorcycle groups in Wyoming. The data would be similar to those presented in Figures 117 through 130, and Tables 19 and 20, which belonged to 2019. It should be noted that Figure 130 presents a map of motorcycle crash hot spots representative of the year 2017 since this was the most recent year during which precise GIS coordinates of crash locations were available.

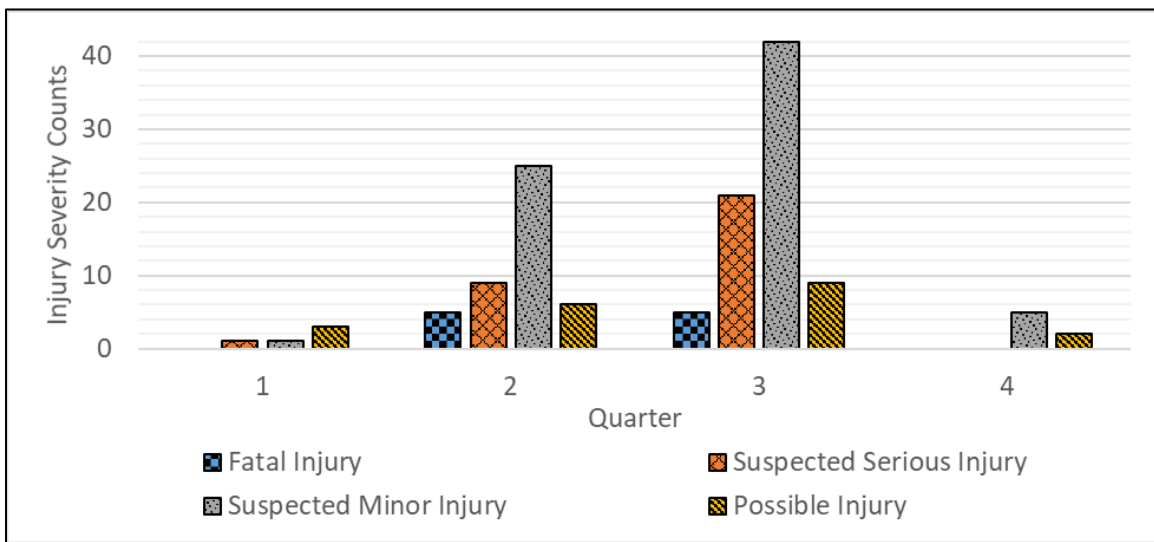


Figure 117: 2019 counts of killed and injured motorcycle operators.

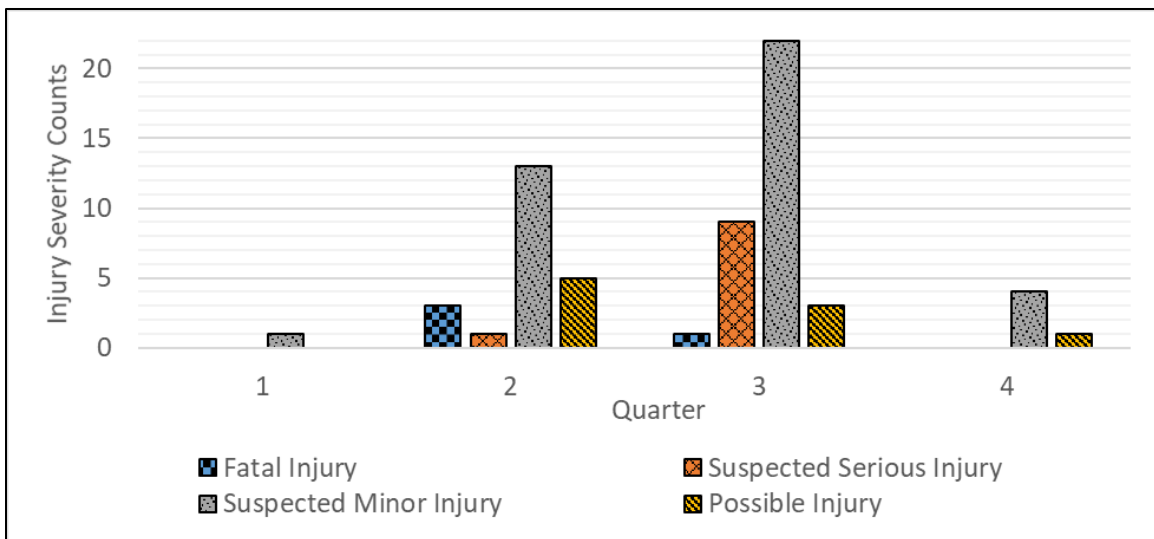


Figure 118: 2019 counts of killed and injured motorcycle operators wearing helmets.

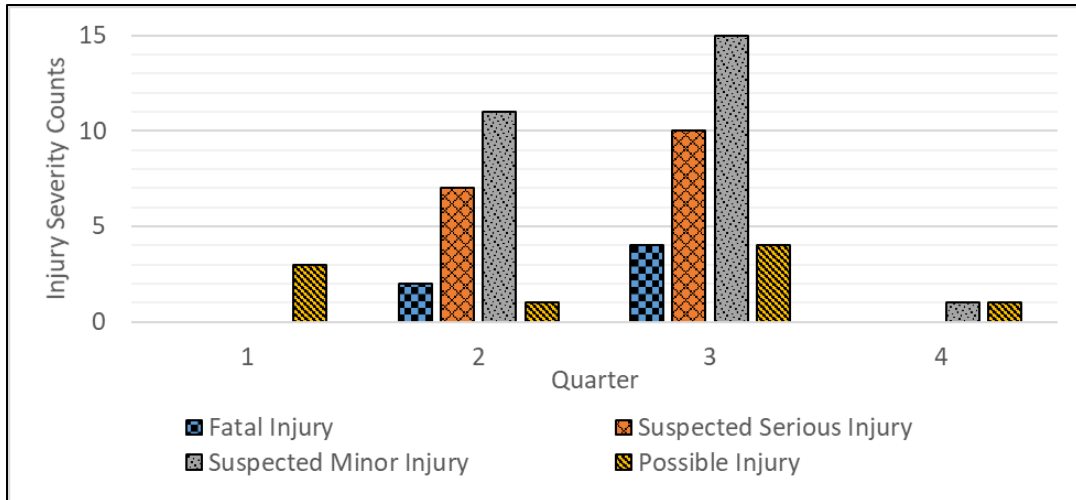


Figure 119: 2019 counts of killed and injured motorcycle operators not wearing helmets.

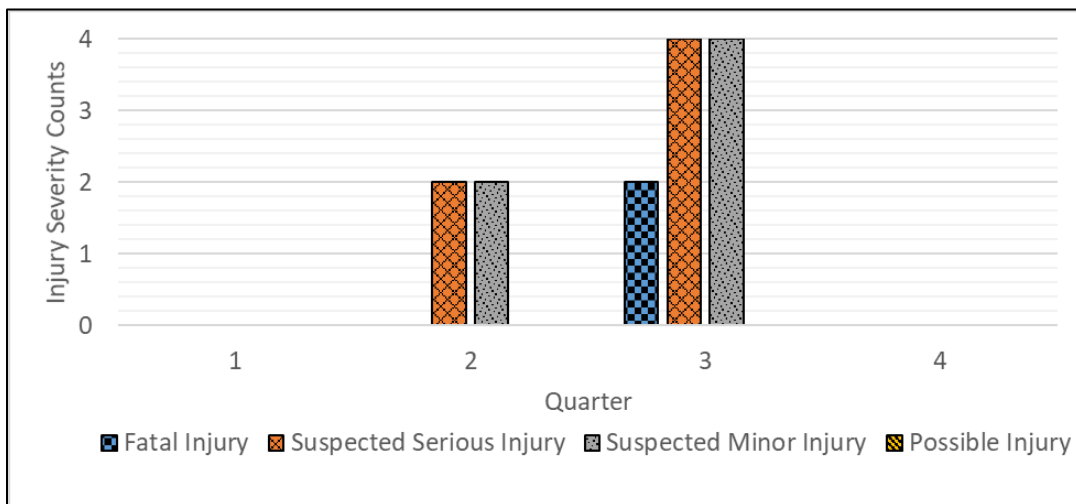


Figure 120: 2019 counts of killed and injured motorcycle passengers.

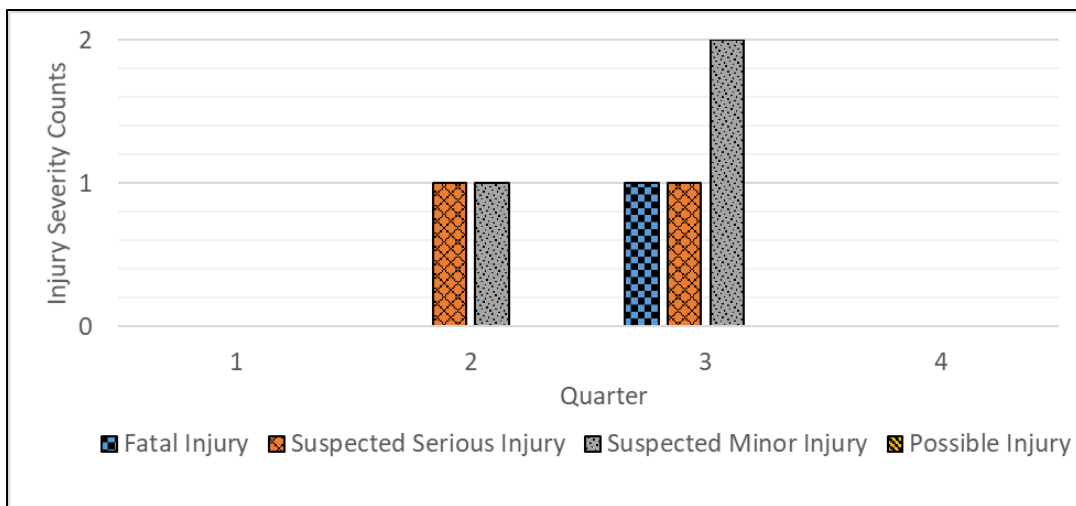


Figure 121: 2019 counts of killed and injured motorcycle passengers wearing helmets.

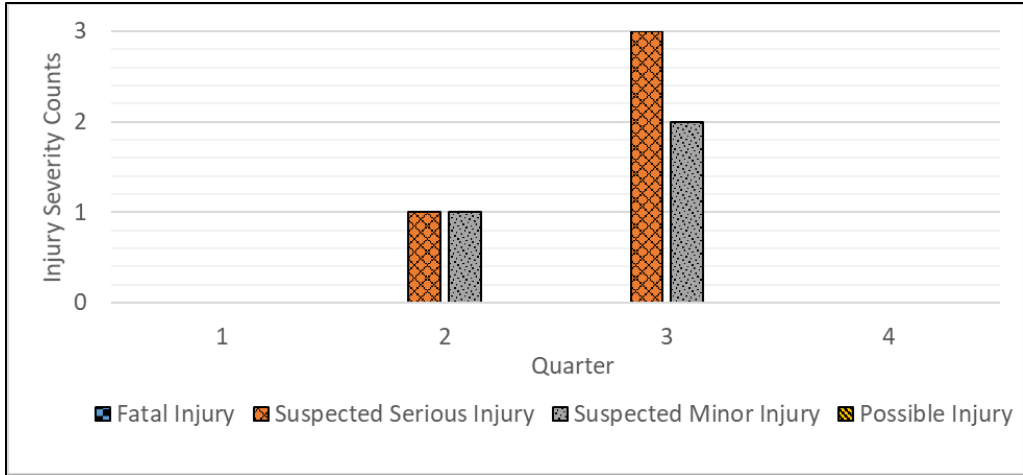


Figure 122: 2019 counts of killed and injured motorcycle passengers not wearing helmets.

