Traffic Safety in Appalachia

Final Report

APPALACHIAN REGIONAL COMMISSION

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Executive Summary

Introduction

The Appalachian Region of the United States (the Region) is a unique environment with specific ecological, roadway, and cultural elements. The Region comprises counties in 13 states, including parts of Alabama, Georgia, Kentucky, Maryland, Mississippi, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, and Virginia, and the entirety of West Virginia. Appalachia is characterized by expansive rural regions, mountainous and curved terrain, and dense forests exposed to extreme weather elements. Drivers in Appalachia must contend with these environmental concerns as well as a number of cultural and health factors that can create unique traffic safety problems within the Region. Considering these traffic safety determinants in the context of Appalachia's 13-state spread requires a diverse set of explanatory variables and countermeasures.

Project Description and Methodology

On behalf of the Appalachian Regional Commission (ARC), the University of North Carolina (UNC) Highway Safety Research Center conducted an extensive investigation of traffic safety in Appalachia. This investigation consisted of multiple steps, specifically the following:

1. A comprehensive literature synthesis to describe traffic safety culture and how it relates to traffic safety in Appalachia and the culture of health within the Region.
2. A thorough analysis of Appalachian traffic fatalities. Crash fatality data was compared across Appalachian subregions and between the Appalachian and non-Appalachian United States to identify and describe specific traffic safety concerns within the Region.
3. A deeper investigation into fatal crash data to identify concerns related to drugged driving in the Region.
4. A case study of one Appalachian state—North Carolina—to verify findings from the broader fatal crash analysis.
5. Finally, an evaluation of the Appalachian Development Highway System (ADHS) as a potential intervention measure for treating traffic safety problems in the Region.

Synthesis of Traffic Safety and Health Research

To characterize the traffic safety culture in Appalachia, the research team scanned hundreds of journal articles, government reports, conference proceedings, and other research documents to find any studies of Appalachian traffic safety. Specifically, the research team sought to answer the following questions:

- What are the key characteristics of Appalachia that should be considered in a traffic safety analysis?
- What are common traffic safety problems throughout Appalachia?
- What potential explanations are there for these traffic safety problems?
- What is traffic safety culture, and what are its determinants?
- What is a culture of health, and how does it relate to traffic safety culture?
- What countermeasures and post-crash factors affect the outcome of traffic safety incidents in Appalachia?
- What are the research gaps that need to be filled?

After the completion of this literature synthesis, the research team proposed the following definition of traffic safety culture in Appalachia:

> Traffic safety culture in Appalachia is the collective force of social norms, behaviors, and values that determine the average person's posture toward engaging or not engaging in road-use behaviors that can influence their safe or unsafe use of the unique roadway environments that characterize the Region.

The above definition is necessarily ambiguous due to the lack of available research on the specific traffic safety needs and characteristics in Appalachia. Appalachian concerns are regularly excluded from state Strategic Highway Safety Plans, and the limited evaluations of crash data tend to focus on seatbelt usage or broad projections of the benefits of the Appalachian Development Highway System. Simply put, the definition of traffic safety culture in Appalachia is limited because traffic safety research in Appalachia is limited.

However, in completing this research project, the research team has identified several important questions that may help future research efforts sharpen the definition of traffic safety culture in the Region and inform future projects, including the following:

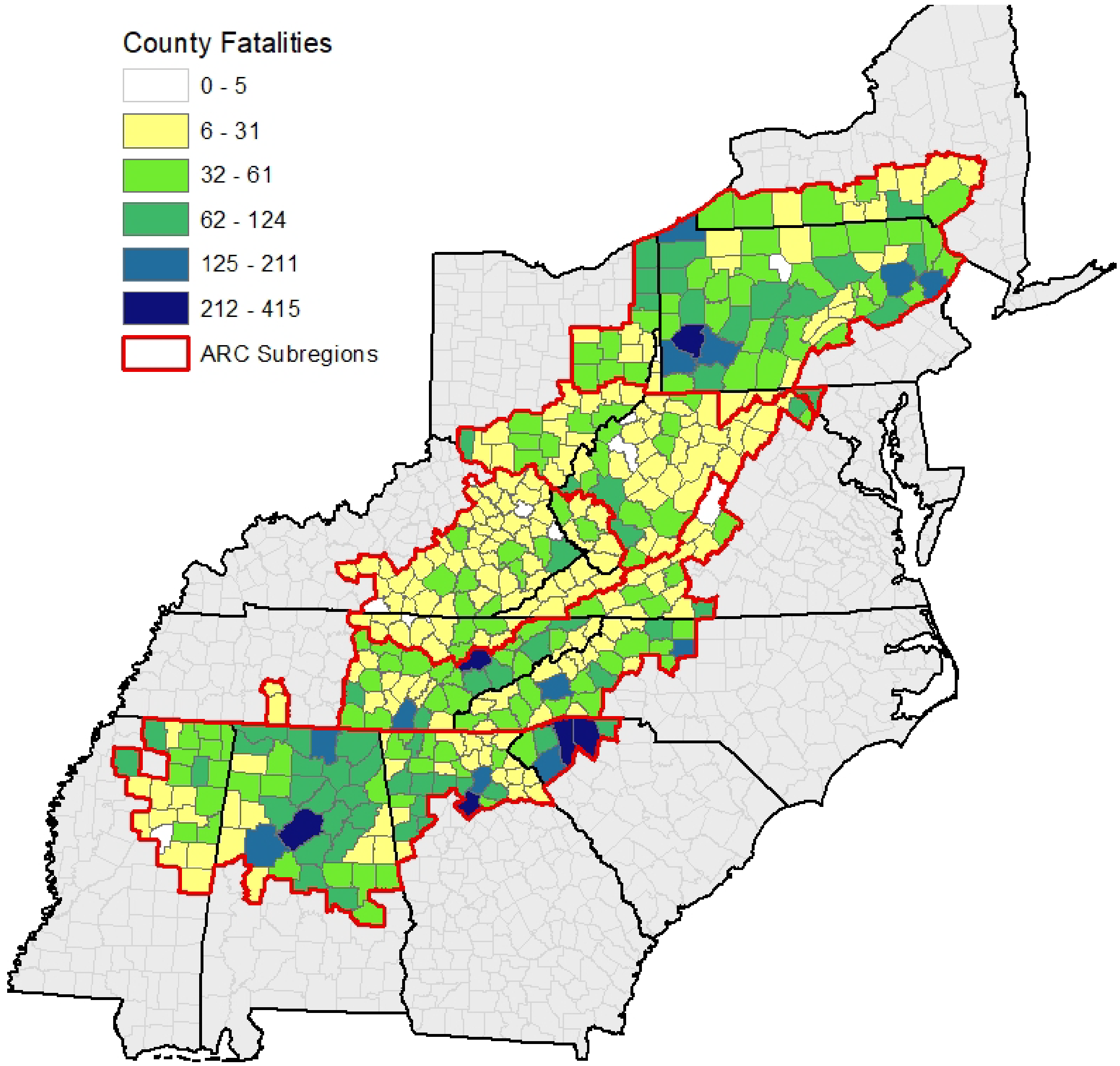
- How does roadway geometry (specifically curvature) affect the roadway departures identified by all states as a key focus area?
- How does the isolation of Appalachian roadways interplay with roadway lighting, access to emergency medical services, and access to definitive medical treatment affect crash outcomes in Appalachia?
- How dangerous are rural roads in Appalachia?
- What is the existing traffic safety culture in Appalachia?
- What poor driving behaviors are perpetuated by the existing traffic safety culture in Appalachia?
- What other cultural aspects of Appalachia affect safety in the Region?

While this project has answered many of these questions to a limited extent, answering each more fully will provide a better understanding of the culture that informs traffic safety in the Region.

Fatal Crashes in Appalachia

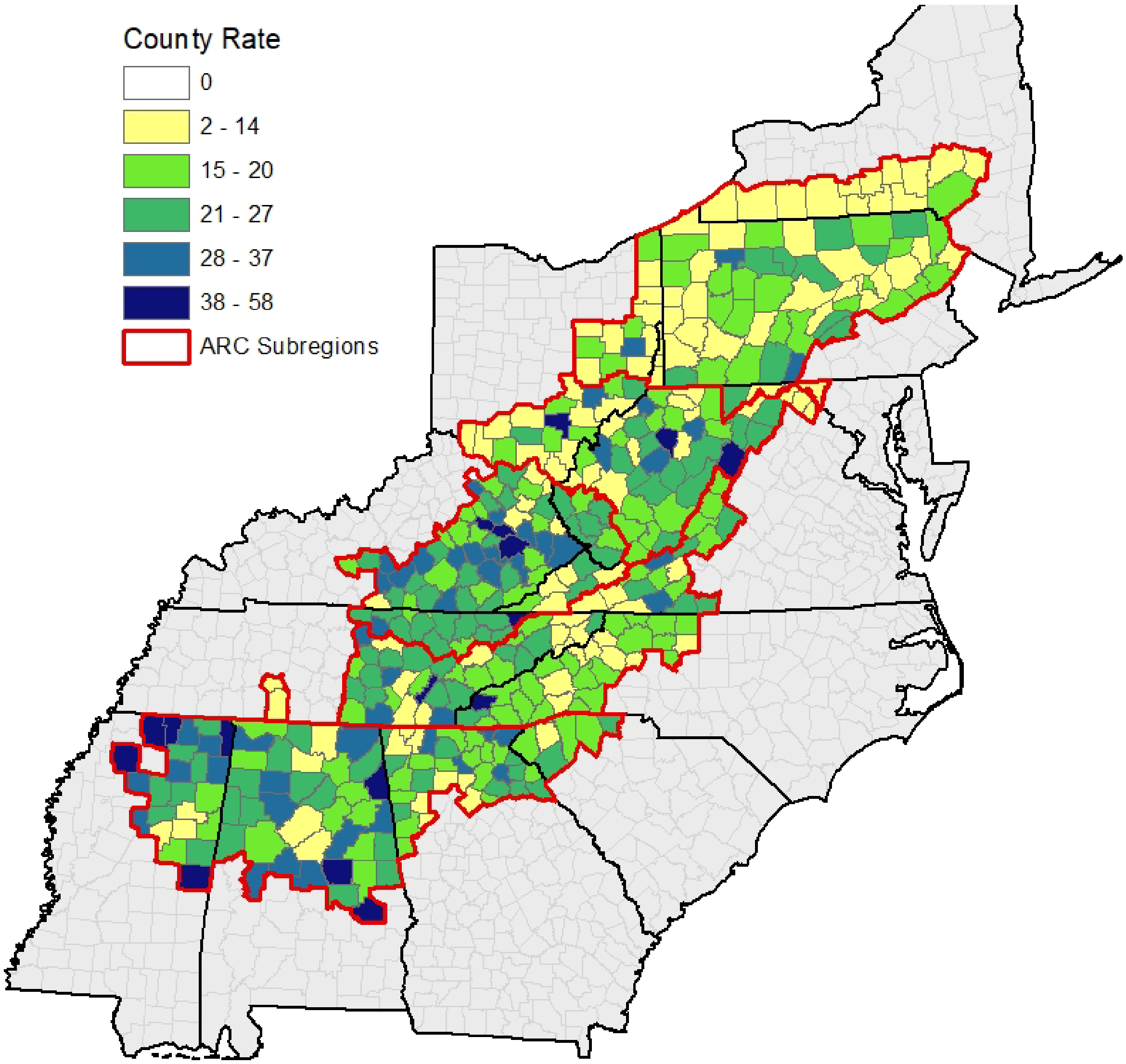
To conduct both the fatal crash analysis and the more specific drugged driving analysis, the research team collected traffic fatality data between 2013 and 2017 from the Fatality Analysis Reporting System (FARS) and compared traffic fatality rates within the Appalachian region and between Appalachian counties and non-Appalachian counties using odds ratios. The fatality counts are shown by county in Executive Summary Figure 1. The fatality rates are shown by county in Executive Summary Figure 2.

Executive Summary Figure 1: Map of Fatality Counts by Appalachian County, 2013–2017



Data Source: Fatality Analysis Reporting System

Executive Summary Figure 2: Map of Fatality Rates (per Population) by Appalachian County, 2013–2017



Data Source: Fatality Analysis Reporting System

The extensive analysis conducted for this project revealed a number of traffic safety concerns that are more prominent within the Region than in the greater United States. These concerns include the following:

- **Traffic fatality rates:** The Appalachian Region has higher traffic fatality rates than the rest of the United States. This pattern is consistent over time and across demographic characteristics. While traffic fatality rates in both Appalachia and non-Appalachia have declined dramatically over the last two decades, the decline has been more modest for Appalachia, indicating that national advances in traffic safety may not have permeated this region. Furthermore, there are striking differences in traffic fatality rates across Appalachian subregions, with the Central subregion having nearly twice the traffic fatality rate of the Northern subregion.

- **Youth and young adults:** Appalachian youth and young adults 15–24 years of age have the highest traffic fatality rates at 18.8 fatalities per 100,000 person-years. It has long been recognized that novice drivers have a higher risk of crashing. While interventions as well as cultural and economic factors have led to a reduction in youth and young adult traffic fatalities, more needs to be done to further reduce this rate for this vulnerable age group.
- **Older adults:** The median age of Appalachian traffic fatalities is 43 years of age, which is one year older than non-Appalachian traffic fatalities. Older adults (greater than or equal to 65 years of age) make up more than one-quarter of all Appalachian traffic fatalities and have fatality rates 20% higher than non-Appalachia. Older adults are more likely to sustain serious injuries in a motor vehicle collision due to increased fragility. In addition, older adults are susceptible to visual and cognitive declines that may put them at a higher risk of being involved in a crash, especially in the absence of safety improvements (e.g., improved roadway lighting and signage).
- **Working-age adults:** While working-age Appalachian adults 25–44 years of age do not have the highest traffic fatality rates by age group, this group had the highest relative difference in traffic fatality rates as compared to non-Appalachia. Since working-age adults are also at the greatest risk of suffering from “diseases of despair” (alcoholic liver disease/cirrhosis, drug overdose, and self-harm/suicide), these two seemingly disparate mechanisms of mortality may share some risk factors, such as poverty.
- **Non-motorist fatalities:** Traffic fatality rates among Appalachian pedestrians and cyclists are 22% and 46% lower than their non-Appalachian counterparts, respectively. This likely reflects a lower prevalence of walking and biking in this region, rather than a traffic safety success story. Due to the prevalence of obesity and other chronic health comorbidities in Appalachia, Appalachian states could benefit from making infrastructure improvements that are more conducive to active forms of transportation.
- **ATV rider fatalities**: ATV riders make up a surprising large proportion of traffic fatalities in Appalachia, especially in the Central subregion. Since these devices are not designed for on-road transportation, legislation should be implemented to minimize presence on public roadways.
- **Rurality:** In Appalachia, rural fatality rates are 64% higher than urban fatality rates. While rural fatality rates are also higher in non-Appalachia, a far greater proportion of Appalachian traffic fatalities occur in rural areas. While much lower than rural traffic fatality rates, urban fatality rates are 35% higher in Appalachia than in non-Appalachia. There is no clear explanation for this statistic, so more research is needed to determine what is driving traffic fatalities in urban Appalachia.
- **Ambient light and weather conditions:** Appalachian traffic fatalities are more likely to occur under dark, unlighted conditions and during inclement weather events than non-Appalachian traffic fatalities. There are numerous roadway improvements that can help prevent traffic crashes under dark, low visibility, and other adverse conditions such as better roadway lighting, high visibility signage, low visibility and adverse weather event alert systems, and road treatments to improve traction.
- **Age of vehicles:** Among traffic fatalities, the median age of Appalachian motor vehicle occupants’ and motorcyclists’ vehicles is one year older than non-Appalachian vehicles. In addition, the vehicles of Appalachian crash victims are 28% more likely to be greater than 20 years of age, as compared to the vehicles of non-Appalachian crash victims. Older vehicles are not as safe as newer vehicles.

- **Safety restraint and motorcycle helmet use:** Appalachian motor vehicle occupant fatalities are 31% more likely to be unrestrained at the time of crash than non-Appalachian occupant fatalities. The proportion of Appalachian occupants who are unrestrained at the time of crash varied from 48% (South Central subregion) to 62% (Central subregion). While seatbelt usage is generally high in the Appalachian as well as non-Appalachian United States, the relatively low frequency of restraint use suggests a segment of the Appalachian population has a traffic safety culture that does not place as high of a value on personal protection as it does on personal liberty. Somewhat conversely, Appalachian motorcyclist fatalities are more likely to be helmeted at the time of crash. The high frequency of motorcycle helmet use in Appalachia is a result of universal helmet laws in ten of the 13 Appalachian states.
- **Two-lane roads:** In Appalachia, 85% of motor vehicle occupant and motorcyclist fatalities happen in crashes on two-lane roads, 105% higher than in non-Appalachia. There is an increased risk of head-on collisions on two-lane roads related to vehicle passing. In addition, many two-lane roads occur in rural areas, so are subject to some of the same deleterious conditions described previously under "rurality." Many Appalachian states have directly addressed the need to make two-lane roads safer in their Strategic Highway Safety Plans (SHSPs).

Alcohol- and Drug-Involved Fatal Crashes in Appalachia

A goal of this project was to identify, as possible, the impacts of drug- and alcohol-impaired driving in Appalachia. Due to limitations in state-conducted drug testing at the time of crash, the analysis relied upon data from the FARS. These data, while severely limited in some regards, allowed some broad conclusions to be drawn regarding driver impairment in fatal crashes within the Region compared to the rest of the United States. Two key findings from this analysis include the following:

- **Driver alcohol impairment:** Nearly one-fifth of all Appalachian drivers involved in fatal traffic crashes are alcohol-impaired at the time of crash. While driver alcohol impairment is slightly lower in Appalachia than non-Appalachia, it is still alarmingly high, especially among men aged 20 to 34 and drivers involved in crashes during the late night and early morning hours.
- **Driver drug impairment:** Due to the limitations of the FARS drug test data reporting, motor vehicle driver drug impairment cannot be assessed and described in this report, with less than half of all U.S. drivers involved in fatal crashes having a drug test result. More research is needed to further characterize motor vehicle driver drug impairment, as well as effective countermeasures.

Case Study of Severe Crashes in Appalachian North Carolina

To verify some of the findings of the broader Appalachian results from the fatal crash analysis, the team investigated fatal and severe injury crashes in Appalachian North Carolina using crash data from 2013 to 2017. Crash trends were analyzed using annual proportions of fatal and severe injury crashes within total crashes for a variety of variables; odds ratios were also calculated for some variables.

These analyses verified many of the results from the regional fatal crash analysis. Key findings of the comparison between Appalachian and non-Appalachian North Carolina include the following:

- **Alcohol involvement:** Alcohol Involvement in fatal and severe injury crashes is lower in North Carolina than in fatal crashes in Appalachia, perhaps indicating a benefit related to North Carolina's liquor policies.

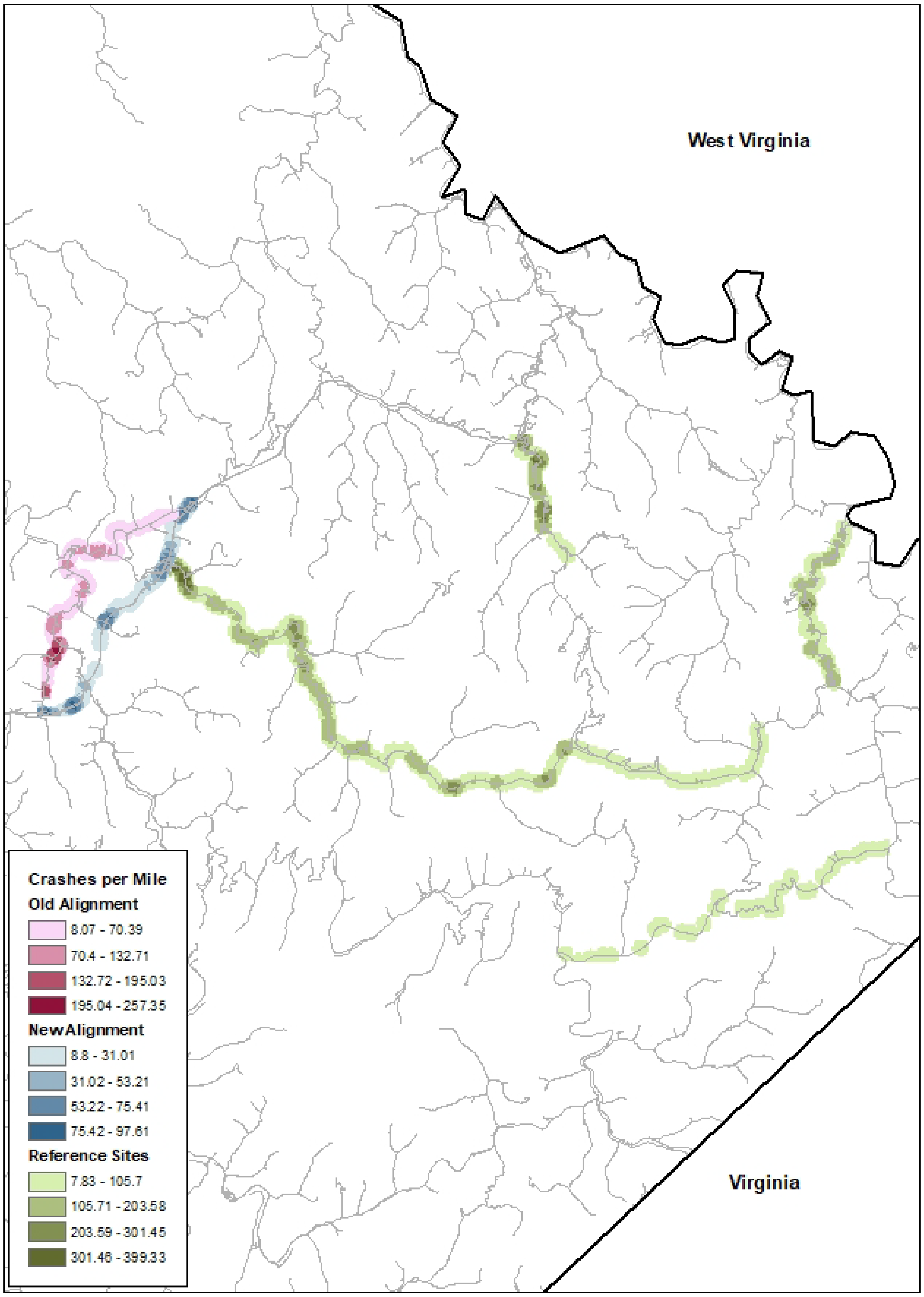
- **Seasonal trends:** The North Carolina case study verified the regional fatal crash study regarding the dangers of fall driving. Enforcement options should be considered to improve traffic safety in the fall in Appalachia.
- **Rurality and ambient lighting:** In both groups of counties, darkness in rural settings seemed to be a salient risk factor for fatal and severe injury crashes. As such, improved lighting on rural roads might have safety benefits for road users.
- **Restraint use:** North Carolina drivers seem to benefit from strong state seatbelt laws, although the death and injury rate of unbelted vehicle occupants in Appalachian counties indicate a need for universal restraint laws.
- **Helmet use:** The proportion of motorcyclists not wearing helmets when involved in a fatal or severe injury crash did increase over the years, mostly in 2016 and 2017, and this trend was evident for both Appalachian counties and non-Appalachian counties. Therefore, the motorcycle helmet law remains relevant for the state.
- **Age of vehicles:** Drivers involved in fatal and serious injury crashes in North Carolina Appalachian counties tend to drive older vehicles, so economic incentives for replacing older vehicles may be an important policy option to improve traffic safety in the Appalachian Region.

Safety Effects of the Appalachian Development Highway System

Finally, the research team evaluated the ADHS as a potential treatment of the aforementioned traffic safety concerns. Due to limitations in data collection, the research team focused on total crashes, injury crashes, multi-vehicle crashes, single-vehicle crashes, and nighttime crashes. The team collected crash, traffic volume, and roadway data within six states on both Region corridors and reference corridors with similar geometric properties; these data were analyzed using both simple rates and a cross-sectional analysis that considered the system of roadways post-ADHS corridor completion in respect to the non-upgraded corridor.

Crashes along one ADHS corridor and several reference corridors in Kentucky are shown in Executive Summary Figure 3.

Executive Summary Figure 3: Map of Sampled Crashes along Reference Corridors and ADHS Corridors in Kentucky



Data Source: Kentucky State Police, ARC

The key findings of this analysis include the following:

- **General crash rates:** On average, all of the studied ADHS alignments demonstrated lower crash rates than pre-upgrade corridors, indicating that at the traffic volumes present in the Region, the four-lane highways may outperform two-lane highways in terms of safety.

- **Total crashes:** For total crashes, the team found a potential crash reduction factor equal to 23.6% with a standard error of 0.127, meaning that the effect of the ADHS treatment on total crashes is positive.
- **Injury crashes:** For injury crashes, the team found a potential crash reduction factor equal to 29.8% with a standard error of 0.147, meaning that the effect of the ADHS treatment on injury crashes is positive.
- **Multi-vehicle crashes:** For multi-vehicle crashes, the team found a potential crash reduction factor of 36.1% with a standard error of 0.130, meaning that the effect of the ADHS treatment on multi-vehicle crashes is positive.
- **Single-vehicle and nighttime crashes:** For single-vehicle crashes and nighttime crashes, the team found no statistically significant changes after treatment. This result indicates that, based on the research assumptions, the ADHS upgrade is linked to no losses in safety and likely reduces total crash frequency.

The crash modification factors (CMFs) produced as part of this analysis are summarized in Executive Summary Table 1. Note that CMFs can be used, with proper calibration based on local traffic volume and operational data, to make project-level decisions about roadway design alternatives. Because these CMFs were developed based on historic traffic volume data, crash reductions will likely diminish as traffic volume increases or other changes are made to roadways. Moreover, these CMFs may be more appropriate for rural areas than for urban areas, given the bypass-nature of the ADHS upgrade.

Executive Summary Table 1: Crash Modification Factors Developed for the ADHS Upgrade

Crash Type	CMF for ADHS Treatment	Standard Error of CMF
Total Crashes	0.764*	0.127
Injury Crashes	0.702*	0.147
Multi-Vehicle Crashes	0.639*	0.130
Single-Vehicle Crashes	1.00	-
Nighttime Crashes	1.00	-

*Indicates statistical significance

Summary and Recommendations for Appalachia Regional Commission and Partners

After completing each subtask of this report, the team derived a revised version of the traffic safety culture working definition that incorporates many of the key findings of this project. While still ambiguous, this definition more clearly accounts for the positive and negative trends uncovered in the project and points toward future research needs.

> Traffic safety culture in Appalachia is the collective force of social norms, behaviors, and values that determine the average person's posture toward engaging in positive road use behaviors (like helmet use or not drinking and driving) or negative road use behaviors (like not wearing restraints) while navigating older (on average) vehicles on (frequently rural) roadways (often) characterized by two-lane, curved alignments with minimal lighting.

Based on the results summarized above and on the in-depth analyses contained in each chapter, the following key actions are recommended for each subtopic of this project. For each recommendation, the target audience or responsible party is identified. When possible, potential benefits for each recommendation are discussed. A full list of recommendations is contained in the conclusion of this report.

- **Traffic Safety Culture and Appalachian Research:** The key takeaway from the literature synthesis component of this project is that far more research into Appalachian traffic safety, and how traffic safety interacts with broader culture and health trends in the Region, is necessary. Specific research topics may include the following:
    a. A more substantial safety evaluation of roadways in the Appalachian Region, including non-ADHS roadways and more than just fatal crashes, to investigate the effects of roadway properties on traffic safety (e.g., horizontal curvature, roadway lighting, rural designation).
    b. Research on mode choice and the connection between transportation access and traffic safety in the Region.
    c. The effect of economic development on roadway investment, and how that connection affects traffic safety, in the Region.
- **Fatal Crashes in Appalachia:** Although the analysis of fatal crash data in the Appalachian Region uncovered a number of negative traffic safety trends in the Region, there were unexpected and positive outcomes. Therefore, the recommendations below highlight both ways that positive trends can be supported or improved and ways that negative trends may be addressed:
    a. ARC partners, such as state departments of transportation (DOTs) and local jurisdictions, should consider evaluating current roadway lighting programs to identify gaps in lighting coverage, especially on rural highways. Although different effects are reported in the literature for roadway lighting, research suggests nighttime crash reductions of close to 28% following provision of highway lighting.
    b. ARC partners, such as local governments, should consider implementing economic development efforts or policy efforts to lower the age of vehicles in the Appalachian vehicle fleet. The project found that the median age of vehicles involved in crashes was 12 years. The National Highway Traffic Safety Administration's Car Allowance Rebate System financial stimulus program resulted in a changeover from older vehicles to newer vehicles, so ARC and its partners along with local or state governments in Appalachia may consider other stimulus programs to introduce younger, safer vehicles to the driving public.
    c. While restraint use in the Appalachian and non-Appalachian United States is generally high, Appalachian motor vehicle occupant fatalities are more likely to be unrestrained at the time of crash than non-Appalachian vehicle occupant fatalities. These results indicate that there may be a negative aspect of traffic safety culture surrounding restraint use in the Region. ARC may consider working with state partners to address this shortcoming through social marketing and legislation.
- **Drug-Impaired Driving and Fatal Crashes in Appalachia:** Although this project examined drug-impaired driving trends using the FARS database, it is critical that readers recognize that there are a number of significant limitations when it comes to interpreting drug-impaired driving trends using these data. FARS data are limited by state testing and reporting requirements, and a positive drug screen does not necessarily mean that the driver was impaired at the time of

crash. Therefore, most of our recommendations regarding drug-impaired driving trends are centered on data collection and reporting needs.

  a. ARC may consider working with state agencies, like DOTs and departments of motor vehicles (DMVs), to convey the importance of routine drug testing and data collection. It can be difficult to identify problematic trends if data are not collected in a systematic way.
  b. States should set standards for drug testing and test for drug use in every fatal crash.
  c. State partners to ARC should consider following these revised data standards and drug testing protocols to perform more roadside drug and alcohol testing to better understand the frequency of impairment, especially in relation to alcohol outlets. Addressing drug-impaired driving (and its overlap with alcohol-impaired driving) will require systemic changes to the existing traffic safety culture that promotes impaired driving, so more data are needed to identify upstream causes of these behaviors.

- **Severe Crashes in Appalachia:** The North Carolina case study was primarily conducted to verify key trends identified in the fatal crash data in the broader Appalachian Region. Therefore, the team does not recommend any actions specific to North Carolina. However, some general recommendations derived from this case study and the broader fatal crash analysis include:
  a. ARC should inform state DOTs about seasonal trends in fatal and injury crashes. Both analyses found that death and serious injury crashes in Appalachian counties tend to peak during the fall months, and this peak may be due to seasonal tourism. State DOTs may in turn consider funding highway improvement projects for known tourist locations.
  b. State DOTs should consider funding rural road improvements, such as those identified through state SHSPs, to improve conditions on high-risk rural roads (HRRRs).
- **Appalachian Development Highway System:** The ADHS evaluation produced safety performance functions (SPFs) and crash modification factors (CMFs) based on a sample of crash data. These models may change as more data are collected and used in the evaluation. However, based on our current results, we can make the following recommendations:
  a. The ADHS system seems to show significant safety benefits when new alignments are compared to old alignments. Therefore, if the assumptions for traffic volume distribution hold true, the team recommends use of the ADHS system to reduce total and injury crashes.
  b. However, the models indicate no significant changes in single-vehicle and nighttime crashes. Therefore, ARC should work with state DOTs to calibrate statewide safety targets and identify countermeasures for nighttime and single-vehicle crashes to be implemented alongside ADHS improvements.
  c. All state partners should consider revising data standards and exploring data sharing with the Region to allow Region-wide safety targets to be met.

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Glossary of Acronyms

AADT	Annual average daily traffic
ADHS	Appalachian Development Highway System
ARC	Appalachian Regional Commission
aRR	Adjusted rate ratio
ATV	all-terrain vehicle
BAC	Blood alcohol concentration
CI	Confidence interval
CMF	Crash Modification factor
DMV	Department of motor vehicles
DOT	Department of transportation
DUIC	Driving under the influence of cannabis
EMS	Emergency Medical Services
FARS	Fatality Analysis Reporting System
Mph	Miles per hour
MPO	Metropolitan Planning Organization
MVM	Million vehicle miles
NHTSA	National Highway Traffic Safety Administration
P-yrs.	Person-years
RR	Rate ratio
RMVM	Rate per (100) million vehicle miles of travel
SHSP	Strategic Highway Safety Plan
SPF	Safety Performance Function
VMT	Vehicle miles traveled
Vpd	Vehicles per day
YPPL	Years of potential life lost

Chapter 1: Project Description and Literature Synthesis

1.1 Introduction

The Appalachian Region of the United States is a unique environment with specific ecological, roadway, and cultural elements. The Region comprises counties in 13 states: parts of Alabama, Georgia, Kentucky, Maryland, Mississippi, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, and Virginia, and the entirety of West Virginia. Appalachia is largely characterized by expansive rural regions, mountainous and curved terrain, and dense forests exposed to extreme weather elements. Drivers in Appalachia must contend with these environmental concerns as well as a number of cultural and health factors that can create unique traffic safety problems within the Region. Considering these traffic safety determinants in the context of Appalachia's 13-state spread requires a diverse set of explanatory variables and countermeasures.

The purpose of this literature synthesis is to identify a range of factors that may explain the current traffic safety profile of Appalachia. To accomplish this goal, the research team conducted an extensive search of literature that answers several important questions:

1. What are the key characteristics of Appalachia that should be considered in a traffic safety analysis?
2. What are common traffic safety problems throughout Appalachia?
3. What potential explanations are there for these traffic safety problems?
4. What is traffic safety culture, and what are its determinants?
5. What is a culture of health, and how does it relate to traffic safety culture?
6. What countermeasures and post-crash factors affect the outcome of traffic safety incidents in Appalachia?
7. What are research gaps to be filled?

This literature review examines these questions and highlights noteworthy variables for further investigation. Although the research team found limited Appalachia-specific literature, where possible, subsections are included to highlight Appalachian-specific concerns and studies.

1.2 Unique Characteristics of Appalachia

This section offers a brief scan of Appalachian Regional Commission (ARC) studies focused on data relevant to traffic safety culture and culture of health. The primary topics covered include demographics, roadway elements, and descriptors of health. Relevant data that contextualize these topics are synthesized to provide a more comprehensive view of the issues facing road users in Appalachia.

1.2.1 Demographic Trends in Appalachia

Traffic safety is influenced by myriad factors, and a key determinant is demographic trends and the ways in which these trends influence the culture(s) of traffic safety in a region. Pollard and Jacobsen studied a number of these trends and how key demographic characteristics, like population, age, and education, influence the health of the Appalachian Region. Specifically, many of the demographic characteristics of Appalachia's population may explain the social norms that drive crash trends and influence traffic safety in the Region (1).

1.2.1.1 Population

As will be demonstrated by the analysis of crash data in subsequent chapters of this report, traffic mortality is generally considered worse in the Appalachian Region than in non-Appalachian United States (2). There are several population characteristics that may factor into this elevated rate. The population of the Appalachian Region has been steadily growing since 2010 (up 1.1%), but at a slower rate than growth in the United States. Most of this growth is concentrated in Southern and South Central Appalachia. This growth is also concentrated in metropolitan areas (+3.7% in large metros and +1.6% in small metros). Some states are also experiencing growth in Appalachian counties, including Alabama, Georgia, North Carolina, South Carolina, and Tennessee (1). Although these general trends say little about traffic safety culture, they do indicate that special attention should be paid to the Appalachian states with growth in Appalachian counties. Typically, population increases correspond to more vehicles and more drivers, and therefore a greater potential for collisions. However, shrinking counties may also experience their own challenges, including lack of emergency medical resources (although rural trauma care is a complex issue not dependent solely on population size) (3). Therefore, Appalachian health organizations should note changes in populations and adapt as necessary.

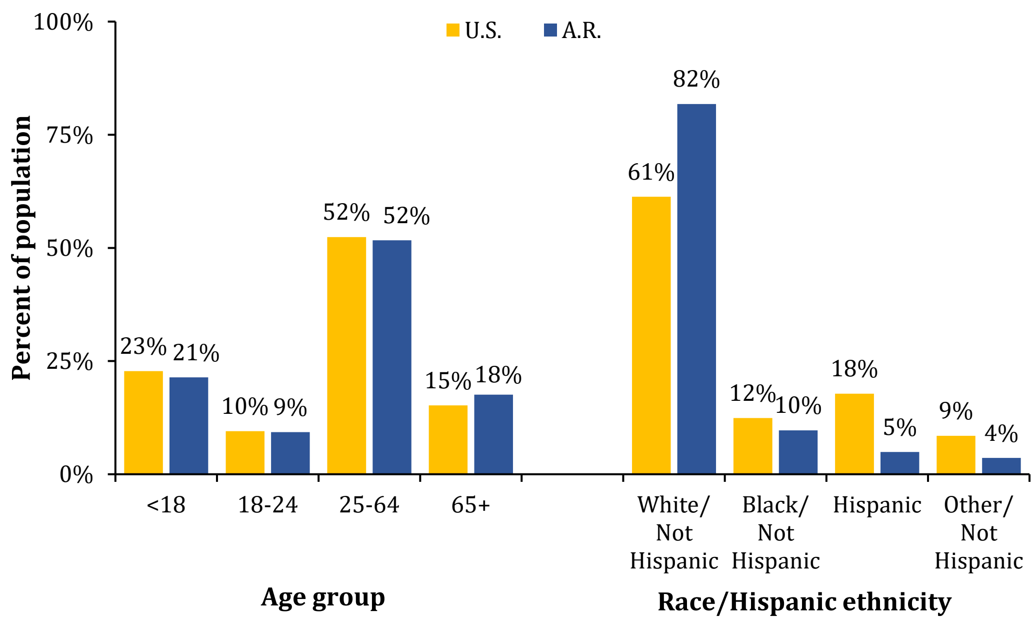
One major characteristic of Appalachia is the substantial rural area it comprises. As reported by Pollard and Jacobsen, approximately ten percent of Appalachia's population lives in counties classified as rural, and many "non-rural" counties have rural areas. Therefore, approximately 42% of the population in Appalachia lives in rural areas (compared to 19.3% of the broader U.S. population), and many more must utilize rural roads for work or travel (1). While this percentage is small compared to the metro population, it still poses a considerable risk of road injury.

Figure 1 displays the population breakdown for the Region and the broader United States by age group and ethnicity. Overall, the population of Appalachia is older and less racially and ethnically diverse than the United States (1). The median age of the Appalachian population is 40.9 years, approximately three years older than the median U.S. population (38.0 years). In addition, the proportion of the Appalachian population 65 years of age and older is growing rapidly. This increase is partly due to the aging of the baby boom cohort in the Region, as well as the exodus of younger adults to other geographic regions of the United States.

In terms of racial/ethnic makeup, non-Hispanic whites make up a much larger proportion of the Appalachian population than the rest of the United States (1). While non-Hispanic whites have lower rates of both population-based and vehicle miles traveled- (VMT-) based rates of fatal crashes than people of Hispanic, non-Hispanic black, and American Indian racial/ethnic origins on a national level, this trend may not hold true for non-Hispanic white residents of the Appalachian Region (4,5). For example, one study found that traffic crashes contributed a disproportionate burden of premature mortality among white residents of Appalachian counties, as compared to non-Appalachian counties (6). However, it is worth noting that the impacts of traffic safety on all demographics in Appalachia should be compared to that of the rest of the country.

While the proportion of the Appalachian population that is American Indian is low, the Region does contain a substantial population of the Eastern Band of Cherokee Indians in and adjoining the Eastern Cherokee Reservation. American Indians have some of the highest traffic fatality rates in the United States, with population-based rates more than double that of non-Hispanic whites and non-Hispanic blacks (5,7). Possible explanations for the elevated traffic fatality rates among American Indians include a higher prevalence of driving while impaired, lower usage of safety restraints, lower usage of motorcycle helmets, poorer road conditions on reservations, and lack of familiarity with traffic laws (8,9).

Figure 1: Demographic Characteristics: U.S. and Appalachia, 2016



Data Source: Pollard and Jacobsen. *The Appalachian Region: A Data Overview from the 2012–2016 American Communities Survey Chartbook*. 2018.

1.2.1.2 Age

The report by Pollard and Jacobsen highlights one extremely interesting demographic factor that may influence traffic safety in the region. As will be discussed more thoroughly throughout this synthesis, very young and very old drivers may be more vulnerable to death or serious injury; moreover, young drivers may lack experience that makes them more prone to risk, and older drivers may have visual and cognitive declines that may affect their driving ability. Interestingly, the percentage of the population over the age of 65 is higher in the Appalachian Region than in the rest of the United States (17.6% vs. 15.2%). Some counties in Appalachia also have a young population segment (under the age of 24) that is greater than that same segment in non-Appalachian counties, although this difference is less pronounced and not consistent across states. Worth noting, however, is the demographic concentration in rural areas. Both the under-age-18 demographic and the age-18-to-24 demographic have higher concentrations in rural areas than in several other areas, but this does not hold true for persons older than 65 (1). See Table 1 for more details. These statistics reveal that there may be high concentrations of vulnerable road users in certain Appalachian counties and rural areas that require attention. Some research indicates that crash involvement may be highest for drivers aged 21–29, so Appalachian counties with high populations of young and inexperienced drivers may be a particular concern for traffic safety (10).

The growing senior population in the Region, and the concomitant growing population of senior drivers in the Region, may impact the incidence of fatal motor vehicle crashes within the Region. Per vehicle mile driven, adults 70 years of age and older are more likely to be involved in a police-reported crash and more likely to be involved in a fatal crash, despite being less likely to drive while intoxicated and more likely to wear a seatbelt than younger drivers (11,12). For example, drivers aged 70–74, 75–79, and older than 80 were 1.8, 2.3. and 4.7 times more likely to be involved in a fatal crash per 100 million VMT than drivers 35–54 years of age, respectively (13). The increased risk of death by motor vehicle among older adults is multifactorial, and may include factors such as decreased visual, physical, and cognitive functioning; increased fragility; increased prevalence of chronic diseases and other comorbidities; and increased use of medications with psychotropic properties (14–17).

Table 1: Select Age Demographics in Appalachia (1)

Population by Age Group	Total Population, July 1, 2016	Percent of Population				Median Age (Years)
		Under Age 18	Ages 18–24	Ages 25–64	Ages 65 and over	
United States	**323,127,513**	**22.8**	**9.5**	**52.4**	**15.2**	**38.0**
Appalachian Region	**25,552,573**	**21.4**	**9.3**	**51.7**	**17.6**	**40.9**
Subregions						
Northern Appalachia	8,235,997	19.8	9.6	51.6	19.0	42.6
North Central Appalachia	2,413,170	21.0	9.2	51.8	17.9	41.3
Central Appalachia	1,877,400	21.5	8.4	52.2	17.9	41.8
South Central Appalachia	4,845,592	20.3	9.5	51.1	19.1	42.2
Southern Appalachia	8,180,414	23.7	9.2	52.1	15.0	38.4
County Types						
Large Metros (pop. 1 million +)	6,073,724	22.7	8.5	53.3	15.5	39.5
Small Metros (pop. <1 million)	10,811,590	21.0	10.0	51.5	17.5	40.6
Nonmetro, Adjacent to Large Metros	2,194,785	21.4	9.5	50.9	18.1	41.5
Nonmetro, Adjacent to Small Metros	3,959,266	20.7	8.6	50.9	19.8	43.2
Rural (nonmetro, not adj. to a metro)	2,513,208	21.2	9.5	50.7	18.6	41.6

Data Source: Pollard and Jacobsen. *The Appalachian Region: A Data Overview from the 2012–2016 American Communities Survey Chartbook*. 2018.

1.2.1.3 Education

Although education was not a variable that routinely appeared in the traffic safety culture literature, it may serve as a proxy factor for other culture of health explanations, such as economic status and access to information. In general, the population of the Appalachian Region is less educated than the rest of the population in the United States. A higher percentage of residents of the Appalachian Region has less than a high school diploma than their counterparts in the rest of the United States (14.1% to 13.0%). More starkly, only 23.2% of Appalachian residents have a Bachelor's degree or more, compared to 30.3% for U.S. residents (1). Again, the link between education and traffic safety culture is vague and undefined in the literature, but a lower education rate may explain some cultural elements, such as the percentage of blue-collar jobs that require regular driving. This variable may be difficult to explore through crash data, but the research team will examine vehicle choice at the least.

1.2.2 Descriptors of Health and Safety in Appalachia

Beyond the more general concerns of vulnerable demographic groups and specific roadway design risks common to Appalachia, drivers in the Region may also be susceptible to a variety of other risks that have been identified in the literature. These risks may affect both the culture of traffic safety in the region and the likelihood of severity in a crash. They should therefore be considered when analyzing crash data to identify factors affecting traffic safety problems in the region.

1.2.2.1 Economic Development and Housing

As hinted at in the previous paragraph, economic development and social stability may affect traffic safety culture in Appalachia. Housing trends reported by Pollard and Jacobsen seem to indicate high incidence of vacant housing in rural Appalachia. Less than 80% of housing units were occupied in 23 Appalachian counties from 2012–2016, and almost all of the Appalachian counties with vacancy rates above 20% were located outside metropolitan areas (1). These data suggest less economic stability in the region, especially in rural areas. Labor data also confirm this finding. Pollard and Jacobsen reported that although the percent of prime working age residents (ages 25– 64) was comparable to the general U.S. rate, there were 53 counties from 2012 to 2016 where less than 60% of residents in the prime working age were employed in the civilian labor force. Almost all of these counties are outside large metropolitan areas (1). Pollard and Jacobsen also reported that from 2012 to 2016, the mean income of Appalachian households was only 80% of the total U.S. average; lower income households were disproportionately located in rural areas and in Central Appalachia (1). These data seem to suggest that populations in Appalachia, especially residents in rural areas, are more vulnerable to economic forces and may have less mobility and access to health care. Pollard and Jacobsen also reported higher incidence of veteran status and lower earnings as a result of education rates, and these data may be connected to low migration rates within the Appalachian Region (1). While none of these elements themselves are explicitly linked to crash risk, potential relationships should be explored as determinants of traffic safety culture, if possible. As Ward mentions, rural locations are characterized by slow change and little economic differentiation; these conditions are linked to the kind of culture that takes root in an area, so further research on the connection between economic conditions and traffic safety culture is warranted.

1.2.2.2 Health and Mortality

Many of the health issues discussed in this report are especially relevant to Appalachia and directly influence the potential for death or serious injury in a crash. According to Lane et al., counties in Appalachia on average rank below the national norm for health care coverage. That means that Appalachian residents, especially those in poor and rural communities, typically have higher health care costs and lower access than both the U.S. average and non-Appalachian counties in their own states (18). Interestingly, Pollard and Jacobsen reported that, on average, fewer residents are uninsured in Appalachia (10.9% for all ages) than the average number of U.S. residents (11.7% for all ages) (1). However, Lane et al. contextualized these data by indicating that even in Appalachian counties with high health insurance coverage, access to medical resources was limited (18). To further contextualize these data, Pollard and Jacobsen reported that there are more persons in Appalachia with a disability for all age groups (16.1%) than in the United States in general (12.5%). Unfortunately, as reported by Marshall et al., the Appalachian Region has a lower supply of healthcare providers than the United States as a whole, and a 25% higher rate of “potential life lost” (YPLL) (19)—an estimate of the average amount a time a person would have lived had they not died prematurely (20). In fact, persons in non-Appalachian counties on average die younger from preventable causes than those in non-Appalachian counties (18). Lower access to quality healthcare, disability status and other health comorbidities, and rural isolation may all contribute to a lower likelihood of survival post-crash. Appalachia has a high incidence rate of drug overdoses (20,21), and drugged driving as a risk factor for a crash is a major concern. For all these reasons, the Appalachia region is a nexus of unique challenges to traffic safety.

1.2.3 The Appalachian Development Highway System

A key characteristic of the Appalachian Region is the Appalachian Development Highway System (ADHS). The ADHS was founded in 1965 by the Appalachian Regional Development Act (ARDA) and was authorized by Congress to receive federal assistance for highway construction that same year. Although the primary goal of the system was economic development, a study published in 1998 by ARC claimed that upgrading the transportation system in the Region would produce a number of traffic safety benefits (22).

Roadways in Appalachia are characterized by narrow, winding stretches through diverse topography, limited sight distances, single lanes in each direction, limited shoulders, high amounts of access, and trees and other obstructions close to the roadway. That is to say, Appalachian highways are characteristically rural, two-lane highways with frequent access points. Their isolation and steep grades can make emergency response difficult.

When Congress initially approved the ADHS, they authorized 3,025 miles of roadway for reconstruction or new construction. The bulk of these new miles are four-lane highways, although some upgraded two-lane highways remain; in some cases six- and eight-lane highways are also authorized (22). As of the most recent status report, 2,614.4 miles of the now 3,090.1 eligible miles in the ADHS system are complete. Table 2 shows the completed miles by state and status.

Table 2: Status of ADHS Completion in Miles (23)

State	Miles Open to Traffic		Miles Not Open to Traffic			Total Miles Eligible for ADHS Funding
	Complete	Remaining Stage Construction	Construction Under Way	Design Stage	Location Stage	
Alabama	187.8	42.2	3.2	19.2	43.3	295.7
Georgia	101.5	0.0	0.0	10.5	20.5	132.5
Kentucky	408.7	0.0	9.1	0.5	8.0	426.3
Maryland	77.0	3.7	0.0	0.0	2.5	83.2
Mississippi	109.2	0.0	0.0	8.3	0.0	117.5
New York	220.7	1.3	0.0	0.0	0.0	222.0
North Carolina	178.2	8.0	0.0	0.0	18.1	204.3
Ohio	178.2	0.0	16.2	0.0	7.1	201.5
Pennsylvania	336.9	2.9	17.5	8.4	87.4	453.1
South Carolina	22.9	0.0	0.0	0.0	0.0	22.9
Tennessee	250.4	61.4	3.4	0.0	14.1	329.3
Virginia	163.5	0.0	6.5	7.5	14.7	192.2
West Virginia	379.4	0.0	7.0	7.9	15.3	409.6
System Totals	2614.4	119.5	62.9	62.3	231.0	3090.1

Data Source: Appalachian Regional Commission, 2018.

1.3 Traffic Safety Concerns in Appalachia

A key focus of this synthesis is the way traffic safety concerns manifest in the Appalachian Region. To that end, unique safety concerns in Appalachia were identified through both research literature and through state documents. Research literature is first presented in this section to characterize the roadway environment of the Region. Next, the unique concerns related to driver behavior and other risk factors are described through a synthesis of the Appalachian states' Strategic Highway Safety Plans (SHSPs).

1.3.1 Roadway Characteristics in Appalachia

One element not widely examined in the traffic safety culture section of this synthesis was the effect of land use and roadway environment on traffic safety culture. As mentioned, the reason for this limitation is the importance of engineering countermeasures; traffic safety culture is more focused on behavioral countermeasures, while engineering countermeasures are a continuous need. However, one hypothesis of this project is that Appalachia may possess unique roadway characteristics that increase crash risk for residents in the Region. Therefore, the research team also investigated literature about Appalachia to identify specific indicators of risk related to land use and roadway design in the region.

1.3.1.1 Rural Area

As illustrated throughout this synthesis, rural roads are generally associated with greater crash risk and greater risk of death or injury. The reasons for this heightened risk for drivers on rural roads are many, but common factors include driving distances, lower population density, high speed limits, roadside hazards, poor clearance zones, and more (24). The culture of health discussion illustrates that rural areas can also have decreased access to emergency medical care, thereby increasing the potential for someone in a crash to be killed or seriously injured. Lane et al. reported significant lack of access to health care for much of Southern and South Central Appalachia, and many of these areas with low access also contain vulnerable rural populations (18). Complicating these issues is the fact that the largely rural nature of the ADHS means that the roads travel through rugged and environmentally challenging areas that may present dangerous roadway curvature or grade to drivers (25). Therefore, the rural or urban nature of crashes analyzed will be considered to determine what function rurality plays for traffic safety in the region.

Several Appalachian states reported disproportionate safety burdens on rural roads in their SHSPs. In 2015, 63% of fatalities occurred on rural roads in Alabama. Complicating this burden on rural roads is the fact that the 45% of fatal crashes in Alabama that year occurred on locally owned roads (26); rural roads are often isolated, resulting in difficulties in maintenance and emergency care that can exacerbate crash severity. While this crash distribution varies among Appalachian states, the pronounced rurality of the Region raises a number of concerns for traffic safety.

1.3.1.2 Quality of Infrastructure

One of the primary concerns of the present study is the quality of infrastructure in the Appalachian Region, with a particular focus on how the ADHS may or may not improve safety. To this end, the research team scanned literature to identify specific concerns with roadway infrastructure in the area. In 2014, the University of Illinois at Urbana-Champaign Regional Economic Applications Laboratory published a report on economic diversity in Appalachia. In this report, the authors concluded that the Region would benefit greatly from growing and enhancing infrastructure, especially in isolated rural counties (27). Much of the Region is connected by two-lane, undivided highways with minimal safety considerations due to rural isolation that can result in a lesser allocation of resources (24). As reported by the Economic Development Research Group, the design standards of these roads are significantly lower than that of access-controlled freeways, which could lead to potentially dangerous designs. The highways throughout the region also serve as freight corridors that increase the motoring public's exposure to potentially severe crashes with heavy vehicles (25). Based on these reports, it is evident that Appalachia's roadways need improvement, and that these improvements may come with additional benefits. Not only would residents benefit economically from infrastructure growth (25), but improving these highways would likely result in safer shoulders, improved guard rail placement, and less potential for conflicts through access control. However, improved facilities and the increased traffic they may draw may actually increase the likelihood of conflicts between vehicles due to increased exposure. Therefore, the crash modeling component of this study will be critical for providing safety recommendations to ARC.

1.4 Road User Behavior, Human Factors, and Roadway Crashes

1.4.1 Traffic Safety

In this section, statistics related to traffic safety and the culture of health that it affects are provided to create a composite look of health and morbidity in Appalachia.

1.4.1.1 Relationship between Health, Culture, and the Epidemiology of Motor Vehicle Traffic-Related Injuries and Fatalities in Appalachia

For decades, the Appalachian Region has faced numerous public health challenges related to a lack of educational and professional opportunities, poverty, geographic isolation, etc. (28). While Appalachia's unique combination of socioeconomic, demographic, behavioral, cultural, and environmental attributes have created a vibrant, diverse, and distinctive way of life, it has also contributed to excess premature mortality from heart disease, lung cancer, colorectal cancer, chronic obstructive pulmonary disease, Type II diabetes, suicide, and unintentional injury (20,21,29).

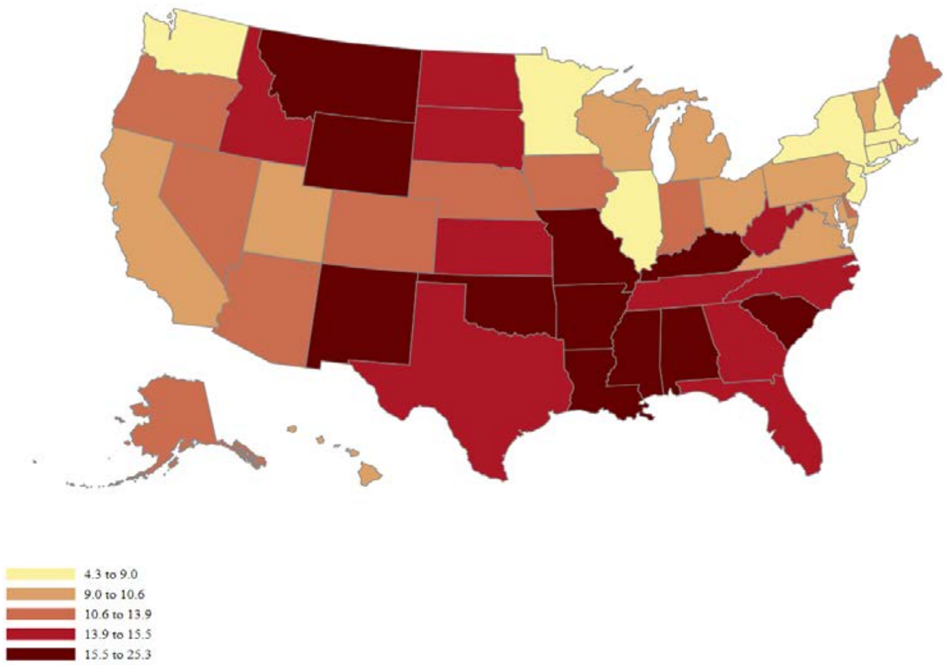
Several studies have examined the relationship between health, socioeconomic, and cultural factors and increased infectious and chronic disease morbidity and mortality in the Region. However, few studies have examined the relationship between health, culture, and motor vehicle crash morbidity and mortality in Appalachia.

1.4.1.2 Mortality

Over the last several years, the U.S. life expectancy has declined for the first time since the early 1990s (30). While fatality rates of six of the ten leading causes of death decreased during this period, the unintentional injury fatality rate increased by 10% from 2015–2016 (31). Unintentional injury fatality rates are not consistent across the nation, however. In 2016, West Virginia had the highest age-adjusted unintentional injury fatality rate at 90.0 deaths per 100,000 person-years, 1.8 times the national average. Overall, nine of the thirteen states within Appalachia had higher unintentional injury fatality rates than the national average of 49.9 deaths per 100,000 person-years (5). The two leading causes of unintentional injury fatalities were drug overdoses and motor vehicle traffic crashes (30).

Figure 4 displays the 2016 age-adjusted U.S. fatality rates of motor vehicle traffic-related deaths per 100,000 person-years. Traffic fatality rates were higher than the national average of 12.0 deaths per 100,000 person-years for eight Appalachian states (deaths per 100,000 person-years in parentheses): Alabama (23.3), Georgia (14.9), Kentucky (18.5), Mississippi (25.3), North Carolina (14.2), South Carolina (20.9), Tennessee (15.3), and West Virginia (14.6) (5).

Figure 2: Map of Motor Vehicle Traffic-Related Deaths per 100,000 Person-Years: United States, 2016



Data Source: National Center for Injury Prevention and Control, Centers for Disease Control and Prevention, 2018.

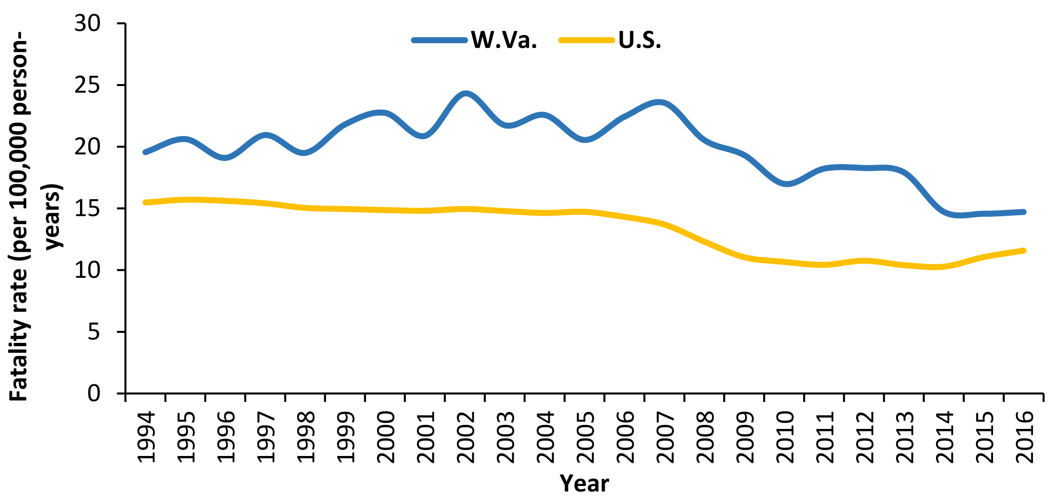
Since peaking in the 1970s, the number of motor vehicle traffic fatalities has decline steeply (32). Much of this decline has been attributed to the following factors (among others):

- **Increased seatbelt use:** Research indicates that wearing a seatbelt reduces the risk of fatal injury by 45% (33). In 1984, New York passed the first state law requiring seatbelts, at which time the national prevalence of seatbelt use was 14%. Today, all states except New Hampshire require seatbelts (34). As of 2018, the national prevalence of seatbelt use was 89.6% (35)
- **Increased use of child car seats, booster seats, and/or other forms of child restraints:** Over the period 1999–2008, the number of children under age 15 who died in motor vehicle crashes decreased by 45%. Part of this decline was attributed to the widespread use of child restraint systems following passage of child restraint legislation in all 50 states in combination with educational and promotional campaigns (36).
- **Improved requirements on teen driver's licenses:** Teen drivers are at an increased risk of being involved in motor vehicle collisions, as compared to adult drivers (37). However, the number of teen traffic fatalities has declined by 37% since 2007. Much of this decline has been attributed to the passage of graduated driver licensing (GDL) systems, with passage of GDL legislation associated with a 16-to-21% reduction in the rate of fatal crashes involving teenagers (38).
- **Decreased driving under the influence of alcohol:** Although the proportion of intoxicated drivers involved in fatal motor vehicle collisions has remained steady in recent years, since the early 1980s, the number of fatal crashes attributed to driving under the influence of alcohol has decreased by approximately 40%. This decrease has been attributed to increased public awareness of the dangers of drinking and driving, passage and enforcement of maximum blood alcohol content (BAC) legislation, and an increase in the minimum legal drinking age (39).

