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Utah Department of Transportation - Research Division
4501 South 2700 West - P.O. Box 148410 - SLC,UT 84114-8410

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A PEER EVALUATION OF SAFETY AT SIGNALIZED INTERSECTIONS IN UTAH

Prepared For:

Utah Department of Transportation
Research & Innovation Division

Final Report
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16. Abstract

The Utah Department of Transportation (UDOT) has made significant efforts to reduce crashes at signalized intersections and is constantly seeking to improve safety across the state. The purpose of this research is to quantify and evaluate the safety rates and frequencies at signalized intersections in Utah compared to other states. Once the crashes have been quantified, the secondary purpose is to determine why there may or may not be differences. A survey was developed to understand how states analyze, prioritize, and implement safety at signalized intersections, including different policies, procedures, and countermeasures. Crash data from eight states were analyzed and compared to Utah to determine how specific crashes of interest compare across the states. Comparison tables were generated to evaluate the crash frequency of crash attributes of interest amongst states. Additionally, odds ratio analyses were conducted to compare the odds of a crash being severity K (fatal), A (suspected serious injury), and B (suspected minor injury) in Utah compared to other states. The results highlight how different states compare to Utah regarding red-light running, speeding, unrestrained crashes, angle crashes, distracted driving, and older driver crashes at signalized intersections. Recommendations were made for future research regarding policies, procedures, and countermeasures related to red-light cameras, advanced warning flashers, bulb-outs, left-turn phasing options, and programs related to distracted driving, older drivers, and unrestrained crashes.

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LIST OF ACRONYMS

AAA	American Automobile Association
AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway Transportation Officials
ATSPM	Automated Traffic Signal Performance Measures
BYU	Brigham Young University
CAMS	Crash Analysis Methodology for Segments
CMF	Crash Modification Factor
CTE	Committee on Traffic Engineering
DARE	Dynamic All-Red Extension
DOT	Department of Transportation
DUI	Driving Under the Influence
EB	Empirical Bayes
EPDO	Equivalent Property Damage Only
FHWA	Federal Highway Administration
FYA	Flashing Yellow Arrows
GIS	Geographic Information Systems
HSM	Highway Safety Manual
ICE	Intersection Control Evaluation
ISAM	Intersection Safety Analysis Methodology
ISAR	Intersection Safety Analysis Report
ITS	Intelligent Transportation Systems
LiDAR	Light Detection and Ranging
LOSS	Level of Service Safety
LPI	Leading Pedestrian Interval
MUTCD	Manual on Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administration
PDO	Property Damage Only
PSI	Potential Safety Improvement

RLR	Red-Light Running
RSAM	Roadway Safety Analysis Methodology
RSI	Relative Severity Index
RTM	Regression-to-the-mean
SPF	Safety Performance Function
STORM	Signal Timing Routine Maintenance
TAC	Technical Advisory Committee
TOMS	Two-Output Model for Safety
UCPM	Utah Crash Prediction Model
UCSM	Utah Crash Severity Model
UDOT	Utah Department of Transportation
UICPM	Utah Intersection Crash Prediction Model
VBA	Visual Basic for Applications
VRU	Vulnerable Road Users

EXECUTIVE SUMMARY

The Utah Department of Transportation (UDOT) has made significant efforts to reduce crashes at signalized intersections and is constantly seeking to improve safety across the state. In coordination with UDOT, Brigham Young University (BYU) conducted research to determine what policies, procedures, countermeasures, or future research could be implemented to improve safety at signalized intersections. This was carried out by first synthesizing current literature affiliated with signalized intersection safety to understand principles related to defining, analyzing, and implementing safety specifically at signalized intersections. Then, a survey was sent to all 50 states to understand what policies, procedures, and countermeasures these states have implemented. An analysis of crash data was then performed comparing crash attributes at signalized intersections in Utah to those states that were willing to share data. The connection between the data analysis and the survey results is designed to compare safety rates and frequencies at signalized intersections between states and explain why there may or may not be differences in Utah. Based on the results of both the data analysis and survey, the research team developed a list of different policies, procedures, countermeasures, and future research to improve safety at signalized intersections in Utah.

Respondents from 23 states, Puerto Rico, and the District of Columbia completed the survey, and respondents from eight states also shared crash data that was comparable to Utah for the purposes of this research. The research team focused on six crash attributes as discussed with the Technical Advisory Committee (TAC): red-light running (RLR) crashes, speed-related crashes, unrestrained crashes, angle crashes, distracted driving crashes, and older driver crashes. A comparison table was generated to compare signalized intersection crashes with these crash attributes. The results focused on those states that have a lower percentage of KAB crashes on the KABCO severity scale. Additionally, the odds ratio results also focused on those states where crash attributes had statistically lower odds of a KAB crash occurring. The survey results, data analysis, and existing literature were used to recommend policies, procedures, countermeasures, and future research to address safety at signalized intersections in Utah. Recommendations included, but were not limited to, red-light cameras, advanced warning flashers, bulb-outs, left-turn phasing options, and programs related to distracted driving, older drivers, and unrestrained crashes.

1.0 INTRODUCTION

1.1 Problem Statement

From January 1, 2019, through December 31, 2023, Utah reported 296,629 crashes along its roadways. Of those, 123,510 (41.6 percent) were intersection-related, and 70,056 (56.7 percent) of those intersections were signalized. The Utah Department of Transportation (UDOT) has made significant efforts to reduce crashes at signalized intersections and is constantly seeking to improve safety across the state.

To better understand how Utah intersection-related crashes compare to other peer states across the nation, this research quantified and evaluated the crash rates and crash frequencies at signalized intersections in Utah compared to other states. Evaluating the comparative difference in crashes amongst other states will allow the UDOT Traffic and Safety Division to identify new and innovative ways to improve safety by evaluating what other states are doing to reduce signalized intersection crashes.

In coordination with UDOT, the Brigham Young University (BYU) Civil and Construction Engineering Department analyzed crash data across various states to compare safety rates to Utah. This effort was supported by the BYU Statistics Department. The team also conducted a survey to better understand best practices from other states to improve safety at signalized intersections. Based on the results of both the data analysis and survey, the research team developed a list of policies, procedures, and countermeasures, combined with recommendations for future research to improve safety at signalized intersections in Utah.

This research may help UDOT identify new and innovative ways to improve safety across the state at signalized intersections based on the practices implemented by peer states. This may also contribute to UDOT's Zero Fatalities: A Goal We Can All Live With® campaign to continually reduce the number of fatalities on Utah roadways.

1.2 Objectives

The purpose of this research was to quantify and evaluate the apparent safety rates and crash frequencies at signalized intersections in Utah compared to other states. This required collecting crash data from various states, including Utah, to understand in-depth crash trends. Once the crashes were quantified, the secondary purpose was to determine why there may or may not be differences. This required an understanding of the different policies, procedures, and countermeasures that each state uses and how those compare to Utah.

1.3 Scope

The scope of this research included a review of literature related to the definition, measurement, and improvement of safety at signalized intersections. In other words, a review of different safety analyses, practices, and countermeasures was performed for this study. Additionally, a survey was sent to all 50 states to understand different policies, procedures, and countermeasures implemented across the United States. Crash data were also collected from those states willing to share it to compare signalized intersection crashes in Utah to other states. Using that data, the percentage of specific crash attributes was compared for signalized intersections across different states. Additional statistical analysis was also conducted to compare how the odds of different levels of crash severity (specifically K (fatal), A (suspected serious injury), and B (suspected minor injury)) in Utah compared to other states. This study led to recommending specific countermeasures to be implemented in the State of Utah to reduce crash rates and severity at signalized intersections.

1.4 Outline of Report

The body of the report is organized in the following manner:

- Chapter 1 introduces the research topic, objectives, scope, and report outline.
- Chapter 2 synthesizes current literature on relevant topics affiliated with safety at signalized intersections.
- Chapter 3 describes the processes used to collect data from other states.
- Chapter 4 evaluates the data collected from the survey and summarizes the findings.

- Chapter 5 evaluates the crash data collected and summarizes findings from the statistical analysis.
- Chapter 6 provides conclusions about research results including findings, limitations, and challenges.
- Chapter 7 provides recommendations and implementation on ways that safety can be improved at signalized intersections based on the peer evaluation.

The chapters are followed by a references section and appendices detailing survey questions and responses, crash data collection and analysis, and other information related to the research.

2.0 LITERATURE REVIEW

2.1 Overview

Signalized intersections play a vital role in managing traffic flow and ensuring roadway safety by assigning the right-of-way to different approaches and movements. These intersections are controlled by traffic signals that reduce the likelihood of severe crashes and improve the interaction of high-volume, multi-modal traffic. According to the Manual on Uniform Traffic Control Devices (MUTCD), a traffic signal is warranted based on specific criteria, including crash experience, traffic volume, and pedestrian activity (FHWA, 2024).

Despite the proven safety benefits of signalized intersections, the complexities of their design and operation require detailed evaluation methods to prioritize improvements. The Highway Safety Manual (HSM) provides a robust framework for assessing signalized intersections through 13 performance measures, each offering a unique perspective on crash frequency, severity, and contributing factors. The choice of performance measure depends on factors such as data availability and the need to address regression-to-the-mean (RTM) bias—a statistical method that is used to look at the random fluctuation of crash frequencies at a specific location over time. This ensures that safety evaluations are accurate and actionable (AASHTO, 2010).

In Utah, signalized intersections are a critical focus area for UDOT, contributing to 41 percent of statewide crashes (Numetric, 2025). To prioritize safety improvements, UDOT primarily employs the Potential Safety Improvement (PSI) methodology found in the HSM, which identifies intersections with the greatest potential for crash reduction by comparing observed crash frequencies to expected values (AASHTO, 2010). In addition to the PSI method, UDOT benefits from advanced tools developed through research conducted by BYU, such as the Utah Intersection Crash Prediction Model (UICPM) and the Intersection Safety Analysis Methodology (ISAM) (Schultz et al,. 2018). These tools utilize Bayesian statistical modeling and automated processes to analyze crash data and identify high-risk intersections effectively. This literature review explores the methodologies used to evaluate and enhance safety at signalized intersections. It begins by defining safety at signalized intersections including an in-depth examination of performance measures outlined in the HSM. Next, the review discusses the UDOT methodology for prioritizing safety improvements followed by a section on the development of advanced analytical tools for expanding the analysis of safety in Utah. Common crash types at signalized intersections are then analyzed to identify contributing factors. The final section explores proven countermeasures designed to improve intersection safety, especially for common crash types at signalized intersections in Utah.

2.2 Defining Safety at Signalized Intersections

Signalized intersections are intersections that are controlled by "electrically operated traffic control devices that provide indication for roadway users to advance their travels by assigning right-of-way to each approach and movement" (FHWA, 2013b). The MUTCD (11th Edition) outlines nine warrants that determine when a traffic signal is warranted. An intersection qualifies for a traffic signal when at least one of the nine warrants is met. Warrant 7 specifically looks at crash experiences at an intersection to determine if a traffic signal is needed. According to the MUTCD, a traffic signal is warranted if (FHWA, 2024):

1. Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency; and
2. Five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; and
3. For each of any 8 hours of an average day, the vehicles per hour (vph) given in both of the 80 percent columns of Condition A in Table 4C-1 (see Section 4C.02 of the MUTCD), or the vph in both of the 80 percent columns of Condition B in Table 4C-1 exists on the major-street and the higher-volume minor-street approach, respectively, to the intersection, or the volume of pedestrian traffic is not less than 80 percent of the requirements specified in the Pedestrian Volume warrant. These major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.

The FHWA confirms that the installation of traffic signals should be considered if one of the purposes of the installation is to reduce the crash frequency and/or severity (FHWA, 2024). Signalization contributes to the safety of an intersection by providing guidance on right-of-way, reducing the likelihood of severe angle crashes, and managing the interaction of high-volume and mixed-modal traffic. Crash frequency and crash severity are the most common metrics to determine the safety of a signalized intersection, however, they are not the only metrics that can be used to determine if a signalized intersection is safe or how safe it is.

The HSM (AASHTO, 2010) outlines 13 performance measures designed to assess the safety of signalized intersections. These measures are:

1. Average Crash Frequency
2. Crash Rate
3. Equivalent Property Damage Only (EPDO) Average Crash Frequency
4. Relative Severity Index (RSI)
5. Critical Rate
6. Excess Predicted Average Crash Frequency Using Method of Moments
7. Level of Service of Safety (LOSS)
8. Excess Predicted Average Crash Frequency Using Safety Performance Functions (SPFs)
9. Probability of Specific Crash Types
10. Excess Proportion of Specific Crash Types
11. Expected Average Crash Frequency with Empirical Bayes (EB) Adjustments
12. EPDO Average Crash Frequency with EB Adjustments
13. Excess Expected Average Crash Frequency with EB Adjustment

The 13 performance measures found in the HSM (AASHTO, 2010) are the third of five steps in the HSM network screening process, which systematically identifies and prioritizes high-risk locations. First, it establishes a focus, defines the roadway network, and groups locations into reference populations for meaningful comparisons. Then, it selects performance measures and evaluates results to prioritize sites for safety improvements. The performance measures are used to evaluate the potential of reducing the crash frequency and/or severity at a site. The HSM recommends that multiple performance measures be used to evaluate a site as it may help to improve the level of confidence in the analysis. However, not every performance measure can be used for a given site depending on data availability, the impact of RTM bias, and the methodology for establishing performance thresholds at the site.

The three factors used to determine when it is effective to use the HSM performance measures are data availability, the impact of RTM bias, and the methodology for establishing performance thresholds (AASHTO, 2010). Each measure provides a unique lens for evaluating intersection safety, enabling agencies to select the most appropriate metric for their specific goals and resources.

Data availability refers to the ease and practicality of obtaining the necessary data to calculate a performance measure. Some performance measures, such as crash frequency or crash rate, rely on readily accessible data, including crash records and traffic volumes. Other measures may require more extensive data, such as calibrated SPFs, a mathematical function used to determine the expected crash frequency at a specific site based on roadway characteristics, traffic volume, and other influencing factors. Some measures may also require overdispersion parameters, which are statistical values used in crash modeling to account for variability in crash data that cannot be explained solely by roadway characteristics and traffic volume, helping to improve the accuracy of SPFs by adjusting for unobserved factors such as weather conditions, driver behavior, and enforcement levels (AASHTO, 2010).

