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Chasing Target Zero: Contributing Factors of Fatal Crashes in South Carolina

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CHASING TARGET ZERO: CONTRIBUTING FACTORS OF FATAL CRASHES IN SOUTH CAROLINA

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by
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Accepted by:
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Dr. Jennifer Ogle

ABSTRACT

South Carolina consistently ranks in the top-10 in fatal crashes per 100,000 capita and 100 million vehicle miles traveled. This thesis summarizes an analysis of contributing factors for fatal crashes in South Carolina. A primary objective of this thesis is to investigate differences in contributing factors for fatal crashes as compared to all crashes in South Carolina. 2018 South Carolina fatal crashes (N=970) and all crashes (N=152,973) were analyzed and compared using classic Venn diagrams to compare differences in contributing factors between fatal crashes and all crashes. Fatal, non-fatal, and all crashes were aggregated into one of seven possible contributing categories based on crash contributing factor assignment as either driver, environment, vehicle, or a combination thereof. The data showed that the driver contributes to 94.9% of all crashes, which is like findings from earlier studies. An interesting finding of this research is that only 83.6% of fatal crashes had a driver contribution. Even more interesting, the contribution from environmental factors increased from 18.1% in all crashes to 49.6% in fatal crashes. Odds Ratios were used to quantify the strength of associations between fatal crashes and non-fatal crashes for specific contributing factors associated with the aggregated contributing factor categories. From these Odds Ratios, it was found that non-motorist contributing factors have a disproportionate association with fatal crashes compared to non-fatal crashes. Fixed objected related crashes were also found to have significant odds ratios values as well. Also, 2020 South Carolina fatal crash data (N=960) and all-crash data (N=133,189) were analyzed to compute Odds Ratios in comparison to 2018 South Carolina crash data to quantify the changes in fatal crash contributing factors considering the COVID-19 pandemic. These findings will be useful to South Carolina officials as statewide countermeasure plans are developed and implemented to ultimately help achieve the mission of "Target Zero," which is to eliminate fatalities on South Carolina's roadways.

ACKNOWLEDGMENTS

I would like to thank Dr. Wayne Sarasua for serving as my advisor and mentor. My gratitude for his guidance and support during my tenure as a graduate student at Clemson cannot be sufficiently formulated into words. Without Dr. Sarasua taking a chance on me after a lunch interview 2 days prior to my undergraduate graduation from Anderson University in December 2019, I'm not sure if my dream to become a civil engineer could have been accomplished. I am extremely humbled and grateful for the opportunity to work for Dr. Sarasua as a Geomatics TA and to obtain knowledge from one of the most highly touted traffic engineers in the Southeastern United States.

I would also like to thank Dr. Jennifer Ogle and Dr. Pamela Murray-Tuite for serving on my committee. Dr. Ogle's transportation safety and roadway design classes were some of the mentally stimulating and beneficial I've taken during my time at Clemson University, and I appreciate her limitless knowledge and passion for the transportation safety. I am also thankful for Dr. Pam's analytical approach to the courses I have taken with her, and her ability to relate numerically based approaches to real-world problems. Her statistical analysis and modeling expertise proved to be vital and useful for this thesis.

This thesis would not have been possible without the diligent work of my colleague Fengjiao Zou, who spent countless hours poring through crash reports and crash data spreadsheets. Her work ethic and her tenacious personality will lead her to success in whatever she chooses to do.

Lastly, I would like to thank Dr. Kweku Brown and Dr. Jeff Davis from the Citadel and Andrew Stokes from SCDOT for each of their contributions to this thesis. The analysis of this thesis would not have been possible without the persistent work and collection of crash data by Andrew Stokes. The framework of the statistical analysis and the formulation of the results would have

been significantly more strenuous without the assistance and expertise of Dr. Brown and Dr. Davis. Each of these gentlemen's tireless work and efforts in this research are greatly appreciated.

DEDICATION

I would like to dedicate this thesis to my Aunt Penny. Just over 16 years ago Aunt Penny was on her way home from Christmas present shopping for her grandson Tyler. About 2 miles from her home, Aunt Penny and a drunk driver collided head on at crest of a hill. Aunt Penny died upon impact, and left her family and friends shattered. In her honor, the findings in this thesis will hopefully save the lives of many road users across the world and save their families the emotional turmoil our family experienced on that November day in 2005.

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Introduction

Highway and transportation agencies across the United States, and beyond, strive to plan, design, construct, operate, and maintain extensive mobility networks that accommodate demand for vitally important movement of people, services, and goods in an effective and efficient manner. The primary objective for individual roadway network users is to travel from origin to destination in a safe and time efficient manner. Due to the magnitude of travel demand, highly variable roadway characteristics, and multitude of safety factors, it is inevitable that crashes will occur throughout the roadway network ranging in severity from minor crashes to fatal crashes. While there are an extensive list of factors that contribute to crashes, by far the largest category of contributing factors falls under the category of driver related (29).

A traditional approach used to better understand the trends in highway safety involve creation of classic crash Venn Diagrams showing three major factor categories that contribute to crashes: 1) human related factors, 2) roadway related factors; and 3) vehicle related factors. Figure 1 provides a Crash Venn Diagram based on a landmark study conducted by Treat, et al (29). The seminal Treat Venn diagram is included in the Highway Safety Manual (9) to help emphasize the important context this work provided through their novel highway safety research. This key Venn diagram indicates that human factors contribute to well over 90% of all vehicle crashes. In applying a classic Venn diagram approach for understanding crashes and evaluating contributing factor relationships and magnitudes, it is widely recognized a different set of factors exists between all crashes versus the consequential subset of fatal crashes.

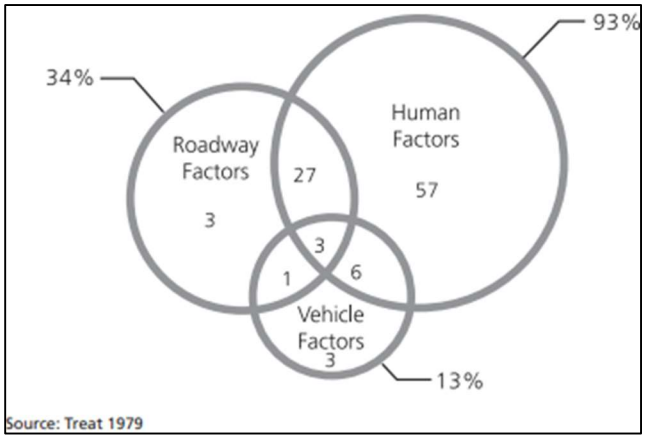

Figure 1: Treat 1979 Venn Diagram (9)

While a great deal of research has been done to identify and evaluate the effectiveness of countermeasures to reduce crashes, many of these countermeasures have little effect on fatal crash incidence. An underlying premise of this crash countermeasure research is that traffic crashes are a function of vehicle conflicts. While this is true for the vast majority of all crashes, it is not true for fatal crashes (24). Nearly half of South Carolina's fatal crashes involve roadway departure and nearly a third are the result of impaired driving. Many of these fatal crashes are single vehicle crashes where conflicts with other vehicles do not contribute to the fatal crash.

In the last few years, South Carolina instituted a Target Zero initiative with a goal of achieving zero traffic fatalities. South Carolina's Target Zero plan is multifaceted in that it identifies several preventative measures to reduce fatalities (28). While South Carolina's Target Zero plan is aspirational, the reality is that there is not an expectation that zero fatalities will ever be a reality. The goal research is to analyze the contributions of fatal crashes in South Carolina and to quantify how these contribution factors differ from non-fatal crashes. Developing a better understanding of the contributing factors of fatal crashes may lead to solutions that can eventually make Target Zero a reality. The first objective of this thesis is to classify contributing factors of fatal crashes and quantify the contributing factors for fatal crashes. This research will tabulate a distribution of contributing factors to fatal crashes and evaluate how factors differ from the distribution for all crashes, through analysis of 2019 South Carolina fatal crash data, and compiling results using the Treat 1979 Venn Diagram framework, as shown in Figure 1. Using these classifications, a Venn Diagram was populated based on the total number of crashes for each classification category. Figure 2 provides a template of the contributing factor Venn Diagram used in this thesis.

The second objective of this thesis is to quantify the differences in contributing factors between fatal crashes and non-fatal crashes using Odds Ratios. For this portion of the thesis, 2018 South Carolina fatal crash data was analyzed to determine contributing factors for fatal crashes in South

Carolina and contrasts these factors in comparison to the factors for all crashes during the same 2018 period. The 2018 crash dataset, provided by the South Carolina Department of Transportation (SCDOT), was utilized because it was the most recent dataset that is considered complete.

The third objective of this thesis is to compare the differences between the 2018 crash data and

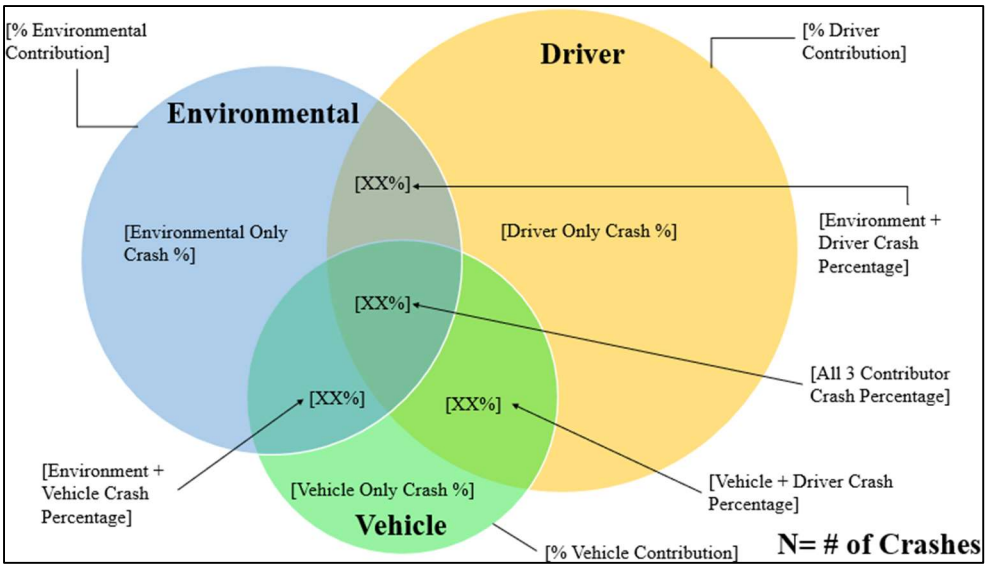

Figure 2: Contributing Factor Venn Diagram Template.