- **Improved vehicle engineering and design:** Over the last few decades, there have been major advancements made to the design of motor vehicles for the protection and safety of occupants. These improvements include the development and application of frontal, side, and curtain air bags; better vehicle lighting; electronic stability control; antilock braking systems; automatic crash intervention and warning systems; and improved structural design and crashworthiness. According to Farmer and Lund (40), improvements to vehicle design prevented nearly 8,000 deaths in 2012.

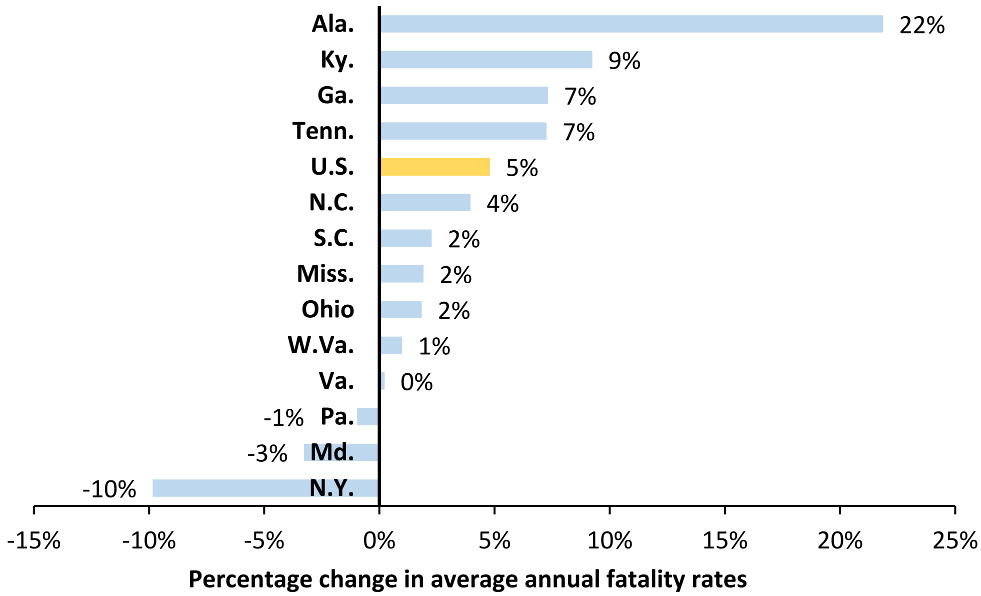
Despite the downward trend over the last three decades, rates of motor vehicle traffic-related deaths have fluctuated over time, and trends have not been consistent across all geographic regions. Figure 5 displays the unadjusted motor vehicle fatality rates for the United States and West Virginia, the only state with all counties located within the Appalachian Region, over the period 1994–2016. For the entire period, West Virginia had a higher traffic fatality rate than the United States. Over the course of 1994–2007, there was relatively little change in the U.S. traffic fatality rate. However, following the Great Recession in 2008, the U.S. rate declined sharply, and then, beginning in 2015, increased. A similar trend was not observed for West Virginia. The reason for the rise in the rate of U.S. traffic fatalities in 2015 is unknown (although it may be attributed to exposure), but the largest percent increases in fatality rates were observed for nonoccupants (motorcyclists, bicyclists, and pedestrians), drivers under the age of 25, and drivers 65 years of age and older (41). Among states containing counties within the Region, Alabama, Kentucky, Georgia, and Tennessee had the largest percent increases in traffic fatality rates from 2015 to 2016 (Figure 6) (42). Fatality rates will be discussed more thoroughly later in this report.

Figure 3: Motor Vehicle Traffic-Related Deaths per 100,000 Person-Years: U.S. and W.Va., 1994–2016



Data Source: National Highway Traffic Safety Administration, 2018b.

Figure 4: Percent Change in the Rate of Motor Vehicle Traffic-Related Deaths: U.S. and W.Va., 2015–2016 (with Other Appalachian States for Comparison)



Data Source: National Highway Traffic Safety Administration 2018b.

1.4.2 Driver Behavior and Risky Behaviors

To gain an initial understanding of potential traffic safety problems in Appalachia, we scanned a variety of resources. These resources include both research literature and each of the Appalachian states' SHSPs (26,43–54). Although none of the Appalachian states' SHSPs explicitly mentioned Appalachian roadway concerns (West Virginia's fully Appalachian status excluded), a number of roadway issues were frequently addressed, especially as they related to rural roads. Given the rural nature of many Appalachian counties, and the frequency with which these items were mentioned, the following roadway concerns are prime targets for analysis in Appalachian traffic safety.

- Roadway departures, especially as they relate to speeding and impaired driving (26,43,46,48–51,53).
- Aggressive driving, especially on horizontal curves where roadway lighting and signage may be poor (26,44,45,52).
- Distracted and impaired driving (26,43–45,47,48,50–52).
- Lack of restraint use (26,43,45,47-51,54).
- Need for improved emergency medical services (EMS) access, especially in rural areas (46,52).
- Lack of data quality and availability for quickly addressing safety problems (43,45,46,49,53,54).

Although these challenges are not unique to Appalachian counties or even rural counties, they may still represent exaggerated risks in the Appalachian Region. Ohio's SHSP shows that many roadway safety emphasis areas—including roadway departures, speeding, restraint use, motorcycle operation, and distraction—are greater concerns on rural roads (here defined as roads outside municipal corporation limits), so these emphasis areas may be of particular concern in Appalachia (48). Given West Virginia's status as the only fully Appalachian state in the region, its SHSP provides a helpful validation of the traffic safety concerns raised by the other state SHSPs. Much like the other Appalachian states, West Virginia's SHSP identifies roadway departures, alcohol- and drug -mpaired driving, occupant protection, speeding and aggressive driving, and improving highway safety data as key concerns (53). Fatal crash data analysis may indicate if these issues are indeed exacerbated throughout the Region. These concerns represent research gaps for potential analysis.

Unfortunately, little research has focused on the specific impacts of these emphasis areas on traffic safety in Appalachia. As mentioned, none of the state SHSPs focused specifically on Appalachian topics, and even in cases where these topics are researched for rural areas, the scope is rarely as specific as the Appalachian Region. However, a few references to Appalachian-specific issues are detailed below.

1.4.2.1 Roadway Departures

In 2011, the National Association of Counties hosted a webinar specific to roadway departure issues. One presenter from Douglas County, Georgia, discussed the unique concerns of roadway departures in a specific Appalachian County. In this presentation, the presenter noted that although lane widths, striping, and pavement condition meet expected design standards, the county's high growth rate resulted in a higher number of drivers than many other counties in Georgia. These high vehicle miles of travel are problematic for the county due to a number of poorly designed horizontal curves (marked by sharp turning radii, fixed objects near the lane, and poor shoulders) that create a higher rate of crashes per 10,000 licensed drivers than many other counties in the state. Douglas County launched a project to target 35 risky curve locations and treated those locations with improved signage and clearance zones to mitigate the dangers of speeding and aggressive driving. A simple before-after evaluation revealed a potential decrease in roadway departures equal to 20%. Although these results cannot be extrapolated to the rest of Appalachia, given the SHSP emphasis on roadway departures, they may be emblematic of unique safety problems in Appalachia worth exploring (55).

1.4.2.2 Restraint Use

The research team found one study that compared crash rates inside and outside Appalachian counties while accounting for seat-belt usage and potential lives saved. For this study, Birru et al. closely examined Fatality Analysis Reporting System (FARS) data and used the National Highway Traffic Safety Administration (NHTSA) method of estimating lives saved through seatbelt usage as reported in crash data. The authors concluded that seatbelt usage is lower in Appalachia than in the rest of the United States (81.6% vs. 86.9%), and that if seatbelt use had been 100% in 2012, 1,955 fatalities may have been avoided. The authors attribute this low seatbelt usage to a variety of implicit and explicit demographic factors, but a likely explanation is the endemic traffic safety culture of the Region. As will be discussed later in this document, traffic safety culture is driven by prevailing norms and beliefs in an area; there are all manner of cultural elements that may induce a lack of restraint use, including convenience, isolation, religiosity, political beliefs, and even the age of available vehicles (56–58). These deeply rooted cultural elements can be difficult to change, especially in isolated rural areas or areas with strong cultural identities (59). It may therefore be worth investigating how economic development in the region affects optimism for residents. Regardless, countermeasures that work to address the fatalism may be effective in increasing seatbelt usage in Appalachia.

1.4.2.3 Impairment: Alcohol

Driver consumption of alcohol has long been known to increase the risk of being injured or killed in a motor vehicle crash. Drivers with BACs of 0.04, 0.08 and 0.10 have 1.2, 2.7 and 4.8 times the risk of being involved in a motor vehicle crash as compared to drivers with BACs of 0.0, respectively (60). Although no studies have directly compared the prevalence of driving while intoxicated among Appalachian drivers to non-Appalachian drivers, there is reason for concern.

Prevalence of Alcohol Use Disorders

Appalachia consists of a significantly rural area, and rural residents are at a greater risk of being involved in a fatal alcohol-related crash than non-rural residents (61). In addition, Appalachian counties have higher fatality rates related to alcoholic liver disease and cirrhosis (11.4 deaths per 100,000 person-years) as compared to the rest of the United States (10.6 deaths per 100,000 person-years) with economically distressed Appalachian counties faring particularly poorly (15.4 deaths per 100,000 person-years) (21). Higher rates of alcoholic liver disease are indicative of a higher burden of alcohol use within a community. In turn, alcohol dependence is associated with a higher risk of being involved in a fatal motor vehicle crash (62). However, it is unclear if the Appalachian Region has a higher prevalence of alcohol dependence as compared to the rest of the country. Dwyer-Lindgren et al. (63) did not identify the Appalachian Region as having an undue burden of alcohol use disorders. In addition, a CDC study of binge drinking found that West Virginia had one of the lowest reported age-adjusted prevalence of binge drinking of any U.S. state (12%; binge drinking was defined as four or more drinks for a woman or five or more drinks for a man on a single occasion during the past 30 days) (64). For comparative purposes, the U.S. average was 17% and the state with the highest prevalence, North Dakota, had an adult prevalence of binge drinking of 25% of the state population. More research is needed to describe the relationship between alcohol and traffic fatalities in Appalachia.

1.4.2.4 Impairment: Other Drugs

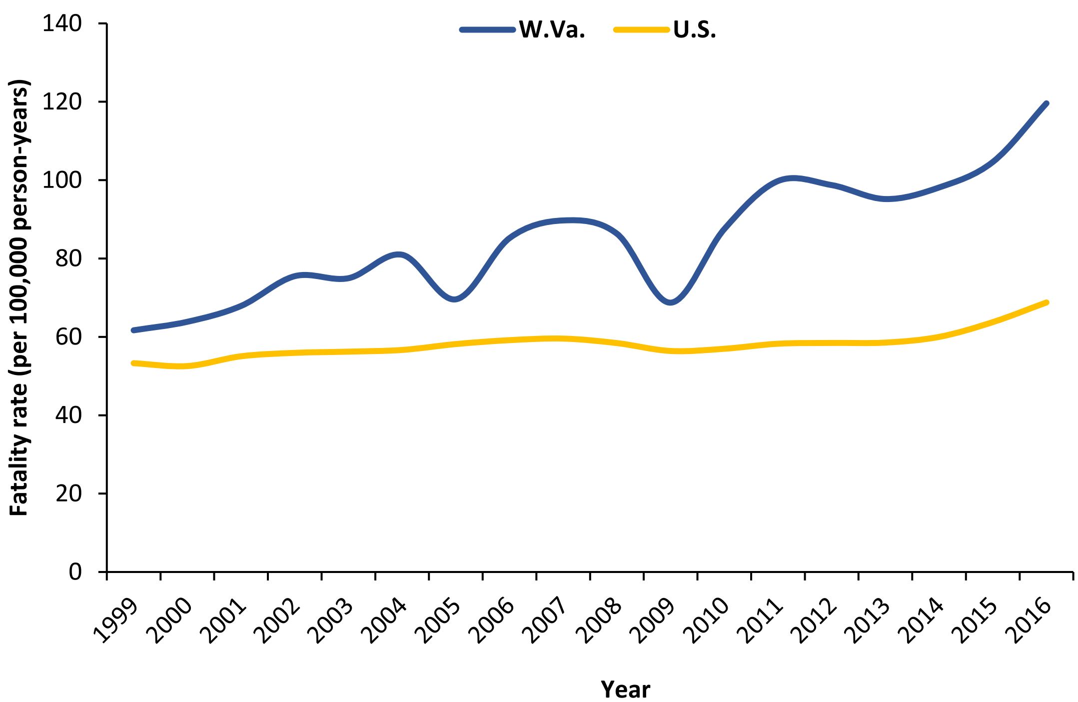
While it is unclear if the Appalachian Region has a higher prevalence of alcohol dependence and other alcohol use disorders, the evidence is quite clear that it is one of the U.S. regions with the highest prevalence of drug dependence, specifically opioids. Opioids are a class of drugs derived from compounds that resemble the psychoactive chemicals naturally produced by the opium poppy. Opioids are available as prescription medications (e.g., Oxycontin® and Vicodin®) and as illicit "street" drugs (e.g., heroin). For hundreds of years, opioids have been used to treat moderate to severe pain. Unfortunately, opioids are highly addictive, and overdoses can lead to respiratory depression and death (65).

The Opioid Overdose Crisis

While opioid addiction has been present for centuries, it was not until recently that a significant proportion of the U.S. population has become dependent on opioids. Starting in the late 1980s, the medical community incorporated the use of opioid medications into the standard regimen for treating chronic pain. Historically, opioid medications were used primarily for acute pain relief. In 1990, an estimated two million patients filled at least one opioid prescription. By 1999, this number had increased to 11 million, and by 2016 had increased to a substantial 62 million patients (66). The frequency of prescription opioid dispensing has resulted in an increased incidence of prescription opioid overdose deaths. In 1999, there were 1.2 fatal prescription overdose deaths per 100,000 person-years in the United States. By 2016, this rate had increased to 5.2 deaths per 100,000 person-years; an increase of more than 300%. In turn, the rise in prescription opioid misuse, abuse, and dependence has fueled a parallel rise in heroin and fentanyl overdoses (67,68).

Appalachia has been especially hard-hit by the drug overdose crisis. Although they may not be representative of overdose rates throughout the entire Region, rates in West Virginia may illustrate one aspect of mortality linked to drug use in Appalachia. Figure 8 displays drug overdose fatality rates (includes all types of licit and illicit drugs and medications) for the United States and West Virginia. Since 1999, West Virginia has had a higher drug overdose fatality rate than the United States as a whole (5). The reasons why the Appalachian Region has a higher prevalence of drug misuse, abuse, and dependence are complex and interconnected, but include a high prevalence of workplace injuries and chronic pain, lack of patient and provider education, poverty, and a lack of adequate drug treatment and mental health facilities (21,69,70).

Figure 5: Drug Overdose Deaths per 100,000 Person-Years: W. Va. and United States, 1999–2016



Data Source: National Center for Injury Prevention and Control, Centers for Disease Control and Prevention 2018.

The Relationship Between Opioid Use and Motor Vehicle Collision

There are few studies that have examined the association between opioid use and the risk of motor vehicle collision. Evidence suggests that opioid use may lead to cognitive and psychomotor impairment (71). A 2017 meta-analysis performed by Chihuri and Li (72) found a significant association between prescription opioid use and motor vehicle crash involvement. The summary odds ratio (OR) and confidence interval (CI) from the pooled data was 2.29 (95% CI: 1.59–3.48); that is, prescription opioid use more than doubles the risk of crash involvement. A 2018 study released since the meta-analysis was published found that three percent of survey respondents admitted to driving under the influence of prescription opioids. Survey respondents who reported driving under the influence of opioids were 1.97

times more likely to report being in a motor vehicle collision as compared to individuals who did not report driving under the influence (73). An older survey from 2007 found even higher rates (11.0% for daytime and 14.4% for nighttime) of drug-positive results among drivers; low self-reporting may be responsible for the lower percentage in the 2018 study (74).

Estimates of the proportion of traffic fatalities related to drugged driving are difficult to obtain. For example, the proportion of persons killed in traffic crashes who are tested for drugs varies widely by state (the range is 2% to 96%). In addition, toxicological testing protocols vary over time and across geographic locations. Even within a state, methods and reporting may differ. That said, among fatally injured drivers with known drug test results, 44% were drug-positive in 2016. In addition, among drivers with positive drug test results, 41% tested positive for marijuana and 20% tested positive for opioids. Unfortunately, these estimates cannot be used to establish a causal relationship between drug use and traffic fatality (75). Many drugs, such as marijuana, can still be detected in drug tests long after the potentially-impairing effects have diminished.

Perhaps related to the challenges of examining drug-related motor vehicle crashes, few studies have examined the relationship between opioid use and risk of being involved in a motor vehicle crash in Appalachia, specifically. In 2016, Rudisill et al. (16) published a case-crossover study examining the risk of being involved in a drug-related motor vehicle crash among older adult residents of West Virginia. Few study participants tested positive for drugs, so the study was underpowered. However, the authors found an association between testing positive for tramadol, a synthetic opioid analgesic, and being involved in a motor vehicle crash (OR: 11.41, 95% CI: 1.27–102.15). Despite the paucity of epidemiologic studies, it is likely that Appalachian residents are at a greater risk of being involved in a drug-related motor vehicle crash due to the high prevalence of opioid misuse, abuse, and dependence in the region; however, far more research is required.

1.4.3 Traffic Safety Culture

It is commonly held that culture is a powerful influence on the traffic safety of a region through its creation of social norms and beliefs that distill themselves through behaviors. However, the link between social norms and driving behaviors is itself complicated, and perceptions may differ from actual behaviors on the road. Therefore, this section explores the link between culture and safety, attempts to establish a working definition of safety culture, highlights common elements of safety culture studies, discusses potential explanations for these elements and their influence on measured traffic safety, and offers potential countermeasures for dealing with these identified elements.

1.4.3.1 The Link between Safety and Traffic Safety Culture

To properly define traffic safety culture, the link between culture and safety must first be established. Culture, broadly, is both an outcome of—and an influence on—attitudes, behaviors, and experiences that prevail within a specific geographical region and/or population. It is a mechanism for people to understand themselves and how they relate to their world (76), and it is therefore intrinsically linked to the demographic makeup of that region or population, including age of population, average level of education, and median household income (77). Culture both responds to and influences prevailing perceptions and beliefs held deeply by these demographic groups, and it is possible for multiple cultures to exist in the same region. In the United States, multiple cultures can and do exist simultaneously, varying both at a regional level and within much smaller jurisdictions. Although the Appalachian Region is not a monolithic culture, there are sufficient similarities among its states' counties that there are likely to be common influences on traffic safety throughout the Region.

If culture, then, is the set of dominant attitudes, behaviors, and experiences that are created by and prevail over a specific demographic set, culture influences safety by directly linking those behaviors and attitudes. More specifically, members of the demographic set perceive the behaviors and attitudes of others within their group and then adopt those behaviors and attitudes (78). These perceived attitudes and behaviors themselves may not be true to the real nature of safety within a region, and it is possible for authority figures within a region to shape those norms. For example, state and city officials can write laws that make certain unsafe behaviors illegal, thereby creating a negative perception of those behaviors; enforcement can have a similar effect by rewarding and encouraging positive behaviors and deterring negative behaviors (78). Those laws and enforcement are, in fact, crucial for shaping traffic safety culture to produce safe outcomes because research has shown that simply changing opinions is insufficient to change behaviors. For example, many drivers still speed or use cell phones while driving despite having an opinion that these behaviors are unsafe (79). For this reason, the research team explored not only influencers of traffic safety culture but also countermeasures to those factors.

In 2015, Ward et al. more clearly defined the mechanisms by which traffic safety culture influences traffic safety. According to the authors, traffic safety culture explains risky driver behavior, supports the acceptance of existing traffic safety policies, defines high-risk groups of drivers, and defines a new paradigm to support a vision of zero traffic fatalities (80). In other words, traffic safety culture explains the social norms that affect traffic safety and identifies the groups that are most at risk of death or serious injury on the roads because of those norms. This identification allows policymakers to intervene in culture to address these social norms. This intervention is the explicit goal of traffic safety; behaviors must be changed to align with cultural goals for safety (81).

Understanding this link between traffic safety culture and traffic safety is critical for reaching goals within any roadway jurisdiction. As Wang et al. noted in 2018, the traditional approaches to improving traffic safety, namely engineering, education, and enforcement, may be limited in their ability to change the behaviors that produce crashes. While each element may be capable of improving roadway safety in a limited aspect, all three must be used together and supplemented with other traffic safety culture countermeasures to truly change the system that produces crashes (82). A strong culture of traffic safety, then, promotes a social environment where traffic produces zero deaths or serious injuries (83).

1.4.3.2 Defining Traffic Safety Culture

Although the previous subsection thoroughly explained the link between traffic safety culture and traffic safety, a precise definition of traffic safety culture has not yet been offered. Therefore, this section provides multiple definitions seen in the literature, explains these definitions, and synthesizes those definitions into a single working definition for the purpose of this project. Direct quotations from experts are provided where possible. It should be noted, however, that traffic safety culture is still an evolving concept, and it is unlikely that an analysis of crash data alone can characterize the culture of Appalachia.

An early definition of traffic safety culture was proposed by Eby and Bingham in 2007 as "the totality of socially transmitted behavioral patterns, arts, beliefs, institutions, valuations, and all other products of human work and thought regarding traffic safety and the incidence of motor-vehicle-related crashes, injuries, and fatalities that guide social and individual behavior and are propagated through processes of individual learning" (84). In 2014, Li et al. noted that, "While there is no common, tangible definition of a safety culture, there is consensus that traffic safety culture does not merely focus on risky behaviors and their consequences, but also on change in social norms, values, and beliefs."

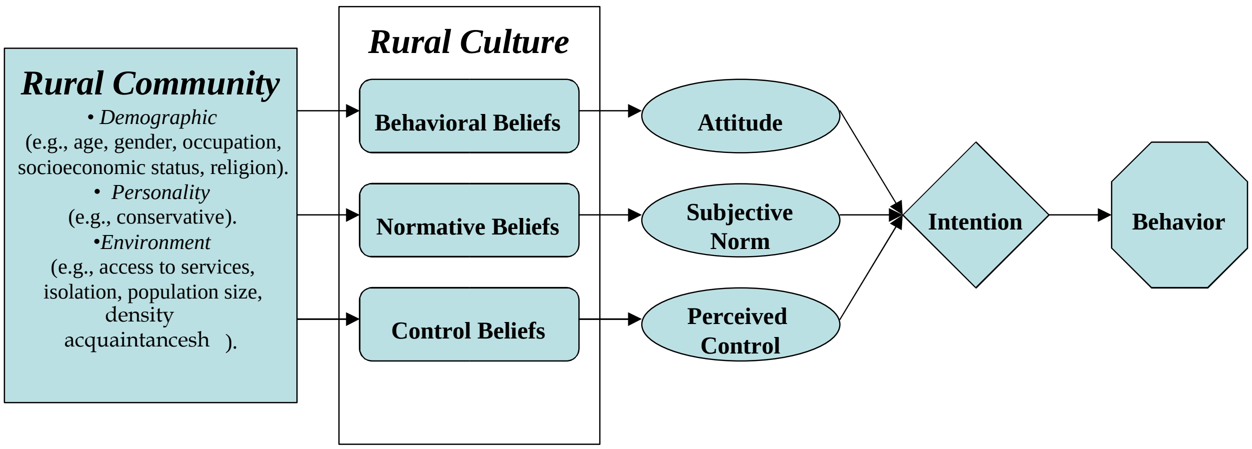
However, other researchers have endeavored to develop a precise definition. Atchley et al. explored traffic safety culture in 2014 by investigating cultural values of different nations. The authors noted that the perceived norms of other drivers affect an individual's driving behavior. The authors then linked these perceived norms to a wide range of cultural values grouped into four distinct classes: economics, governance, cultural dimensions, and value dimensions. Most relevant to this study are the culture dimensions and value dimensions. Atchley et al. note that a traffic safety culture can be affected by the interplay between cultural dimensions like individualism and long term orientation (85) and value dimensions like egalitarianism and embeddedness (86). While these concepts are relatively abstract, they do indicate aspects of rural areas (such as perceptions of individualism or power distance) that may affect how quickly rural areas adopt safety interventions; they also hint at possible organizational interventions to improve traffic safety, such as governance through voice and accountability to instill a norm of safe driving behavior (78).

In 2015, Ward et al. offered a refined definition of traffic safety culture as "the socially constructed abstract system of meaning, norms, beliefs, and values" that determine a driver's intention to behave in either a safe or risky manner (80). Attitudes are composed of both experiential and instrumental attitudes (i.e., feelings and behavioral beliefs). Perceived norms are composed of normative beliefs (informed by others' expectations) and descriptive norms (others' behavior). Agency is composed of perceived control and self-efficacy. All of these personal elements combine to form intentions, which then mix with knowledge and skills, salience of behaviors, environmental constraints, and habits to produce behaviors (80). These perceptions and behaviors are also influenced by regional contexts and norms. What this reveals is that traffic safety culture is the product of many inputs and therefore may be addressed holistically with a number of countermeasures (87).

Two other definitions support this model of traffic safety culture. Otto et al. defined traffic safety culture as "the values and beliefs shared among groups of road users and stakeholders that influence their decisions to behave or act in ways that affect traffic safety" (81). Otto et al. also put forth this definition in a different 2016 report while noting that the goal of traffic safety is to change behaviors affecting crash risk to reduce harm when driving errors are made (88). Otto et al. also illustrated how many overlapping social environments inform culture. Although one individual driver may seemingly choose independently to engage in risky behaviors, that individual's decisions are partially driven by the larger social and environmental context, in this case the United States, the Appalachian Region, the state, and the community (88). For this reason, our research team is investigating Appalachia to identify regional culture norms.

Focusing specifically on the rural context of traffic safety culture, Ward suggested another framework for how rural culture influences particular behaviors. This framework is shown in Figure 6. Ward hypothesizes that the unique aspects of rural communities, namely demographics, sociological identities, and environmental influence, produce a set of cultural beliefs unique to rural areas, which then lead to attitudes, norms, and perceptions, that then influence intentions, and ultimately produce behaviors (24). An example of this framework could relate to the slower adoption of seatbelts in rural areas (89). Ward notes that rural communities are often isolated. If a rural teen grows up in an isolated community and sees few drivers in his community using seatbelts (perhaps for reasons of comfort, social or access to technology), he may believe that his community does not use seatbelts for a reason. This belief could then create an attitude that seatbelts are unnecessary, so the teen may then develop an intention to not wear his seatbelt and then act on that intention. Obviously, a traffic safety culture that places higher value on safety could produce the opposite behavior.

Figure 6: Rural Traffic Safety Culture Schema



Data Source: Ward, N.J. The Culture of Traffic Safety in Rural America. 2007.

Although many of the definitions thus far used for traffic safety culture focus on psychological and sociological terms, many traffic safety professionals still consider traffic safety culture a rigorous and useful scientific measure. McNeely and Gifford refer to culture as a toolkit of symbols, practices, and views, meaning that traffic safety culture is a repertoire of resources to alter driving behaviors (90). Wang et al. defined traffic safety culture as “the application of scientific methods to understand the culture which emerges in a geographical area that may influence a) driver responses and perceptions of risk associated with system hazards and b) driver intentions to engage in risky behaviors that result from the social environment and that affect traffic safety” (82). Wang et al. operationalized this definition through a proposed logic model of countermeasure selection. Addressing a traffic safety issue begins with exposing the population to a particular strategy until that strategy organically takes root within a culture and changes it. This then produces a change in behavior that ultimately reduces crash risk (82). The shift from culture transformation to behavior change is explicit because culture directly influences willfulness and intention (59). Ideally, the countermeasures proposed in this document can produce a similar risk reduction. According to Foss, however, to produce a “truly meaningful traffic safety culture,” these countermeasures “must embrace only the principle of effectiveness” (91). In a world of limited resources, traffic safety stakeholders must take stock of all options, weigh them by their relative efficacy and impact on traffic safety culture, and fund those that are most effective.

Based on these various definitions, a working definition of traffic safety culture in Appalachia is as follows.

Traffic safety culture in Appalachia is the collective force of social norms, behaviors, and values that determine the average person's posture toward engaging or not engaging in road-use behaviors that can influence their safe or unsafe use of the unique roadway environments that characterize the Region.

1.4.3.3 Common Variables in Traffic Safety Culture Literature

Studies of traffic safety culture routinely investigate a fairly consistent set of variables that may increase crash risk (or risk of a severe crash). These variables are typically investigated through analysis of crash data, cultural surveys, and group consensus building. Listed below are these variables with references to the studies that investigated them.

Distracted Driving

Although not always considered a major safety problem, recent traffic safety culture research has focused heavily on the issue of distracted driving (56,77,79,83). In fact, a recent phone survey conducted by the AAA Foundation for Traffic Safety indicated that drivers feel that distracted driving is one of the most pressing safety issues and that it has only become more of a problem over time (92). This perception is likely linked to the ubiquity of smart phones and the many ways in which technology has become embedded in all aspects of daily life. In the same AAA survey, 65% of respondents indicated that they regularly see drivers talking on cellphones, and 49% indicated that they regularly see drivers text messaging or emailing (92). Unfortunately, many of these same respondents indicated that they also engage in risky cellphone use while driving, despite recognizing the hazards inherent in not focusing on the road (92). There are myriad reasons why drivers may become distracted (including social reward (77), but because it is now so culturally ingrained, reducing distracted driving in the United States broadly and in Appalachia specifically will be a difficult task.

Speeding

Speeding, too, is regularly seen as an indicator of a problematic traffic safety culture. A wide range of studies have shown that speeding is both rampant and harmful, yet many drivers continue to speed despite the risks (56,79,80,83,88,92,93). Speeding greatly increases the risk of death or serious injury as a function of a collision, yet many roads are designed to facilitate high speeds; numerous studies have indicated that speeding is a common problem on freeways (83,92). Unfortunately, speeding is also common in residential areas where vulnerable road users may be at risk, but there is greater social disapproval of speeding on rural roads (92). Although the Appalachian Region is largely connected by two-lane highways, the increased speed and capacity of Appalachian Development Highway System facilities warrants careful consideration of the perception of speeding as a component of Appalachia's traffic safety culture.

Impaired Driving

Although drunk driving has long been a target of traffic safety culture interventions, drugged driving's prominence in the research has grown recently following both the legalization of marijuana in several states and the opioid crisis affecting much of the country. Therefore, general substance use before driving should be a consideration for traffic safety culture interventions (79,80,83). Studies investigating the use of alcohol and driving have shown that much of the United States has an ingrained culture of excessive alcohol use that interacts with the strong, historical car culture to deadly effect (77,92,94). Thankfully, substantial gain has been made in reduction of drunk driving; this change is due to a number of factors, but the decrease in drinking and driving may be due to advocacy efforts, organizational culture efforts, and demographic changes (95). More recent is an emergent cultural effect of driving under the influence of cannabis (DUIC) (81,92). One study in particular found that despite the loss of reaction time caused by cannabis use that can result in crashes, there is a strong social perception that DUIC actually decreases a driver's risk (59). Drivers may have similar views of other substances, so careful consideration should be given to intoxicated driving perceptions in Appalachia.

Drowsy Driving

Although less commonly studied in traffic safety culture research, drowsy driving can significantly increase a driver's risk of a collision (79). Particularly, driving after receiving fewer than six hours of sleep is extremely hazardous and similar to other impairments (92). Despite this, the AAA Foundation reported that 42.4% of drivers have at least one day in a week where they sleep fewer than six hours, and 30.8% of drivers admit to driving at some point in the past month despite being so tired they could not keep their eyes open. These numbers are even more shocking considering that 95.2% of drivers consider drowsy driving an unacceptable behavior (92). These numbers also highlight that persistent safety threats can be difficult to remove from traffic safety culture, even when perceptions do not support behaviors.

Occupant Protection

Convincing drivers to use occupant protection, including seatbelts and child safety seats, has long been a goal of traffic safety professionals, so restraint use is a common variable in traffic safety culture literature (56,57,79,80,82,88,94,96). Increasing occupant protection is also widely regarded as one of the key victories of traffic safety professionals in establishing a nationwide culture of traffic safety. Estimates of seatbelt use generally indicate that approximately 90% of drivers in the United States use seatbelts (57). This number was achieved through a mix of interventions that both altered perceptions and enforced new norms. Unfortunately, estimates of seatbelt use indicate less widespread adoption in Appalachia, with approximately 82% of drivers in the Region regularly using restraints (57). Motorcycle helmet usage and child occupant protection are also consistent concerns for traffic safety culture interventions (94), especially when it comes to countering "freedom to choose" messages embedded in a culture (97).

Red-Light Running

Recent studies have indicated that red-light running may be a traffic safety culture problem in the United States. In a survey of older drivers, Mizenko et al. found strong disapproval of red-light running among older drivers, despite the fact that approximately 30% of respondents have engaged in the activity at least once (79). The AAA Foundation reported even more problematic numbers, with 42.7% of respondents to their survey admitting to red-light running within the past 30 days despite 92.9% of respondents viewing this as an unacceptable behavior (92). Red-light running seems to be another issue where perceptions differ from behaviors. Thankfully, there are countermeasures that can help affect social norms, as will be discussed in the next section.

Wrong-Way Driving

One driving behavior that traffic safety culture researchers have recently investigated is wrong-way driving. This behavior, though rare, is especially dangerous because of the vast crash energies that result from head-on collisions; wrong-way driving crashes are often fatal. Such crashes are a concern on divided highways and in rural areas due to common geometric designs. Although geometry can be used as a countermeasure to this crash type, Wang et al. also demonstrated that culture can be influenced to produce safer conditions that limit wrong-way driving (82).

Vehicle Size Choice

A recent variable that has appeared in traffic safety culture literature is vehicle choice. Although many consider larger vehicles to be safer, these safety benefits may be offset by the larger masses that increase crash energy and by the risk to pedestrians and cyclists from taller bumper profiles. Vehicle choice is driven by a wide range of cultural factors, ranging from fuel costs to social norms, so traffic safety professionals should carefully examine a range of determinants within a culture to identify the motivation for driving larger vehicles to assess potential systemic safety effects (96).

1.4.3.4 Explanations of Traffic Safety Culture in the United States

In addition to the variables listed in the previous subsection, traffic safety literature offers a range of cultural explanations for crash phenomena. As discussed, traffic safety culture is a collective force of social norms, behaviors, and values; many of these are intrinsically linked to the prevailing demographics and economic development of a region. Therefore, crashes are caused not just by a risky driving behavior but also by the driver's beliefs about other drivers and by the design of the system itself as influenced by prevailing social values. For example, a driver may crash while under the influence of cannabis, but that driver may have driven under the belief that it was safe to do so because his friends all partake and because there is no standard measure of cannabinoid influence that makes a driver high. Moreover, the driver may have crashed while under the influence partially because a road was not well-lit at night because improving lighting on a rural road was not a priority of the county department of transportation. As will be discussed later in this synthesis, organizational safety culture is a key distillation of traffic safety culture and may lend greater insight into how to achieve changes in safety culture in a region. There may be many more explanations for why the crash occurred, and this complexity makes analyzing traffic safety difficult. However, that complexity may also facilitate a wide range of countermeasures. Based on this reasoning, various cultural explanations of traffic safety are discussed in this subsection.

Demographics and Traffic Safety Culture

Intrinsically linked to traffic safety culture are demographics (77). Different age groups or other demographic groups may be socially inclined to accepting or not accepting traffic risks. Younger drivers may take more risks partially because of cognitive development. Young males especially have been shown to be more inclined to thrill-seeking and other dangerous behaviors, especially when compared to female drivers (92,94). For example, 54.1% of male drivers admitted to driving 15 miles per hour (mph) over the speed limit on a freeway in the past 30 days compared to only 46.7% of females (92). Other differences between males and females indicate greater risk acceptance for most behaviors (though not all) among males (58,92). Socially speaking, some demographic groups may be at greater risk of death or serious injury due to inequalities and economic disadvantages. For example, Vachal and Kubas reported that American Indian drivers are at higher risk of fatal crashes due to cultural forces that discourage occupant protection and influence substance use. Many of these cultural forces are linked to long-term inequalities between American Indians and the rest of the United States and inadequate safety funding on tribal lands (94). There may be other demographic subsets of the United States that are also at greater risk due to social forces, such as those that prevail in rural areas. One of the goals of this research project is to identify some of the prevailing forces that shape traffic safety culture in Appalachia.

Historical and Political Factors and Traffic Safety Culture

Historical factors are also at work in shaping traffic safety culture in the United States. Multiple researchers have noted the strong, historical predisposition toward individualism in this country; Americans are far less collective than other peoples (see Table 3) and are more likely to view responsibilities (like safety) as individual mandates because of an emphasis on personal freedoms over collective protection. This inclination toward individualism and the pursuit of personal freedoms has multiple outcomes that influence traffic safety culture. The United States transportation system is designed around personal automobile usage, and as such, American transportation users accept more personal risk while traveling; other modes are statistically safer but are seen as less convenient (56,78,96).

Another important cultural element linked to American individualism is a stubbornness toward accepting limiting legislation. Atchley et al. noted that Americans are unwilling to abide by laws that may limit their personal freedoms (even if those laws improve safety), so lawmakers are unwilling to legislate behavior changes. This often results in targeted safety interventions taking hold in vehicle design rather than in system-wide design (78). This unwillingness to push policies that may impinge upon individual liberties also affects business and organization administrators. Managers at businesses that center around transportation, such as freight or delivery companies, often do not establish organizational visions of safety that could recast safe driving as a norm (98). The difficulty of overcoming individualism excuses a lack of unifying safety goals. Finally, individualism presents itself as a barrier to safer behaviors. Because Americans often prioritize convenience and access over safety, drivers may forgo driving practices that would be collectively safer. One example identified in the literature is yielding. Consistent yielding at intersections protects pedestrians and prevents collisions, but Americans have been observed to yield far less frequently than drivers in other countries (96). Speeding and red-light running are likely also tied to this cultural characteristic.

Table 3: Cultural Factors Comparison between the United States, China, and Japan (78)

	China	Japan	US
Current fatality rate	83.61	6.15	12.77
Trends 1990–2010	Fourteen-fold increase in vehicles Large improvements in per vehicle risk	Fatalities down by 67% Crashes and injury rate steady	Largest number of registered vehicles Fatality and injury rate down about 50%
Historical factors	New driving culture Recent traffic safety laws	Established driving culture Acceptance of national traffic safety programs	Established driving culture Some resistance to new traffic safety laws
Structural factors	New road construction programs	Modern (toll-based) highway system	Modern (publicly funded) highway system
	Mixed vehicle safety	Fewer car safety laws	More car safety laws
Cultural factors	Highest risk tolerance Emphasis on getting ahead leads to ‘‘scrambling’’	Low risk tolerance Emphasis on protecting others	Moderate risk tolerance Emphasis on personal freedom

Data Source: Atchley P, Shi J, Yamamoto T. Cultural foundations of safety culture: A comparison of traffic safety culture in China, Japan and the United States. *Transportation Research Part F: Traffic Psychology and Behaviour*. 2014 Sep;26:317–325.

Economic and Land Development and Traffic Safety Culture

Economic development may also be an important factor in traffic safety culture. Transportation itself is driven largely by economics; vehicles sold, modes financed, and even trips taken are all dictated to some degree by the market forces within a region (78,87). Historically, industries drove road expansion in the United States. New roads were paved and new capacity added to allow access to jobs and to facilitate the movement of goods and people (78). Although road expansion itself is not inherently unsafe, the emphasis on high-speed, high-capacity roadways does preclude the design and development of lower-speed, safer roads or less risky modes of transportation. Considered in conjunction with American individualism and car culture, the economic motive for transportation, then, is a powerful determinant of traffic safety culture. A prevailing traffic culture affects the perception of acceptable speed for roadways, and the current U.S. traffic culture accepts higher speeds at the expense of safety (83), although there may be regional variations in these perceptions.

Another important influence on traffic safety culture is rurality. Research has shown that there are often critical differences in the traffic safety culture between rural and urban regions (56,83). Rural roads often have higher speed limits and lower traffic, and due to population density, drivers in these areas may need to drive greater distances to access important services. These conditions result in increased exposure to risk, and that danger is compounded by the fact that rural regions often lack the funding for safety improvements that are implemented in urban regions due to less economic development. Although these systemic issues are critical, there are also demographic factors that influence perceptions of safety in rural areas. Studies have shown that rural drivers are more likely to engage in risky driving behaviors, such as speeding or driving while drowsy. Some of these norms may be responses to systemic design issues, but some may also be byproducts of the more isolated, individualistic conditions of rural living (56,96).

Other Factors and Traffic Safety Culture

Researchers have found a number of other potential explanations for U.S. traffic safety culture. First, the United States has an interesting alcohol culture that fosters alcohol abuse in some areas, particularly in regions with universities and culturally important sports programs (56). This alcohol culture compounds the dangers of car culture and risk taking in rural areas to produce drunk driving in some regions. Second, a culture's long-term orientation and goals can influence traffic safety. The United States is a relatively young country dominated by a car culture; the long-term orientation of U.S. transportation patterns, then, may not be directed toward safety (87). Third, more political orientation and religiosity may influence fatalism and therefore safety, but these variables are unlikely to be gleaned from crash data (56–58). Fourth, driver psychology can influence both perceptions of safety and willingness to engage in safe driving behaviors. Many drivers attribute crashes not to a complicated system of environmental and behavioral risks but to individual shortcomings in which they do not engage, so they are less likely to perceive their own unsafe behaviors and drive with decreased caution. Because of these perceptions, safety advocates often insist solely on education efforts while ignoring other means of limiting risk (58,91). Last, licensing laws, influenced by U.S. individualism, directly impact safety by controlling the access to driving that younger, more vulnerable drivers have; nations that have stricter licensing laws, like Australia, tend to have fewer crashes (96). The research team will attempt to investigate licensure directly in this study.

1.4.3.5 Research into Appalachian Traffic Safety Culture

In the course of scanning traffic safety literature for this synthesis, the research team identified one specific study of traffic safety culture in an Appalachian state. In 2011, the University of Tennessee Center for Transportation Research and the Center for Applied Research and Evaluation surveyed 928 drivers in Tennessee to identify both self-reported driving behaviors and perceptions that influence traffic safety in the state. Below are summarized key findings from this survey. As a case study, potential countermeasures to some of the reported issues are provided. However, it should be noted that survey respondents may not reflect prevailing cultural perceptions in Appalachian Tennessee or the larger Region.

Distracted Driving

There is a significant disparity between how many drivers consider it acceptable to text and drive and the number of drivers who engage in the behavior and believe others perceive it as acceptable. Only five percent of survey respondents indicated acceptance for texting while driving, but 31% of respondents believe others consider it acceptable. Additionally, distracted driving (primarily due to cell phone use) was cited as the leading cause for a perceived decline in traffic safety in the state (as perceived by 42.1% of respondents), and 20% of drivers admitted to texting while driving in the twelve months prior (99). Perhaps an effective countermeasure to distracted driving would be a targeted social norms intervention intended to increase awareness of the fact that most drivers in Tennessee (80%) do not text while driving. This could help correct misperceptions about texting and driving and encourage safer driving behaviors. Social norms programs have been successfully employed in Montana to reduce drinking and driving (100).

Drinking and Driving

Only four of 100 drivers admitted drinking and driving in the prior 30 days (99). Because acceptance for drunk driving is so minimal, perhaps targeted enforcement—such as sobriety checkpoints in areas with high concentrations of drinking and driving crashes—could be used to target the small sample of the population that still drinks and drives while sending a message to the remaining members of the population that this behavior is unacceptable. The infrequency of drinking and driving may also indicate a use for social norms interventions that target those populations most prone to the behavior.

Younger and Older Drivers

There was broad support among survey respondents for legal tests of driving capability for both younger and older drivers. A majority of respondents (93.7%) supported on-road safety tests for new drivers (not just teens), and 90.8% of respondents supported in-class education tests prior to licensure. A majority of respondents also supported health screening tests and on-road safety tests for drivers older than 75 years of age (82.7% and 82.16%) (99). These responses indicate the strong link between legal structure and traffic safety culture. This link could be leveraged by safety professionals and policymakers to enforce safety laws that reduce the risk of crashing and improve traffic safety culture in the state, although any policies adopted should be aligned with leading research into efficacy.

Although this study did indicate differences in perceptions and behaviors for a number of different elements of traffic safety culture in Tennessee, no comparison was made between Appalachian counties and non-Appalachian counties. Therefore, additional analysis is required to identify traffic safety culture issues in the Appalachian Region.

State Highway Safety Plans and Traffic Safety Culture in Appalachian States

In their 2017 SHSP, Drive Safe Alabama undertook a series of assessments to analyze the traffic safety culture in the Alabama DOT and its partners. These analyses included both a study of safety roles across relevant bureaus and a peer roundtable with experts to identify gaps in safety knowledge and training at the DOT. These organizational culture measures allowed the state to develop greater capacity to address the safety and behavioral challenges highlighted in its SHSP. Of note is the fact that the state identified traffic safety culture as a specific strategic challenge in its SHSP. To shift traffic safety culture in Alabama to one of respect and responsibility, Alabama DOT prescribed two strategies (26):

1. Assess traffic safety culture perceptions and beliefs of the driving public and target populations.
2. Identify opportunities and programs/initiatives to enhance traffic safety culture of the driving/walking/biking public.

The SHSP also listed two strategies to enhance organization safety culture at the DOT and within its traffic safety partners. Although organizational safety culture is discussed more later in this synthesis as a method of mitigating crash severity and other safety issues, the two specific strategies listed by Alabama include the following (26):

1. Assess organizational safety culture of Alabama DOT and its safety stakeholder agencies.
2. Identify opportunities/strategies to enhance safety culture.

Although the Maryland SHSP mentions traffic safety culture, the emphasis is placed on a culture of safety for pedestrians and bicyclists. To improve traffic safety, the Maryland DOT suggests encouraging and promoting safe bicycling and walking through legislative and policy action. The SHSP also suggests creating an accepting culture of traffic safety around bicycling and walking by training and supporting safety professionals to deal specifically with pedestrian and bicyclist issues (45).

Other Appalachian states emphasize the importance of cultures of safe speeds in their counties. New York's SHSP mentions the need for creating a culture of responsible road use to improve safety for all road users, although New York's emphasis is placed specifically on creating a culture where speeding is unacceptable (47). North Carolina's SHSP discusses community and stakeholder engagement as a method for improving the culture around speed. The state's goal is to influence drivers to simply expect safe speeds on roadways through enforcement, roadway design, education, and communication between drivers themselves (54).

Pennsylvania's SHSP emphasizes the importance of building cultural change around unsafe and distracted driving, although fewer strategies are provided for creating this culture change (49). Tennessee's emphasis on transforming traffic safety culture is similarly vague, although the need for this transformation is mentioned in that state's SHSP (51). Although Virginia's SHSP provides few concrete strategies for changing traffic safety culture, the plan does evoke the public health success of smoking cessation as a potential guide for eliminating drunk driving (52).

1.5 Crash Mitigation Factors and Countermeasures

1.5.1 Countermeasures to Risk Factors

The strength of analyzing traffic safety culture is that identifying the various behaviors, perceptions, and beliefs that increase crash risk also allows interventions to be targeted at those myriad aspects. This section presents a wide-ranging list of potential countermeasures to safety problems as reported in the literature. Some of these countermeasures address the roadway environment that implicitly influences driving behavior (through enforcement of laws and designs), while others directly enforce good behaviors and punish unsafe habits.

1.5.1.1 Changing Traffic Laws

Although this countermeasure is broad and ambiguous, both Li et al. and Otto et al. asserted that legislation has the power to shape culture and thereby the social norms of driving (77,88). Law works as a mechanism of positive change in traffic safety culture by directly influencing social norms and perceptions. For example, legislators can pass laws to severely fine speeders, thereby creating a social deterrent to speeding. Speeding then develops a negative association for many drivers, and those drivers share that perception with their peers, further disincentivizing speeding. In fact, the literature suggests that laws related to cellphone use, driving while intoxicated, and limiting driving for populations that can no longer do so safely due to physiological changes (e.g., seniors with declining visual acuity) positively affect traffic safety culture and decrease the risk of crash (79). These legal limitations can deter risky driving behaviors by encouraging operation of motor vehicles only when drivers are fully engaged in the driving task. Research has also indicated the efficacy of seatbelt laws; in fact, the high national compliance with seatbelt laws suggest immense potential for using regulations to alter traffic safety culture (94). Seatbelts are important for preventing ejections and other negative crash outcomes that can increase crash severity, so laws of this kind must remain an important part of traffic safety culture toolkits in all regions.

1.5.1.2 Enforcement

It is critical to note, however, that for laws to be effective in reducing crash risk and risk of severe injury, enforcement is crucial. Enforcement supplements laws by demonstrating the negative outcomes of detrimental driving behaviors. Enforcement creates a social norm of compliance with safe behaviors that then encourages good driving behaviors (83,94), and is most effective when it is high in visibility (91). For example, studies have shown that the most (and, in some jurisdictions, only) effective enforcement efforts are high-visibility programs like DWI checkpoints. These checkpoints work through consistent presence and immediate, administrative deterrence (91) for explicitly identified behavioral targets (93). Worth noting, however, is that enforcement need not be conducted in person; this is an important consideration for especially vulnerable populations that may already have negative perceptions regarding authority figures. Although enforcement of laws at checkpoints can modify behaviors immediately in a specific vicinity (94), long-term deployment of enforcement technologies have also shown substantial benefits for curtailing risky behaviors that influence crash outcomes. For example, Mizenko et al. reported that speed cameras and red-light cameras can enforce laws and the social norms they represent (79) without requiring officers to be present, although these systems may still be prone to negative perceptions. Technology should be used in tandem with enforcement and legislation to enforce desirable driving behaviors while discouraging risky ones.

1.5.1.3 Rule Codification

In addition to the more concrete tools of enforcement and legislation, the research regularly indicates that social norms are influenced by organization structures. The perceptions of an individual’s peers, supervisors, and family members influence that individual’s driving behaviors. For example, if a parent believes that speeding is dangerous and teaches their children that speeding is dangerous, a familial norm can be created. However, simple perceptions alone may not be sufficient to change a smaller subculture like a family unit. Research suggests that rules must be codified to set a particular behavior as the acceptable norm. In the familial example, the parent can set a rule that a child is not allowed to drive with other distracting teens in the car in order to create a perceived norm that distraction is unsafe (80). This same type of codification can be effective in the workplace; for example, a manager could establish a rule that employment depends upon abiding by traffic safety laws while also encouraging drivers to engage in safe practices because their lives and health are important (88). Conversely, if subordinates within an organization desire safer driving conditions, they must hold their administrators accountable for creating a culture of safety. If, for example, commercial truckers want safer vehicles, they may engage in union activities to pressure management to adopt safer vehicles, thereby improving the safety culture of the entire structure (98). The interdependence between members of a culture is a powerful tool, even in nations like the United States where individualism is strong, so traffic safety professionals must leverage these connections between system users to create a culture of safety (98).

1.5.1.4 Education and Communication

When not conducted in isolation of other countermeasures, education and communication can be powerful influencers of behavior. Research has demonstrated the efficacy of well-crafted media campaigns to establish social norms about traffic safety (94). For example, teens and young adults in university communities may perceive that most of their fellow students drink alcohol, and this creates a social norm of acceptance for drinking. However, research conducted by Foss, Marchetti and Holladay found that two out of three students at a large university in the Southeast United States returned home with a zero blood alcohol content (BAC) on so called “party nights” (Thursday, Friday, and Saturday between 10 p.m. and 2 a.m.). The researchers used these results to develop a social norms program to correct misperceptions about alcohol use at the university (101). The campaign was effective because it directly affected the beliefs of substance users or would-be substance users; simple messaging alone may be ineffective at influencing culture, but altering beliefs can alter norms, in turn altering behavior (81,102). Well-designed messaging and education campaigns may also be effective for leveraging the interdependence between individuals that can promote safety interventions. For example, an effective media campaign may promote designated driving, which can in turn foster a mutual interdependence in a group that increases the safety of all members (82). This concept is sometimes referred to as safety citizenship, and it leverages connections (built on mutual perceptions) between people to foster a shared responsibility for safety that promotes safety culture. Otto, Finley and Ward found that effective education and messaging interventions in a community increase bystander engagement in promoting mutual safety—that is, one individual, when appropriately encouraged to be safe, can intervene in the life of another individual to improve their safety as well (88). These media and education campaigns must simply be designed in such a way that allows a “safety citizen” to be comfortable intervening (by, for example, equipping the intervener with simple skills and memorable information) (88), and they must not be fear-based because fear-based interventions have been shown to be ineffective (59).

Educational influence on traffic safety culture may also be exerted through driver education. In 2007, Eby and Bingham suggested that driver education for novice and inexperienced drivers could, if constructed properly, be used to inform riskier drivers of the expected norms and behaviors that align with a culture of good traffic safety. They suggest that driver education should function as a feedback system that provides stimulus and response and leverages social factors to motivate behavior change. Their recommendations for driver education guidelines include (84):

- Feedback to drivers must appear to be objective and credible (i.e., driver educators must be competent and credible).
- Terms for driving events must be specific and accurate (to convey information clearly).
- Changeable behaviors, rather than personality traits, should be the focus of education interventions.
- Behaviors that align with good traffic safety must be highlighted, rather than just bad or unsafe behaviors.
- Feedback should be non-judgmental and used to motivate positive behavior change.
- Feedback should be provided immediately following an incident while the experience is fresh.
- Driver educators should leverage social norms (e.g., community values regarding speeding) to motivate behavior changes.
- Feedback should be specific for the intended audience.

These lessons apply to more than just driver education and can be deployed through organizational safety culture as well.

1.5.1.5 De-Anonymization

Most of the countermeasures listed above are aimed at shifting traffic safety culture through behavior changes. However, behavioral countermeasures, if implemented ineffectively, may be quite expensive and produce few long-term benefits. To that end, Dula and Geller recommend seven principles of behavioral interventions to prevent those complications (103):

1. Begin with observable behavior.
2. Look for external factors to understand and improve behaviors.
3. Direct with activators and motivate with consequences.
4. Focus on positive consequences to motivate behavior.
5. Apply the scientific method to assess and improve interventions.
6. Use theory to integrate information.
7. Consider the feelings and attitudes of others.

These principles are shared here as any attempt to shift traffic safety culture should follow these steps. To illustrate this process for the Appalachian Region, consider speeding as a problem to be countered. First, law enforcement may observe a high incidence of speeding on a particular rural highway on the ADHS system. Second, city engineers may investigate this location, say through a road safety audit, to determine if perhaps wide lanes or inappropriate speed limits may be externally motivating speeding. Third, law enforcement may set administrative penalties for speeding at this location and work with the local community to incentivize young drivers to not speed through peer-to-peer messaging. Fourth, local news agencies could coordinate with law enforcement to highlight the benefits to health and community that result from decreases in speed. Fifth, local safety engineers would track crash records at this site over multiple years to determine the impact of these efforts on safety. Sixth, data regarding speeding could be shared with the media to continue to show how safety is improving. Seventh, the media could also share stories of those affected negatively by speeding in the community.

1.5.2 Organizational Safety Culture

In 2007, Wiegmann, von Thaden, and Gibbons, writing in the AAA Foundation for Traffic Safety compendium on traffic safety culture, drew from examples of safety culture in other industries to define safety culture as "the enduring value and priority placed on worker and public safety by everyone in every group at every level of an organization" (104). Organizations, whether social, work, or governmental, bear an important role in creating and shaping the safety culture that can directly influence members' willingness to engage in risky or safe driving behaviors as well as willingness to engage in behaviors that affect the safety of the general public (104). These behaviors have an important effect on both the likelihood of a crash (e.g., speeding) and the outcome of a crash (e.g., wearing a seatbelt). Lonero argues that, "The traditional bureaucratic constraints on the ability of governments to influence crash prevention through driver behavior must be faced and overcome. To facilitate this, organizational behavior change must become a legitimate area for study and action in road safety. Critical issues are coordination, evaluation, and accountability in program management" (105). Organizations can influence traffic safety-related behaviors—or lack thereof (76)—and address these issues through a variety of measures. Some key methods of influence are highlighted in the following list.

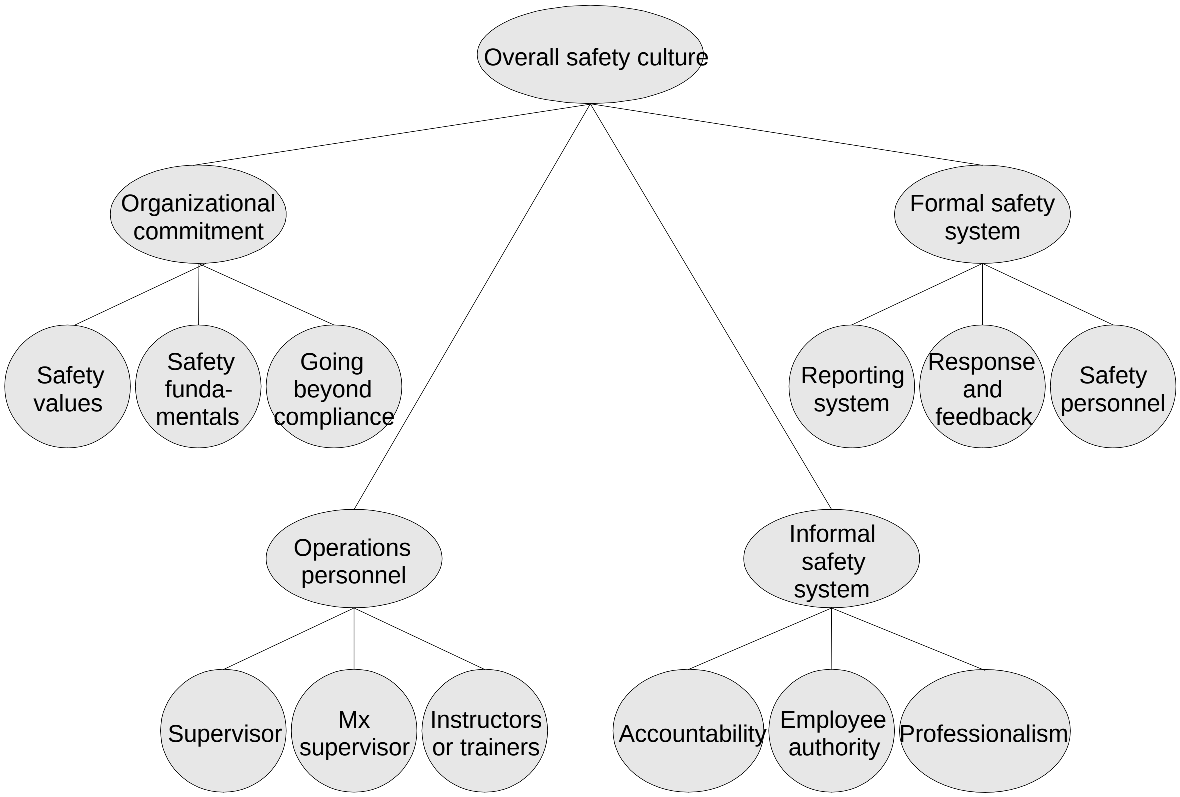
- Goal setting: In the preface to the AAA Foundation's 2007 compendium on Traffic Safety, Kissinger notes that one reason the United States may lag behind other countries in reducing crashes is a lack of organizational goal-setting. While this goal may apply broadly to the federal government, it also applies to state DOTs and smaller governmental organizations (like Metropolitan Planning Organizations); if DOTs and other organizations responsible for transportation do not set ambitious safety goals and do not work to meet those goals, a message may be sent both to DOT employees and the traveling public that safety is of little importance. This unintentional messaging may create a social norm that safety is unimportant, so behaviors that create better safety outcomes (like wearing seatbelts) are unnecessary. Conversely, rigorous goals may create social norms that encourage reductions in speeding and in roadway designs that encourage speeding. For these reasons, goal-setting is important (106).
- Law and regulation: In an important link to Kissinger's comments on goal-setting, Lonero notes the specific role of the federal government in shaping culture through legal and regulatory means. While regulations themselves are a direct method of shaping social norms, they also indirectly influence organizational safety culture by setting a tone for how lower organizations conduct themselves. For example, if the federal government established strong standards regarding licensure, state governments may take similar stances. This organizational culture then may filter down to the state residents and drivers, thereby influencing safety (105). The role of regulation and rule-setting is especially important because of the way that power shapes culture. In an organizational sense, power can be concentrated hierarchically, so it is important for administrators to leverage rule-setting and regulation to shape the relations between members of the organization so that those members adopt safe behaviors, like not speeding. Moeckl and Lee offer a tangible example of the way rule-setting can be leveraged to shift culture. Freight agencies often require drivers to place "How's my driving?" placards on their trucks; these placards encourage drivers to drive safely to avoid negative consequences, leading to long-term, embedded behaviors in traffic safety (76). The key consideration for effective legislation is that it must not be entirely dependent on law enforcement; instead, leaders must

be positioned throughout all organization levels to ensure that effective legislation and regulations are adopted (103).