Because of RTM, short-term crash data might not accurately reflect the long-term average crash frequency. This variability means that relying solely on short-term data can lead to misleading conclusions about the safety of a location or the impact that a countermeasure may have on that location. RTM suggests that if a location experiences an unusually high number of crashes during one period, it is statistically likely that crash frequencies will decrease in subsequent periods, even without safety interventions. Conversely, locations with abnormally low crash frequencies may see an increase over time. Without addressing RTM in safety analysis, safety measures might be improperly prioritized or evaluated based on data that reflects random variation rather than genuine safety impacts. If the RTM is not accounted for at a site, then it introduces the potential for the RTM bias (AASHTO, 2010).

A performance threshold serves as a benchmark for comparing performance measure scores across a group of sites. Sites are evaluated to determine whether their performance measure scores are above or below the threshold. Those that fall below the threshold may warrant further investigation to identify opportunities for reducing crash frequency or severity. The method for establishing a performance threshold depends on the chosen performance measure. Thresholds can be subjectively determined or calculated through a defined methodology. Common approaches include using the average crash frequency for a reference population, applying SPFs, or utilizing EB methods. More sophisticated methods that incorporate RTM bias and require additional data typically result in more reliable performance thresholds (AASHTO, 2010).

In the following sections, each of the 13 performance measures will be discussed. The discussion will include an overview of the measure, the type and accessibility of data required for its application, the extent to which it is influenced by RTM bias, and the approach used to establish its performance threshold. This structured analysis will offer a comprehensive understanding of the tools available for intersection safety evaluation and their practical applications. Table 2.1 provides an overview of requirements needed for the use of each performance measure as discussed in the following subsections.

2.2.1 Average Crash Frequency

Intersection crash frequency "is defined as the number of crashes occurring within a specific intersection" over a period of time (FHWA, 2011). Crash frequency helps to identify intersections with a history of crashes, spatially display crash locations on a heat map, and obtain a summary of crash types at an intersection or location. Crash frequency is an appealing screening method due to its simplicity; it relies solely on crash data and physical location information. This eliminates the need for additional data, such as traffic volumes or roadway features, making the approach relatively straightforward, quick, and cost-effective (AASHTO, 2010). However, the absence of exposure data can limit the depth of analysis and may overlook critical context for certain intersections. Strengths and limitations of the Average Crash Frequency performance measure are (FHWA, 2013a):

Strengths:

- Simple

Limitations:

- Does not account for traffic volume
- Does not account for RTM bias
- Does not identify a predicted threshold to compare sites with similar characteristics
- Does not effectively identify low-volume collision sites where simple, cost-effective mitigation measures could easily be implemented

2.2.2 Crash Rate

Crash rate analysis for a site evaluates relative safety by incorporating exposure data—often represented by average annual daily traffic (AADT) volumes. This method calculates crash rates to compare the site with other sites with similar volumes and is valuable in prioritizing safety concerns. Strengths and limitations of the Crash Rate performance measure are (AASHTO, 2010):

Strengths:

- Simple
- Can be modified to account for severity if an EPDO or RSI-based crash count is used

Limitations:

- Does not account for RTM bias
- Does not establish a sure benchmark to identify locations with crash frequencies exceeding the expected levels for sites with similar characteristics
- Cannot make comparison across sites with significantly different traffic volumes
- May mistakenly prioritize low volume and low collision sites

Table 2.1 Summary of Data Needs and Stability of Performance Measures (AASHTO, 2010)

Performance Measure	Crash Data	Roadway Information for Categorization	Traffic Volume	Calibrated SPFs and Overdispersion Parameter	Other	Accounts for RTM Bias	Method Estimates a Performance Threshold
Average Crash Frequency	X	X				No	No
Crash Rate	X	X	X			No	No
EPDO Average Crash Frequency	X	X			EPDO Weighting Factors	No	No
RSI	X	X			Relative Severity Indices	No	Yes
Critical Rate	X	X	X			Considers data variance but does not account for RTM bias	Yes
Excess Predicted Average Crash Frequency Using Method Moments	X	X	X			Considers data variance but does not account for RTM bias	Yes
LOSS	X	X	X	X		Considers data variance but does not account for RTM bias	Expected average crash frequency $\pm$ 1.5 standard deviations

Table 2.1 Continued

Performance Measure	Crash Data	Roadway Information for Categorization	Traffic Volume	Calibrated SPFs and Overdispersion Parameter	Other	Accounts for RTM Bias	Method Estimates a Performance Threshold
Excess Predicted Average Crash Frequency Using SPFs	X	X	X	X		No	Predicted average crash frequency at the site
Probability of Specific Crash Types	X	X				Considers data variance; not affected by RTM Bias	Yes
Excess Proportion of Specific Crash Types	X	X				Considers data variance; not affected by RTM Bias	Yes
Expected Average Crash Frequency with EB Adjustments	X	X	X	X		Yes	Expected average crash frequency at the site
EPDO Average Crash Frequency with EB Adjustments	X	X	X	X	EPDO Weighting Factors	Yes	Expected average crash frequency at the site
Excess Expected Average Crash Frequency with EB Adjustment	X	X	X	X		Yes	Expected average crash frequency at the site

2.2.3 Equivalent Property Damage Only Average Crash Frequency

The EPDO Average Crash Frequency performance measure assigns weight factors to crashes based on their severity (e.g., fatal, injury, property damage only (PDO)) to calculate a combined score that reflects both crash frequency and severity for a given site. These weighting factors are typically derived relative to the costs of PDO crashes. By summarizing crash costs across different KABCO severities, an EPDO value is calculated as illustrated in Tables 2.2 and 2.3. While some agencies use alternative methods for assigning weights, the HSM consistently utilizes crash costs to illustrate this performance measure. Crash costs encompass both direct and indirect expenses. Direct costs may include items such as ambulance services, police and fire response, property damage, or insurance claims. Indirect costs, on the other hand, reflect societal values placed on pain, suffering, and loss of life resulting from crashes. Strengths and limitations of the EPDO Average Crash Frequency performance measure are (AASHTO, 2010):

Strengths:

- Simple
- Considers crash severity

Limitations:

- Does not account for traffic volume
- Does not account for RTM bias
- Does not identify a predicted threshold to compare sites with similar characteristics
- Depending on the weighting factors that are used, locations with a low frequency of severe crashes may be overemphasized

Table 2.2 KABCO and UDOT Crash Severity Scales

KABCO	UDOT	Severity
K	5	Fatal Injury
A	4	Suspected Serious Injury
B	3	Suspected Minor Injury
C	2	Possible Injury
O	1	Property Damage Only

Table 2.3 Updated Crash Costs for Use in Benefit Calculations (2020 Dollars)

Severity	Severity No.	Crash Cost Weighted	Crash Cost Unweighted	Unweighted EPDO
K (Fatal)	5	$3,078,500	$14,010,300	828
A (Sus. Serious Injury)	4	$3,078,500	$805,800	47
B (Sus. Minor Injury)	3	$264,000	$264,200	16
C (Possible Injury)	2	$148,000	$148,000	9
O (PDO)	1	$17,000	$17,000	1
KA (Severe)	5,4	$3,078,500	N/A	182
KAB (Injury)	5,4,3	$806,700	N/A	48
KABC (Anticipated Injury)	5,4,3,2	$415,100	N/A	24
KABCO (Total Crashes)	5,4,3,2,1	$134,300	N/A	8

2.2.4 Relative Severity Index

The RSI compares average crash costs of similar sites to the individual intersection crash costs to determine the safety concern. This performance measure assigns crash severity using the KABCO scale—a severity rating system ranging from fatal crashes, K, to non-injury crashes, O (see Tables 2.2 and 2.3). Classifying crashes using a simple system, such as KABCO, makes reporting easy for law enforcement. This, in turn, provides more summarized data that can be used to prioritize intersections with the highest safety concerns. Strengths and limitations of the RSI performance measure are (AASHTO, 2010):

Strengths:

- Simple to use
- Considers collision type and crash severity

Limitations:

- Does not account for traffic volume
- Does not account for RTM bias
- May overemphasize locations with a small number of severe crashes depending on weighting factors that are used
- Will prioritize low-volume, low-collision sites by mistake

2.2.5 Critical Rate

The Critical Rate performance measure compares the observed crash rate at a site to a calculated threshold specific to that location, known as the critical crash rate. This threshold is determined by considering the average crash rate of similar sites, traffic volume, and a statistical constant compensating for variance in data. Sites where the observed crash rate exceeds the critical crash rate are flagged for further investigation. This measure allows for relative comparisons among sites with similar characteristics and helps identify locations that may need safety improvements. Strengths and limitations of the Critical Rate performance measure are (AASHTO, 2010):

Strengths:

- Establishes a threshold for comparison
- Considers variance in crash data
- Reduces exaggerated effect of sites with low volumes

Limitations:

- Does not account for RTM bias

2.2.6 Excess Predicted Average Crash Frequency Using Method of Moments

The Excess Predicted Average Crash Frequency Using Method of Moments performance measure compares the observed average crash frequency of a site to a pre-defined average crash frequency. Any site that exceeds the average crash threshold is prioritized for safety improvements. Individual sites are also adjusted to account for variance in the crash data. Strengths and limitations of the Excess Predicted Average Crash Frequency Using Method of Moments performance measure are (AASHTO, 2010):

Strengths:

- Establishes a threshold of predicted performance for a site
- Considers variance in crash data
- Allows all types of sites to be ranked in one list
- Similar concepts to EB methods

Limitations:

- Does not account for traffic volume
- Does not account for RTM bias

- Sites may be flagged due to unusually low frequencies of non-target crash types, which can misdirect prioritization
- Ranking results are influenced by reference populations, which can lead to sites near boundaries of reference populations potentially being over-emphasized

2.2.7 Level of Service Safety

The LOSS performance measure ranks sites based on a qualitative assessment where observed crash counts are compared to predicted average crash frequency for a considered reference population. Each site is categorized into one of four LOSS classifications depending on how significantly its observed crash frequency deviates from the predicted average. LOSS is divided into the following four levels: LOSS I (low crash frequency), LOSS II (near average), LOSS III (slightly above average), and LOSS IV (high crash frequency, indicating potential safety concerns). The predicted crash frequencies are derived using SPFs tailored to local conditions. Strengths and limitations of the LOSS performance measure are (AASHTO, 2010):

Strengths:

- Accounts for traffic volume
- Considers variance in crash data
- Establishes a threshold for measuring potential to reduce crash frequency

Limitations:

- Effects of RTM bias can still be present in results

2.2.8 Excess Expected Average Crash Frequency Using Safety Performance Functions

The Excess Expected Average Crash Frequency Using SPFs performance measure evaluates a site by comparing its observed average crash frequency to a predicted frequency derived from an SPF. The difference between these two values represents the excess predicted crash frequency. A positive value indicates more crashes than expected, while a negative value suggests fewer crashes than predicted. Strengths and limitations of the Excess Expected Average Crash Frequency Using SPFs performance measure are (AASHTO, 2010):

Strengths:

- Accounts for traffic volume
- Estimates a threshold for comparison

Limitations:

- Effects of RTM bias can still be present in results

2.2.9 Probability of Specific Crash Types Exceeding Threshold Proportion

The Probability of Specific Crash Types Exceeding Threshold Proportion prioritizes sites based on the likelihood that the true proportion of a particular crash type or severity (e.g., long-term predicted proportion) exceeds a defined threshold. This threshold is typically determined using the proportion of the target crash type or severity in a reference population. This method can also be applied diagnostically to identify crash patterns at intersections or roadway segments. Strengths and limitations of the Probability of Specific Crash Types Exceeding Threshold Proportion performance measure are (AASHTO 2010):

Strengths:

- Can be used diagnostically to explore crash patterns
- Considers variance in crash data
- Not affected by RTM bias

Limitations:

- Does not account for traffic volume
- Sites may be flagged for further study due to unusually low frequencies of non-target crash types, which can misdirect prioritization

2.2.10 Excess Proportions of Specific Crash Types

The Excess Proportion of Specific Crash Types measure prioritizes sites by comparing the observed proportion of a particular crash type or severity to a threshold proportion established for the reference population. Sites with observed proportions exceeding this threshold are flagged for further analysis. This method helps evaluate specific crash types and identify locations with higher risks for targeted improvements. Strengths and limitations of the Excess Proportions of Specific Crash Types performance measure are (AASHTO, 2010):

Strengths:

- Can be used diagnostically to explore crash patterns
- Considers variance in crash data
- Not affected by RTM bias

Limitations:

- Does not account for traffic volume
- Sites may be flagged due to unusually low frequencies of non-target crash types, which can misdirect prioritization

2.2.11 Expected Average Crash Frequency with Empirical Bayes Adjustments

The Expected Average Crash Frequency with EB Adjustments method adjusts observed crash frequencies using predictions from SPFs and weights them with expected values based on local crash data. The EB adjustment accounts for RTM bias and produces a more accurate estimate of expected crash frequency. Sites are ranked based on how their crash frequencies deviate from expectations. Strengths and limitations of the Expected Average Crash Frequency with EB Adjustments performance measure are (AASHTO, 2010):

Strengths:

- Accounts for RTM bias, providing more reliable results

Limitations:

- Requires SPFs tailored to local conditions, which can be resource-intensive

2.2.12 Equivalent Property Damage Only Average Crash Frequency with Empirical Bayes Adjustments

The EPDO Average Crash Frequency with EB Adjustments measure combines crash severity and frequency using EPDO weights, which assign higher values to crashes based on their KABCO severity (e.g., fatal or injury crashes compared to PDO crashes). The EB adjustment is applied to refine predictions and account for RTM bias. Strengths and limitations of the EPDO Average Crash Frequency with EB Adjustments performance measure are (AASHTO, 2010):

Strengths:

- Accounts for RTM bias
- Considers crash severity, allowing for a more nuanced assessment

Limitations:

- May overemphasize sites with a small number of severe crashes, depending on the weighting factors used

2.2.13 Excess Expected Average Crash Frequency with Empirical Bayes Adjustments

The Excess Expected Average Crash Frequency with EB Adjustment method combines observed crash frequencies and predicted crash frequencies derived from an SPF to calculate an adjusted expected crash frequency. The difference between the EB-adjusted crash frequency and the predicted crash frequency represents the excess crash frequency. If the excess value is greater than zero, the site experiences more crashes than expected, while a value below zero indicates fewer crashes than predicted. Strengths and limitations of the Excess Expected Average Crash Frequency with EB Adjustments performance measure are (AASHTO, 2010):

Strengths:

- Accounts for RTM bias, enhancing the reliability of results
- Provides a threshold to identify sites with crash frequencies exceeding expectations for similar locations

Limitations:

- Requires SPFs calibrated to local conditions, which can be resource-intensive to develop

2.2.14 Gap in Research

The Federal Highway Administration (FHWA) and the HSM provide guidelines on when the various methods can be used depending on the context-sensitive locations and the priorities of the agency in addressing safety at signalized intersections. The research remains inconclusive regarding the superiority of any single method. A significant gap exists in the literature as no known studies have systematically compared the differences between various methods or identified the most appropriate contexts for their application.