2020 crash data to determine if there were any significant changes in contributing factors for fatal and non-fatal crashes during the COVID-19 pandemic. During the COVID-19 pandemic, a majority of states in the U.S. issued travel bans. These travel bans had significant impacts on the traffic volumes and vehicle miles traveled during this time period. In 2018, the total traffic volumes was 1,410,571,781 vehicles, compared to 2020 where the total volume was 1,486,314,083 vehicles. It is evident that travel activity was impacted by the pandemic, and this thesis will outline the differences in contributing factors between fatal crashes in 2020 compared to 2018 in light of the pandemic using statistical analysis.

The final objective of this research approach is to align findings supporting the South Carolina Target Zero initiative. Developing a better understanding of contributors to fatal crashes is critical

in devising a plan that credible to the public, decision makers, and drivers to help further Target Zero crucially important goals and objectives.

This thesis is composed of five chapters: introduction, literature review, methodology and data summarization, analysis & findings, and conclusions. The introduction chapter provides an outline of the methods used during this research, as well as establish the objectives for the thesis. The literature review provides a detailed composition of literature and former research regarding crash contributing factors and other elements related to crashes. The methodology chapter presents the different classification methods used to quantify contributing factors as well as provides a general description of the Odds Ratio statistical analysis used to determine the likelihood of contributing factors contributing to a fatal crash compared to a non-fatal crash. The analysis & findings portion of this thesis presents the results of the Odds Ratio statistical analysis as well as the crash-volume comparison performed on the 2018 & 2020 South Carolina crash data. The closing chapter of this thesis provides a summary of the significant results of this research as well as readdress the status and completion of the objectives stated in the introduction chapter.

Literature Review

Driver-Related Contributing Factors and Characteristics

There are a multitude of contributing factors to crashes, however, there is a particular subset of prevalent contributing factors that correspond with fatal crashes. Specifically, driver-related contributing factors play an increased role in the crash environment (29). According to Bédard et al., age, gender, alcohol use, and restraint use are among the major driver-related contributing factors to fatal crashes (2). Despite considerable efforts to reduce driving under the influence (DUI) in the United States, about twenty percent of drivers continue to do so (5) which results in thousands of fatal automobile crashes every year (19, 26).

Age is a driver-related characteristic that appreciably impacts fatal crash occurrence. The National Highway Traffic Safety Administration estimates young drivers are involved in three times as many fatal crashes as all other drivers (21). In combination with age, Peek-Asa, et. al compared rural roadway factor prevalence in fatal crash occurrence and determined rural teen crashes were 4.7 times more likely to lead to a fatal or severe crash than urban teen crashes (25).

Use of a seatbelt restraint has proven to be an effective means of lessening the severity of vehicle crashes. Evans and Wasielewski conducted a study focusing on risk factors in driver-related crashes, determining drivers who are involved in more crashes tend to use seat belts less (6). The proportion of fatally injured drivers using seatbelt restraints in the fatal crashes compared to no seatbelt restraint, exhibits an “inverted U-shape” relationship, where younger and older populations have a higher severity impact ratio compared to middle-aged populations (2).

Another driver-related factor that contributes to fatal crash occurrence is exceeding the posted speed limit and other speed-related contributing factors. In fatal crashes, about 55 percent of all speeding-related crashes were due to “exceeding posted speed limits” as compared to the 45

percent that were due to “driving too fast for conditions (12).” In a report completed by AAA, it states that 30.7 percent of all fatal crashes from 2003 to 2007 involved a speeding driver (1). Aggressive driving is another notable driver related crash contributing factor. A study of data from the Fatality Analysis Reporting System (FARS) found that 55.7% of fatal crashes involved one or more unsafe driving behaviors typically associated with aggressive driving (1,11).

Environmental Contributing Factors and Characteristics

Another critical element of fatal crashes is related to the surrounding roadway environment where crashes occur. The Treat study explicitly states that environmental factors consist of obstructed view, slick roads, transient hazards (non-motorists), design problems, and other control hindrances (29). Among contributing factors, one of the most critical factors are trees, utility poles, and other fixed objects located within the clear zone. Turner and Mansfield conducted a study on trees and fixed objects located within clear zones and determined that trees account for more fixed-object fatal crashes than any other roadway element (30). Another study performed by Ogle et al., states that fixed object crashes account for 20% of all crashes in South Carolina, and nearly 50% of all fatal crashes (22).

Road surface condition is an environmental related factor that can contribute to fatal crashes. Wang and Zhang conducted a study showing the ratio of fatal crashes for wet conditions compared to dry conditions is lower due to the driver’s expected alertness and awareness of the road conditions and resulting driver adjustment actions taken (31).

Among the most prevalent and impactful environmental contributing factors are non-motorists. Based on the crash report template in the Model Minimum Uniform Crash Criteria (MMUCC), non-motorist factors consist of pedestrians, pedal cyclists, wild animals, and other similar nonvehicle factors (15). An environmental contributing factor category to consider in the crash

environment are animal-related crashes. Although the majority of animal-vehicle crashes involve human injury (86.9%) or human fatality (77%), most animal-vehicle crashes in the U.S., also, involve deer (14).

One of the major environmental contributing factors that are prevalent in the fatal crash environment. The three dominant contributing factors in non-motorist/pedestrian crashes are: alcohol/drugs, impaired, and improper crossing (17). Research on pedestrian-vehicle crashes determined pedestrian crashes account for a small proportion of crashes (approximately 2-3%) but represent a considerably higher proportion of fatal crashes (approximately 11-13%) (4,16). The pedestrian's action during the crash can certainly play a critical role in the crash environment. According to DaSilva, nearly 29% of crashes involving pedestrians crossing improperly, and over 37% of pedestrians were illegally in the roadway (17).

Vehicle Contributing Factors and Characteristics

Of note regarding vehicle contributing factors is these factors generally attribute a very small influence in crash occurrence. According to the NHTSA, vehicle-related factors contribute to approximately 2% of fatal crashes (18). Some vehicle-related contributions include tires, brakes, steering, and other vehicle-related problems (18). Haq et al. conducted a study have that determined vehicle-related defects contribute to approximately 9-18% of all crashes, however, the influence of these factors is considerably lower for fatal crashes (7).

Furthermore, condition and durability of a vehicle's tires play a critical role in the ability to control the vehicle (7). Tire blow out is the most common type of tire defect and causes the most lack of control of any other vehicle defect (23).

Methodology and Data Summarization

Crash Characteristics

The first step in conducting this study was to analyze South Carolina crash reports (Form TR-310) to examine the different crash characteristics for the purpose of identifying primary contributing factors to a crash. According to FHWA's Highway Safety Improvement Program (HSIP), crash contributing factors can be related to roadway geometrics, roadway condition, human factors (e.g., drivers, motorcyclist, pedestrians), vehicle factors that contribute to the crash avoidance and survivability, and other environmental conditions (8). South Carolina crash reports follow the Model Minimum Uniform Crash Criteria (MMUCC) guidelines (15). Crash reports include a variety of different characteristics and data elements including crash data elements, person data elements, roadway data elements and several other elements. Based on South Carolina crash reports, the crash characteristics considered for this study include first harmful event (FHE), most harmful event (MHE), roadway surface condition (RSC), weather conditions (WCC), light condition (ALC), and contributing factor fields, which are analogous to the MMUCC contributing circumstances (15).

Table 1 summarizes a data dictionary of selected codes associated with the crash fields used to determine contributing factor categories for each crash. The methodology used for this study parallels categories used by Treat (29). In that study, vehicle driver contributions were separated from other human factor contributions such as pedestrians, bicyclists, and other non-motorists. Other human factor contributions were included within the roadway environment category.

Table 1 also includes a contributing field category for each field. Common contributing factor codes associated with driver-related crashes include driving too fast for conditions, failing to yield the right-of-way, running off the road, aggressive driving, and driving under the influence.

Table 1: Fatal Crash Data Coding Dictionary Guide (20).