- Messaging and framing: One often overlooked influencer of organizational safety culture is the media (107); communications and messaging, both external and internal, can depict specific behaviors as norms for employees to adopt. Lonero notes the media currently perpetuates a driving culture that is ill-conducive to safety, so organizations may wish to communicate internally (through whatever channels are available) to counter greater media messaging. Alternatively, government agencies can work with media partners to reframe how the media discusses traffic issues, with particular emphasis on sensitivity to safety issues (108). These efforts may help shift cultural norms for organizations (105), although Girasek cautions that all safety communication, particularly that of a scientific nature, should be crafted carefully so as to be intelligible and evocative to all stakeholders rather than minimizing the priority of the issue (58).
- Place-based identity: One particular form of organizational safety culture that may be especially relevant to transportation agencies in Appalachia is place-based identity. Moeckl and Lee note that "place plays a role in how we experience and shape traffic safety culture." The authors offer an anecdote about how the state of Montana resisted open-container laws (a beneficial regulation to curb drunk driving) because of strong constituency opposition. An organizational, place-based approach to safety culture may have included messaging like, "Montanans don't drink and drive!" Similarly, transportation agencies could draw upon the unique Appalachian culture and remind employees, whether in DOTs or freight groups, that Appalachians drive safely (76).

In their 2007 paper, Wiegmann et al. also outline several indicators of an organization's safety culture that may be used to identify points of intervention to improve traffic safety. These indicators include organizational commitment (reflected in safety values, safety fundamentals, and going beyond compliance), operational personnel (including supervisors, maintenance supervision, and trainers), formal safety system (including a reporting system, feedback and response, and safety personnel), and informal safety system (that features accountability, authority, and employee professionalism) (104). The safety culture indicated by these measures is shown hierarchically in Figure 7.

Figure 7: Organizational Safety Culture



Data Source: Weigman, D.A., von Thaden, T.L., and Gibbons, A.M. *A review of safety culture theory and its potential application to traffic safety*. 2007. (104)

Wiegmann et al. further explain how each of the main indicators of organizational safety culture might apply in a community setting:

- Organizational commitment to safety: In the context of a community, senior management may refer to government administrators and decision-makers responsible for ensuring adequate resources for safety. Therefore, a commitment to safety in a state or regional context likely means allocating funding for roadway improvements and maintenance, setting policies regarding safe design standards and signage, and committing to law enforcement for safety violations.
- Operational personnel's involvement in safety: In the context of a community, operational personnel likely consists of law enforcement responsible for supervising the activities of the driving public and public transit managers who must transport residents safely. Therefore, these personnel should emphasize safety as the primary (or at least critically important) goal of their activities, with enforcers engaging with the public to prevent unsafe violations first and foremost.
- Formal safety system: In the context of a community, this indicator likely appears as a formal system for residents and road users to report safety problems. For an Appalachian state, this requirement may entail a phone line or email inbox for drivers in rural areas to report safety issues (such as downed trees, ice on the road, malfunctioning signals, etc.). If such a system exists, the system administrator must also prioritize quick response to ensure road users that

their concerns are heard and addressed. Quick response will facilitate trust and strengthen the feedback loop within the organization.

- Informal safety system: This indicator is far more difficult to identify in a community because it refers to unwritten norms and behaviors. Therefore, this element of organizational safety is dependent upon the other countermeasures for unsafe behaviors addressed as part of traffic safety culture, although Wiegmann et al. suggest public awareness and education campaigns to build trust in the system (104).

Bahar and Morris identified many of these same attributes, noting the importance of both individual and management commitment to safety under a clear mission and vision for accomplishing safety and an organizational structure that prioritizes safety. To this list of attributes they added an emphasis on data and reporting systems (109). This suggestion is especially relevant for Appalachia given the safety issues discussed in this literature review; a quality data collection and reporting system throughout the Region may allow the responsible agencies to more adequately allocate resources across its rural and often isolated roadways.

Dula and Geller further described organizational safety culture as a series of organizational goals or policies that can either be dependent, independent, or interdependent. Dependent traffic safety initiatives tend to be driven from the top down and rely on disincentives to produce behavior change. Independent traffic safety initiatives are typically conducted by appealing to the individual's desire to achieve protection. Dula and Geller argue that a true and fully realized culture of safety must be organizationally interdependent, with constituents attending to the safety of others and producing mutual benevolence for the entire organization. Interdependent programs are those that value safety and leverage these values for the good of all. For example, in Appalachia, an interdependent organizational safety culture could entail drivers adopting some slogan like "Appalachians do not speed" as a genuine belief, and the local governments would support this belief through policies that disincentivize speeding and frame speeding as against Appalachian values. In this type of system, both dependent and independent actions can be taken, but they are leveraged together and iterative of each other to produce interdependence (103). Table 4 adapts Dula's and Geller's organization values under each of these paradigms.

While traffic safety culture entails road use and the intersections between norms and the environment to promote safe or unsafe usage, organizational safety culture encourages using psychosocial and engineering countermeasures in tandem to address safety issues. If traffic safety culture is the combined force of social influences that create a predilection toward certain driving behaviors, organizational safety culture is an organizational climate that encourages implementation of countermeasures to address safety problems or promote safe road use.

Table 4: Values in Different Organizational Paradigms

Dependent Framework	Independent Framework	Interdependent Framework
Top-down organization	Bottom-up organization	Empowerment
Conditions of licensure	Personal commitment	Team/community commitment
Safety for ticket avoidance	Safety for self	Safety for self and others
Disincentives for outcomes	Incentives for outcomes	Recognition for behavior
Environment focus	Behavior focus	Environment/behavior/person
Fault finding	Fact finding	Systems thinking
Safety is important	Safety is a priority	Safety is a value
Quick fix	Eventual fix	Continuous improvement

Data Source: Dula, C.S. and Geller, E.S. *Creating a total safety traffic culture*. 2007.

1.5.3 Engineering, Roadway Design, and Access to Health Care

1.5.3.1 Roadway Design Countermeasures

One of the most important, long-term steps states or regions can take to improve traffic safety and promote a culture of good traffic safety is to provide roadways that decrease risk and deter unsafe behaviors. Drivers respond subconsciously to environmental cues in the environment; if all roadways in a rural area are straight, wide roadways, it should be expected that drivers will engage in speeding and other risky behaviors (like driving distracted or fatigued) (24,93). Departments of transportation should, therefore, seek to design roads that discourage unsafe driving behaviors (such as speeding) while also reducing severity if incidents do occur (perhaps through allocation of EMS resources) (24). Harsha lists both short-term and long-term approaches that can be used to deter speeding. Short-term engineering measures can include the following: vertical deflection (e.g., speed humps or tables), horizontal deflection and curvature (e.g., roundabouts), transitional signing, pavement markings, roadside design to provide visual friction, and better signal timing and speed limit setting (93). Long-term efforts should focus less on speed management and more on safe design from the outset (e.g., visual deflection) while also ensuring adequate funding for speed management programs (93).

1.5.3.2 Roadway Design in Appalachia

The ADHS standards specified by ARC detail a number of design features intended to improve traffic safety in the region through engineering methods. These standards and suggested improvements include:

- Improved horizontal alignment with increased sight distance
- Improved access control
- Roadway separation
- Wider shoulders
- Recovery zones with guardrails
- Climbing lanes on steep grades
- Interchanges and/or turn lanes at major intersections

These engineering improvements are intended to facilitate an average operating speed of 50 mph with an uncongested level of service. Where four-lane facilities are not feasible, two-lane highways should still accommodate access control and separation (22).

In their 1999 study of the safety impacts of the ADHS system, ARC compared crash rates on completed ADHS sections to uncompleted sections, identifying potential crash reductions for different facility types. Although this comparison is rather simplistic, it provides some estimates of the benefits the suggested engineering treatments may provide. Table 5 summarizes the crash reductions estimated in that study (22). The percent rate reductions shown are for changes in the rate per 100 million vehicle miles of travel (MVM).

Table 5: Percent Reduction in Total Crash, Injury, and Fatality Rates for different ADHS Engineering Improvements

Treatment to Existing Roadway	Percent Reduction in Total Crash Rate per 100 MVM	Percent Reduction in Injury Rate per 100 MVM	Percent Reduction in Fatality Rate per 100 MVM
Upgrade existing two-lane highway in unbuilt section to four-lane highway with access control	61%	61%	41%
Upgrade existing two-lane highway in unbuilt section to current design standards for two-lane highways	37%	40%	24%
Upgrade existing four-lane divided highway with no access control to six-lane highway with access control	65%	61%	89%
Upgrade existing two-lane ADHS corridor to four-lane highway with access control	30%	36%	48%

Data Source: ARC. *Impact of the Appalachian Development Highway System on Highway Safety*. 1999. (22)

1.5.3.3 Infrastructure Maintenance

In their SHSPs, Appalachian states routinely noted the following infrastructure and maintenance management strategies to improve roadway safety:

- Provide ball bank equipment and training to engineers at different jurisdictional levels to reduce roadway departure crashes (26).
- Conduct road safety assessments to identify infrastructure needing maintenance (26).
- Dispense funds through Highway Safety Improvement Program tools to allow engineers and maintenance staff to address critical safety needs (26).
- Plan, design, construct, and maintain roundabouts to reduce severe crashes (26).
- Assess horizontal curves to identify roadway departure risks (26,43).
- Improve signage on horizontal curves (48,50).
- Assess rail-grade crossings (26).
- Install increased mileage of shoulder rumble strips and cable median barrier to prevent roadway departure from distracted driving (44,46,48,50–52,54).
- Install high friction surface treatments at intersections or on risky curves during maintenance (44,46,48,49,51,53).

- Improve roadway delineation (through retroreflective markers) during maintenance (44,50,53).
- Remove fixed objects from the edge of the road during maintenance (44,48,49,53).
- Upgrade guardrail during maintenance (44,54).
- Improve recovery areas for roadway departures during maintenance (44,46,49,50).
- Install Safety Edge along roadway edges (44,50,53,54).
- Restripe and resign routes systemically to improve communication to drivers (46).
- Install infrastructure improvements specifically for vulnerable road users (including better maintenance of safety in work zones where motorcyclists may operate) (47).
- Assess speed limits during maintenance cycles to better align statutory speed limits and signage with horizontal curvature (48,50–52,54).
- Reevaluate passing zones (49).
- Improve median cross-slope (50).
- Improve lighting on horizontal curves (50,52,53).
- Identify locations for shoulder widening (51).

1.5.3.4 Access to Emergency Medical Services

One critical factor that may affect traffic safety in Appalachia is the distribution of EMS in the Region. In 2007, Ward discussed the isolated nature of rural areas and noted that with typically lower traffic volumes, crashes in rural areas may take much longer to detect and therefore be reported to EMS. Compounding this complication is the fact that some rural areas lack the economic capacity to maintain 24-hour EMS, resulting in a lack of critical coverage and potential reliance on volunteer staff who may lack the training of more qualified medical professionals. All considered, it may take twice as long for crash victims to be located and transported to emergency care in rural areas as it does in urban areas. Given these complications in rural areas, some researchers estimate that only 7% of rural fatal crash victims are transported to emergency care within the supposed critical time period, or "golden hour." By comparison, 30% of urban fatal crash victims may be transported within that critical period (24). Given Appalachia's largely rural profile, EMS proximity may be a critical concern for traffic safety in the Region.

1.5.3.5 Terrain, Speed, and Curvature

Rurality

As defined by ARC in collaboration with the U.S. Department of Agriculture's (USDA's) Economic Research Service, over 40% of the Appalachian population resides in a rural county, as compared to 20% of the total U.S. population (20). While the total number of police-reportable crashes is higher in urban areas, rates of motor vehicle crash-related injuries and crash-related deaths are higher in rural areas, with most studies suggesting that rural residents are two to three times more likely to die as a result of a crash than urban residents (110–112).

Although distinguishing between rural and urban areas can be difficult, Ward argues that rural areas have unique characteristics that distinguish them from urban areas. These distinctions come in the form of a variety of factors linked to both traffic safety culture more broadly and to traffic safety specifically. Table 6, adapted from Ward (2007), lists some of these factors (24).

Table 6: Relevant Social Differences between Urban and Rural Areas

Dimension	Urban	Rural
Demographics	Clustered in denser, often metropolitan areas.	Low population densities isolated outside urban boundaries.
Economics	Typically higher economic indicators, involving economic complexity and diverse labor divisions.	Typically lower economic indicators, involving economic simplicity and low labor diversity.
Social Structure	Characterized by distant, formal, and heterogeneous forms of social interactions and small and less dense social linkages.	Characterized by intimate, informal, and homogeneous forms of social interactions and small but dense social linkages.
Culture	Modern, liberal, and responsive to change.	Reluctance to share local problems, distrust of government, and traditional and slow to change.

Data Source: Ward, N.J. The Culture of Traffic Safety in Rural America. 2007.

These diverse social and cultural factors are intrinsically linked to the types of land development and roadway designs that can increase crash risks in rural areas. Therefore, there are numerous explanations for why fatality rates are higher in rural locations than in urban locations. In terms of pre-crash factors, roadway engineering and design likely play an important role. For example, many rural roads are decades old and need repair. TRIP, a national transport research nonprofit, estimates that 17% of major rural arterial roads in West Virginia are in poor condition and in need of repaving or reconstruction (113); by comparison, TRIP estimates 16% to 47% of roads in the five largest urban areas in West Virginia have poor pavement conditions (114). In addition, many rural roads were designed and constructed according to outdated standards, and so have operational and traffic safety deficiencies, such as narrow lane and shoulder width (115). While these concerns are not exclusive to rural roads, they may exacerbate safety issues in rural areas; TRIP reports that the fatality rate on West Virginia's rural roads is three times that of all other roads in the state (114). Ward described rural roads as being more visually complex and cognitively demanding, which, when considered over the much longer distances rural drivers typically travel, results in a much higher exposure to crash risk than in urban areas (24). The relationship between Appalachian/rural roadway factors and traffic safety is described in more detail in the section on traffic safety culture.

Another pre-crash factor to consider is vehicle speed. According to De Leonardis, Huey, and Green (116), average vehicle speed was 15–17 miles per hour faster for both rural major arterial roads and minor arterial/collector roads, as compared to urban roads. Although the relationship between speed and the risk of being involved in a motor vehicle crash is complex, on a given road, the risk of being involved in a crash increases with increasing speed (117). In general, a one percent increase in mean vehicle speed will result in a two percent increase in the injury crash rate, a three percent increase in the severe injury crash rate, and a four percent increase in the fatal crash rate (118).

Other pre-crash factors include motor vehicle occupant characteristics, such as driver impairment and occupant seatbelt use. According to Blatt and Furman, rural drivers involved in fatal crashes are more likely to be under the influence of alcohol (BAC >0.08 g/dL) and have higher levels of intoxication than their urban counterparts (61). In a study by Greene, Murphy, and Rossheim, young rural drivers provided the following explanations for engaging in drinking and driving: limited alternative transportation options, low population density/traffic volume, lack of law enforcement by police, low likelihood of being apprehended, and social/cultural acceptance (119). Rural drivers are also less likely to wear seatbelts than urban drivers. Beck, et al. found that self-reported seatbelt use ranged from 75% in the most rural counties to 89% in the most urban counties (120). Another occupant characteristic worth considering is driver drowsiness. According to the National Highway Traffic Safety Administration, 2.4% of all fatal crashes are related to “drowsy driving” (120). A Tennessee study of drowsy-driving-related fatalities and serious injuries determined that 75% of all drowsy-driving-related crashes occurred on rural roads, many of which were within the Appalachian Region (121).

In terms of the crash event itself, rural crashes may be more likely to result in serious injuries and fatalities partly due to the vehicle fleet composition within rural areas, including much of the Region. As mentioned previously, vehicle technology and crashworthiness has increased considerably over the last few decades; however, drivers in rural areas are more likely to operate vehicles greater than 10 years of age than their urban counterparts (40,122).

After a rural crash, injured survivors are at a significant disadvantage in receiving timely medical treatment, as compared to their urban and suburban peers. Rural EMS often cover large, sparsely populated geographic areas (123). This may result in EMS taking longer to respond to a call, longer to arrive at the event, and longer to transport the patient from the event to an appropriate treatment facility, especially for counties without an existing hospital. Along with adequate delivery of prehospital services, decreasing the time from injury to treatment at a receiving facility (i.e., “prehospital” time) has been associated with improved survival for severely injured patients, although this finding is contested (124,125). However, rural areas have longer prehospital transport times. Gonzalez et al. found that mean EMS prehospital time for fatal motor vehicle crashes was 66% longer for rural Alabama counties as compared to urban Alabama counties, with prehospital times of 42.1 and 25.4 minutes, respectively (126). While many publications refer to the importance of transporting patients within 60 minutes (i.e., the golden hour), this concept is outdated, as the majority of EMS transports are well within this period, even for the most rural areas. For many agencies, focus has shifted to delivering seriously injured patients quickly, but safely, to trauma centers and delivering state-of-the-art prehospital care while in the patient is in transport (125,127).

Another factor related to health outcomes post-crash is a lack of access to adequate and timely health care services within rural regions. According to Halverson, Ma, and Harner, as of 2004, 318 (76%) out of the 420 counties within the Region had health professional shortages in all or part of the counties (29). Eighty-one Appalachian counties contained no hospitals whatsoever. Even counties with hospitals may lack access to basic services, such as post-acute care, diagnostic services, and surgical services (128).

Even fewer Appalachian residents outside of metropolitan areas have ready access to organized trauma care. Implementation of an organized trauma system has been shown to reduce the risk of dying from a motor vehicle collision by 8% (129). Kentucky, a state with two Level I adult trauma centers, one Level I pediatric trauma center, and five secondary and tertiary trauma centers, had, on average, 5.8 hours elapse between arrival at a community hospital and transfer to a Level I designated trauma center (130,131). Other states with counties within the Region may have even longer transfer delays than Kentucky; Alabama (Birmingham) has only one Level I designated trauma center and, as of 2018, Mississippi did not have a single designated trauma center (130).

Weather, Wildlife, and Other Natural and Environmental Factors

The Appalachian Mountain Range traverses the center of the Appalachian Region. The counties within this geographic zone are prone to unique environmental, topographical, and climatic conditions. Much of the region is covered with second-growth broadleaf forests, although higher elevations can support coniferous forests of spruce and fir. Average annual temperatures range from about 50°F in the northern part of the Region to 64°F in the southern part of the region (132). Average annual precipitation ranges from 35 inches in the lower elevations to more than 80 inches in the higher elevations; mountain peaks in the Region experience the highest precipitation levels in the Eastern United States. Generally, precipitation totals are higher in the southern part of the range, although there may be considerable variation for both temperature and precipitation over short distances. For example, south-facing slopes tend to be warmer and drier than north-facing slopes. Appalachian counties neighboring the Appalachian Mountains also commonly experience frequent precipitation and shifts in temperature; however, the events tend to be less extreme.

Weather and Environmental Events

The weather conditions experienced in the Appalachian Mountains can cause treacherous driving conditions. Over the period 1994–2012, about 16% of total U.S. traffic fatalities could be attributed to adverse weather conditions, with an average annual traffic fatality rate of 2.3 deaths per billion VMT (133). Most adverse weather-related traffic fatalities were attributed to rainy/wet conditions followed by snowy/icy conditions. In the entire continental United States, West Virginia had the highest adverse weather-related traffic fatality rate of 4.8 deaths per billion VMT. The following Appalachian states also had above-average rates of adverse weather-related traffic fatalities (rate per billion VMT in parentheses): Mississippi (3.7), Alabama (3.0), Tennessee (2.8), South Carolina (2.6), North Carolina (2.6), Kentucky (4.0), Ohio (2.6), Pennsylvania (3.1), and New York (2.6).

Appalachian residents are also at an increased risk of being involved in a visibility-related weather or environmental event (e.g., dense fog, smoke, blowing soot/dirt/soil/sand) (134). While the risk of being involved in a visibility-related event is lower than a rain/snow event, decreased visibility can yield catastrophic multi-casualty events. For example, on March 31, 2013, dense fog in Carroll County, Virginia, resulted in a chain reaction collision that involved 95 vehicles and resulted in three deaths.

Wildlife and Motor Vehicle Collisions

The dense forests of the Appalachian Region also facilitate wildlife and motor vehicle interactions. West Virginia has the distinction of being the state with the highest rate of deer-motor vehicle collisions in the United States (135). Other high-risk states with counties located within the Region are Mississippi, Alabama, Georgia, South Carolina, North Carolina, Virginia, Kentucky, Ohio, Maryland, and Pennsylvania (136).

1.6 Research Gaps

The purpose of this literature synthesis was to aggregate resources on traffic safety culture, health culture, and other indicators of traffic safety with a specific eye on the unique challenges to traffic safety in Appalachia; the research team then used the resources to investigate crash data and identify potential countermeasures to address these risks throughout the region. While the sections about traffic safety culture and culture of health are extensive, both are restricted to major highlights that can be used to inform countermeasure development and policy suggestions. The specific section on Appalachia served primarily to support the broader findings regarding cultures of health and safety.

However, in the course of synthesizing the existing literature, we discovered a number of prominent gaps and research questions that need to be answered for the Appalachian Region. Broadly, these research gaps include specific safety indicators for the Region, potential countermeasures for identified safety problems, and general limitations of the existing literature.

1.6.1 Needs for Further Research on Safety Indicators

Throughout this synthesis, we highlighted both driver behaviors and environmental factors that can influence safety generally, that can exacerbate crash risk in rural areas specifically, and that may exist in Appalachia itself. However, there are many questions that remain to be answered. Many of these questions were highlighted by the state SHSPs and traffic safety culture literature. They include the following:

- How does roadway geometry (specifically curvature) affect the roadway departures identified by all states as a key focus area?
- How does the isolation of Appalachian roadways interplay with roadway lighting and EMS access to affect the severity of crashes in Appalachia?
- How dangerous are rural roads in Appalachia?
- What is the existing traffic safety culture in Appalachia?
- What poor driving behaviors are perpetuated by the existing traffic safety culture in Appalachia?
- What other less tangible aspects of safety culture in Appalachia affect safety in the Region?

Although we had some initial hypotheses regarding potential variables to investigate through our analysis of FARS data, these questions (and the literature that led us to them) highlighted several key comparisons to make between Appalachian fatal crashes and general crashes in the United States, including:

- Crashes on horizontal curves
- Crashes under poor lighting conditions
- Crashes in rural rather than urban areas
- Crashes involving speed and alcohol use
- Crashes involving older vehicles or specific demographic subsets (such as older drivers)

1.6.2 Need for Potential Countermeasures for Appalachian Safety

Generally speaking, research that focuses specifically on the Appalachian Region is limited. While some surveys and studies have examined speeding, distracted driving, and drug use, these studies are limited in scope and do not paint a broader image of traffic safety culture in Appalachia. Moreover, few evaluations of potential countermeasures focus specifically on Appalachian contexts.

One key avenue for analysis is the lack of restraint use in Appalachia. How does restraint use in the Region compare to the broader United States, and what traffic safety culture exists that encourages a lack of restraint use (57)? While this question may be difficult to answer given only FARS data, comparing restraint use and other variables related to occupant protection, such as motorcycle helmet use, may lend some insights. For example, statistics related to motorcycle helmet use in crashes in the Region may indicate policy avenues for legislation regarding seatbelt enforcement. Other policies that can influence traffic safety culture should also be explored.

Another key variable to examine is the ADHS itself. A significant portion of this project is dedicated to evaluating the purported safety benefits of the ADHS. If the ADHS can be proven to provide a safety improvement, evidence will then exist for how to address some of the safety concerns of Appalachian states. For example, the suite of upgrades entailed by the ADHS, namely realigning with additional lanes, increased shoulder width, and limited access, may be a good countermeasure to roadway departures. To evaluate this efficacy, we will specifically examine single-vehicle crashes along the ADHS compared to non-ADHS corridors.

1.6.3 General Limitations

In general, the lack of literature, including the state SHSPs, indicated a greater need for more data. Data quality and availability are limited in several Appalachian states (39), so even this study contributes greatly to the Appalachian literature. More specifically, we will explore the available FARS data to identify potential limitations related to drugged driving data. Our expectation is that there will be limited findings regarding drugged driving in Appalachia, and if we can verify this, we can make recommendations toward data collection. We will also use the analyses to make more general recommendations regarding organizational safety culture in the Region.

Chapter 2: Results from the Fatality Analysis Reporting System (FARS)

2.1 Introduction and Methodology

2.1.1 Introduction

Traffic crashes are major sources of mortality in the United States. The Appalachian Region has long been recognized as having higher traffic mortality rates than the U.S. average (2). Therefore, in this part of the report, we describe the characteristics of traffic fatalities in Appalachia to identify potential explanatory factors contributing to the high burden of fatal traffic crashes in this region.

The overarching objectives of this part of the study are the following:

1. Describe the incidence and characteristics of traffic crash fatalities in Appalachia (Section 2.2),
2. Compare the incidence and characteristics of traffic crash fatalities across Appalachian subregions (Section 2.2),
3. Compare the incidence and characteristics of traffic crash fatalities in Appalachia to non-Appalachia (Section 2.3),
4. Describe the characteristics of drivers involved in fatal traffic crashes in Appalachia (Section 2.4),
5. Compare the characteristics of drivers involved in fatal traffic crashes in Appalachia to non-Appalachia (Section 2.5).

2.1.2 Data Sources

Traffic fatality data

We obtained traffic fatality data from the Fatality Analysis Reporting System (FARS) for the years 1994–2017. FARS is directed and managed by the National Center for Statistics and Analysis located within the National Highway Traffic Safety Administration (NHTSA). FARS is a census of all fatal traffic crashes within the 50 states, the District of Columbia, and Puerto Rico. To meet the criteria for inclusion in FARS, a crash must involve a motor vehicle, occur on a public roadway, and result in the death of one or more vehicle occupants or non-occupants within 30 days of the crash. Trained FARS analysts extract data from law enforcement crash reports, death certificates, vehicle registration forms, coroner/medical examiner reports, driver licensing files, emergency medical services run reports, and vital statistics to characterize the people, circumstances, events, and vehicles involved in fatal traffic crashes. Since the number, type, and method of variable collection has changed over the four decades that FARS has been active, we have restricted most of our analyses to the five-year period 2013–2017. Note that individual state reporting of traffic fatalities may differ slightly from the counts reported by FARS. This is related to definitional variation across states as well as corrections to the raw data made by the trained FARS analysts. FARS is the most accurate and comprehensive source of data in the United States for studying fatalities resulting from motor vehicle crashes (155).

Population data

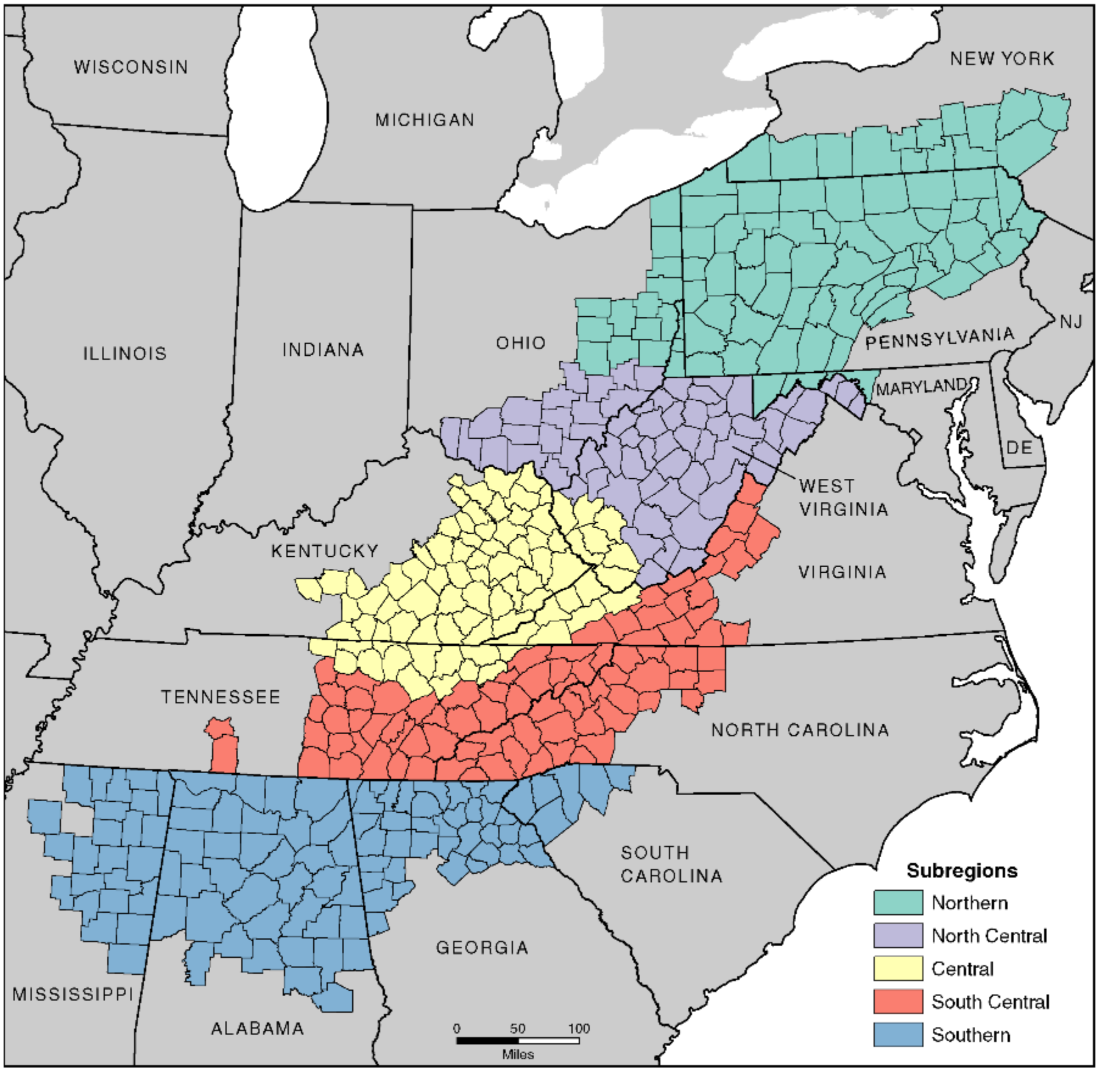
For the calculation of population-based fatality rates, we obtained 1994–2017 U.S. Bridged-race population estimates from the National Center for Health Statistics (NCHS). These estimates are prepared annually and are based on U.S. Census intercensal estimates (137).

2.1.3 Methods

Classification of geographic region

Appalachia encompasses 420 counties spread across 13 states: Alabama (Ala.), Georgia (Ga.), Kentucky (Ky.), Maryland (Md.), Mississippi (Miss.), New York (N.Y.), North Carolina (N.C.), Ohio (Ohio), Pennsylvania (Penn.), South Carolina (S.C.), Tennessee (Tenn.), Virginia (Va.), and West Virginia (W. Va.). Appalachia can be further subdivided into five subregions based on geographic, topographic, demographic, and socioeconomic characteristics: Northern, North Central, Central, South Central, and Southern subregions. Figure 8 displays a map of the five Appalachian subregions (138). For all analyses stratified by Appalachian Region or subregion, we classified the traffic fatality based on county of crash, not county of residence. This decision was based on the organizational structure of FARS, which systematizes fatal crashes according to location of crash, rather than location of residence.

Figure 8: Map of Appalachian Subregions



Map by: Appalachian Regional Commission, November 2009.

Data Source: Appalachian Regional Commission, 2009.

We also classified traffic fatalities based on rurality. To examine rurality, we used the urban/rural designation assigned by the reporting law enforcement officer. For the calculation of unadjusted and adjusted traffic fatality rates, we used the county of crash for urban/rural classification. This classification was based on the NCHS urban-rural classification scheme for counties. The NCHS classifies counties into one of six categories: large central metro, large fringe metro, medium metro, small metro, micropolitan, and noncore. For this study, all counties categorized as one of the first five designations were classified as “urban” and counties with a designation of “noncore” were classified as “rural” (139).

Imputation of blood alcohol concentration

Alcohol testing is not always performed on traffic fatalities and motor vehicle drivers involved in fatal traffic crashes. For example, in 2009, 71% of fatally injured motor vehicle drivers and 27% of surviving drivers had blood alcohol concentration (BAC) results (140). Therefore, NHTSA has developed a multiple imputation methodology for estimating BACs for motor vehicle occupants and nonoccupants missing this information (141). We used this methodology for all BAC test results displayed in this report.

Drug-impaired driving analyses

A focus of this report is an exploration of drug-impaired driving in Appalachia. However, FARS reports only include drug testing status and the presence or absence of selected drugs. Therefore, in this report we describe the proportion of drivers involved in fatal crashes who had drug test results and, among drivers with a positive drug test, the proportion of drivers who tested positive for licit and illicit substances identified as being potentially impairing.

It is important to note that the FARS toxicology data have several serious limitations. Policies and procedures related to drug testing vary between and within states. These differences affect who gets screened for drugs, what drugs are screened for, the thresholds for detecting and reporting drug test results, and how this information is reported to FARS. For example, for the period 2013–2017, the percent of drivers involved in fatal traffic crashes who were tested for drugs ranged from 3% (N.C.) to 78% (N.H.).

There are several other factors that greatly limit the usefulness of FARS data for understanding the role of drugs in fatal crashes:

- There are hundreds of classes of drugs that may influence driving behaviors.
- Not all drugs impact the body in the same way. Hallucinogens, central nervous system depressants, and stimulants impact the body—and therefore driving ability—in different manners.
- People metabolize drugs differently, and there is no widely accepted dose response curve for any impairing substance except alcohol (and marijuana, to a lesser extent). Drug metabolism may influence the time of onset and the level of impairment (i.e., at a specific dose, one person may be impaired while another person may not be impaired).
- Some individuals will test positive for days (or even weeks) for some substances (e.g., certain metabolites of marijuana), and therefore a positive test does not necessarily indicate impairment.
- Finally, FARS does not collect information on who reported the toxicology results (e.g., primary source [testing laboratory] or secondary source [investigating law enforcement officer]), the date/time when the specimen was collected, the composition of the drug panel, the method of analysis (immunoassay, gas chromatography/mass spectrometry, liquid chromatography, etc.), and sensitivity of the test (e.g., reporting limits and thresholds) (142).

An accurate assessment of drug-impaired driving is not possible due to the considerable limitations of the toxicology data collected by FARS. Therefore, the data presented in section 2.5 of this report are meant for illustrative purposes only.

Statistical analyses

This report displays several summary statistical measures, including counts, proportions, unadjusted rates, adjusted rates and rate ratios, and unadjusted odds ratios.

We calculated unadjusted fatality rates for comparisons across Appalachian subregions. For comparisons between Appalachia and non-Appalachia, we also calculated fatality rates, unadjusted and adjusted fatality rate ratios, and 95% confidence intervals. We adjusted for sex, age (five-year age categories), and urban/rural county of crash using Poisson regression analysis, with non-Appalachia as the reference group. For all analyses, we considered results with non-overlapping 95% confidence intervals to be statistically significant.

For comparisons within Appalachia and between Appalachia and non-Appalachia, we also calculated unadjusted odds ratios and Wald 95% confidence intervals using logistic regression. For comparisons within Appalachia, we used the Southern subregion as the referent, as it had the most observations and seemed most like non-Appalachia out of the five subregions. For comparisons between Appalachia and non-Appalachia, we considered non-Appalachia to be the referent. For all analyses, we considered results with non-overlapping 95% confidence intervals to be statistically significant.

We performed all statistical analyses using SAS version 9.4 (SAS®, Cary, N.C.).

2.2 Characteristics of Persons Killed in Motor Vehicle Crashes in Appalachia

2.2.1 Trends: Persons Killed in Motor Vehicle Collisions in Appalachia

Key findings:

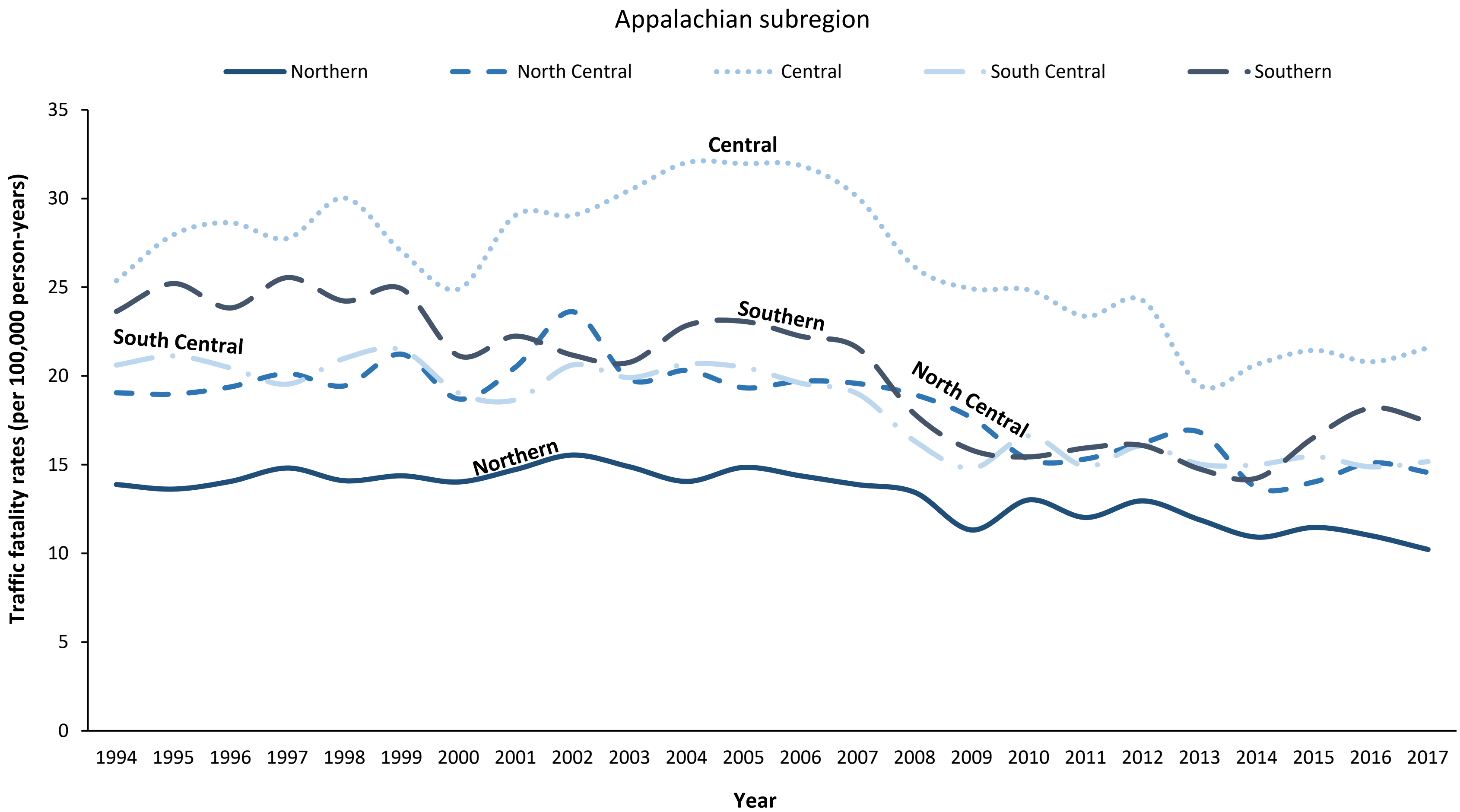
- From 1994 to 2017, 103,292 persons lost their lives on Appalachian trafficways.
- The annual number of fatalities declined from 4,328 in 1994 to 3,771 in 2017; a decrease of 13%.
- Appalachian traffic fatality rates decreased by 23% from 1994 (19.1 deaths per 100,000 person-years) to 2017 (14.7 deaths per 100,000 person-years).

Table 7 and Figure 9 display the traffic fatality rates by region for the period 1994–2017. Over this period, the Central subregion had the highest traffic fatality rate (26.4 fatalities per 100,000 person-years), out of the five Appalachian subregions. Traffic fatality rates declined for all Appalachian subregions, with the Northern subregion experiencing the largest decline (26%) while the Central subregion had the smallest decline (15%) between 1994 and 2017.

Table 7: Traffic Fatalities and Traffic Fatality Rates (per 100,000 Person-Years), by Year: Appalachia, 1994–2017

	Appalachian subregion N=103,292 traffic fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
	N	Rate	N	Rate	N	Rate	N	Rate	N	Rate	N	Rate
Year												
1994	1,184	13.88	434	19.05	470	25.37	820	20.61	1,420	23.64	4,328	19.11
1995	1,162	13.62	435	18.98	521	27.96	854	21.13	1,544	25.21	4,516	19.76
1996	1,198	14.05	446	19.38	535	28.63	839	20.45	1,487	23.83	4,505	19.56
1997	1,259	14.81	465	20.13	520	27.75	813	19.53	1,625	25.55	4,682	20.17
1998	1,195	14.09	450	19.44	564	30.03	884	20.99	1,571	24.22	4,664	19.96
1999	1,216	14.37	492	21.23	509	27.01	914	21.46	1,645	24.91	4,776	20.30
2000	1,184	14.02	434	18.70	470	24.90	820	19.04	1,420	21.14	4,328	18.28
2001	1,241	14.73	476	20.50	548	29.06	810	18.66	1,517	22.24	4,592	19.30
2002	1,309	15.54	551	23.62	549	29.05	902	20.62	1,464	21.17	4,775	19.95
2003	1,253	14.88	465	19.81	577	30.47	878	19.91	1,457	20.77	4,630	19.22
2004	1,182	14.05	479	20.31	607	32.02	919	20.66	1,626	22.84	4,813	19.86
2005	1,246	14.84	458	19.33	608	31.96	921	20.48	1,671	23.07	4,904	20.09
2006	1,206	14.37	470	19.71	608	31.86	894	19.59	1,647	22.24	4,825	19.57
2007	1,164	13.87	469	19.57	575	30.07	877	18.99	1,629	21.57	4,714	18.96
2008	1,127	13.44	456	18.94	501	26.14	762	16.32	1,369	17.84	4,215	16.82
2009	949	11.32	426	17.63	478	24.92	695	14.79	1,227	15.82	3,775	14.99
2010	1,091	13.01	371	15.30	477	24.85	785	16.62	1,206	15.44	3,930	15.56
2011	1,007	12.02	372	15.32	448	23.36	706	14.91	1,252	15.94	3,785	14.95
2012	1,083	12.96	394	16.23	463	24.25	764	16.07	1,270	16.08	3,974	15.68
2013	991	11.89	408	16.82	370	19.46	717	15.03	1,174	14.75	3,660	14.41
2014	907	10.91	332	13.71	391	20.65	718	14.99	1,143	14.24	3,491	13.72
2015	948	11.46	339	14.02	404	21.44	743	15.45	1,339	16.53	3,773	14.81
2016	905	11.00	364	15.10	390	20.80	720	14.88	1,487	18.19	3,866	15.14
2017	838	10.22	350	14.56	403	21.58	740	15.17	1,440	17.43	3,771	14.72
TOTAL	**26,845**	**13.32**	**10,336**	**18.19**	**11,986**	**26.40**	**19,495**	**18.05**	**34,630**	**19.89**	**103,292**	**17.63**

Figure 9: Traffic Fatality Rates (per 100,000 Person-Years), by Appalachian Subregion and Year: 1994–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

2.2.2 Basic Descriptors of Persons Killed in Motor Vehicle Collisions in Appalachia

Key Findings:

- When stratified by person type, the Central subregion had the highest traffic fatality rate (fatalities per 100,000 person-years in parentheses) for motor vehicle drivers (16.2), the South Central subregion had the highest traffic fatality rate for motorcyclists (2.7), and the Southern subregion had the highest traffic fatality rate for pedestrians (1.7).
- For all Appalachian subregions, young adults (20–24 years of age) had the highest traffic fatality rate out of all five-year age groups (22.5).
- For all Appalachian subregions, traffic fatality rates were higher among males (20.7) than females (8.6).

Table 8 and Figures 10, 11, and 12 display traffic fatality rates by person type, stratified by Appalachian subregion. There were regional differences in traffic fatality rates by person type, with the Central subregion having the highest motor vehicle driver fatality rate, the South Central subregion having the highest motorcyclist fatality rate, and the Southern subregion having the highest non-motorist fatality rate.

Table 8: Traffic Fatalities and Fatality Rates (per 100,000 Person-Years) by Person Type: Appalachia, 2013–2017

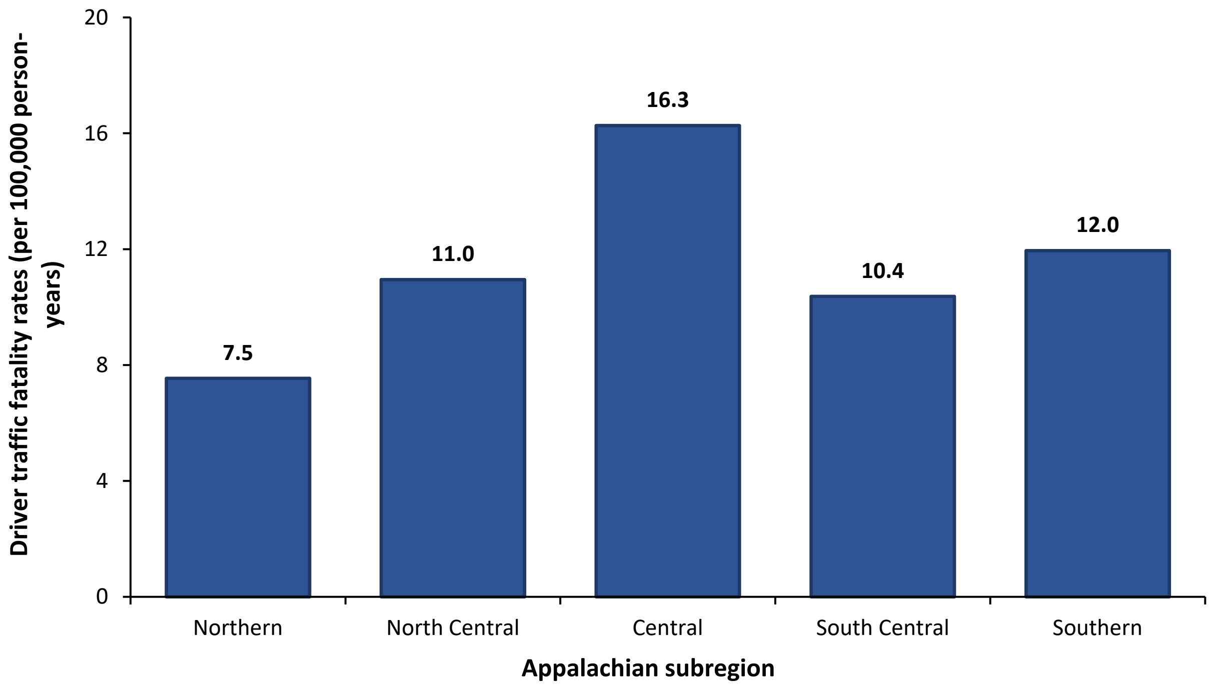
	Appalachian subregion N=18,561 traffic fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
Person type	**N**	**Rate**	**N**	**Rate**	**N**	**Rate**	**N**	**Rate**	**N**	**Rate**	**N**	**Rate**
Vehicle occupant												
Driver*	2,609	7.54	1,092	10.95	1,259	16.27	2,078	10.37	3,889	11.95	10,927	10.42
Passenger	764	1.85	331	2.74	372	3.95	666	2.76	1,167	2.88	3,300	2.59
Subtotal	*3,386*	*8.19*	*1,429*	*11.83*	*1,641*	*17.42*	*2,747*	*11.40*	*5,067*	*12.50*	*14,270*	*11.20*
Motorcyclist												
*Subtotal**	*663*	*1.92*	*210*	*2.11*	*189*	*2.44*	*539*	*2.69*	*747*	*2.30*	*2,348*	*2.24*
Non-motorist												
Pedestrian	449	1.09	135	1.12	118	1.25	306	1.27	692	1.71	1,700	1.33
Pedal cyclist	61	0.15	12	0.10	6	0.06	32	0.13	65	0.16	176	0.14
Subtotal	*540*	*1.31*	*154*	*1.27*	*128*	*1.36*	*352*	*1.46*	*769*	*1.90*	*1,943*	*1.52*
TOTAL	**4,589**	**11.10**	**1,793**	**14.84**	**1,958**	**20.78**	**3,638**	**15.10**	**6,583**	**16.25**	**18,561**	**14.56**

Unknown/Missing: Vehicle occupant status, N=43; non-motorist status, N=67

*Denominator consists of persons ≥ 15 years of age; denominators for all other person types consist of persons ≥ 0 years of age.

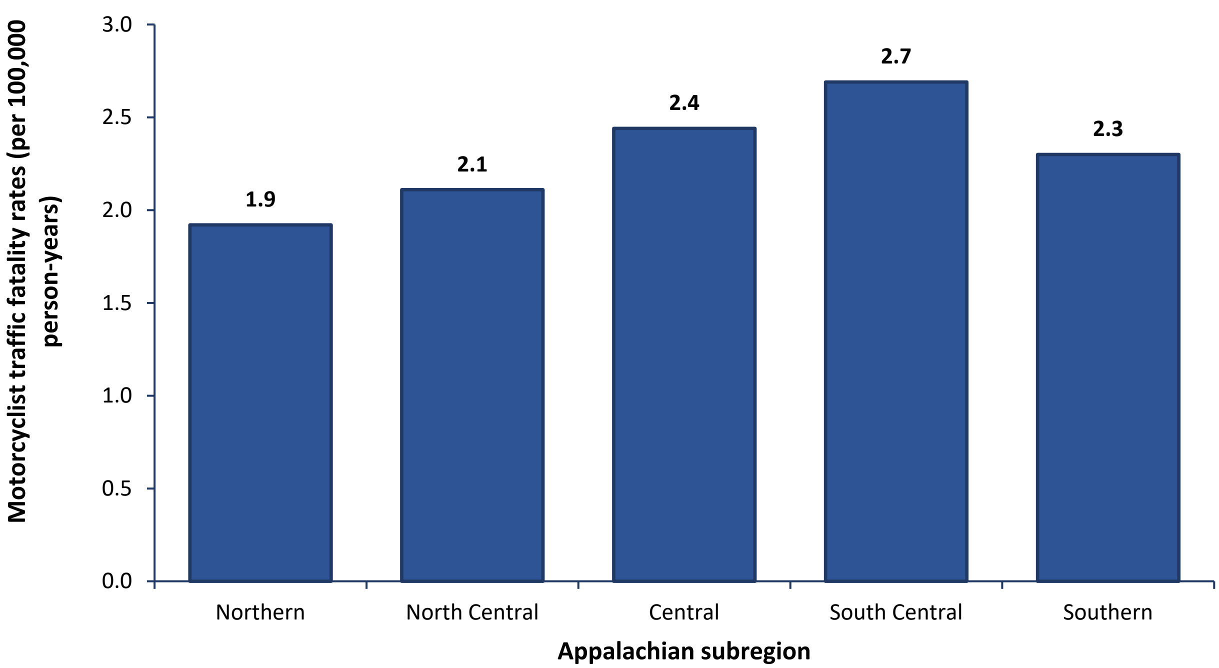
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 10: Motor Vehicle Driver Traffic Fatality Rates (per 100,000 Person-Years), by Year and Appalachian Subregion: 2013–2017*



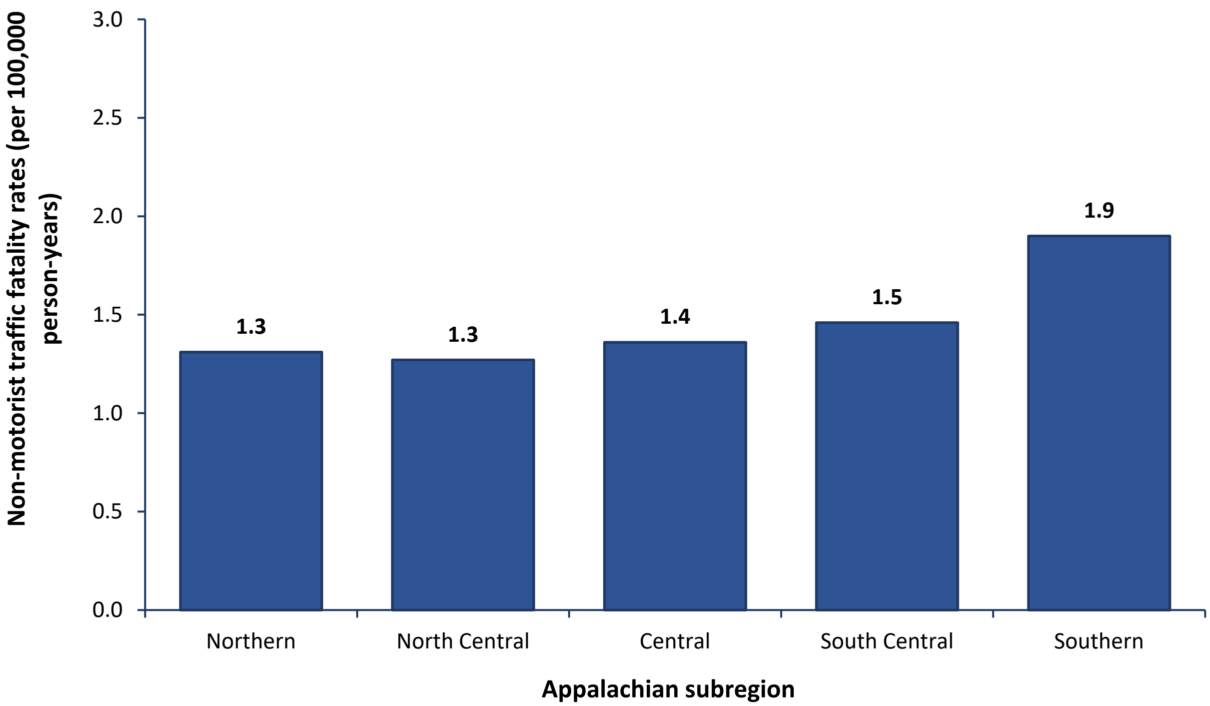
*Denominator consists of persons > 15 years of age

Figure 11: Motorcyclist Traffic Fatality Rates (per 100,000 Person-Years), by Year and Appalachian Subregion: 2013–2017*



*Denominator consists of persons > 15 years of age

Figure 12: Non-Motorist Traffic Fatality Rates (per 100,000 Person-Years), by Year and Appalachian subregion: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 9 displays the demographic characteristics of Appalachian traffic fatalities. Traffic fatalities in the South Central region skewed slightly older (median age of 46 years) than the Appalachian average (median age of 43 years). Traffic fatality rates were highest among young adults 20–24 years of age (22.6 fatalities per 100,000 person-years) and adults older than 74 years of age (19.0 fatalities per 100,000 person-years). Since Appalachia has a higher proportion of older adults than the U.S. average, this age group may be a worthwhile target for interventions designed to decrease older adult driver morbidity and mortality, such as comprehensive clinical and on-road assessments of driving fitness (1,143).

Table 10 displays Hispanic ethnicity and race of traffic fatalities, stratified by Appalachian subregion. Most Appalachian fatalities were white (87%) and non-Hispanic (97%). The racial make-up of traffic fatalities from the Southern subregion was more diverse, reflecting differences in the underlying population distribution (1).

For all age groups, except children younger than 10 years of age, males had higher traffic fatality rates than females (Figure 13). Overall, the traffic fatality rate for males (20.7 fatalities per 100,000 person-years) was more than twice that of females (8.6 fatalities per 100,000 person-years).