2.3 Utah Department of Transportation Methodology

UDOT determines which signalized intersections are prioritized for safety improvements using a data-driven approach based on the PSI methodology outlined in the HSM. This procedure follows the HSM performance measure, excess expected average crash frequency with EB adjustments. Unlike traditional methods that rely solely on crash rates, the UDOT approach compares the observed crash frequency at an intersection to the expected crash frequency derived from similar intersections with comparable characteristics, such as traffic volumes, lane configurations, and signal phasing (UDOT, 2025).

The PSI score, calculated as the difference between observed and expected injury angle crash frequencies, highlights intersections where safety improvements have the greatest potential to reduce crashes. UDOT focuses specifically on injury angle crashes, which are the most severe and costly. By converting PSI values into a 20-year present value of societal crash costs, the analysis provides a standardized unit for comparing intersections (UDOT, 2025).

This prioritization approach identifies intersections with the highest potential for effective safety enhancements, even if their traditional crash rate appears lower. Analysts are encouraged to investigate further using the PSI-based story map, incorporating additional details including crash narratives and predominant crash types, and to recommend tailored countermeasures such as signal phasing upgrades, left-turn lanes, and other intersection-specific improvements (UDOT, 2025).

2.4 Expanding Utah Safety Analysis Methodology

Schultz et al. (2018) conducted a series of comprehensive studies to assist UDOT with their goal of improving safety across the state. As a result of the research, the team developed the UICPM and the ISAM. This research aimed to identify intersection hotspots and prioritize safety interventions. Leveraging previous developments, such as the Utah Crash Prediction Model

(UCPM) and the Utah Crash Severity Model (UCSM), the UICPM applied a Bayesian generalized linear modeling framework to predict crash distributions based on roadway characteristics and historical crash data. The ISAM process streamlined the analysis by incorporating automated tools within Microsoft Excel's Visual Basic for Applications (VBA), combined with R statistical software. The methodology consisted of three phases: data preparation, model execution, and report creation, culminating in Intersection Safety Analysis Reports (ISARs) for detailed safety assessments (Schultz et al., 2018).

Researchers at BYU continued to collaborate with UDOT to develop improved tools, including the Roadway Safety Analysis Methodology (RSAM). The RSAM employed VBA and R-based automation, similar to that used in ISAM, for efficient data processing and model execution. The UICPM adapted these principles to address intersection safety concerns, processing crash data assigned to intersections based on functional areas. Inputs such as roadway attributes (e.g., speed limits, lane configurations, traffic volumes, etc.) and crash data were integrated to produce actionable safety insights. The ISAM automation significantly simplified data handling and report generation, enabling user-friendly visualization through geographic information system (GIS) mapping and concise ISARs for regional safety planning. The research illustrated the importance of addressing intersection-related crashes and claims that the methodology used will result in better safety project planning in Utah (Schultz et al., 2018).

Further research led to the development of the Crash Analysis Methodology for Segments (CAMS), an addition to the ISAM that focuses on identifying roadway segments with high potential for safety improvements. This methodology compares segments with the same AADT, functional class, number of lanes, speed limit, and urban code to provide a better comparison between roadway segments. CAMS research also added to the data used in ISAM to create an in-depth analysis of both intersection and roadway segment crashes (Schultz et al., 2020). Additional research led to the development of the Two-Output Model for Safety (TOMS) which combined the CAMS and ISAM methodologies to concurrently analyze crash hotspots and severity distributions on roadway segments and intersections. This expansion of crash analysis methodology furthers UDOT goals of reducing fatalities by improving identification of high-risk areas along the Utah roadway network (Schultz et al., 2023).

2.5 Common Crash Types at Signalized Intersections

With an understanding of the performance measures used to evaluate intersection safety and the factors that define a safe signalized intersection, the next steps are to explore the common crash types that occur at signalized intersections and analyze what the contributing factors are for each crash type. By identifying the causes of these crash types, countermeasures can be identified that will improve the overall intersection safety as described in Section 2.6 of this report. Based on the topics discussed on the FHWA Proven Safety Countermeasure website, some of the FHWA's safety concerns include pedestrian visibility, intersection visibility, driver attentiveness, and other intersection improvements (FHWA, 2021). In Utah, from 2019 through 2023, intersection crashes reflected 42.6 percent of all crashes. Side-angle crashes represent 44.5 percent of intersection crashes, and rear-end crashes represent 31.9 percent (Numetric, 2025). This section will discuss different crash types and their contributing factors as they pertain to signalized intersections, specifically angle crashes, rear-end crashes, pedestrian crashes, and red-light running (RLR) crashes.

2.5.1 Angle Crashes

Angle crashes can be categorized into two types: right-angle crashes, which occur when vehicles collide at a 90-degree angle, and side-angle crashes, which occur at angles other than those classified as rear-end, head-on, or right-angle collisions. Since both types of crashes often reflect similar causes, this section will address all angle crashes. A variety of different types of factors influence angle crashes including intersection geometry, signal operations, and approach speed. Additionally, the number of through lanes, time of day, and presence of permissive movements were found to be statistically significant in their contribution to angle crashes (Wang and Abdel-Aty, 2007).

2.5.2 Rear-End Crashes

Rear-end crashes occur when the front of one vehicle collides with the back of another vehicle. Factors related to this crash type include, but are not limited to, driver inattention, traffic signal compliance, visibility, approach speed, and intersection features (Bhattarai et al., 2024; Ni and Li, 2013; Wang and Abdel-Aty, 2007). The distance between intersections, both signalized and unsignalized, was also found to be correlated with the number of rear-end collisions (Wang and Abdel-Aty, 2007), but the traffic volumes did not show a strong correlation, suggesting that denser traffic does not directly correlate with higher crash frequency (Bhattarai et al., 2024).

2.5.3 Pedestrian-Related Crashes

Pedestrian crashes are a common concern in urban areas because of the high pedestrian traffic and the recurring conflict between permissive vehicle movements and pedestrians. The National Highway Traffic Safety Administration (NHTSA) recorded that 18 percent of fatal intersection crashes involved a pedestrian between 2018 and 2022 (NHTSA, 2025). These crashes have potential to be severe as pedestrians are exposed to the full impact of a vehicle. Pedestrian-vehicle crashes are common in areas where permissive turning movements conflict with the pedestrian phase and where drivers have visibility issues along a pedestrian route (Arun et al., 2023).

2.5.4 Red-Light Running Crashes

RLR is a common safety risk at signalized intersections and is a leading cause of urban intersection crashes (FHWA, 2013c; Khalilabadi et al., 2024). In Utah, crash reports attribute 17 percent of signalized intersection crashes to RLR (Numetric, 2025). Several factors contribute to drivers' signal compliance whether intentional or unintentional. Some of these factors include approach speed, intersection geometry, the age of the driver, and the time of day (Dias and Dissanayake, 2014; FHWA, 2022a). This wide variety of factors makes it difficult to define effective countermeasures that reduce RLR crashes (Le et al., 2018).

2.6 Safety Countermeasures at Signalized Intersections

In response to high crash numbers and identifiable factors, several countermeasures have been implemented to reduce crash rates and severity. Building on the discussion of causes of common crash types at signalized intersections, this section will introduce the Crash Modification Factor (CMF) Clearinghouse and explore countermeasures implemented at signalized intersections and current discussion on their effectiveness and implementation. Special attention will be given to FHWA Proven Countermeasures, including retroreflective backplates, leading pedestrian intervals (LPIs), and yellow change intervals, including current discussion on their effectiveness. Other countermeasures discussed in this section include rear-end crashes and side-angle crashes, the most frequent crash types reflected in the Utah crash dataset.

2.6.1 Crash Modification Factor Clearinghouse

A CMF is a measure used to relate countermeasures to their effect on crashes. This measure serves to compare and identify the most effective methods for reducing crashes with a specific roadway context. Equation 2.1 outlines the process for determining crash reduction based on the CMF and the existing crash rate. This equation can be reworked to solve for the CMF given the average crashes before and after implementing a countermeasure. A factor less than 1 indicates that a countermeasure is effective in reducing crashes, while a factor greater than 1 indicates that it is ineffective in reducing crashes (FHWA, 2022b).

$$CMF_i = \frac{Expected\ crash\ frequency\ if\ change\ i\ is\ made}{Expected\ crash\ frequency\ if\ change\ i\ is\ NOT\ made} \tag{2.1}$$

The CMF Clearinghouse is an FHWA-sponsored database containing information on different countermeasures and their effectiveness. This data stems from numerous studies that evaluate the effectiveness of different countermeasures on certain roadway contexts and classifications. Each study includes the observed CMF, the context classification, the types of crashes addressed, and the level of confidence of the study. This information further contributes to the discussion regarding the effectiveness and context of different countermeasures (FHWA, 2022b).

2.6.2 Signal Backplates with Retroreflective Borders

Retroreflective backplates are a common countermeasure at signalized intersections because they draw attention to the signal and its current phase (Moreland et al., 2024). Figure 2.1 illustrates a signal head equipped with a backplate and retroreflective border. The FHWA has identified a 15 percent reduction in total crashes by installing reflective backplates, and the safety effects far outweigh the low production, installation, and maintenance costs (Dias and Dissanayake, 2014; FHWA, 2011). Although the FHWA has declared installing retroreflective backplates as a proven safety countermeasure, few studies have been conducted that test their effectiveness. One study has found effectiveness in reducing RLR (Dias and Dissanayake, 2014), and another found that retroreflective backplates provided no significant changes in crash rates after installation (Moreland et al., 2024). The CMF Clearinghouse contains only one study that contributes to the discussion on retroreflective sheeting on backplates (Sayed et al., 2005). Additional research is needed to evaluate the effectiveness of retroreflective backplates in reducing intersection crashes across diverse contexts, offering more definitive evidence of their impact.

Figure 2.1 Signal Head with a Backplate and Retroreflective Border (FHWA, 2021)

2.6.3 Leading Pedestrian Interval

In an effort to increase the likelihood of motorists seeing and yielding to pedestrians, some cities and states initiate the pedestrian crossing phase a few seconds before the adjacent green phase for vehicles (FHWA, 2019). This style of signal timing where pedestrians are given a separate start phase is known as an LPI. The FHWA recognizes LPIs as a proven countermeasure with an estimated 13 percent reduction in pedestrian-vehicle crashes (FHWA, 2022a). Other studies have found a pedestrian crash reduction ranging from 10 to 59 percent with no negative effects for vehicle-vehicle crashes (Arun et al., 2023; Fayish and Gross, 2009; Goughnour et al., 2018; Saneinejad and Lo, 2019).

Although LPIs are a proven safety countermeasure for addressing pedestrian-related crashes, they are not suitable for every intersection. Table 2.4 displays a worksheet for determining the need of LPIs at a signalized intersection. This table highlights that LPIs are not effective at every intersection and should be assessed before they are implemented. Factors that determine the benefit of LPIs at signalized intersections include turning-movement volumes, pedestrian volumes, intersection visibility, proximity to schools, and impact on traffic flow (FHWA, 2022a; Saneinejad and Lo, 2019). If driver yield compliance is already high for pedestrians and there are no visibility issues, then an LPI may not be effective at reducing crashes.

Table 2.4 Leading Pedestrian Interval Suitability Worksheet (Saneinejad and Lo, 2019)

Factor	Values	Score	Score Allocation Guide
a. Is the pedestrian crossing at a T-Intersection (crossing is parallel to a road that ends at the intersection) and/or Is the pedestrian crossing parallel to a one-way road?		0 to 2	Yes = 2 No = 0
b. Are there issues such as safety concerns verified by staff or visibility issues caused by features such as irregular intersection geometry, wide-turning radius, crosswalk placement, obstructions such as buildings or base of a bridge, blinding sun angle?		0 to 2	Yes (4 or more issues) = 2 Yes (between 1 to 3 issues) = 1 No = 0
c. 8-h volume of pedestrians (p) crossing the leg being considered for LPI		0 to 2	2 if $p > 1,000$ 1 if $200 < p \leq 1,000$ 0 if $p \leq 200$
d. What is the overall total impact on vehicles using the intersection? *(a)* What is the increase in intersection total or average delay (%)? *(b)* What is the through phase V/C ratio of the signal with LPI?		0 to -6	Overall impact = -1 x |Min(A,B) x C| where A = {0 if $a < 10\%$, -1 if $10\% < a \leq 30\%$, -2 if a > 30%} B = {0 if b < 0.9, -1 if b ≥ 0.9}

Table 2.4 Continued

Factor	Values	Score	Score Allocation Guide
(c) What is the total 8-h vehicular volume at intersection?			C = {-1 if c < 16,000, -2 if 16,000 ≤ c < 30,000, -3 of c ≥ 30,000}
e. What is the rate of annual collisions between pedestrians and left- or right-turning vehicles per 1,000 8-h pedestrian crossings at the specific crossing in the past 5 years?		0 to 2	None = 0 0-3 = 1 >3 = 2
f. What is the rate of conflicts (conflicts per 1,000 8-h observations) between pedestrians and left- or right-turning vehicles at the specific crossing during 8 h of observation during area-specific pedestrian peak and nonpeak periods?		0 to 2	None = 0 0-3 = 1 >3 = 2
g. How far is the location from the nearest elementary school?		0 to 2	< 200 m = 2 > 200 m and < 850 m = 1 ≥ 850 m = 0
h. What is the elderly demand score (*e*) of the area where the intersection is located?		0 to 2	2 if *e* = 51 if 4 ≤ *e* < 50 if *e* < 4
Total Score			

2.6.4 Signal Timing Countermeasures for Red-Light Running

The duration of the yellow change interval plays a critical role in signal operations, as it notifies drivers that their allowable time to enter the intersection is coming to an end. If the yellow change interval is too short, then the dilemma zone for an intersection approach increases and leads to unintentional RLR. By contrast, if the yellow change interval is too long, then drivers may attempt to cross the intersection, causing an increase in RLR (Dias and Dissanayake, 2014; FHWA, 2022a). The appropriate length of the yellow change interval has been a topic of discussion regarding RLR. Some studies show that an increased yellow change interval is effective at reducing RLR (FHWA, 2022a; Khalilabadi et al., 2024), while others suggest that its effectiveness is contingent on the intent of the driver and is ineffective for reducing severe RLR cases (Bonneson et al., 2001; Khalilabadi et al., 2023).