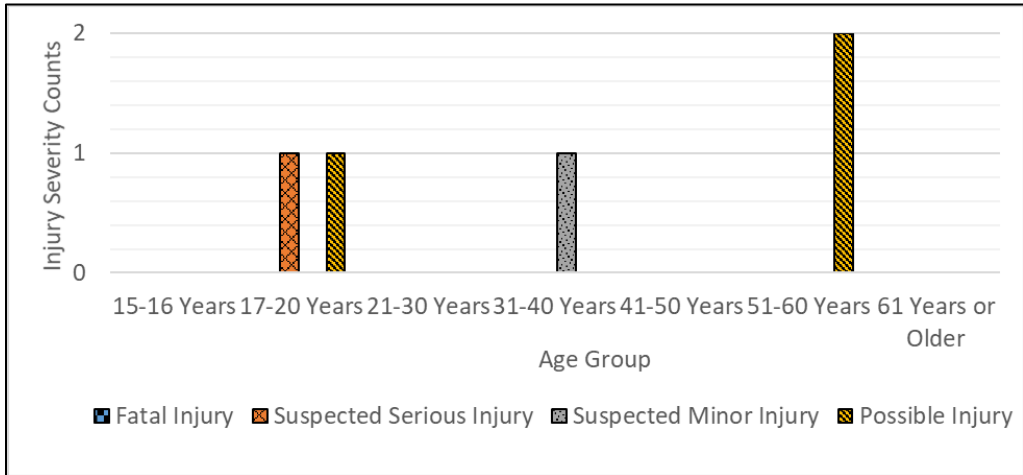


Figure 123: 2019 counts of killed and injured motorcycle operators by age in the first quarter.

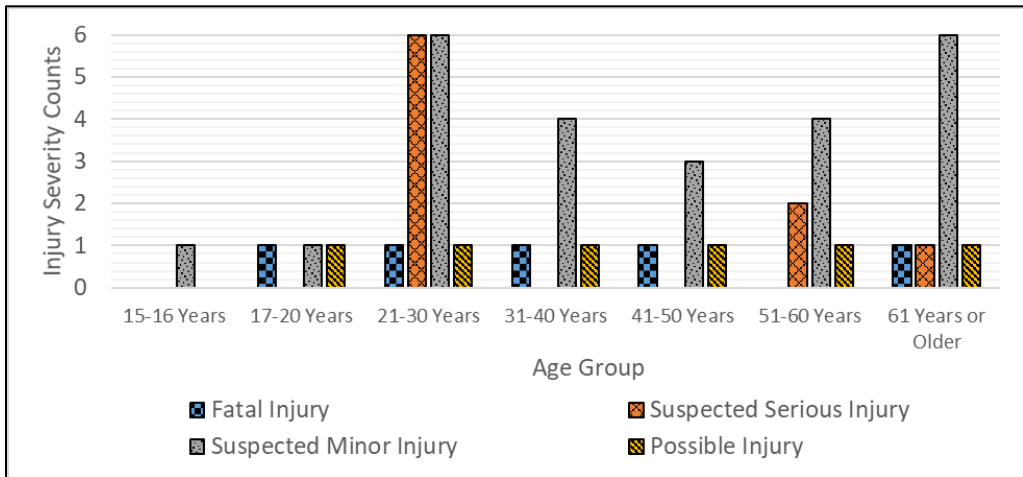


Figure 124: 2019 counts of killed and injured motorcycle operators by age in the second quarter.

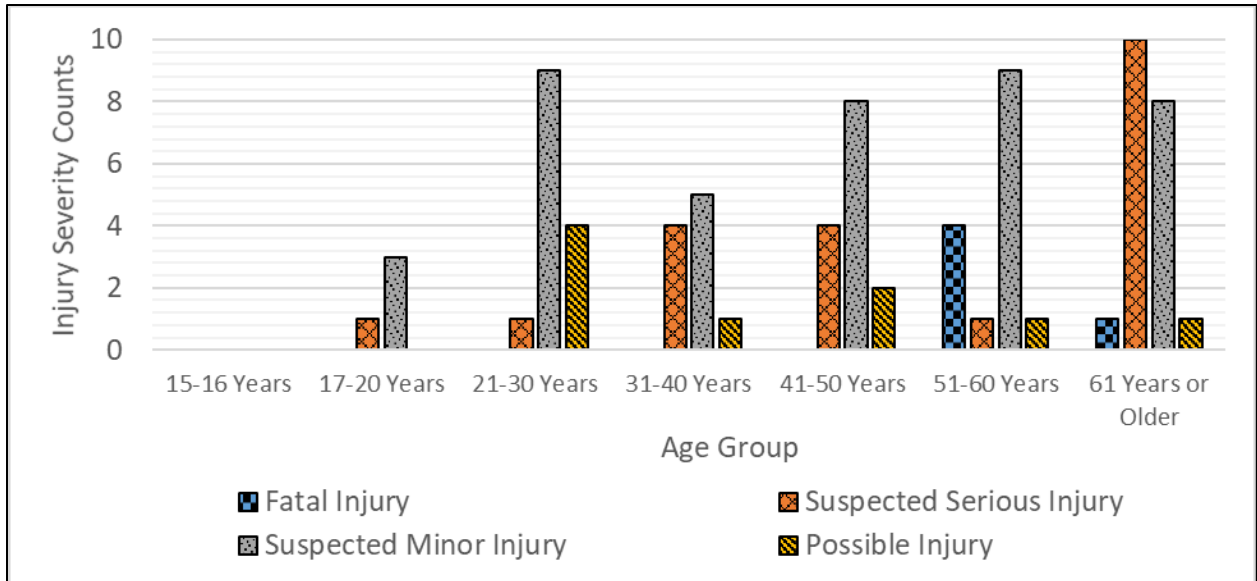


Figure 125: 2019 counts of killed and injured motorcycle operators by age in the third quarter.

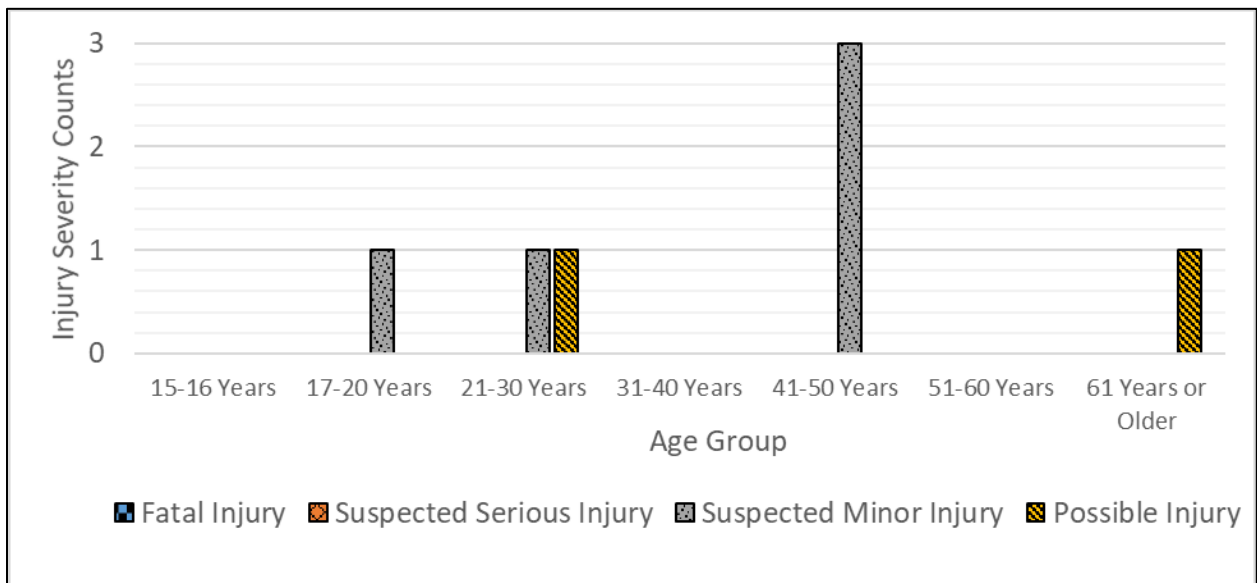


Figure 126: 2019 counts of killed and injured motorcycle operators by age in the fourth quarter.

Table 19: 2019 Counts of Motorcycle Crashes by Manner of Collision

Manner of Collision	Quarter				Total
	1	2	3	4	
Angle (Front to Side), Opposing Direction	0	3	4	0	7
Angle Right (Front to Side, includes Broadside)	2	4	4	0	10
Angle Same Direction (Front to Side)	1	1	0	0	2
Head On (Front to Front)	0	1	3	0	4
Rear End (Front to Rear)	0	3	12	1	16
Sideswipe Opposite Direction (Meeting)	0	1	1	0	2
Sideswipe Same Direction (Passing)	1	2	1	0	4
Not a Collision with Two Vehicles in Transport	3	37	68	7	115
Other	0	2	0	0	2
Total	7	54	93	8	162

Table 20: 2019 Counts of Citations Issued to Motorcycle Operators at the Crash Scenes

Citation	Quarter				Total
	1	2	3	4	
Exceeding the Speed Limit	0	0	1	0	1
Failed to Grant Right-of-Way to Motor Vehicle	0	0	2	0	2
Following Too Closely	0	0	5	0	5
Improper Lane Use	0	1	4	0	5
Improper Passing	1	0	1	0	2
Improper Turning	0	1	0	0	1
Disregarding the Stop Sign	0	1	0	0	1
Careless Driving	0	5	3	0	8
Reckless Driving	0	1	1	1	3
Disregard the Officer	0	1	1	0	2
Hitting-and-Running	0	1	0	0	1
Driver's License Violation	1	9	11	1	22
No Insurance	2	5	7	1	15
Vehicle Registration Violation	1	1	6	1	9
Other	1	2	6	0	9
Total	6	28	48	4	86

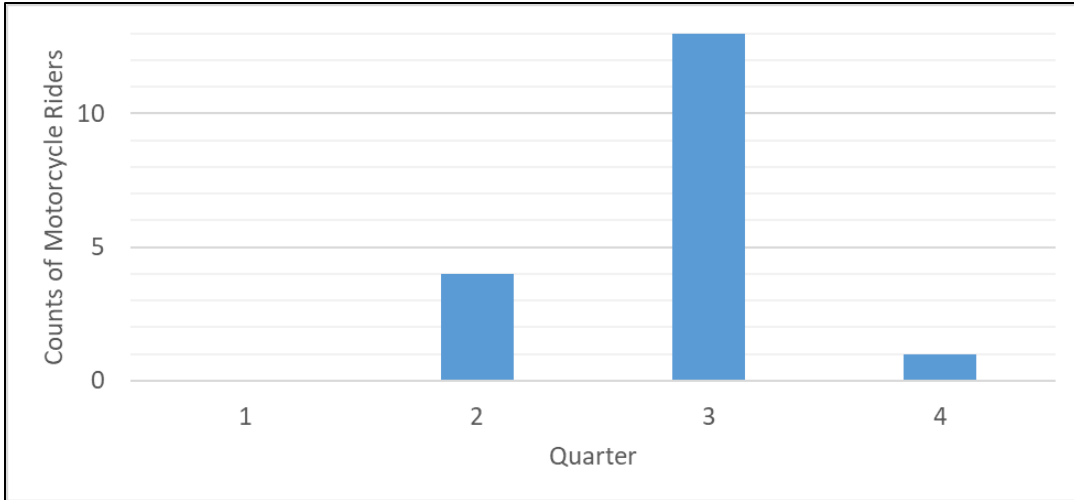


Figure 127: 2019 counts of impaired motorcycle operators.