Table 9: Age and Sex of Traffic Fatalities: Appalachia, 2013–2017

Selected characteristic	Appalachian subregion N=18,561 traffic fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
Age (y), median (IQR)	**44 (26–61)**		**44 (26–59)**		**44 (29–60)**		**46 (28–63)**		**40 (26–57)**		**43 (27–60)**	
	N	%	N	%	N	%	N	%	N	%	N	%
Age group (y)												
0–4	37	0.8%	20	1.1%	19	1.0%	38	1.0%	86	1.3%	200	1.1%
5–9	47	1.0%	17	0.9%	18	0.9%	41	1.1%	69	1.1%	192	1.0%
10–14	47	1.0%	18	1.0%	19	1.0%	47	1.3%	77	1.2%	208	1.1%
15–19	346	7.5%	147	8.2%	103	5.3%	210	5.8%	547	8.3%	1,353	7.3%
20–24	504	11.0%	187	10.4%	194	9.9%	348	9.6%	731	11.1%	1,964	10.6%
25–29	423	9.2%	153	8.5%	150	7.7%	324	8.9%	648	9.9%	1,698	9.2%
30–34	305	6.7%	121	6.7%	169	8.6%	250	6.9%	536	8.2%	1,381	7.4%
35–39	283	6.2%	132	7.4%	152	7.8%	233	6.4%	505	7.7%	1,305	7.0%
40–44	311	6.8%	119	6.6%	171	8.7%	266	7.3%	448	6.8%	1,315	7.1%
45–49	298	6.5%	150	8.4%	142	7.3%	256	7.0%	484	7.4%	1,330	7.2%
50–54	370	8.1%	156	8.7%	150	7.7%	281	7.7%	495	7.5%	1,452	7.8%
55–59	363	7.9%	127	7.1%	165	8.4%	277	7.6%	486	7.4%	1,418	7.6%
60–64	267	5.8%	112	6.2%	128	6.5%	246	6.8%	395	6.0%	1,148	6.2%
65–69	261	5.7%	102	5.7%	121	6.2%	232	6.4%	314	4.8%	1,030	5.6%
70–74	181	3.9%	73	4.1%	92	4.7%	183	5.0%	261	4.0%	790	4.3%
>74	542	11.8%	159	8.9%	164	8.4%	402	11.1%	489	7.4%	1,756	9.5%
Sex												
Male	3,265	71.1%	1,259	70.2%	1,347	68.8%	2,539	69.9%	4,555	69.2%	12,965	69.9%
Female	1,324	28.9%	534	29.8%	610	31.2%	1,097	30.2%	2,024	30.8%	5,589	30.1%
TOTAL	**4,585**	**100.0%**	**1,793**	**100.0%**	**1,958**	**100.0%**	**3,638**	**100.0%**	**6,583**	**100.0%**	**18,561**	**100.0%**

Abbreviations: IQR, interquartile range; y, year

Unknown/Missing: Age, N=21; Sex, N=7

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 10: Hispanic Ethnicity and Race of Traffic Fatalities: Appalachia, 2013–2017

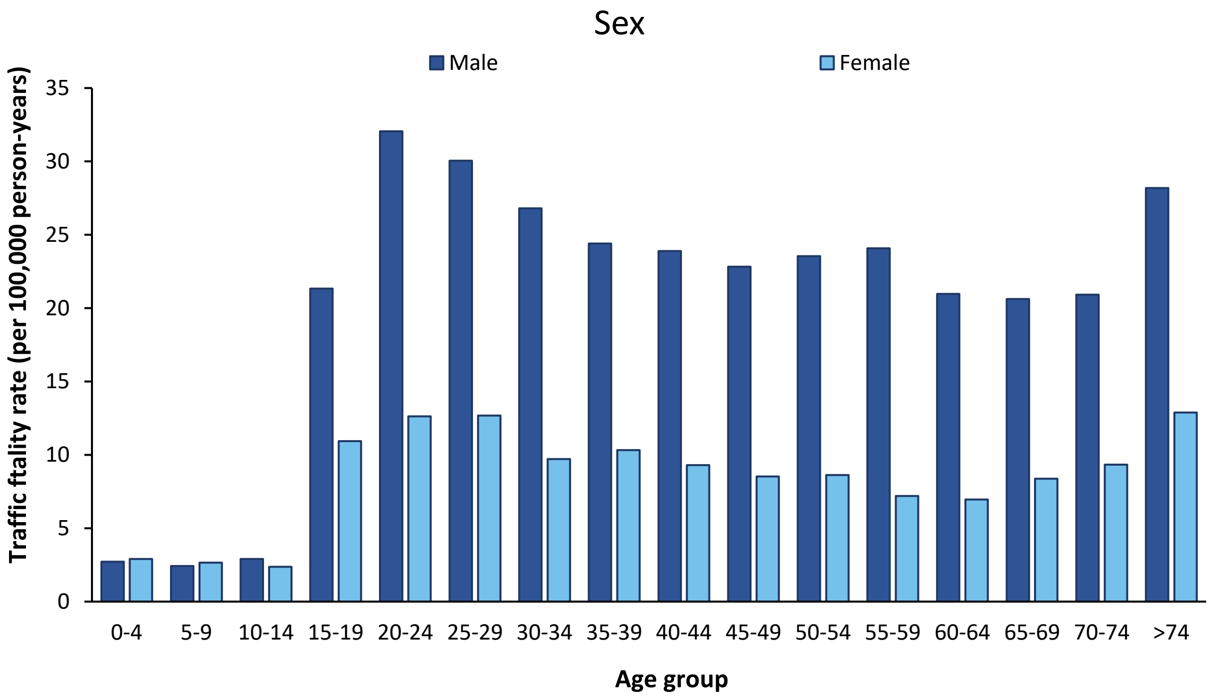
Selected characteristic	Appalachian subregion N=18,561 traffic fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Hispanic ethnicity												
Not Hispanic/Latino	1,537	97.6%	1,777	99.3%	1,875	99.0%	3,206	96.4%	5,695	95.6%	14,090	96.9%
Hispanic/Latino	38	2.4%	13	0.7%	18	1.0%	119	3.6%	265	4.4%	453	3.1%
Race												
White	1,439	91.1%	1,737	97.0%	1,785	97.9%	3,020	90.7%	4,673	78.4%	12,654	87.4%
Black	93	5.9%	41	2.3%	32	1.8%	238	7.1%	1,191	20.0%	1,595	11.0%
Asian/PI	19	1.2%	5	0.3%	3	0.2%	20	0.6%	61	1.0%	108	0.7%
AI/AN	2	0.1%	1	0.1%	1	0.1%	13	0.4%	8	0.1%	25	0.2%
Other race	26	1.6%	6	0.3%	2	0.1%	39	1.2%	24	0.4%	97	0.7%
TOTAL	**4,585**	**100.0%**	**1,793**	**100.0%**	**1,958**	**100.0%**	**3,638**	**100.0%**	**6,583**	**100.0%**	**18,561**	**100.0%**

Abbreviations: AI, American Indian; AN, Alaska Native; PI, Pacific Islander

Unknown/Missing: Hispanic ethnicity, N=4,018; race, N=4,082

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 13: Traffic Fatality Rates (per 100,000 Person-Years), by Appalachian Subregion and Year: 1994–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

2.2.3 Frequency of Appalachian Traffic Fatalities by Rurality, Time of Day, and Environmental Conditions

Key findings:

- In Appalachia, most traffic fatalities occurred in rural areas; however, there were differences by subregion, with the Central subregion having the highest proportion of fatalities occurring in rural areas.
- While most traffic fatalities occurred on clear days, there were considerable regional differences in the frequency of traffic fatalities that occurred on rainy and snowy days.

Table 11 and Figure 14 display the proportion of traffic fatalities by urban/rural location of crash. Approximately two-thirds (65%) of all Appalachian traffic fatalities occurred on rural roads. The Central subregion had the highest proportion of rural traffic fatalities (90%). According to the Appalachian Regional Commission and the USDA Economic Research Service, 42% of the Appalachian population lives in rural areas. Explanations for why rural roads have a higher burden of traffic fatalities include increased EMS response and transport times, poorer quality infrastructure with inadequate and outdated safety measures, higher vehicle speeds, and differences in driver safety culture (i.e., riskier driving behaviors) (113,144–146).

Table 11: Frequency of Traffic Fatalities, by Urban/Rural Location of Crash*: Appalachia, 2013–2017

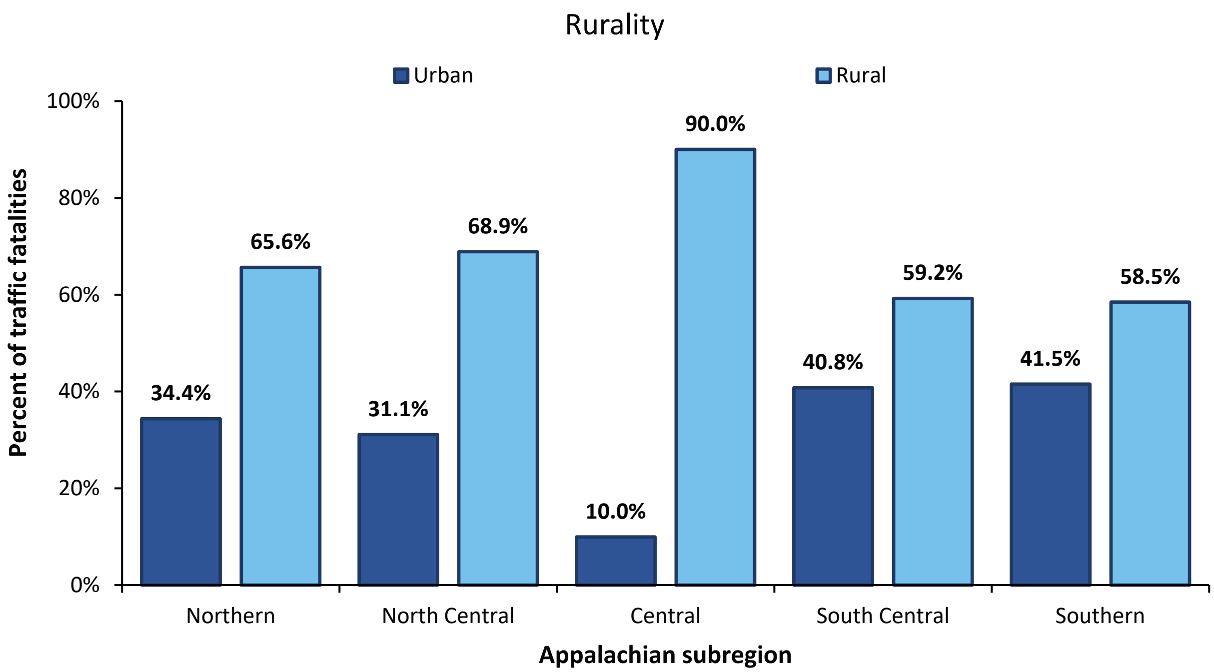
	Appalachian subregion N=18,561 traffic fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Location of crash												
Urban	923	34.4%	326	31.1%	119	10.0%	896	40.8%	1,754	41.5%	4,018	35.4%
Rural	1,764	65.6%	722	68.9%	1,075	90.0%	1,302	59.2%	2,469	58.5%	7,332	64.6%
TOTAL	**2,687**	**100.0%**	**1,048**	**100.0%**	**1,194**	**100.0%**	**2,198**	**100.0%**	**4,223**	**100.0%**	**11,350**	**100.0%**

Unknown/Missing: Urban/rural location of crash, N=7,211

*Rurality designated by investigating law enforcement officer.

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 14: Frequency of Traffic Fatalities in Appalachia, by Urban/Rural Location of Crash: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 12 and Figure 15 display the frequency of traffic crash fatalities by time of crash. For all Appalachian subregions, the time of day with the highest proportion of traffic crash fatalities was during the hours of 17:00–17:59, corresponding to the evening commute from work. Overall, there were few regional differences for time of crash. However, the Northern subregion had the highest proportion of late-night crashes of the five subregions.

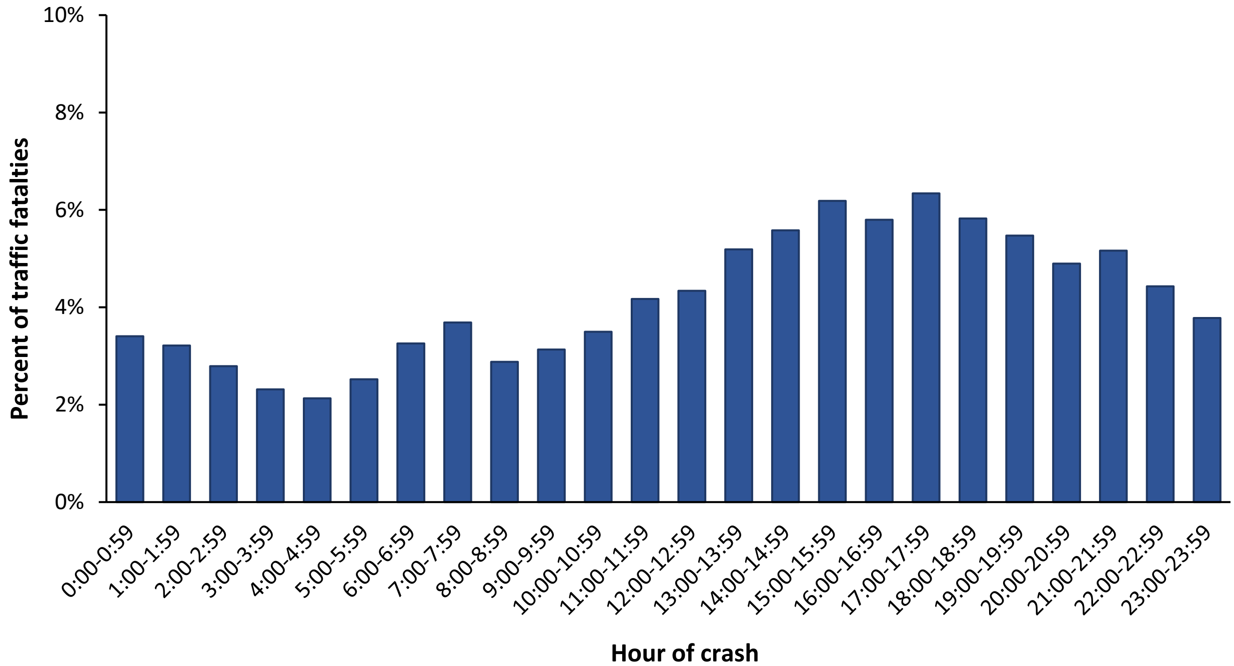
Table 12: Frequency of Traffic Fatalities, by Hour of Crash: Appalachia, 2013–2017

	Appalachian subregion N=18,561 traffic fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Hour of crash												
0:00–3:59	650	14.2%	184	10.3%	159	8.2%	382	10.7%	788	12.0%	2,163	11.7%
4:00–7:59	483	10.5%	204	11.4%	196	10.1%	352	9.9%	904	13.8%	2,139	11.6%
8:00–11:59	636	13.9%	229	12.8%	282	14.5%	489	13.7%	887	13.5%	2,523	13.7%
12:00–15:59	979	21.4%	391	21.9%	465	24.0%	850	23.9%	1,242	18.9%	3,927	21.3%
16:00–19:59	1,043	22.7%	443	24.8%	489	25.2%	869	24.4%	1,477	22.5%	4,321	23.4%
20:00–23:59	794	17.3%	338	18.9%	350	18.0%	619	17.4%	1,268	19.3%	3,369	18.3%
TOTAL	**4,585**	**100.0%**	**1,789**	**100.0%**	**1,941**	**100.0%**	**3,561**	**100.0%**	**6,566**	**100.0%**	**18,442**	**100.0%**

Unknown/Missing: Hour of crash, N=119

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 15: Frequency of Traffic Fatalities, by Hour of Crash: Appalachia, 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 13 displays the weather conditions at the time of the crash. While 70% of Appalachian traffic crash fatalities occurred in clear conditions, there were some regional differences related to weather conditions. The Central Appalachian subregion had the highest frequency of traffic fatalities that occurred during rainy (12.4%) and foggy/smoggy/smoky weather conditions (2.7%).

Figure 16 displays regional comparisons for selected environmental conditions. In the Northern subregion, traffic fatalities were 14 times more likely to have occurred during snowy/sleety conditions than the Southern subregion (OR: 15.48, 95% CI: 10.23–23.41). The Central subregion had 1.4 (OR: 1.41, 95% CI: 1.20–1.65) and 2.8 times (OR: 2.80, 95% CI: 1.94–4.04) the odds of happening on rainy and foggy/smoggy/smoky days respectively than the Southern subregion. Rain, snow, fog, and other adverse weather conditions increase the likelihood of traffic crashes through several pathways, including the creation of slick road conditions (e.g., rain, ice, and snow) and decreased visibility (e.g., rain, snow, fog). There are several strategies for preventing weather-related traffic crashes. These include incorporating weather-resilient signage, infrastructure, and road design (e.g., better drainage); setting adverse-weather speed limits; and treating road surfaces prior to weather events (e.g., sand, salt) (133).

Table 13 also displays the frequency of traffic fatalities by ambient light condition. Slightly over one-half of all Appalachian traffic fatalities happened during daylight conditions. Among the 45% of fatalities that occurred during dark/dawn/dusk conditions, most happened under dark conditions with no or unknown lighting. Figure 17 compares the odds of a traffic fatality occurring in dark, lighted conditions by Appalachian Region. Only 3% of all traffic fatalities in the Central subregion occurred under dark, lighted conditions (OR: 0.33, 95% CI: 0.25–0.43; Figure 2.9). Street lighting is one road treatment that is effective in reducing the incidence of traffic crashes and fatalities. Since street lighting requires the use of limited resources, priority should be awarded to sections of road for which nighttime crashes are overrepresented (147).

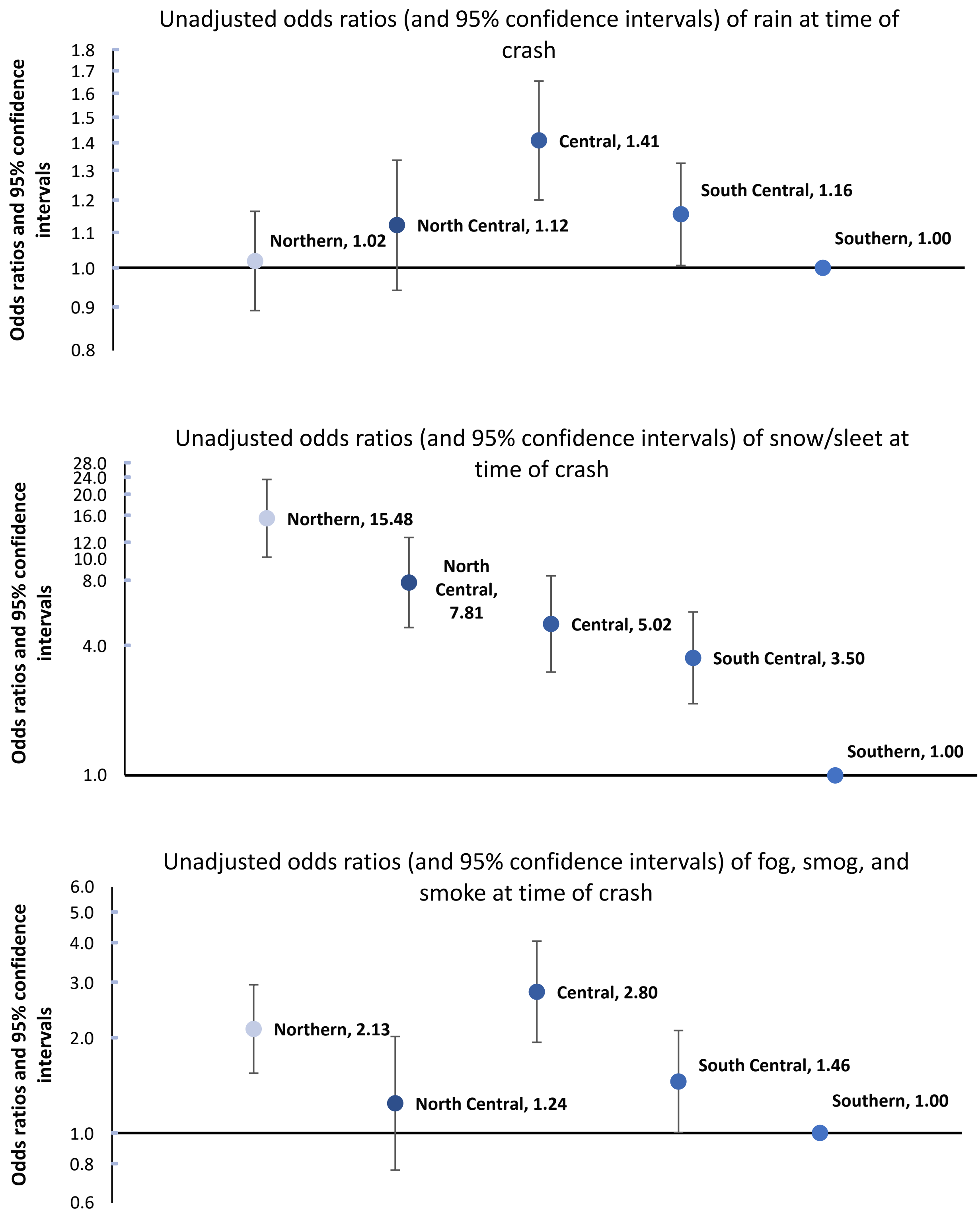
Table 13: Frequency of Traffic Fatalities, by Selected Environmental Conditions: Appalachia, 2013–2017

Environmental condition	Appalachian subregion N=18,561 traffic fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Weather condition												
Clear	3,117	73.4%	1,185	66.3%	1,170	61.4%	2,368	68.2%	4,733	72.3%	12,573	70.0%
Cloudy	386	9.1%	341	19.1%	407	21.4%	646	18.6%	1,118	17.1%	2,898	16.1%
Rain	394	9.3%	181	10.1%	236	12.4%	361	10.4%	597	9.1%	1,769	9.9%
Snow/Sleet	238	5.6%	52	2.9%	36	1.9%	46	1.3%	25	0.4%	397	2.2%
Fog, smog, smoke	89	2.1%	22	1.2%	52	2.7%	50	1.4%	65	1.0%	278	1.5%
Other	23	0.5%	7	0.4%	4	0.2%	3	0.1%	4	0.1%	41	0.2%
Ambient light												
Daylight	2,523	55.1%	1,005	56.3%	1,164	59.8%	2,068	57.2%	3,383	51.6%	10,143	54.9%
Dawn/Dusk	186	4.1%	76	4.3%	85	4.4%	152	4.2%	215	3.3%	714	3.9%
Dark—Lighted	470	10.3%	82	4.6%	63	3.2%	303	8.4%	609	9.3%	1,527	8.3%
Dark—Unlighted/ Unknown	1,400	30.6%	623	34.9%	636	32.6%	1,093	30.2%	2,354	35.9%	6,106	33.0%
TOTAL	**4,247**	**100.0%**	**1,788**	**100.0%**	**1,905**	**100.0%**	**3,474**	**100.0%**	**6,542**	**100.0%**	**17,956**	**100.0%**

Unknown/Missing: Weather condition, N=605; ambient light, N=71

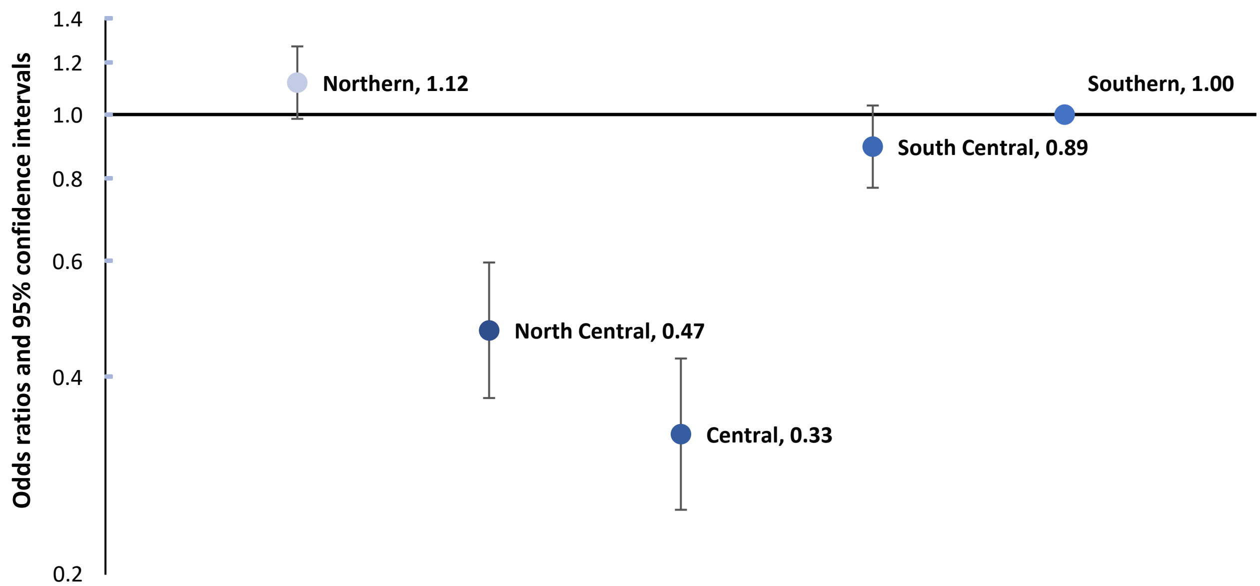
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 16: Unadjusted Odds Ratios (and 95 Percent Confidence Intervals) of Selected Weather Conditions at Time of Fatal Crash, by Appalachian Subregion: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 17: Unadjusted Odds Ratios (and 95 Percent Confidence Intervals) of Dark, Lighted at Time of Crash, by Appalachian Subregion: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

2.2.4 Frequency of Appalachian Traffic Fatalities by Vehicle Characteristics and Use of Safety Restraints (Motor Vehicle Occupants and Motorcyclists Only)

Key findings:

- There were regional differences in traffic fatalities by vehicle type. Traffic fatalities in the Northern and Central subregions were 33% more likely to be motorcyclists than other categories of motor vehicle occupant fatalities from the Southern subregion. In addition, traffic fatalities from the North Central and Central subregions had five times the odds of being off-road vehicle riders (i.e., riders of all-terrain vehicles and snowmobiles) than occupant fatalities from the Southern subregion, respectively.
- Over one-half of all Appalachian motor vehicle occupant fatalities were not restrained at the time of crash.
- Over two-thirds of all Appalachian motorcyclist fatalities were wearing helmets at the time of crash. There was considerable variation by subregion, likely related to the presence or absence of universal helmet laws.

Table 14 displays the frequency of Appalachian motor vehicle occupant and motorcyclist traffic fatalities according to vehicle body type. Figures 18, 19, and 20 display the unadjusted ORs, and corresponding 95% CIs, for selected vehicle types. Overall, nearly half of all Appalachian traffic fatalities occurred among occupants of passenger cars.

The frequency of motorcyclist traffic fatalities varied across subregions, with Northern (OR: 1.3395% CI: 1.19–1.49) and South Central (OR: 1.33, 95% CI: 1.18–1.50) subregions being overrepresented (Figure 19). Even greater regional differences were observed for off-road motor vehicles. For example, traffic fatalities in the Central Appalachian subregion were five times (OR: 5.22, 95% CI: 3.75–7.27) as likely to be off-road vehicle riders than fatalities in the Southern subregion (Figure 20). Many, although not all, Appalachian states allow off-road motor vehicles on trafficways under certain conditions, with West Virginia having one of the least restrictive policies (148–150).

Table 14: Frequency of Motor Vehicle Occupant and Motorcyclist Traffic Fatalities, by Vehicle Type: Appalachia: 2013–2017

	Appalachian subregion N=16,618 motor vehicle occupant and motorcyclist fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Vehicle type												
Passenger car	1,821	45.0%	662	40.4%	793	43.3%	1,460	44.4%	2,591	44.6%	7,327	44.1%
SUV	619	15.3%	283	17.3%	265	14.5%	460	14.0%	958	16.5%	2,585	15.6%
Van/Truck*	807	19.9%	393	24.0%	480	26.2%	765	23.3%	1,418	24.4%	3,863	23.2%
Motorcycle	663	16.4%	210	12.8%	189	10.3%	539	16.4%	747	12.8%	2,348	14.1%
Off-Road Vehicle**	108	2.7%	76	4.6%	93	5.1%	32	1.0%	59	1.0%	368	2.2%
Other/Unknown vehicle type†	31	0.8%	15	0.9%	10	0.5%	30	0.9%	41	0.7%	127	0.8%
TOTAL	**4,049**	**100.0%**	**1,639**	**100.0%**	**1,830**	**100.0%**	**3,286**	**100.0%**	**5,814**	**100.0%**	**16,618**	**100.0%**

Abbreviations: SUV, sport utility vehicle

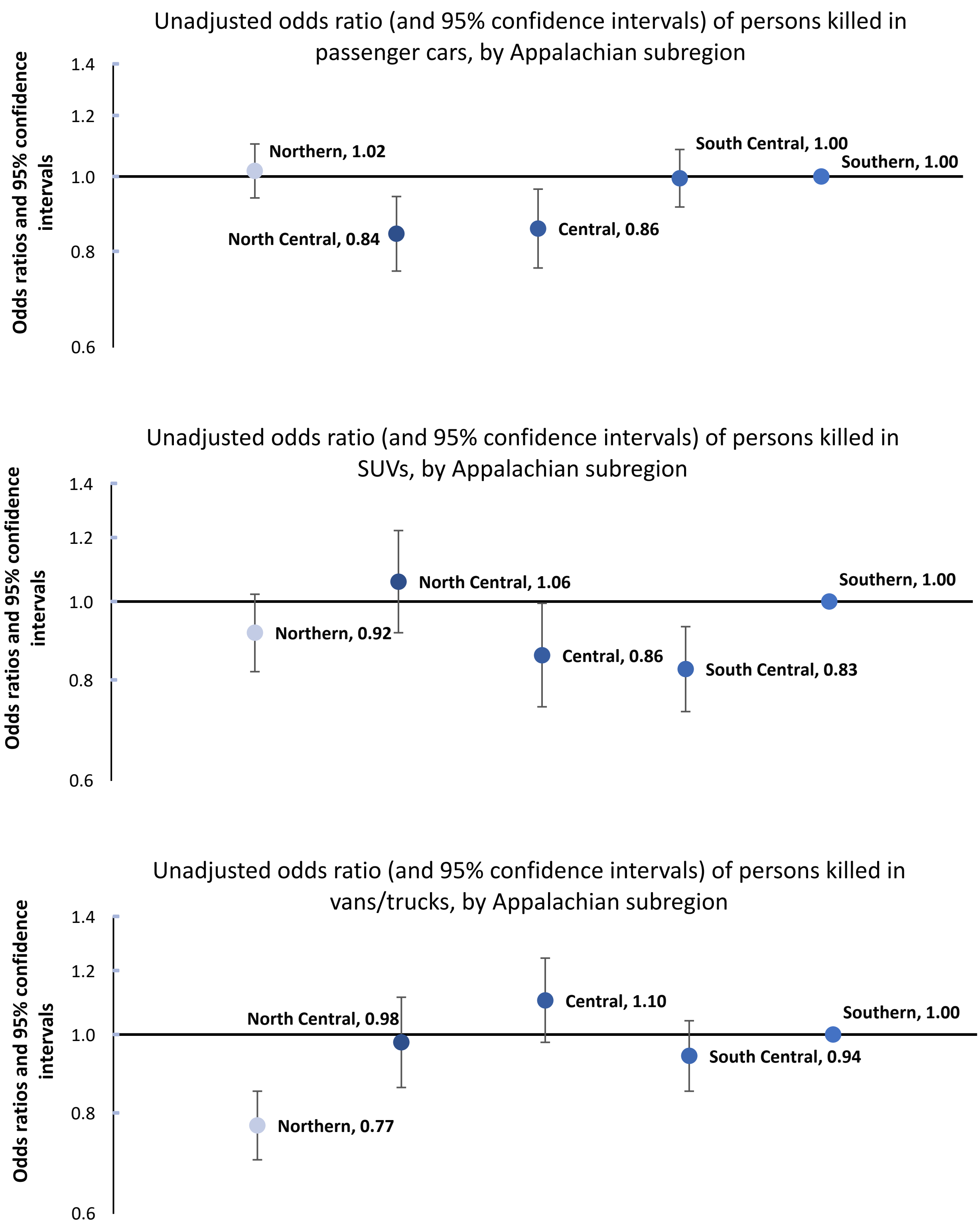
*Includes vans, pickup trucks, other light trucks, and medium/heavy trucks.

**Includes all-terrain vehicles and snowmobiles.

†Includes farm equipment, construction equipment, low speed vehicles, golf carts, and other and unknown vehicle types.

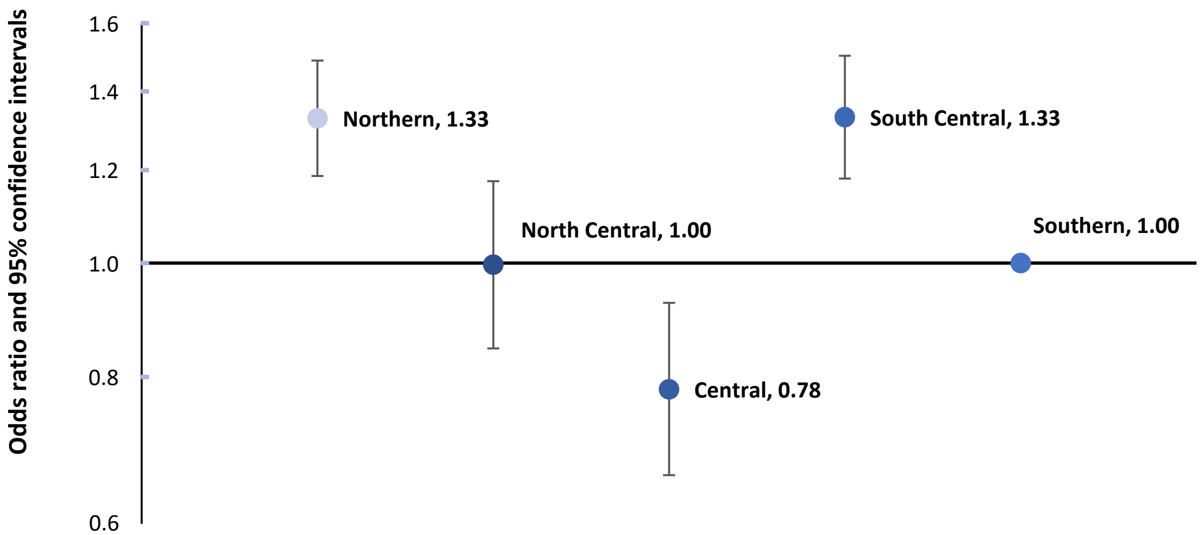
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 18: Unadjusted Odds Ratios (and 95 Percent Confidence Intervals) of Motor Vehicle Occupant Traffic Fatalities, by Selected Vehicle Types and Appalachian Subregion: 2013–2017



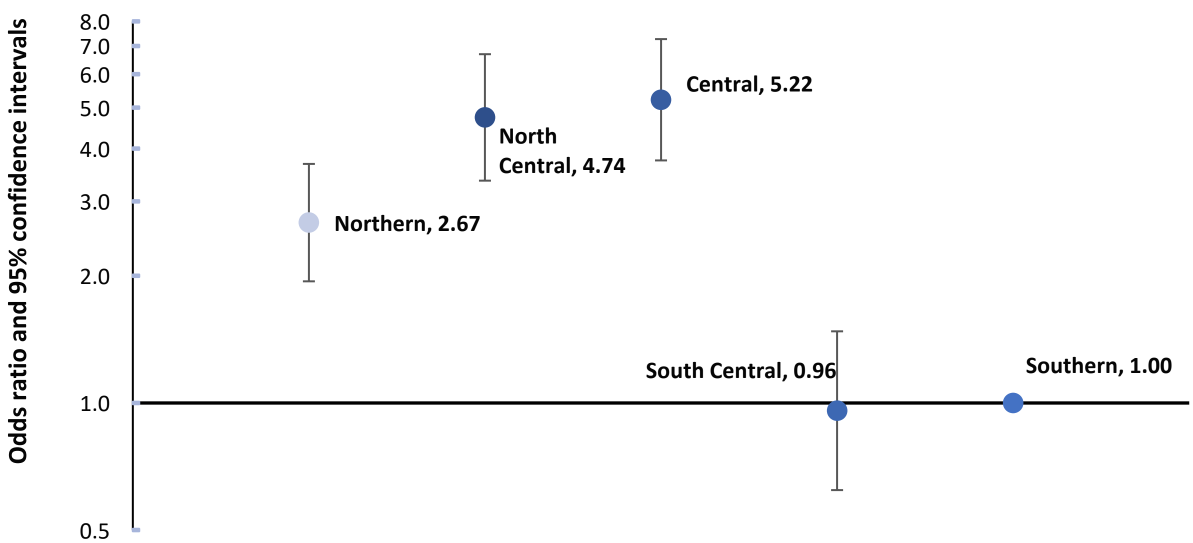
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 19: Unadjusted Odds Ratios (and 95 Percent Confidence Intervals) of Persons Killed on Motorcycles, by Appalachian Subregion: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 20: Unadjusted Odds Ratios (and 95% Confidence Intervals) of Persons Killed on Off-Road Motor Vehicles, by Appalachian Subregion: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

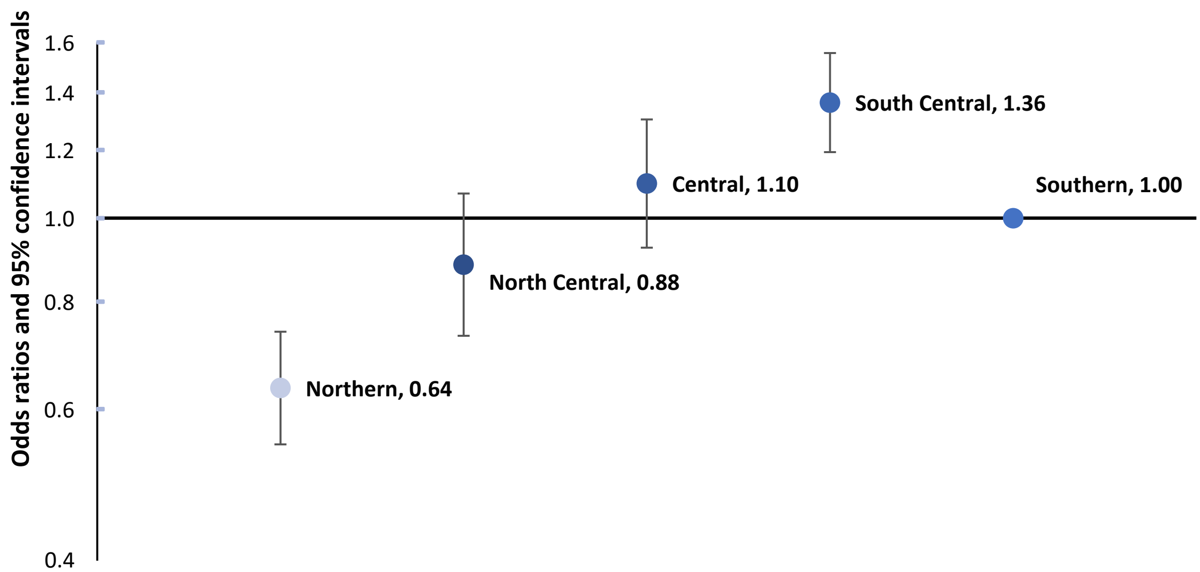
Table 15 displays the age of vehicles involved in Appalachian motor vehicle occupant and motorcyclist traffic fatalities. The median age of motor vehicles involved in fatal traffic crashes was 11 years, ranging in age from a low of 10 years (Northern subregion) to a high of 12 years (Central subregion). The subregion with the highest proportion of vehicles over 20 years of age was the South Central subregion, with 13% of traffic fatalities riding in or on vehicles more than 20 years old. Traffic fatalities in the South Central subregion were 1.4 times (OR: 1.36, 95% CI: 1.19–1.56) as likely to involve a vehicle greater than 20 years old than the Southern subregion (Figure 21).

Table 15: Frequency of Motor Vehicle Occupant and Motorcyclist Traffic Fatalities, by Age of Vehicle: Appalachia: 2013–2017

	Appalachian subregion N=16,618 motor vehicle occupant and motorcyclist fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
Vehicle age (y), median (IQR)	**10 (5–14)**		**11 (6–15)**		**12 (7–16)**		**11 (7–16)**		**11 (6–15)**		**11 (6–15)**	
	N	%	N	%	N	%	N	%	N	%	N	%
Vehicle age (y)												
<1	135	3.4%	43	2.7%	35	2.0%	82	2.5%	139	2.4%	434	2.6%
1–5	703	17.6%	241	14.9%	232	13.0%	439	13.4%	867	15.1%	2,482	15.1%
6–10	1,148	28.7%	370	22.8%	436	24.4%	744	22.8%	1,430	24.9%	4,128	25.1%
11–15	1,217	30.4%	522	32.2%	555	31.0%	942	28.8%	1,719	29.9%	4,955	30.2%
16–20	535	13.4%	299	18.4%	336	18.8%	629	19.2%	1,010	17.6%	2,809	17.1%
>20	266	6.6%	146	9.0%	196	10.9%	433	13.2%	579	10.1%	1,620	9.9%
TOTAL	**4,004**	**100.0%**	**1,621**	**100.0%**	**1,790**	**100.0%**	**3,269**	**100.0%**	**5,744**	**100.0%**	**16,428**	**100.0%**

Abbreviations: y, years; IQR, interquartile range
Unknown/Missing: Vehicle age, N=190
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 21: Unadjusted Odds Ratios (and 95% Confidence Intervals) of Motor Vehicle Occupants and Motorcyclists Killed in Vehicles Older than 20 Years, by Appalachian Subregion: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 16 displays restraint use (i.e., seatbelt and child restraint use) among traffic fatalities in Appalachia. Less than one-half (45%) of all Appalachian motor vehicle occupant fatalities were restrained at the time of crash. Studies have shown that restraint use is low in fatal crashes with slightly more than half (53%) of motor vehicle occupant fatalities being restrained at the time of crash (151). Although an estimated 90% of motor vehicle occupants in the United States use restraints (National Center for Statistics and Analysis, 2018), persons who are unrestrained are at much higher risk of serious injury or death if they are involved in a crash. The subregion with the highest proportion of unrestrained fatalities was the Central subregion (62%). Motor vehicle occupant fatalities from this subregion were 1.5 times as likely to be unrestrained at the time of crash than fatalities from the Southern subregion (OR: 1.47, 95% CI: 1.31–1.65; Figure 22). A recent CDC study found that as rurality increases, restraint use decreases, and motor vehicle occupant fatality rates increase (152). Therefore, it is not unanticipated that fatalities from the most rural subregion with the highest traffic fatality rate, the Central subregion, would be the most likely to be unrestrained at the time of crash.

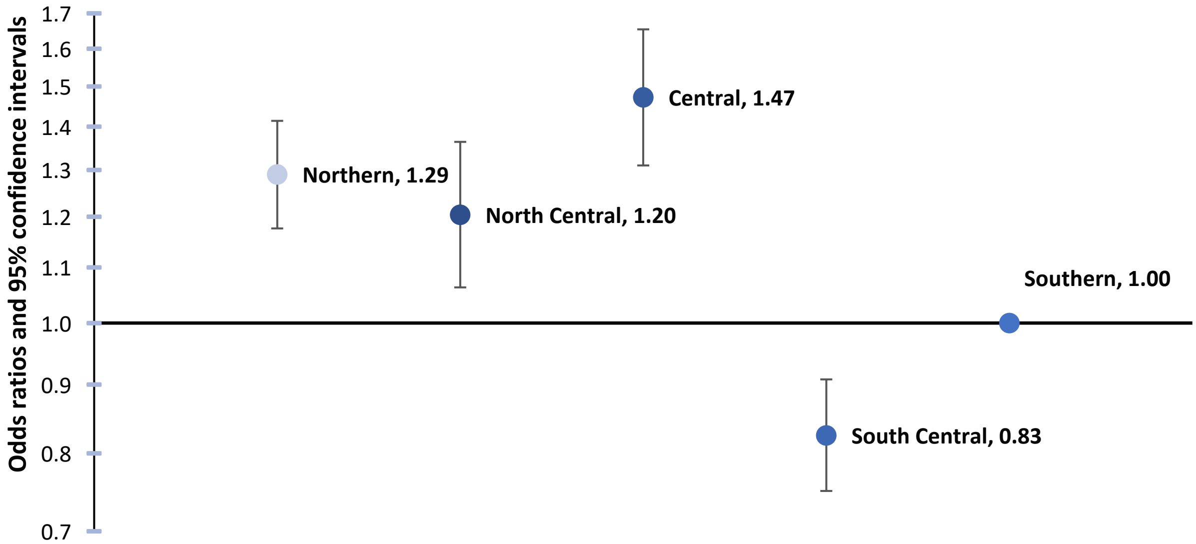
Table 16: Use of Safety Restraints* among Motor Vehicle Occupant Traffic Fatalities: Appalachia, 2013–2017

	Appalachian subregion N=14,270 motor vehicle occupant fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Use of safety restraint												
No restraint	1,778	59.1%	730	57.5%	990	62.3%	1,244	48.1%	2,525	52.9%	7,267	54.9%
Restraint	1,228	40.9%	540	42.5%	599	37.7%	1,343	51.9%	2,249	47.1%	5,959	45.1%
TOTAL	**3,006**	**100.0%**	**1,270**	**100.0%**	**1,589**	**100.0%**	**2,587**	**100.0%**	**4,774**	**100.0%**	**13,226**	**100.0%**
Unknown/Missing	380		159		52		160		293		1,044	

*Includes seatbelts, child restraints, and other/unknown type of restraints.

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 22: Unadjusted Odds Ratios (and 95% Confidence Intervals) for Motor Vehicle Occupant Traffic Fatalities Unrestrained at Time of Fatal Crash, by Appalachian Subregion: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 17 displays the proportion of motorcyclist traffic fatalities who were helmeted at the time of crash. There was wide variation across the Appalachian subregions, ranging from 50% to 95% of motorcyclist fatalities wearing motorcycle helmets at the time of crash. Much of this variation is explained by the presence (or absence) of state universal motorcycle helmet laws. For example, all states within the South Central subregion had active universal helmet laws during the study period. These laws mandate that all riders (drivers and passengers, youth and adults) wear helmets when operating a motorcycle. Among states with universal helmet laws, the prevalence of motorcyclist helmet use is about 97%. In states without such laws, less than one-half of all motorcyclists choose to wear helmets (153). Motorcyclist traffic fatalities from the Northern subregion, the subregion with the lowest proportion of helmeted fatalities, were 1.8 times (OR: 2.85, 95% CI: 2.28–3.57) less likely to be wearing helmets at the time of crash, than fatalities from the Southern subregion (Figure 23). Two states with counties within the Northern subregion have partial helmet laws, Ohio (covers riders 17 years of age and younger) and Pennsylvania (covers rider 20 years of age and younger) (153).

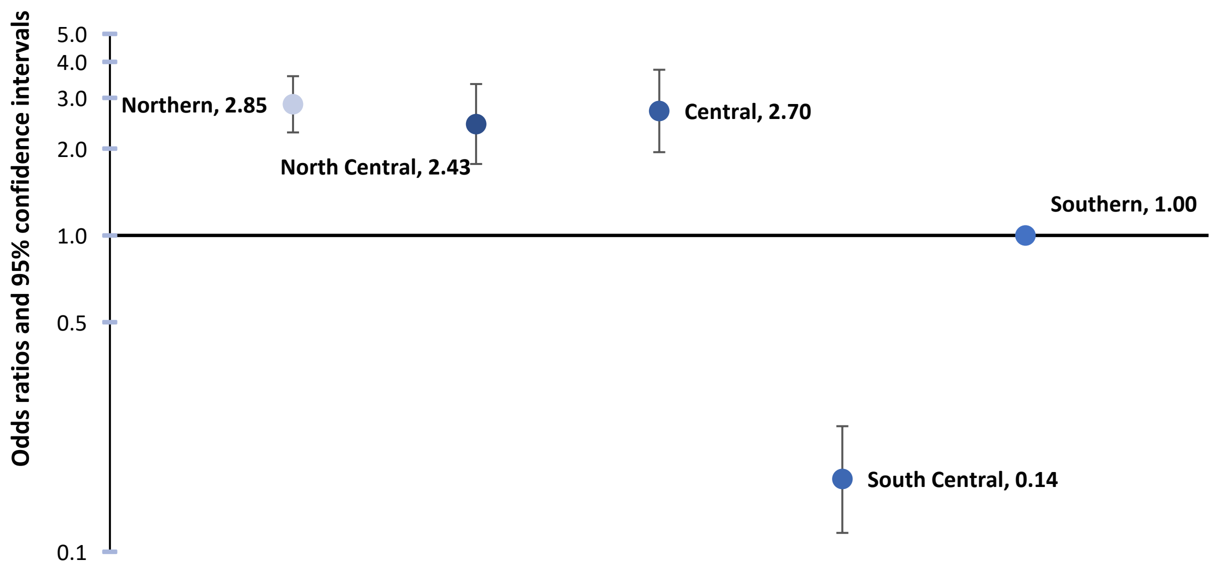
Table 17: Use of Helmets among Motorcyclist Traffic Fatalities: Appalachia, 2013–2017

	Appalachian subregion N=2,348 motorcyclist fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Motorcycle helmet use												
No helmet	330	50.5%	96	46.6%	93	49.2%	26	4.9%	194	26.4%	739	31.9%
Helmet	323	49.5%	110	53.4%	96	50.8%	509	95.1%	541	73.6%	1,579	68.1%
TOTAL	**653**	**100.0%**	**206**	**100.0%**	**189**	**100.0%**	**535**	**100.0%**	**735**	**100.0%**	**2,318**	**100.0%**

Unknown/Missing: Motorcycle helmet use, N=30

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 23: Unadjusted Odds Ratios (and 95% Confidence Intervals) for Un-Helmeted Motorcyclist Traffic Fatalities, by Appalachian Subregion: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

2.2.5 Frequency of Appalachian Traffic Fatalities by Selected Crash Circumstances

Key findings:

- Less than one-third of all motor vehicle occupant and motorcyclist traffic fatalities were identified as being involved in speed-related crashes (as determined by the investigating law enforcement officer). The exception was Northern Appalachia, in which twice as many traffic fatalities were killed in speed-related crashes, as compared to Southern Appalachia.
- About one-fifth of all Appalachian traffic fatalities died in alcohol-involved crashes.
- As compared to other Appalachian subregions, traffic fatalities in the Central subregion were more likely to occur on graded roads and roadway curves.

Table 18 displays the frequency of motor vehicle occupant and motorcyclist traffic fatalities who were involved in crashes that were classified as being "speed-related." FARS labels a crash "speed-related" if a law enforcement officer indicated that one or more driver's speeds contributed to the fatal crash. A speed-related crash can be due to exceeding the posted speed limit, traveling too fast for conditions, racing, and for other and unknown speed-related reasons (154). Most Appalachian traffic fatalities were not involved in speed-related crashes. The exception was the Northern subregion. Traffic fatalities from this region were 2.2 times as likely to have died in speed-related crashes, than fatalities from the Southern Appalachian subregion (OR: 2.20, 95% CI: 2.02–2.40; Figure 24).

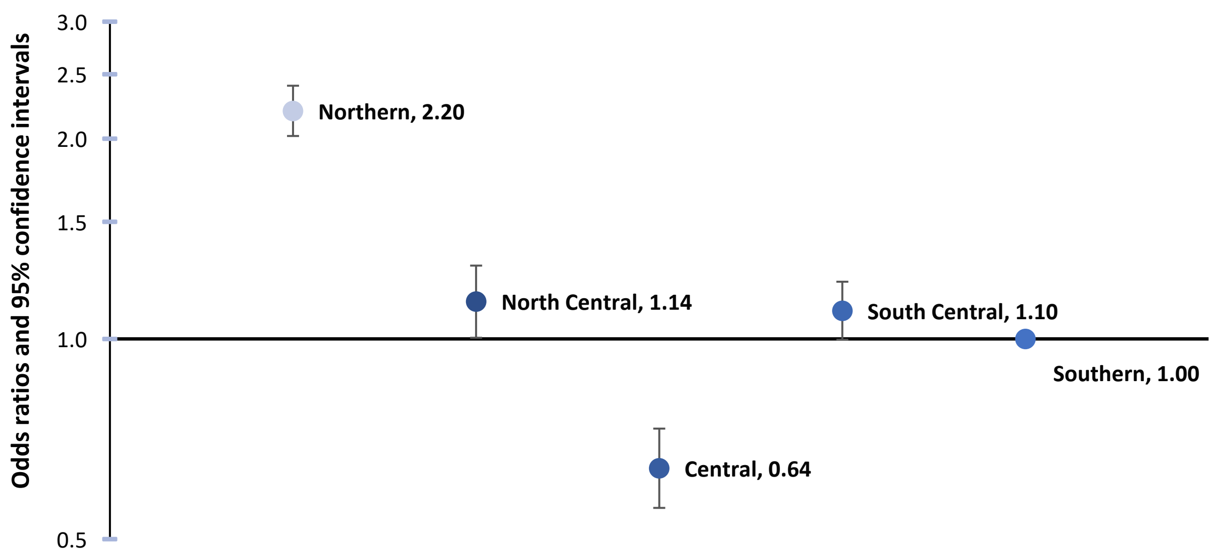
Table 18: Frequency of Motor Vehicle Occupant and Motorcyclist Traffic Fatalities Involved in Excessive Speed-Related Crashes: Appalachia, 2013–2017

	Appalachian subregion N=16,618 motor vehicle occupant and motorcyclist fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Speed-related												
No	2,316	57.8%	1,177	72.6%	1,450	82.5%	2,211	73.2%	4,199	75.1%	11,353	71.0%
Yes	1,691	42.2%	444	27.4%	307	17.5%	808	26.8%	1,392	24.9%	4,642	29.0%
TOTAL	**4,007**	**100.0%**	**1,621**	**100.0%**	**1,757**	**100.0%**	**3,019**	**100.0%**	**5,591**	**100.0%**	**15,995**	**100.0%**

Unknown/Missing: Speed-relatedness, N=623

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 24: Unadjusted Odds Ratios (and 95% Confidence Intervals) for Motor Vehicle Occupant and Motorcyclist Traffic Fatalities Involved in Excessive Speed-Related Crashes, by Appalachian Subregion: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 19 displays the frequency of motor vehicle occupant and motorcyclist traffic fatalities who died in crashes that involved alcohol. FARS labels a crash "alcohol-involved" if a law enforcement officer indicated that alcohol factored into the crash. This variable does not necessarily mean that alcohol caused the crash (155). Most Appalachian fatal crash victims were not killed in alcohol-involved crashes. The Northern subregion had the highest proportion of traffic fatalities killed in alcohol-involved crashes (29%). Traffic fatalities from the Northern subregion were 56% more likely to have died in alcohol-involved crashes, than fatalities from the Southern subregion (OR: 1.56, 95% CI: 1.39–1.75; Figure 25).

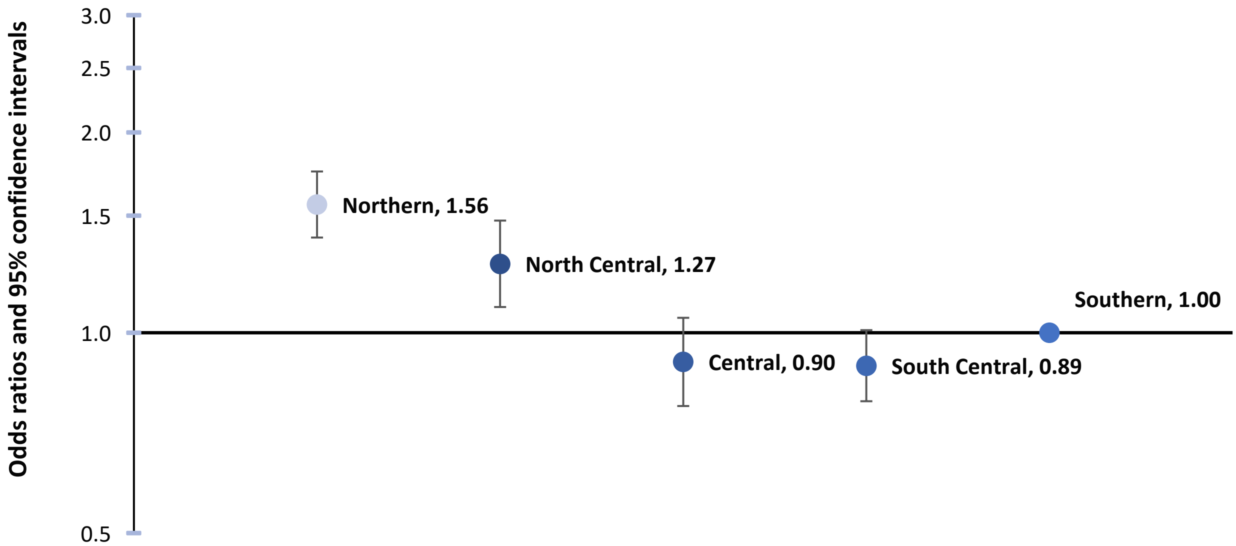
Table 19: Frequency of Traffic Fatalities Involved in Alcohol-Related Crashes: Appalachia, 2013–2017

	Appalachian subregion N=18,561 traffic fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Alcohol-related												
No	1,885	70.7%	938	74.7%	1,151	80.6%	2,197	80.8%	2,993	79.0%	9,164	77.3%
Yes	782	29.3%	317	25.3%	277	19.4%	522	19.2%	797	21.0%	2,695	22.7%
TOTAL	**2,667**	**100.0%**	**1,255**	**100.0%**	**1,428**	**100.0%**	**2,719**	**100.0%**	**3,790**	**100.0%**	**11,859**	**100.0%**

Unknown/Missing: Alcohol relatedness, N=6,702

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 25: Unadjusted Odds Ratios (and 95% Confidence Intervals) for Traffic Fatalities Involved in Alcohol-Related Crashes, by Appalachian Subregion: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 20 displays the frequency of Appalachian traffic fatalities by roadway characteristics. Over 80% of all traffic fatalities occurred on two-lane roadways. More than ten percent of all traffic fatalities in the South Central and Southern subregions were on roadways with four or more lanes. Overall, about 40% of all Appalachian traffic fatalities occurred on curves. Fatalities on the four nonreferent subregions were all significantly more likely to occur on curves than straight sections of roadways, as compared to the Southern subregion. Traffic fatalities from the Central subregion were nearly twice as likely to occur on curves, as compared to the Southern subregion (OR: 1.76, 95% CI: 1.59–1.96; Figure 26). These findings may be indicative of the state Strategic Highway Safety Plans discussed in the literature synthesis for this project; all of the Appalachian states identified roadway departures and lane departures as emphasis areas for safety interventions, and all identified engineering countermeasures (e.g., roadway lighting, improved delineation, better signage at horizontal curves) to address these types of crashes at locations with problematic roadway curvature (26,43–54).

Table 20: Frequency of Motor Vehicle Occupant and Motorcyclist Traffic Fatalities, by Other Roadway Characteristics: Appalachia, 2013–2017

Roadway characteristic	Appalachian subregion N=16,618 motor vehicle occupant and motorcyclist fatalities											
	Northern		North Central		Central		South Central		Southern		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Number of lanes												
One lane	73	1.8%	11	0.7%	19	1.0%	22	0.7%	30	0.5%	155	0.9%
Two lanes	3,539	88.4%	1,502	91.9%	1,598	88.1%	2,620	80.7%	4,682	81.4%	13,941	84.7%
Three lanes	193	4.8%	71	4.3%	98	5.4%	195	6.0%	413	7.2%	970	5.9%
Four or more lanes	200	5.0%	50	3.1%	99	5.5%	411	12.6%	629	10.9%	1,389	8.4%
TOTAL	**4,005**	**100.0%**	**1,634**	**100.0%**	**1,814**	**100.0%**	**3,248**	**100.0%**	**5,754**	**100.0%**	**16,455**	**100.0%**
Alignment												
Straight	2,319	57.9%	937	57.4%	943	52.3%	1,960	60.3%	3,795	65.9%	9,954	60.5%
Curved	1,689	42.1%	694	42.6%	860	47.7%	1,292	39.7%	1,962	34.1%	6,497	39.5%
TOTAL	**4,008**	**100.0%**	**1,631**	**100.0%**	**1,803**	**100.0%**	**3,252**	**100.0%**	**5,757**	**100.0%**	**16,451**	**100.0%**
Grade												
Level	2,289	57.1%	991	60.9%	1,055	58.6%	1,899	58.5%	3,514	61.2%	9,748	59.4%
Some grade	1,717	42.9%	637	39.1%	746	41.4%	1,347	41.5%	2,227	38.8%	6,674	40.6%
TOTAL	**4,006**	**100.0%**	**1,628**	**100.0%**	**1,801**	**100.0%**	**3,246**	**100.0%**	**5,741**	**100.0%**	**16,422**	**100.0%**

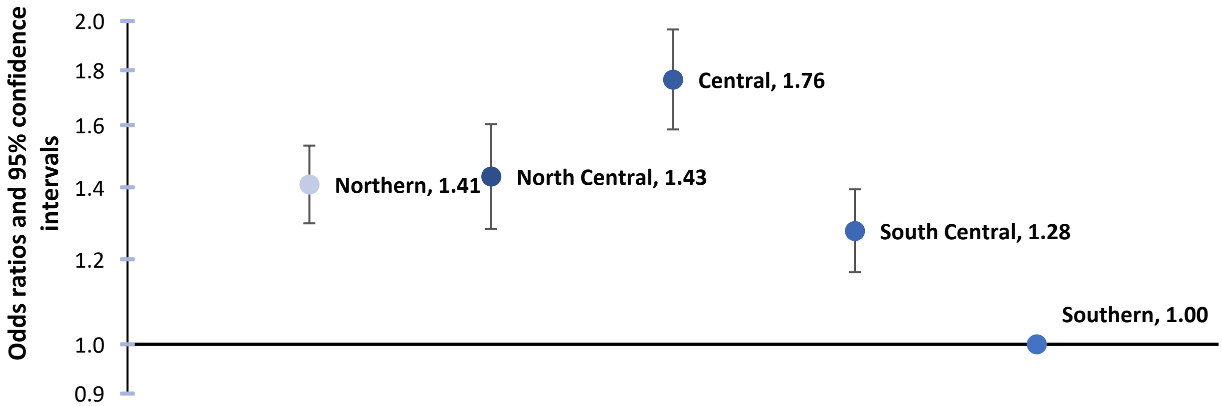
Unknown/Missing: Number of lanes, N=163; alignment, N=167; grade, N=196; surface condition, N=190

*Motor vehicle crashes occurring on non-trafficways excluded from analyses.