The FHWA has identified yellow change intervals as a proven safety countermeasure with a 12 percent reduction in injury crashes, however, the timing of the interval is not explicitly mentioned. The agency recommends a regular evaluation on intersection performance to determine the appropriate length of the yellow change interval (FHWA, 2022a). The MUTCD suggests that the length of a yellow change interval should range from 3 to 6 seconds depending on the intersection approach speeds (FHWA, 2024). This suggests that each agency should identify the appropriate yellow time for each intersection and adjust the timing—not simply increase the yellow change interval. In Los Angeles, a 0.5-second increase in the yellow change interval reduced RLR crashes by 20 to 25 percent (Beeber, 2011). In other areas, a slight reduction in the yellow change interval may achieve comparable safety outcomes. This highlights the need for a thorough performance evaluation at each intersection to determine the optimal yellow change interval that maximizes safety.

The timing of the red clearance interval has also been a topic of discussion regarding RLR. When drivers know that there is a prolonged red clearance interval, they may feel more inclined to run the red light knowing that the next phase will not start immediately. If a red clearance interval is too short, then post-encroachment times are shorter, and the risk of crashes increases. In an effort to manipulate the red clearance interval timing as a safety measure, North Carolina has implemented the Dynamic All-Red Extension (DARE). This signal operation extends the red clearance interval when sensors encounter vehicles that will run the red light. Since the red clearance interval is not consistently extended, this reduces the driver adaptation that is often caused by extending the red clearance interval (Simpson, 2022). UDOT has also implemented DARE at one intersection in Salt Lake City.

2.6.5 Countermeasures for Rear-End Crashes

Considering that the distance between intersections is an influential factor in rear-end crashes, limiting access along roadways, especially those of higher speeds and lower visibility, is important in reducing vehicle collisions. The FHWA has addressed this concept, commonly known as access management, as an important consideration in improving the safety of a roadway network. The FHWA found that by limiting available access points, in KA crashes decreased by an estimated 25 to 31 percent along urban and suburban arterials (FHWA, 2021). UDOT has also established administrative rule R930-6 that dictates how access management should be implemented across different roadway classifications. Their goal is to increase safety while also providing efficient highway operations (UDOT, 2019).

The CMF Clearinghouse also has a list of countermeasures that address rear-end crashes at signalized intersections. These countermeasures are divided into two categories as shown in Table 2.5. The table demonstrates that many of the countermeasures have a CMF greater than 1, implying that these measures increase crashes rather than reduce them. The installation of red-light cameras, speed cameras, and other red-light intelligent transportation system (ITS) devices increased rear-end crashes at signalized intersections (Himes et al., 2017; Izadpanah et al., 2015). The high CMF observed when testing driveway presence on the receiving intersection corner confirms the need for access management at signalized intersections. A conflicting observation was observed regarding access management where driveway presence at an intersection approach decreased the number of crashes (Le et al., 2018). Perhaps by expecting a vehicle to enter the roadway, drivers are more cautious in their approach to the intersection.

Table 2.5 Countermeasures for Rear-End Crashes

Countermeasure		CMF range	Area	Sources
Advanced Technology and ITS	Install red-light cameras	1.08	Urban, Suburban	Izadpanah et al., 2015
	Install red-light indicator lights	1.02	Not specified	Himes et al., 2017
	Install automated speed camera at signalized intersection	1.09	Urban, Suburban	Izadpanah et al., 2015
Access Management	Driveway on an intersection approach corner	0.63 - 0.79	Not specified	Le et al., 2018
	Driveway on an intersection receiving corner	1.36 - 1.86	Not specified	Le et al., 2018

2.6.6 Countermeasures for Side-Angle Crashes

In response to a search query for angle crashes, the CMF Clearinghouse populated several results categorized by the countermeasure type—intersection geometry, advanced technology and ITS, and access management. Table 2.6 summarizes the countermeasures populated by the search query, a range of CMFs as determined by various studies, the area type studied (i.e., urban, suburban, or rural), and the attributing sources.

This information confirms that increasing the intersection sight distance for right-turn movements decreases the number of crashes, specifically in urban areas (Barua, 2018). Additionally, this information confirms that red-light cameras and automated speed cameras are useful in reducing angle crashes, but at the same time, that red-light indicator lights need further studies to draw an accurate conclusion (Himes et al., 2017; Izadpanah et al., 2015). The remaining countermeasures studied verify the need for limited access near a signalized intersection (Le et al., 2018).

Table 2.6 Countermeasures for Angle Crashes

Countermeasure		CMF range	Area	Sources
Intersection Geometry	Change right-turn geometry to increase line of sight (approach level)	0.41	Not specified	Schattler et al., 2016
Advanced Technology and ITS	Install red-light cameras	0.62	Urban, Suburban	Izadpanah et al., 2015
	Install red-light indicator lights	0.75 - 1.04	Not specified	Himes et al., 2017
	Install automated speed camera at signalized intersection	0.69	Urban, Suburban	Izadpanah et al., 2015
Access Management	Driveway on an intersection approach corner	1.03 - 1.06	Not specified	Le et al., 2018
	Driveway on an intersection receiving corner	1.42 - 2.02	Not specified	Le et al., 2018

2.7 Summary

This chapter provides a comprehensive discussion on signalized intersections and their role in traffic safety. Signalized intersections utilize electrically operated traffic control devices to assign right-of-way to various approaches and movements, enhancing safety by reducing conflicts and clarifying traffic flow. The MUTCD outlines nine warrants to justify signal installation, with Warrant 7 focusing on crash experience. A signal is warranted under this criterion if attempts to reduce crash frequency through alternatives fail, if there are five or more reportable crashes within a year that could be mitigated by a signal, and if traffic volumes or pedestrian traffic meet specific thresholds during peak hours. Signalized intersections can reduce crash severity, particularly for high-risk movements, and provide a structured framework for managing interactions at complex intersections.

The HSM outlines 13 performance measures to assess signalized intersection safety, ranging from crash frequency and crash rates to advanced methods like excess expected average crash frequency with EB adjustments. These measures consider factors like data availability, RTM bias, and methodologies for setting performance thresholds. For instance, simpler metrics like crash frequency and crash rate are cost-effective but lack depth and fail to account for RTM bias. Advanced methods, such as those utilizing EB adjustments, address these limitations by providing refined estimates and thresholds for safety evaluations. The selection of countermeasures depends on the specific context, goals, and resources of the analysis.

UDOT has adopted a data-driven approach, exemplified by the PSI methodology outlined in the HSM which follows the HSM performance measure, excess expected average crash frequency with EB adjustments. UDOT has developed other methods for intersection safety such as the UICPM, ISAM, and TOMS, to prioritize safety improvements. These models integrate Bayesian generalized linear modeling with automated tools in Microsoft Excel and R to analyze crash data and produce actionable insights. The ISAM process automates data preparation, model execution, and report generation, streamlining the identification of intersection hotspots and facilitating the development of targeted safety interventions. Data preparation and model execution were enhanced through the CAMS and TOMS processes, allowing for improved crash hotspot identification and severity distributions. This approach aligns with the HSM's emphasis on advanced statistical methodologies, providing UDOT with robust tools to enhance intersection safety planning and resource allocation.

Frequent and severe crash types are determined using crash data and safety analysis methods. They include angle crashes, rear-end crashes, pedestrian crashes and RLR crashes. By understanding the contributing factors of each crash type, countermeasures can be implemented, according to the context of an intersection, to reduce crash frequency. Retroreflective backplates, LPIs, and yellow change intervals were identified by FHWA as proven safety countermeasures. The CMF Clearinghouse has also identified countermeasures with predicted CMF values for an intersection given a specific roadway classification. Additional discussion on RLR suggests that other changes to signal operations could also reduce RLR crashes. Further analysis of each intersection will determine the utility of these countermeasures at reducing specific crash types.

3.0 DATA COLLECTION

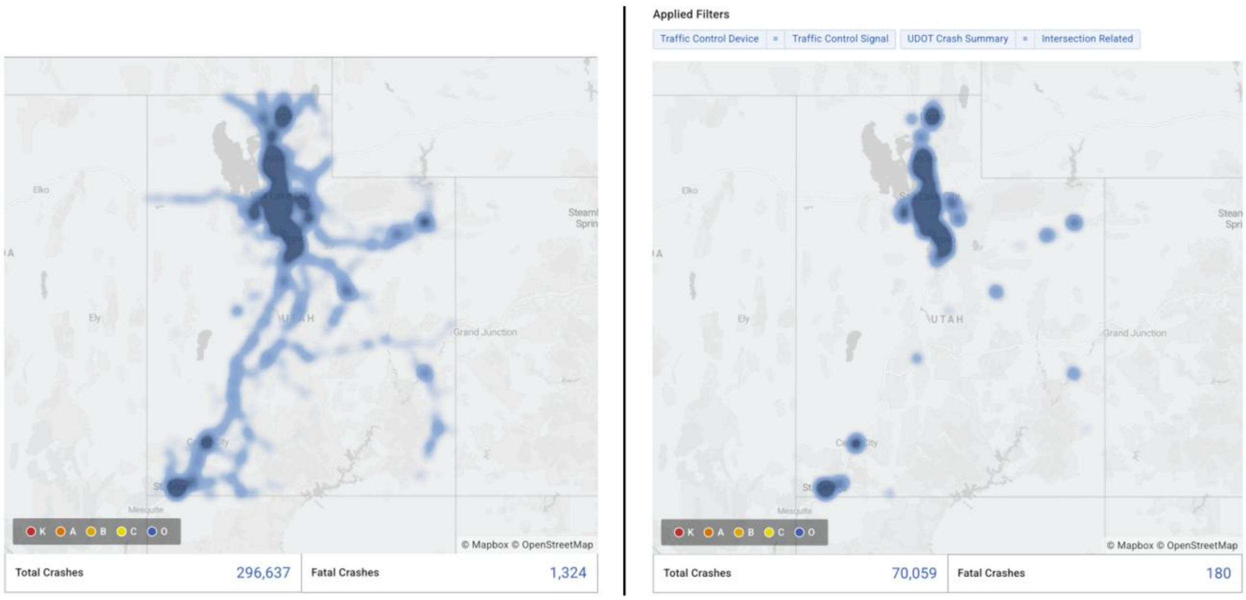
3.1 Overview

This chapter describes the tasks associated with data collection for this research study, namely, determining relevant data for peer comparison, creating and distributing a survey, and selecting peer states for quantitative data analysis. The type of crash data collected in Utah was used as the standard for generating survey questions and for requesting crash data. The survey provides holistic and qualitative information on the policies, procedures, and countermeasures implemented in each state. The crash data provides quantitative information on trends in peer states used to compare to crash trends in Utah. The outcomes of this data collection further the research goals of understanding best safety practices at signalized intersections and implementing those findings in Utah.

3.2 Selecting Relevant Data

An important step to collecting data was deciding which information would be comparable across states and helpful in determining best practices. Crash data generally comes from police reports, including crash date, time of day, weather conditions, manner of collision, contributing circumstances, and other factors. The level to which this information is recorded varies from state to state; thus, it was important that the selected data fields for comparison were accessible from each state.

The research team used Utah-specific crash data as a guideline to determine what data to collect from other states. Utah uses the AASHTOWare Safety Tool to store crash data online and analyze crash behaviors at roadways and intersections. The AASHTOWare Safety Tool is an online roadway safety software used to visualize and analyze crash data (Numetric, 2025). Figure 3.1 demonstrates two heatmaps of crash data in Utah—one representing all crashes, and another filtered to represent crashes at signalized intersections. The information listed in the AASHTOWare Safety Tool was filtered to represent crashes at signalized intersections from January 1, 2019, through December 31, 2023, using the filters "UDOT Crash Summary = Intersection related" and "Traffic Control Device = Traffic Control Signal." This search resulted in 70,056 relevant crashes in Utah over the 5-year period. From this dataset, the research team determined several categories of interest including functional classification, urban/rural setting, collision manner/crash type, crash severity, weather condition, light condition, and age group. Several contributing factors were also determined to be relevant including left turns, driving under the influence (DUI), RLR, distracted driving, vulnerable road user (VRU) involvement, and speed. This information was important in understanding crash trends in Utah and in comparing those trends to other states. Appendix A includes a full list of crash data attributes requested to perform crash analysis.



(a) (b)

Figure 3.1 AASHTOWare Safety Crash Heatmaps for (a) All Crashes and (b) Filtered Data

Trends regarding the number of lanes and intersection width were also of interest to the research team. A file containing this data, known as the Signal Timing Routine Maintenance (STORM) Supernova dataset, was provided to the research team by UDOT Traffic Management Division engineers (Taylor, 2025). Using the STORM dataset, crosswalk length data was joined with corresponding crash data using GIS geoprocessing tools. Other intersection-related data of interest was found using the AASHTOWare Safety Tool, including junction type, number of approaches, and intersection geometry. These intersection data types were requested from the other states to understand factors related to crash trends across the states. Appendix A also contains a full list of intersection data attributes requested for crash analysis.

3.3 Survey Development

Understanding how other states have addressed safety at signalized intersections is an important aspect in identifying best practices to improve safety. A survey was developed to understand how states analyze, prioritize, and implement safety at signalized intersections. This information will aid UDOT in determining ways to improve safety at signalized intersections. Survey questions were categorized based on their relation to different crash trends, contributing factors, policies, procedures, and countermeasures. These categories were selected to encompass the planning, policy, and engineering aspects related to signalized intersection safety and data analysis. The survey was developed using Qualtrics for its ease of secure access and sent to state traffic and safety engineers in all 50 of the United States. While special emphasis was directed to selected peer states, each state's response was considered in the context of improving safety at signalized intersections in Utah.