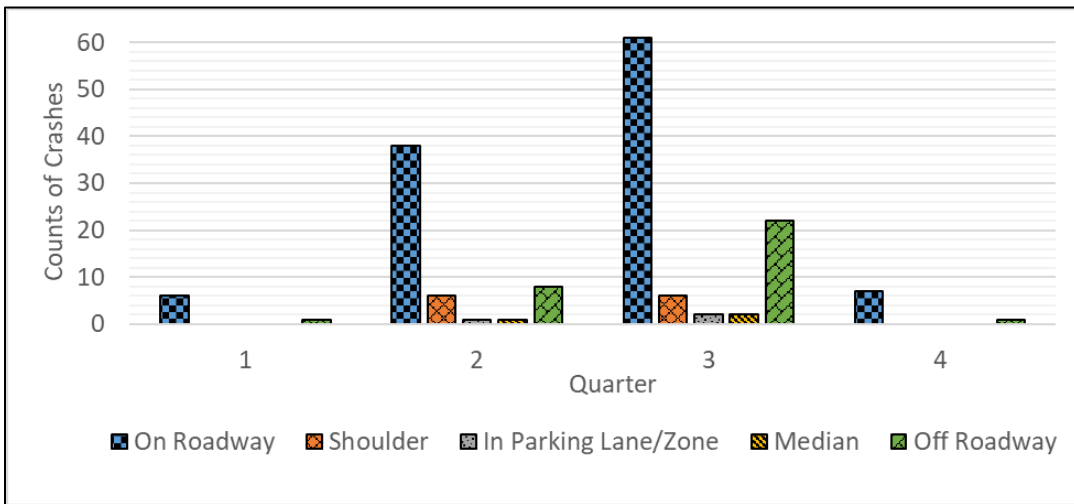


Figure 128: 2019 counts of motorcycle crashes by first harmful event location.

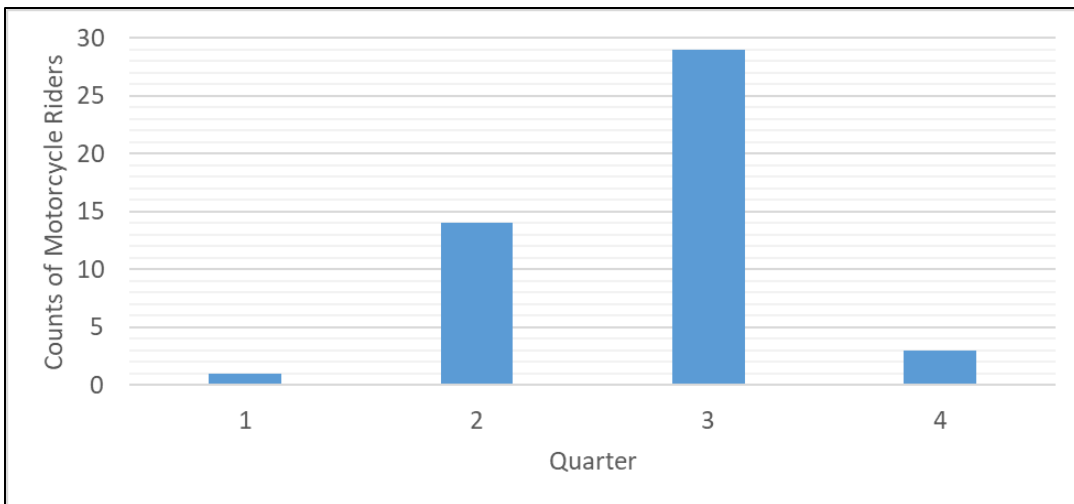


Figure 129: 2019 counts of motorcycles involved in horizontal curve related crashes.

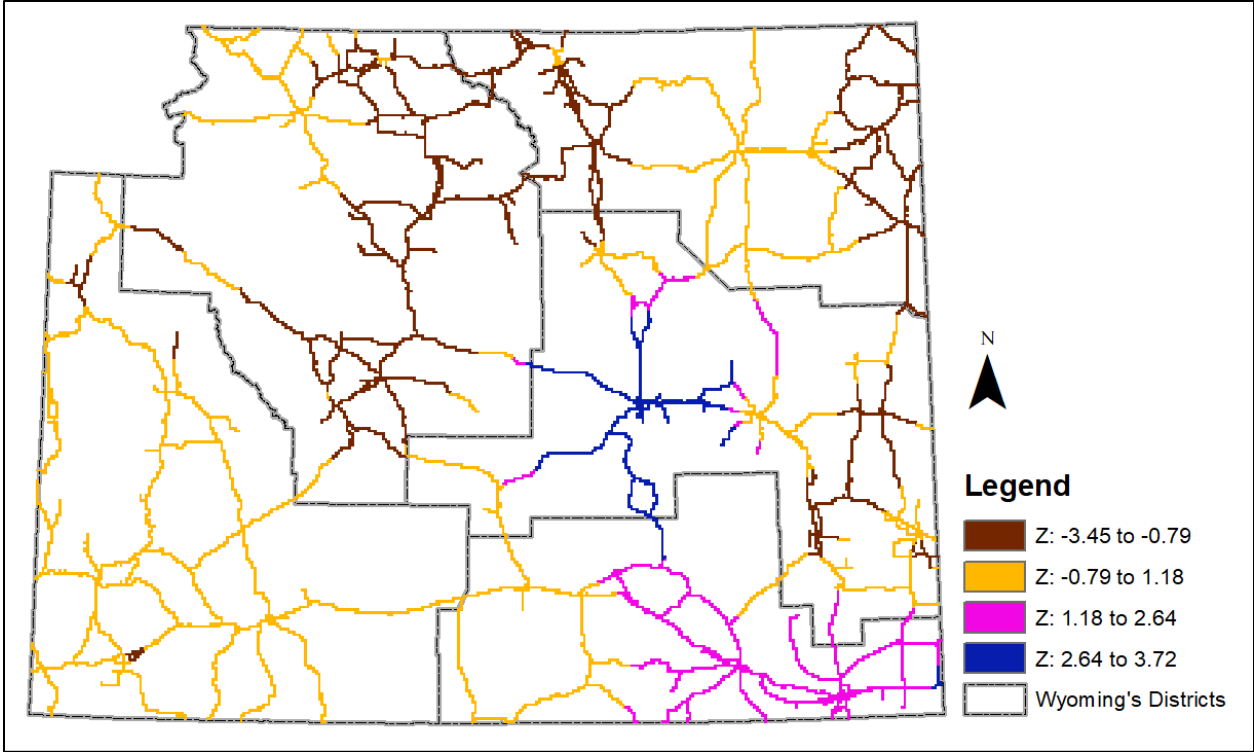


Figure 130: 2017 heat map of motorcycle crashes.

CHAPTER 4: IDENTIFYING CRITICAL HUMAN FACTORS AND APPROPRIATE CRASH DATA REPORTING TIME FRAMES

The second objective of this study was to identify the human factors influencing road safety in Wyoming and crash data reporting periods by employing advanced big data analytics methods. An analysis was conducted to assess the impact of several human factors on crash severity in Wyoming via logistic regression and random forest modeling. Ascertaining appropriate periods to share road safety data is equally important. That is to diagnose road safety concerns and address them promptly. For instance, if crashes of which data were delivered to WYDOT’s partner groups six months after their occurrences, the groups may identify specific problems, such as low seat belt use rates among a specific age group, at a belated time. Yet, as per the survey results of most groups, it is preferred that crash data from police reports be circulated at WYDOT’s earliest convenience in addition to the sharing of processed quarterly road safety data summary statistics. Nevertheless, analyses were conducted to detect variations in crash counts throughout the days in order to ascertain appropriate road safety data delivery periods.

Identifying the Critical Human Factors

Multiple human factors were examined, including the driver’s age, the driver’s gender, driving too fast for the conditions, safety restraint use status, driving recklessly, driving under the influence of alcohol or drugs, driving while distracted, driving while exhausted or sleepy and leaving the crash scene. A sample of crash records was extracted from WYDOT’s road safety database for the years 2018 and 2019 to explore the influence of the human factors on crash severity. The descriptive statistics of the sample’s parameters are presented in Table 21. Note that there were records of 21,837 crashes collected.

Table 21: Descriptive Statistics of the 2018 and 2019 Crash Records’ Sample

Parameter	Frequency	Percent
Fatal or Suspected Serious Injury Crash	799	3.66
Driver Aged Twenty Years or Younger Involved in the Crash	4,838	22.16
Driver Aged Sixty-One Years or Older Involved in the Crash	4,974	22.78
Female Driver Involved in the Crash	10,265	47.01
Speed Related Crash	1,403	6.42
Improper or Non-Use of Safety Restraints Citation(s) Issued at the Crash Scene	349	1.60
Reckless Driving Related Crash	1,213	5.55
Driving under the Influence Related Crash	1,584	7.25
Distracted Driving Related Crash	1,756	8.04
Hit-and-Run Crash	1,680	7.69

As shown in the Table, severe (fatal and suspected serious injury) crashes represented 3.7 percent of the data. Drivers aged twenty years or younger and those aged above sixty were involved in 22.2 percent and 22.8 percent of the crashes, respectively. Female drivers were involved in almost half of the crashes. Also, speed related crashes, reckless driving related crashes, DUI related crashes, distracted driving related crashes and hit-and-run crashes comprised considerable proportions of the crash records. The WYDOT database included information on the driver’s status, whether sound or not. With that, the data’s records included drivers whose statuses were described as exhausted, sleepy or unconscious. It was possible that the drivers were subject to blackouts due to the trauma. Therefore, the driver’s status variable was omitted to avoid biasing the analysis results. Instead, a separate analysis was conducted on this variable. That is, a contingency table test, also known as a χ^2 test, was carried out to compare the injury severities of awake drivers to those of drivers who were exhausted, sleepy or fell unconscious using data of the WYDOT database belonging to the years, 2010 through 2019. The results are presented in Table 22. They indicated that driving while exhausted, drowsy or experiencing a blackout may give rise to a fatal or serious injury.