	Driver/Human	Environmental/Roadway	Vehicle
Harmful Event ▪ **FHE** ▪ **MHE**	13= Over-Correcting 16= Under the Influence	**Fixed Object:** 49= Fence 54= Light Lum. Support 55= Mailbox 56= Median Barrier 58,59= Other Fixed Object 60= Tree 61= Utility Pole **Natural Elements:** 14= Swerving to Avoid Obj. 20,21= Animals 38,39= Other Movable Obj. **Roadway Elements:** 40,42= Bridge Components 44= Culvert 46,47= Ditch/Embankment	3= Downhill Runaway 4= Equipment Failure 18= Other Non-Collision
Contributing Factor ▪ **PRC** ▪ **OCF1** ▪ **OCF2** ▪ **OCF3** ▪ **OCF4**	***16= Under the Influence*** **Inattentive:** 1= Disregarded Signal 2= Distracted/Inattention 7= Fatigued/Asleep 19= Cell Phone **Speed-Related:** 3= Too Fast for Conditions 4= Exceeded Speed Limit **Aggressive Driving:** 8= Followed Too Closely 12= Aggressive Driving **Violations/Maneuvers:** 5= Failed to Yield ROW 6= Run Off Road 9= Improper Turn 13= Overcorrect./Oversteer 14= Swerving to Avoid Obj. 15= Wrong Side/Wrong Way 18= Improper Lane Use/Chg. 28= Other Improper Action **Other:** 10= Medical Related 29= Unknown	**Roadway Elements:** 30= Debris 31= Non-Hwy Work 32= Obstruct. In Rdwy 33= Road Surf. Cond. (Wet) 34= Rut, Hole, Hump 35= Shoulders 36= Traffic Control Device (Miss.) 37= Work Zone (Contr./Maint.) 38= Worn, Travel Polish. Surf. 48= Unknown Rdwy Factor 62= Obstruction **Non-Motorist:** 50= Non-Motor. Inattentive 51= Lying/Illegally in Rdwy 52= Non-Mot. Fail Yield ROW 53= Not Visible (Dark Clothing) 54= Non-Motor Disregarded Sign/Signal 55= Improper Crossing	70= Brakes 71= Steering 72= Power Plant 73= Tires 74= Lights 75= Signals 76= Windows 77= Restraint Systems 78= Truck Coupling 79= Cargo 80= Fuel System 88= Other Vehicle Defect 89= Unknown Vehicle Defect

		56= Darting 57= Non-Motor. Wrong Side Road 58= Other Non-Motor. Factor 59= Non-Motorist Unknown 66= Non-Motor. Under Influence 67= Other Person Under Influence	
Light Condition ▪ **ALC**		*Covered in contributing factors with dark clothing	
Road Surface Condition ▪ **RSC**		*If RSC=2 or "Wet" and Contrib. Factor=3 or "Too Fast for Condit."	

Harmful events considered to be driver related include wrong side or wrong way, and over-correcting/over-steering. Additionally, several road element codes related to environmental contributors include obstructions, roadway surface condition, and stationary objects coded as harmful events (e.g., ditches, trees, and utility poles) were classified under the road environment category. Striking traffic control devices was not included as an environmental contributor. Vehicle-related contributing factor codes include mechanical issues, tire blowout/condition, and other defects related to the vehicle.

2019 SC Contributing Factor Data Field Population and Coding (Detailed Approach)

In addition to the deterministic approach for quantifying contributing factors for the 2018 South Carolina crash data, a detailed approach was implemented on 2019 South Carolina fatal crash data. The detailed approach for coding the crash contributing factors assigns a code based on the of level of contribution for each contributing factor category in each crash. A collection of Clemson University civil engineering students, staff, and myself analyzed each of the crashes in the 2019 fatal crash dataset and determined the contribution for each of the three (3) contributing

factor classes, or a combination thereof. Each crash was examined and assigned a coded value based on the codes provided in the FHE, primary contributing factor (PRC), other contributing factor (ORC 1, ORC 2, ORC 3, and ORC 4), and RSC fields of our dataset. The identification codes for these respective fields were provided by the South Carolina Department of Public Safety (SCDPS) Office of Highway Safety Data in the *Traffic Records Users Data Dictionary*. Table 2 shows the coding classification used to code the 2019 data based on their contribution level to the crash.

Table 2: Detailed Approach Coding Classification Guide.

Code Value	Definition
0	Did not contribute to crash
1	Definitely contributed to crash
2	Probably contributed to crash
3	Maybe committed to crash
4	Special environmental/non-motorist contrib.

After retrieving all of the data from the Clemson University civil engineering students and staff, I personally checked each of the crashes to ensure they were coded uniformly based on pre-defined criteria for each contributing factor category. Upon completing this quality control measure and adjusting inconsistent/biased coding, each of the crashes were assigned to one of the seven (7) contributing factor categories defined in the previous section.

2018 SC Contributing Factor Data Field Population and Coding (Binary Approach)

After establishing classifications for crash contributing factors, analysis of the 2018 South Carolina fatal crash dataset was conducted. First, four new fields were designated to group crashes aligned with simplified contributing factor categories including 1) driver, 2) environment,

3) vehicle, and 4) contributing factor combination. The driver, environment, and vehicle categories are binary. Using contributing category information in Table 1, the driver, environment, and vehicles categories were populated for each crash with a "1" if the category contributed to the crash, or a "0" if the category did not contribute to the crash. For example, if for a particular crash contributing factor codes are 16 (under the influence) and 33 (roadway surface condition) a "1" would be entered in the driver field and a "1" was also entered in the environmental field. The crash contribution factor attribution process of translating 2018 SC crash records was implemented using a Microsoft Excel spreadsheet. The data set included 970 fatal crash records and 152,974 total crashes occurring during 2018 in South Carolina.

The next step was to populate contributing category code fields. Seven (7) possible entries contingent upon whether driver, environment, and vehicle fields were assigned using a value of "1." Seven (7) possible aggregated crash category entries include:

1) Driver Only
2) Environment Only
3) Vehicle Only
4) Driver and Environment
5) Driver and Vehicle
6) Environment and Vehicle
7) Driver, Environment, and Vehicle.

2019 South Carolina Fatal Crash Contributing Factor Venn Diagram

Based on the aggregated contributing factor category code field assignment, percentages for each combination of contributing factor category pertaining to fatal crashes were calculated. Venn Diagram percentages for 2019 SC fatal crashes (N=919) are summarized in Figure 3.

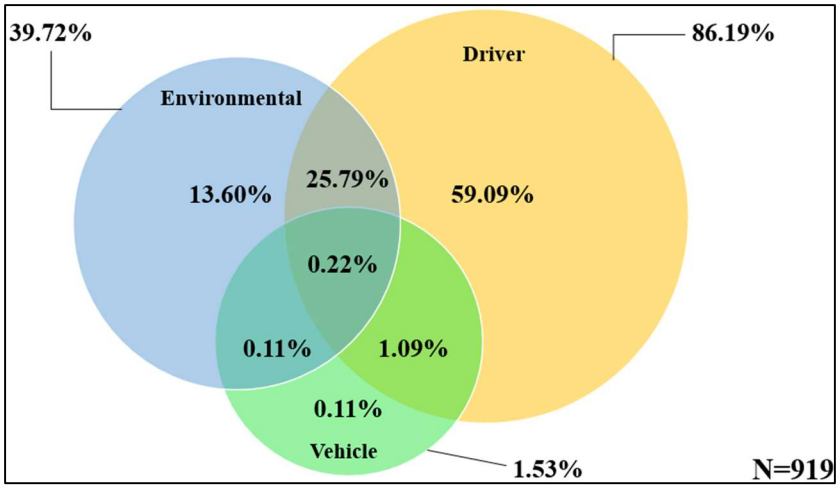

Figure 3: 2019 SC Fatal Crash Contributing Factor Venn Diagram (N=919).

As indicated in Figure 3, it is evident that driver-related factors play a significant role in a majority of 2019 SC fatal crashes. The driver contributes to 86.18% of fatal crashes combined, with more than 59% of fatal crashes being attributed solely to the driver. Additionally, environmental contributing factors contribute to 39.72% of fatal crashes. Lastly, vehicle contributing factors contribute to only 1.53% of fatal crashes.

2018 South Carolina Crash Contributing Factor Venn Diagrams

Based on the aggregated contributing factor coding assignment, percentages for each combination of contributing factor category pertaining to fatal crashes were calculated. Venn Diagram percentages for 2018 SC fatal crashes (N=970) are summarized in Figure 4. Venn Diagram percentages for all 2018 SC crashes (N=152,974) are summarized in Figure 5 for the purpose of providing a useful baseline to contrast and compare with contributing category factors affecting the subset of fatal crashes occurring during the same period.

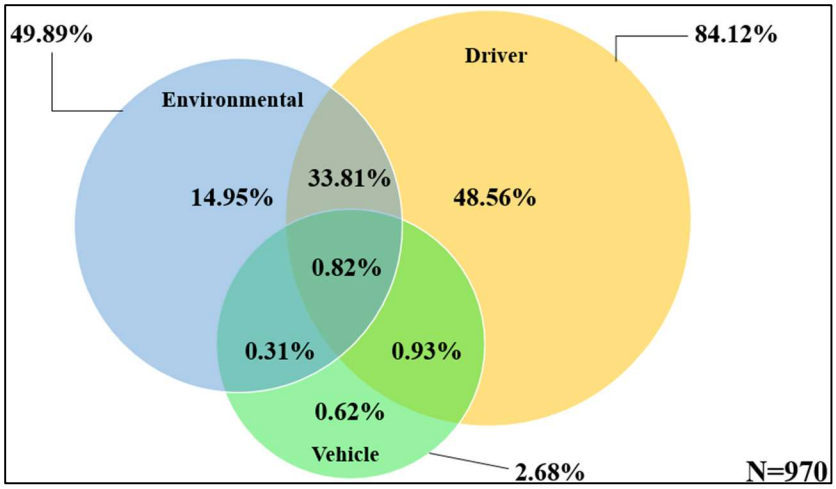

Figure 4: 2018 SC Fatal Crash Contributing Factor Venn Diagram (N=970).