A printed form of the survey questions can be found in Appendix B with each category divided into sections, referred to in the survey as blocks or standards. This section of the report explains each section of the survey and how it relates to the research. The first section asks questions about the respondent and their employment as a transportation professional. The second section asks questions about defining safety, including the use of the HSM performance measures. The third section covers trends in crash data. The fourth section covers methods used for safety evaluation and progress. The fifth section asks respondents about how their states implement countermeasures. The sixth section asks respondents about traffic signal intervals and installation policy. The seventh section covers other miscellaneous categories related to intersection safety. The final section asks respondents for contact information and other feedback related to intersection safety and crash data.

3.3.1 General Information

The survey states that its purpose is to help UDOT improve safety at signalized intersections. The first section of the survey asks personal questions about the respondent, including the state they represent, their role/title, and the agency or department in which they are employed.

3.3.2 Defining Safety

Understanding how different agencies define and analyze safety is the first step in determining different policies, procedures, and countermeasures. This section includes questions regarding states' use of the 13 HSM performance measures in identifying areas of concern. The methods states use to define and analyze safety influences the types of locations that are prioritized. Differences in prioritization may reflect differences in crash data across the different states. By understanding the differences in defining and analyzing safety, and the consequences of the different methods, an improved prioritization process can be achieved that better identifies locations of greatest concern—and what those concerns are.

3.3.3 Crash Data and Trends

Data trends are a key topic in comparing safety at signalized intersections. Understanding the results of different states' programs, analysis methods, and countermeasures is most evident in the crash trends identified from state to state. This section addresses data trends that have occurred in each state over the past 5 years and contributing factors of those trends. Respondents are asked about their data collection and analysis software, crash frequency and severity trends, and contributing factors to observed crashes. This information will help compare Utah to other states and determine specific areas of improvement in the state.

3.3.4 Safety Evaluation and Programs

In response to crashes, it is common for state agencies to implement a systemic safety analysis or audit program to target specific crash types and minimize their frequency. This section of the survey addresses systemic safety analysis and/or audit programs implemented to improve safety at signalized intersections. A description of the programs and their methods are requested by each respondent to identify effective safety evaluation and safety improvement programs across the United States. By understanding the various programs states use, UDOT engineers and analysts can adapt these programs and implement them in the context of their area.

3.3.5 Countermeasures and Practices

Improving safety at signalized intersections requires effective countermeasures to be implemented. These countermeasures could be physical changes to the roadway, changes to signal operations, or even installing lighting or additional signage near an intersection. This section asks respondents about countermeasures implemented, guidelines for implementation, and ranking of effectiveness at reducing crashes. This information will help identify which countermeasures work well in other states and aid in creating an implementation plan in Utah.

3.3.6 Signal Installation and Policy

The use of traffic signals and various signal operations can greatly impact safety at an intersection. This section asks about traffic signal installation and policy. Respondents are asked to describe policies for signal installation, lighting, and the use of different intervals and operations. Questions include policies on the clearance intervals, exclusive pedestrian phasing, and split phasing.

3.3.7 Other Considerations

Many other factors can have an impact on intersection safety. This section asks respondents about other considerations related to intersection safety, including questions about sunlight glare, roadway width data, and demographic information on age and gender. Roadway width data is of particular interest as Utah has wide roads. Crash trends have also been observed between different age and gender groups. Any correlation resulting from these other factors is important to identify as part of the data analysis.

3.3.8 Feedback and Policy

The final section of the survey prompts respondents to include any additional information relevant to the research and to include contact information for continued discussion on data analysis. Contact information is also used to gain access to crash data from other states for further analysis. This allows for deeper discussion on selected topics based on survey results and analysis.

3.4 Selecting Peer States to Request Crash Data

While the survey was sent out to all 50 states, and all data are considered in the analysis, not every state has roadway characteristics that are comparable to Utah. The main goal of the data collection was to identify several states with roadway and socioeconomic characteristics similar to Utah that can be compared for data analysis. The research team and members of the Technical Advisory Committee (TAC) discussed how geographic features—location, urbanization level, and climate—should be similar to Utah to provide a more direct comparison of crash trends. States in the Mountain West were determined to be the best peer states based on their similar topography, weather conditions, and socioeconomic trends. Many cities throughout this region follow a similar roadway grid configuration and have high rates of population growth, leading to similar capacity and, consequently, safety trends.

It is also important to consider data collection methods when determining peer states. Several states use the AASHTOWare Safety Tool for data collection and analysis. Data collected from these states is expected to be formatted similarly to Utah's data, making better comparisons between states. Figure 3.2 displays different states that also use the AASHTOWare Safety software. Some of these states were selected for review based on their methods of data analysis.

Figure 3.3 displays a map of selected peer states for quantitative data analysis. Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, and Wyoming were all considered peer states based on geographic features as part of the mountain west region. Of those states, those shaded in blue—Idaho, Montana, and New Mexico, also used the AASHTOWare Safety Tool for crash visualization and analysis, providing a comparable data collection process.

A request was sent to those survey respondents who indicated they were willing to share crash data as part of the data analysis. This provided a sample of states larger than the peer states for comparison. Although efforts were made to collect crash data from peer states, all states with available data were considered for data analysis.

Figure 3.2 AASHTOWare Safety States (Numetric, 2025)

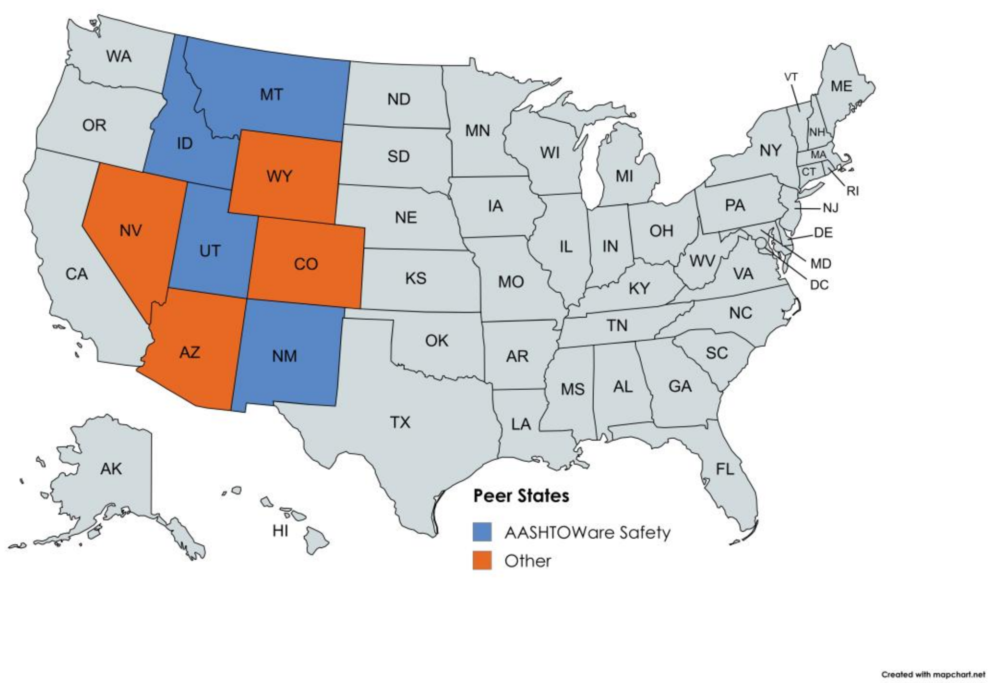


Figure 3.3 Select Peer States for Crash Data Analysis (Minas, 2025)

3.5 Summary

Collecting and understanding data across the different states was essential to develop recommendations on how to improve safety at signalized intersections in Utah. Determining what data to request was important to provide a broad range of data analysis that would compare crash trends across states. A survey was developed to understand how states analyze, prioritize, and implement safety at signalized intersections, including different policies, procedures, and countermeasures. In deliberation with the TAC, peer states were selected, and crash data was requested from all 50 states with emphasis on selected states for data analysis. These tasks furthered the research in efforts to draw conclusions on best safety practices and in providing ample safety recommendations for UDOT.

4.0 DATA EVALUATION – SURVEY

4.1 Overview

Understanding how other states have addressed safety at signalized intersections is an important aspect in identifying best practices to improve safety. As summarized in Chapter 3, a survey was developed to understand how states analyze, prioritize, and implement safety at signalized intersections. Survey results reflected various areas of signalized intersection safety, including crash data trends, safety analysis measures, effective countermeasures, and other policies and practices. This chapter summarizes the results of the survey on safety at signalized intersections and provides greater context to its importance in Utah.

4.2 Survey Results

The Qualtrics survey was distributed to members of the AASHTO Committee on Traffic Engineering (CTE) on June 23, 2025, and was open until August 20, 2025. Respondents from 23 states, as well as Puerto Rico and the District of Columbia, completed the survey as shown in Figure 4.1. Respondents from five additional states submitted an incomplete survey. For the states that completed the survey, not all questions were answered by every respondent. Thus, the number of responses varies from question to question. Some states also had multiple people complete the survey which increased the total number of responses received. At the close of the survey, 51 responses, whether complete or incomplete, were recorded. Survey respondents consisted of 42 (82 percent) State Department of Transportation (DOT) traffic and safety engineers and nine (18 percent) State DOT employees in management roles. The survey was divided into eight categories to organize questions as they related to policies, procedures, and countermeasures implemented in each state. A summary of these categories and their purposes can be found in Section 3.3. This section summarizes the results of each survey category as it relates to safety at signalized intersections, namely, defining and analyzing safety, crash data and trends, safety evaluation and programs, countermeasures and practices, signal installation and policy, other considerations, and feedback. A full report of survey responses and questions can be found in Appendix B.

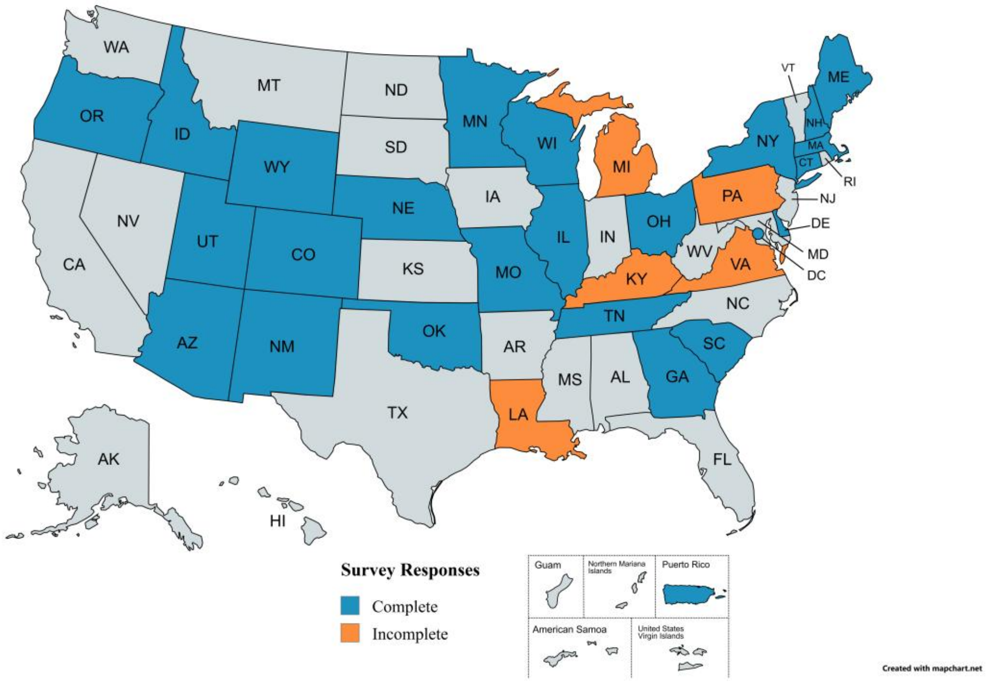


Figure 4.1 Survey Response Summary

4.2.1 Defining and Analyzing Safety

Intersection safety must be well defined and understood to measure progress and establish countermeasures that lead to improved safety. Survey respondents were asked what makes a signalized intersection safe. Of the 32 respondents who answered the question, 10 (31 percent) said that good visibility or visibility of the traffic signal made intersections safe. Eight (25 percent) reported that safe intersections accommodate all mode users, and four (13 percent) reported that safe intersections have attentive drivers and efficient traffic flow. Respondents also defined safety by providing several countermeasures. Seven respondents (22 percent) said that signal timing and slower speeds make intersections safe. Other common responses included increased law enforcement presence, LPIs, protected turns, and adequate lighting.

The use of HSM performance measures demonstrates how states analyze safety at signalized intersections. The HSM performance measures help establish a focus, define the roadway network, and group locations into reference populations for meaningful comparisons. They then help with selecting performance measures and evaluating results to prioritize sites for safety improvements. Of the 38 respondents who answered the question regarding the use of the

HSM performance measures, 12 (32 percent) acknowledged use of the HSM performance measures as part of their safety analysis. Table 4.1 displays the number and percentage of respondents who use any of the 13 HSM performance measures. The most notable measures used include average crash frequency, crash rate, expected predicted average crash frequency using SPFs, and LOSS. Eleven of the 12 respondents (92 percent) who acknowledge HSM use indicated using average crash frequency to measure safety while 10 respondents (83 percent) reported using crash rate to measure safety. Seven (58 percent) and six (50 percent) respondents indicated their use of excess predicted average crash frequency using SPFs and LOSS measures, respectively.

Table 4.1 Respondent Use of HSM Performance Measures

HMS Performance Measure	Number of Responses
Average Crash Frequency	11 (92%)
Crash Rate	10 (83%)
Excess Predicted Average Crash Frequency Using SPFs	7 (58%)
Level of Service of Safety	6 (50%)
EPDO Average Crash Frequency	4 (33%)
Excess Proportion of Specific Crash Types	4 (33%)
Expected Average Crash Frequency with EB Adjustments	4 (33%)
Excess Expected Average Crash Frequency with EB Adjustments	4 (33%)
Expected Predicted Average Crash Frequency Using Method of Moments	3 (25%)
Probability of Specific Crash Types	3 (25%)
Relative Severity Index	1 (8%)
Critical Rate	1 (8%)
EPDO Average Crash Frequency with EB Adjustments	1 (8%)

Other factors outside of HSM performance measures contribute to how a state analyzes safety at signalized intersections. Figure 4.2 demonstrates a weighted average of respondents' rankings of different safety analysis measures on a 10-point scale. The weighted average shows that crash severity, crash frequency, and crash rate were the top three safety measures used. Crash severity was ranked as the most important by 19 (57 percent) respondents. Crash frequency was ranked second with 23 (70 percent) respondents ranking it in the top three. Crash rates and the presence of VRUs were also ranked near the top.