**Other surface condition includes “oil”, “sand”, “gravel”, “mud”, and “other” road surface conditions.

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 26: Unadjusted Odds Ratios (and 95% Confidence Intervals) of Motor Vehicle Occupant and Motorcyclist Traffic Fatalities on Curves, by Appalachian Subregion: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

2.3 Selected Comparisons of Persons Killed in Motor Vehicle Collisions in the Appalachian and Non-Appalachian United States

2.3.1 Trends: Persons Killed in Motor Vehicle Collisions in Appalachia and Non-Appalachia

Key findings:

- The average annual traffic fatality rate for Appalachia was 17.6 deaths per 100,000 person-years. During this same period, the traffic fatality rate for non-Appalachia was 12.8 fatalities per 100,000 person-years.
- The Appalachian traffic fatality rate in 2017 (14.7 deaths per 100,000 person-years) represented a 23% decrease since 1994 (19.1 fatalities per 100,000 person-years). Non-Appalachia had a 27% decrease from 1994 (15.1 fatalities per 100,000 person-years) to 2017 (11.1 fatalities per 100,000 person-years).

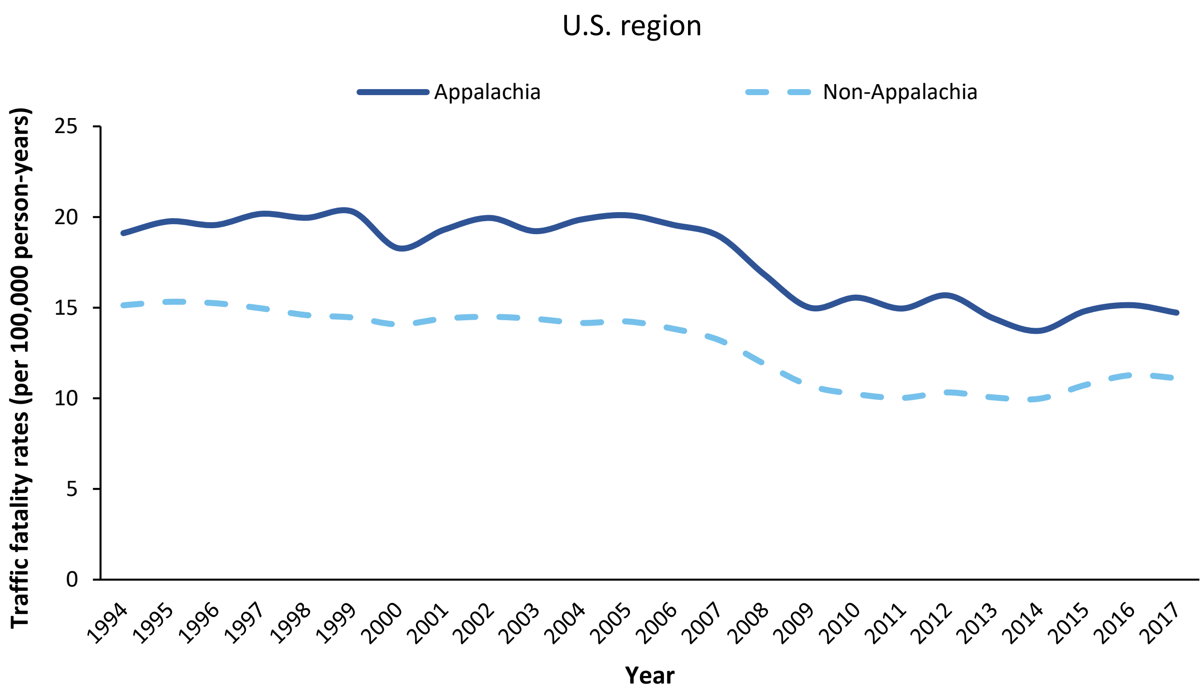
Table 21 and Figure 27 display the traffic fatality rates by U.S. region for the period 1994–2017. The average annual traffic fatality rate for this period was 17.6 deaths per 100,000 person-years for Appalachia and 12.8 deaths per 100,000 person-years for non-Appalachia. While traffic fatality rates declined for both U.S. regions over this more than 20-year period, the decline was less pronounced for the Appalachian Region.

Table 21: Traffic Fatalities and Traffic Fatality Rates (per 100,000 Person-Years), by Year: Appalachia and Non-Appalachia, 1994–2017

	United States region N=935,224 traffic fatalities			
	Appalachia		Non-Appalachia	
	N	Rate	N	Rate
Year				
1994	4,328	19.11	36,388	15.13
1995	4,516	19.76	37,301	15.32
1996	4,505	19.56	37,560	15.25
1997	4,682	20.17	37,331	14.97
1998	4,664	19.96	36,837	14.59
1999	4,776	20.30	36,941	14.46
2000	4,328	18.28	36,388	14.08
2001	4,592	19.30	37,604	14.40
2002	4,775	19.95	38,230	14.50
2003	4,630	19.22	38,254	14.38
2004	4,813	19.86	38,023	14.16
2005	4,904	20.09	38,606	14.24
2006	4,825	19.57	37,883	13.84
2007	4,714	18.96	36,545	13.22
2008	4,215	16.82	33,208	11.90
2009	3,775	14.99	30,108	10.69
2010	3,930	15.56	29,069	10.23
2011	3,785	14.95	28,694	10.02
2012	3,974	15.68	29,808	10.33
2013	3,660	14.41	29,233	10.05
2014	3,491	13.72	29,253	9.98
2015	3,773	14.81	31,711	10.73
2016	3,866	15.14	33,595	11.28
2017	3,771	14.72	33,362	11.12
TOTAL	**103,292**	**17.63**	**831,932**	**12.75**

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 27: Incidence of Traffic Fatalities (Rates per 100,000 Person-Years), by Year, Appalachia and Non-Appalachia: 1994–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

2.3.2 Basic Descriptors of Persons Killed in Motor Vehicle Collisions in Appalachia and Non-Appalachia

Key Findings:

- Appalachia had a higher average annual traffic fatality rate than non-Appalachia for the period 2013–2017. Although the relative difference was attenuated (i.e., reduced) after controlling for sex, age, and rural/urban county of event, after adjustment the traffic fatality rate was still 22% higher than the rest of the United States.
- Traffic fatality rates were higher in Appalachia for motor vehicle and motorcyclists, but lower for non-motorists.
- Urban traffic fatality rates were 35% higher in Appalachia than non-Appalachia. On the other hand, rural traffic fatalities rates were 16% lower in rural Appalachia than rural non-Appalachia.

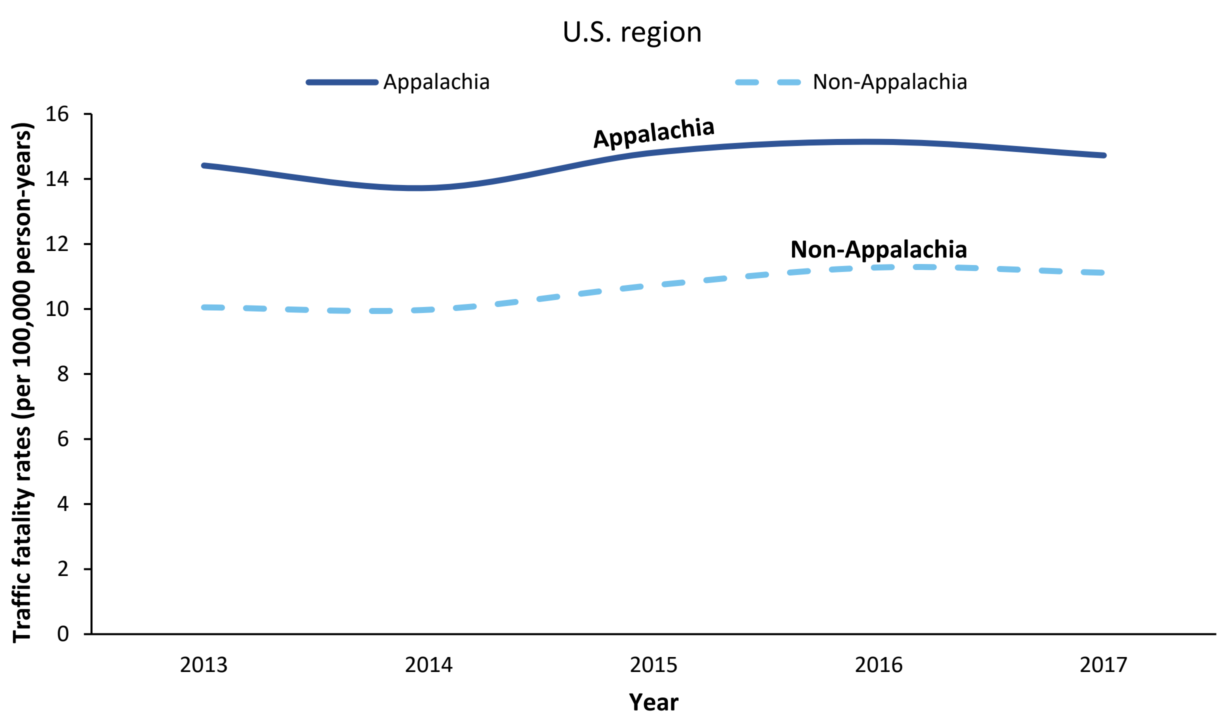
Table 22 and Figure 28 display the traffic fatality rates by year, stratified by U.S. region. For the entire period (2013–2017), Appalachia had a higher average annual traffic fatality rate (14.6 deaths per 100,000 person-years) than non-Appalachia (10.6 deaths per 100,000 person-years). While controlling for age, sex, and urban/rural county of crash diminished the effect size, after adjustment Appalachia still had a traffic fatality rate that was 22% higher than non-Appalachia (OR: 1.22, 95% CI: 1.21–1.24).

Table 22: Traffic Fatalities and Traffic Fatality Rates (per 100,000 Person-Years), by Year: Appalachia and Non-Appalachia, 2013–2017

	United States region N= 175,715				Rate ratios			
	Appalachia		Non-Appalachia		Crude RR and 95% CI		Adjusted RR and 95% CI*	
	N	Rate	N	Rate	RR	CI	aRR	CI
Year								
2013	3,660	14.41	29,233	10.05	1.43	(1.39–1.48)	1.27	(1.23–1.32)
2014	3,491	13.72	29,253	9.98	1.38	(1.33–1.43)	1.22	(1.18–1.27)
2015	3,773	14.81	31,711	10.73	1.38	(1.33–1.43)	1.23	(1.19–1.28)
2016	3,866	15.14	33,595	11.28	1.34	(1.30–1.39)	1.21	(1.17–1.25)
2017	3,771	14.72	33,362	11.12	1.32	(1.28–1.37)	1.19	(1.15–1.23)
TOTAL	**18,561**	**14.56**	**157,154**	**10.64**	**1.37**	**(1.35–1.39)**	**1.22**	**(1.21–1.24)**

Abbreviations: CI, confidence interval; RR, rate ratio; aRR, adjusted rate ratio
*Adjusted for sex, age, and urban/rural county of crash. Urban/rural county designation based on NCHS classification scheme (www.cdc.gov/nchs/data_access/urban_rural.htm).

Figure 28: Traffic Fatality Rates (per 100,000 Person-Years), by U.S. Region and Year: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

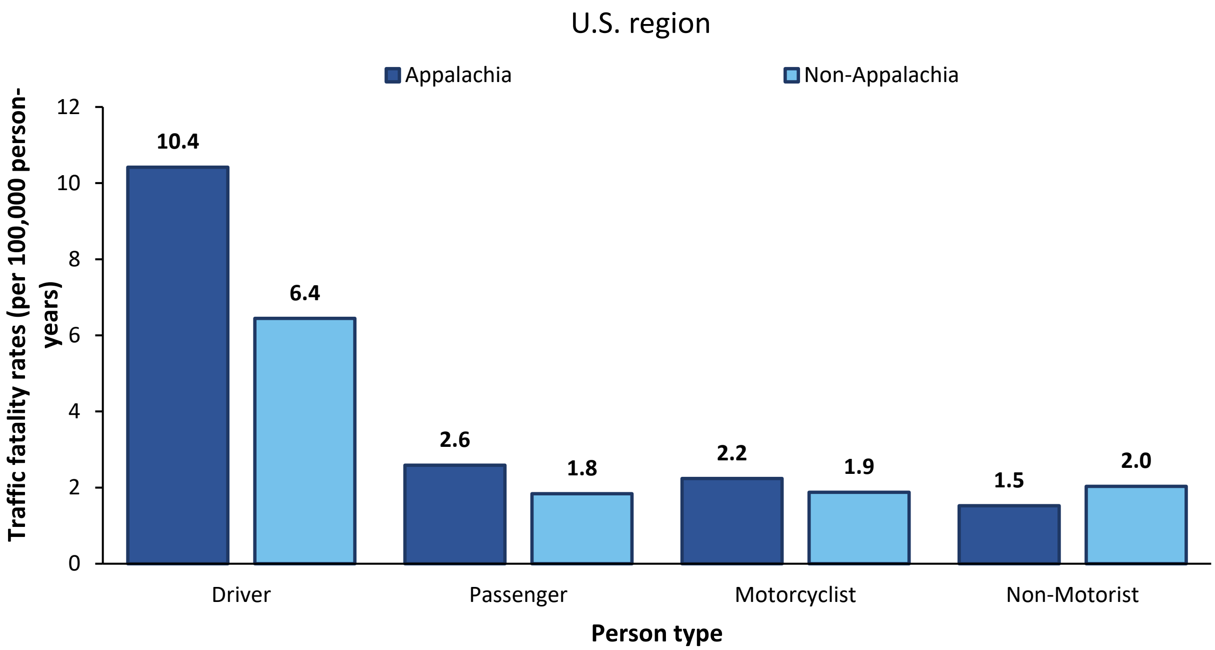
Table 23 and Figure 29 display traffic fatality adjusted rate ratios (aRR) by person type for the Appalachian and non-Appalachian U.S. Traffic fatality rates were 41% higher among Appalachian motor vehicle drivers than non-Appalachian drivers (aRR: 95% CI: 1.38–1.44). While still elevated, the relative difference in Appalachian and non-Appalachian motor vehicle passenger (aRR: 1.23, 95% CI: 1.18–1.27) and motorcyclist (aRR: 1.16, 95% CI: 1.11–1.21) traffic fatality rates were lower than for motor vehicle drivers. Traffic fatality rates were lower for non-motorists in Appalachia, as compared to non-Appalachia, with pedestrian and cyclist traffic fatality rates being 22% (aRR: 0.78, 95% CI: 0.74–0.82) and 46% (aRR: 0.54, 95% CI: 0.47–0.63) lower in Appalachia, respectively. These results are similar to a study by Zhu et al. (2) that also found low fatality rates among non-motorists in Appalachia. The low non-motorist fatality rates are likely related to lower levels of walking and cycling in Appalachia, as indicated by low levels of reported physical activity (20). While studies point to a high prevalence of chronic health conditions and a cultural aversion to exercise for explanations of low physical activity levels in Appalachia, inadequate infrastructure also plays a role (20,155,156). Rural two-lane roads with high speeds and large elevation changes are not conducive to walking and cycling. Even more developed areas may lack adequate pedestrian/bicycle infrastructure, with one study finding that many small Appalachian towns completely lacked sidewalks and, among towns that did have sidewalks, most were in poor to fair condition (157).

Table 23: Traffic Fatalities and Traffic Fatality Rates (per 100,000 Person-Years), by Person Type: Appalachia and Non-Appalachia, 2013–2017

Person type	United States region N= 175,715				Rate ratios			
	Appalachia		Non-Appalachia		Crude RR and 95% CI		Adjusted RR and 95% CI*	
	N	Rate	N	Rate	RR	CI	aRR	CI
Vehicle occupant								
Driver**	10,927	10.42	77,014	6.44	1.62	(1.58–1.65)	1.41	(1.38–1.44)
Passenger	3,300	2.59	27,156	1.84	1.41	(1.36–1.46)	1.23	(1.18–1.27)
Subtotal	*14,270*	*11.20*	*104,671*	*7.08*	*1.58*	*(1.56–1.61)*	*1.36*	*(1.33–1.38)*
Motorcyclist**								
Subtotal	*2,348*	*2.24*	*22,431*	*1.88*	*1.19*	*(1.14–1.24)*	*1.16*	*(1.11–1.21)*
Non-motorist								
Pedestrian	1,700	1.33	25,447	1.72	0.77	(0.74–0.82)	0.78	(0.74–0.82)
Pedal cyclist	176	0.14	3,754	0.25	0.54	(0.47–0.64)	0.54	(0.47–0.63)
Subtotal	*1,943*	*1.52*	*30,052*	*2.03*	*0.75*	*(0.72–0.79)*	*0.75*	*(0.72–0.79)*
TOTAL	**18,561**	**14.56**	**157,154**		**1.37**	**(1.35–1.39)**	**1.22**	**(1.21–1.24)**

Abbreviations: CI, confidence interval; RR, rate ratio; aRR, adjusted rate ratio
Unknown/Missing: Vehicle occupant status; N=544; non-motorist status, N=918
*Adjusted for sex, age, and urban/rural county of crash. Urban/rural county designation based on NCHS classification scheme (www.cdc.gov/nchs/data_access/urban_rural.htm).
**Denominator consists of persons ≥ 15 years of age; denominators for all other person types consist of persons ≥ 0 years of age.
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 29: Traffic Fatality Rates (per 100,000 Person-Years), by U.S. Region and Person-Type: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Tables 24 and 25 display the demographic characteristics of Appalachian and non-Appalachian traffic fatalities. Traffic fatalities in Appalachia had a median age one year older (median age of 43 years, IQR: 27–60) than non-Appalachia (median age 42 years, IQR: 26–59; Table 3.4.). As compared to non-Appalachia, a greater proportion of fatalities were white (87% versus 78%) and non-Hispanic (97% versus 84%; Table 25). The racial/ethnic make-up of the Appalachian traffic fatalities reflects the demographic characteristics of Appalachian residents (1).

Table 24 displays the rates, unadjusted rate ratios (RRs), and adjusted RRs comparing Appalachia to non-Appalachia by demographic characteristics. Appalachian traffic fatality rates were higher than non-Appalachian traffic fatalities for all age groups and for males and females. Regarding age, Appalachian adults 25–44 years of age had the aRR with the largest relative effect size, with traffic fatality rates 31% higher than their non-Appalachian counterparts (aRR: 1.31, 95% CI: 1.27–1.34). Interestingly, the relative difference in traffic fatality rates for this age group corresponds to the disparity documented by Meit et al. (21) in their exploration of "diseases of despair" (alcoholic liver disease/cirrhosis, drug overdose, and self-harm/suicide). While traffic collision is not generally classified as a disease of despair, it is possible that it shares some common explanatory factors with diseases of despair, such as poverty and a lack of economic development.

As expected, rural traffic fatality rates were considerably higher than urban traffic fatality rates for both Appalachia and non-Appalachia (Table 26). Somewhat surprisingly, rural traffic fatality rates were lower in Appalachia as compared to non-Appalachia (aRR: 0.86, 95% CI: 0.83–0.89). A similar finding was also reported by Zhu et al. in their epidemiologic study of traffic fatalities in Appalachia (2). More research is needed to identify some of the factors driving this result.

Table 24: Age and Sex of Traffic Fatalities: Appalachia and Non-Appalachia, 2013–2017

Selected characteristic	United States region N= 175,715			
	Appalachia		Non-Appalachia	
Age (y), median (IQR)	**43 (27–60)**		**42 (26–59)**	
	N	**%**	**N**	**%**
Age group (y)				
0–4	200	1.1%	1,704	1.1%
5–9	192	1.0%	1,556	1.0%
10–14	208	1.1%	1,889	1.2%
15–19	1,353	7.3%	11,095	7.1%
20–24	1,964	10.6%	18,955	12.1%
25–29	1,698	9.2%	15,888	10.1%
30–34	1,381	7.4%	12,594	8.0%
35–39	1,305	7.0%	10,671	6.8%
40–44	1,315	7.1%	10,092	6.4%
45–49	1,330	7.2%	10,679	6.8%
50–54	1,452	7.8%	12,363	7.9%
55–59	1,418	7.6%	11,818	7.5%
60–64	1,148	6.2%	9,746	6.2%
65–69	1,030	5.6%	7,649	4.9%
70–74	790	4.3%	5,862	3.7%
>74	1,756	9.5%	14,140	9.0%
Sex				
Male	12,965	69.9%	111,616	71.1%
Female	5,589	30.1%	45,393	28.9%
TOTAL	**18,561**	**100.0%**	**157,154**	**100.0%**

Abbreviations: y, year; IQR, interquartile range
Unknown/Missing: Age, N=474; sex, N=152
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 25: Hispanic Ethnicity and Race of Traffic Fatalities: Appalachia and Non-Appalachia, 2013–2017

Selected characteristic	United States region N= 175,715			
	Appalachia		Non-Appalachia	
	N	%	N	%
Hispanic ethnicity				
Not Hispanic/Latino	14,090	96.9%	117,364	83.7%
Hispanic/Latino	453	3.1%	22,905	16.3%
Race				
White	12,654	87.4%	114,694	78.3%
Black	1,595	11.0%	22,117	15.1%
Asian/PI	108	0.7%	3,711	2.5%
AI/AN	25	0.2%	3,074	2.1%
Other race	97	0.7%	2,879	2.0%
TOTAL	**18,561**	**100.0%**	**157,154**	**100.0%**

Abbreviations: PI, Pacific Islander; AI, American Indian; AN, Alaska Native
Unknown/Missing: Hispanic ethnicity, N=20,903; race, N=14,761
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 26: Traffic Fatalities and Traffic Fatality Rates (per 100,000 Person-Years), by Selected Characteristics: Appalachia and Non-Appalachia, 2013–2017

Selected characteristic	United States region N= 175,715				Rate ratios			
	Appalachia		Non-Appalachia		Crude RR and 95% CI		Adjusted RR and 95% CI*	
	N	Rate	N	Rate	RR	CI	aRR	CI
Age group (y)								
0–14	713	3.16	5,975	2.11	1.49	(1.38–1.62)	1.27	(1.16–1.38)
15–24	3,204	18.82	29,224	14.50	1.30	(1.25–1.35)	1.17	(1.13–1.21)
25–44	5,699	18.46	49,245	12.54	1.47	(1.43–1.51)	1.31	(1.27–1.34)
45–64	5,348	15.21	44,606	11.62	1.31	(1.27–1.35)	1.18	(1.15–1.22)
>64	3,576	16.36	27,651	12.75	1.28	(1.24–1.33)	1.20	(1.15–1.24)
Sex								
Male	12,965	20.70	111,616	15.34	1.35	(1.32–1.37)	1.21	(1.19–1.24)
Female	5,589	8.62	45,393	6.05	1.42	(1.39–1.46)	1.25	(1.21–1.29)
Urban/Rural county of crash†								
Urban	14,736	13.39	137,455	9.81	1.36	(1.34–1.39)	1.35	(1.33–1.37)
Rural	3,825	22.02	19,699	25.58	0.86	(0.83–0.89)	0.86	(0.83–0.89)
TOTAL	**18,561**	**14.56**	**157,154**	**10.64**	**1.37**	**(1.35–1.39)**	**1.22**	**(1.21–1.24)**

Abbreviations: y, year; CI, confidence interval; RR, rate ratio; aRR, adjusted rate ratio
Unknown/Missing: Age, N=474; sex, N=152
*Adjusted for sex, age, and urban/rural county of crash. Urban/rural county designation based on NCHS classification scheme (www.cdc.gov/nchs/data_access/urban_rural.htm).
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

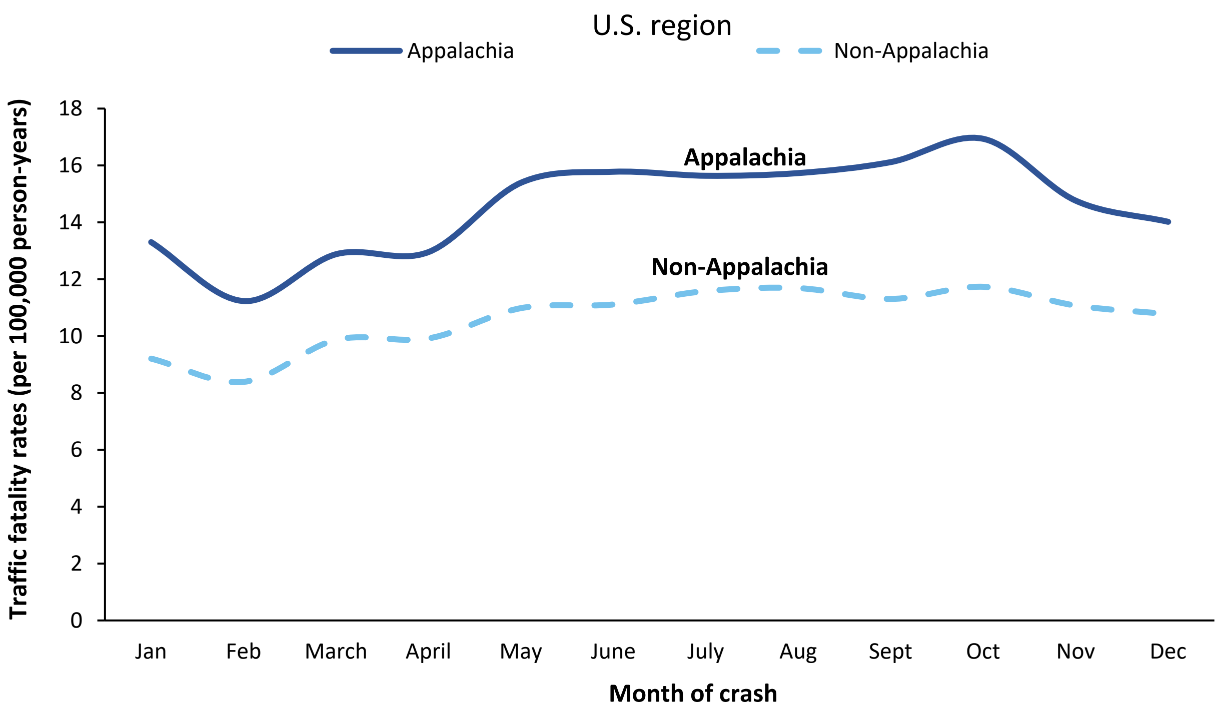
2.3.3 Frequency of Appalachian and Non-Appalachian Traffic Fatalities by Time of Year, Time of Day, and Environmental Conditions

Key findings:

- In Appalachia, traffic fatality rates peaked in the month of October with 16.9 deaths per 100,000 person-years.
- For both Appalachia and non-Appalachia, the highest proportion of traffic fatalities occurred during the late afternoon and evening hours of 16:00–19:59; however, a lower proportion of traffic fatalities in Appalachia occurred during the late night and early morning hours of 22:00–5:59 (25%) as compared to non-Appalachia (30%).
- As compared to non-Appalachia, Appalachian traffic fatalities were more likely to have occurred during inclement weather, such as rain, snow/sleet, and fog/smog/smoke.
- While traffic fatalities were more likely to have occurred after dark in non-Appalachia than Appalachia (48% versus 41%), traffic fatalities were 64% less likely to have occurred under dark, lighted conditions in Appalachia.

Figure 30 displays the average monthly traffic fatality rates for the period 2013–2017 for Appalachia and non-Appalachia. Both regions of the United States demonstrated strong seasonal trends. For both Appalachia and non-Appalachia, the month with the lowest traffic fatality rate was February, with rates of 11.2 and 9.2 fatalities per 100,000 person-years, respectively. Following the trough observed in winter and early spring, fatality rates increased throughout the summer and fall, peaking in October with fatality rates of 16.9 and 11.7 fatalities per 100,000 person-years for Appalachia and non-Appalachia, respectively. While both Appalachia and non-Appalachia experienced peak fatality rates in October, Appalachia had a much larger spike in traffic fatality rates. Interestingly, the seasonal pattern does not reflect U.S. travel patterns, with per capita U.S. vehicle miles traveled typically peaking in July (158). However, it is possible that fall foliage tourism (i.e., “leaf peeping”), an estimated $30 billion industry, could increase traffic on Appalachian roadways and, therefore, traffic fatality rates, during the fall (159). In addition, as mentioned previously, heavy rainfall and low visibility events often peak in late summer and early fall in the Appalachian Region, and may have contributed to the elevated traffic fatality rates observed during this period (134).

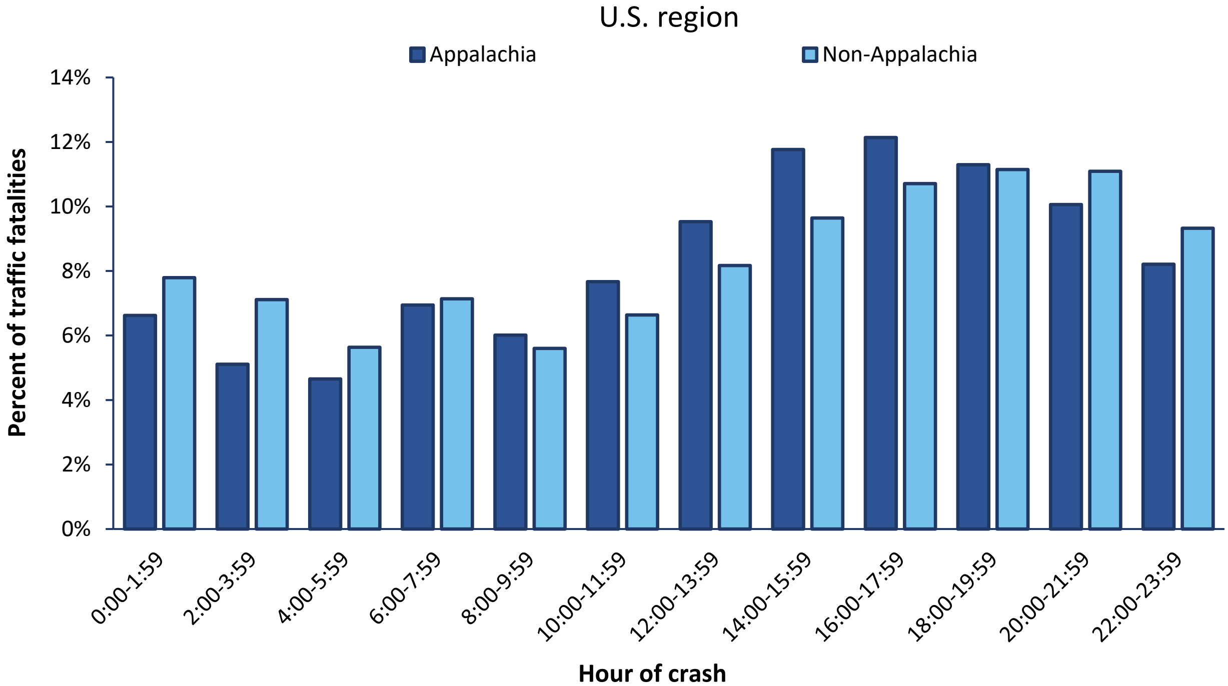
Figure 30: Traffic Fatality Rates (per 100,000 Person-Years) in Appalachia and Non-Appalachia, by Month of Crash: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 31 displays the frequency of traffic fatalities by hour of crash. Trends were relatively similar for Appalachia and non-Appalachia, with fatalities peaking in the late afternoon and early evening hours, corresponding to the time of day when people are commuting home from work (160). Despite these similarities, Appalachian traffic fatalities were slightly *less likely* to have happened during the late night/early morning hours of 22:00–5:59, with 25% of fatalities occurring during this period as compared to 30% of non-Appalachian traffic fatalities. In general, a disproportionate number of fatal and severe traffic crashes tend to occur during the late night/early morning hours, related to such factors as reduced visibility, lack of restraint use, alcohol involvement, speeding, and driver drowsiness/fatigue (161–163).

Figure 31: Frequency of Traffic Fatalities in Appalachia and Non-Appalachia, by Hour of Crash: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 27 compares the frequency of traffic fatalities by selected weather and light conditions for Appalachia and non-Appalachia. Appalachia had higher frequencies of traffic fatalities during adverse weather conditions, with fatalities 46% more likely to have occurred during rainy conditions (OR: 1.46, 95% CI: 1.39–1.54), 36% more likely to have occurred during snowy/sleety conditions (OR: 1.36, 95% CI: 1.22–1.51), and 31% more likely to have occurred during foggy/smoggy/smoky conditions (OR: 1.31, 95% CI: 1.16–1.49). Adverse weather conditions may increase the risk of a fatal crash through decreased vehicle performance (e.g., traction), decreased visibility, decreased pavement friction, lane obstruction/submersion, and infrastructure damage. According to FHWA, rain contributes to 8% of traffic fatalities nationwide, snow/sleet contributes to 2% of traffic fatalities, and fog contributes to 2% of traffic fatalities (164).

Table 27 also displays the frequency of traffic fatalities by ambient light condition, stratified by U.S. region. In Appalachia, traffic fatalities were more likely to have occurred during *daylight* (OR: 1.36, 95% CI: 1.32–1.40) and *dark-unlighted/unknown* conditions (OR: 1.23, 95% CI: 1.19–1.27), but less likely to have occurred during *dark-lighted* conditions (OR: 0.37, 95% CI: 0.35–0.39). Under low light conditions, driver spatial and temporal reasoning is impaired, sensitivity to contrast is decreased, and color vision is reduced or eliminated. This can lead to many driving difficulties, including the inability to ascertain the speed and distance of other vehicles and to react accordingly (161). As compared to optimal lighted conditions, under dark-unlighted conditions, drivers have longer reaction times and may require an additional nine meters of stopping distance (for a vehicle traveling 50 mph) to account for diminished visual conspicuity (165). As mentioned previously, improved nighttime lighting can lead to decreased traffic crash morbidity and mortality (147). In addition, the incorporation of adaptive driving beam headlights into the U.S. vehicle fleet (illegal under current U.S. headlight standards, but legal in Europe and Canada) has the potential to increase roadway lighting by up to 86%, thereby decreasing the frequency of nighttime crashes (166).

While these environmental conditions are intriguing explanatory factors for the elevated mortality rates observed in Appalachia, they may simply reflect exposure. For example, crashes are more common where people live and work. If more Appalachian residents live on or near unlighted roads than non-Appalachian residents, than a greater proportion of fatal crashes will occur on these roads. Therefore, more research is needed to further characterize the relationship between environmental conditions and fatal crashes in Appalachia.

Table 27: Frequency of Traffic Fatalities, by Selected Environmental Conditions: Appalachia and Non-Appalachia, 2013–2017

	United States region N=175,715 traffic fatalities				Unadjusted odds ratio and 95% CI	
	Appalachia		Non-Appalachia		OR	CI
	N	%	N	%		
Weather						
Clear	12,573	70.0%	112,032	73.6%	0.84	(0.81–0.87)
Cloudy	2,898	16.1%	24,732	16.2%	0.99	(0.95–1.04)
Rain	1,769	9.9%	10,599	7.0%	1.46	(1.39–1.54)
Snow/Sleet	397	2.2%	2,493	1.6%	1.36	(1.22–1.51)
Fog, smog, smoke	278	1.5%	1,804	1.2%	1.31	(1.16–1.49)
Other	41	0.2%	554	0.4%	0.63	(0.46–0.86)
Unknown/Missing	605		4,940			
Ambient light						
Daylight	10,143	54.9%	73,864	47.3%	1.36	(1.32–1.40)
Dawn/Dusk	714	3.9%	6,680	4.3%	0.90	(0.90–0.83)
Dark—Lighted	1,527	8.3%	30,911	19.8%	0.37	(0.35–0.39)
Dark—Unlighted/ Unknown	6,106	33.0%	44,818	28.7%	1.23	(1.19–1.27)
Unknown/Missing	71			881		
TOTAL	**18,561**	**100.0%**	**157,154**	**100.0%**		

Abbreviations: CI, confidence interval; OR, odds ratio
Unknown/Missing: Weather, N=5,545; ambient light, N=952
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

2.3.4 Frequency of Appalachian and Non-Appalachian Traffic Fatalities by Vehicle Characteristics and Use of Safety Restraints (Motor Vehicle Occupants and Motorcyclists, Only)

Key findings:

- In Appalachia, motor vehicle occupant and motorcyclist traffic fatalities were slightly more likely to have been occupants of SUVs and vans/trucks than fatalities from non-Appalachia.
- Appalachian traffic fatalities were twice as likely to have been off-road vehicle riders than non-Appalachian traffic fatalities.
- Among motor vehicle occupants, Appalachian traffic fatalities were more likely to be occupants of older vehicles than those of non-Appalachian traffic fatalities, with a median age of 12 years (one year older than non-Appalachian vehicles). Appalachian traffic fatalities were 28% more likely to be occupants of vehicles greater than 20 years of age.
- More than one-half of all Appalachian motor vehicle occupant fatalities were not wearing safety restraints at the time of crash, with Appalachian occupant fatalities being 1.3 times as likely to not be wearing restraints as compared to non-Appalachian traffic fatalities.
- In Appalachia, motorcyclist traffic fatalities were less likely to be not helmeted at the time of crash as compared to traffic fatalities from non-Appalachia.

Motor vehicle type did not vary greatly between Appalachian and non-Appalachian traffic fatalities, although Appalachian traffic fatalities were slightly more likely to have been occupants of SUVs (OR: 1.09, 95% CI: 1.01–1.14) and vans/trucks (OR: 1.09, 95% CI: 1.05–1.13; Table 28). On the other hand, Appalachian traffic fatalities differed considerably from non-Appalachian traffic fatalities in relation to non-occupant deaths. In Appalachia, traffic fatalities were 23% less likely to be motorcyclists (OR: 0.77, 95% CI: 0.73–0.80) and 112% more likely to be off-road vehicle riders (OR: 2.12, 95% CI: 1.89–2.38). While ATVs, the most common class of off-road vehicle, are not designed for on-road usage, some states permit the operation of ATVs on public roadways under certain conditions. In West Virginia, one of the states with the highest number of ATV traffic fatalities, ATVs are legal on roads without a center line and fewer than three lanes. In addition, ATVs can cross larger roads and highways, as long as the operator crosses in a ninety-degree angle to the direction of the road, makes a complete stop prior to crossing, yields the right-of-way to oncoming traffic, and has illuminated head/taillights (if applicable) (150). A prior NHTSA study (149) found that 42% of ATV operators or passengers were legally impaired at the time of crash, 12% were helmeted, 74% were killed in single-vehicle crashes, 86% were killed in rural areas, and 54% were killed in nighttime crashes. Restricting ATVs from public roads and increased enforcement could decrease the number of off-road vehicle traffic fatalities in Appalachia.

Table 28: Frequency of Motor Vehicle Occupant and Motorcyclist Fatalities, by Vehicle Type: Appalachia and Non-Appalachia, 2013–2017

	United States region N=143,720 motor vehicle occupant and motorcyclist fatalities				Unadjusted odds ratio and 95% CI	
	Appalachia		Non-Appalachia		OR	CI
	N	%	N	%		
Vehicle type						
Passenger car	7,327	44.1%	56,286	44.3%	0.99	(0.96–1.03)
SUV	2,585	15.6%	18,352	14.4%	1.09	(1.04–1.14)
Van/truck	3,863	23.2%	27,625	21.7%	1.09	(1.05–1.13)
Motorcycle	2,348	14.1%	22,431	17.6%	0.77	(0.73–0.80)
Off-road vehicle	368	2.2%	1,344	1.1%	2.12	(1.89–2.38)
Other/Unknown vehicle type	127	0.8%	1,064	0.8%	0.91	(0.76–1.10)
TOTAL	**16,618**	**100.0%**	**127,102**	**100.0%**		

Abbreviations: CI, confidence interval; OR, odds ratio; SUV, sport utility vehicle

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

In Appalachia, motor vehicles had a median age of 12 years (IQR: 8–16), this was one year older than the median vehicle age of non-Appalachian traffic fatalities (11 years, IQR: 7–15; Table 3.9). In addition, Appalachian traffic fatalities were 13% more likely to have been occupants of vehicles 16 to 20 years of age (OR: 1.13, 95% CI: 1.08–1.19) and 28% more likely to have been occupants of vehicles greater than 20 years of age (OR: 1.28, 95% CI: 1.20–1.36). Newer vehicles contain a variety of safety improvements not available in older models, including side and frontal airbags, antilock braking systems, electronic stability control, lane departure warning systems, forward collision warning and avoidance systems, and improved crashworthiness. NHTSA (167) reported that drivers of vehicles 4–7, 8–11, 12–14, 15–17, and ≥18 years of age were 10%, 19%, 32%, 50%, and 71% more likely to be fatally injured in collisions as compared to drivers of vehicles 0–3 years of age. Implementing a targeted vehicle retirement program (e.g., “Cash for Clunkers”) in the Appalachian Region could remove many of the older, and therefore more dangerous, motor vehicles from Appalachian roadways.

Table 29: Frequency of Passenger Car, SUV, Van, and Pick-Up Truck Traffic Fatalities, by Age of Vehicle: Appalachia and Non-Appalachia: 2013–2017

	United States Region N=116,038 passenger car, SUV, van, and pick-up truck fatalities				Unadjusted odds ratio and 95% CI	
	Appalachia		Non-Appalachia			
Vehicle age (y), median (IQR)	**12 (8–16)**		**11 (7–15)**			
	N	**%**	**N**	**%**	**OR**	**CI**
Vehicle age (y)						
<1 y	321	2.3%	2,981	2.9%	0.79	(0.71–0.89)
1–5	1,867	13.6%	16,967	16.6%	0.79	(0.75–0.83)
6–10	3,316	24.1%	25,649	25.2%	0.95	(0.91–0.99)
11–15	4,319	31.4%	31,150	30.6%	1.04	(1.00–1.08)
16–20	2,551	18.6%	17,083	16.8%	1.13	(1.08–1.19)
>20	1,369	10.0%	8,121	8.0%	1.28	(1.20–1.36)
TOTAL	**13,743**	**100.0%**	**101,951**	**100.0%**		

Abbreviations: SUV, sport utility vehicle; CI, confidence interval; OR, odds ratio; y, years
Unknown/Missing: Vehicle age, N=168
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Among motor vehicle occupant fatalities, 55% of Appalachian and 48% of non-Appalachian motor vehicle occupant fatalities were not wearing safety restraints (seatbelts, child restraints, etc.) at the time of crash (Table 30). In Appalachia, motor vehicle occupant traffic fatalities were 31% more likely to be unrestrained than non-Appalachian traffic fatalities (OR: 1.31, 95% CI: 1.26–1.36). Seatbelts have been demonstrated to be one of the most effective means of preventing fatal injuries in the event of a motor vehicle collision, reducing the likelihood of a serious injury or death by 60% (168). One of the most effective measures for improving seatbelt usage is to enact statewide primary seatbelt laws that allow law enforcement to stop and ticket motor vehicle occupants for not wearing seatbelts. In states with secondary laws, law enforcement can only ticket occupants if they have been stopped for other reasons (169). In Appalachia, ten states have primary seatbelt laws (Ala., Ga., Ky., Md., Miss., N.Y., N.C., S.C., Tenn., and West Va.) and three states do not (Ohio, Pa., and Va.); however, many of the states listed as having primary seatbelt laws have primary enforcement for front seat occupants only (e.g., N.C.) (170). Switching from a secondary to a *comprehensive* primary state seatbelt law can increase observed seatbelt usage by a median of 14% and decrease the number of fatal injuries by a median of 8%. Another evidence-based intervention is enhanced enforcement (increasing number of officers on patrol, increasing ticketing, establishing seatbelt checkpoints, etc.) in conjunction with increased media publicity highlighting the importance of wearing seatbelts. Such high visibility enforcement programs have been demonstrated to increase seatbelt usage by 16% (169).

Table 30: Use of Safety Restraints* among Motor Vehicle Occupant Traffic Fatalities: Appalachia and Non-Appalachia, 2013–2017

	United States region N=118,941 motor vehicle occupant fatalities				Unadjusted odds ratio and 95% CI	
	Appalachia		Non-Appalachia		OR	CI
	N	%	N	%		
Use of safety restraint						
No restraint	7,267	54.9%	45,876	48.2%	1.31	(1.26–1.36)
Restraint	5,959	45.1%	49,306	51.8%	--	
TOTAL	**13,226**	**100.0%**	**95,182**	**100.0%**		

Abbreviations: CI, confidence interval; OR, odds ratio
Unknown/Missing: Use of safety restraint, N=10,533
*Includes seatbelts, child restraints, and other/unknown type of restraints.
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

In Appalachia, motorcyclist fatal crash victims were less likely to *not be helmeted* at the time of crash (OR: 0.70, 95% CI: 0.64–0.77; Table 31). Many Appalachian states have universal helmet laws, requiring all motorcyclists to wear helmets. Universal helmet laws are highly effective, increasing helmet usage by a median of 47% and decreasing the number of motorcyclist fatalities by a median of 32% (171). However, four Appalachian states (Ky., Ohio, Penn., S.C.) do not currently have universal helmet laws (153). Among the four Appalachian states referenced above, NHTSA (172) estimates that 170 total annual lives would be saved with 100% helmet use among motorcyclists.

Table 31: Use of Helmets among Motorcyclist Traffic Fatalities: Appalachia and Non-Appalachia, 2013–2017

	United States region N=24,779 motorcyclist fatalities				Unadjusted odds ratio and 95% CI	
	Appalachia		Non-Appalachia		OR	CI
	N	%	N	%		
Use of motorcycle helmet						
No helmet	739	31.9%	8,716	40.1%	0.70	(0.64–0.77)
Helmet	1,579	68.1%	13,044	59.9%	--	
TOTAL	**2,318**	**100.0%**	**21,760**	**100.0%**		

Abbreviations: CI, confidence interval; OR, odds ratio
Unknown/Missing: Use of motorcycle helmet, N=24,078
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

2.3.5 Frequency of Appalachian and Non-Appalachian Traffic Fatalities by Selected Crash Circumstances

Key findings:

- Appalachian traffic fatalities were 34% less likely to be in alcohol-involved crashes than non-Appalachian traffic fatalities.
- There were differences in the roadway characteristics of fatal traffic crashes among the two U.S. regions. In Appalachia, traffic fatalities were more likely to have died on two-lane, curved, and graded roadways.

Table 32 displays the frequency of motor vehicle occupant and motorcyclist traffic fatalities involved in speed-related crashes by U.S. region. There was no statistical difference between the two U.S. regions.

Table 32: Frequency of Motor Vehicle Occupant and Motorcyclist Traffic Fatalities Involved in Speed-Related Crashes: Appalachia and Non-Appalachia, 2013–2017

	United States region N=143,720 motor vehicle occupant and motorcyclist fatalities				Unadjusted odds ratio and 95% CI	
	Appalachia		Non-Appalachia			
	N	%	N	%	OR	CI
Speed-related						
No	11,353	71.0%	84,705	70.7%	--	
Yes	4,642	29.0%	35,186	29.3%	0.98	(0.95–1.02)
TOTAL	**15,995**	**100.0%**	**119,891**	**100.0%**		

Abbreviations: CI, confidence interval; OR, odds ratio
Unknown/Missing: Speed-relatedness, N=7,834
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Appalachian traffic fatalities were less likely to be killed in alcohol-involved crashes, as compared to non-Appalachian traffic fatalities (OR: 0.66, 95% CI: 0.63–0.69; Table 3.13). Excessive drinking (consuming ≥ five drinks for men and ≥ four drinks for women in a single episode) is less common in Appalachia (15%) than non-Appalachia (18%) and is even lower in rural (13%) and economically distressed (12%) Appalachian counties (20). There is a strong correlation between excessive drinking and driving while impaired, with excessive adult drinkers being 14 times more likely to drive while impaired (173). Explanations for why excessive drinking is lower in the Appalachian Region include the prevalence of religious beliefs that limit or prohibit alcohol consumption, lower discretionary income to spend on alcoholic beverages, and opioids overtaking alcohol as the drug of preference in this region (174).

Table 33: Frequency of Motor Vehicle Occupant and Motorcyclist Traffic Fatalities Involved in Alcohol-Related Crashes: Appalachia and Non-Appalachia, 2013–2017

	United States region N=143,720 motor vehicle occupant and motorcyclist fatalities				Unadjusted odds ratio and 95% CI	
	Appalachia		Non-Appalachia		OR	CI
	N	%	N	%		
Alcohol-related						
No	9,164	77.3%	55,717	69.2%	--	
Yes	2,695	22.7%	24,757	30.8%	0.66	(0.63–0.69)
TOTAL	**11,859**	**100.0%**	**80,474**	**100.0%**		

Abbreviations: CI, confidence interval; OR, odds ratio
Unknown/Missing: Alcohol-relatedness, N=51,387
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 34 displays the frequency of traffic fatalities by selected roadway characteristics, stratified by U.S. region. In Appalachia, traffic fatalities were two times as likely to have died on two-lane roadways, as compared to non-Appalachia (OR: 2.05, 95% CI: 1.60–2.14). In addition, Appalachian traffic fatalities were more likely to have been killed on curves (OR: 1.76, 95% CI: 1.71–1.82) and/or grades (OR: 1.94, 95% CI: 1.88–2.01). These types of roadways are often prone to roadway departures, and all of the Appalachian state SHSPs emphasize reductions in roadway departure crashes as key focus areas. Two-lane roads with severe curvature are often found in rural areas and may be characterized by less access to EMS. There are several countermeasures for reducing the frequency of crashes on rural two-lane roadways, including adding clearance areas, wider shoulders, rumble strips, skid-resistant pavement surface treatments, reflectors, dynamic curve warning systems, and improved signage (175).

Table 34: Frequency of Motor Vehicle Occupant and Motorcyclist Traffic Fatalities by Other Roadway Characteristics: Appalachia and Non-Appalachia, 2013–2017

Roadway characteristics	United States region N=143,720 motor vehicle occupant and motorcyclist fatalities				Unadjusted odds ratio and 95% CI	
	Appalachia		Non-Appalachia		OR	CI
	N	%	N	%		
Number of lanes						
One lane	155	0.9%	2,104	1.7%	0.56	(0.47–0.66)
Two lanes	13,941	84.7%	91,704	73.0%	2.05	(1.60–2.14)
Three lanes	970	5.9%	11,772	9.4%	0.61	(0.57–0.65)
Four or more lanes	1,389	8.4%	19,991	15.9%	0.49	(0.46–0.52)
TOTAL	**16,455**	**100.0%**	**125,571**	**100.0%**		
Alignment						
Straight	9,954	60.5%	90,289	73.0%	--	
Curved	6,497	39.5%	33,432	27.0%	1.76	(1.71–1.82)
TOTAL	**16,451**	**100.0%**	**123,721**	**100.0%**		
Grade						
Level	9,748	59.4%	86,891	73.9%	--	
Some grade	6,674	40.6%	30,660	26.1%	1.94	(1.88–2.01)
TOTAL	**16,422**	**100.0%**	**117,551**	**100.0%**		

Abbreviations: CI, confidence interval; OR, odds ratio

Unknown/Missing: Number of lanes, N=1,694; alignment, N=3,548; grade, N=9,747

*Motor vehicle crashes occurring on non-trafficways excluded from analyses.

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

2.4 Selected Comparisons of Drivers Involved in Fatal Motor Vehicle Collisions in the Appalachian and Non-Appalachian United States

2.4.1 Driving History of Drivers Involved in Fatal Motor Vehicle Collisions in Appalachia and Non-Appalachia

Key Findings:

- Appalachian drivers involved in fatal traffic crashes were more likely to have a valid license at the time of crash and less likely to have no license or an expired license than non-Appalachian drivers.
- In Appalachia, drivers involved in fatal traffic crashes were 37% more likely to be driving an unregistered motor vehicle than drivers from non-Appalachia.
- Appalachian drivers involved in fatal traffic crashes were 52% more likely to have a prior law enforcement reported crash and 14% more likely to have a prior driving-while-impaired (DWI) conviction recorded on their driving record, as compared to non-Appalachian drivers involved in fatal crashes.

While the previous three sections described the characteristics of traffic fatalities, the following two sections will compare Appalachian drivers involved in fatal collisions to non-Appalachian drivers involved in fatal collisions. It is important to note that not all these drivers were killed, with 52% of Appalachian drivers and 46% of non-Appalachian drivers sustaining fatal injuries. The reason for this investigation is that through examining driver characteristics, we may learn more about some of the specific factors and behaviors (e.g., driver impairment) that contributed to fatal crashes in Appalachia.

The majority of Appalachian and non-Appalachian drivers were licensed at the time of the fatal crash (Table 35). Appalachian drivers were slightly more likely to have a valid license at the time of crash (OR: 1.16, 95% CI: 1.12–1.21) and less likely to have no license (OR: 0.58, 95% CI: 0.54–0.63) or an expired license (OR: 0.71, 95% CI: 0.61–0.82) than non-Appalachian drivers. Appalachian drivers were also slightly more likely to have a license that had been suspended, revoked, or denied at the time of crash (OR: 1.09, 95% CI: 1.04–1.15).

Table 35: License Status of Motor Vehicle Drivers Involved in Fatal Crashes: Appalachia and Non-Appalachia, 2013–2017

	United States region N=243,034 motor vehicle drivers				Unadjusted odds ratio and 95% CI	
	Appalachia		Non-Appalachia		OR	CI
	N	%	N	%		
License status						
Valid license	22,134	88.7%	183,632	87.1%	1.16	(1.12–1.21)
No license	693	2.8%	9,853	4.7%	0.58	(0.54–0.63)
Suspended/Revoked/Denied license	1,917	7.7%	14,930	7.1%	1.09	(1.04–1.15)
Expired license	197	0.8%	2,334	1.1%	0.71	(0.61–0.82)
TOTAL	**24,941**	**100.0%**	**210,749**	**100.0%**		

Abbreviations: CI, confidence interval; OR, odds ratio
Unknown/Missing: License status, N=7,344
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Over one-half of Appalachian and non-Appalachian drivers were also the registered owners of the vehicles involved in fatal U.S. traffic crashes over the period 2013–2017 (Table 4.2). Appalachian drivers were 37% more likely than non-Appalachian drivers to be operating an unregistered vehicle at the time of the fatal crash (OR: 1.37, 95% CI: 1.27–1.48). In the United States, all passenger vehicles used on public roadways must be registered; however, many states do not require registration for farm and agricultural vehicles. Due to the rural nature of Appalachia, it is possible that some of the unregistered vehicles involved in fatal traffic crashes were farm and agricultural vehicles. However, although illegal, some drivers do not register motor vehicles to avoid paying registration fees, paying taxes, and/or to avoid vehicle emissions tests. Failure to register a motor vehicle may be in an indicator of a propensity to engage in risky driving behavior. An Australian study found that drivers who failed to register their vehicles were more likely to have been convicted of traffic violations, such as driving while impaired (176).

Table 36: Vehicle Registration Status of Motor Vehicle Drivers Involved in Fatal Crashes: Appalachia and Non-Appalachia, 2013–2017

	United States region N=243,034 motor vehicle drivers				Unadjusted odds ratio and 95% CI	
	Appalachia		Non-Appalachia		OR	CI
	N	%	N	%		
Registration status						
Vehicle not registered	800	3.2%	4,996	2.4%	1.37	(1.27–1.48)
Driver was registered owner	14,462	57.8%	119,491	56.4%	1.06	(1.03–1.09)
Driver was not registered owner	6,990	27.9%	61,002	28.8%	0.96	(0.93–0.99)
Business/Government vehicle	2,549	10.2%	23,755	11.2%	0.90	(0.86–0.94)
Rental vehicle	146	0.6%	1,658	0.8%	0.75	(0.63–0.88)
Stolen vehicle	24	0.1%	491	0.2%	0.41	(0.28–0.62)
Other registration status	45	0.2%	607	0.3%	0.63	(0.46–0.85)
TOTAL	**25,016**	**100.0%**	**212,000**	**100.0%**		

Abbreviations: CI, confidence interval; OR, odds ratio
Unknown/Missing: Registration status, N=6,018
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

As compared to non-Appalachian drivers, Appalachian drivers involved in fatal crashes had 1.5 times the odds of being involved in a law enforcement-reported crash within the last five years (OR: 1.52, 95% CI: 1.46–1.57; Table 4.3). A motor vehicle crash history is a strong predictor of risky driving behavior and future crashes, especially for novice and older adult drivers (177). A potential intervention for these at-risk drivers are licensing restrictions and, if necessary, license revocation (178). Although slight, Appalachian drivers were also more likely to have been convicted of a DWI within the last five years, as compared to non-Appalachian drivers (OR: 1.14, 95% CI: 1.07–1.23). Interestingly, this seemingly contradicts the results presented in Section 2.3, in which Appalachian traffic fatalities were less likely to have been killed in an alcohol-involved crash. This may reflect differences in enforcement priorities in Appalachia versus non-Appalachia.

Table 37: Driving Record of Motor Vehicle Drivers Involved in Fatal Crashes: Appalachia and Non-Appalachia, 2013–2017

	United States region N=243,034 motor vehicle drivers				Unadjusted odds ratio and 95% CI	
	Appalachia		Non-Appalachia		OR	CI
	N	%	N	%		
Driving record						
Prior recorded crash	4,566	21.7%	29,759	15.4%	1.52	(1.46–1.57)
Prior recorded license suspension/revocation	3,368	13.6%	31,180	14.9%	0.90	(0.86–0.93)
Prior DWI	910	3.7%	6,539	3.2%	1.14	(1.07–1.23)
Prior speeding conviction	4,390	17.7%	39,619	19.5%	0.89	(0.86–0.92)
Other prior moving violation	4,419	17.8%	40,709	20.1%	0.86	(0.83–0.89)
TOTAL	**25,259**	**100.0%**	**217,775**	**100.0%**		

Abbreviations: CI, confidence interval; OR, odds ratio; DWI, driving while impaired
Unknown/Missing/Not reported: Prior recorded crash, N=29,048; prior recorded license suspension/revocation, N=8,869); prior recorded DWI, N=8,869; prior recorded speeding conviction, N=8,869; other prior moving violation, N=8,869
*FARS records prior driving convictions for events occurring within five years of the date of crash. Drivers can have more than one conviction; therefore, totals do not sum to 100%.
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

2.5 A Closer Look at Impairment: Drivers Involved in Fatal Motor Vehicle Collisions Under the Influence of Alcohol and Drugs in Appalachia

2.5.1 Drivers Involved in Fatal Motor Vehicle Collisions Under the Influence of Alcohol in Appalachia and Non-Appalachia

Key Findings:

- A lower proportion of Appalachian drivers involved in fatal traffic crashes were legally alcohol-impaired (BAC > 0.08 g/dL; 18%), than non-Appalachian drivers (20%).
- For both U.S. regions, young adults 20–29 years of age were the most likely to be alcohol impaired.
- The proportion of alcohol-impaired drivers involved in fatal traffic crashes was highest for the late night/early morning hours of 22:00–5:59; there was little difference by U.S. region.
- The proportion of alcohol-impaired drivers involved in fatal traffic crashes was higher in Appalachian counties for the following Appalachian states: Ky., Md., N.Y., and Penn.

Less than one-half of all U.S. drivers involved in fatal traffic crashes had alcohol test results during the period 2013–2017 (Table 38). Among drivers with alcohol test results, most had blood tests. The lack of alcohol testing among drivers involved in fatal traffic crashes is a well-documented problem (141). Therefore, FARS has developed a multiple imputation methodology to impute values for missing data points. All BACs reported in this section incorporate FARS's multiple imputation methodology.