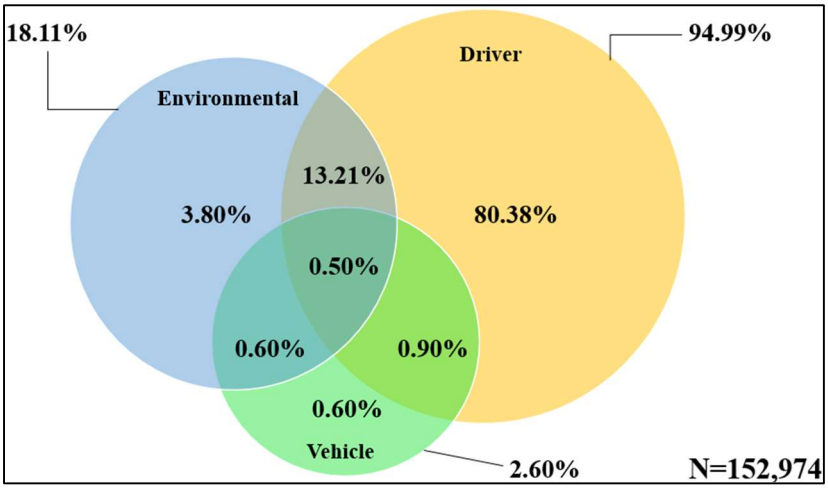

Figure 5: 2018 SC All Crash Contributing Factor Venn Diagram (N=152,974).

From a driver contribution standpoint, Venn Diagram percentages summarized in Figure 5 for all 2018 SC crashes (N=152,974) largely parallels distributions presented in the Treat Venn Diagrams. As summarized in Figure 4, the environment's contribution (18.1%) for all crashes is lower for the 2018 SC crash data when compared to the Treat Venn Diagrams percentage (34%). Similarly, as shown in Figure 5 for the vehicle contribution, the Venn Diagram for all 2018 SC crashes indicate that vehicles contribute to a much smaller proportion of crashes (2.6%) in comparison to the Treat Venn Diagram percentage (13%). It should be noted that while Treat's

results are based on 1978 crash data, the lower proportion of vehicle contribution for 2018 SC crashes may be due in part to manufacturing improvements of today's vehicles.

As indicated in Figure 4, it is evident that driver-related factors play a significant role in a majority of 2018 SC fatal crashes. However, driver contribution to fatal crashes (83.6%) is noticeably lower than driver contribution for all 2018 SC crashes (94.9%). There is also a noticeable increase in environmental contribution from all crashes in 2018 (18.12%) to fatal crashes in 2018 (49.9%).

2020 SC Crash Data Venn Diagrams and Traffic Volumes Comparison

Similar to the 2018 SC crash data, the binary approach was used to identify and quantify the contributing factors for fatal and all crashes in the 2020 SC crash data. Based on the aggregated contributing factor coding assignment, percentages for each combination of the contributing factor categories pertaining to fatal crashes were calculated. Venn Diagram percentages for 2020 SC fatal crashes (N=960) are summarized in Figure 6. Venn Diagram percentages for all 2020 SC crashes (N=132,973) are summarized in Figure 7 for the purpose of providing a useful baseline to contrast and compare with contributing category factors affecting the subset of fatal crashes

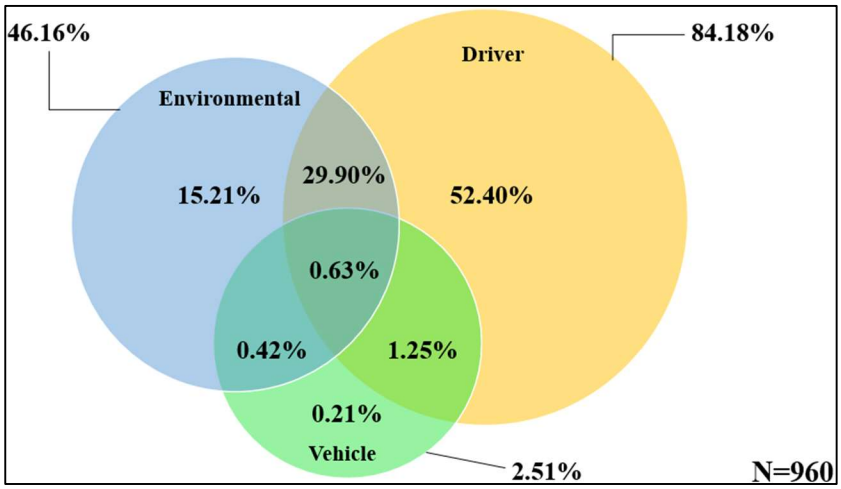

Figure 6: 2020 SC Fatal Crash Contributing Factor Venn Diagram (N=960).

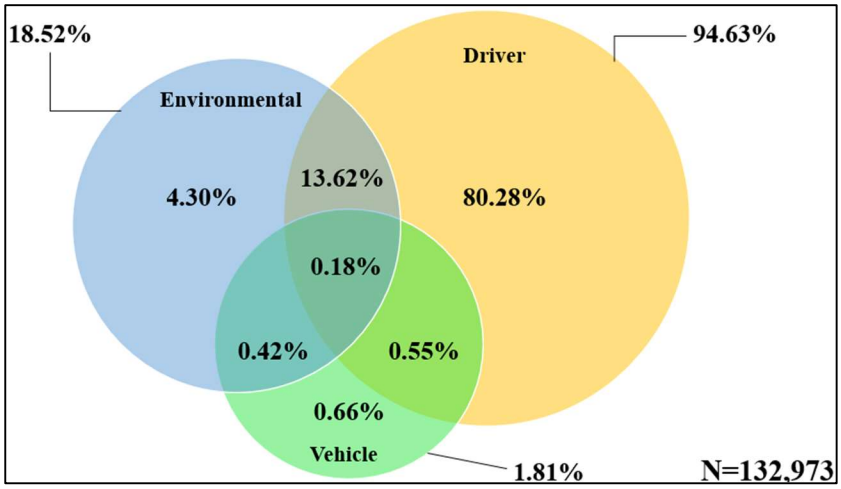

Figure 7: 2020 SC All Crash Contributing Factor Venn Diagram (N=132,973).

occurring during the same period. One of the major differences between the 2018 data and 2020 data is the total number of crashes overall (13% decrease from 2018 to 2020). This noticeable change could be a byproduct of the limited travel during the peak of the COVID-19 pandemic. However, it is even more interesting to note that the number of fatal crashes were very similar for 2018 (N=970) and 2020 (N=960). Comparative to the 2018 data, the 2020 Venn Diagram suggests that the driver's contribution is substantially larger compared to environmental and vehicle contributions. Compared to the detailed approach used for the 2019 data, the 2020 data mirrors the same results derived from the 2018 data in regard to the contribution differences between the binary approach and the detailed approach.

Additionally, traffic volume data was retrieved from SCDOT to determine the overall change in traffic volumes between 2018 and 2020, in order to determine whether a change in traffic volume was indicative of the change in the total number of crashes and the frequency in which these crashes occurred. In addition, 2019 volume data was analyzed to compare the effects of the COVID-19 pandemic had on traffic volumes from 2019 to 2020.

Basis of Odds Ratio Calculations

For the purpose of quantifying, understanding, and explaining important differences in crash percentages, an odds ratio approach was used to compare and contrast contributing factors between 2018 SC fatal crashes (N=970) and all 2018 SC crashes (N=152,974).

In this research, odds ratios are used to quantify the strength of association between fatal crashes and non-fatal crashes for the previously identified list of 1-7 aggregated categories of contributing factors. By definition, an odds ratio is the ratio of the odds of an event occurring in one group with respect to the odds of an event occurring in another group. As an example, given the following example contingency table, the Odds Ratio (OR) is calculated using the equation identified in Table 3 below.

Table 3: Sample Contingency Table for Odds Ratio Calculations.

	Fatal Crashes	Non-Fatal Crashes
Crashes with contributing factor (e.g., DUI)	a	b
Crashes without contributing factor	c	d
Formula for Odds Ratio (OR) calculation	$Odds\ Ratio = \frac{a/c}{b/d}$	

Based on the application of the definitions, variables and formula delineated above, an odds ratio greater than 1.00 implies that there are higher odds of fatal crashes with a particular contributing factor over non-fatal crash. If the confidence interval for an Odds Ratio does not include the number 1.00 then the calculated odds ratio is statistically significant. The Odds Ratio Analysis is discussed in the next chapter.

Using the framework presented in Table 3, several contributing factor subcategories were analyzed in this thesis including driver-related contributing factors, fixed object contributing factors, and non-motorist contributing factors. Table 4 below outlines the specific contributing factors analyzed associated with the contributing factor subcategories. Odds Ratios were calculated for each of these contributing factors for both the 2018 and 2020 South Carolina crash data.

Table 4: South Carolina Crash Data Odds Ratio Contributing Factor Outline.

Contributing Factor Sub-Category	Associated Contributing Factors
Driver-Related	▪ Driving Under the Influence ▪ Speed-Related ▪ Inattentive/Distracted Driving ▪ Aggressive Driving
Fixed Object	▪ Culvert ▪ Tree ▪ Utility Pole ▪ Ditch ▪ Embankment
Non-Motorist	▪ Illegally in the Roadway ▪ Improper Crossing/Darting ▪ Dark Clothing ▪ Failed to Yield Right of Way ▪ Non-Motor. Under the Influence

Analysis and Findings

Odds Ratio Calculations for Fatal vs Non-Fatal 2018 SC Crashes (Combined)

Odds ratio crash tabulations, calculations, 95% confidence intervals, and statistical significance are all based on 2018 South Carolina crash data of 970 fatal crashes and 152,974 non-fatal crashes. Table 5 provides the estimated Odds Ratios for 2018 fatal crashes versus non-fatal crashes for the contributing factor categories combined.

Table 5: 2018 Fatal versus Non-Fatal Contributing Factor Category Odds Ratio Calculations (Combined).

	CF Fatal	CF Non-Fatal	Non-CF Fatal	Non-CF Non-Fatal	Odds Ratio	From	To	Signif.
Driver Combined	816	145,317	154	7,657	0.28	0.23	0.33	Yes
Environmental Combined	484	27,717	486	125,257	4.50	3.97	5.11	Yes
Vehicle Combined	26	3,982	944	148,992	1.03	0.70	1.52	No

- **Driver Combined** is a significant contributing factor based on Odds Ratio calculations presented in Table 5. Results indicate there is a significant difference for driver combined contributing factors between non-fatal and fatal crashes, with driver combined contributing factors being more prevalent in non-fatal crashes. In other words, driver combined contributing factors are 3.57 times more likely to contribute to a non-fatal crash than a fatal crash. This finding has a data-based explanation that will explore the significance of several driver-related contributing factors using Odds Ratios later in this thesis.