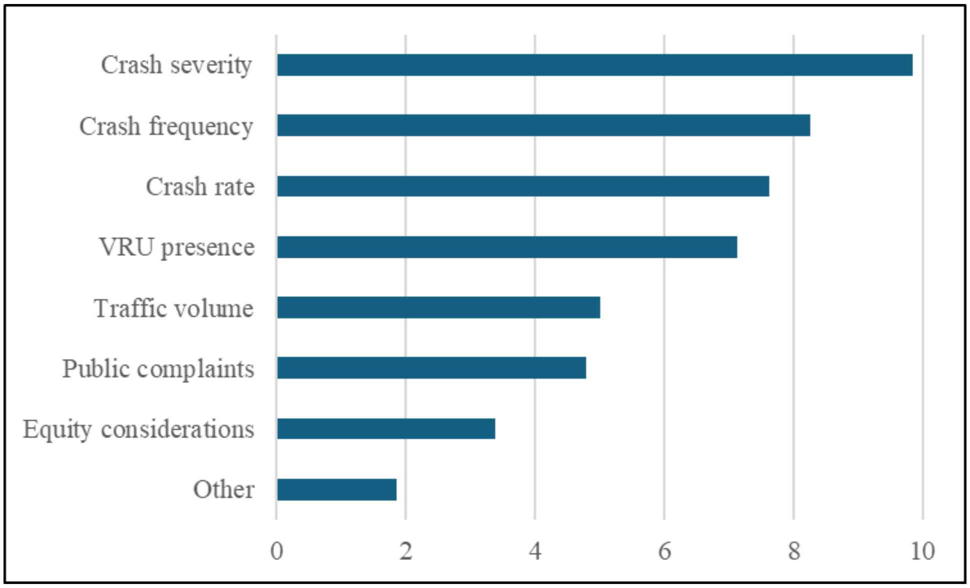


Figure 4.2 Weighted Average: Safety Analysis Measures

4.2.2 Crash Data and Trends

Understanding the results of different states' safety programs, analysis methods, and countermeasures is most evident in the crash trends identified from state to state. Of the 34 who responded, 22 respondents (65 percent) reported that their state did not see a change in crash frequency over the last 5 years. Of the 12 that did, seven (58 percent) saw an increase in crash frequency while five (42 percent) saw a decrease. Of those that saw an increase, four respondents (57 percent) attributed it to distracted driving and two (29 percent) attributed it to speeding. Respondents who saw a decrease in crash frequency attributed it to various factors such as improved signal timing, lower speeds, flashing yellow arrows (FYAs), and LPIs.

Respondents were asked if they have observed trends in crash severity. Eleven respondents (32 percent) reported an increase in severity, and four respondents (12 percent) reported a decrease in severity. As noted by survey respondents, factors relating to an increase in crash severity include speeding, RLR, and reckless driving. Factors related to a decrease in crash severity were reported to include signal timing and FYAs.

Respondents were also asked to rate their state's top crashes of concern. A weighted average on a 10-point scale of their responses was recorded as shown in Figure 4.3. Angle crashes and VRU crashes were the most concerning with 25 respondents (76 percent) placing one of these two as the number one concern. Speed related, rear-end, and distracted driving crashes were also ranked high.

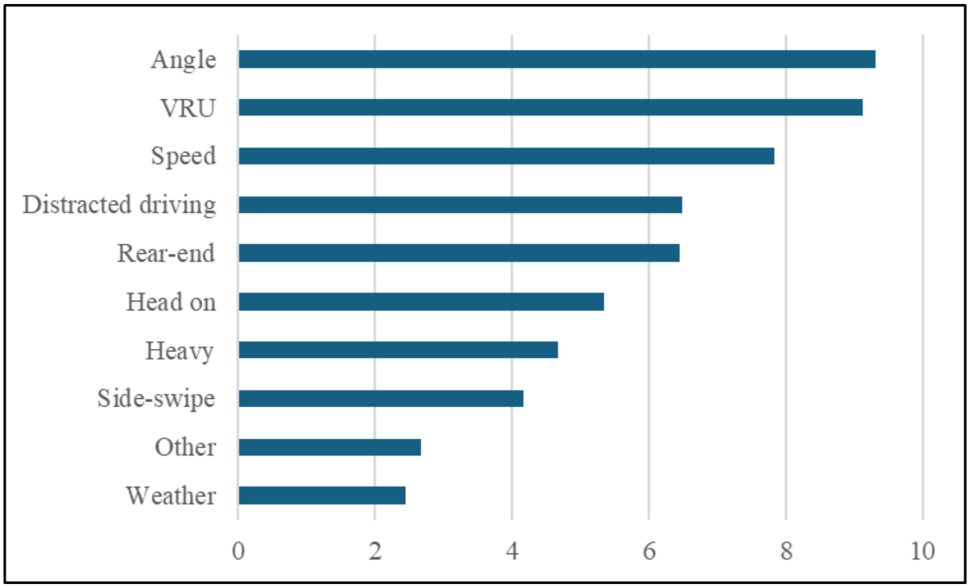


Figure 4.3 Weighted Average: Top Crashes of Concern

4.2.3 Safety Evaluation and Programs

In response to high crash frequency and severity, it is common for state agencies to implement a systemic safety analysis or audit program to target specific crash types and minimize their frequency. Thirteen respondents (39 percent) indicated that their state conducts a systemic safety analysis or safety audit program that includes, but is not specific to, signalized intersections. Methods included automated traffic signal performance measures (ATSPM), FHWA Intersection Control Evaluation (ICE), and HSM Performance Measures. Some respondents also noted that they prioritize areas with VRUs, speed-related crashes, and KABCO K and A crashes.

4.2.4 Countermeasures and Practices

Improving safety at signalized intersections requires effective countermeasures to be implemented. These countermeasures could be physical changes to the roadway, changes to signal operations, or even installing lighting or additional signage near an intersection. Countermeasures are typically appropriate in specific settings, thus, guidelines of practice should also be established to determine when they are effective and should be implemented. This section will present the countermeasures survey respondents found effective and summarize guidelines for implementing the countermeasures where respondents provided the most feedback for implementation.

4.2.4.1 Effective Countermeasures

Table 4.2 presents the number of respondents who found a particular countermeasure effective. Of 31 respondents, protected-only left-turn phasing and LPIs are the most frequently implemented as they were selected by 27 respondents (87 percent) and 24 respondents (77 percent), respectively. Bulb-outs, advanced warning flashers, permissive left-turn phases, and median barriers were also found to be effective by more than a third of respondents.

Table 4.2 Countermeasures States Have Found Effective

Countermeasure	Number of Responses
Protected-only left-turn phasing	27 (87%)
LPIs	24 (77%)
Bulb-outs/curb extensions	18 (58%)
Advanced warning flashers	15 (48%)
Permissive left-turn phasing	14 (45%)
Median barriers	12 (39%)
Channelized right turn lanes	11 (35%)
Delayed permissive left-turn phasing	10 (32%)
Other (please specify)	9 (29%)
Dual red-light displays	7 (23%)
Red-light enforcement cameras	5 (16%)

Respondents also ranked each countermeasure they use in order of its effectiveness. Some respondents closed the survey before ranking the countermeasures, so the numbers differ slightly from that of Table 4.2. A weighted average of these results was taken on a 10-point scale as shown in Figure 4.4. Of the 23 respondents who ranked protected-only left-turn phasing as effective, 20 respondents (87 percent) ranked it as the most effective countermeasure. LPIs were also highly rated as an effective countermeasure by 16 (76 percent) of 21 respondents. Although not used by many states, red light cameras were ranked as the second or third most effective by states that use them.

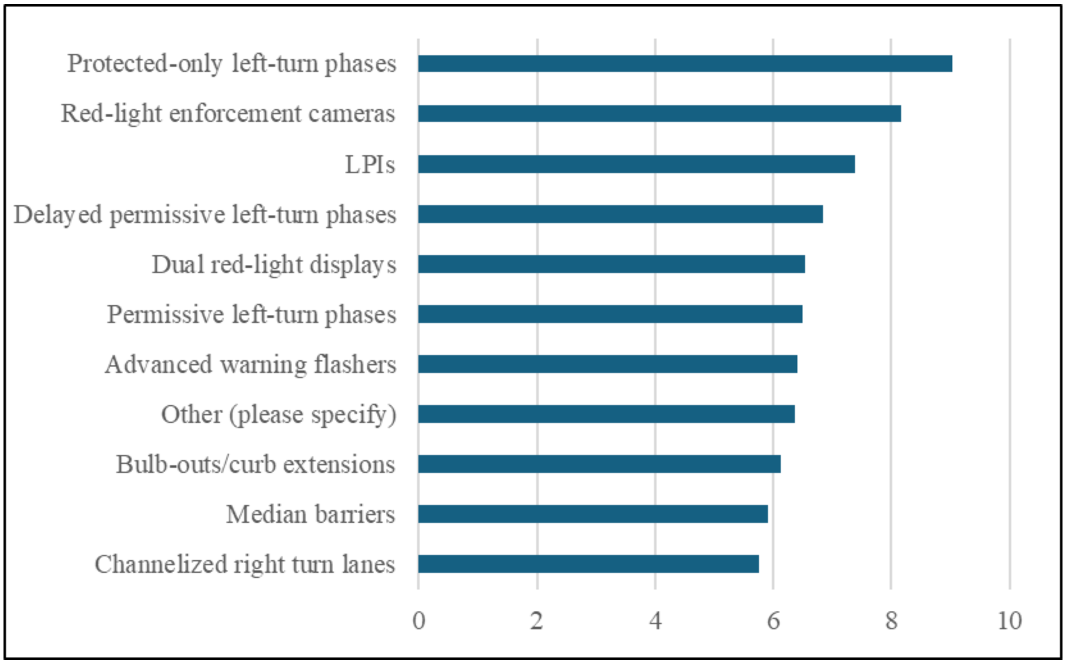


Figure 4.4 Weighted Average: Countermeasure Rank

4.2.4.2 Guidelines for Countermeasure Implementation

Table 4.3 displays a summary of responses regarding guidelines for implementing specific countermeasures. The numbers presented in the table reflect the responses of those who indicated that they use a specific countermeasure and whether their state has an established guideline for using that countermeasure. Of the 28 respondents who use protected/permissive left-turn phasing, 18 (64 percent) have an established guideline for when to implement the countermeasure. Those 18 respondents mentioned using traffic volumes to determine when to use protected/permissive phasing. Six respondents (33 percent) specify left-turning volumes as a threshold for determining which left-turn phasing to use. Other thresholds for countermeasure implementation include number of lanes, number of crashes, and sight distance.

Of the 23 respondents who use LPIs, 11 (48 percent) have guidelines for implementation. Three respondents (27 percent) said that LPIs are a default condition where pedestrian phasing exists, including the presence of sidewalks and accessible pedestrian signals. Other respondents included factors such as pedestrian volumes, crash history, corner radii, and visibility.

Of the 15 respondents who use advanced warning flashers, 7 (47 percent) have guidelines to establish when to use them. Of the respondents with guidelines, three (43 percent) consider traffic volumes and visibility when deciding to install advanced warning flashers. Other responses regarding when to use advanced warning flashers include the transition from rural to urban roads, crash history, and speed. One respondent also detailed the threshold as any intersection with speeds over 45 miles per hour (mph) that has sight distance issues.

Table 4.3 Implementation Guidelines for Countermeasures

Countermeasure	Yes	No	In Development
Protected/Permissive Left-Turn Phasing	18 (64%)	8 (29%)	2 (7%)
LPIs	11 (48%)	9 (39%)	3 (13%)
Advanced Warning Flashers	7 (47%)	8 (53%)	0 (0%)
Delayed Permissive Left-Turn Phase	5 (50%)	4 (40%)	1 (10%)
Channelized Right Turn	5 (45%)	6 (55%)	0 (0%)
Bulb-Outs/Curb Extensions	5 (29%)	12 (71%)	0 (0%)
Median Barriers	4 (33%)	7 (58%)	1 (8%)
Dual Red-Light Displays	3 (43%)	3 (43%)	1 (14%)

4.2.5 Signal Operations

The use of various traffic signal operations can have an impact on safety at an intersection. Figure 4.5 displays the different signal operations that respondents use in their state. Out of 32 respondents, 29 (91 percent) reported the use of red clearance intervals. Twenty-seven respondents (84 percent) reported that their state uses split phasing. Guidelines that respondents reported for split phasing include geometric alignment constraints, road capacity, or an imbalance of opposing traffic volumes. Fifteen respondents (47 percent) reported the use of an exclusive pedestrian phase; however, responses varied regarding consistent guidelines for implementation. Additionally, two states are replacing exclusive pedestrian intervals with concurrent phasing.

Five respondents (16 percent) reported that their state has speed thresholds for installing traffic signals. Additionally, 20 respondents (63 percent) reported that their state uses detectors to extend the length of the green interval if a vehicle is in the dilemma zone. Fourteen respondents (50 percent) said that their state has overhead lighting at all signalized intersections. Six respondents (21 percent) said that their state installs overhead lighting at pedestrian crossings while three (10 percent) base lighting on the percentage of nighttime crashes. Four respondents (14 percent) said their state does not have any signalized intersection lighting standards.