Table 22: Results of the Driver’s Status-Injury Severity Contingency Table Test

Driver’s Status	Driver’s Injury Severity	
	Suspected Minor Injury, Possible Injury or No Injury	Fatal or Suspected Serious Injury
Awake	236,891 (Row Proportion = 98.53%)	3,538 (Row Proportion = 1.47%)
Exhausted, Drowsy or Fallen Unconscious	8,472 (Row Proportion = 87.89%)	1,167 (Row Proportion = 12.11%)
χ^2	5,678.406	
Degrees of Freedom	1	
P-Value	< 0.001	

Preliminary analysis was conducted on the human factors data (Table 21) using the logistic regression structure. In particular, the severity of the crash records (fatal or suspected serious injury versus suspected minor injury, possible injury and property damage only) was modeled as a function of the human factors. Under the logistic regression model, the probability of incurring a severe injury, P_i , is defined for each crash, i , as follows (Washington et al., 2011):

$$P_i = \frac{\exp(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_p X_{pi})}{1 + \exp(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_p X_{pi})} \quad (1)$$

The terms, X ’s, are the human factor attributes that give rise to the crashes and the β ’s are their respective regression coefficients obtained using maximum likelihood estimation. The model is assessed using the log-likelihood ratio test. It involves computing a χ^2 value which is equivalent to the difference between the model’s log-likelihood and that of a model with the constant term, β_0 , only, also known as the null model. The degrees of freedom are considered as the count of the

model's parameters excluding the constant. Another metric used for evaluating the goodness of fit of logistic regression models is the area under the receiver operating characteristic (ROC) curve. It is a measure of the model's ability to distinguish between severe and non-severe crashes. The influence of the parameters on crash severity is interpreted using odds ratios. An odds ratio is the ratio of the odds of witnessing a severe crash provided that a parameter is in effect to those of encountering the severe crash assuming that the parameter is not in effect.

The logistic regression model was run using the logistic procedure (SAS Institute, 2013) of the SAS software package. The 95th percentile confidence interval was selected as the basis for ascertaining the parameters' statistical significances. The model's results are presented in Table 23, and the parameters' odds ratios are presented in Table 24.

Table 23: Logistic Regression Model's Results

Parameter	Estimate	P-Value
Constant	-3.246	< 0.001
Driver Aged Twenty Years or Younger Involved in the Crash	-0.310	0.004
Driver Aged Sixty-One Years or Older Involved in the Crash	0.216	0.015
Female Driver Involved in the Crash	-0.651	< 0.001
Speed Related Crash	-	-
Improper or Non-Use of Safety Restraints Citation(s) Issued at the Crash Scene	1.399	< 0.001
Reckless Driving Related Crash	-	-
Driving under the Influence Related Crash	1.851	< 0.001
Distracted Driving Related Crash	-	-
Hit-and-Run Crash	-2.123	< 0.001
Model Fit Summary		
Log-Likelihood	-3,113.115	
Log-Likelihood of Null Model	-3,427.293	
χ^2	628.358	
Degrees of Freedom	6	
P-Value	< 0.001	
Area under ROC Curve	0.717	

Note: - = statistically insignificant parameter at the 95th percentile confidence interval removed.

Table 24: Logistic Regression Model's Odds Ratios

Parameter	Odds Ratio	95 th Percentile Confidence Limits	
		Lower Limit	Upper Limit
Driver Aged Twenty Years or Younger Involved in the Crash	0.734	0.596	0.903
Driver Aged Sixty-One Years or Older Involved in the Crash	1.241	1.042	1.477
Female Driver Involved in the Crash	0.522	0.445	0.611
Improper or Non-Use of Safety Restraints Citation(s) Issued at the Crash Scene	4.051	2.961	5.542
Driving under the Influence Related Crash	6.366	5.343	7.586
Hit-and-Run Crash	0.120	0.072	0.199

Each parameter's effect on crash severity was interpreted assuming all else was controlled. As shown in Table 24, the involvement of a driver, aged twenty or younger, in the crash reduced the odds of resulting in fatalities or suspected serious injuries considerably. Perhaps, young drivers are inexperienced and hence are less inclined to execute risky driving maneuvers. Yet, as per Braitman et al. (2008), teenage drivers are likely to commit traffic violations which lead to crashes. The presence of an elderly driver, aged sixty-one or above, raised the odds of sustaining severe injuries possibly because of the deteriorated health conditions of elderly drivers (Amiri et al., 2020). The involvement of female drivers substantially curtailed the odds of giving rise to fatalities and suspected serious injuries. Plausibly, male drivers are more aggressive than female drivers (Insurance Institute for Highway Safety, 2021). Thus, crashes solely involving male drivers are likely to be severe relative to those involving female drivers. Other than age and gender, being cited for not properly buckling up substantially elevated the risk of incurring fatalities and suspected serious injuries, a result consistent with that of the National Highway Traffic Safety Administration (2017). Likewise, a crash involving driving under the influence of alcohol or drugs would drastically increase the odds of giving rise to severe consequences, a finding in-line with Holdridge et al. (2005). On the contrary, a hit-and-run crash was found to be less likely to lead to fatalities and suspected serious injuries possibly because such crashes incur damages to property that are worth less than the minimum reporting thresholds. Speeding, reckless driving and distracted driving were not found to be associated with crash severity. Imprialou et al. (2016) maintained that speeding gives rise to severe crashes. Also, aggressive driving related crashes represented a considerable proportion of fatal crashes according to the Insurance Information Institute (2021). Regarding distracted driving, Lym and Chen (2021) investigated distracted driving related crashes and concluded that their severities varied by the nature of the crash site, whether roundabouts or work zones, among others.

The random forest modeling method (James et al., 2013b), which is a data mining method, was selected to ascertain the importance of the human factor parameters influencing crash severity in

Wyoming as an accompanying subtask. The random forest method is a modification of the decision tree method. It entails the application of bootstrapping. Bootstrapping is a resampling technique in which data points are drawn from the original dataset with replacement and the collected records comprise a new set, termed the bootstrapped set. A large number of bootstrapped sets is generated and a decision tree is developed for each set. However, when the trees are fitted, the tree nodes are split based on calculations performed on a randomly selected number of parameters. This number is equivalent to the square-root of p , the data's parameter count. The random forest model may also be implemented to estimate the relative importance of the parameters in terms of their effects on the outcome crash severity. James et al. (2013b) elaborate on the random forest regression method.

The random forest model was developed using the randomForest package (Brieman et al., 2018) of the R software package. The default number of 500 bootstrapped samples was selected for the model. The model's variable importance chart is presented in Figure 131. As shown in the figure, the importance of each variable was gauged using the mean decrease in the Gini index measure (James et al., 2013b). The Gini index indicates the purity of the tree leaves where a pure leaf is one of which observations are all allocated to the same class of the outcome (severe crash versus non-severe crash). The top three influential variables were identified as DUI, improper or non-use of safety restraints and leaving the crash scene.

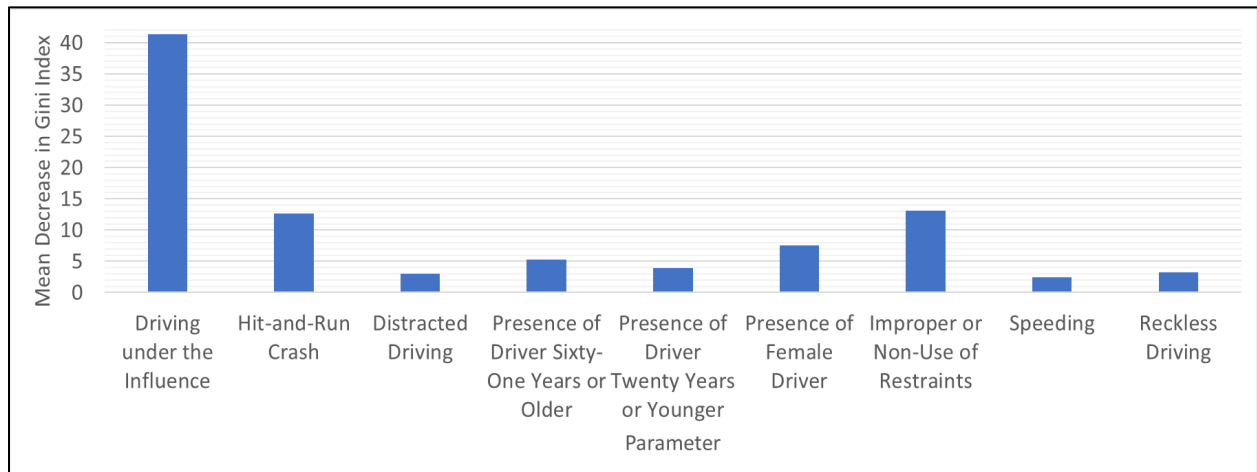


Figure 131: Random forest model's variable importance chart.

It is worth comparing the human factors' analysis results with those of multiple studies related to this project. The studies would include Rezapour and Ksaibati (2021b), Rezapour and Ksaibati (2021a), Rezapour et al. (2021) and Rezapour and Ksaibati (2021c). They were related to safety restraint use, bicycle safety, truck safety and crashes involving child passengers. Each study is discussed in the following content.

Rezapour and Ksaibati (2021b) employed observational safety restraint use survey data collected in 2019 from several counties in the State of Wyoming. A total of 18,286 drivers participated in the survey. The data variables were restraint use status, driver's gender, area type (urban or

rural), weather condition (clear or not), vehicle class (van, sports utility vehicle, pick-up truck or other), time of day, roadway facility type, vehicle registration (Wyoming or out-of-state) and day of week (weekday or weekend). The authors implemented the multinomial logit model, latent class multinomial logit model and latent class multinomial logit model with decision rules. The latent class model with decision rules exhibited the best fit. Also, it was concluded that gender, vehicle class, time of day and roadway facility type would all influence the driver's inclination to buckle up.

In another effort, Rezapour and Ksaibati (2021a) utilized bicycle crash data from WYDOT belonging to the years 2011 through 2019. The data variables were alcohol use, age of the bicyclist, whether the bicycle crash was a hit-and-run crash, driver's action prior to the crash (turning or not), number of travel lanes, lighting conditions, speed limit and the injury severity of the bicycle crash among others. The authors applied a Hamiltonian Monte Carlo method to investigate the influence of the bicycle crash contributing factors on crash severity. According to the study's conclusions, elderly bicyclists, a large number of lanes, dark conditions, high speed roads, alcohol use and other parameters were associated with a greater risk of incurring severe injuries. The authors suggested the establishment of an educational campaign addressing bicycle safety.