- **Environmental combined** is a significant contributing factor based on Odds Ratio calculations presented in Table 5. Results indicate there is a significant difference in

environmental contributing factors between fatal and non-fatal crashes with 49.9% of fatal crashes having environmental contribution(s) versus 18.1% for non-fatal. Furthermore, Odds Ratio calculations suggests that for all environmental combined crashes, there is a 4.50 greater likelihood this type crash contributing factor will involve a fatality.

- **Vehicle Combined** is not considered a significant contributing factor based on Odds Ratio calculations presented in Table 5. Results indicate there is not a significant difference for vehicle combined factors between non-fatal and fatal crashes because the Odds Ratio 95% confidence interval includes 1.00.

Odds Ratio Calculations for Fatal vs Non-Fatal 2018 SC Crashes (Individual)

Table 6 presents the Odds Ratios for the 2018 fatal crash versus non-fatal for each of the seven individual contributing factor categories.

Table 6: 2018 SC Fatal versus Non-Fatal Contributing Factor Odds Ratio Calculations (Individual).

	CF Fatal	CF Non-Fatal	Non-CF Fatal	Non-CF Non-Fatal	Odds Ratio	From	To	Signif.
Driver Only	471	122,960	499	30,014	0.23	0.20	0.26	Yes
Driver + Environmental	328	20,213	642	132,761	3.36	2.94	3.84	Yes
Driver + Vehicle	9	1,378	961	151,596	1.03	0.53	1.99	No
Driver + Env. + Vehicle	8	766	962	152,208	1.65	0.82	3.33	No
Environmental Only	145	5,819	825	147,155	4.44	3.72	5.31	Yes
Environmental + Vehicle	3	919	967	152,055	0.51	0.16	1.60	No
Vehicle Only	6	919	964	152,055	1.03	0.46	2.30	No

Three of the seven odds ratio comparisons summarized in Table 6 were determined to be statistically significant. Discussion of the three significant factor categories is summarized as follows:

- **Driver Only** is a significant contributing factor category based on Odds Ratio calculations presented in Table 6. Results indicate there is a significant difference between fatal and non-fatal crashes with 48.56% of fatal crashes being solely attributed to the driver, whereas the driver is the sole contributor in 80.38% of non-fatal crashes. Thus, a driver is 4.35 times more likely to be the sole contributor of a non-fatal crash compared to a fatal crash.

- **Driver and Environment** is a significant contributing factor based on Odds Ratio calculations presented in Table 6. Results indicate there is a significant difference in driver and environmental joint contribution between fatal and non-fatal crashes with 33.81% of fatal crashes falling into this category versus 13.2% for non-fatal. Furthermore, odds ratio calculation suggests that for all driver and environment joint contribution crashes, there is a 3.32 greater chance this type crash contributing factor category will involve a fatality.

- **Environment Only** is a significant characteristic based on Odds Ratio calculations presented in Table 6. Results indicate there is a significant difference between fatal and non-fatal crashes with 14.8% of fatal crashes falling into this category versus 3.8% for non-fatal. Furthermore, Odds ratio calculation suggests that for all environment only crashes, there is a 4.41 greater chance this contributing factory category will contribute to a fatal crash versus a non-fatal crash.

Driver Odds Ratio Calculations for Fatal vs Non-Fatal 2018 SC Crashes

There were several crash related contributing factors to the driver. Table 7 provides the basis for calculating estimated odds ratios for fatal versus non-fatal crashes for different driver contributing factors. Odds ratio crash tabulations, calculations, 95% confidence intervals, and statistical significance are all based on 2018 South Carolina crash data of 970 fatal crashes and 152,974 total crashes.

Table 7: 2018 Fatal versus Non-Fatal Driver Contributing Factor Odds Ratio Calculations.

	CF Fatal	CF Non-Fatal	Non-CF Fatal	Non-CF Non-Fatal	Odds Ratio	From	To	Signif.
DUI	186	5,049	784	147,925	6.95	5.91	8.18	Yes
Speed-Related	255	45,071	715	107,903	0.85	0.74	0.99	Yes*
Inattentive/Distracted	150	10,634	820	142,340	2.45	2.06	2.92	Yes
Aggressive Driving	27	1,293	943	151,681	3.36	2.28	4.94	Yes

Odds Ratio comparisons summarized in Table 7 were determined to be statistically significant. Discussion of the three significant factor categories is summarized as follows:

- **DUI** is a significant contributing factor based on Odds Ratio calculations presented in Table 7. Results indicate DUIs were present in approximately 19.4% of fatal crashes and 3.3% of non-fatal crashes. As a result, DUI related crashes are computed to be 6.95 times more likely to contribute to a fatal crash than a non-fatal crash.

- **Speed-related** contributing factors were found to be a significant contributing factor based on Odds Ratio calculations presented in Table 7. Based on the data, approximately 26.3% of fatal crashes are contributed to speed-related contributing factors, while nearly 29.5% of non-fatal crashes contain speed-related contributing factors. Although this contributing factor category is considered "significant," it is worth noting that the highest

value in the 95% interval is very close to 1, which could indicate a lessened significance of this give contributing factor category.

- **Inattentive/Distracted** are a significant contributing factor based on Odds Ratio calculations presented in Table 7. Results indicate inattentive/distracted drivers contributed to approximately 15.5% of fatal crashes in 2018 compared to 6.95% of non-fatal crashes. As a result, Inattentive/Distracted related contributing factors are 2.50 times more likely to contribute to fatal crashes than non-fatal crashes.

- **Aggressive Driver** are a significant contributing factor based on Odds Ratio calculations presented in Table 7. Results indicate aggressive driving was found to be present in approximately 2.8% of fatal crashes, while it contributes to less than 1% of non-fatal crashes. Based on the Odds Ratio calculation, it can be said that aggressive driving is 3.36 times more likely to contribute to a fatal crash than a non-fatal crash.

Fixed Object Odds Ratio Calculations for Fatal vs Non-Fatal 2018 SC Crashes

Table 8 provides the basis for calculating estimated Odds Ratios for fatal versus non-fatal crashes and presence or absence of different fixed object crash-related factor characteristics.

Table 8: 2018 Fatal versus Non-Fatal Fixed Object Contributing Factor Odds Ratio Calculations.

	CF Fatal	CF Non-Fatal	Non-CF Fatal	Non-CF Non-Fatal	Odds Ratio	From	To	Signif.
Culvert	13	344	957	152,630	6.03	3.45	10.52	Yes
Ditch	63	6,794	907	146,180	1.49	1.16	1.93	Yes
Embankment	26	1,153	944	151,821	3.63	2.45	5.38	Yes
Tree	109	4,738	861	148,236	3.96	3.24	4.84	Yes
Utility Pole	9	1,353	961	151,621	1.05	0.54	2.03	No

Odds Ratio crash tabulations, calculations, 95% confidence intervals, and statistical significance are all based on 2018 South Carolina crash data of 970 fatal crashes and 152,974 total crashes.

Four odds ratio comparisons summarized in Table 8 were determined to be statistically significant. Discussion of the four significant factor categories is summarized as follows:

- **Presence of Culverts** are a significant contributing factor based on Odds Ratio calculations presented in Table 8.While culverts were only present in 1.34% of fatal crashes and less than 1% of non-fatal crashes, the likelihood of culverts contributing to fatal crashes compared to non-fatal crashes. Culvert related crashes are computed to be 6.16 times more likely to contribute to a fatal crash than a non-fatal crash.

- **Presence of Ditches** are a significant contributing factor based on Odds Ratio calculations presented in Table 8. According to the data, ditches were present in approximately 6.5% of fatal crashes, and 12.8% of non-fatal crashes. Using Odds Ratios, it was determined that there is a 1.49 greater likelihood that a ditch with contribute to a fatal crash compared to a non-fatal crash.

- **Presence of Embankments** are a significant contributing factor based on Odds Ratio calculations presented in Table 8. Results indicate embankments were present in 2.7% of fatal crashes, whereas in non-fatal crashes ditches contributed to less than 1% of crashes. As a result, embankment-related crashes are computed to 3.63 times more likely to involve a fatal crash than a non-fatal crash.

- **Presence of Trees** are a significant contributing factor based on Odds Ratio calculations presented in Table 8. Results indicate trees were present in approximately 11.2 % of fatal crashes, while only 3.1% of non-fatal crashes had the presence of trees. In other words,

trees have a 3.96 times greater likelihood of being present in a fatal crash than a non-fatal crash.

Utility poles had an odds ratio of 1.05, with a confidence interval ranging from 0.56-2.07, which includes 1 and is not significant. There were very few utility pole (N=9) related fatal crashes, which also precluded this finding from achieving significance. Culverts, ditches, embankments, and trees were all significant and with increased odds of fatal crashes.

Non-Motorist Odds Ratio Calculations for Fatal vs Non-Fatal 2018 SC Crashes

Table 9 provides the basis for calculating estimated odds ratios for fatal versus non-fatal crashes and presence or absence of non-motorist crash related factor characteristics. Odds ratio crash tabulations, calculations, 95% confidence intervals, and statistical significance are all based on 2018 South Carolina crash data of 970 fatal crashes and 152,974 total crashes.

Table 9: 2018 SC Fatal versus Non-Fatal Non-Motorist Contributing Factor Odds Ratio Calculations.