Table 38: Frequency of Alcohol Testing among Motor Vehicle Drivers Involved in Fatal Crashes: Appalachia and Non-Appalachia, 2013–2017

Alcohol testing characteristic	United States region N=243,034 motor vehicle drivers			
	Appalachia		Non-Appalachia	
	N	%	N	%
Alcohol test status				
Test given	12,339	48.8%	103,636	47.6%
Test not given/refused	11,532	45.7%	93,274	42.8%
Unknown if tested/not reported	1,388	5.5%	20,865	9.6%
Type of alcohol test given				
Test not given/refused	11,532	45.7%	93,274	42.8%
Blood	11,712	46.4%	93,506	42.9%
Breath	86	0.3%	2,062	0.9%
Urine	187	0.7%	736	0.3%
Other test type	191	0.8%	1,325	0.6%
Unknown if tested/not reported	1,551	6.1%	26,872	12.3%
TOTAL	**25,259**	**100.0%**	**217,775**	**100.0%**

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

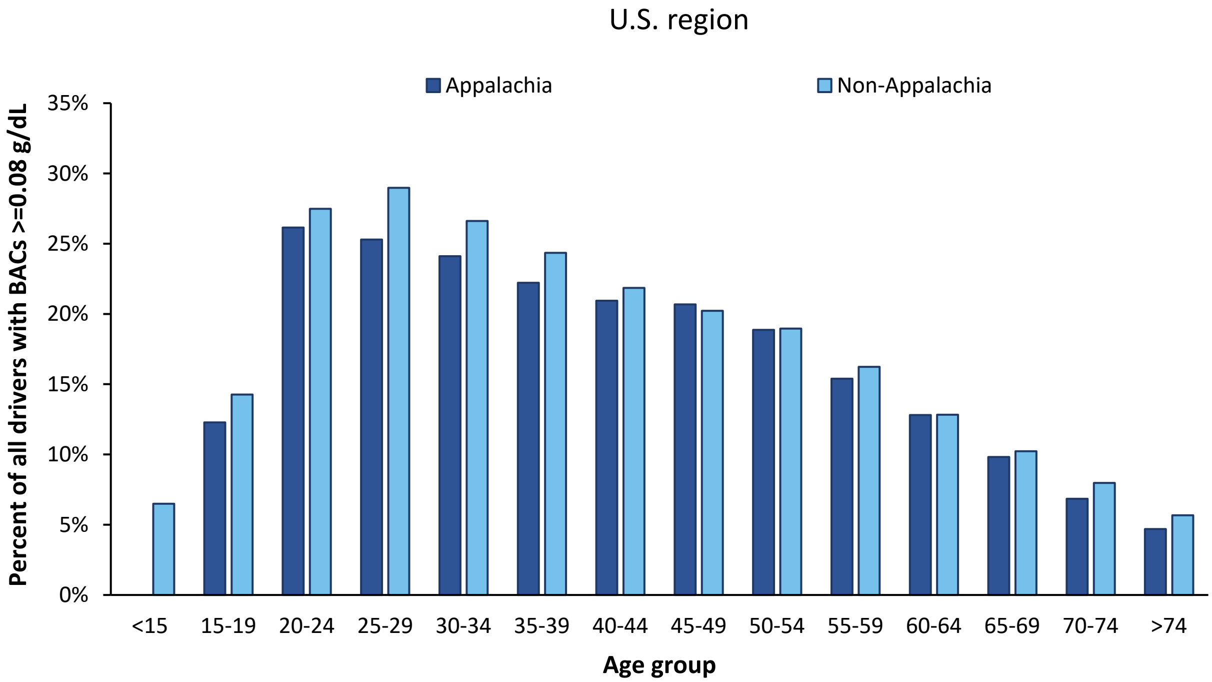
Table 39 and Figure 32 display the demographic characteristics of legally alcohol-impaired U.S. drivers (BAC ≥0.08 g/dL) involved in fatal traffic crashes for the period 2013–2017. The proportion of drivers who were impaired at the time of crash was somewhat lower for Appalachia (18%) than non-Appalachia (20%). The demographic characteristics of alcohol-impaired drivers involved in fatal traffic crashes were similar for Appalachia and non-Appalachia, with drivers in their twenties being the most likely to be impaired at the time of crash. In Appalachia and non-Appalachia, male drivers were more likely to be impaired than female drivers.

Table 39: Demographic Characteristics of Motor Vehicle Drivers Involved in Fatal Crashes with Blood Alcohol Concentrations (BAC) > 0.08 g/dL*, by Age and Sex: Appalachia and Non-Appalachia, 2013–2017

Selected characteristic	United States region N=242,320 motor vehicle drivers with imputed BAC levels**					
	Appalachia			Non-Appalachia		
	BAC ≥0.08 g/dL		Total drivers	BAC ≥0.08 g/dL		Total drivers
	N	%	N	N	%	N
Age group (y)						
<15	0	0.0%	33	18	6.5%	277
15–19	215	12.3%	1,751	1,966	14.3%	13,777
20–24	718	26.1%	2,746	7,499	27.5%	27,289
25–29	623	25.3%	2,463	7,073	29.0%	24,411
30–34	519	24.1%	2,153	5,416	26.6%	20,349
35–39	453	22.2%	2,039	4,266	24.3%	17,522
40–44	425	20.9%	2,029	3,619	21.9%	16,562
45–49	430	20.7%	2,079	3,391	20.2%	16,771
50–54	408	18.9%	2,163	3,343	19.0%	17,636
55–59	305	15.4%	1,982	2,655	16.2%	16,357
60–64	203	12.8%	1,585	1,632	12.8%	12,720
65–69	129	9.8%	1,313	984	10.2%	9,616
70–74	67	6.9%	978	540	8.0%	6,774
>74	79	4.7%	1,684	702	5.7%	12,381
Sex						
Male	3,793	20.7%	18,360	35,044	22.2%	157,574
Female	785	11.8%	6,654	8,143	14.8%	55,167
TOTAL	**4,627**	**18.4%**	**25,200**	**44,365**	**20.4%**	**217,120**

Abbreviations: BAC, blood alcohol concentration; g/dL, grams/deciliter; y, year
Unknown/Missing: Age, N=6,194; sex, N=5,792
*NTHSA imputes BACs for drivers with unknown alcohol test results.
**714 drivers missing BACs.
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 32: Frequency of Motor Vehicle Drivers Legally Impaired at Time of Fatal Crash (BAC > 0.08 g/dL), in Appalachia and Non-Appalachia, by Age Group: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

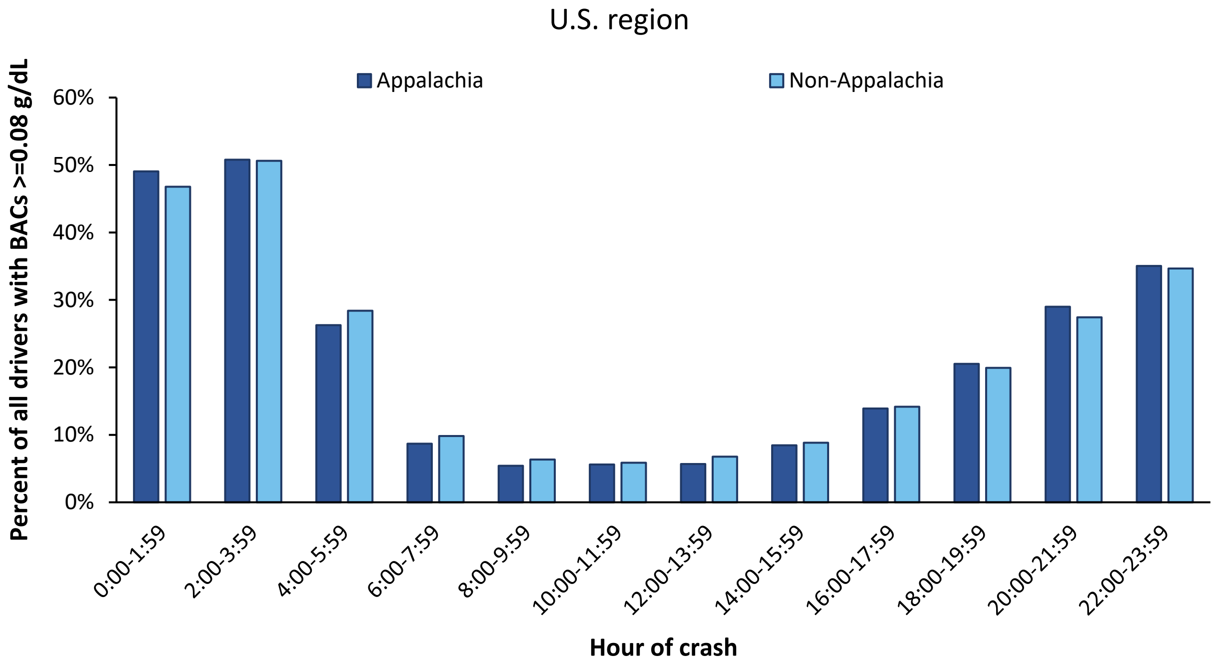
Table 40 and Figure 33 display the proportion of U.S. drivers involved in fatal traffic crashes who were alcohol-impaired at the time of crash. Both U.S. regions demonstrated similar trends, with the proportion of impaired drivers increasing during the nighttime hours. For example, among fatal traffic crashes that occurred during the hours 2:00–3:59, 51% of Appalachian and non-Appalachian drivers were alcohol-impaired. On the other hand, among fatal traffic crashes that occurred during the hours of 8:00–9:59, only 5% of Appalachian drivers and 6% of non-Appalachian drivers were impaired.

Table 40: Frequency of Motor Vehicle Drivers Involved in Fatal Crashes with Blood Alcohol Concentrations (BAC) > 0.08 g/dL*, by Hour of Crash: Appalachia and Non-Appalachia, 2013–2017

	United States region N=242,320 motor vehicle drivers with imputed BAC levels**					
	Appalachia			Non-Appalachia		
	BAC >0.08 g/dL		Total drivers	BAC >0.08 g/dL		Total drivers
	N	%	N	N	%	N
Hour of crash						
0:00–1:59	649	49.1%	1,323	6,632	46.8%	14,173
2:00–3:59	521	50.8%	1,026	6,466	50.6%	12,772
4:00–5:59	286	26.3%	1,089	3,174	28.4%	11,178
6:00–7:59	159	8.7%	1,830	1,572	9.8%	16,004
8:00–9:59	88	5.4%	1,625	847	6.3%	13,357
10:00–11:59	115	5.6%	2,052	927	5.9%	15,801
12:00–13:59	149	5.7%	2,630	1,324	6.8%	19,575
14:00–15:59	276	8.4%	3,269	2,027	8.8%	22,978
16:00–17:59	454	13.9%	3,263	3,594	14.2%	25,353
18:00–19:59	582	20.5%	2,835	4,792	19.9%	24,034
20:00–21:59	674	29.0%	2,324	6,195	27.4%	22,594
22:00–23:59	633	35.0%	1,807	6,294	34.7%	18,153
TOTAL	**4,586**	**18.3%**	**25,073**	**43,844**	**20.3%**	**215,972**

Abbreviations: BAC, blood alcohol concentration; g/dL, grams/deciliter
Unknown/Missing: Hour of crash, N=1,837
*NTHSA imputes BACs for drivers with unknown alcohol test results.
**714 drivers missing BACs.
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 33: Frequency of Motor Vehicle Drivers Legally Impaired at Time of Fatal Crash (BAC > 0.08 g/dL), in Appalachia and Non-Appalachia, by Hour of Crash: 2013–2017



Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 41 and Figure 34 display the frequency of driver alcohol impairment among states within the Appalachian Region, comparing Appalachian counties to non-Appalachian counties. While for most Appalachian states, driver impairment was higher among non-Appalachian counties (such as Ala.), the proportion of drivers involved in fatal crashes who were impaired at the time of crash was higher in Appalachian counties in four states: Kentucky, Maryland, New York, and Pennsylvania.

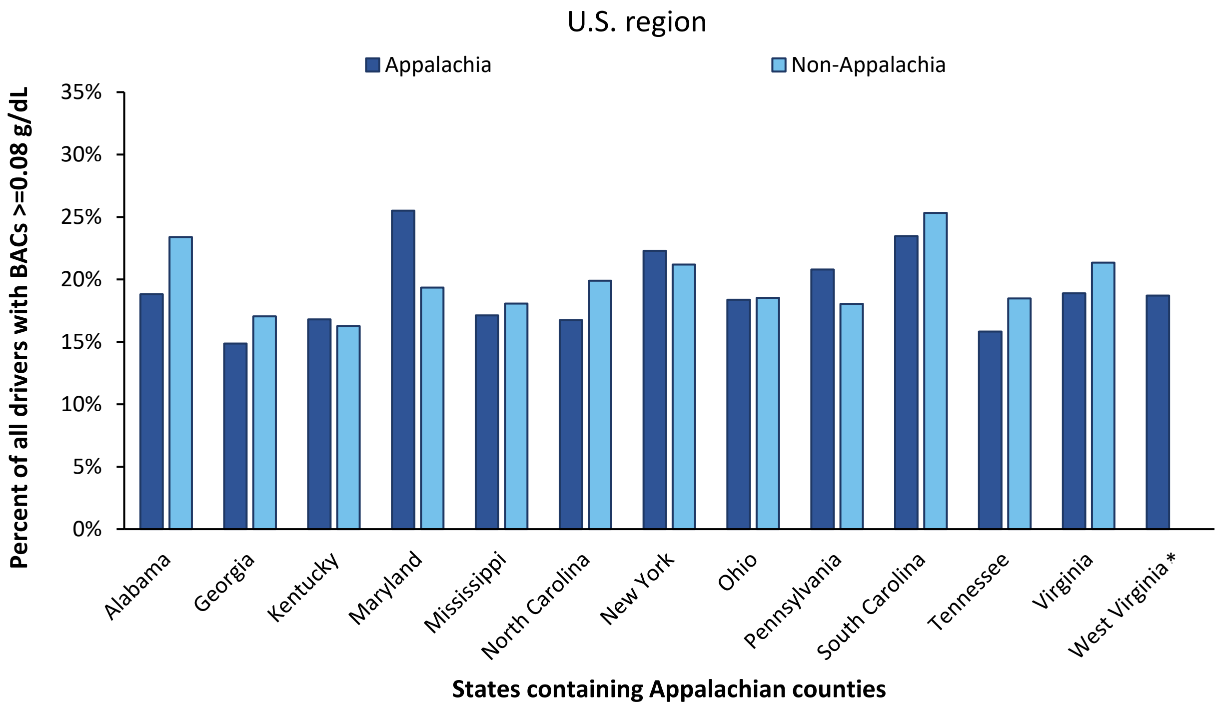
The effects of alcohol on driving ability has been studied extensively. Alcohol has negative impacts on a driver's reaction time; attention and information processing; visual tracking, functioning, and perception; and psychomotor abilities (179). Romano et al. (180) found that alcohol-impaired drivers 16–20, 21–35, >35 years of age were respectively 20, 12, and seven times more likely to be killed in a crash compared to sober (BAC =0.00 g/dL) drivers. While the proportion of fatally injured drivers impaired at the time of crash declined precipitously from the early 1980s to the mid-1990s, this decline has since stabilized with little progress made since the 2000s (181). There are numerous evidence-based interventions that can reduce the prevalence of alcohol-impaired driving and, therefore, the number of alcohol-related traffic fatalities, including: medical provider-based screening and brief intervention programs (182); publicized sobriety checkpoint programs (183); policies that hold alcohol retail establishments liable for injuries and fatalities related to their customers' consumption of alcohol (184); ignition interlock programs (185); policies that reduce statewide BAC limits to 0.05 g/dL (178); and replacing the current criminal justice approach with an administrative approach incorporating immediate, predetermined penalties (such as vehicle impoundment and monetary fines) (186,187).

Table 41: Frequency of Motor Vehicle Drivers Involved in Fatal Crashes with Blood Alcohol Concentrations (BAC) > 0.08 g/dL*, by State (States Containing Appalachian Counties, Only): Appalachia and Non-Appalachia, 2013–2017

	United States region N=81,635 motor vehicle drivers with BAC >= 0.08 g/dL**					
	Appalachia			Non-Appalachia		
	Tested ≥ 0.08 g/dL		Total drivers	Tested ≥ 0.08 g/dL		Total drivers
	N	%	N	N	%	N
State						
Alabama	688	18.8%	3,658	534	23.4%	2,282
Georgia	423	14.9%	2,845	1,169	17.0%	6,860
Kentucky	285	16.8%	1,696	550	16.3%	3,381
Maryland	50	25.5%	196	644	19.3%	3,329
Mississippi	177	17.1%	1,034	582	18.1%	3,222
North Carolina	282	16.7%	1,685	1,542	19.9%	7,751
New York	134	22.3%	601	1,403	21.2%	6,619
Ohio	291	18.4%	1,584	1,156	18.5%	6,237
Pennsylvania	944	20.8%	4,540	691	18.0%	3,831
South Carolina	338	23.5%	1,440	1,224	25.3%	4,833
Tennessee	516	15.8%	3,261	684	18.5%	3,701
Virginia	146	18.9%	773	937	21.3%	4,389
West Virginia†	353	18.7%	1,887		--	
TOTAL	**4,627**	**18.4%**	**25,200**	**11,116**	**19.7%**	**56,435**

Abbreviations: BAC, blood alcohol concentration; g/dL, grams/deciliter
*NTHSA imputes BACs for drivers with unknown alcohol test results.
**219 drivers missing BACs.
†All West Virginia counties are located within Appalachia.
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Figure 34: Frequency of Motor Vehicle Drivers Legally Impaired at Time of Fatal Crash (BAC > 0.08 g/dL), in Appalachia and Non-Appalachia, by State (States with Appalachian Counties, Only): 2013–2017



*All West Virginia counties are located within Appalachia.
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

2.5.2 Drivers Involved in Fatal Motor Vehicle Collisions Testing Positive for Drugs in Appalachia and Non-Appalachia

Key Findings:

- Over the period 2013–2017, 44% of Appalachian drivers and 38% of non-Appalachian drivers had drug test results. Among U.S. drivers with drug test results, 50% of Appalachian and 44% of non-Appalachian drivers tested positive for one or more drugs.
- Among drivers involved in fatal traffic crashes, the most common class of drugs for which drivers tested positive was cannabinoids (e.g., marijuana). Appalachian drivers were less likely to test positive for marijuana (13%) as compared to non-Appalachian drivers (17%).
- The second most common class of drugs for which drivers tested positive for was tranquilizers, sedatives, and other non-narcotic central nervous system (CNS) depressants. A larger proportion of Appalachian drivers (12%) tested positive as compared to non-Appalachian drivers (8%).
- The third most common class of drugs for which drivers tested positive was narcotics, including opioid analgesics. A larger proportion of Appalachian drivers tested positive for narcotics (11%) as compared to non-Appalachian drivers (8%).

Please see Section 2.1 for an overview of the limitations of the FARS drug reporting data (142). Using current FARS data, it is simply not possible to assess the frequency of drug-involved fatal crashes in Appalachia or the rest of the United States. In FARS, a positive result indicates the presence of a drug;

the data do not indicate impairment. Similarly, the absence of a positive result does not mean that a person was not under the influence of a drug; it could also mean that the drug was not tested for or the test was not sensitive enough to detect it (188). In addition, drug testing policies and procedures are not uniform within states and across states. Table 42 displays the frequency of drug testing in the United States; 44% of Appalachian drivers and 38% of non-Appalachian drivers had drug test results. The state with the highest proportion of drivers tested was New Hampshire (78%) and the state with the lowest proportion of drivers tested was North Carolina (3%). There are several explanations for the low prevalence (and high variability) across states, including a lack of resources and equipment, a lack of consistent policies around drug testing, and the widespread practice of not testing drivers who have already tested positive for alcohol (188). Due to the variability in drug testing by state, data from three Appalachian states (Miss., N.C., and N.Y.) and eight non-Appalachian states (Del., Fla., Iowa, Maine, Neb., N.M., Ore., Texas) were excluded from analyses because these states reported drug test results for less than one-third of all drivers involved in fatal traffic crashes.

Table 42: Frequency of Drug Testing among Motor Vehicle Drivers Involved in Fatal Crashes: Appalachia and Non-Appalachia, 2013–2017

Drug test characteristic	United States region N=243,034 motor vehicle drivers			
	Appalachia		Non-Appalachia	
	N	%	N	%
Drug test status				
Test given	11,115	44.0%	82,369	37.8%
Test not given/refused	12,726	50.4%	112,851	51.8%
Unknown if tested/not reported	1,418	5.6%	22,555	10.4%
Type of drug test given				
Test not given/refused	12,726	50.4%	112,851	51.8%
Blood	10,160	40.2%	72,823	33.4%
Urine	451	1.8%	3,765	1.7%
Blood and urine	326	1.3%	3,655	1.7%
Other/unknown test type	178	0.7%	2,126	1.0%
Unknown if tested/not reported	1,418	5.6%	22,555	10.4%
TOTAL	**25,259**	**100.0%**	**217,775**	**100.0%**

Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

Table 43 displays selected drug tests results among U.S. drivers involved in fatal traffic crashes during the period 2013–2017. There were approximately 80 different types of drug metabolites detected among drivers involved in fatal traffic crashes. Among drivers involved in fatal traffic crashes, the most common class of drug detected was cannabinoids (e.g., marijuana), with 13% of Appalachian drivers and 17% of non-Appalachian drivers testing positive for this class of drug. In 2017, only eight states had legalized marijuana for recreational purposes, none of which were located within Appalachia; however, many more states and municipalities had legalized medical marijuana and/or decriminalized the recreational use of marijuana at this time (e.g., N.Y.) (189). Cannabis can adversely impact driving ability by impairing driver reaction time, information processing, and coordination (190). Cannabis does not have the same level of deleterious effect on driving ability as alcohol, with estimates suggesting that cannabis-impaired drivers are 1.3 times as likely as non-impaired drivers to be involved in motor vehicle collisions (191,192). However, there is considerable variation for the magnitude of effect size reported in the literature. Since the metabolites of cannabis can remain in the body for days to weeks after consumption, determining level of impairment (particularly in decedents) is difficult.

The second most common class of drug detected was tranquilizers, sedatives, and other non-narcotic CNS depressants, with 12% of Appalachian and 8% of non-Appalachian drivers involved in fatal traffic crashes testing positive for this class of drug. This broad class of drugs include benzodiazepines, barbiturates, muscle relaxants, sedatives/hypnotics, etc. The most common types of CNS depressants observed were benzodiazepines, such as Alprazolam (Xanax®). Benzodiazepines have been estimated to increase the risk of being involved in a traffic collision by 60–80% (193). When benzodiazepines are used concurrently with other common CNS depressants, such as alcohol and opioids, the risk of adverse health events is exacerbated; however, the magnitude of effect on driving ability is unclear (194) (Table 43).

In 2013–2017, the third most common class of drugs observed among U.S. drivers killed in traffic crashes was narcotics. It is important to note that the broad category of narcotics includes both illegal drugs (e.g., heroin) and drugs available by prescription (e.g., hydrocodeine). Also, it is not illegal to operate a motor vehicle after taking prescription narcotics, as long as the driver is not functionally impaired. The proportion of drivers who tested positive for narcotics was higher among Appalachian drivers (11%) than non-Appalachian drivers (8%). The most common type of narcotic detected was heroin/morphine/opium. It is not surprising that Appalachian drivers were more likely to test positive for narcotics, such as opioids. Appalachia was the birthplace of the opioid misuse/dependence crisis, which originated from a complex interplay of factors, including a high prevalence of disability, chronic pain, depression, substance abuse, inadequate access to healthcare, poverty, and deliberate targeting by the pharmaceutical industry (69,70). Widespread opioid misuse/dependence has had a dramatic impact on the health of Appalachia (and the nation as a whole) producing skyrocketing rates of opioid overdoses. Meit et al. (21) found that Appalachian residents were 65% more likely to die from drug overdoses than non-Appalachian residents. However, the impact that opioid abuse/misuse has had on other health outcomes, such as traffic fatality rates, is still unclear. According to a meta-analysis by Chihuri and Li (72), drivers under the influence of opioid analgesics were 2.3 times more likely to be involved in motor vehicle collisions than non-impaired drivers. Alcohol seems to exacerbate the risk, with drivers testing positive for opioid analgesics and alcohol having 22 times the odds of being involved in a fatal traffic crash as compared to drivers testing negative for these substances (195). For these reasons, the higher rate of narcotics among fatally injured drivers in Appalachia may simply reflect higher use of narcotics and/or the higher prevalence of testing for narcotics among this population. It does not necessarily indicate that narcotic use *caused* the fatal crash (Table 43).

Appalachian drivers were less likely than non-Appalachian drivers to test positive for stimulants, hallucinogens, and other/unknown drugs (Table 43).

Table 43: Selected Drug Test Results for Motor Vehicle Drivers Involved in Fatal Crashes: Appalachia and Non-Appalachia: 2013–2017*

	United States region N=72,536 motor vehicle drivers with drug test results			
	Appalachia		Non-Appalachia	
	N	%	N	%
Positive toxicology screen**	**5,214**	**49.7%**	**27,162**	**43.8%**
Cannabinoids	1,335	12.7%	10,326	16.6%
Stimulants	890	8.5%	6,175	10.0%
Tranquilizers/Sedatives/Other non-narcotic CNS depressants	1,266	12.1%	4,868	7.8%
Narcotics	1,189	11.3%	4,855	7.8%
Hallucinogens	40	0.4%	310	0.5%
Other/Unknown drugs	6	0.1%	165	0.3%
Negative toxicology screen	**5,271**	**50.3%**	**34,889**	**56.2%**
TOTAL	**10,485**	**100.0%**	**62,051**	**100.0%**

Abbreviations: CNS, central nervous system
*States with less than one-third of all drivers tested for drugs were excluded from analyses (Del., Fla., Iowa, Maine, Miss., N.C., Neb., N.M., N.Y., Ore., Texas).
**FARS records up to three drug test results; therefore, drivers may test positive for more than one substance, so column percentages do not sum to 100%.
Data Source: National Center for Statistics and Analysis, NHTSA. Fatality Analysis Reporting System.

In contrast to the problem of driver alcohol impairment, there are fewer evaluated interventions designed to prevent drug-impaired driving. The first step is improving the data; without better data it is impossible to understand the prevalence of drug-impaired driving and how drug-impaired driving contributes to the frequency of motor vehicle crashes. The second step is addressing the underlying issue of opioid misuse/dependence in Appalachia. There are several evidence-based strategies for tackling the opioid crisis, including targeted naloxone distribution in community and criminal justice settings, medication-assisted treatment for opioid dependence, “Good Samaritan” legislation (provides limited immunity to individuals who report overdoses), and syringe exchange programs (196). There are fewer evidence-based strategies that have been shown to specifically reduce the prevalence of drug-impaired driving. It has been assumed that successful alcohol impairment reduction strategies can also be applied to drug-impaired driving. However, this assumption may not be correct. For example, the passage and enforcement of zero-tolerance drug-impaired driving laws is assumed to reduce the prevalence of drug-impaired driving. However, identifying drug impairment can be difficult, and law enforcement officers often fail to investigate drug impairment unless the driver appears impaired and has a low BAC. Trained drug recognition experts (DREs) can be useful in investigating drug impairment cases, but training and fielding DREs requires resources beyond the capacity of many smaller law enforcement agencies (197).

2.6 Conclusions

In the literature synthesis, we identified a series of variables hypothesized to be associated with excess traffic mortality in Appalachia. In Part I, we tested some of these hypotheses using FARS data. While this investigation is not exhaustive (FARS collects data on many, but not all, of the variables identified in our synthesis), and involves case-series analyses only (i.e., traffic fatalities), it is a useful exercise in further clarifying key targets for future research and intervention. The following list recapitulates some of the highlights from the FARS analyses:

- **Traffic fatality rates:** The Appalachian Region has higher traffic fatality rates than the rest of the United States. This pattern is consistent over time and across demographic characteristics. While traffic fatality rates in both Appalachia and non-Appalachia have undergone dramatic declines over the last two decades, the decline has been more modest for Appalachia, indicating that advances in traffic safety may not have permeated this region to the extent of the rest of the United States. Furthermore, there are striking differences in traffic fatality rates across Appalachian subregions, with the Central subregion having nearly twice the traffic fatality rate of the Northern subregion.
- **Youth and young adults:** Appalachian youth and young adults 15–24 years of age have the highest traffic fatality rates at 18.8 fatalities per 100,000 person-years. It has long been recognized that novice drivers are at an increased risk of crash due to inexperience (198,199). While interventions as well as cultural and economic factors have led to a reduction in youth and young adult traffic fatalities, more still needs to be done to further reduce this rate for this vulnerable age group, including the incorporation of stronger graduated drivers' licensing systems (38).
- **Older adults:** The median age of Appalachian traffic fatalities is one year older than non-Appalachian traffic fatalities at 43 years of age. Older adults (greater than 65 years of age) make up more than one-quarter of all Appalachian traffic fatalities and have fatality rates 20% higher than non-Appalachia. Older adults are more likely to sustain serious injuries in a motor vehicle collision due to increased fragility (143). In addition, older adults are susceptible to visual and cognitive declines that may put them at a higher risk of being involved in a crash, especially in the absence of safety improvements (e.g., improved roadway lighting and signage) (200).
- **Working-age adults:** While working-age Appalachian adults 25–44 years of age do not have the highest traffic fatality rates by age group, this group had the highest relative difference in traffic fatality rates as compared to non-Appalachia. Since working-age adults are also at the greatest risk of suffering from "diseases of despair" (alcoholic liver disease/cirrhosis, drug overdose, and self-harm/suicide), these two seemingly disparate mechanisms of mortality may share some risk factors, such as poverty (21).
- **Non-motorist fatalities:** Traffic fatality rates among Appalachian pedestrians and cyclists are 22% and 46% lower than their non-Appalachian counterparts, respectively. This likely reflects a lower prevalence of walking and biking in this region, rather than a traffic safety success story (20). Due to the prevalence of obesity and other chronic health comorbidities in Appalachia, Appalachian states could benefit from making infrastructure improvements that are more conducive to active forms of transportation, such as the popular Rails-to-Trails program, which converts old railbeds to multi-use trails. Rail trails, such as the popular Virginia Creeper Trail in

Virginia and the Caperton and Decker's Creek Trails in West Virginia have been shown to encourage physical activity and wellness and promote economic growth (201–204).

- **ATV rider fatalities:** ATV riders make up a surprisingly large proportion of traffic fatalities in Appalachia, especially in the Central subregion. Since these devices are not designed for on-road transportation, legislation should be implemented to minimize presence on public roadways.
- **Rurality:** In Appalachia, rural fatality rates are 64% higher than urban fatality rates. While rural fatality rates are also higher in non-Appalachia, a far greater proportion of Appalachian traffic fatalities occur in rural areas. Many of the reasons why rural areas have higher traffic fatality rates than urban areas were addressed in the literature review (e.g., traffic safety culture, lack of adequate infrastructure, distance from definitive medical care, etc.) (24,113,123). While much lower than rural traffic fatality rates, urban fatality rates are 35% higher in Appalachia. There is not a clear explanation for this result, so more research is needed to determine what is driving traffic fatalities in urban Appalachia.
- **Ambient light and weather conditions:** Appalachian traffic fatalities are more likely to occur under dark-unlighted conditions and during inclement weather events than non-Appalachian traffic fatalities. There are numerous roadway improvements that can help prevent traffic crashes under dark, low visibility and other adverse conditions, such as better roadway lighting, high visibility signage, low visibility and adverse weather event alert systems, and road treatments to improve traction (205).
- **Age of vehicles:** Among traffic fatalities, the median age of Appalachian motor vehicle occupants' and motorcyclists' vehicles is one year older than non-Appalachian vehicles. In addition, the vehicles of Appalachian crash victims are 28% more likely to be greater than 20 years of age, as compared to the vehicles of non-Appalachian crash victims. Older vehicles are not as safe as newer vehicles (167). Programs to support the purchase of newer vehicles among Appalachian residents could help reduce traffic mortality rates in Appalachia, with the added benefit of improving air quality in the region.
- **Safety restraint and motorcycle helmet use:** Appalachian motor vehicle occupant fatalities are 31% more likely to be unrestrained at the time of crash than non-Appalachian occupant fatalities. The proportion of Appalachian occupants who are unrestrained at the time of crash varied from 48% (South Central subregion) to 62% (Central subregion). While seatbelt usage is generally high in the Appalachian as well as non-Appalachian United States (206), the relatively low frequency of restraint use suggests a segment of the Appalachian population has a traffic safety culture that does not place as high of a value on personal protection as it does on personal liberty. These cultural views are not immutable, however, and a combined enforcement/public media campaign with appropriate cultural context could help increase acceptance of safety restraints. Somewhat conversely, Appalachian motorcyclist fatalities are more likely to be helmeted at the time of crash. The high frequency of motorcycle helmet use in Appalachia is a result of universal helmet laws in ten of the 13 Appalachian states. Appalachia could further reduce its motorcyclist traffic fatality rates through an expansion of universal helmet laws to encompass all Appalachian states.
- **Two-lane roads:** In Appalachia, 85% of motor vehicle occupant and motorcyclist fatalities happen in crashes on two-lane roads, 105% higher than in non-Appalachia. There is an increased risk of head-on collisions on two-lane roads related to vehicle passing. In addition, many two-lane roads occur in rural areas, so are subject to some of the same deleterious conditions

described previously under "rurality" (113). Many Appalachian states have directly addressed the need to make two-lane roads safer in their SHSPs.

- **Geometric design of roads:** Appalachian traffic fatalities are more likely to occur on curved and graded sections of roadways, as compared to non-Appalachian traffic fatalities. Curved and graded roads can lead to traffic crashes by contributing to driver loss of control. Infrastructure improvements can be incorporated to mitigate some of the risks associated with curved and graded roads (207).
- **Driver alcohol impairment:** Nearly one-fifth of all Appalachian drivers involved in fatal traffic crashes are alcohol-impaired at the time of crash. While driver alcohol impairment is slightly lower in Appalachia than non-Appalachia, it is still alarmingly high, especially among men between the ages of 20 and 34, and drivers involved in crashes during the late night and early morning hours.
- **Driver drug impairment:** Due to the limitations of the FARS drug test data reporting and results, motor vehicle driver drug impairment cannot be assessed and described in this report, with less than half of all U.S. drivers involved in fatal crashes having a drug test result. More research is needed to further characterize motor vehicle driver drug impairment, as well as effective countermeasures.

Chapter 3: Results from the North Carolina Case Study

3.1 Introduction

In the previous chapter, we used FARS data to identify a number of traffic safety concerns unique to the Appalachian Region. However, these analyses focused solely on fatal crashes; while fatal crashes can reveal important insights about crashes—and are top priorities for states to prevent, as attested in the SHSPs referenced in the literature synthesis—these are a small proportion of total crashes and may not fully explain traffic safety problems in an area. Therefore, to supplement the analyses from the last chapter, we used historic crash data collected for the state of North Carolina to present a small case study of traffic safety in an Appalachian state. The goal of this case study is to provide additional context to the broader traffic safety analysis of Appalachia rather than to present a comprehensive safety profile of North Carolina.

In this section we present the characteristics of fatal and severe injury crashes in North Carolina from 2013 to 2017 and make comparisons between Appalachia and non-Appalachia counties, when applicable. Characteristics of crashes, occupants, and vehicles are described. Because our goal was to provide additional context to the Appalachian fatal crash analysis, we focused on key variables highlighted in that study. Each subsection of this chapter, therefore, consists of summaries of crash, occupant, and vehicle characteristics for the entire state and then highlights specific differences between Appalachian and non-Appalachian counties in North Carolina.

Our chief variables of interest between Appalachian and non-Appalachian in this case study include the following:

- Alcohol use
- Temporal differences in crash patterns
- Differences in rural and urban crash patterns
- The effect of ambient lighting on crashes
- Restraint use
- Motorcyclist helmet use
- Age of vehicles involved

Additional observations about broader crash trends in North Carolina are also provided for context. Where possible, inferences made in the FARS chapter are evaluated. However, differences between the FARS database and state-reported crash data limit our ability to analyze some variables, including indicators of drugged driving.

We obtained the North Carolina crash data file from the North Carolina Department of Transportation (NCDOT). In North Carolina, any crash in which the total damage is estimated to exceed $1000 is required to be reported by police (prior to 1995, the reporting threshold was $500). Crash data are collected directly by police officers who investigate crashes. In North Carolina, injury severity is indicated with the KABCO scale:

- K: Killed
- A: Disabling injury
- B: Evident injury
- C: Possible injury
- O: No injury (sometimes called property damage only or PDO)
- Unknown

This section focuses on the proportion of fatal and severe injuries (K and A injury type) among all crashes under various conditions, as well as occupant and vehicle characteristics with fatal and severe injuries. We focused on the proportion of fatal and severe injury crashes as these are the most dire crash types and are the primary focus of the state's SHSP (54).

Although the analysis is largely descriptive, we also present unadjusted odds ratios with 95% confidence intervals to aid comparisons, when appropriate. We performed all statistical analyses using SAS version 9.4 (SAS®, Cary, N.C.).

3.2 Characteristics of Fatal and Severe Injury Crashes in North Carolina

3.2.1 Alcohol Usage

From 2013 to 2017, about 19% of North Carolina crashes that involved fatal or severe injuries were alcohol-related. This percentage is lower than the 23% of fatal crashes in the entire Region that occurred during the same time period. This lower average suggests that other states in the Region may have greater percentages of severe crashes that involve alcohol use, but this hypothesis cannot be substantiated without more data. The lower percentage throughout North Carolina is also lower than that of the rest of non-Appalachian United States, indicating that while alcohol remains a problem to be addressed in North Carolina, its effects are not as pronounced in this state as in others. A potential explanation for this could be the traffic safety culture in North Carolina—the literature synthesis hinted at greater religiosity in Appalachia that may be less encouraging of drinking—and may provide a potential case study for how establishing a specific traffic safety norm in a state can keep negative behaviors relatively low.

Table 44: Frequency of Fatal and Severe Injury Crashes Involving Alcohol in North Carolina: 2013–2017

Number of Fatal or Severe Injury Crashes Per Year												
Alcohol-Related	2013		2014		2015		2016		2017		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
No	448	81.8%	431	79.5%	924	80.1%	1042	80.6%	1368	81.9%	4213	80.9%
Yes	100	18.3%	111	20.5%	230	19.9%	251	19.4%	303	18.1%	995	19.1%
Total	548	100.0%	542	100.0%	1154	100.0%	1293	100.0%	1671	100.0%	5208	100.0%

Data Source: North Carolina Department of Transportation.

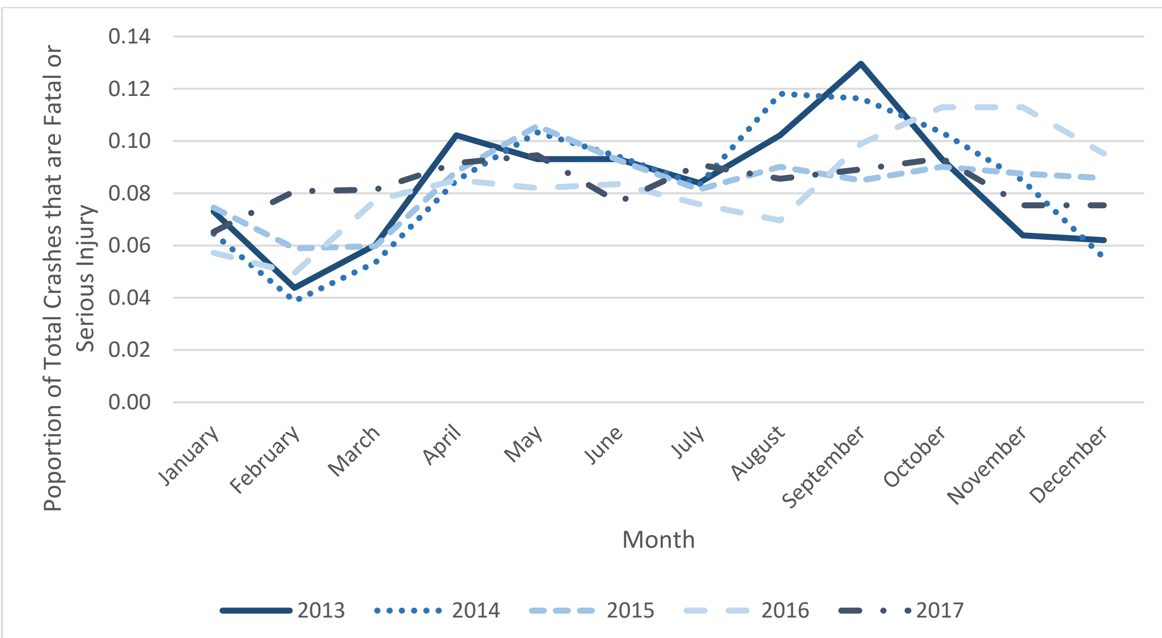
3.2.2 Temporal Trends

The cyclical nature of fatal and severe crashes over a monthly time scale can be seen in the Figure 35; this figure suggests that a larger proportion of severe crashes occur in the early fall months, while a smaller proportion occur in winter months. As referenced in the FARS analysis, crashes seem to peak in the Appalachian Region during the fall, rather than during summer as might be expected. The North

Carolina data seem to indicate the same "leaf peeping" behavior identified in the FARS analysis, potentially indicating that during fall months, Appalachian states should consider increased safety enforcement to ensure safe driving when there are more, potentially unfamiliar, tourist drivers on the road (158,159).

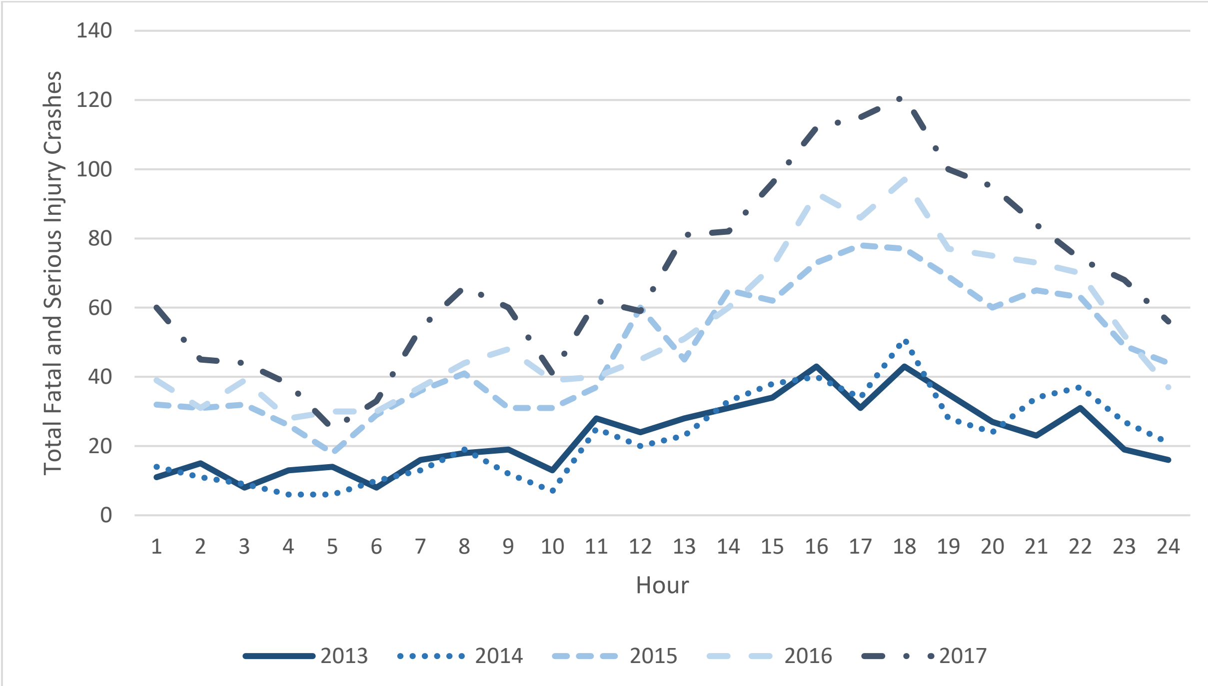
Additionally, it appears that severe and fatal crashes peak in the afternoon hours between 3:00 p.m. and 6:00 p.m., as seen in Figure 36. These results are in line with the findings for both Appalachian and non-Appalachian United States and correspond to general travel patterns (160). It is worth noting that the third highest peak percentage of crashes that were fatal or severe during the study years occurred at approximately 2,200, indicating nighttime driving. As mentioned in the FARS analysis, a disproportionate number of crashes occur in the dark, potentially indicating a need for improved lighting and retroreflectivity on roadways throughout the state.

Figure 35: Monthly Proportion of Fatal and Severe Injury Crashes in North Carolina: 2013–2017



Data Source: North Carolina Department of Transportation

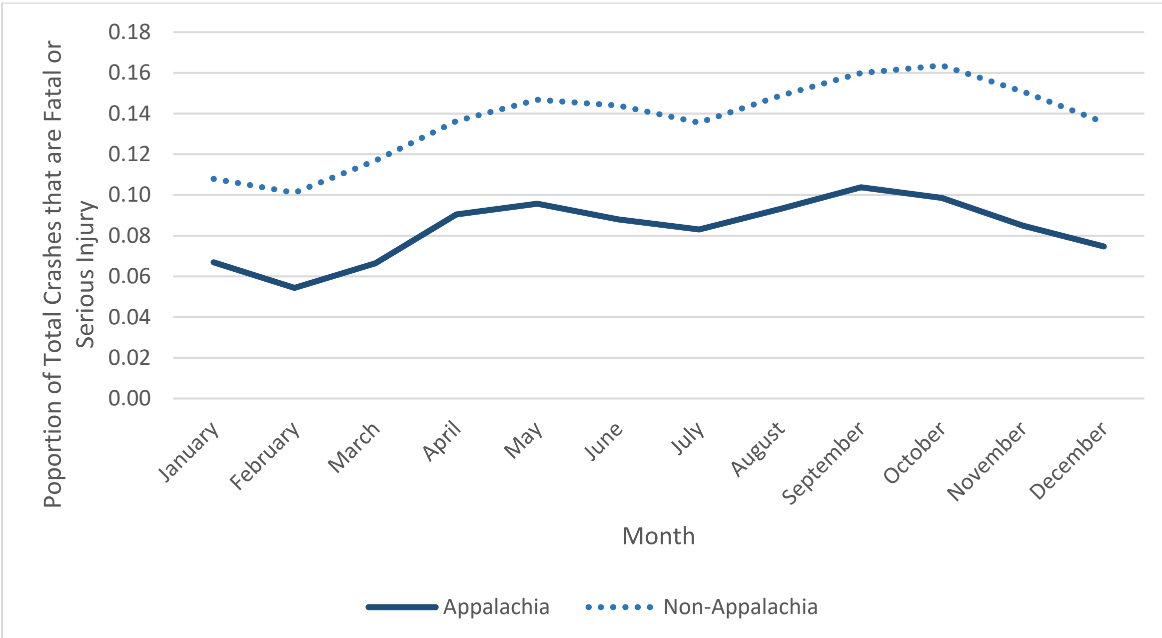
Figure 36: Hourly Proportion of Fatal and Severe Injury Crashes in North Carolina: 2013–2017



Data Source: North Carolina Department of Transportation

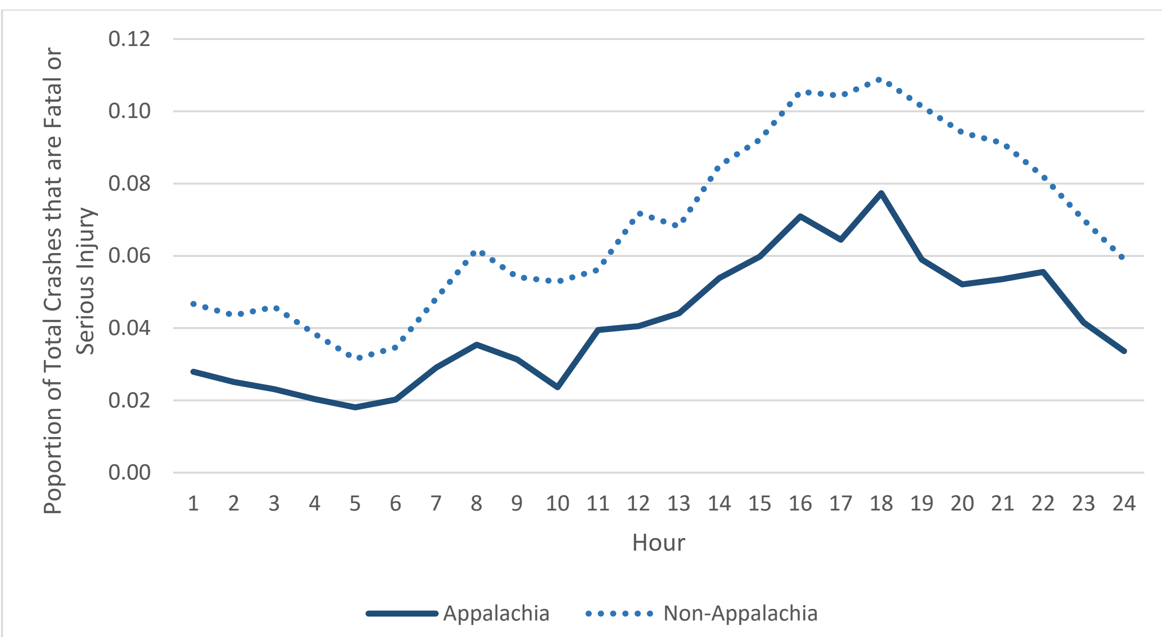
In comparison to Appalachian counties, the non-Appalachian counties in North Carolina have a higher proportion of fatal and severe injury crashes each month of the year and each hour of the day, although the general trend over the five years is consistent. These results are unsurprising given the smaller population. The same conclusions regarding the trends of peak death and injury periods are evident in Figures 37 and 38 as in Figures 35 and 36.

Figure 37: Average Monthly Proportion of Fatal and Severe Injury Crashes in North Carolina: Appalachia and Non-Appalachia, 2013–2017



Data Source: North Carolina Department of Transportation

Figure 38: Average Hourly Proportion of Fatal and Severe Injury Crashes in North Carolina: Appalachia and Non-Appalachia, 2013–2017



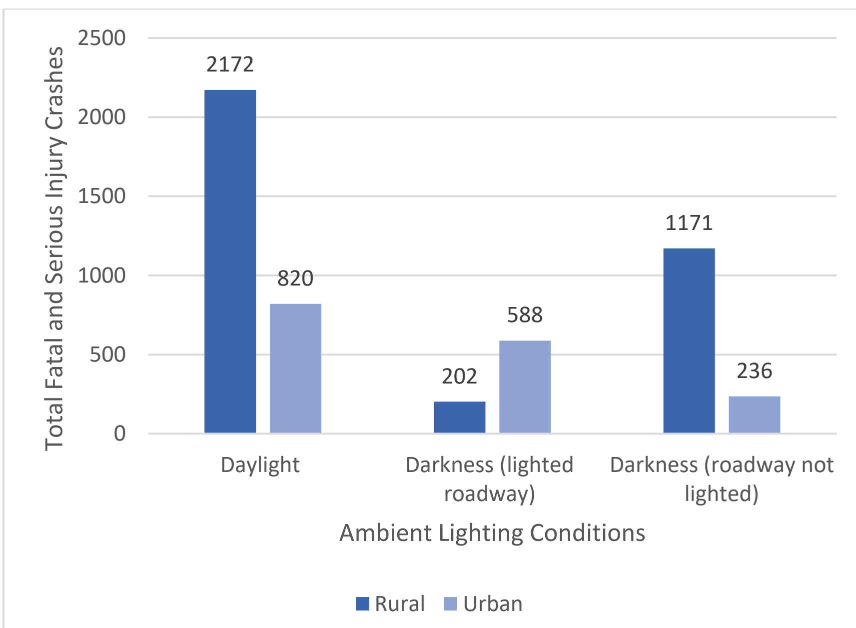
Data Source: North Carolina Department of Transportation

3.2.3 Rurality and Ambient Lighting

Figures 39, 40, and 41 combine statistics regarding the ambient lighting in which fatal and severe injury crashes occurred in urban and rural areas in North Carolina. Here rurality is defined by NCDOT as occurring in an unincorporated area or an area with a population less than 5,000 people (208). As seen in Figure 5, far more fatal and severe injury crashes occurred in rural areas than urban areas. However, this trend is not consistent when looking at the distribution of crashes in dark but lighted versus dark but unlighted roadway conditions. More dark but lighted fatal and severe crashes occurred in urban areas than rural areas, but far more dark but unlighted crashes occurred in rural areas than urban areas. As seen in Figure 6, in N.C. Appalachian counties, there were more fatal or severe injury crashes in rural settings than in urban settings from 2013 to 2017. Nonetheless, the proportions of fatal and severe injury crashes in different lighting conditions that occurred in urban versus rural settings were similar between Appalachian counties and non-Appalachian counties, as can be seen by comparing Figures 6 and 7. In both Appalachian and non-Appalachian counties, more fatal and severe crashes occur on rural roads in both daylight conditions and in dark but unlighted conditions; only for fatal and serious injury crashes occurring in dark but lighted conditions is the proportion higher on urban roadways. All three figures indicate a need for improved roadway lighting or retroreflectivity in rural areas.

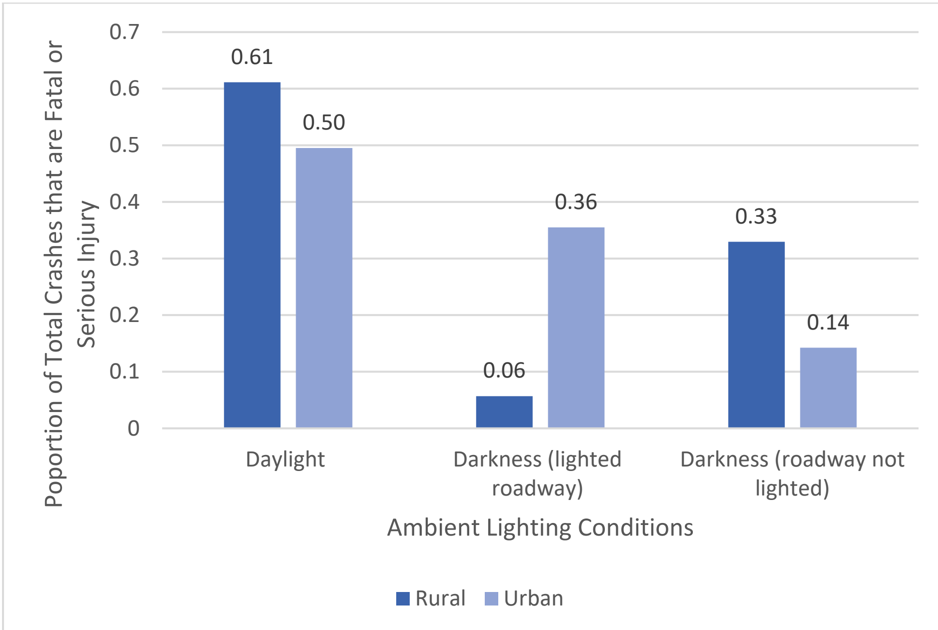
In both Appalachian and non-Appalachian counties, the unadjusted odds ratios revealed that the odds of having a fatal or severe injury crash occurring in darkness in rural settings were two times that in urban settings (OR=2.06, 95% CI = 1.91–2.21), whereas the odds of having a fatal or severe injury crash occurring in lighted roadways in rural settings were about one-seventh that in urban settings (OR=.14, 95% CI = .13–.15).

Figure 39: Ambient Light and Fatal and Severe Injury Crashes in North Carolina: Rural and Urban



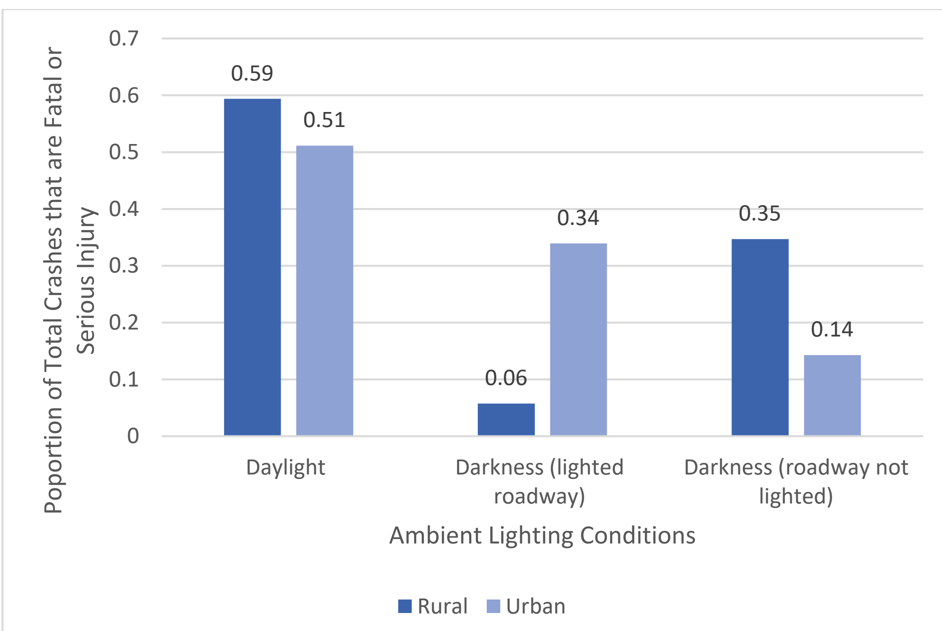
Data Source: North Carolina Department of Transportation

Figure 40: Ambient Light and Proportions of Fatal and Severe Injury Crashes in Appalachian Counties in North Carolina: Rural and Urban



Data Source: North Carolina Department of Transportation

Figure 41: Ambient Light and Proportions of Fatal and Severe Injury Crashes in Non-Appalachian Counties in North Carolina: Rural and Urban



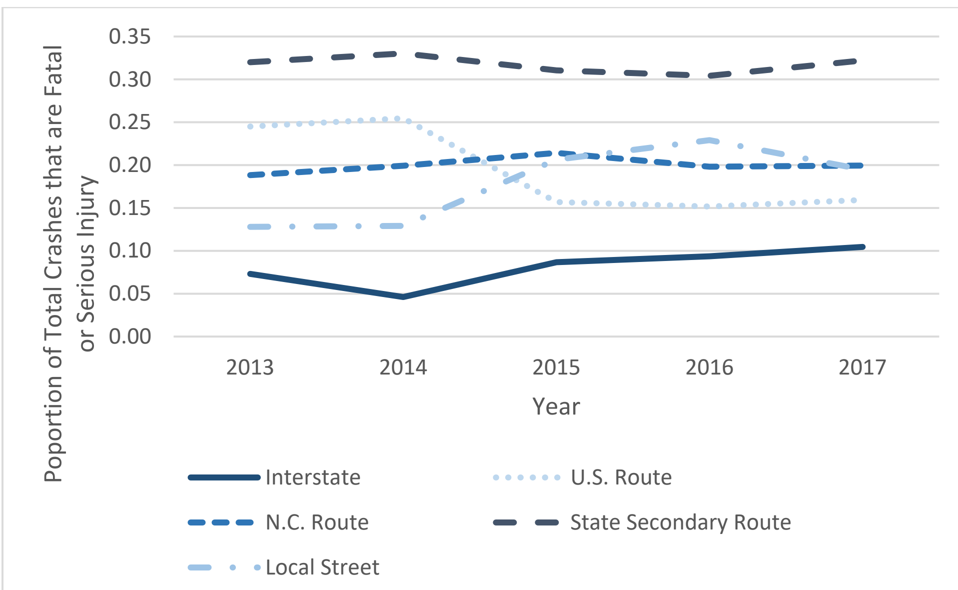
Data Source: North Carolina Department of Transportation

3.2.4 Roadway Functional Classification

Across the five years, fatal and severe injury crashes were most likely to occur on state secondary routes, and least likely to occur on interstate highways. In addition, there appeared to be a decrease in the proportion of such crashes on U.S. routes but an increase in the proportion of such crashes on local streets.

One of the reasons for developing the Appalachian Development Highway System was to upgrade potentially unsafe roadway types to higher design standards (i.e., improved lane width, improved shoulder width, better access control) (22). Although the engineering properties of state secondary routes in North Carolina can vary significantly from NCDOT district to district, the greater proportion of fatal and injury crashes seen in Figure 42 may indicate the need for improved design standards that may be present, by comparison on interstate highways. Therefore, these results hint at the potential benefits and improved safety performance offered by ADHS upgrades.