Other than the bicycle safety study (Rezapour and Ksaibati, 2021a), Rezapour et al. (2021) conducted analyses that culminated in suggesting safety mitigation measures aimed at improving truck safety. Data of crashes involving trucks having a gross weight vehicle rating exceeding 10,000 pounds were collected from WYDOT and the crash years were 2011 through 2014. Also, truck drivers' ticketing data were collected from the Wyoming Highway Patrol. The authors focused on Interstate- (I-) 80, I-25, portions of US-30 with heavy truck traffic and sections of US-26 with considerable truck traffic. In particular, the data variables were weather condition (clear or not), road surface condition (dry or not), crash season (winter or not), ticket issuance season (winter or not), crash day of the week (weekend or not), crash time (off-peak or not), ticket issuance time (off-peak or not), speed limit, whether the speed limit was exceeded, whether the truck driver was the culpable driver in the crash, and crash type (single-vehicle or multiple vehicle), among others. As per the results, the majority of truck crashes on I-80 and I-25 were witnessed in the winter. For those highways, wet, icy or snowy conditions raised the risk of observing higher truck crash counts. Hence, the authors suggested directing attention to winter weather related truck crashes. The authors also recommended tighter enforcement policies targeting truck drivers traveling along I-80 and I-25 since the analysis results indicated that truck drivers were the ones who were blameworthy in a considerable number of truck crashes on those highways. Other suggestions included addressing low visibility conditions, educating truck drivers (Wyoming and out-of-state truck drivers) on the hazards of traversing mountainous terrain, tightening the enforcement of speeding policies, tightening the enforcement of tailgating policies, tightening the enforcement of erroneous lane change policies and deploying rumble

strips along both aforementioned interstates. The suggestions stated might be discussed in truck drivers' periodicals and newsletters.

Rezapour and Ksaibati (2021c) carried out a study on crashes involving children in Wyoming. Data of crashes involving 12,209 children aged nine and younger were obtained from WYDOT. The crash years were from 2013 to 2019. With that, the data parameters were the safety restraint use status of the driver, road surface condition (icy/snowy or not), alcohol or drug use, weather condition (rainy, snowy or other), child restraint use status by type of restraint (booster seat, forward-facing seat, rear-facing seat, etc.), crash type (rear-end, angle, etc.) and crash severity, among others. The authors selected an ordinal finite mixture modeling approach to conduct their analyses. As per the study's results, incorporating random effects into the modeling improved the goodness of fit. Furthermore, child restraints would reduce crash injury severity and multiple-vehicle crashes would be less severe than single-vehicle crashes. Driving under the influence of alcohol or drugs and the involvement of unbelted drivers would contribute to a higher chance of sustaining severe injuries. Also, icy or snowy road surfaces would decrease the chance of incurring severe injuries possibly because drivers would compensate by traveling vigilantly on non-dry roads. Based on the study's findings, the authors suggested raising the civil fine amounts of intoxicated drivers with child passengers and drivers with unrestrained child passengers to protect children from excessive harm. The authors also shared their concerns about the likelihood of unrestrained drivers with children being involved in severe crashes.

Identifying Appropriate Crash Reporting Time Frames

Other than identifying the crucial human factors influencing crash severity in Wyoming, it is essential that crash-reporting time frames be established. Providing WYDOT's safety partners the relevant data promptly would enable them to diagnose and address safety problems in a timely fashion. The 2019 road safety data of WYDOT were utilized to estimate the appropriate reporting periods. As such, assessments were made on the changes in counts of specific crash types from one day to the other throughout 2019. The crash types were:

- total crashes
- crashes involving fatalities, suspected serious injuries or suspected minor injuries
- crashes involving the issuing of citations for improper use or non-use of restraints
- speeding related crashes
- adverse weather related crashes
- animal crashes
- DUI related crashes
- crashes involving non-motorists
- motorcycle crashes

The bcp package of R (Wang et al., 2018) was employed to evaluate such fluctuations. It implements Markov chain Monte Carlo analyses. Details of the package's procedure are available in Wang et al. (2018). The analysis results are presented in Figures 132 through 140.

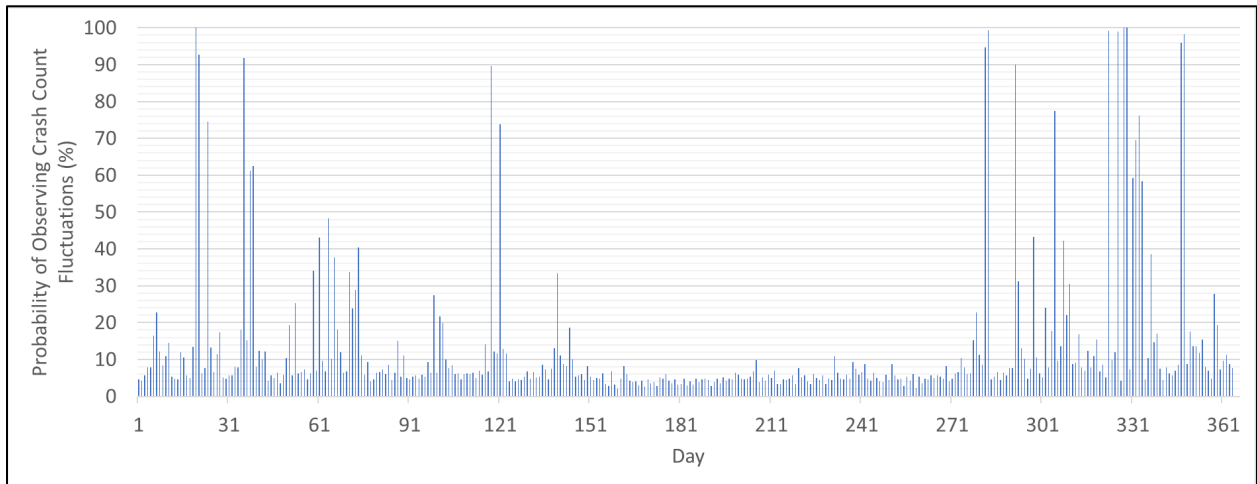


Figure 132: Estimated probabilities of observing fluctuations in crash counts throughout 2019.

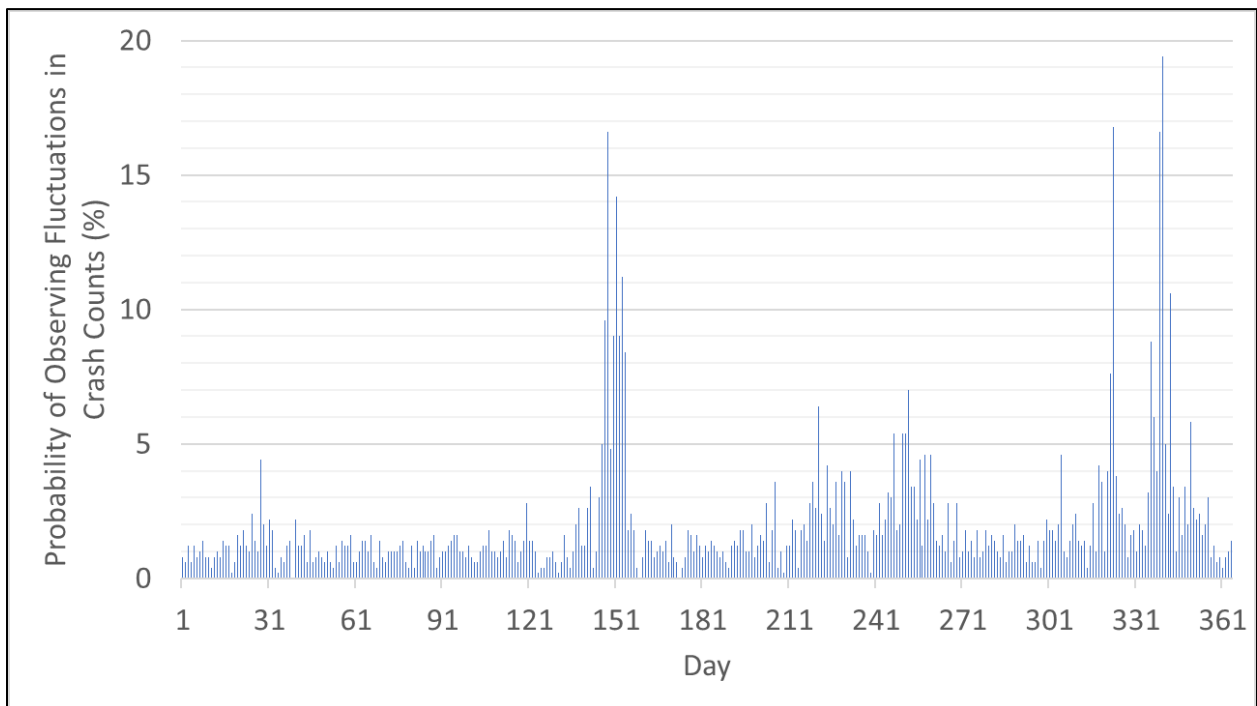


Figure 133: Estimated probabilities of observing fluctuations in counts of fatal, suspected serious injury and suspected minor injury crashes throughout 2019.

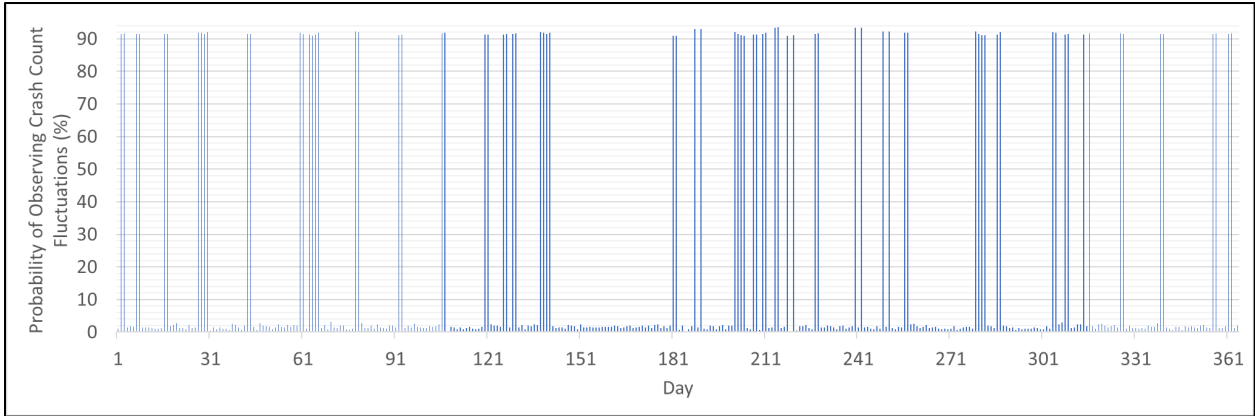


Figure 134: Estimated probabilities of observing fluctuations in counts of crashes involving improper or non-use of safety restraints throughout 2019.