	CF Fatal	CF Non-Fatal	Non-CF Fatal	Non-CF Non-Fatal	Odds Ratio	From	To	Signif.
Illegally in Roadway	84	228	886	152,746	63.52	49.04	82.27	Yes
Yield ROW/Wrong Side	10	90	960	152,884	17.69	9.18	34.11	Yes
Dark Clothing	3	37	967	152,937	12.82	3.95	41.66	Yes
Improper Crossing/ Darting	38	193	932	152,781	32.28	22.66	45.97	Yes
Non-Motorist Under the Influence	12	75	958	152,899	25.54	13.84	47.12	Yes

All five (5) Odds Ratio comparisons summarized in Table 9 were determined to be statistically significant. Discussion of the five (5) significant factor categories are summarized as follows:

- **Non motorist, Illegally on Road** is a significant contributing factor based on Odds Ratio calculations presented in Table 9. Results indicate that a non-motorist illegally on the road contributed approximately 8.66% of fatal crashes, and less than 1% of non-fatal crashes. Moreover, a non-motorist who is illegally in the road is at 63.52 greater odds to be involved in a fatal crash compared to a non-fatal crash. This particular contributing factor generated the highest Odds Ratio value in this analysis.

- **Non motorist, Failure to Yield/Wrong Side** is a significant contributing factor based on Odds Ratio calculations presented in Table 9. Results indicate a non-motorist failing to yield or being on the wrong side of the road contributed to just over 1% of fatal crashes and just more than 0.5% of non-fatal crashes. As a result, Failure to Yield/Wrong Side related non-motorist crashes are computed to be 18.08 times more likely to contribute to a fatal crash than a non-fatal crash.

- **Non motorist, Dark Clothing** is a significant contributing factor based on Odds Ratio calculations presented in Table 9. In 2018, non-motorist who wore dark clothing contributed to less than 1% of both fatal and non-fatal crashes. Due to the small number of dark clothing crashes (both fatal and non-fatal) the 95% confidence interval's range was wider than usual. As a result, Dark Clothing related crashes are computed to be 12.82 times more likely to involve a fatal crash than a non-fatal crash.

- **Non motorist, Improper Crossing/Darting** is a significant contributing factor based on Odds Ratio calculations presented in Table 9. Results indicate that non-motorist who performed an improper crossing or darted in the roadway contributed to approximately

3.92% of fatal crashes and less than 1% of non-fatal crashes. Furthermore, non-motorist who cross improperly or dart into the roadway are estimated to be 32.28 greater odds to be involved in a fatal crash compared to a non-fatal crash.

- **Non-motorist, Under Influence** is a significant contributing factor based on Odds Ratio calculations presented in Table 9. Results indicate that a non-motorist who is under the influence contributed to approximately 1.2% of fatal crashes, while contributing to less than 1% of non-fatal crashes. As a result, non-motorist who are under the influence are 25.54 times more likely to contribute to a fatal crash than a non-fatal crash.

Odds Ratio Calculations for Fatal vs Non-Fatal 2020 SC Crashes (Combined)

Odds ratio crash tabulations, calculations, 95% confidence intervals, and statistical significance are all based on 2020 South Carolina crash data of 960 fatal crashes and 132,973 non-fatal crashes. Table 10 provides the estimated Odds Ratios for 2020 fatal crashes versus non-fatal crashes for the contributing factor categories combined.

Table 10: 2020 SC Fatal versus Non-Fatal Contributing Factor Category Odds Ratio Calculations (Combined).

	CF Fatal	CF Non-Fatal	Non-CF Fatal	Non-CF Non-Fatal	Odds Ratio	From	To	Signif.
Driver Combined	808	125,825	152	7,148	0.30	0.25	0.36	Yes
Environmental Combined	443	24,622	517	108,351	3.77	3.32	4.28	Yes
Vehicle Combined	24	2,934	936	130,579	1.40	0.93	2.10	No

- **Driver Combined** is a significant contributing factor based on Odds Ratio calculations presented in Table 10. Results indicate there is a significant difference for driver combined contributing factors between non-fatal and fatal crashes, with driver combined

contributing factors being more prevalent in non-fatal crashes. In other words, driver combined contributing factors are 3.33 times more likely to contribute to a non-fatal crash than a fatal crash. This finding has a data-based explanation that will explore the significance of several driver-related contributing factors using Odds Ratio later in this section.

- **Environmental combined** is a significant contributing factor based on Odds Ratio calculations presented in Table 10. Results indicate there is a significant difference in environmental contributing factors between fatal and non-fatal crashes with 46.15% of fatal crashes having environmental contribution(s) versus 18.52% for non-fatal. Furthermore, Odds Ratio calculations suggests that for all environmental combined crashes, there is a 3.77 greater likelihood this type crash contributing factor will involve a fatality.

- **Vehicle Combined** is not considered a significant contributing factor based on Odds Ratio calculations presented in Table 10. Results indicate there is not a significant difference for vehicle combined factors between non-fatal and fatal crashes because the Odds Ratio 95% confidence interval includes 1.00.

Driver Odds Ratio Calculations for Fatal vs Non-Fatal 2020 SC Crashes

There were several crash related contributing factors to the driver. Table 11 provides the basis for calculating estimated odds ratios for fatal versus non-fatal crashes for different driver contributing factors.

Table 11: 2020 SC Driver Contributing Factor Odds Ratio Calculations.

	CF Fatal	CF Non-Fatal	Non-CF Fatal	Non-CF Non-Fatal	Odds Ratio	From	To	Signif.
DUI	220	5,656	740	127,317	6.69	5.74	7.80	Yes
Speed-Related	335	38,563	625	94,410	1.31	1.15	1.50	Yes
Inattentive/Distracted	78	23,088	882	109,885	0.42	0.33	0.53	Yes
Aggressive Driving	73	12,331	887	120,642	0.81	0.63	1.02	No

Odds ratio crash tabulations, calculations, 95% confidence intervals, and statistical significance are all based on 2020 South Carolina crash data of 960 fatal crashes and 132,973 total crashes.

Three odds ratio comparisons summarized in Table 11 were determined to be statistically significant. Discussion of the three significant factor categories is summarized as follows:

- **DUI** is a significant contributing factor based on Odds Ratio calculations presented in Table 11. Results indicate DUI's contribute to 22.92% of fatal crashes and 4.25% non-fatal crashes. Furthermore, DUI related crashes are estimated to be 6.69 times more likely to contribute to a fatal crash than a non-fatal crash.

- **Speed-Related** contributing factors are significant based on Odds Ratio calculations presented in Table 11. Results indicate Speed-related contributing factors were present in 28.75% fatal crashes and 37.63% of non-fatal crashes. As a result, speed-related crashes are computed to be 1.31 times more likely to contribute to a fatal crash than a non-fatal crash.

- **Inattentive/Distracted** contributing factors are significant based on Odds Ratio calculations presented in Table 11. Results indicate inattentive/distracted driving contributed to 8.13% of fatal crashes and 17.36% of non-fatal crashes. Moreover,

inattentive/distracted driving is 2.38 times more likely to occur in a non-fatal crash compared to a fatal crash.

Fixed Object Odds Ratio Calculations for Fatal vs Non-Fatal 2020 SC Crashes

Table 12 provides the basis for calculating estimated Odds Ratios for fatal versus non-fatal crashes and presence or absence of different fixed object crash related factor characteristics. Odds Ratio crash tabulations, calculations, 95% confidence intervals, and statistical significance are all based on 2020 South Carolina crash data of 960 fatal crashes and 132,973 total crashes.

Three odds ratio comparisons summarized in Table 12 were determined to be statistically significant.

Table 12: 2020 SC Fixed Object Contributing Factor Odds Ratio Calculations.

	CF Fatal	CF Non-Fatal	Non-CF Fatal	Non-CF Non-Fatal	Odds Ratio	From	To	Signif.
Culvert	15	369	945	132,604	5.70	3.39	9.60	Yes
Ditch	59	6,461	901	126,512	1.28	0.98	1.67	No
Embankment	21	1,110	939	131,863	2.66	1.72	4.11	Yes
Tree	119	4,714	841	128,259	3.85	3.17	4.67	Yes
Utility	7	1,310	953	131,663	0.74	0.35	1.56	No

Discussion of the three significant factor categories is summarized as follows:

- **Presence of Culverts** are a significant contributing factor based on Odds Ratio calculations presented in Table 12. Results indicate culverts were present in 1.5% of fatal and less than 1% of non-fatal crashes. Furthermore, the presence of culverts increases the likelihood of contribution to fatal crashes by a magnitude of 5.70.

- **Presence of Embankments** are a significant contributing factor based on Odds Ratio calculations presented in Table 12. Results indicate embankments contributed to 2.19% of fatal crashes and less than 1% of non-fatal crashes. As a result, embankment-related

crashes are estimated to be 2.54 times more likely to contribute to a fatal crash compared to a non-fatal crash.

- **Presence of Trees** are a significant contributing factor based on Odds Ratio calculations presented in Table 12. Results indicate trees contributed to 12.4% of fatal crashes fatal crashes and 3.55% of non-fatal crashes. Based on the data, trees are estimated to be 3.85 times more likely to contribute to a fatal crash compared to a non-fatal crash.

All fixed objects other than utility poles were determined to be associated with increased odds of fatalities. Utility poles had an odds ratio of 0.74, with a confidence interval ranging from 0.35-1.56, which includes 1 and is not significant. There were very few utility pole- related fatal crashes (N=7), which also precluded this finding from achieving significance. Culverts, ditches, embankments, and trees were all significant and with increased odds of fatal crashes.

Non-Motorist Odds Ratio Calculations for Fatal vs Non-Fatal 2020 SC Crashes

Table 13 provides the basis for calculating estimated odds ratios for fatal versus non-fatal crashes and presence or absence of non-motorist crash related factor characteristics. Odds ratio crash tabulations, calculations, 95% confidence intervals, and statistical significance are all based on 2020 South Carolina crash data of 961 fatal crashes and 133,189 total crashes.