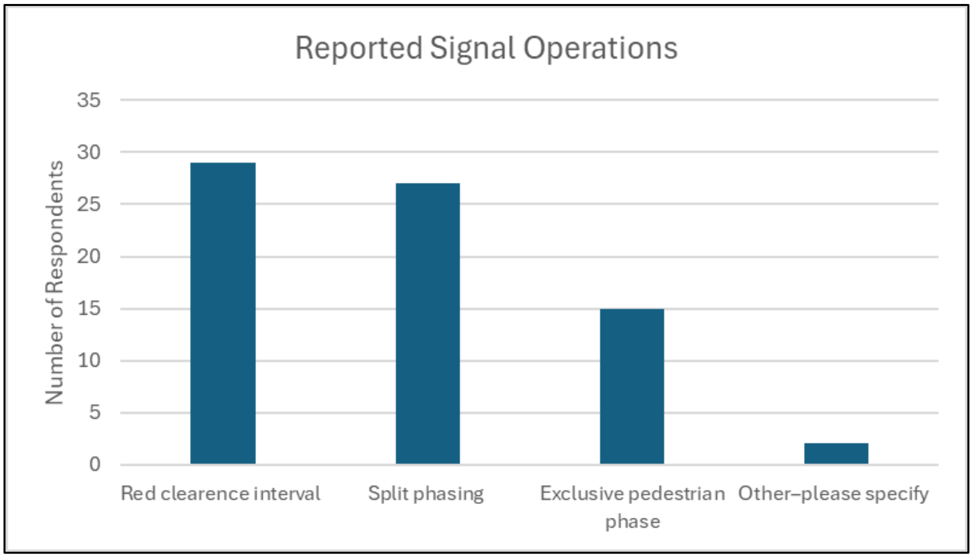


Figure 4.5 Signal Operations

4.2.6 Other Considerations

The impact of other factors on intersection safety was considered, including sunlight glare, roadway width, and intersection geometry. Table 4.4 displays a summary of the data responses collected and if a relationship was observed to signalized intersection crashes. Fifteen respondents (47 percent) reported the collection of sunlight glare data. Of those that responded, seven (47 percent) identified a relationship between safety and sunlight glare while eight (53 percent) did not. Of the 4 respondents (13 percent) that collect roadway width data, two respondents (50 percent) observed a correlation between roadway width and crashes at signalized intersections. Nine respondents (28 percent) also noticed a correlation between intersection geometry and crash rates while 23 (72 percent) reported no correlation.

Table 4.4 Data Collection and Trends

Data Collected	Collected	Crash Relationship
Sunlight Glare	15 (47%)	7 (47%)
Roadway Width	4 (13%)	2 (50%)
Intersection Geometry	9 (28%)	9 (100%)

4.2.7 Feedback and Participation

This section provides a summary of respondents who were willing to contribute to further discussion, including an analysis of the crash data. Table 4.5 displays a summary of responses given in this section. Responses were summarized into general categories relating to the additional comments received. Of the 13 respondents who answered this question, six (46 percent) mentioned analysis methods such as ICE, safety audits, and screening criteria. Three respondents (23 percent) consider alternative intersections that could replace signalized intersections including roundabouts, stop-controlled intersections, and restricted crossing U-turns. Three respondents (23 percent) also mentioned innovative countermeasures that they choose to implement, including bimodal blank-out signs, wide backplates in areas with high sun glare, and supplemental far-left signal heads. One respondent discouraged the use of FYAs because they lose their effectiveness over time. This feedback was valuable as it provided additional information to consider when considering safety at signalized intersections.

Twenty-four respondents (77 percent) indicated that they would be willing to participate in a follow-up discussion regarding safety at signalized intersections. Each of these respondents included contact information as part of their survey response. Additionally, 21 respondents (68 percent) sent contact information so that the research team could contact them to collect crash data for analysis.

Table 4.4 Summary of Feedback and Participation Section

Category	Number of Responses
Analysis Method	6
Alternative Intersection Consideration	3
Countermeasure Implementation	3
Administrative Context	3
ITS	2

4.3 Summary

A survey on safety at signalized intersections was sent to traffic experts throughout the United States to better understand policies, procedures, and countermeasures used to improve safety. Through a series of questions related to analyzing, prioritizing, and improving safety, responses provided valuable information on what other agencies are focused on, as well as how these agencies approach safety improvements. Respondents discussed crash trends and safety concerns in their states, explained countermeasures used, ranked the effectiveness of the countermeasures, and provided other recommendations to improve safety at signalized intersections. This information, in conjunction with the crash data sent from other states, will help identify best practices to reduce crashes at signalized intersections. The survey results, along with the crash data analysis in Chapter 5, will be used to identify best practices and make limited recommendations on ways to improve safety at signalized intersections.

5.0 DATA EVALUATION – CRASH DATA

5.1 Overview

Crash data were collected from 12 states, including Utah, for data analysis. Of these states, eight had crash attributes that could be compared to signalized intersection crashes in Utah. Crash trees were generated for Utah to identify high crash attributes specific to the state. After identifying areas of interest, random forest statistical analyses and regression modeling were performed to identify additional crash attributes that contributed to high severity crashes, such as pedestrian involvement, unrestrained driving, number of vehicles involved, aggressive driving, and RLR. Comparison tables were also generated to compare the crash frequency of Utah to other states. Additionally, odds ratio analyses were conducted to compare the odds of a crash being severe in Utah to other states. This method highlights statistically significant findings in comparing Utah to other states. Conducting the data analysis led to selection of crash attributes of interest, namely, RLR crashes, speed-related crashes, unrestrained crashes, and angle crashes. The results of these, and other areas of interest to UDOT, will be presented in this chapter.

This chapter will summarize the results of crash data collection, explain the procedures for analyzing the crash data, and summarize the results of those crash attributes selected. This contributes to the research goals by identifying which crash attributes are of interest and determining which states to review for further recommendations.

5.2 Crash Data Collection Results

In conjunction with the survey sent to state DOTs as outlined in Chapter 3, a request for crash data was sent to respondents who noted in the survey responses that they were willing to share crash data. Additionally, Connecticut crash data is open source and included in conjunction with information from the survey. Figure 5.1 displays the 12 states, including Utah, that sent their crash data to the research team for data analysis. Some states did not have a filter for signalized intersections making the data incomparable to Utah for the purposes of this research.

Eight states had comparable data to Utah in at least some of the crash attributes of interest and were selected for data analysis.

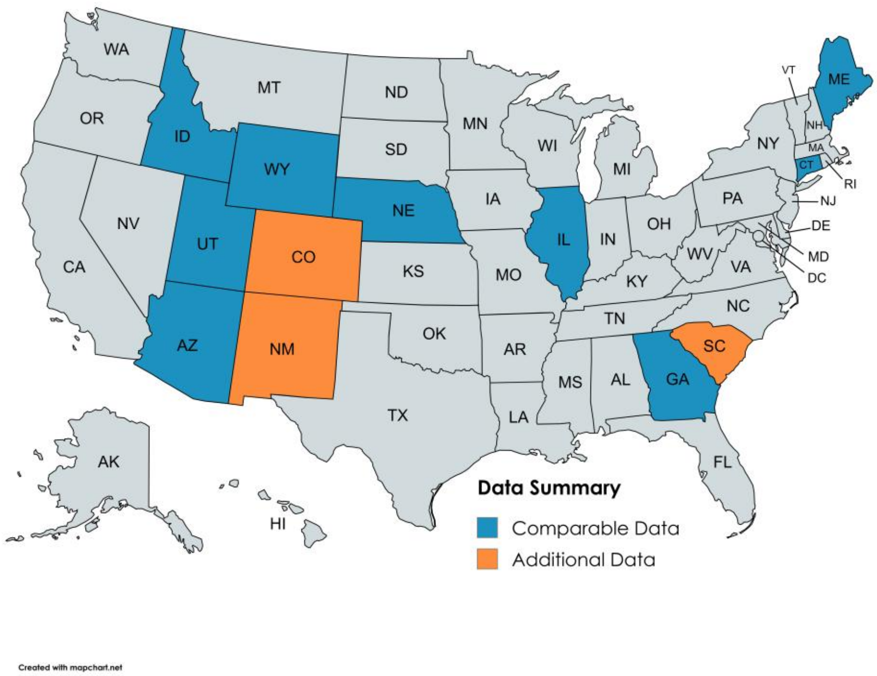


Figure 5.1 Crash Data Response Summary (Minas, 2025)

Data were collected at the crash level, unit level, and person level from each state, where applicable, to gain more insight as to specific crash fields. Each level records data in a different way, which in turn affects the percentage of crashes observed when comparing the same crash attributes on different levels. The crash level describes data attributes related specifically to the crash event such as manner of collision or crash severity. The unit level describes characteristics of the different modes involved in a crash such as turning movements or vehicle speeds. The person level describes characteristics of individuals involved in a crash such as driver age or DUI. Some states measured crash attributes on different levels than other states, thus limiting the information available for comparison. Utah reports crash data attributes across multiple levels when applicable, making one-to-one comparisons possible amongst states with multiple recording methods.

5.3 Crash Analysis Procedures

Several methods of crash data analysis were conducted to determine areas of most importance when comparing Utah crash data to other states. First, crash trees were generated to determine which crash attributes were of highest concern in Utah. Next, information was gathered from crash trees to generate a comparison table displaying crash frequency trends for each state. Comparison tables were created for KABCO (total crashes), KAB (injury) crashes, and KA (severe) crashes. Then, statistical analysis was conducted to identify differences in crash severity between Utah and other states. This section presents the procedures for conducting each of the analyses described.

5.3.1 Crash Tree Generation

Crash trees are visual representations of crash data trends for a given dataset. Each level of a crash tree represents a crash attribute, and each branch of a tree represents a collection of specific data attributes. Figure 5.2 presents an example of a crash tree based on Utah crash data using Microsoft Excel. The levels of this crash tree display RLR crashes grouped by manner of collision (angle, rear end, and sideswipe (same direction)). Each branch of the crash tree presents the frequency of that particular crash characteristic on the B, A, K, KAB, and KA severity levels as well as the total number of crashes for that crash attribute. A nested percentage for each level of the crash tree is included to display the percentage of which a particular crash attribute contributes to the characteristic above it. Using Figure 5.2 as an example, 30,083 (43 percent) of all signalized intersection crashes (70,056) are angle crashes, and 11,331 (38 percent) of those angle crashes involve RLR.

Crash trees were generated to analyze crash attributes including driver age, manner of collision, and other contributing factors. The research team determined several crash attributes of interest including manner of collision, functional classification, and age group. Other relevant crash attributes include left-turn movements, distracted driving, RLR, and speed. This information was important in understanding crash trends in Utah and in comparing those trends to other states. Appendix A provides a list of the crash data attributes analyzed as part of this research. Some states did not have all the crash attribute fields requested in Appendix A, however, each state selected for data analysis provided relevant contributions to the varying data fields of interest. Appendix C provides crash trees for all of the states analyzed. This information was used to identify areas of interest in Utah that would be further analyzed using the comparison tables and statistical tests.

Figure 5.2 Crash Tree Example: Manner of Collision and Red-Light Running

5.3.2 Comparison Tables

Comparison tables were generated to provide a quick glance comparing the frequency of different crash attributes amongst various states. Table 5.1 demonstrates a comparison table addressing dark lighting weather conditions for KABCO, KAB, and KA crash severities. The "AVG. (w/o UT)" column is the average percentage of every state but Utah. The percent change "**%Δ**" column was calculated by subtracting the average excluding Utah from Utah's percentage and dividing that result by the average excluding Utah as shown in Equation 5.1. The values in this column are negative if the percentage for Utah is lower than the calculated average, and positive if the percentage for Utah is higher.

$$\%\Delta = \frac{Utah - Avg}{Avg} \tag{5.1}$$

Table 5.1 Comparison Table Example: Weather Condition

Dark	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	2.4%	0.8%	1.3%	1.5%	1.6%	0.6%	6.2%	4.4%	0.1%	2.0%	17.9%
KAB	2.4%	0.8%	1.4%	1.9%	1.9%	0.7%	9.5%	4.7%	0.0%	2.6%	-8.4%
KA	3.2%	1.3%	1.5%	2.1%	2.1%	1.3%	13.1%	5.9%	0.1%	3.4%	-6.4%

Data are recorded in crash view for all states

The comparison table was used to provide a quick glance comparing Utah's crash rates to other states based on specific crash attributes and to determine what information was of most interest for further statistical analysis. Additionally, the results of this comparison provide insight as to how each state compares to Utah, furthering the research goals of comparing other states to Utah and documenting where there are differences. Appendix D provides a list of comparison tables for each crash attribute analyzed.

5.3.3 Statistical Analysis

The crash trees and crash tables were used to identify areas where further statistical analyses would be helpful. A random forest variable importance analysis was conducted to identify other variables that were impactful. Random forests are a statistical method where variable-based decision algorithms, commonly referred to as decision trees, are generated to predict the response variable of interest. Each decision tree uses a combination of variables from a dataset to further ensure a robust analysis. The importance of a variable is determined by measuring the average decrease in accuracy between all decision trees using a specified variable in comparison to all those without that variable (James et al., 2023).

A random forest analysis was conducted based on a logistic regression method which predicts whether a crash was a KAB crash or not. The random forest uses several different crash attributes to measure how the variables affect predicting KAB crashes. Figure 5.3 displays results from the KAB random forest analysis. A higher importance value corresponds with a higher accuracy in predicting crash severity when a specific variable is present. Based on the random forest analysis, manner of collision, pedestrian presence, number of vehicles involved, motorcycle presence, and RLR (labeled as disregard traffic control device involved) are important in determining if a crash is KAB or not. These results helped determine which crash attributes should be further analyzed to provide a more thorough comparison to other states and gain a better understanding of how they differ.