Figure 42: Proportion of Fatal and Severe Injury Crashes on Various Road Types in North Carolina: 2013–2017

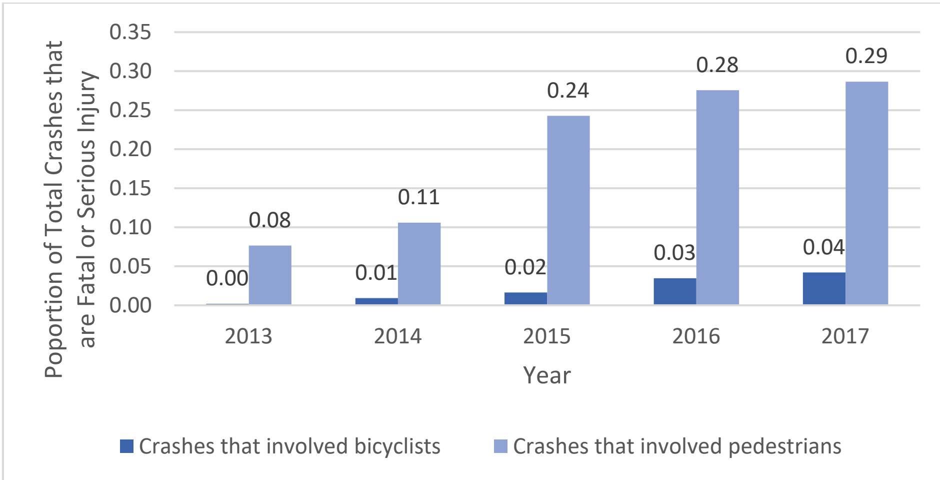


Data Source: North Carolina Department of Transportation

3.2.5 Pedestrians and Bicyclists

There were large increases in the percentage of fatal or severe injury crashes that involved pedestrians or bicyclists over the past five years in North Carolina. In 2013, less than 10% of these crashes involved a pedestrian; in 2017, that percentage jumped to over 25%, as seen in Figure 43. Given, however, the lower involvement of pedestrians and bicyclists in crashes throughout the Appalachian Region, these results are primarily due to vulnerable road-user fatalities and serious injuries in non-Appalachia.

Figure 43: Proportion of Fatal and Severe Injury Crashes that Involved Pedestrians or Bicyclists in North Carolina: 2013–2017



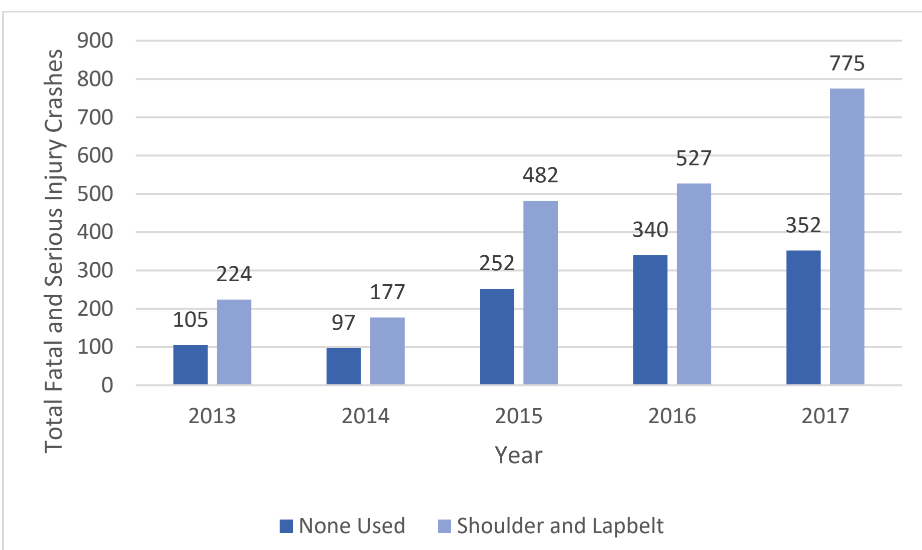
Data Source: North Carolina Department of Transportation

3.3 Restraint Use in Fatal and Severe Injury Crashes

3.3.1 Drivers

Drivers involved in fatal and severe injury crashes in North Carolina were more likely to be belted than unbelted (Figure 44), and the difference was consistent across the five-year period and in both Appalachian and non-Appalachian counties (Figure 45). The difference between restraint and lack of restraint is interesting given the fact that in the FARS data, 55% of vehicle occupants in Appalachia were killed while not wearing a restraint. This finding may indicate the efficacy of primary seatbelt laws in North Carolina compared to the three states that do not have primary seatbelt laws.

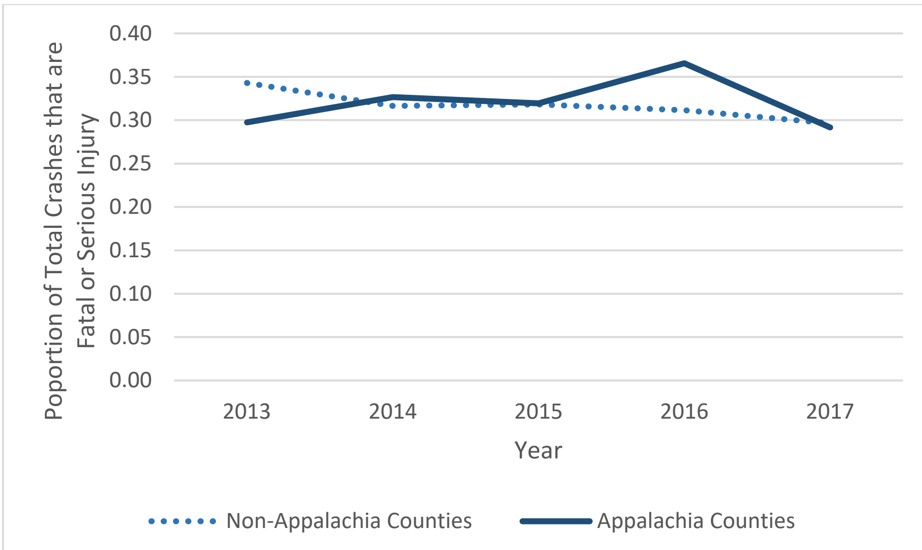
Figure 44: Restraint Use in Fatal and Severe Injury Crashes among North Carolina Drivers: 2013–2017



Data Source: North Carolina Department of Transportation

Compared with non-Appalachian counties, there was a slight jump in the proportion of unrestrained drivers involved in fatal or severe injury crashes in Appalachia counties in 2016. As of 2017, the number of unrestrained drivers in both Appalachian and non-Appalachian counties involved in fatal or serious injury crashes was 30%. These results may indicate an effective traffic safety culture around restraint use in North Carolina Appalachian counties. Further research on restraint use in North Carolina should be conducted to assess this traffic safety culture, and the laws that influence it, to find applicable policy options for other Appalachian states.

Figure 45: Proportion of Unrestrained Drivers Involved in Fatal and Severe Injury Crashes in Appalachian and Non-Appalachian North Carolina: 2013–2017

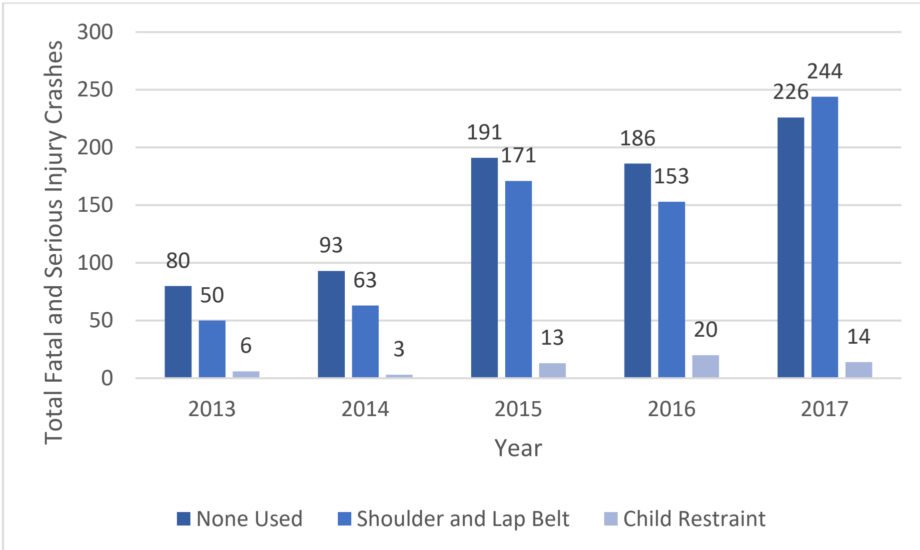


Data Source: North Carolina Department of Transportation

3.3.2 Non-Drivers

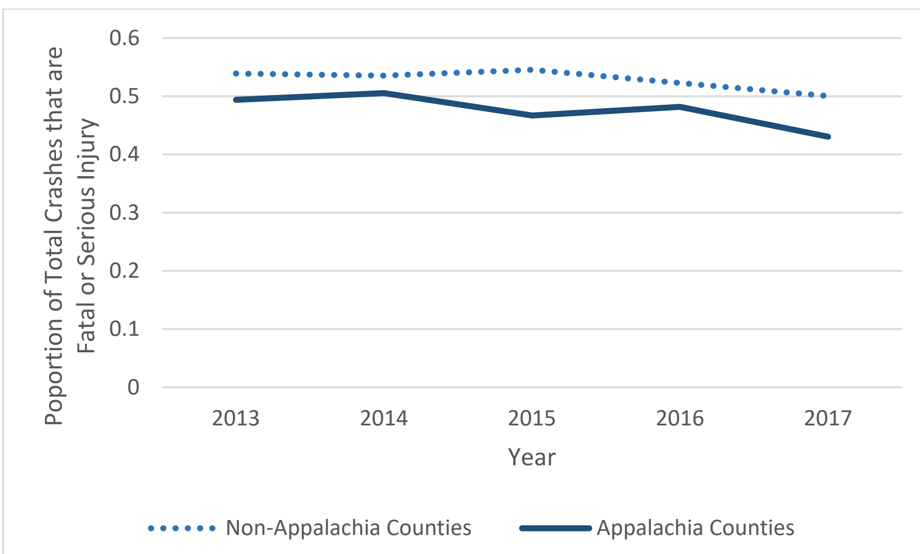
Compared to drivers, however, non-drivers involved in fatal and severe injury crashes were more likely to be unbelted than belted from 2013 to 2016 throughout North Carolina (Figure 46). In 2017, this trend seemed to have reversed slightly, although, as can be seen in Figure 47, the proportion of unbelted occupants killed or seriously injured was still close to half of all occupants. Compared with non-Appalachian counties, passengers involved in fatal or severe injury crashes in Appalachian counties were slightly less likely to be unrestrained over the years from 2013 to 2017. This result is interesting and again may indicate some effective traffic safety culture around restraint use in Appalachian North Carolina that should be studied for applicability to other Appalachian states. However, it is worth noting that the higher proportion of Appalachian unbelted occupants compared to Appalachian unbelted drivers (Figure 11) may indicate the need for comprehensive seatbelt laws in the state.

Figure 46: Restraint Use in Fatal and Severe Injury Crashes among North Carolina Non-Drivers: 2013–2017



Data Source: North Carolina Department of Transportation

Figure 47: Proportion of Unrestrained Passengers Involved in Fatal and Severe Injury Crashes in Appalachian and Non-Appalachian North Carolina: 2013–2017

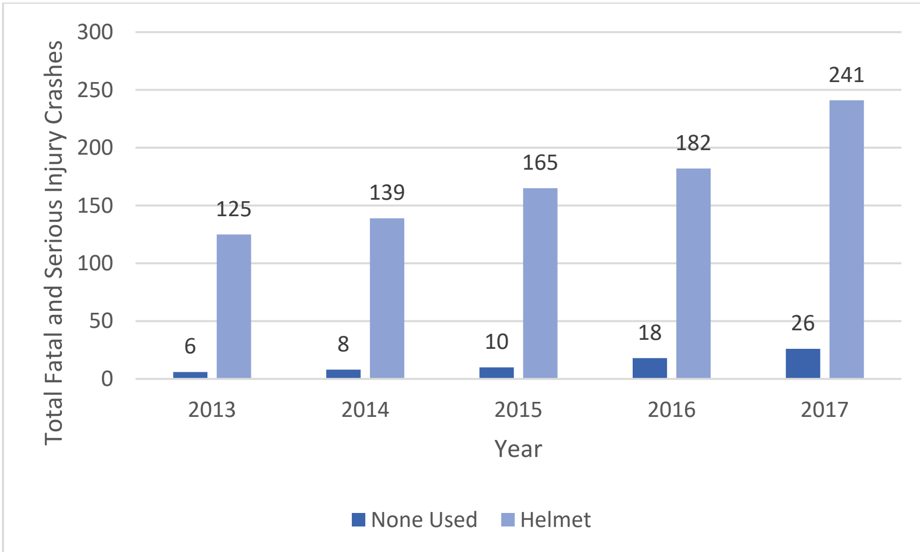


Data Source: North Carolina Department of Transportation

3.3.3 Motorcyclists

Throughout North Carolina, the majority of motorcyclists involved in fatal or serious injury crashes wore their helmets, as seen in Figure 48. Still, there were motorcyclists who did not use any restraint when they were found to be involved in a fatal or severe injury crash, and the number seemed to be increasing over the years throughout the state.

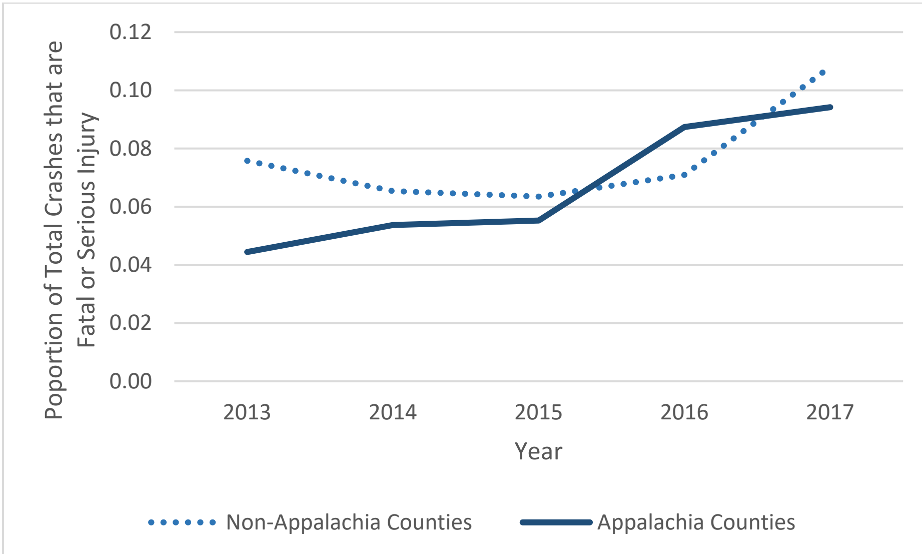
Figure 48: Helmet Use in Fatal and Severe Injury Crashes among North Carolina Motorcyclists: 2013–2017



Data Source: North Carolina Department of Transportation

Figure 49 demonstrates that this trend is consistent for both Appalachian and non-Appalachian counties. The proportion of motorcyclists not wearing helmets when involved in a fatal or severe injury crash did increase over the years, mostly in 2016 and 2017. Although the proportion of motorcyclists in Appalachian counties not wearing helmets was slightly below those in non-Appalachian counties, the growth in lack of helmet use in fatal and serious injury crashes is concerning. However, the proportion of unhelmeted motorcyclists in Appalachian North Carolina is still lower than that in the rest of the Appalachian Region, likely due to North Carolina's universal helmet laws. Therefore, other Appalachian states should explore implementing and enforcing this type of law.

Figure 49: Proportion of Motorcyclists Not Wearing Helmets Involved in Fatal and Severe Injury Crashes in Appalachian and Non-Appalachian North Carolina: 2013–2017

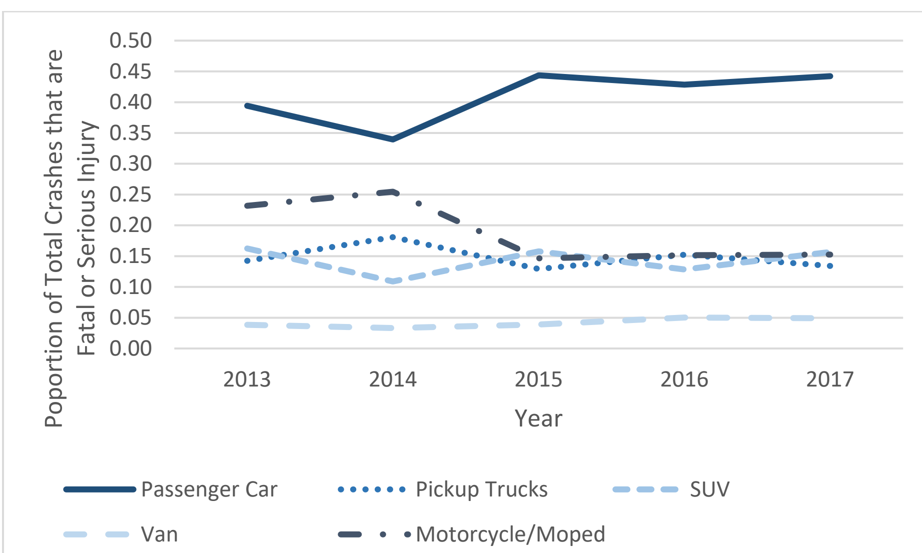


Data Source: North Carolina Department of Transportation

3.4 Characteristics of Vehicles in Fatal and Severe Injury Crashes

Overall, about 40% of the vehicles involved in fatal and severe injury crashes in North Carolina from 2013 to 2017 were categorized as passenger cars, while pickup trucks and SUVs accounted for about 15% of the crashes, as seen in Figure 50. Notably, there was a drop in the proportion of motorcycles/mopeds in 2015 and it remained at a stable level for the following years.

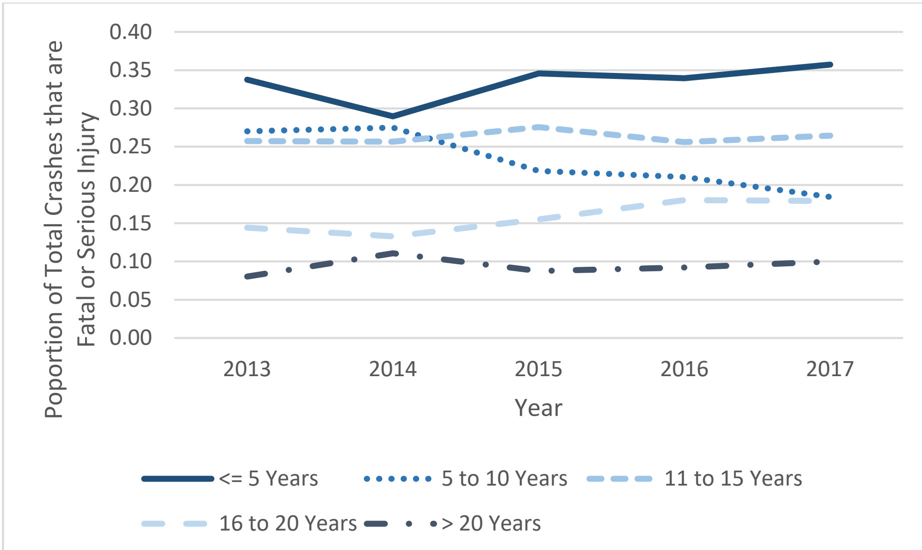
Figure 50: Proportion of Vehicle Types Involved in Fatal and Severe Injury Crashes in North Carolina: 2013–2017



Data Source: North Carolina Department of Transportation

Also, throughout North Carolina, vehicles involved in fatal and severe injury crashes were more likely to be five years old or newer, and least likely to be 20 years old or older, as seen in Figure 51.

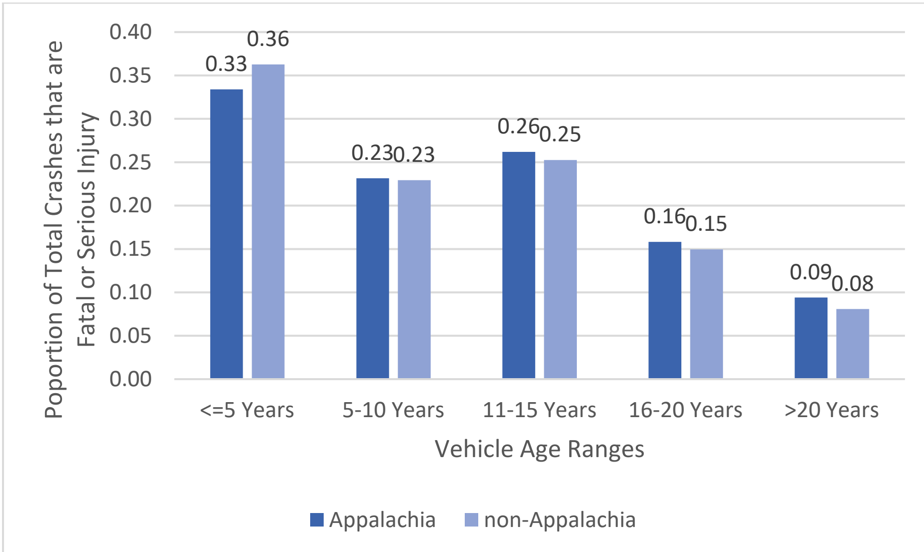
Figure 51: Proportion of Vehicle Age in Fatal and Severe Injury Crashes in North Carolina: 2013–2017



Data Source: North Carolina Department of Transportation

Compared with non-Appalachian counties, a slightly lower percentage of vehicles involved in fatal or severe injury crashes were five years old or newer in Appalachian counties, as seen in Figure 52. However, for vehicles older than five years, the proportion of these vehicles involved in fatal or serious injury crashes in Appalachia was equal to or greater than that of non-Appalachia in North Carolina. These results correspond closely to the results of the FARS analysis, which showed that fatal crash victims in Appalachia tended to drive older vehicles, although the proportion was lower for vehicles older than 20 years in Appalachian North Carolina. As mentioned in the fatal crash analysis, a potential method for improving traffic safety in Appalachia may be to implement financial incentives for drivers to replace older vehicles; this countermeasure may be applicable for North Carolina as well.

Figure 52: Proportion of Fatal and Severe Injury Crashes Involving Vehicles of Different Age Groups in Appalachian and non-Appalachia North Carolina: 2013–2017



Data Source: North Carolina Department of Transportation

3.5 Summary

Overall, there were few major differences between Appalachian and non-Appalachian counties in fatal and severe injury crashes North Carolina. However, several findings are worth noting:

1. The rate of alcohol involvement in fatal and serious injury crashes is lower in North Carolina than in the of alcohol involvement in fatal crashes in the entire Appalachian Region, perhaps indicating a benefit related North Carolina's liquor policies.
2. The North Carolina case study verifies the fatal crash study regarding the dangers of fall driving. Enforcement options should be considered to improve traffic safety in the fall in Appalachia.
3. In both groups of counties, darkness in rural settings seemed to be a salient risk factor for fatal and severe injury crashes. As such, improving lighting on rural roads might have safety benefits for road users.
4. North Carolina drivers seem to benefit from strong seatbelt laws in the state, although the death and injury of unbelted occupants in Appalachian counties indicate a need for universal restraint laws.
5. The proportion of motorcyclists not wearing helmets when involved in a fatal or severe injury crash did increase over the years, mostly in 2016 and 2017, and this trend was evident for both Appalachian counties and non-Appalachian counties. Therefore, motorcycle helmet laws remain relevant for the state.
6. Drivers involved in fatal and serious injury crashes in North Carolina Appalachian counties tend to drive older vehicles, so economic incentives for replacing older vehicles may be an important policy option to improve traffic safety in the Appalachian Region.

While the findings in this section did not directly address crash risk due to a lack of exposure information, they presented a broad picture of fatal and severe injury crashes in North Carolina and potentially provided support for certain points of intervention.

Chapter 4: Evaluation of the Appalachian Development Highway System

4.1 Summary

In this chapter, we evaluate the safety impacts of roadway improvements made as part of the ADHS program. To accomplish this task, we coordinated with ARC and state DOT representatives to acquire and compile crash data, traffic volume data (annual average daily traffic, or AADT), and roadway data for use in evaluation. In this chapter, we discuss the methodology used for analysis, present a summary of the data collection process, present the results of the analysis, and discuss the implications of that analysis.

4.2 Methodology

To perform a quantifiable and meaningful evaluation of the ADHS as a suite of packaged roadway treatments and to measure how that suite of treatments affects traffic safety, we proposed calculations of simple crash rates and development of safety performance functions (SPFs); we then used the SPFs to estimate crash modification factors (CMFs) using the negative binomial regression (referred to as NB hereafter) cross-sectional analysis method for a variety of crash types. In discussion with ARC, we found that two types of treatments typically occur when a roadway is upgraded to an ADHS designation. These upgrades can be grouped as follows:

- Improved alignment: addition of lanes, addition of median, (potential) widening of shoulder, access control, (potential) speed limit change
- New alignment: construction of lanes, construction of median, construction of shoulder, access control

An example of a new alignment treatment to an existing corridor is shown in Figure 53. In this example, the old alignment is KY-1426, a two-lane, undivided highway in Kentucky. This highway had lane widths of 12 feet (ft), shoulder widths ranging from 2 ft to 12 ft, and a speed limit ranging from 35 miles per hour (mph) to 55 mph. There was no access control on this highway. The treatment, a new alignment designated Corridor G, has four lanes, 12-ft lane widths, 12-ft shoulder widths, a 40-ft median, and a speed limit of 55 mph. Access control is limited. Because the treatment consisted of multiple upgrades—addition of lanes, shoulder width widening, addition of a median, partial access control, and change in speed limit—implemented simultaneously, it would be extremely difficult to attribute any improvement in safety performance to any particular upgrade. Therefore, the upgrades are considered together as a new treatment in our analysis.

Figure 53: Example Old Alignment (KY-1426) and New Alignment Treatment (ADHS Corridor G).

Data Source: Appalachian Regional Commission

4.2.1 Cross-Sectional Studies

As mentioned previously, the goal of this chapter is to compare safety performance between old roadways in the Region and the upgraded ADHS corridors. To perform this comparison, we settled on a two-step analysis. First, we calculated simple crash rates for the old corridors and the new corridors to facilitate DOT comparisons between upgraded and non-upgraded roadways. This simple comparison, however, is not without limitations, so we also calculated CMFs. The second analysis, then, is a CMF comparing upgraded roadways as distinct facilities to non-upgraded facilities, with the new alignment or improved alignment treatment serving as the variable of comparison. As part of this analysis we also developed models wherein the system of roadways after treatment (i.e., the new alignment plus old alignment) are compared to the old alignment before treatment.

The crash rates are calculated as the rate per 100 million vehicle miles of travel (RMVM), as shown in the following equation.

$$RMVM = (A * 100{,}000{,}000)/(AADT * L * 365)$$

where *RMVM* is the rate per million vehicle miles (here we use 100 million), *A* is the number of crashes in a given year, *AADT* is the annual average daily traffic on a specific roadway, *L* is the length of that roadway, and 365 is the number of days in a year (in calculations we use 366 for leap years). Crash rates give a quick estimate of the safety performance of a roadway, but they do not account for major changes to traffic volumes or the roadway environment. Additionally, a linear relationship between traffic volume and number of crashes is assumed, but this assumption is often invalid. This bias can obfuscate the true relationship between safety and roadway properties due to extreme or aberrant fluctuations in the data; that is to say, assumptions regarding performance at high and low volumes may lead to aberrant crash predictions. Therefore, these rate estimates give rough ideas of safety, but they do not capture the full safety performance of a roadway.

To perform the second analysis type, we used NB regression and the cross-sectional method to build the SPFs that would enable us to specify the CMFs for the ADHS treatments. This predictive method generally follows the development of predictive models outlined in the *Highway Safety Manual* (HSM) (209) with some specific considerations given to data functional form, as outlined by Ezra Hauer (210,211). The HSM method suggests the development of SPFs as generalized linear models that allow practitioners to predict the number of crashes that might occur on a specific roadway given the prevailing traffic conditions and roadway properties. The following is an example SPF for two-lane highway segments in the HSM (209):

$$SPF = AADT * L * 365 * 10^{-6} * e^{-0.4865}$$

where *SPF* is the number of predicted crashes per year, *AADT* is the annual average daily traffic, and *L* is the length of the corridor.

There are two methods commonly used to assess the safety efficacy of a treatment on a roadway. The first is the Empirical Bayes (EB) method, which requires detailed data on the before-and-after conditions of a roadway. Although we collected crash and volume data for each corridor before and after treatment, as possible, the nature of the ADHS treatment made analyzing the corridors in this manner difficult due to limited before/after years for the treatment sites. The second method, which we used in this study, is a cross-sectional analysis. This method is often used when construction dates are unknown or when it is difficult to collect sufficient data before and after a project's completion. For the cross-sectional analysis for the ADHS treatment, a dummy variable indicating the after period at the treatment sites was included in the model, allowing us to derive the CMF from the parameter estimate of this dummy variable. The exponent of this parameter's coefficient is the value of the CMF. The value of this CMF gives an estimate of the effectiveness of the treatment (209,212).

For the purpose of the ADHS evaluation, we considered the ADHS treatment as either the effect of an improved alignment or the effect of a new alignment on traffic safety. Therefore, the goal of this evaluation was to develop a CMF that would answer the question of how many crashes can be expected on an upgraded corridor in comparison to a non-upgraded version of that corridor carrying the same traffic volume (212). Based on this definition, the CMF for this treatment is essentially of the form below (based on the general form in the HSM [210]) as:

$$CMF = \frac{Predicted\ Average\ Crash\ Frequency\ with\ ADHS\ Treatment}{Predicted\ Average\ Crash\ Frequency\ without\ ADHS\ Treatment}$$

where CMF is the crash modification function for the ADHS treatment.

As mentioned previously, we developed two different sets of cross-sectional CMFs, each of which captures a different assumption about the nature of the ADHS roadways. The first set assumes that all traffic carried by a non-upgraded corridor will be carried by an upgraded corridor after treatment. This assumption essentially results in a pure comparison of the upgraded roadways as the treatment group and the non-upgraded roadways (i.e., the existing highway without treatment) as the base group. The second set assumes that some amount of traffic will be split between new alignment and old alignment after treatment and that, therefore, the proper comparison to conduct is between the system of roadways that replaced the old roadway; that is, an accurate assessment of safety should consider the safety performance of both the new alignment and old alignment after construction compared to the old alignment before construction with the same amount of traffic volume.

In both assumptions, the reference corridors and treatment corridors in the before period were used to develop the SPFs used to predict crashes on the treatment corridors based on traffic properties. Observed crashes are all crashes in the data, and these are divided into both "before" and "after" periods. These "before" and "after" periods differ depending on treatment type (improved alignment or new alignment), as shown in Table 45. Note that construction start/end years were excluded for calculating the total crashes in the before/after periods. As the main objective of this study is to evaluate the safety effects of the new alignment/improvement alignment, we excluded work-zone and animal-related crashes since these two factors are not directly associated with projects or no longer had effects after construction was done.

Table 45: Explanations of "Before" and "After" Periods for Crash Data for Old Alignments, Improved Alignments, and New Alignments

Treatment Type	Crashes in Before Period	Crashes in After Period
Old Alignment	All crashes occurring on the old alignment before construction occurred (in the case construction might have affected safety on old alignment (i.e., too close)) or before the new corridor was opened to traffic (in the case of new alignment)	Crashes occurring on the old alignment after construction of new alignment are summed with crashes occurring on the new alignment in a single after period
Improved Alignment	All crashes occurring before construction was initiated on the corridor	All crashes occurring after construction was completed on the corridor
New Alignment	Note that a "before" period does not exist for new alignment	All crashes occurring on the new alignment after the corridor was opened to traffic

One frequently overlooked limitation of predictive methods is the functional form of the individual variables used in the estimation of SPFs. If multiple roadway features are used as variables in predicting crashes, these variables may each have specific functional data forms that can provide goodness of fit to the data or, on the negative side, create a predictive model that is stripped of its ability to meaningfully predict crashes in a real-world scenario (210,211). To circumvent this concern, we checked the cumulative residual (CURE) plots for each variable compared to crashes. CURE plots are essentially figures depicting the confidence boundaries of predictive variables based on the cumulative differences between predicted crashes and observed crashes. Variables with functional forms that stay within these bounds typically provide better goodness of fit. A discussion of CURE plots and regression modeling is beyond the scope of this report, but more information can be found in Hauer's book (211).

4.2.2 Data Cleaning

To facilitate the model development, we spent time cleaning and preparing the data for analysis. This proposed analysis is unusual for two reasons. First, it requires data to be compiled from multiple states into a single sample. This compilation was necessary due to the limited data we were able to collect from any one treatment corridor. For most of the corridors in the study, we were unable to use all of the years of crash data collected because construction periods were long and had to be excluded to prevent errors due to inclusion of crashes caused by construction. See the discussion of "before" and "after" periods in this chapter. Due to this limitation, we were unable to perform the type of state-by-state comparison that is common when evaluating treatments (213).

The second reason the proposed analysis is unusual is the nature of the ADHS treatment itself. As stated earlier, the ADHS treatment is more properly considered a suite of treatments. In safety evaluation, countermeasures are typically assessed for efficacy one by one, with CMFs developed per individual countermeasure. If we want to measure the effects of multiple treatments, the HSM recommends multiplying the CMFs together (209).

However, for this study, given our interest in analyzing the potential of the ADHS treatment as a whole for crash mitigation, we instead considered the range of improvements made to the roadways (addition of lanes, shoulder widening, access control, roadway division, etc.) as a single treatment. As mentioned previously, this treatment can happen in one of two ways, either through improvement of the existing alignment or construction of new alignment. Thankfully, there is some precedent for using suite-style treatment to evaluate the combined effects of multiple improvements at once. One such study that informed our modeling development was the evaluation of bypass roads conducted by Cena et al. (214,215). These researchers evaluated the potential safety benefits of splitting traffic off existing highways through town onto new highways that bypassed population centers. The researchers developed predictive models based on the number of crashes per mile and carefully observed the effect of shifts in traffic volume along the main highway and bypass highway. We concluded, after discussions with ARC, that the new alignment treatment is similar to the bypass treatment; therefore, the ADHS upgrade can be evaluated in the same manner.

However, preparing the dataset from multiple states required the elimination of potentially confounding subsets of data from the model. The reasons for expunging these crash data include the following:

1. The crash type was denoted as an animal-vehicle crash, and we cannot account for the effect of this non-engineering element in the data.
2. For the improved alignment corridors, the crash occurred during the construction period, and we cannot reasonably assume stable traffic flow and lack of interaction with work zone equipment during these periods.
3. For the improved alignment, the construction period was sufficiently long to effectively preclude a "before" period, resulting in no way to properly assess a "before-after" relationship.

4. Crashes occurred in a work zone.

After eliminating crash data that could not be used for analysis, we also needed to clean and prepare the data into a uniform set. Although all crash data are collected using police-reported crash forms, states inconsistently categorize and label these data. Therefore, we needed to address the following issues in the subsets of crash data:

- Time of crash was listed inconsistently, with these times listed in military time, 12-hour time with a.m. or p.m., or in some aberrant text format in the data. Some manual changes to time were necessary.
- Not all states used the single-vehicle or multi-vehicle indicator. For the crashes from Virginia, we assigned crashes with the appropriate typing (1—rear end; 2—angle; 3—head on; 4—sideswipe—same direction; 5—sideswipe—opposite direction) to multi-vehicle crashes and crashes with the appropriate typing (6—fixed object in road; 9—fixed object—off road) to single-vehicle crashes.
- States either designated the “light condition” differently or did not include this variable in the requested dataset, so we instead defined nighttime crashes as those occurring between 7:00 p.m. and 7:00 a.m. from November to February and between 8:00 p.m. and 6:00 a.m. from March to October.

After accounting for these potential issues, we were able to analyze the effect of the ADHS treatment using the final dataset listed in Tables 46 and 47.

4.2.3 Model Fitting

To find the best-fitting CMF for the ADHS treatment, we tested multiple combinations of explanatory variables for each crash type of interest. We evaluated these combinations by checking statistical significance per variable (at the $p<0.05$ level) and the CURE plots for predicted values for each crash type for accuracy of predicted crashes. After that, we arrived at a final set of SPFs and CMFs for the different crash types.

4.2.4 ADHS Upgrades

Treatment Corridor Selection

To guide our data collection effort, ARC provided a data shell of ADHS corridors, including both improved alignments and additional alignments. This data shell is a condensed sample of completed ADHS corridors and does not contain all corridors in the ADHS system. The data shell lists corridors in Alabama, Kentucky, Mississippi, North Carolina, New York, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia. After further discussion with ARC, we decided to limit our data collection efforts to a subset of the corridors in the data shell. These corridors are shown in Table 46.

To properly link data and allow for more accurate evaluation, we assigned a site identification code (ID) to each ADHS treatment corridor. In cases where individual segments had unique properties along the same corridor, we also assigned Segment ID numbers to each segment. These ID numbers can be seen in Table 46.

Unfortunately, due to issues discussed further in this chapter on crash data collection, we ultimately excluded Alabama and West Virginia corridors from the study, resulting in a smaller subset of corridors from Kentucky, Mississippi, North Carolina, Ohio, Tennessee, and Virginia. As will be discussed later in this chapter, the data requirements of SPF and CMF development are substantial; including all of the corridors in the sample data shell was beyond the scope of this project.

Each of the corridors in the sample subset shown in Table 46 corresponds to an old roadway, referred to hereafter as the “old alignment.” Most of the engineering properties of these old alignments, including lane width, number of access points, horizontal curvature, speed limit, etc. were unknown. To fill in these gaps and to generate a sufficiently robust dataset for evaluation, we coordinated with ARC and state DOT representatives to retrieve multiple data types, including the following:

1. Crash data
2. Traffic volume (AADT)
3. Roadway properties and project dates

Each of these data types is discussed in the following subsections.

Table 46: ADHS Corridors Initially Chosen for Analysis

State	Corridor	Project Description	Official ADHS Section Designation	Completion Type	Old Alignment	Corridor ID	Segment ID
KY	G	North of Pikeville to east of Meta in Pike County	G 02.0.0	New Alignment	KY-1426	T-002	T-002-1
KY	G	East of Meta in Pike County	G 02.1.0	New Alignment	KY-1426	T-002	T-002-2
KY	Q	South of Pikeville in Pike County	Q 01.0.0	New Alignment	US 460	T-003	T-003-1
KY	Q	East of Greasy Creek in Pike County	Q 01.1.0; Q 02.0.0; Q 02.2.0	New Alignment	US 460	T-003	T-003-2
KY	Q	East of Greasy Creek in Pike County	Q 02.1.0	New Alignment	US 460	T-003	T-003-3
MS	V	From State Route 23 to Alabama state line in Itawamba County	A 12.2.0	New Alignment	SR 23	T-004	T-004-1
NC	K	Rount Top in Graham County	K 08.6.0	Improved Alignment	SR 28	T-005	T-005-1
OH	C1	South of Chillicothe in Ross County	C1 02.0.0	New Alignment	Old US 35	T-006	T-006-1
TN	J	South of Spencer in Van Buren County	J 14.1.0	Improved Alignment	SR 111	T-007	T-007-1

State	Corridor	Project Description	Official ADHS Section Designation	Completion Type	Old Alignment	Corridor ID	Segment ID
TN	J	At the border between Overton and Clay Counties	J 26.8.0	New Alignment	SR 52	T-008	T-008-1
VA	Q	In Grundy of Buchanan County	Q 05.2.0	New Alignment	US 460	T-009	T-009-1
VA	Q	South of Grundy in Buchanan County	Q 05.8.0	New Alignment	US 460	T-009	T-009-2
VA	Q	South of Grundy in Buchanan County	Q 7.2.0	New Alignment	US 460	T-009	T-009-3

Data Source: Appalachian Regional Commission

Reference Corridor Selection

We used the cross-sectional method for development of SPFs and CMFs. This method requires a robust SPF to predict number of crashes for each crash type on corridors where the treatment was not implemented. In order to develop robust SPFs, additional sites, hereafter referred to as "reference corridors," which are similar to the old alignment of treatment corridors, are needed. Then the efficacy of the engineering treatment, in this case either improvement of alignment or construction of new alignment, can be correctly identified.

Based on the above requirement for the EB method, we compiled a list of at least five reference corridors per state to supply the necessary sample of reference crashes in the dataset. We selected these corridors for consistency with the old alignments shown in Table 46. Specifically, we used Google Maps® and consulted with state DOT representatives to locate two-lane undivided highway corridors near the treatment sites and with uncontrolled access. The reference corridors we identified per state are shown in Table 47, as are the corresponding ADHS corridors. The ID numbers assigned to each reference and corresponding treatment corridor are shown in Table 47 as well.

Table 47: Reference Corridors Identified for Evaluation of ADHS Treatment

State	Reference Corridor Description	Reference Corridor ID	Beginning Coordinates	Ending Coordinates	Corresponding ADHS Treatment Corridor	Treatment Corridor ID
KY	KY 194 from US 119 to KY 632	R-006	37.5581, -82.4237	37.4976, -82.3495	G G2.0.0–G G2.1.0	T-002
KY	KY 632 from KY 194 to KY 199	R-007	37.4976, -82.3495	37.4935, -82.2501	G G2.0.0–G G2.1.0	T-002
KY	KY 199 from US 119 to KY 1056	R-008	37.5979, -82.2769	37.5599, -82.2592	G G2.0.0–G G2.1.0	T-002
KY	KY 194 from KY 1499 to KY 2060	R-009	37.4302, -82.2687	37.4605, -82.1326	G G2.0.0–G G2.1.0	T-002
KY	KY 194 from KY 632 to KY 319	R-010	37.5146, -82.1523	37.5637, -82.1460	G G2.0.0–G G2.1.0	T-002
KY	KY 80 from KY 195 to US 460	R-011	37.3681, -82.4127	37.3420, -82.3750	Q 1.0.0–Q 2.2.0	T-003
KY	KY 80 from US 460 to KY 1373	R-012	37.3420, -82.3750	37.3137, -82.3589	Q 1.0.0–Q 2.2.0	T-003
KY	KY 195 from KY 80 to new US 460	R-013	37.3681, -82.4127	37.3435, -82.4224	Q 1.0.0–Q 2.2.0	T-003
KY	KY 195 from new US 460 to KY 611	R-014	37.3435, -82.4224	37.3136, -82.4680	Q 1.0.0–Q 2.2.0	T-003
KY	KY 122 from Bear Fork St. to US 23	R-015	37.3861, -82.5763	37.3872, -82.5394	Q 1.0.0–Q 2.2.0	T-003
MS	MS 23 from Mt. Gilead Rd. to MS 76	R-016	34.3292, -88.2124	34.4036, -88.1986	V A12.2.0	T-004
MS	MS 25 from Burntfields Rd. to Ryan Salem Rd.	R-017	34.3669, -88.3177	34.4109, -88.2953	V A12.2.0	T-004
MS	MS 178 from E of MS 25 to MS 23	R-018	34.2629, -88.3258	34.2361, -88.2634	V A12.2.0	T-004
MS	MS 23 from MS 178 to Mt. Gilead Rd.	R-019	34.2361, -88.2634	34.3292, -88.2124	V A12.2.0	T-004
MS	MS 178 from MS 23 to State Line Rd.	R-020	34.2361, -88.2634	34.2191, -88.2106	V A12.2.0	T-004
NC	NC 28 from NC 143 to SR 1235	R-021	35.3784, -83.7102	35.3743, -83.6730	K 8.6.0	T-005
NC	NC 143 from SR 1219 to NC 28	R-022	35.3306, -83.7678	35.3784, -83.7102	K 8.6.0	T-005
NC	NC 28 from SR 1241 to NC 143	R-023	35.4089, -83.7193	35.3784, -83.7102	K 8.6.0	T-005

State	Reference Corridor Description	Reference Corridor ID	Beginning Coordinates	Ending Coordinates	Corresponding ADHS Treatment Corridor	Treatment Corridor ID
NC	NC 28 from SR 1267 to SR 1241	R-024	35.4202, -83.7288	35.4089, -83.7193	K 8.6.0	T-005
NC	NC 28 from SR 1287 to SR 1267	R-025	35.4229, -83.7614	35.4202, -83.7288	K 8.6.0	T-005
OH	CR 222 from US 23/35 to CR 223	R-026	39.3384, -82.9480	39.3296, -82.8742	C1 2.0.0	T-006
OH	OH 772 from CR 159 to CR 602	R-027	39.2900, -83.0542	39.3183, -82.9793	C1 2.0.0	T-006
OH	OH 28 from CR 100 to US 50	R-028	39.3529, -83.1462	39.3482, -83.0637	C1 2.0.0	T-006
OH	OH 138 from CR 72 to US 35	R-029	39.4075, -83.2955	39.4483, -83.2154	C1 2.0.0	T-006
OH	OH 207 from CR 97 to CR 101	R-030	39.4949, -83.1390	39.4667, -83.1001	C1 2.0.0	T-006
TN	TN 284 from Piney Rd. to Fall Creek Rd.	R-031	35.6322, -85.4567	35.6229, -85.4246	J 14.1.0	T-007
TN	TN 8 from Curtistown Rd. to Grissom Rd.	R-032	35.5826, -85.5780	35.5419, -85.5263	J 14.1.0	T-007
TN	TN 30 from Laurelburg Rd. to Mitchell Hollow Rd.	R-033	35.7341, -85.5892	35.7355, -85.5506	J 14.1.0	T-007
TN	TN 285 from TN 111 to Hickory Valley Rd.	R-034	35.8078, -85.4586	35.8027, -85.4282	J 14.1.0	T-007
TN	TN 285 from TN 30 to Turkey Scratch Rd.	R-035	35.7425, -85.3928	35.7707, -85.4032	J 14.1.0	T-007
TN	TN 52 from Hidden Cove Ln. to TN 136	R-036	36.4883, -85.3975	36.4897, -85.4028	J 26.8.0	T-008
TN	TN 52 from Livingston Boatdock Rd. to Fletcher Cir.	R-037	36.4768, -85.3755	36.4815, -85.3889	J 26.8.0	T-008
TN	TN 136 from W J Davis Ln. to TN 52	R-038	36.4891, -85.4057	36.4897, -85.4028	J 26.8.0	T-008
TN	TN 294 from Old Stover Rd. to Oakley Allons Rd.	R-039	36.4982, -85.3010	36.5077, -85.3107	J 26.8.0	T-008
TN	TN 294 from Joe D Coffee Rd. to Old Eagle Creek Rd.	R-040	36.4415, -85.2694	36.4492, -85.2733	J 26.8.0	T-008

State	Reference Corridor Description	Reference Corridor ID	Beginning Coordinates	Ending Coordinates	Corresponding ADHS Treatment Corridor	Treatment Corridor ID
VA	VA 83 from E of US 460 to Hurley Rd.	R-041	37.2786, -82.0981	37.2807, -82.0890	Q 5.2.0–Q 7.2.0	T-009
VA	VA 83 from Mill Branch Rd. to VA 686	R-042	37.2865, -82.0765	37.2864, -82.0612	Q 5.2.0–Q 7.2.0	T-009
VA	US 460 from VA 604 to VA 656	R-043	37.3073, -82.1558	37.3100, -82.1295	Q 5.2.0–Q 7.2.0	T-009
VA	US 460 from VA 656 to Southerland Hill Dr.	R-044	37.3100, -82.1295	37.2906, -82.1256	Q 5.2.0–Q 7.2.0	T-009
VA	VA 83 from VA 619 to VA 620	R-045	37.2121, -82.1144	37.2195, -82.1030	Q 5.2.0–Q 7.2.0	T-009

Data Source: Various State Departments of Transportation and Appalachian Regional Commission

4.3 Data Collection

4.3.1 Crash Data Collection

We corresponded with ARC to identify both ARC liaisons to each of the eight states represented in the dataset, and potential DOT representatives who could provide crash data. We then spent the first six months of the project contacting both the ARC representatives and the state DOT representatives to request crash data for all of the treatment and reference corridors. Specifically, we requested the following crash data variables:

- Severity
- Date
- Time
- Milepost
- Route number
- Crash type
- Number of vehicles
- Weather
- Pavement condition
- Light condition
- Animal-related
- Work-zone-related
- City/town/district name

For each corridor, we requested at least 10 years of crash data. However, some state DOTs do not grant access to older data or have limitations or restrictions on the years of data that can be provided at one time. In addition, the construction start and end dates were not the same in the different treatment corridors. Due to these issues, we only obtained a few years of crash data for the “before improvement” period and/or the “after improvement” period for certain corridors. The effect of construction on the crash data also necessitated the preclusion of some years of data from the analysis because the construction period of an upgrade from old alignment to improved alignment could not be accurately considered a pure “before” set of crash data. Therefore, we collected as much crash data as possible for all of the reference corridors, but there were some limitations to the final set.

Unfortunately, during the course of data collection, we were unable to connect with representatives from West Virginia and Alabama. Therefore, the final dataset only consisted of crash data from Kentucky, Mississippi, North Carolina, Ohio, Tennessee, and Virginia.

Of the six states in the dataset, we directly received the requested crash data from DOT representatives in Mississippi, North Carolina, Ohio, and Tennessee. The contact at Kentucky Transportation Cabinet referred us to Kentucky’s State Police data portal (216). The contact at Virginia DOT referred us to Virginia’s public tableau Crash Analysis Tool (217). Therefore, for Kentucky and Virginia crash data, we collected crash data for as many years as possible for all treatment and reference corridors.

After collecting crash data for all study corridors, we separated crashes for the treatment sites into “before” periods and “after” periods based on project start and end dates and type of treatment. This separation was needed to measure the effect of the ADHS upgrade on the treatment sites using cross-sectional methodology, where the improved and new alignments act as distinct treatments from the old roadways.

Tables 48 through 54 show the crash data collected for each of the six states. These data tables show the minimum, maximum, and average number of crashes for all reference sites and treatment sites used in the dataset. Standard deviations and sums are also provided as applicable. We have also developed a GIS shapefile with crashes linked to the corresponding identification numbers shown in Table 46.

Table 48 shows the aggregated crash data by corridor type for the Kentucky roads in the dataset. For reference corridors, we retrieved 15 years of crash data for all corridors, totaling 2,080 crashes. For the treatment corridors, we retrieved seven years of crash data per corridor on average (with a range of three years to nine years per corridor) for the “before” period, totaling 812 total crashes. For the “after” period, we retrieved seven years of crash data per corridor on average (with a range of five years to 11 years per corridor), totaling 585 crashes in the treatment group. Note that because this treatment type is new alignment, the “before” period corresponds to all crashes occurring on the treatment corridors prior to the new alignment being opened for traffic, and the “after” period corresponds to all crashes occurring on both the new and old alignments after the new alignments were opened to traffic. Due to the fact that Kentucky had two treatment corridors available for analysis (T-002 and T-003) with five segments across those corridors, we collected data from ten comparable reference corridors. These efforts resulted in the largest subset of data from any of the states in the dataset.

Table 48: Summary Statistics for Crashes by Corridor Type in Kentucky

Corridor Type	Crash Type	Years of Crash Data	Minimum Annual Crash Count	Maximum Annual Crash Count	Mean Annual Crash Count	Standard Deviation	Sum
Reference Corridors	Total	15	0	49	13.9	9.8	2080
	Injury	15	0	20	5.8	4.6	866
	Single-Vehicle	15	0	23	6.4	5	954
	Multi-Vehicle	15	0	28	7.5	6.1	1126
	Nighttime	15	0	11	3.2	2.6	482
Treatment Corridors (Before Period)	Total	9 (max)	0	79	23.2	26.6	812
	Injury	9 (max)	0	38	9	10.7	314
	Single-Vehicle	9 (max)	0	58	17.6	21.1	617
	Multi-Vehicle	9 (max)	0	21	5.6	6.1	195
	Nighttime	9 (max)	0	18	4.2	5.2	146
Treatment Corridors (After Period)	Total	11 (max)	1	46	16.7	14.1	585
	Injury	11 (max)	0	17	6	5.5	210
	Single-Vehicle	11 (max)	0	32	9.9	9.2	348
	Multi-Vehicle	11 (max)	0	20	6.8	5.8	237
	Nighttime	11 (max)	0	11	3.2	3.3	113

Data Source: Kentucky State Police Department

Table 49 shows the crash data collected for Mississippi for all study corridors included in the final analysis. There were fewer crashes in the Mississippi dataset than there were for Kentucky, likely due partially to the fact that we only included one treatment corridor in the analysis, and that treatment corridor was only 2.4 miles long. For reference corridors, we received 12 years of crash data per corridor, totaling to 173 crashes. For the “before” period for the treatment corridor, we collected five years of crash data with a total of 16 crashes across those five years. For the “after” period for the treatment corridor, we collected six years of crash data with a total of 20 crashes across those six years. Note that because the Mississippi corridor (T-004) was upgraded with new alignment, the “before” period represents all crashes occurring on the old alignment prior to traffic opening on the new alignment, and the “after” period represents all crashes occurring on the old and new alignment prior to traffic opening on the new alignment.

Table 49: Summary Statistics for Crashes by Corridor Type in Mississippi

Corridor Type	Crash Type	Years of Crash Data	Minimum Annual Crash Count	Maximum Annual Crash Count	Mean Annual Crash Count	Standard Deviation	Sum
Reference Corridors	Total	12	0	13	2.9	2.3	173
	Injury	12	0	5	1.2	1.2	74
	Single-Vehicle	12	0	6	1.1	1.2	68
	Multi-Vehicle	12	0	7	1.8	1.5	105
	Nighttime	12	0	3	0.7	0.8	39
Treatment Corridors (Before Period)	Total	5	0	7	3.2	2.8	16
	Injury	5	0	4	1.6	1.8	8
	Single-Vehicle	5	0	5	2	2.3	10
	Multi-Vehicle	5	0	3	1.2	1.3	6
	Nighttime	5	0	1	0.2	0.4	1
Treatment Corridors (After Period)	Total	6	1	8	3.3	2.5	20
	Injury	6	1	4	2	1.3	12
	Single-Vehicle	6	0	5	2.2	1.7	13
	Multi-Vehicle	6	0	3	1.2	1	7
	Nighttime	6	0	2	0.8	0.8	5

Data Source: Mississippi Department of Transportation

Table 50 presents the crash data for the North Carolina corridors. As with Mississippi, North Carolina was represented by only one treatment corridor, resulting in fewer crashes in the sample than those from Kentucky. For the reference corridors, we collected 11 years of crash data per corridor, totaling 185 crashes. For the “before” period of the treatment corridor, we collected five years of crash data, totaling only four crashes. For the “after” period of the treatment corridor, we collected five years of crash data, with a total of only seven crashes across those five years. This North Carolina treatment corridor (Y-005) is also relatively short, perhaps explaining the sparse crash frequency. Note that this treatment type was an improved alignment, so the “before” period corresponds to crashes that occurred prior to construction, and the “after” period corresponds to crashes that occurred after construction was finished.

Table 50: Summary Statistics for Crashes by Corridor Type in North Carolina

Corridor Type	Crash Type	Years of Crash Data	Minimum Annual Crash Count	Maximum Annual Crash Count	Mean Annual Crash Count	Standard Deviation	Sum
Reference Corridors	Total	11	0	19	3.4	3.5	185
	Injury	11	0	12	1.7	2	93
	Single-Vehicle	11	0	7	0.8	1.3	46
	Multi-Vehicle	11	0	12	2.5	2.5	139
	Nighttime	11	0	7	0.9	1.4	50
Treatment Corridors (After Period)	Total	5	0	3	1.4	1.3	7
	Injury	5	0	2	0.6	0.9	3
	Single-Vehicle	5	0	2	0.8	0.8	4
	Multi-Vehicle	5	0	2	0.6	0.9	3
	Nighttime	5	0	1	0.2	0.4	1

Data Source: North Carolina Department of Transportation

Table 51 shows the crashes from the Ohio subset used in the evaluation. We received data for one treatment corridor (T-006), with ten years of crash data totaling to 276 crashes. We collected a total of 10 years of crash data for the reference corridors, totaling 415 crashes. For treatment sites, we found a total of 276 crashes over ten years.

Table 51: Summary Statistics for Crashes by Corridor Type in Ohio

Corridor Type	Crash Type	Years of Crash Data	Minimum Annual Crash Count	Maximum Annual Crash Count	Mean Annual Crash Count	Standard Deviation	Sum
Reference Corridors	Total	10	0	21	8.3	5.4	415
	Injury	10	0	9	3.1	2.3	154
	Single-Vehicle	10	0	9	3	2.5	149
	Multi-Vehicle	10	0	13	5.3	3.7	266
	Nighttime	10	0	9	2.5	2.1	124
Treatment Corridors (After Period)	Total	10	17	41	27.6	7.4	276
	Injury	10	2	13	6.3	3.7	63
	Single-Vehicle	10	3	16	8.8	4.5	88
	Multi-Vehicle	10	14	28	18.8	4.5	188
	Nighttime	10	5	14	9	2.9	90

Data Source: Ohio Department of Transportation

Table 52 presents the crash data used in this evaluation from Tennessee. For this state, we were able to collect eight years of crash data on both reference corridors and treatment corridors. For reference corridors, we found 64 total crashes, and for treatment corridors, we found 18 total crashes.

Table 52: Summary Statistics for Crashes by Corridor Type in Tennessee

Corridor Type	Crash Type	Years of Crash Data	Minimum Annual Crash Count	Maximum Annual Crash Count	Mean Annual Crash Count	Standard Deviation	Sum
Reference Corridors	Total	8	0	7	0.8	1.3	64
	Injury	8	0	3	0.3	0.6	27
	Single-Vehicle	8	0	4	0.3	0.7	25
	Multi-Vehicle	8	0	4	0.5	0.9	39
	Nighttime	8	0	1	0.2	0.4	13
Treatment Corridors (After Period)	Total	8	0	5	1.4	1.8	18
	Injury	8	0	1	0.3	0.5	4
	Single-Vehicle	8	0	3	0.8	1.3	11
	Multi-Vehicle	8	0	3	0.5	1	7
	Nighttime	8	0	1	0.2	0.4	3

Data Source: Tennessee Department of Transportation

Table 53 presents the crash data for the Virginia corridors. For the reference corridors, we collected 192 total crashes across 13 years. For the “before” period of the treatment corridors, we collected an average of 6.3 years of crash data for all corridors (with a range of one year to nine years), totaling 58 crashes. For the “after” period of the treatment corridors, we collected an average of five years of crash data (with a range of three years to nine years), totaling to only 20 crashes in the “after” period. Note that for the Virginia corridors (the segments of T-009), the treatment type was new alignment, so the “before” period consists of all crashes occurring on the old alignments prior to traffic opening on the new alignments, and the “after” period consists of all crashes occurring on the new and old alignments after traffic opened on the new alignments.

Table 53: Summary Statistics for Crashes by Corridor Type in Virginia

Corridor Type	Crash Type	Years of Crash Data	Minimum Annual Crash Count	Maximum Annual Crash Count	Mean Annual Crash Count	Standard Deviation	Sum
Reference Corridors	Total	13	0	12	3	2.4	192
	Injury	13	0	8	1.6	1.7	105
	Single-Vehicle	13	0	8	1.9	1.8	123
	Multi-Vehicle	13	0	6	1.1	1.2	69
	Nighttime	13	0	3	0.5	0.8	31
Treatment Corridors (Before Period)	Total	9 (max)	0	8	4.1	2.7	58
	Injury	9 (max)	0	4	1.8	1.2	25
	Single-Vehicle	9 (max)	0	7	3.8	2.5	53
	Multi-Vehicle	9 (max)	0	1	0.4	0.5	5
	Nighttime	9 (max)	0	2	0.3	0.6	4
Treatment Corridors (After Period)	Total	9 (max)	0	5	1.3	1.4	20
	Injury	9 (max)	0	3	0.5	0.8	7
	Single-Vehicle	9 (max)	0	4	0.9	1.2	14
	Multi-Vehicle	9 (max)	0	2	0.4	0.6	6
	Nighttime	9 (max)	0	1	0.1	0.3	1

Data Source: Virginia Department of Transportation

Table 54 shows the summary statistics for total, injury, single-vehicle, multi-vehicle, and nighttime crashes for the full dataset based on treatment type. All six of the sample states (Kentucky, Mississippi, North Carolina, Ohio, Tennessee, and Virginia) contributed to the reference corridor crash subset, and all six states contributed to the treatment corridor crash subset. In total, we collected 4,921 crashes for this evaluation, 3,109 of which occurred on reference corridors, and 1,812 occurred on treatment corridors. Of those treatment corridors, a substantially larger number of crashes occurred on the new alignment type corridors compared to the improved alignment corridors. Of the 1,812 treatment crashes, 1,759 occurred on new alignment. For these reasons, the results of the evaluation may be more applicable to new-alignment-type treatments.