Table 13: 2020 SC Non-Motorist Contributing Factor Odds Ratio Calculations.

	CF Fatal	CF Non-Fatal	Non-CF Fatal	Non-CF Non-Fatal	Odds Ratio	From	To	Signif.
Illegally on Road	97	320	863	132,653	46.59	36.77	59.04	Yes
Yield ROW/Wrong Side	12	157	948	132,816	10.71	5.93	19.33	Yes
Dark Clothing	40	132	920	132,841	43.76	30.54	62.69	Yes

Improper Crossing/ Darting	38	241	922	132,732	22.70	16.02	32.15	Yes
Non-Motorist Under the Influence	26	112	934	132,861	33.02	21.45	50.84	Yes

All five (5) Odds Ratio comparisons summarized in Table 13 were determined to be statistically significant. Discussion of the five (5) significant factor categories are summarized as follows:

- **Non motorist, Illegally on Road** is a significant contributing factor based on Odds Ratio calculations presented in Table 13. Results indicate non-motorists illegally on the road was present in 10.1% of fatal crashes and less than 1% for non-fatal crashes. As a result, non-motorist illegally on the road crashes are computed to be 46.59 times more likely to contribute to a fatal crash compared to a non-fatal crash.

- **Non motorist, Failure to Yield/Wrong Side** is a significant contributing factor based on Odds Ratio calculations presented in Table 13. Results indicate failure to yield/wrong side was present at 1.25% of fatal crashes and less than 0.5%. Moreover, failure to yield/wrong side related crashes are estimated to be 10.71 times more likely to contribute to fatal crashes compared to a non-fatal crash.

- **Non motorist, Dark Clothing** is a significant contributing factor based on Odds Ratio calculations presented in Table 13. Results indicate dark clothing was present in 4.17% of fatal crashes, and less than 0.1% of non-fatal crashes. As a result, Dark Clothing related crashes are computed to be 43.76 times more likely to contribute to a fatal crash than a non-fatal crash.

- **Non motorist, Improper Crossing/Darting** is a significant contributing based on Odds Ratio calculations presented in Table 13. Non-motorists performing an improper crossing/darting was present in 3.96% of fatal crashes and less than 1% of non-fatal crashes. As a result, improper crossing/darting-related crashes are computed to be 22.71 times more likely to contribute to a fatal crash than a non-fatal crash.

- **Non-motorist, Under the Influence** is a significant contributing factor based on Odds Ratio calculations presented in Table 13. Results indicate non-motorist, under influence was present at 2.71% fatal crashes and less than 1% non-fatal crashes. As a result, non-motorist, under the influence related crashes are estimated to be 33.02 times more likely to contribute to a fatal crash compared to a non-fatal crash.

2018 versus 2020 Odds Ratio Comparison Summary

Table 14 below provides a summary of the Odds Ratio values computed for 2018 and 2020 South Carolina crash data.

Table 14: 2018 vs. 2020 Odds Ratio Comparison Summary.

	2018 CF Odds Ratio	2018 CF Odds Ratio Signif.	2020 CF Odds Ratio	2020 CF Odds Ratio Signif.
DUI	6.95	Yes	6.69	Yes
Speed-Related	0.85	Yes	1.31	Yes
Inattentive/Distracted	2.45	Yes	0.42	Yes
Aggressive Driving	3.36	Yes	0.81	No
Culvert	6.03	Yes	5.70	Yes
Tree	3.96	Yes	3.85	Yes
Embankment	3.63	Yes	2.66	Yes
Ditch	1.49	Yes	1.28	No
Utility Pole	1.05	No	0.74	No
Illegally in Roadway	63.52	Yes	46.59	Yes
Improper Crossing/Darting	32.28	Yes	22.70	Yes
Dark Clothing	12.82	Yes	43.76	Yes
Fail Yield ROW/Wrong Side	17.69	Yes	10.71	Yes
Non-Motor. Under Influence	25.54	Yes	33.02	Yes

Based on Table 14, there are a few noticeable differences between the 2018 and 2020 South Carolina Odds Ratio statistical analysis results. The first difference is the decreased odds of inattentive/distracted driving and aggressive driving occurring in a fatal crash in 2020 compared to 2018. The marginal decrease in odds suggests there could have been a potential change in the coding of these types of crashes. Another observation is the magnitude of non-motorist contributing factors is still disproportionately higher than all of the other contributing factors analyzed in this thesis. Lastly, in addition to the utility pole contributing factor, both aggressive driving and ditch contributing factors were found to be insignificant in 2020, where they were previously significant contributing factors in 2018.

COVID-19 Effects on Travel and Fatal Crashes

COVID-19 took the world by storm in late-2019/early-2020. The volatile nature of the COVID-19 virus forced states to enforce isolation policies, which resulted in travel bans. Using 2018, 2019, and 2020 volume data from SCDOT, we examined the changes in volume and fatal crashes for South Carolina. Table 15 shows the volume for each of the representative years, as well as the number of fatal crashes in those years.

Table 15: South Carolina Volume-Crash Comparison (2018-2020).

South Carolina Volume-Crash Comparison (2018-2020)				
	Fatal Crashes	% Change in Fatal Crashes	Total Volume	% Change in Volume
2018	970	0	1,410,571,781	0
2019	919	-5%	1,592,921,684	+13%
2020	960	+4%	1,486,314,083	-7%

The volume data collected from SCDOT are weekly counts collected from 166 sites across the state. It should be noted that the 2018 volume data was received in a different format than the 2019/2020 data, and that is due to the data having to be retrieved from a private software contractor SCDOT is partnered with. From Table 15, it is evident that there was a marginal decrease in total volume from 2019 to 2020. However, it is interesting to note that the number of fatal crashes increased by 4% despite the total volume decreasing by 7% in the same time period.

Odds Ratio Calculation for 2018 Fatal Crash versus 2020 Fatal Crash (Overall)

Table 16 provides the basis for calculating estimated Odds Ratios for fatal crashes in 2018 versus fatal crashes in 2020. An Odds Ratio crash tabulation, calculation, 95% confidence interval, and statistical significance are based on 2018 fatal crashes (N=970) , 2018 non-fatal crashes (N=152,974), 2020 fatal crashes (N=960), and 2020 non-fatal crashes (N=132,973).

Table 16: 2018 versus 2020 Fatal Crash Odds Ratio Calculation.

	2020 Fatal	2020 Non-Fatal	2018 Fatal	2018 Non-Fatal	Odds Ratio	To	From	Signif.
Overall	960	132,973	970	152,974	1.14	1.04	1.25	Yes

Based on the results from Table 16, one is 1.14 times more likely to be involved in a fatal crash in 2020 compared to 2018. Although the total number of fatal crashes was higher in 2018, the frequency of fatal crashes in 2020 was higher than 2018.

Conclusions

There were four (4) main objectives established at the beginning of this these. The first object was to identify and quantify contributing factors of fatal crashes using South Carolina crash data. During this research we were able to complete our first objective in determining the categories of contributing factors in fatal crashes using the SCDPS User Data Dictionary and SC TR-310 crash reports. Based on the three (3) major categories of crashes, which are driver, environmental, and vehicle, we were able to create several subgroups of these contributing factors to use for our analysis. A few of the notable contributing factor subcategories include driving under the influence, fixed objects, and non-motorist. Using the contributing category classification, we were able to quantify contributing factors for both the fatal and non-fatal crashes for 2018 and 2020 South Carolina crash data, as well as quantify fatal crash contributing factors for 2019 South Carolina crash data. The quantities obtained from these datasets were used to populate Venn Diagrams for each of the datasets. The 2018 and 2020 South Carolina all crash Venn Diagrams show strong similarities to the Treat 1979 Venn Diagram, the framework for our Venn Diagram comparison. The Venn diagrams for fatal and non-fatal crashes show significant differences between driver and environmental related crashes for both the 2018 and 2020 crash data. Driver related crashes are more prevalent in non-fatal crashes while the environment is more prevalent in fatal crashes. Vehicle related contribution remains relatively the same in fatal and non-fatal crashes for both 2018 and 2020 crashes.

The second objective of this thesis was to quantify the differences in contributing factors between fatal and non-fatal crashes using Venn Diagram comparisons and Odds Ratio statistical analysis in 2018 and 2020 South Carolina crash data. In comparing fatal (N=970) with non-fatal (N= 152,973) 2018 SC crashes, three contributing factor categories were determined to be significant based on the Odds Ratio calculations. These contributing factor categories include driver only,

environmental only, and driver & environmental combined; with environmental only having the most increased odds for contributing to a fatal crash compared to a non-fatal crash (OR=4.50).The two main contributing factor subcategories for environmental contributing category are fixed objects and non-motorist. The Odds Ratio values for non-motorist contributing factors are disproportionately higher compared to other contributing factor categories. For example, non-motorist who are illegally on the road have a 63.52 times greater likelihood to be involved in a fatal crash compared to a non-fatal crash. Other notably higher non-motorist contributing factor Odds Ratio values include failure to yield/wrong side (OR=17.69), dark clothing (OR=12.82), improper crossing/darting (OR=32.28), and non-motorist under influence (OR=25.54). The Odds Ratio statistical analysis of the 2020 South Carolina crash data produced similar results to the 2018 South Carolina crash data analysis, with the magnitude of contribution varying for contributing factors being the main difference. For example, driving under the influence in 2020 had an Odds Ratio value of 6.69, while in 2018 that same contributing factor had an Odds Ratio value of 6.95. The one noticeable difference between the two datasets was the difference in magnitude and significance for aggressive drivers. For instance, in 2018, aggressive driving produced an Odds Ratio of 3.36, while in 2020 an Odds Ratio of 0.81 was computed and determined to be an insignificant contributing factor for the 2020 dataset. This particular result indicates there may have been a difference in police coding/interpretation of crash contribution because the methodology used to determine crash contribution for the 2018 and 2020 are identical. Furthermore, the findings of the Odds Ratio statistical analysis on the 2018 and 2020 South Carolina datasets suggest that there are differences in contributing factors between fatal and non-fatal crashes.