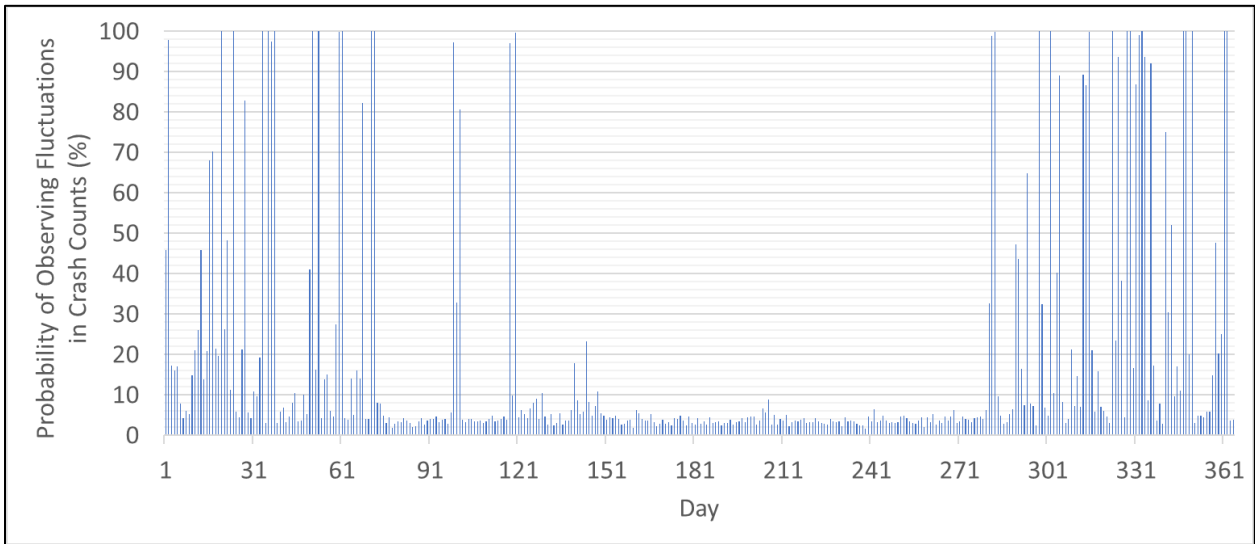


Figure 135: Estimated probabilities of observing fluctuations in counts of speed related crashes throughout 2019.

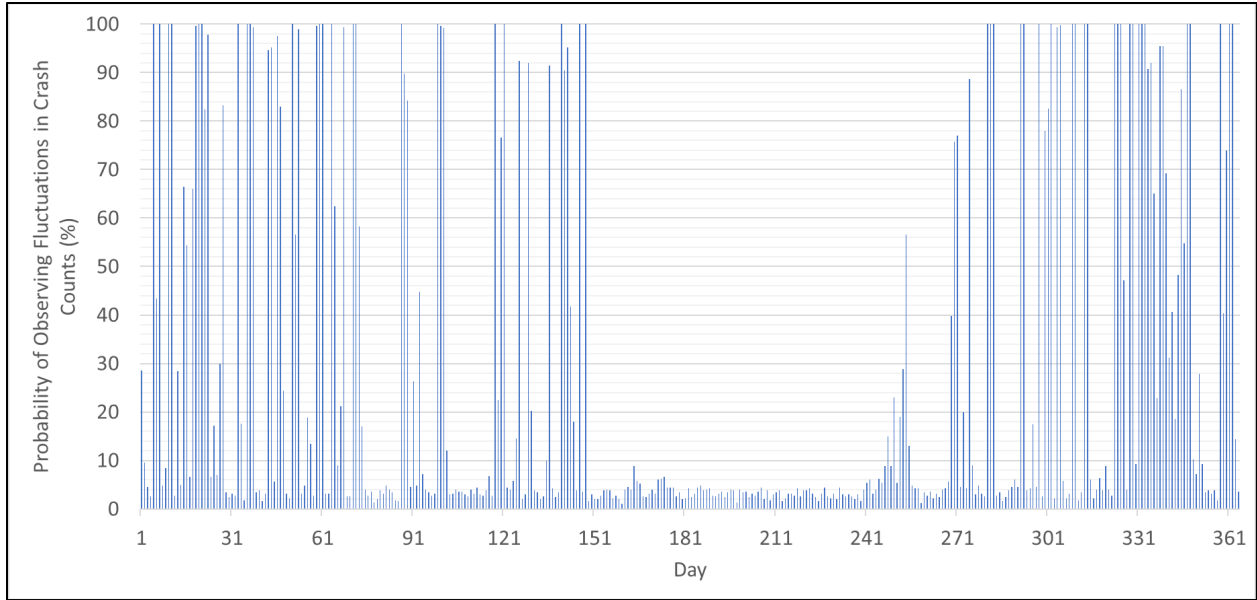


Figure 136: Estimated probabilities of observing fluctuations in counts of adverse weather related crashes throughout 2019.

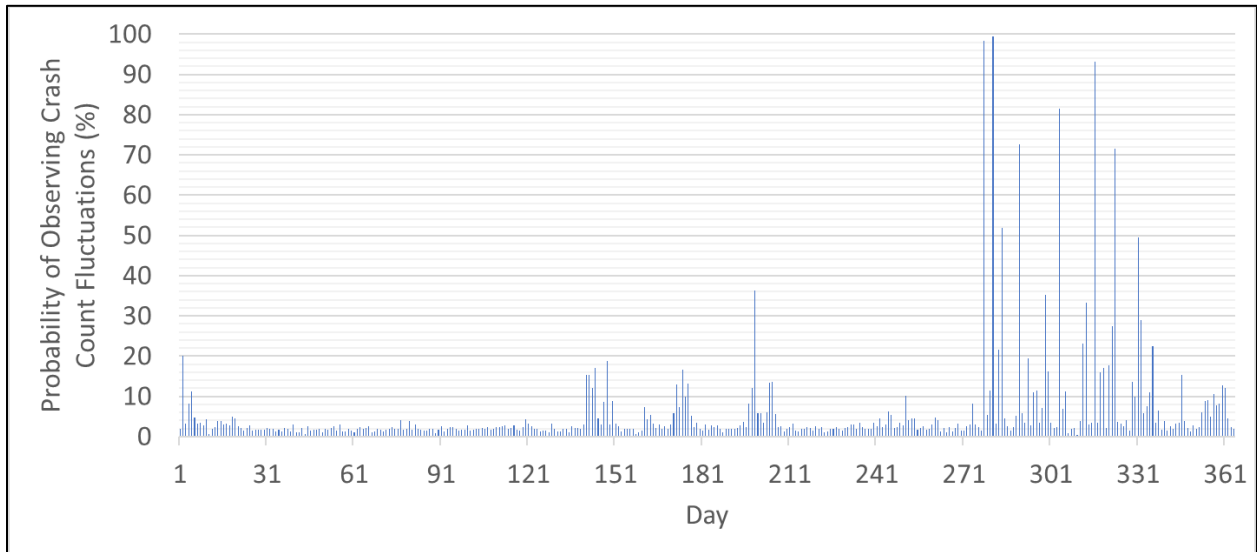


Figure 137: Estimated probabilities of observing fluctuations in counts of animal crashes throughout 2019.

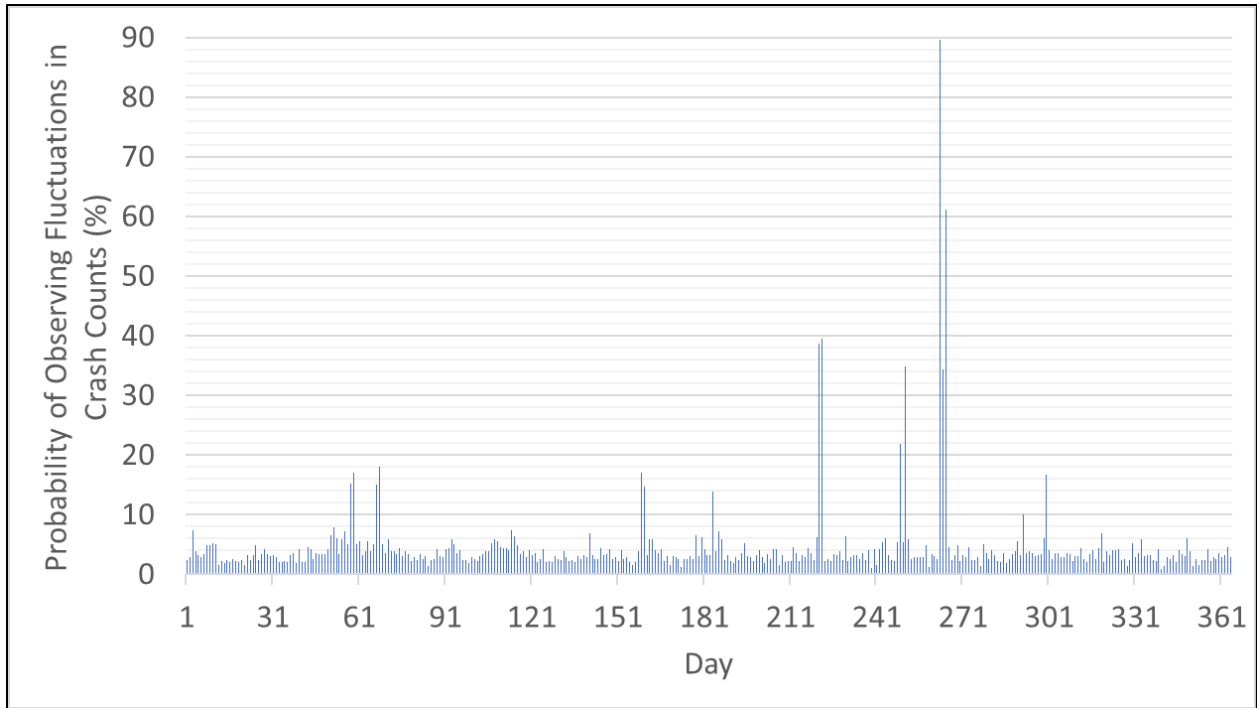


Figure 138: Estimated probabilities of observing fluctuations in counts of driving under the influence crashes throughout 2019.

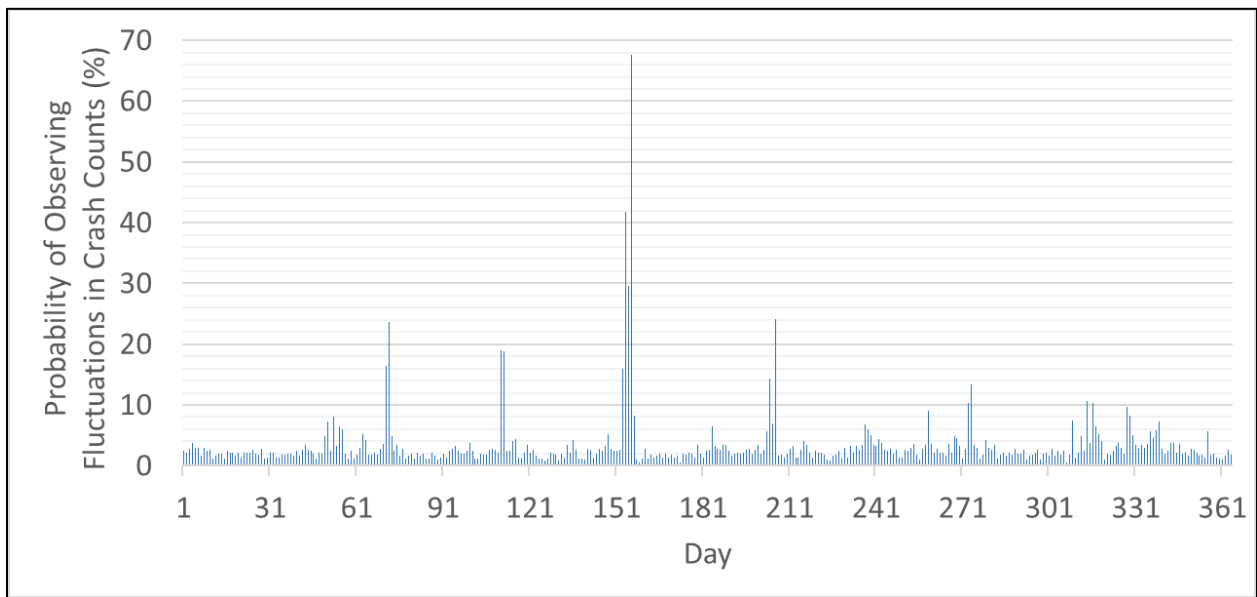


Figure 139: Estimated probabilities of observing fluctuations in counts of non-motorist crashes throughout 2019.