Table 54: Summary Statistics for Crashes by Corridor Type for Full Dataset

Corridor Type	Crash Type	Years of Crash Data	Minimum Annual Crash Count	Maximum Annual Crash Count	Mean Annual Crash Count	Standard Deviation	Sum
Reference Corridors	Total	15 (max)	0	49	6.8	8.1	3109
	Injury	15 (max)	0	20	2.9	3.6	1319
	Single-Vehicle	15 (max)	0	23	3	4	1365
	Multi-Vehicle	15 (max)	0	28	3.8	4.8	1744
	Nighttime	15 (max)	0	11	1.6	2.2	739
Improved Alignment Treatment Corridors (Before Period)	Total	5 (max)	5	8	6.8	1.5	27
	Injury	5 (max)	2	3	2.5	0.6	10
	Single-Vehicle	5 (max)	5	7	6.3	1	25
	Multi-Vehicle	5 (max)	0	1	0.5	0.6	2
	Nighttime	5 (max)	0	2	0.8	1	3
Improved Alignment Treatment Corridors (After Period)	Total	9 (max)	0	5	1.2	1.5	26
	Injury	9 (max)	0	2	0.3	0.6	7
	Single-Vehicle	9 (max)	0	3	0.8	1.1	16
	Multi-Vehicle	9 (max)	0	3	0.5	0.9	10
	Nighttime	9 (max)	0	1	0.2	0.4	4
New Alignment Treatment Corridors (Before Period)	Total	9 (max)	0	79	17.2	24.1	859
	Injury	9 (max)	0	38	6.7	9.6	337
	Single-Vehicle	9 (max)	0	58	13.1	18.9	655
	Multi-Vehicle	9 (max)	0	21	4.1	5.6	204
	Nighttime	9 (max)	0	18	3	4.8	148

Corridor Type	Crash Type	Years of Crash Data	Minimum Annual Crash Count	Maximum Annual Crash Count	Mean Annual Crash Count	Standard Deviation	Sum
New Alignment Treatment Corridors (After Period)	Total	11 (max)	0	46	14.3	13.9	900
	Injury	11 (max)	0	17	4.6	4.9	292
	Single-Vehicle	11 (max)	0	32	7.3	8	462
	Multi-Vehicle	11 (max)	0	28	7	7.4	438
	Nighttime	11 (max)	0	14	3.3	3.9	209

Data Source: State Departments of Transportation and Kentucky State Police Department

4.3.2 Traffic Volume Data Collection

In addition to crash data, we also requested that each state DOT representative provide the AADT values for each year of the "before" and "after" periods (i.e., at least five years of data per period). However, when we did receive AADT, which was not the case for all states, they were only available for specific years. For example, Kentucky provided us AADT data ranges for "before" years (2006 and 2011) and "after" years (2009 and 2017). North Carolina sent us Graham County AADT maps for 2016 in addition to historic engineering plans. Ohio provided one year of traffic data for the old alignment and treatment corridors. These data provided starting points for building the AADT datasets, and we supplemented these data with additional sources. Below are listed additional sources we used when compiling AADT data:

- Kentucky: Planning Highway Information System (HIS) GIS Extracts page and KYTC Traffic Database (218)
- Mississippi: MDOT Traffic Count Application (219)
- North Carolina: NCDOT AADT Mapping Application (220)
- Ohio: Transportation Data Management System (221) and Traffic Survey Reports and Maps (222)
- Tennessee: Annual Average Daily Traffic Maps (223)
- Virginia: The VDOT Traffic Data Geodatabase (224)

Although these data sources allowed AADT values to be determined for most years in the dataset, the nature of traffic data sampling can cause some data to be missing for certain years. For example, although NCDOT's online GIS traffic maps are comprehensive for the entire state, it is not uncommon for traffic counts to be missing for every other year (or even multiple years) for some roadways (220). Therefore, we also checked the Federal Highway Administration's Highway Performance Monitoring System (HPMS) to fill in as many missing years as possible. A public geospatial database contains counts from 2011 to 2017 for all highways that are part of the HPMS-defined Federal-Aid System. This geodatabase can be found at https://www.fhwa.dot.gov/policyinformation/hpms/shapefiles.cfm (225).

Next, we interpolated missing values for any remaining years in the dataset using either published growth rates (in the case of Kentucky) or linear interpolation (for the other states) using the closest years of data. For the few gaps in Kentucky data, missing AADT values were calculated using FHWA's published 2000 (226) and 2015 (227) highway statistics for VMT (228). When necessary, we also used a weighted average approach to interpolate missing AADT values when the nearest counting stations were not located on study corridors. Due to the nature of AADT data (which are typically derived from sampling sites) (219), interpolation methods are common (229).

Table 55 below lists the minimum, maximum, and average AADT values in vehicles per day (vpd) per state for both reference and treatment sites. For Kentucky, the mean AADT values for both treatment "before" and "after" sites (10,353.3 and 4,646.6, respectively) surpassed the mean AADT for the reference sites (3244.8 vpd). The trend is consistent with minimum and maximum AADT values as well. For Mississippi, the mean AADT for "before" treatment sites (3120.0 vpd) exceeded the mean AADT values for both reference sites and treatment "after sites" (1569.7 and 1368.1 vpd, respectively). The North Carolina data were similar to the Mississippi data in that the mean reference corridor AADT (1618.9 vpd) exceeded the mean treatment "before" AADT (941.9 vpd) but not the mean treatment "after" AADT (2380.0 vpd). The reference corridors featured the lowest minimum AADT (738.2 vpd). For Ohio, reference corridor data included minimum, maximum, and mean AADT values equal to 1910.6 vpd, 5141.0 vpd, and 2971.5 vpd, respectively. No "before" treatment data were included for Ohio. For Tennessee, reference corridor AADT values ranged from 311.3 vpd to 3585.6 vpd, with a mean of 1510.1 vpd. No "before" treatment data were included for Tennessee. For Virginia, the mean AADT value was greatest on the treatment "after" corridors (13343.9 vpd) compared to the reference corridors (6056.9 vpd) and treatment "before" corridors (12230.7 vpd), respectively. The mean AADT values in Virginia exceeded those of other states. The average values for AADT or crash types were first calculated for each site, then the summary information in Table 55 was generated based on those average values. A missing standard error corresponds to a state corridor type with only one site in the sample.

Table 55: Summary Statistics for AADT Data Collected for State Corridor Types

State	Corridor Type	Minimum Annual Average Daily Traffic (vehicles per day)	Maximum Annual Average Daily Traffic (vehicles per day)	Mean Annual Average Daily Traffic (vehicles per day)	Standard Deviation
Kentucky	Reference	780.3	6526	3244.8	1670.1
	Treatment Before	7549.8	13601.3	10353.3	2245.1
	Treatment After	8887	15796	10907	2919
Mississippi	Reference	744.2	2225	1569.7	549.0
	Treatment Before	3120.0	3120.0	3120.0	0
	Treatment After	3283	3283	3283	.
North Carolina	Reference	738.2	2836.4	1618.9	954.7
	Treatment After	2543	2543	2543	.
	Treatment Before	2380.0	2380.0	2380.0	.

State	Corridor Type	Minimum Annual Average Daily Traffic (vehicles per day)	Maximum Annual Average Daily Traffic (vehicles per day)	Mean Annual Average Daily Traffic (vehicles per day)	Standard Deviation
Ohio	Reference	1910.6	5141.0	2971.5	1295.8
	Treatment After	13138	13138	13138	.
	Treatment Before	.	.	.	.
Tennessee	Reference	311.3	3585.6	1510.1	1151.3
	Treatment After	3586	4480	4033	633
	Treatment Before	.	.	.	.
Virginia	Reference	4930.8	7484.6	6056.9	967.6
	Treatment Before	11235	14000	12230.7	1536.2
	Treatment After	10876	12162	11304	742.7
All States	Reference	311.3	7484.6	2715.9	1883.8
	Improved Alignment Treatment Before	2380	2380	2380	0
	Improved Alignment Treatment After	2543	2543	2543	0
	New Alignment Treatment Before	3120	14000	10175	3307
	New Alignment Treatment After	3283	15796	10192	3339

Data Source: Various (please see references 219–229)

4.3.3 Roadway Properties and Project Date Data Collection

As the ADHS designation represents a suite of roadway treatments, a proper safety evaluation requires a consideration of multiple roadway and engineering features. Therefore, while requesting crash data from the DOT representatives, we also asked a series of questions relating to the ADHS corridors and the old roadways they replaced or bypassed as designated in the initial data shell. These questions included the following:

- Can you verify the length and upgrades reported for each corridor?

- Can you identify/verify the corresponding route that this new alignment replaced/bypassed?
- Can you provide specifications for the old route?
- Can you provide traffic volumes on the old route before/after project completion?
- Can you provide traffic volumes on the new/upgraded route after completion?
- Do you know of any similar ADHS projects that are not listed on the attached spreadsheet?
- Can you provide start/end coordinates for both old routes and new routes?
- Can you provide the coordinates of other two-lane rural highways that we can use as comparison/reference sites for our project?

As mentioned in the previous subsection for traffic volume data collection, we received AADT data for specific years for most of the treatment corridors. We also received detailed responses to these questions from most states, with North Carolina even submitting historic engineering plans. We used these responses to fill in the data shell.

However, given that there were still some inconsistencies in the project start and completion dates listed in the data shell, and given the need to collect roadway data for the reference corridors, we conducted supplementary data collection efforts using online roadway information, GIS platforms, and Google Maps®. Google Maps® is frequently used for supplemental data collection (213), and the historic site images stored in the platform allowed us to verify years of construction when these dates could not be verified by the DOT representatives. Ultimately, we needed to verify the start and end dates of the following select treatment corridor projects:

- Kentucky Corridor T-003: Start date estimated from historic KYTC documentation (230).
- North Carolina Corridor T-005: Start date verified in historic NCDOT engineering plans.
- Virginia Corridor T-009: Start and end dates verified using Google Maps® historic site photos.

Using Google Maps® and GIS, we measured the following properties on all reference corridors:

- Roadway length in miles (mi)
- Speed limit in miles per hour (mph) (identified by checking signage)
- Lane width in feet (ft) (taken as average over corridor)
- Shoulder width (ft) (taken as average over corridor)
- Number of access points per mile (taken as any adjoining drives on the corridor)
- Number of three-legged intersections per mile (signalized or stop-controlled)
- Number of four-legged intersections per mile (signalized or stop-controlled)
- Number of interchanges per mile
- Horizontal curvature (categorical indication of curvature)

Table 56 indicates the average, minimum, and maximum values of the observed roadway properties per corridor type for Kentucky. Note that roadway curvature was collected as a categorical variable indicating relative curvature, and as such, this variable is excluded from the table. For reference corridors, the length in miles ranged from 2.20 to 11.40 mi, with an average of 1.69 three-legged, stop-controlled intersections per mile; zero four-legged, stop-controlled intersections per mile; 0.16 three-legged, signalized intersections per mile; 0.02 four-legged, signalized intersections per mile; 1.86 access points per mile; and zero interchanges per mile. For this corridor type, we found 10-ft lane widths, a range of 1.00–3.14 ft for shoulder widths, and a range of 35 to 55 mph speed limits. For the treatment corridors, the old alignment length in miles ranged from 1.40 to 7.10, while the length of new alignment ranged from 1.20 to 5.60 mi. We found an average of 1.44 three-legged, stop-controlled intersections per mile; zero four-legged, stop-controlled intersections; 0.23 three-legged, signalized intersections per mile; zero four-legged, signalized intersections per mile; 1.67 access points per mile; and 0.20 interchanges per mile. Lane widths were all found to be 12.00 ft, shoulder widths ranged from 2.00 to 3.00 ft, and speed limits ranged from 45 mph to 55 mph.

Table 56: Collected Roadway Property Data for Kentucky Corridors

Corridor Type	Roadway Property	Minimum	Maximum	Mean	Standard Deviation
Reference Corridors	Length (miles)	2.20	11.40	5.47	3.53
	Number of 3-Leg, Stop-controlled Intersections per mile	0.37	3.33	1.69	1.09
	Number of 4-Leg, Stop-controlled Intersections per mile	0	0	0	0
	Number of 3-Leg, Signalized Intersections per mile	0	0.91	0.16	0.30
	Number of 4-Leg, Signalized Intersections per mile	0	0.20	0.02	0.07
	Access points per mile	0.37	3.33	1.86	1.13
	Lane width (ft)	10.00	10.00	10.00	0
	Shoulder width (ft)	1.00	3.14	1.81	0.66
	Speed limit (mph)	35	55	49	8.43
	Number of Interchanges per mile	0	0	0	0
Treatment Corridors	Length of Old Alignment (miles)	1.40	7.10	3.66	2.24
	Length of New Alignment (miles)	1.20	5.60	2.84	1.72
	Number of 3-Leg, Stop-controlled Intersections per mile	1.11	2.14	1.44	0.41
	Number of 4-Leg, Stop-controlled Intersections per mile	0	0	0	0
	Number of 3-Leg, Signalized Intersections per mile	0	0.71	0.23	0.33
	Number of 4-Leg, Signalized Intersections per mile	0	0	0	0
	Access points per mile	1.27	2.86	1.67	0.68
	Lane width (ft)	12	12	12	0
	Shoulder width (ft)	2.00	3.00	2.20	0.45
	Speed limit (mph)	45	55	47	4.47
	Number of Interchanges per mile	0	1.00	0.20	0.45

Data Source: Appalachian Regional Commission and Google Maps®

Table 57 indicates the average, minimum, maximum, and standard deviation values of the observed roadway properties per corridor type for Mississippi. Note that roadway curvature was collected as a categorical variable indicating relative curvature, and as such, this variable is excluded from the table. For reference corridors, the length in miles ranged from 3.20 to 11.4 mi, with an average of 1.49 three-legged, stop-controlled intersections per mile; 0.31 four-legged, stop-controlled intersections per mile;

zero three-legged, signalized intersections per mile; 0.14 four-legged, signalized intersections per mile; 1.93 access points per mile; and zero interchanges per mile. For this corridor type, we found 10.00-ft lane widths, 2.00-ft shoulder widths, and a range of 50 to 55 mph speed limits. For the treatment corridors, the old alignment length was 3.40 mi, while the length of new alignment was 2.40 mi. We found an average of 1.47 three-legged, stop-controlled intersections per mile; 0.29 four-legged, stop-controlled intersections; zero three-legged, signalized intersections per mile; zero four-legged, signalized intersections per mile; 1.77 access points per mile; and zero interchanges per mile. Lane widths were all found to be 10.00 ft, shoulder widths were 2.00 ft, and speed limits were 55 mph.

Table 57: Collected Roadway Property Data for Mississippi Corridors

Corridor Type	Roadway Property	Minimum	Maximum	Mean	Standard Deviation
Reference Corridors	Length (miles)	3.20	7.70	4.78	1.83
	Number of 3-Leg, Stop-controlled Intersections per mile	0.91	2.19	1.49	0.51
	Number of 4-Leg, Stop-controlled Intersections per mile	0	0.94	0.31	0.37
	Number of 3-Leg, Signalized Intersections per mile	0	0	0	0
	Number of 4-Leg, Signalized Intersections per mile	0	0.31	0.14	0.14
	Access points per mile	1.17	3.4	1.93	0.90
	Lane width (ft)	10.00	10.00	10.00	0
	Shoulder width (ft)	2.00	2.00	2.00	0
	Speed limit (mph)	50	55	52	2.74
	Number of Interchanges per mile	0	0	0	0
Treatment Corridors	Length of Old Alignment (miles)	3.40	3.40	3.40	0
	Length of New Alignment (miles)	2.40	2.40	2.40	0
	Number of 3-Leg, Stop-controlled Intersections per mile	1.47	1.47	1.47	0
	Number of 4-Leg, Stop-controlled Intersections per mile	0.29	0.29	0.29	0
	Number of 3-Leg, Signalized Intersections per mile	0	0	0	0
	Number of 4-Leg, Signalized Intersections per mile	0	0	0	0
	Access points per mile	1.77	1.77	1.77	0
	Lane width (ft)	10.00	10.00	10.00	0
	Shoulder width (ft)	2.00	2.00	2.00	0
	Speed limit (mph)	55	55	55	0
	Number of Interchanges per mile	0	0	0	0

Data Source: Appalachian Regional Commission and Google Maps®

Table 58 indicates the average, minimum, and maximum values of the observed roadway properties per corridor type for North Carolina. Note that roadway curvature was collected as a categorical variable indicating relative curvature, and as such, this variable is excluded from the table. For reference corridors, the length in miles ranged from 1.30 to 6.60 mi, with an average of 1.89 three-legged, stop-controlled intersections per mile; 0.03 four-legged, stop-controlled intersections per mile; zero for other intersection types; 1.92 access points per mile; and zero interchanges per mile. For this corridor type, we found 10.00 ft lane widths, a range of 5.00–6.00 ft for shoulder widths, and a range of 40 to 55 mph speed limits. For the treatment corridors, the old alignment length and new alignment were the same length of 2.70 mi. We found an average of 2.59 three-legged, stop-controlled intersections per mile; zero of other intersection types; 2.59 access points per mile; and zero interchanges per mile. Lane widths were all found to be 10.00 ft, shoulder widths equal to 5.00 ft, and speed equal to 55 mph.

Table 58: Collected Roadway Property Data for North Carolina Corridors

Corridor Type	Roadway Property	Minimum	Maximum	Mean	Standard Deviation
Reference Corridors	Length (miles)	1.30	6.60	3.06	2.04
	Number of 3-Leg, Stop-controlled Intersections per mile	0.76	3.20	1.89	1.18
	Number of 4-Leg, Stop-controlled Intersections per mile	0	0.15	0.03	0.07
	Number of 3-Leg, Signalized Intersections per mile	0	0	0	0
	Number of 4-Leg, Signalized Intersections per mile	0	0	0	0
	Access points per mile	0.83	3.20	1.92	1.15
	Lane width (ft)	10.00	10.00	10.00	0
	Shoulder width (ft)	5.00	6.00	5.21	0.44
	Speed limit (mph)	40	55	47.50	7.07
	Number of Interchanges per mile	0	0	0	0
Treatment Corridors	Length of Old Alignment (miles)	2.70	2.70	2.70	0
	Length of New Alignment (miles)	2.70	2.70	2.70	0
	Number of 3-Leg, Stop-controlled Intersections per mile	2.59	2.59	2.59	0
	Number of 4-Leg, Stop-controlled Intersections per mile	0	0	0	0
	Number of 3-Leg, Signalized Intersections per mile	0	0	0	0
	Number of 4-Leg, Signalized Intersections per mile	0	0	0	0
	Access points per mile	2.59	2.59	2.59	0
	Lane width (ft)	10.00	10.00	10.00	0
	Shoulder width (ft)	5.00	5.00	5.00	0
	Speed limit (mph)	55	55	55	0
	Number of Interchanges per mile	0	0	0	0

Data Source: Appalachian Regional Commission and Google Maps®

Table 59 indicates the average, minimum, and maximum values of the observed roadway properties per corridor type for Ohio. Note that roadway curvature was collected as a categorical variable indicating relative curvature, and as such, this variable is excluded from the table. For reference corridors, the length in miles ranged from 2.90 to 5.70 mi, with an average of 1.23 three-legged, stop-controlled intersections per mile; 0.43 four-legged, stop-controlled intersections per mile; zero three-legged, signalized intersections per mile; 0.04 four-legged, signalized intersections per mile; 1.70 access points per mile; and zero interchanges per mile. For this corridor type, we found 10.00 ft lane widths, a range of 2.00–3.00 ft for shoulder widths, and a range of 45 to 55 mph speed limits. Treatment corridors were typically 12.00 ft wide with 4.00 ft shoulders and 55 mph speed limits.

Table 59: Collected Roadway Property Data for Ohio Corridors

Corridor Type	Roadway Property	Minimum	Maximum	Mean	Standard Deviation
Reference Corridors	Length (miles)	2.90	5.70	4.6	1.04
	Number of 3-Leg, Stop-controlled Intersections per mile	0.88	2.00	1.23	0.45
	Number of 4-Leg, Stop-controlled Intersections per mile	0.2	0.67	0.43	0.18
	Number of 3-Leg, Signalized Intersections per mile	0	0	0	0
	Number of 4-Leg, Signalized Intersections per mile	0	0.20	0.04	0.09
	Access points per mile	1.20	2.67	1.70	0.59
	Lane width (ft)	10.00	10.00	10.00	0
	Shoulder width (ft)	2.00	3.00	2.20	0.45
	Speed limit (mph)	45	55	50	5.00
	Number of Interchanges per mile	0	0	0	0
Treatment Corridors	Length of Old Alignment (miles)	8.90	8.90	8.90	0
	Length of New Alignment (miles)	9.40	9.40	9.40	0
	Number of 3-Leg, Stop-controlled Intersections per mile	0.67	0.67	0.67	0
	Number of 4-Leg, Stop-controlled Intersections per mile	0	0	0	0
	Number of 3-Leg, Signalized Intersections per mile	0	0	0	0
	Number of 4-Leg, Signalized Intersections per mile	0	0	0	0
	Access points per mile	0.67	0.67	0.67	0
	Lane width (ft)	12.00	12.00	12.00	0
	Shoulder width (ft)	4.00	4.00	4.00	0
	Speed limit (mph)	55	55	55	0
	Number of Interchanges per mile	0	0	0	0

Data Source: Appalachian Regional Commission and Google Maps®

Table 60 indicates the average, minimum, and maximum values of the observed roadway properties per corridor type for Tennessee. Note that roadway curvature was collected as a categorical variable indicating relative curvature, and as such, this variable is excluded from the table. For reference corridors, the length in miles ranged from 0.20 to 4.10 mi, with an average of 3.91 three-legged, stop-controlled intersections per mile; 0.15 four-legged, stop-controlled intersections per mile; zero three-legged, signalized intersections per mile; zero four-legged, signalized intersections per mile; 4.06 access points per mile; and zero interchanges per mile. For this corridor type, we found a range of 9.00 to 10.00 ft lane widths, a range of 1.00–10.00 ft for shoulder widths, and a range of 40 to 55 mph speed limits. Treatment corridors were typically 12.00 ft wide with an average of 7.00 ft shoulders and 55 mph speed limits.

Table 60: Collected Roadway Property Data for Tennessee Corridors

Corridor Type	Roadway Property	Minimum	Maximum	Mean	Standard Deviation
Reference Corridors	Length (miles)	0.20	4.10	1.51	1.19
	Number of 3-Leg, Stop-controlled Intersections per mile	0.49	10.00	3.91	2.86
	Number of 4-Leg, Stop-controlled Intersections per mile	0	1.05	0.15	0.35
	Number of 3-Leg, Signalized Intersections per mile	0	0	0	0
	Number of 4-Leg, Signalized Intersections per mile	0	0	0	0
	Access points per mile	0.49	10.00	4.06	2.80
	Lane width (ft)	9.00	10.00	9.50	0.53
	Shoulder width (ft)	1.00	10.00	4.25	4.02
	Speed limit (mph)	40	55	48.50	5.80
	Number of Interchanges per mile	0	0	0	0
Treatment Corridors	Length of Old Alignment (miles)	0.40	3.60	2.00	2.26
	Length of New Alignment (miles)	0.40	3.60	2.00	2.26
	Number of 3-Leg, Stop-controlled Intersections per mile	0	0.83	0.42	0.59
	Number of 4-Leg, Stop-controlled Intersections per mile	0	0.28	0.14	0.20
	Number of 3-Leg, Signalized Intersections per mile	0	0	0	0
	Number of 4-Leg, Signalized Intersections per mile	0	0	0	0
	Access points per mile	0	1.11	0.56	0.79
	Lane width (ft)	12.00	12.00	12.00	0
	Shoulder width (ft)	6.00	8.00	7.00	1.41
	Speed limit (mph)	55	55	55	0
	Number of Interchanges per mile	0	0	0	0

Data Source: Appalachian Regional Commission and Google Maps®

Table 61 indicates the average, minimum, and maximum values of the observed roadway properties per corridor type for Virginia. Note that roadway curvature was collected as a categorical variable indicating relative curvature, and as such, this variable is excluded from the table. For reference corridors, the length in miles ranged from 0.70 to 2.00 mi, with an average of 2.87 three-legged, stop-controlled intersections per mile; zero for other intersection types; 2.87 access points per mile; and zero interchanges per mile. For this corridor type, we found a range of 9.00 to 10.00-ft lane widths, a range of

1.50–2.00 ft for shoulder widths, and a range of 25 to 45 mph speed limits. For the treatment corridors, the old alignment ranged from 0.60 to 1.20 mi, while the new alignments ranged from 0.70 to 1.20 mi. We found an average of 2.04 three-legged, stop-controlled intersections per mile; zero for other intersection types; 2.04 access points per mile; and zero interchanges per mile. Lane widths were all found to be 12.00 ft, shoulder widths ranged from 2.00 to 5.00 ft, and speed limits ranged from 25 mph to 35 mph.

Table 61: Collected Roadway Property Data for Virginia Corridors

Corridor Type	Roadway Property	Minimum	Maximum	Mean	Standard Deviation
Reference Corridors	Length (miles)	0.70	2.00	1.24	0.54
	Number of 3-Leg, Stop-controlled Intersections per mile	1.30	4.29	2.87	1.41
	Number of 4-Leg, Stop-controlled Intersections per mile	0	0	0	0
	Number of 3-Leg, Signalized Intersections per mile	0	0	0	0
	Number of 4-Leg, Signalized Intersections per mile	0	0	0	0
	Access points per mile	1.25	4.29	2.87	1.41
	Lane width (ft)	9.00	10.00	9.40	0.55
	Shoulder width (ft)	1.50	2.00	1.90	0.22
	Speed limit (mph)	25	45	40	8.66
	Number of Interchanges per mile	0	0	0	0
Treatment Corridors	Length of Old Alignment (miles)	0.60	1.20	0.90	0.30
	Length of New Alignment (miles)	0.70	1.20	0.90	0.27
	Number of 3-Leg, Stop-controlled Intersections per mile	1.11	3.33	2.04	1.16
	Number of 4-Leg, Stop-controlled Intersections per mile	0	0	0	0
	Number of 3-Leg, Signalized Intersections per mile	0	0	0	0
	Number of 4-Leg, Signalized Intersections per mile	0	0	0	0
	Access points per mile	1.11	3.33	2.04	1.16
	Lane width (ft)	12.00	12.00	12.00	0
	Shoulder width (ft)	2.00	5.00	3.67	1.53
	Speed limit (mph)	25	35	28.33	5.77
	Number of Interchanges per mile	0	0	0	0

Data Source: Appalachian Regional Commission and Google Maps®

Table 62 indicates the average, minimum, and maximum values of the observed roadway properties per corridor type for the entire dataset used in analysis. Note that roadway curvature was collected as a categorical variable indicating relative curvature, and as such, this variable is excluded from the table. For reference corridors, the length in miles ranged from 0.20 to 11.40 mi, with an average of 2.33 three-legged, stop-controlled intersections per mile; 0.13 four-legged, stop-controlled intersections per mile;

0.04 three-legged, signalized intersections per mile; 0.03 four-legged, signalized intersections per mile; 2.53 access points per mile; and zero interchanges per mile. For this corridor type, we found a range of 9.00 to 10.00 ft lane widths, a range of 1.00–10.00 ft for shoulder widths, and a range of 25 to 55 mph speed limits. Improved alignment corridors ranged from 0.40 to 3.60 miles in length, with an average of 1.27 four-legged, stop-controlled intersections per mile; zero three-legged, stop-controlled intersections; zero three-legged, signalized intersections; an average of 0.07 four-legged, signalized intersections per mile; an average of 1.34 access points per mile; and zero interchanges along this corridor type. Average Lane width and shoulder width were 11.50 ft and 5.25 ft, respectively, and average speed limit was 50 mph. For the new alignment treatment corridors, the old alignment length in miles ranged from 0.60 to 7.1 mi, while the length of new alignment ranged from 0.70 to 5.60 mi. We found an average of 1.64 three-legged, stop-controlled intersections per mile; 0.03 four-legged, stop-controlled intersections per mile; 0.13 three-legged, signalized intersections per mile; zero four-legged, signalized intersections per mile; 1.80 access points per mile; and 0.11 interchanges per mile. Lane widths were all found to range from 10.00 ft to 12.00 ft, shoulder widths ranged from 2.00 to 5.00 ft, and speed limits ranged from 25 mph to 55 mph.

Table 62: Collected Roadway Property Data for All Corridors by Treatment Type

Corridor Type	Roadway Property	Minimum	Maximum	Mean	Standard Deviation
Reference Corridors	Length (miles)	0.20	11.40	3.46	2.68
	Number of 3-Leg, Stop-controlled Intersections per mile	0.37	10	2.33	1.90
	Number of 4-Leg, Stop-controlled Intersections per mile	0	1.05	0.13	0.26
	Number of 3-Leg, Signalized Intersections per mile	0	0.91	0.04	0.16
	Number of 4-Leg, Signalized Intersections per mile	0	0.31	0.03	0.08
	Access points per mile	0.37	10.00	2.53	1.86
	Lane width (ft)	9.00	10.00	9.80	0.41
	Shoulder width (ft)	1.00	10.00	2.93	2.37
	Speed limit (mph)	25	55	48.06	7.17
	Number of Interchanges per mile	0	0	0	0
Improved Alignment Treatment Corridors	Length of Old Alignment (miles)	0.40	3.60	1.98	1.44
	Length of New Alignment (miles)	0.40	3.60	1.98	1.44
	Number of 3-Leg, Stop-controlled Intersections per mile	0	0	0	0
	Number of 4-Leg, Stop-controlled Intersections per mile	0	2.59	1.27	1.11

Corridor Type	Roadway Property	Minimum	Maximum	Mean	Standard Deviation
	Number of 3-Leg, Signalized Intersections per mile	0	0	0	0
	Number of 4-Leg, Signalized Intersections per mile	0	0.28	0.07	0.14
	Access points per mile	0	2.59	1.34	1.08
	Lane width (ft)	10	12	11.5	1
	Shoulder width (ft)	2	8	5.25	2.5
	Speed limit (mph)	35	55	50	10
	Number of Interchanges per mile	0	0	0	0
New Alignment Treatment Corridors	Length of Old Alignment (miles)	0.60	7.10	2.71	2.09
	Length of New Alignment (miles)	0.70	5.60	2.14	1.55
	Number of 3-Leg, Stop-controlled Intersections per mile	1.111	3.333	1.64	0.711
	Number of 4-Leg, Stop-controlled Intersections per mile	0	0.29	0.03	0.10
	Number of 3-Leg, Signalized Intersections per mile	0	0.71	0.13	0.26
	Number of 4-Leg, Signalized Intersections per mile	0	0	0	0
	Access points per mile	1.11	3.33	1.80	0.77
	Lane width (ft)	10	12	11.78	0.67
	Shoulder width (ft)	2	5	2.67	1.16
	Speed limit (mph)	25	55	41.67	11.18
	Number of Interchanges per mile	0	1	0.11	0.33

Data Source: Appalachian Regional Commission and Google Maps®

4.4 Analysis Results

4.4.1 Total Crash Rates

To provide a rough estimate of the safety benefits of the ADHS upgrade, we calculated crash rates (in rate per million vehicle miles, or RMVM) for the old alignments (either before or after treatment) and new alignments. These crash rates—provided for total crashes, injury crashes, multi-vehicle crashes, single-vehicle crashes, and night crashes—show the average number of crashes per 100 million vehicle miles of travel over whatever years are available per specific corridor. Final averages per corridor type are also provided. The results are summarized in Table 62. Note that the provided crash rates are only for old alignments and new alignments, so the crash rates on some upgraded corridors, such as T-005-1 in North Carolina, are not provided.

Table 63: Crash Rates per 100 Million Vehicle Miles Traveled (MVM) for Study Corridors

State	Alignment Type	Corridor	Total Crash rate (per 100 MVM)	Injury Crash Rate (per 100 MVM)	Multi-Vehicle Crash Rate (per 100 MVM)	Single-Vehicle Crash Rate (per 100 MVM)	Night Crash Rate (per 100 MVM)
Kentucky	Old	T-002-1	100.91	33.74	64.89	36.01	13.03
		T-002-2	129.91	55.03	32.44	97.46	20.94
		T-003-1	190.83	73.08	138.42	52.41	39.63
		T-003-2	395.20	149.89	295.77	99.43	71.90
		T-003-3	63.37	21.45	38.02	25.35	10.73
	New	T-002-1	65.58	26.34	31.94	33.64	19.79
		T-002-2	104.65	31.57	47.79	56.86	17.93
		T-003-1	45.45	0.00	0.00	45.45	45.45
Mississippi	Old	T-004-1	107.24	60.29	61.32	45.92	22.94
	New	T-004-1	90.17	58.46	90.17	0.00	0.00
North Carolina	Old	T-005-1	68.81	34.38	32.93	35.88	6.04
Ohio	Old	T-006-1	115.33	39.75	39.15	76.17	45.79
	New	T-006-1	58.89	12.79	18.63	40.25	18.86
Tennessee	Old	T-007-1	43.93	9.56	27.55	16.38	6.14
		T-008-1	191.75	191.75	0.00	191.75	191.75
Virginia	Old	T-009-1	68.85	51.34	51.34	17.51	0.00
		T-009-2	123.97	58.65	92.33	31.64	27.28
		T-009-3	78.53	33.69	70.35	8.18	5.41
	New	T-009-1	55.28	11.29	32.68	22.60	0.00
		T-009-2	74.78	23.06	52.60	22.18	5.55
Average	Old	All old	133.34	64.91	72.85	60.49	38.01
	New	All new	70.69	23.36	39.12	31.57	15.37

As can be seen from the results in Table 63, a rough estimate of the safety performance of the new ADHS alignments to old ADHS alignments seems to indicate a safety benefit for all crash types. These results seem at first intuitive; four-lane roadways, if carrying the same volume as two-lane roadways, should provide less conflicts for motorists, and the control of access and reshaping of hazardous curves should mitigate some risks. However, as previously noted, these crash rates should be considered carefully and may not account for abrupt changes in volume, limited data, and the false linear relationship assumption between traffic volume and crash counts. We only recommend using these rates in a cursory manner for the beginning of safety analyses, and for that reason, the following subsections detail a more thorough CMF development.

4.4.2 CMF Consideration

As mentioned in the methodology section of this chapter, we developed two sets of SPFs and CMFs to test two sets of assumptions:

1. Traffic using an ADHS corridor pre-treatment will be perfectly transmitted to an upgraded ADHS corridor after treatment, so the appropriate cross-sectional comparison is between the new/upgraded alignments and old alignments before treatment.
2. Traffic using an ADHS corridor pre-treatment will use some combination of the old alignment and the new alignment after treatment, so the appropriate cross-sectional comparison is between the new alignment/old alignment combination and the old alignment before treatment.

After comparing the SPF and CMF results corresponding to these two assumptions, and based on our understanding of safety performance and observation of traffic distribution, we determined that the CMFs developed for Assumption 1 above are suspect due to both a lack of statistical significance and unrealistic safety benefits (e.g., several of the CMF values are in the 0.2 range, which corresponds to an approximately 80% reduction in crashes). This dramatic safety benefit is not evident even in the rough crash rates presented in Table 63, so we do not think this set of CMFs is a viable comparison. Therefore, the following subsections detail the SPFs and CMFs for Assumption 2 only.

Based on analysis results, only SPF and CMF results corresponding to a systemic comparison of the new and old alignments are presented in this report.

4.4.3 SPF Variable Selection

To develop SPFs and model the crash modification capabilities of the ADHS treatment, we derived multiple new variables based on different functional forms of all the variables collected in the AADT and roadway design data. These variables are derived from the general variables listed in Tables 55 and 62 and include the following:

- AADT: The AADT on the route for the year in which the crash occurred.
- AADT_1000: The scaled AADT value divided by 1000 (used to identify a more precise coefficient).
- LnAADT: The logarithmic transformation of AADT value (used to fit traffic volume data).
- B_A: Designation of alignment as before construction (B) or after construction (A).
- Lanewd: The lane width of the corridor at the site of the crash.

- State: A categorical variable in SPF development tested to see if the specific state affects the number of expected crashes on an ADHS facility.
- TR: A categorical variable to determine the significance of a crash occurring on either a treatment site or a reference site.
- TR_Pair: The different treatment and reference site pairs, represented by the pairings in Table 47 (e.g., R-039 with T-008), tested to see if the selected reference sites were appropriate.
- Spdlmt_bin: A binary categorization of speed limit into higher speed facilities (i.e., speed limit greater than or equal to 50 mph) and lower speed facilities (i.e., speed limit below 50 mph).
- Spdlmt_cat: A categorical variable breaking speed limit into more than two bins (i.e., speed limit less than or equal to 40 mph, speed limit between 40 and 50 mph, and speed limit greater than 50 mph) to allow for a more granular effect of speed limit on safety.
- Shdwd_wt: A weighted measure of the shoulder width (weighted average by length).
- St4leg_bin: A binary variable indicating whether a crash occurred at a four-legged, stop-controlled intersection tested for significance on reference sites.
- Sg3leg_bin: A binary variable indicating whether a crash occurred at a three-legged, signalized intersection tested for significance on reference sites.
- Rt_3leg_stopint: The raw measure of three-legged, stop-controlled intersections along the route.

Although other functional forms of the variables were tested (by examining CURE plots, statistical significance, and model fit), only these variables are included in the final SPF forms.

4.4.2 Safety Performance Functions

Ultimately, we developed five different SPFs to compare the effects of the ADHS treatment on different crash types. The results of only one SPF, total crashes, are listed below. The results of the other SPFs are similar and are beyond the scope of this report. All five CMFs were derived from these SPFs. We also generated CURE plots to assess goodness of fit, but a full presentation of these plots is beyond the scope of this report.

The total crash model was developed using Proc GENMOD in SAS 9.4. We used a negative binomial distribution to estimate the SPF. The variables that were statistically significant at the p<0.05 threshold include AADT, natural log of AADT, T-R pair, and treatment. The intercept was also statistically significant. A functional form of this SPF can be rendered as the following:

$$N_{tot} = EXP(-5.5384 + 0.7928 * lnaadt - 0.0772 * aadt\_1000 - 0.2689 * B\_A + 0.3127 * TR + TR\_Pair)$$

where N_{tot} is the total number of predicted crashes per year (offset by length) on an ADHS roadway, *LnAADT* is the logarithmic transformation of the AADT value, *AADT_1000* is the scaled annual average daily traffic (vpd/1000) on that roadway, *B_A* is the designation for before or after treatment (1 for after), *TR* is the designation for treatment or reference (1 for treatment), and *TR_Pair* is a categorical variable with different estimates depending on specific T-R pair. The statistically significant T-R pairs correspond to T-002 (Kentucky), T-003 (Kentucky), T-004 (Mississippi), and T-008 (Tennessee) relative to T-009 (Virginia).

Table 64: SPF Model Parameters for Total Crashes

Parameter	Coefficient	Standard Error	P-value	Lower 95% Confidence Interval	Upper 95% Confidence Interval
LnAADT	0.7928*	0.1130	<0.0001	0.5712	1.0143
AADT/1000	-0.0772*	0.0278	0.0054	-0.1316	-0.0228
B_A = A	-0.2689*	0.1274	0.0347	-0.5186	-0.0193
TR = T	0.3127*	0.1500	0.0371	0.0187	0.6067
TR_Pair = T-002	0.3229*	0.1122	0.004	0.103	0.5428
TR_Pair = T-003	0.6491*	0.1098	<.0001	0.4339	0.8643
TR_Pair = T-004	-0.6491*	0.1594	<.0001	-0.9616	-0.3367
TR_Pair = T-005	-0.1550	0.1627	0.3407	-0.4739	0.1639
TR_Pair = T-006	0.0460	0.1265	0.716	-0.2018	0.2938
TR_Pair = T-007	-0.2783	0.2167	0.199	-0.703	0.1464
TR_Pair = T-008	-1.8024*	0.4706	0.0001	-2.7247	-0.8801
Intercept	-5.5384*	0.8538	<0.0001	-7.2118	-3.8650

*Designates statistical significance at the p<0.05 level

The signs on the estimate values for each variable (or variable level) given in the SAS output (Table 62) show the effect of each variable on the total number of predicted crashes. For this model, the most important factors for predicting total crashes included traffic volume, state and treatment designation, and whether the crash occurred before construction or after construction. That final consideration, corresponding to the B_A variable, is critical, as this value corresponds to the CMF specified for the ADHS treatment.

Note that although we attempted multiple combinations of the roadway parameters collected for each corridor, aggregation on roadway variables on both old and new roads is difficult as most variables are related to the treatment. The final predictive models for each crash type only required specification of traffic volume (or logarithmic traffic volume), treatment or reference designation, reference and treatment pair, or before-after designation. These results likely indicate the critical role of traffic volume in causing crashes on ADHS roadways.

4.4.3 Crash Modification Factors

The ultimate goal of developing SPFs and calculating expected crashes through the cross-sectional analysis was to determine the CMF for upgrading from a regular two-lane highway to an ADHS-designated highway. To that end, we calculated the CMF for each crash type by testing the statistical significance of the B-A variable in the SPF model for each crash type. This variable essentially captures the ratio of crashes before and after treatment and shows if treating the corridor resulted in a statistically significant change in crashes.

Table 65 shows the CMFs for the B-A variable (the key variable of the ADHS treatment) per crash type. Note that the B-A variable was statistically significant only for total crashes, injury crashes, and multi-vehicle crashes. The lack of statistical significance for single-vehicle and night crashes indicates no statistically significant reduction in those crash types after treatment, resulting in a CMF equal to 1.0.

Table 65: Measures of Safety for Crash Types to Find Efficacy of ADHS Treatments

Crash Type	CMF for ADHS Treatment	Standard Error of CMF
Total Crashes	0.764*	0.127
Injury Crashes	0.702*	0.147
Multi-Vehicle Crashes	0.639*	0.130
Single-Vehicle Crashes	1.00	-
Nighttime Crashes	1.00	-

*Indicates statistical significance

The CMFs for total crashes, injury crashes, and multi-vehicle crashes are all less than 1.0, indicating a potential decrease in the percent of expected crashes equal to 23.6%, 29.8%, and 36.1%, respectively. For the other crash types, there are no statistically significant changes in the number of crashes predicted after ADHS treatment. These derived CMFs are generally comparable to those developed by Ahmed, Abdel-Aty, and Park for upgrading from two-lane roads to divided, four-lane roads in Florida (231).

Based on these results, we can conclude that the ADHS treatment provides a positive effect on the total number of crashes, number of injury crashes, and number of multi-vehicle crashes. We can also conclude that the ADHS treatment has no significant impact on the number of single-vehicle and nighttime crashes. Therefore, we can conclude that generally, the ADHS treatment provides a positive impact on most crash types. However, it likely also provides more room for drivers to get in single-vehicle crashes (many of which occur at night), resulting in no significant benefit or detriment to those types of crashes that typically occur in low volume conditions.

Note that CMFs can be used, with proper calibration based on local traffic volume and operational data, to make project-level decisions about roadway design alternatives. Because these CMFs were developed based on historic traffic volume data, crash reductions will likely diminish as traffic volume increases. Moreover, these CMFs may be more appropriate for rural areas than for urban areas, given the bypass-nature of the ADHS upgrade.

4.5 Summary

In this chapter, we discussed the research effort to quantify the traffic safety impact of the ADHS system. To accomplish this task, we gathered crash data, traffic volume data, and roadway design data for nine ADHS "treatment" corridors and 45 corresponding two-lane "reference" corridors from six states: Kentucky, Mississippi, North Carolina, Ohio, Tennessee, and Virginia. Across these 54 corridors, we collected a sample of 3,109 crashes as a reference group and 1812 crashes as a treatment group. We divided these crashes based on crash type (total crashes, injury crashes, single-vehicle crashes, multi-vehicle crashes, and nighttime crashes) and whether the crash occurred on an ADHS corridor before it was upgraded or after it was upgraded to a new alignment or an improved alignment. We also collected data on AADT, lane width, shoulder width, number of access points, number of intersections, and speed limit on each corridor type. We then analyzed these data by calculating both crash rates per 100 MVM and CMFs for the ADHS treatment. Based on this analysis, we found a mostly positive impact of the ADHS on traffic safety. Our results indicate decreases in the expected number of total, injury, and multi-vehicle crashes after upgrading to an ADHS corridor. The results also indicate negligible changes in the expected number of nighttime crashes and significant increases in the expected number of single-vehicle crashes. Ultimately, we found that the ADHS upgrade corresponds to an overall positive impact on traffic safety (with minimal effect for specific crash types).

Chapter 5: Conclusions

5.1 Summary

On behalf of the Appalachian Regional Commission, the UNC Highway Safety Research Center team conducted a comprehensive research project analyzing various aspects of traffic safety within the Region. This project entailed a thorough scan of relevant literature to characterize traffic safety culture and its relation to health and mortality, to the extent possible, within the Appalachian Region. This literature synthesis directly influenced the next step of the project: a thorough investigation of fatal crash data using NHTSA's Fatality Analysis Reporting System (FARS) data to identify potential key differences between traffic safety conditions in Appalachian and non-Appalachian counties. This analysis included calculation of rates, rate ratios, and odds ratios, and identification of significant differences between counties in the Region and counties from the non-Appalachian United States, as well as identification of key differences across the Appalachian subregions. We also used FARS data, though limited in scope, to examine drug testing among drivers involved in fatal crashes in the Region. We then conducted a brief, descriptive analysis of crash trends in North Carolina to determine if specific trends noted in the state were similar to fatal crash trends for the Appalachian Region. Finally, we conducted an evaluation of the Appalachian Development Highway System as an engineering treatment to determine its potential for mitigating total crashes, injury crashes, single-vehicle crashes, multi-vehicle crashes, and nighttime crashes throughout the Region.

This final chapter of the report summarizes key findings from each task of the project and concludes with recommendations for future actions. These recommendations encompass potential research projects, policy options, and countermeasure selections. These recommendations are intended to provide a range of actions that can be taken at different jurisdictional levels, ranging from local engineering efforts to statewide strategic plans to regional guidance.

5.1.1 Literature Synthesis

To complete the literature synthesis task, we conducted an extensive and thorough examination of literature sources, including government documents, research journals, and ARC-sponsored research reports. Our goals were to identify traffic safety concerns in Appalachia, characterize traffic safety culture, and link traffic safety culture to the unique conditions in Appalachia. The literature synthesis provides evidence of potential countermeasures for identified problems while also noting the extent of research that remains to be done. Although the full extent of the synthesis goes beyond this summary, three key highlights include the following:

- Little research has been conducted to identify potential safety problems within the Region, and significantly more research is needed to properly differentiate traffic safety culture within the Region from the rest of the United States.
- A working definition of traffic safety culture in Appalachia is as follows: "Traffic safety culture in Appalachia is the collective force of social norms, behaviors, and values that determine the average person's posture toward engaging or not engaging in road use behaviors that can influence their safe or unsafe use of the unique roadway environments that characterize the Region." However, it should be noted that this definition lacks precision, and further research to more properly describe traffic safety culture in Appalachia is needed.

- The literature we did find indicates that traffic safety is likely a major health concern for the Region, so Appalachian states should include Appalachian concerns in statewide traffic safety planning.

After completing each subtask of this report, the team derived a revised version of the traffic safety culture working definition that incorporates many of the key findings of this project. While still ambiguous, this definition more clearly accounts for the positive and negative trends uncovered in the project and points toward future research needs.

Traffic safety culture in Appalachia is the collective force of social norms, behaviors, and values that determine the average person's posture toward engaging in positive road-use behaviors (like helmet use or not drinking and driving) or negative road-use behaviors (like not wearing restraints) while navigating older (on average) vehicles on (frequently rural) roadways (often) characterized by two-lane, curved alignments with minimal lighting.

5.1.2 Fatal Crash Analysis

We conducted the fatal crash analysis of FARS data in two steps. First, we compared fatal crash trends across the five Appalachian subregions, comparing traffic fatality frequencies and population-based fatality rates. We then compared traffic fatality frequencies and population-based fatality rates between Appalachian counties and non-Appalachian United States counties. We analyzed key variables identified in the literature synthesis and, if possible, identified potential explanations for specific safety problems and countermeasures to address traffic safety issues. A full summary of the findings from the FARS analysis chapter is beyond the scope of this summary given the depth and breadth of this analysis, but some key highlights for both steps of the analysis are summarized here:

- Since 1994, 103,292 persons lost their lives on Appalachian traffic ways.
- The average annual number of fatalities declined from 4,328 in 1994 to 3,771 in 2017.
- The Central subregion had the highest traffic fatality rate per 100,000 person-years for motor vehicle operators.
- In Appalachia, a majority of traffic fatalities occurred in rural areas, although this varies by subregion and is most pronounced in the Central subregion.
- Over one-half (54.9%) of all Appalachian motor vehicle occupant fatalities were not restrained at the time of crash (compared to 48.2% in non-Appalachia).
- The average annual traffic fatality rate for Appalachia was 17.6 deaths per 100,000 person-years, compared to 12.8 deaths per 100,000 person-years in non-Appalachia.
- Urban traffic fatality rates were 35% higher in Appalachia than non-Appalachia, but rural traffic fatality rates were 16% lower in rural Appalachia than non-Appalachia.
- Among motor vehicle occupants, Appalachian traffic fatalities were more likely to be occupants of older vehicles than those of non-Appalachian traffic fatalities, with a median age of 12 years. Appalachian traffic fatalities were 28% more likely to be occupants of vehicles greater than 20 years of age.
- In Appalachia, motorcyclist traffic fatalities were more likely to be helmeted at the time of crash as compared to traffic fatalities from non-Appalachia.

- In Appalachia, traffic fatalities were more likely to have occurred on two-lane, curved, and graded roadways.

5.1.3 Alcohol and Drug Involvement in Fatal Crashes

We also analyzed FARS data to identify potential driver alcohol and drug involvement in fatal crashes and to compare trends in Appalachia to non-Appalachia. While the data reported by FARS for driver alcohol involvement are considered adequate, data for driver drug involvement are not (see Chapter 3 for a more thorough discussion of the limitations of the FARS toxicology data). Therefore, due to the significant limitations of the FARS' toxicology data, the following findings from this chapter should be considered carefully:

- A lower proportion of Appalachian drivers involved in fatal crashes were legally alcohol-impaired BAC $\geq$0.08 g/dL; 18%) than non-Appalachian drivers (20%).
- Over the period 2013–2017, 44% of Appalachian drivers and 38% of non-Appalachian drivers had drug test results. Among U.S. drivers with drug test results, 50% of Appalachian and 44% of non-Appalachian drivers tested positive for one or more drugs.
- Among drivers involved in fatal traffic crashes, the most common class of drugs for which drivers tested positive was cannabinoids (e.g., marijuana). Appalachian drivers were less likely to test positive for marijuana (13%) as compared to non-Appalachian drivers (17%).
- The second most common class of drugs for which drivers tested positive includes tranquilizers, sedatives, and other non-narcotic central nervous system (CNS) depressants. A larger proportion of Appalachian drivers (12%) tested positive as compared to non-Appalachian drivers (8%).
- The third most common class of drugs for which drivers tested positive for was narcotics, including opioid analgesics. A larger proportion of Appalachian drivers tested positive for narcotics (11%) as compared to non-Appalachian drivers (8%).

5.1.4 North Carolina Case Study

In an effort to validate findings from the fatal crash analysis or to find specific concerns in the Appalachian counties of a particular state, we calculated descriptive statistics on fatal and injury crash data in North Carolina from 2013 to 2017. Our primary concerns were alcohol use in Appalachian North Carolina, temporal differences, roadway lighting, restraint use, motorcycle helmet use, and the age of vehicles involved in crashes. A full discussion of the statistics regarding these variables can be found in the case study chapter, but three key findings include the following:

- The temporal analysis indicated that crashes in Appalachian North Carolina peak during the fall season, perhaps due to increased tourism in the mountains at that time of the year.
- In Appalachian North Carolina, nearly one-third of all fatal and injury crashes in rural areas occur under dark, not-lighted roadway conditions. Although this proportion is slightly lower than the proportion in non-Appalachian North Carolina counties (0.35), it is still a cause for concern.
- The proportion of vehicles involved in fatal and serious injury crashes that were five years old or older was slightly higher in Appalachian North Carolina than in non-Appalachian North Carolina, a trend that was also observed for the broader Appalachian Region.

5.1.5 Evaluation of the Appalachian Development Highway System

A major component of this traffic safety analysis project was the evaluation of the ADHS system to verify whether the upgrades made to the system for economic development also provide a safety benefit. To perform this evaluation, we collected at least ten years of crash data for both ADHS treatment corridors and comparable, non-treated (i.e., two-lane, undivided, not-access-controlled) reference corridors in six Appalachian states. We also collected AADT data and geometric properties data for these corridors. We used cross-sectional analysis on these data to develop SPFs for five crash types, including total crashes, injury crashes, single-vehicle crashes, multi-vehicle crashes, and nighttime crashes. From these predictive models, we developed CMFs to assess the crash reduction potential of the ADHS treatment for these five crash types. The results for each crash type are as follows:

- For total crashes, we found a potential crash reduction factor equal to 23.6% with a standard error of 0.127, meaning that the effect of the ADHS treatment on total crashes is positive.
- For injury crashes, we found a potential crash reduction factor equal to 29.8% with a standard error of 0.147, meaning that the effect of the ADHS treatment on injury crashes is positive.
- For multi-vehicle crashes, we found a potential crash reduction factor of 36.1% with a standard error of 0.130, meaning that the effect of the ADHS treatment on multi-vehicle crashes is positive.
- For single-vehicle crashes and nighttime crashes, we found no statistically significant changes after treatment. This result indicates that, based on our assumptions, the ADHS upgrade neither increases nor decreases these crash types.
- Simple crash rate calculations seem to verify the safety benefits of the ADHS treatment, although these average crash rates are not recommended for determining expected safety improvements.

The CMFs produced as part of this analysis are summarized in the table below. Note that CMFs can be used, with proper calibration based on local traffic volume and operational data, to make project-level decisions about roadway design alternatives. Because these CMFs were developed based on historic traffic volume data, crash reductions will likely diminish as traffic volume increases. Moreover, these CMFs may be more appropriate for rural areas than for urban areas, given the bypass-nature of the ADHS upgrade.

5.2 Recommendations

Based on the results summarized above and on the in-depth analyses contained in each chapter, the following actions are recommended. For each recommendation, the target audience or responsible party is identified. When possible, potential benefits for each recommendation are discussed. These recommendations are divided based on tasks for this project.

5.2.1 Traffic Safety Culture and Appalachian Research

The key takeaway from the literature synthesis component of this project is that far more research into Appalachian traffic safety, and how traffic safety interacts with broader culture and health trends in the Region, is necessary. Therefore, we recommend the following actions:

- More research is needed on a variety of topics beyond the level of detail included in this project. These topics include the following:

a. A more substantial safety evaluation of roadways in the Appalachian Region, including non-ADHS roadways and more than just fatal crashes, to investigate the effects of roadway properties on traffic safety (e.g., horizontal curvature, roadway lighting, rural designation).
b. Research on mode choice and the connection between transportation access and traffic safety in the Region.
c. The effect of economic development on roadway investment, and how that connection affects traffic safety, in the Region.

- More research is needed to more carefully characterize traffic safety culture in Appalachia. To date, little research has been done to characterize the interplay between culture and traffic safety in the Region, and the supplied working definition still lacks specificity. This research effort may require cooperating with state and local agencies to survey the Appalachian population regarding transportation behaviors and attitudes.
- ARC partners, specifically state DOTs, may consider adding Appalachian-specific concerns to their SHSPs. We found no specific mentions of Appalachian concerns in any of the 13 current SHSPs, but our literature synthesis gives reason to believe that Appalachia may experience either unique safety trends from non-Appalachian counties or may be especially vulnerable to rural road concerns. This recommendation may also improve organizational safety culture within each Appalachian state and allow ARC to bolster messaging around the importance of a positive traffic safety culture.

5.2.2 Fatal Crash Analysis in Appalachia

Although our analysis of fatal crash data in the Appalachian Region uncovered a number of negative traffic safety trends in the Region, we also found unexpected and positive outcomes. Therefore, the recommendations below highlight both ways that positive trends can be supported or improved and ways that negative trends may be addressed.

- Motorcycle helmet use is actually higher in Appalachia than non-Appalachia. This may be due to the fact that ten of the 13 Appalachian states currently have universal helmet laws. State legislatures should consider continued support of these laws where implemented and consider implementation where they are not.
- Appalachian drivers involved in fatal crashes were less likely to be impaired by alcohol than drivers in non-Appalachian fatal crashes. Further research is needed to understand alcohol sale trends, local laws, advocacy efforts, and other factors that may affect the culture around drinking and driving.
- ARC partners, such as state DOTs and local jurisdictions, should consider evaluating current roadway lighting programs to identify gaps in lighting coverage, especially on rural highways. Although different effects and CMFs are reported in the Crash Modification Clearinghouse (232) for roadway lighting, one highly rated study by Elvik and Vaa shows a 28% decrease in nighttime crashes in all area types by “providing highway lighting” (233). Therefore, there may be benefit to traffic safety in the Region following improved roadway lighting.
- ARC partners, such as local governments, should consider implementing economic development efforts or policy efforts to lower the age of vehicles in the Appalachian vehicle fleet. We found that the median age of vehicles involved in crashes was 12 years. This age is not only greater

than in non-Appalachia, but is associated with a 32% increase in risk of death and serious injury should a vehicle of this age be involved in a crash (167). Gayer and Parker report that NHTSA's Car Allowance Rebate System (CARS) financial stimulus program resulted in a changeover from older vehicles to newer vehicles (234). Although this program had other economic trade-offs, it demonstrated that short-term stimulus efforts may reduce the number of older, unsafe vehicles, so ARC partners and local or state Governments in Appalachia may consider other stimulus programs to introduce younger, safer vehicles to the driving public.

- While restraint use in the Appalachian and non-Appalachian United States is generally high, Appalachian motor vehicle occupant fatalities are more likely to be unrestrained at the time of crash than non-Appalachian vehicle occupant fatalities. These results indicate that there may be a negative aspect of traffic safety culture surrounding restraint use in the Region. ARC may consider working with state partners to address this shortcoming through social marketing (such as targeted messaging regarding the benefits of restraint use) (235) from ARC and legislative action and enforcement from state partners.

5.2.3 Drug-Impaired Driving and Fatal Crashes in Appalachia

Although we examined drug-impaired driving trends using the FARS, it is critical that readers recognize that there are a number of significant limitations when it comes to interpreting drug-impaired driving trends using these data. FARS data are limited by state testing and reporting requirements, and a positive drug screen does not necessarily mean that the driver was impaired at the time of crash. Therefore, most of our recommendations regarding drug-impaired driving trends are centered on data collection and reporting needs.

- ARC may consider working with state agencies, like DOTs and DMVs, to convey the importance of routine drug testing and data collection. It can be difficult to identify problematic trends if data are not collected in a systematic way.
- States should set standards for drug testing and test for drug use in every fatal crash.
- State partners to ARC should consider following these revised data standards and drug testing protocols to perform more roadside drug and alcohol testing to better understand the frequency of impairment, especially in relation to alcohol outlets. Addressing drug-impaired driving (and its overlap with alcohol-impaired driving) will require systemic changes to the existing traffic safety culture that promotes impaired driving, so more data are needed to identify upstream causes of these behaviors.

5.2.4 North Carolina Case Study

The North Carolina case study was primarily conducted to verify key trends identified in the fatal crash data in the broader Appalachian Region. Therefore, we do not recommend any actions specific to North Carolina. However, some general recommendations derived from this case study and the broader fatal crash analysis include the following:

- ARC should inform state DOTs regarding seasonal trends in fatal and injury crashes. Both analyses found that death and serious injury crashes in Appalachian counties tend to peak during the fall months, and this peak may be due to seasonal tourism. State DOTs may in turn consider funding highway improvement projects for known tourist locations.

- State DOTs should consider funding rural road improvements, such as those identified through state SHSPs, to improve conditions on high-risk rural roads (HRRRs).

5.2.5 Evaluation of the Appalachian Development Highway System

The ADHS evaluation produced SPFs and CMFs based on a sample of crash data. These models may change as more data are collected and used in the evaluation. However, based on our current results, we can make the following recommendations:

- Based on our findings, the ADHS system seems to show significant safety benefits when new alignments are compared to old alignments. Therefore, if our assumptions for traffic volume distribution hold true, we do not recommend against expansion of the ADHS program.
- However, our models indicate no significant changes in single-vehicle and nighttime crashes. Therefore, ARC should work with state DOTs to calibrate statewide safety targets and identify countermeasures for nighttime and single-vehicle crashes to be implemented alongside ADHS improvements.
- All state partners should consider revising data standards and exploring data sharing with the Region to facilitate the meeting of Region-wide safety targets.

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