In addition to the contributing factor analysis for fatal and non-fatal crashes in the 2018, 2019, 2020 South Carolina crash datasets, the third objective of this thesis focuses on the travel impacts

due to the COVID-19 pandemic in conjunction with fatal crashes. Based on the volume and crash data provided by SCDOT, it is evident that travel was affected by the pandemic as volume decreased during the peak of the pandemic (2019-2020) by 7%, while fatal crashes increased by 4%. Furthermore, these results indicate that there is a potential relationship between total volume and fatal crash frequency. However, additional analysis would need to be performed on "normal conditions" data to determine the traction or relevance of this relationship.

The final objective of this thesis was to align our contributing factor analysis findings that support the SCDPS Highway Safety Improvement Plan's mission Target Zero, which is to eliminate fatalities on South Carolina roadways. Based on the Venn Diagram comparisons of the 2018,2019, and 2020 South Carolina crash data along with Odds Ratio statistical analyses performed on the same data, there are particular contributing factor categories and subcategories that have been highlighted as increased-odds or greater importance in the fatal crash environment. Understanding the primary source of fatal crashes can ultimately help with selecting appropriate countermeasures that can help reduce or eliminate fatal crashes in South Carolina. Although this thesis is not a direct solution to the Target Zero objective, it can serve as a steppingstone for future research to devise a solution capable of tackling the two root causes of fatal crashes: the driver and environment.

In partnership with the Connected Center for Multimodal Mobility (C2M2) project, one potential future research opportunity would be to explore different methods outlining the effectiveness of connected autonomous vehicles (CAVs) implementation and how the technological capabilities of CAVs can help mitigate against some of the more prevalent fatal crash contributing factors in South Carolina. Another possible research opportunity would be to explore the different combinations of fatal crash contributing factors in order to gain a stronger understanding of the fatal crash environment.

References

[1] AAA Foundation for Traffic Safety, 2009. Aggressive Driving: Research Update. AAA Foundation for Traffic Safety, Washington, DC. Available at: http://www.aaafoundation.org/pdf/AggressiveDrivingResearchUpdate2009.pdf.

[2] Bédard, M., Guyatt, G. H., Stones, M. J., & Hirdes, J. P. (2002). *The independent contribution of driver, crash, and vehicle characteristics to driver fatalities*. Accident Analysis & Prevention, *34*(6), 717–727. https://doi.org/10.1016/s0001-4575(01)00072-0.

[3] Cerrelli, E. C. (1997). *Fatal Crash Involvements -- What Are the Odds?* National Highway Transportation Safety Administration. https://doi.org/10.21949/1403431.

[4] Clifton, K. J., Burnier, C. V., & Akar, G. (2009). *Severity of injury resulting from pedestrian–vehicle crashes: What can we learn from examining the built environment?* Transportation Research Part D: Transport and Environment, 14(6), 425–436. https://doi.org/10.1016/j.trd.2009.01.001.

[5] Drew, L. (2010). *National survey of drinking and driving attitudes and behaviors*: 2008. US Department of Transportation, National Highway Traffic Safety Administration.

[6] Evans, L., & Wasielewski, P. Accident Analysis & Prevention. *Risky driving related to driver and vehicle characteristics*, 1983. Volume 15, Issue 2: 121-136.

[7] Haq, M. T., Zlatkovic, M., & Ksaibati, K. Accident Analysis & Prevention. *Assessment of tire failure related crashes and injury severity on a mountainous freeway: Bayesian binary logit approach*, 2020. Volume 145.

[8] Highway Safety Improvement Program Manual- Safety: Federal Highway Administration, 2010. Retrieved February 18,2021. https://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/.

[9] Highway Safety Manual, 2010. Washington, DC: American Association of State Highway and Transportation Officials.

[10] Kockelman, K., Avery, P., Bansal, P., Boyles, S. (2016) Implications of Connected and Automated Vehicles on the Safety and Operations of Roadway Networks: A Final Report. (Report No. FHWA/TX-16/0-6849-1). Texas DOT.

[11] Kristen A. Conner, Gary A. Smith, The impact of aggressive driving-related injuries in Ohio, 2004–2009, Journal of Safety Research, Volume 51, 2014, Pages 23-31, ISSN 0022-4375, https://doi.org/10.1016/j.jsr.2014.08.003.

[12] Liu, C., & Chen, C.-L. (2009). *An Analysis of Speeding-Related Crashes: Performing Organization Code Definitions and the Effects of Road Environments* . Transportation Research Board. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811090.

[13] Mitchell L. Doucette, Andrew Tucker, Marisa E. Auguste, Jonathan D. Gates, David Shapiro, Johnathon P. Ehsani, Kevin T. Burrup, Evaluation of motor vehicle crash rates during and after the COVID-19-associated stay-at-home order in Connecticut, Accident Analysis & Prevention, Volume 162, 2021, 106399, ISSN 0001-4575, https://doi.org/10.1016/j.aap.2021.106399.

[14] Moghaddam, K., Balali, V., Khalilikhah, M., & Rad, A. A. (2020, November). Identifying the Contributing Factors to the Severity of Animal-Vehicle Collisions. In *Construction Research Congress 2020: Infrastructure Systems and Sustainability* (pp. 819-826). Reston, VA: American Society of Civil Engineers.

[15] *MMUCC guideline: Model minimum uniform crash criteria*, 2017. Washington, District of Columbia: National Highway Traffic Safety Administration.

[16] National Highway Traffic Safety Administration, 2001. *Traffic Safety Facts 2000: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*. DOT HS 809 337. US Government Printing Office, Washington, DC.

[17] National Highway Traffic Safety Administration, 2003. *Analysis of Pedestrian Crashes*. DOT HS 809 585. US Government Printing Office, Washington, DC.

[18] National Highway Traffic Safety Administration, 2015. *Traffic Safety Facts 2015: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*. DOT HS 812 384. US Government Printing Office, Washington, DC.

[19] National Highway Traffic Safety Administration (NHTSA) (2016a). Traffic Safety Facts: Alcohol-Impaired Driving (2016 Data). Technical Report Number DOT HS 812 450. Washington; Department of Transportation. Retrieved from: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812450.

[20] National Highway Traffic Safety Administration, 2010. *South Carolina Department of Public Safety: Traffic Records Users Data Dictionary*. SCDPS User Data Dictionary.

[21] National Highway Traffic Safety Administration and the Insurance Institute for Highway Safety, 2006. *Beginning Teenage Drivers*. DOT HS 810 651. Washington, DC.

[22] Ogle, J., W. Sarasua, J. Dillon, V. Bendigieri, S. Anekar, and P. Alluri. 2009. Support for the Elimination of Roadside Hazards: Evaluating Roadside Collision Data and Clear Zone Requirements. Report No. FHWA-SC-09-01. Columbia: South Carolina Department of Transportation. http://www.clemson.edu/t3s/scdot/pdf/projects/fhwa-sc-09-01spr667.pdf.

[23] Osueke, C.O. and Uguru-Okorie, D.C (2012) *The Role of Tire in Car Crash, Its Causes, And Prevention.* International Journal of Emerging Technology and Advanced Engineering, 2 (12).

[24] Papadoullis, A., Quddus, M., Imprialou, M. (2019) Evaluating the Safety Impact of Connected and Autonomous Vehicles on Motorways. Accident Analysis and Prevention. 124:12-22. doi: 10.1016/j.aap.2018.12.019. Epub 2019 Jan 2.

[25] Peek-Asa, C., Britton, C., Young, T., Pawlovich, M., Falb, S., Zwerling, C., Vachal, K., Mayhew, D. R., Maio, R. F., Kmet, L., Karlaftis, M. G., Chen, H. Y., & Baker, D. R. Journal of Safety Research. *Teenage driver crash incidence and factors influencing crash injury by rurality*, 2010. Volume 41, Issue 6: 487-492.

[26] Richard J. Stringer, exploring traffic safety culture and drunk driving: An examination of the community and DUI related fatal crashes in the U.S. (1993–2015), Transportation Research Part F: Traffic Psychology and Behavior, Volume 56, 2018, Pages 371-380, ISSN 1369-8478, https://doi.org/10.1016/j.trf.2018.05.014.

[27] South Carolina Department of Public Safety (SCDPS). (2018). South Carolina Traffic Collision Fact Book, 2017. https://scdps.sc.gov/sites/default/files/Documents/ohsjp/fact%20book/2017%20SC%20Fact%20Book.pdf.

[28] Target Zero: South Carolina's Strategic Highway Safety Plan, 2015. South Carolina Department of Public Safety.

[29] Treat, J. R., Tumbas, N. S., McDonald, S. T., Shinar, D., Hume, R. D., Mayer, R. E., Castellan, N. J., 1979. *Tri-level study of the causes of traffic accidents: Final Report*. Volume I: Casual Factor Tabulations and Assessments.

[30] Treat, J. R., Tumbas, N. S., McDonald, S. T., Shinar, D., Hume, R. D., Mayer, R. E., Castellan, N. J., 1979. *Tri-level study of the causes of traffic accidents: Final Report*. Volume II: Special Analyses.

[31] Turner, D.S., Mansfield, E.R. Journal of Transportation Engineering- ASCE. *Urban trees and roadside safety*, 1989. Volume 116, Issue 1: 90-104.

[32] Wang, Y., Zhang, W. Transportation Research Procedia. *Analysis of roadway and environmental factors affect traffic crash severities*, 2017. Volume 25: 2119-2125.