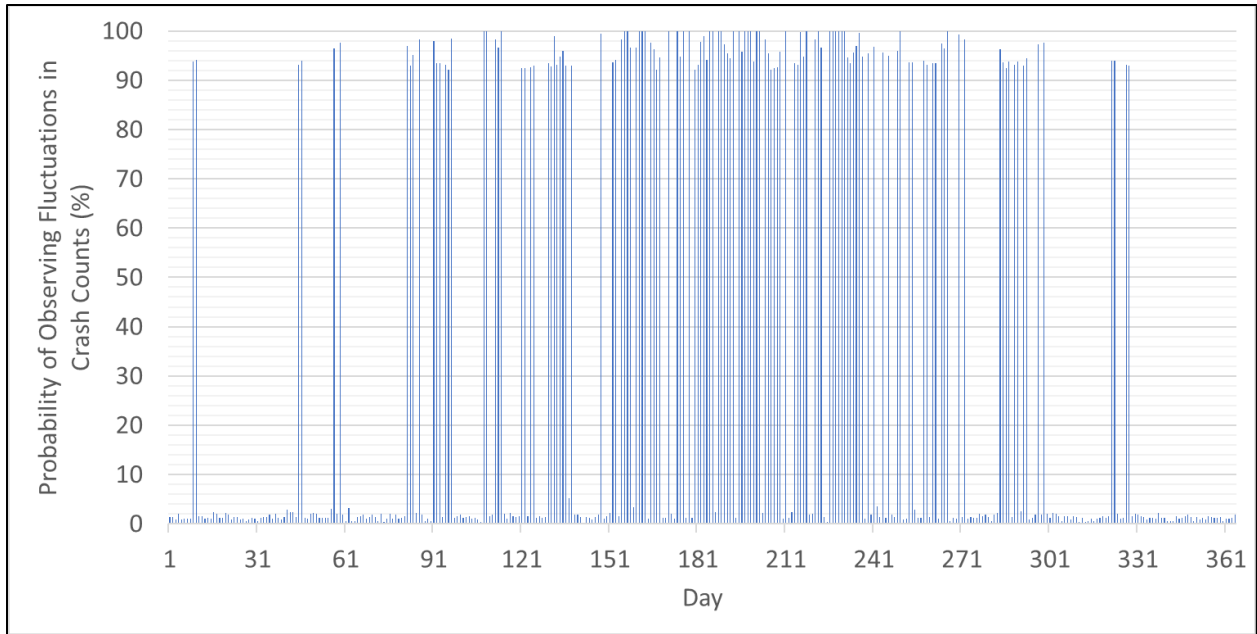


Figure 140: Estimated probabilities of observing fluctuations in counts of motorcycle crashes throughout 2019.

As shown in Figure 132, there were large estimated probabilities of observing fluctuations in crash counts except for the period between June and September. As previously stated, the recommendation is to report crashes, regardless of type, at the earliest convenience to WHP, WASCOP and the counties.

When it comes to fatal, suspected serious injury and suspected minor injury crashes (Figure 133), changes in their observed frequencies from one day to the other did not exceed 20 percent, indicating a steady trend. Similar to the case of total crashes, sharing data of fatal, suspected serious injury and suspected minor injury crashes to WHP, WASCOP and the counties as soon as they are ready for circulation is satisfactory.

The trends of crashes in which citations were issued for improperly buckling up or not buckling up had high estimated likelihoods of fluctuating on a day-to-day basis for multiple months as shown in Figure 134. Hence, it is suggested that data of crashes involving improper use or non-use of safety restraints be provided to the Wyoming Seat Belt Coalition as soon as they are prepared for dissemination. This suggestion is consistent with that provided according to the inferences drawn from the WSBC survey results.

Speeding related crashes exhibited varying trends. The counts of such crashes would fluctuate intermittently except for the period May to September as shown in Figure 135. Reporting speed related crashes to WHP, WASCOP and Wyoming’s counties at the earliest convenience is recommended.

Adverse weather related crash patterns were likely to vary erratically except for the months, June to August, as shown in Figure 136. It is suggested that data of such crashes be shared with WHP, WASCOP and the counties as soon as they are ready for circulation.

Animal crash trends exhibited a low probability of fluctuation except during October and November (Figure 137). The delivery of animal crash data to WHP, WASCOP and Wyoming's counties as soon as practically possible, especially during this period, is recommended.

Concerning DUI related crashes, the trends of DUI related crashes had low likelihoods of constantly fluctuating as shown in Figure 138. Thus, disseminating data of those crashes to WHP, WASCOP, the counties and GCID as promptly as potentially possible is recommended. This recommendation is consistent with those provided according to the interpretations of the corresponding survey results.

Pedestrian and bicycle crash trends exhibited a low probability of continuously oscillating within a week (Figure 139). As previously stated, the surveys' results indicated that it is best to deliver crash data to WHP, WASCOP and Wyoming's counties as rapidly as practically possible. According to the results of the WBPSTF survey, it is also suggested that the WYDOT HSO share its non-motorist crash data to WBPSTF as soon as the data become available.

Unlike non-motorist crash patterns, those of motorcycles were predisposed to vary intermittently from one day to the other. As such, providing motorcycle crash data to WHP, WASCOP, Wyoming's counties and motorcycle groups as promptly as potentially possible is a recommended course of action.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

Ultimately, this study was aimed at assessing the road safety data needs of WYDOT's partner groups, which are the Wyoming Seat Belt Coalition, the Wyoming Highway Patrol, the Wyoming Association of Sheriffs and Chiefs of Police, the Wyoming Transportation Safety Coalition, the Governor's Council on Impaired Driving, Wyoming's counties, the Wyoming Bicycle and Pedestrian System Task Force and motorcycle groups in the state. Even though the aforementioned groups already receive data from WYDOT either in the form of summary statistics documented in reports or database files, there was a dire need to assess the groups' data requirements. This was to inquire about the quality of the data, especially when it comes to crash data reporting time frames and gaps in reporting. Surveys were drafted and disseminated to those groups seeking information on their data needs. The surveys were collected and their results were inferred in order to suggest recommendations for WYDOT regarding road safety data reporting. In particular, the recommendations pertained to specific data elements to be reported, crash data reporting intervals and appropriate formats for presenting the data. Once WYDOT would implement the recommendations, its partners would have access to comprehensive data delivered to them in a timely manner and thus would be able to achieve their objectives efficiently.

Suggestions made for WYDOT include the provision of the following data for WHP, WASCOP and Wyoming's counties:

- Crash statistics by crash type
- Crash injury severity levels statistics by age/gender
- Seat belt use statistics
- DUI statistics
- Fatigued driving related crash statistics
- Distracted driving related crash statistics
- Traffic violation statistics
- Truck policy violation statistics
- Crash statistics by weather condition
- Crash statistics by lighting condition
- Crash statistics by day of the week
- Crash statistics by time of day
- Motorcycle crash statistics
- Hot spots by crash severity level and description (seat belt improper use or non-use, CMV related, etc.)

Other noteworthy suggestions entail the planning for research studies relating to the following topics:

- Effectiveness of speed, seat belt use and other violation enforcement policies

- Effectiveness of traffic safety educational campaigns
- Response times of emergency services, particularly for fatal, suspected serious injury and suspected minor injury crashes

For the other groups, the Wyoming Seat Belt Coalition, Wyoming Transportation Safety Coalition, Governor's Council on Impaired Driving, Wyoming Bicycle and Pedestrian System Task Force and the motorcycle groups, the recommendations are similar. Yet, they are tailored to seat belt use, truck safety, impaired driving, non-motorist safety and motorcycle safety, respectively. Human factors influencing crash severity, including driving under the influence, leaving the crash scene, distracted driving, the involvement of a young driver aged 20 or below, the involvement of an elderly driver aged 61 or above, the involvement of a female driver, improper or non-use of safety restraints, speeding and reckless driving were investigated using two techniques. They were the logistic regression framework and the random forest data mining method. Most of those parameters were found to be influential except for speeding, reckless driving and distracted driving. Furthermore, an analysis was conducted to gauge fluctuations in crash trends. With that, road safety data sharing time frames were suggested. Finally, it is anticipated that WYDOT not only implement the aforementioned recommendations but also develop a strategy to conduct follow-up studies on the aforementioned suggested research topics (e.g. effectiveness of traffic safety educational campaigns, etc.).

REFERENCES

- Abellán, J., López, G., de Oña, J., 2013. Analysis of Traffic Accident Severity Using Decision Rules via Decision Trees. *Expert Systems with Applications* 40 (15), 6047-6054. <https://doi.org/10.1016/j.eswa.2013.05.027>
- Abdel-Aty, M., Abdelwahab, H., 2004. Predicting Injury Severity Levels in Traffic Crashes: A Modeling Comparison. *American Society of Civil Engineers Journal of Transportation Engineering* 130 (2), 204-210. [https://doi.org/10.1061/\(ASCE\)0733-947X\(2004\)130:2\(204\)](https://doi.org/10.1061/(ASCE)0733-947X(2004)130:2(204))
- Albany County Wyoming, 2021. Departments. Albany County Wyoming. <https://www.co.albany.wy.us/35/Departments>. Accessed May 25, 2020.
- American Association of State Highway and Transportation Officials, 2010. *Highway Safety Manual*. American Association of State Highway and Transportation Officials, Washington, D.C.
- Amiri, A., Sadri, A., Nadimi, N., Shams, M., 2020. A Comparison between Artificial Neural Network and Hybrid Intelligent Genetic Algorithm in Predicting the Severity of Fixed Object Crashes among Elderly Drivers. *Accident Analysis & Prevention* 138, 105468. <https://doi.org/10.1016/j.aap.2020.105468>
- Australian Transport Council, 2008. *National Road Safety Action Plan 2009 and 2010*. Australian Transport Council, Australia.
- Braitman, K., Kirley, B., McCartt, A., Chaudhary, N., 2008. Crashes of Novice Teenage Drivers: Characteristics and Contributing factors. *Journal of Safety Research* 39, 47–54. <https://doi.org/10.1016/j.jsr.2007.12.002>
- Breiman, L., Cutler, A., Liaw, A., Wiener, M., 2018. Breiman and Cutler's Random Forests for Classification and Regression. <https://cran.r-project.org/web/packages/randomForest/randomForest.pdf>. Accessed August 6, 2021.
- Carlson, M., Wiggins, J., Rutter, J., Collins, P., Young, T., Emery, A., Greenman, A., Harrist, A., Bravo, D., Caldwell, P., Koehler, J., Hellyer, J., Venable, G., 2018. *Wyoming Bicycle and Pedestrian System Task Force Report 2018*. Wyoming Bicycle and Pedestrian System Task Force, Wyoming.
- Chang, L.-Y., Chien, J.-T., 2013. Analysis of Driver Injury Severity in Truck-Involved Accidents Using a Non-Parametric Classification Tree Model. *Safety Science* 51 (1), 17-22. <https://doi.org/10.1016/j.ssci.2012.06.017>
- Chen, C., Zhang, G., Qian, Z., Tarefder, R., Tian, Z., 2016. Investigating Driver Injury Severity Patterns in Rollover Crashes Using Support Vector Machine Models. *Accident Analysis & Prevention* 90, 128-139. <https://doi.org/10.1016/j.aap.2016.02.011>

- Delen, D., Sharda, R., Bessonov, M., 2006. Identifying Significant Predictors of Injury Severity in Traffic Accidents Using a Series of Artificial Neural Networks. *Accident Analysis & Prevention* 38 (3), 434-444. <https://doi.org/10.1016/j.aap.2005.06.024>
- Delucia, B., Scopatz, R., 2005. *National Cooperative Highway Research Program Synthesis 350 – Crash Records Systems: A Synthesis of Highway Practice*. National Cooperative Highway Research Program, Transportation Research Board of the National Academy of Sciences, Engineering, and Medicine, Washington, D.C.
- Dingus, T., Guo, F., Lee, S., Antin, J., Perez, M Buchanan-King, M., Hankey, J., 2016. Driver Crash Risk Factors and Prevalence Evaluation Using Naturalistic Driving Data. *Proceedings of the National Academy of Sciences of the United States of America* 113 (10) 2636-2641. <https://doi.org/10.1073/pnas.1513271113>
- Environmental Systems Research Institute, 2016. ArcMap 10.4. Environmental Systems Research Institute, West Redlands, California.
- Fernsler, K., 2019. Wyoming Seat Belt Survey. Wyoming State Government, Cheyenne, Wyoming.
- Gordon, M., Carlson, M., James, K., 2021. *Wyoming Highway Safety Behavioral Grants Program FY2021 Highway Safety Plan*. Wyoming Highway Safety Behavioral Grants Program, Wyoming Department of Transportation, Cheyenne, Wyoming.
- Governor's Council on Impaired Driving, 2019. Welcome. Governor's Council on Impaired Driving, Wyoming. <http://www.wygcid.org/home.html>. Accessed May 25, 2021.
- Holdridge, J., Shankar, V., Ulfarsson, G., 2005. The Crash Severity Impacts of Fixed Roadside Objects. *Journal of Safety Research* 36 (2), 139-147. <https://doi.org/10.1016/j.jsr.2004.12.005>
- Imprialou, M.-I., Quddus, M., Pitfield, D., Lord, D., 2016. Re-Visiting Crash–Speed Relationships: A New Perspective in Crash Modelling. *Accident Analysis & Prevention* 86, 173–185. <https://doi.org/10.1016/j.aap.2015.10.001>
- Insurance Information Institute, 2021. Facts + Statistics: Aggressive Driving. <https://www.iii.org/fact-statistic/facts-statistics-aggressive-driving>. Accessed August 6, 2021.
- Insurance Institute for Highway Safety, 2021. Fatality Facts 2019 Males and Females. Insurance Institute for Highway Safety, Arlington, Virginia. <https://www.iihs.org/topics/fatality-statistics/detail/males-and-females>. Accessed August 5, 2021.
- Insurance Institute for Highway Safety, 2021. Fatality Facts 2019 State by State: Fatal Crash Totals. Insurance Institute for Highway Safety, Arlington, Virginia.

- <https://www.iihs.org/topics/fatality-statistics/detail/state-by-state>. Accessed May 24, 2021.
- Insurance Institute for Highway Safety, 2021. *Fatality Facts 2019 State by State: Restraint Use*. Insurance Institute for Highway Safety, Arlington, Virginia.
<https://www.iihs.org/topics/fatality-statistics/detail/state-by-state>. Accessed May 24, 2021.
- James, G., Witten, D., Hastie, T., Tibshirani, R., 2013a. *An Introduction to Statistical Learning with Applications in R*. Springer, New York City, New York.
- James, G., Witten, D., Hastie, T., Tibshirani, R., 2013b. Tree-Based Methods. In: *An Introduction to Statistical Learning with Applications in R*. Springer, New York City, New York., 303–336.
- Kashani, A., Mohaymany, A., 2011. Analysis of the Traffic Injury Severity on Two-Lane, Two-Way Rural Roads Based on Classification Tree Models. *Safety Science* 49 (10), 1314-1320. <https://doi.org/10.1016/j.ssci.2011.04.019>
- Khattak, A., Iranitalab, A., 2016. *Safety Management System Needs Assessment*. Report No. SPR-M025. Nebraska Department of Roads, Lincoln, Nebraska.
- Li, X., Lord, D., Zhang, Y., Xie, Y., 2008. Predicting Motor Vehicle Crashes Using Support Vector Machine Models. *Accident Analysis & Prevention* 40 (4), 1611-1618.
<https://doi.org/10.1016/j.aap.2008.04.010>
- Logan, M., McShane, P., 2006. Emerging Crash Trend Analysis. *Proceedings of the Australasian Road Safety Research, Policing and Education Conference* 10. Clayton, Victoria, Australia.
- Lym, Y., Chen, Z., 2021. Influence of Built Environment on the Severity of Vehicle Crashes Caused by Distracted Driving: A Multi-State Comparison. *Accident Analysis & Prevention* 150, 105920. <https://doi.org/10.1016/j.aap.2020.105920>
- Mitchell, R., Williamson, A., O'Connor, R., 2009. The Development of an Evaluation Framework for Injury Surveillance Systems. *BioMed Public Health* 9 (260).
<https://doi.org/10.1186/1471-2458-9-260>
- Moghaddam, F., Afandizadeh, S., Ziyadi, M., 2011. Prediction of Accident Severity Using Artificial Neural Networks. *International Journal of Civil Engineering* 9 (1), 41-48.
- National Highway Traffic Safety Administration, 2017. *Traffic Safety Facts 2015 Data: Occupant Protection in Passenger Vehicles*. Report Number DOT HS 812 374. National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, D.C.

- National Highway Traffic Safety Administration, 2018. *Traffic Safety Facts - Critical Reasons for Crashes Investigated in the National Vehicle Crash Causation Survey*. Report Number DOT HS 812 506. National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, D.C.
- Rezapour, M., Ksaibati, K., 2021a. Hamiltonian Monte Carlo with Random Effect for Analyzing Cyclist Crash Severity. *Signals* 2 (3), 527-539. <https://doi.org/10.3390/signals2030032>
- Rezapour, M., Ksaibati, K., 2021b. Latent Class Model with Heterogeneous Decision Rule for Identification of Factors to the Choice of Drivers' Seat Belt Use. *Computation* 9 (4), 44. <https://doi.org/10.3390/computation9040044>
- Rezapour, M., Ksaibati, K., 2021c. Modeling Crashes Involving Children, Finite Mixture Cumulative Link Mixed Model. *International Journal of Injury Control and Safety Promotion*. <https://doi.org/10.1080/17457300.2021.1964088>
- Rezapour, M., Wulff, S., Ksaibati, K., 2021. Truck Crashes and Potential Countermeasures on Wyoming Highways and Interstates: Recommendations for All Responsible Agencies. *Journal of Transportation Safety & Security* 13 (4), 436-459. <https://doi.org/10.1080/19439962.2019.1638477>
- SAS Institute, 2013. The Logistic Procedure. In: *SAS/STAT 13.1 User's Guide*. SAS Institute, Cary, North Carolina, 2013, 4486–4738.
- Scopatz, B., Brown, R., Zhou, Y., Benac, J., Peach, K., Bryson, M., Lefler, N., 2017. *Crash Data Improvement Program Guide*. Report Number DOT HS 812 419. National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington, D.C.
- Stylianou, K., Dimitriou, L., Abdel-Aty, M., 2019. Big Data and Road Safety: A Comprehensive Review. *Mobility Patterns, Big Data and Transport Analytics - Tools and Applications for Modeling* 297-343. <https://doi.org/10.1016/B978-0-12-812970-8.00012-9>
- United States Government Accountability Office, 2004. *Highway Safety – Improved Monitoring and Oversight of Traffic Data Program are Needed*. Report Number GAO-05-24. United States Government Accountability Office, Washington, D.C.
- Vapnik, V., 1998. *Statistical Learning Theory 1st Edition*. John Wiley & Sons, Inc., New York City, New York.
- Wang, X., Erdman, C., Emerson, J., 2018. Package “bcp.” <https://cran.r-project.org/web/packages/bcp/bcp.pdf>. Accessed August 6, 2021.
- Washington, S., Karlaftis, M., Mannering, F., 2011. Logistic Regression. In: *Statistical and Econometric Methods for Transportation Data Analysis Second Edition*. Chapman & Hall/Chemical Rubber Company (CRC) Press, Taylor & Francis Group, Boca Raton, Florida, 303-308.

- World Health Organization, 2010. *Data Systems A Road Safety Manual for Decision-Makers and Practitioners*. World Health Organization, Geneva, Switzerland.
- Wyoming Association of Sheriffs and Chiefs of Police, 2021a. About Us. Wyoming Association of Sheriffs and Chiefs of Police, Wyoming. <https://www.wascop.com/about-us>. Accessed May 25, 2021.
- Wyoming Association of Sheriffs and Chiefs of Police, 2021b. Alcohol and Crime in Wyoming. Wyoming Association of Sheriffs and Chiefs of Police, Wyoming. <https://www.wascop.com/alcohol-and-crime-in-wyoming>. Accessed May 25, 2021.
- Wyoming Highway Patrol. 2019. Safety Education. Wyoming Highway Patrol, Cheyenne, Wyoming. http://www.whp.dot.state.wy.us/home/safety_education.html. Accessed May 25, 2021.
- Wyoming Transportation Safety Coalition, 2021. Welcome to the Wyoming Transportation Safety Coalition. Wyoming Transportation Safety Coalition, Wyoming. <https://wyotsc.com/>. Accessed May 25, 2021.
- Yu, R., Abdel-Aty, M., 2014. Analyzing Crash Injury Severity for a Mountainous Freeway Incorporating Real-Time Traffic and Weather Data. *Safety Science* 63, 50-56. <https://doi.org/10.1016/j.ssci.2013.10.012>
- Zeng, Q., Huang, H., 2014. A Stable and Optimized Neural Network Model for Crash Injury Severity Prediction. *Accident Analysis & Prevention* 73, 351-358. <https://doi.org/10.1016/j.aap.2014.09.006>