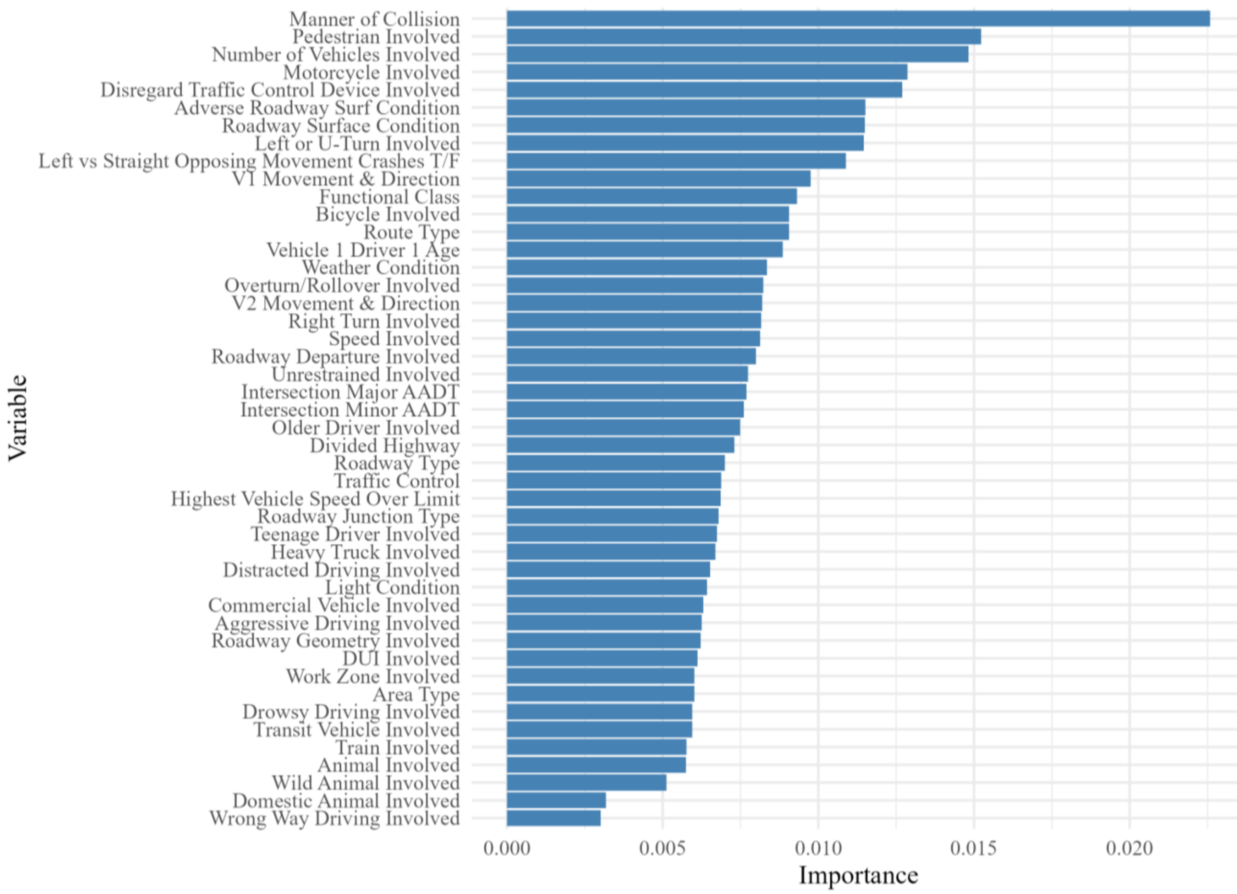


Figure 5.3 Variable Importance: Logistic Regression Model

After identifying the most important variables linked to crash severity, a logistic regression model was generated to further determine the statistical significance of different crash attributes on KAB crashes. Table 5.2 summarizes the results of a logistic regression model in predicting KAB crashes. Variables used in this model include manner of collision, pedestrian involvement, functional classification, left-/U-turn involvement, DUIs, speed-related, RLR, unrestrained, distracted driving, and aggressive driving. The coefficients represent how crash attributes affect the odds of a crash being KAB. If the value is greater than 1, then the odds of a crash being KAB increase when the crash attribute is present, which corresponds to a higher probability. If the value is less than 1, then the odds of a crash being KAB decrease when that attribute is present, which corresponds to a lower probability. Data attributes with a statistically significant influence on KAB crashes are displayed with asterisks. The more asterisks provided, the lower the p-value, and the lower probability of the results occurring due to random chance. Based on this model, head-on collisions, single-vehicle crashes, pedestrian crashes, crashes at major collectors, crashes at arterials, DUIs, speeding, RLR, unrestrained crashes, and aggressive driving are statistically significant in their claim of increasing the odds of a crash being KAB. Additionally, crashes involving rear ends, parked vehicles, sideswipes, and distracted driving are statistically significant in their claim of decreasing the odds of a crash being KAB.

Table 5.2 Logistic Regression Model: KAB Crashes

Variable	Coefficient	Pr(>|z|)
Rear End*	0.3065	0.01
Head On***	1.6780	< 2E-16
Single Vehicle***	1.4679	< 2E-16
Other	0.9245	0.8558
Parked Vehicle*	0.4021	1.7450E-04
Rear to Rear	0.5599	0.3588
Rear to Side	0.3100	0.0514
Sideswipe Opposite Direction*	0.5377	1.5543E-06
Sideswipe Same Direction***	0.1593	< 2E-16
Unknown*	0.7887	0.0360
Pedestrian Involved***	4.7970	< 2E-16
Local	1.1051	0.2645
Major Collector*	1.1943	0.0267
Minor Arterial*	1.2418	0.0267
Minor Collector	0.9906	0.9332
Freeway/Expressway	1.0226	0.9210
Other Principal Arterial*	1.4255	2.4659E-06
Left-/U-turn Involved	1.0297	0.2388
DUI***	2.010	< 2E-16
Speed-Related*	1.115	1.2364E-5
RLR*	2.119	0.01
Unrestrained***	3.6850	< 2E-16
Distracted Driving*	0.9094	1.3504E-6
Aggressive Driving***	2.202	< 2E-16

Significance codes: <0.001 '***' 0.001 '**' 0.05 '*'

After identifying crash attributes of interest, the odds ratios were calculated to compare the severity from crash data in other states to Utah. In statistics, the odds compare the chance of an event occurring to the chance that it does not occur. This differs from probability, which measures the likelihood of an event occurring based on all possible outcomes. Equation 5.2 presents the odds ratio as a function of the probability of an event occurring, x. The odds ratio is more often used for comparing the chance of an event occurring than the likelihood that it occurs, which changes the resulting value associated with the analysis. In the context of the crash dataset, for variables with multiple inputs, such as weather condition, manner of collision, and age group, a control crash attribute was used as a baseline to calculate the odds ratio. For yes/no fields such as RLR and speed-related, the control used for the odds ratio was the percentage of crashes in the "no" category. The odds ratio, which is different from the odds, measures how the odds change when a variable changes. The measured change in odds is a multiplier known as the odds ratio, which was used for this analysis. If the odds ratio is greater than 1.0, then the chance of a crash being KAB is more likely. Conversely, if the odds ratio is less than 1.0, then the chance of a crash being KAB is less likely (Ramsey and Schafer, 2012).

$$odds\ (x) = \frac{p(x)}{1-p(x)} \tag{5.2}$$

Figure 5.4 illustrates an example of odds ratios for snowy weather conditions for each state analyzed. In the context of this crash analysis, the odds of a crash being KAB in snowy weather conditions is calculated by dividing the number of KAB crashes that occurred in snowy weather by the number of KAB crashes that occurred in clear weather conditions. Using Utah's calculated odds as the baseline for the odds ratio amongst states, the numbers displayed for other states represent the odds that a KAB crash is more, or less, likely to have a crash attribute than Utah. Connecticut and Idaho have higher odds of a crash in snowy weather being KAB than in Utah as shown in Figure 5.4. Additionally, the confidence interval for the logistic regression model is presented in this figure as a means for determining statistical significance. There is not a confidence interval for Utah as Utah is the baseline, or standard, for crashes when comparing states. As such, the value for Utah was set to 1.0, and the odds for states are relative to how they compare to Utah. If the confidence interval for a state crosses 1.0, then no certain claim can be made regarding how that state compares to Utah (i.e., the results are inconclusive). If the confidence interval does not pass 1.0, the results are statistically significant. In the figure, the label for Wyoming has an asterisk, meaning that the odds are statistically significant. The results of the odds ratio analysis identify how other states compare to Utah regarding specific crash attributes. This will greatly contribute to the research goals of identifying how other states compare to Utah and explaining significant differences.

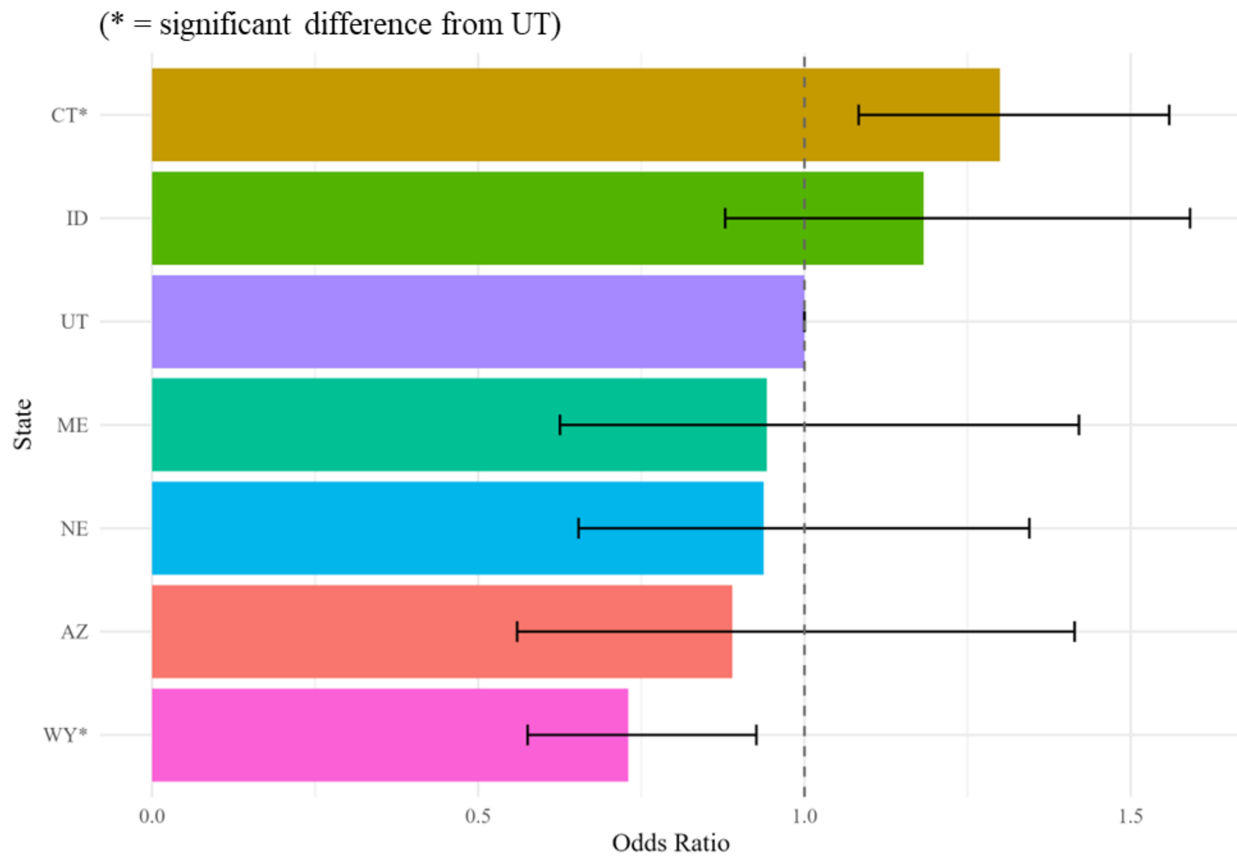


Figure 5.4 KAB Odds Ratio Example: Snowy Weather

5.4 Crash Data Analysis Results

Of the crash attributes that were analyzed, six were selected for further analysis—RLR, speed-related, unrestrained crashes, angle crashes, distracted driving, and older drivers. These emphasis areas were selected by the research team and TAC based on the results of the analysis as well as the priorities of UDOT. The following subsections will summarize each of these areas. Each subsection contributes to the research objective of identifying how Utah crash trends compare to other states, specifically at signalized intersections. The first paragraph in each section will present the crash data for Utah as determined from the crash tree analysis. The next paragraph will discuss the crash data received from other states and present the comparison table for that crash attribute. The final paragraph will discuss any additional statistical analyses performed and their statistical significance. Other analyses not detailed in this section are described in Appendix E.

5.4.1 Red-Light Running

In Utah, RLR crashes represent 19 percent of all signalized intersection crashes, 28 percent of KAB crashes, and 31 percent of KA crashes. Between 2019 and 2023, 58 people were killed and 497 people were seriously injured in crashes involving RLR in Utah. RLR crashes tend to be severe, with 32 percent of Utah's fatal signalized intersection crashes involving RLR. As shown in Figure 5.5, these crashes are predominantly angle crashes (87 percent) which tend to be more severe.

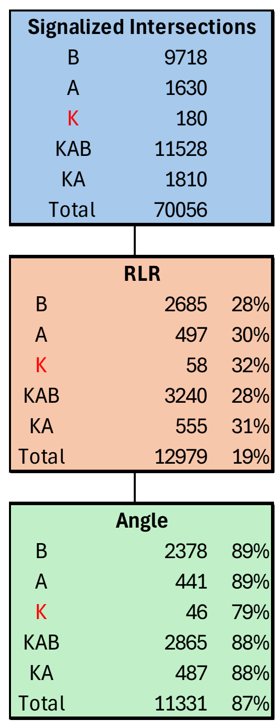


Figure 5.5 Crash Tree: Red-Light Running

Table 5.3 shows the distribution of RLR crashes by state. RLR data for each state was recorded in person view, except for Idaho, which records RLR data in vehicle view. Georgia's RLR data was originally recorded in crash view with multiple entries as if it were in person view. Since it was formatted as if it were person view data, the information was extracted to reflect person-view crash percentages as seen from the other states. Utah has the highest reported percentage of RLR crashes of the states analyzed. The proportion of KABCO RLR crashes in Utah is twice as high as the average proportion of the states analyzed and more than twice as high as the average proportion of KAB and KA crashes. The difference is most pronounced amongst KABCO crashes where Utah's proportion of intersection crashes attributable to RLR is 179 percent higher than the average of the other states. Georgia and Connecticut have the lowest percentage of RLR of the states observed. Georgia observed less than 1 percent KABCO crashes, 6 percent KAB crashes, and 12 percent KA crashes. Connecticut observed 4 percent KABCO crashes, 9 percent KAB crashes, and 12 percent KA crashes.

Table 5.3 Comparison Table: Red-Light Running

Red Light Running	UT	AZ	WY	ME	ID*	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	19%	7%	10%	11%	9%	<1%	7%	4%	7%	179%
KAB	31%	12%	18%	13%	12%	6%	11%	9%	11%	168%
KA	36%	16%	10%	15%	14%	12%	14%	12%	13%	170%

*ID recorded data in vehicle view while other states recorded data in person view

Figure 5.6 displays the odds ratio comparing KAB RLR crashes in Utah to other states. Maine has higher odds of a KAB RLR crash than Utah, but the wide confidence interval makes comparison to Utah inconclusive. Arizona and Illinois have the lowest odds of a KAB RLR crash and were statistically significant in their comparison to Utah. Wyoming and Connecticut have lower odds of a KAB RLR crash than Utah, but these results are inconclusive. Idaho is not included in the odds ratio as its RLR data came from vehicle view unlike the rest of the states which recorded this data in person view. Although Georgia's comparison table data is in person view, this data was also not included in the odds ratio because it is written in crash view as a list of each person involved.

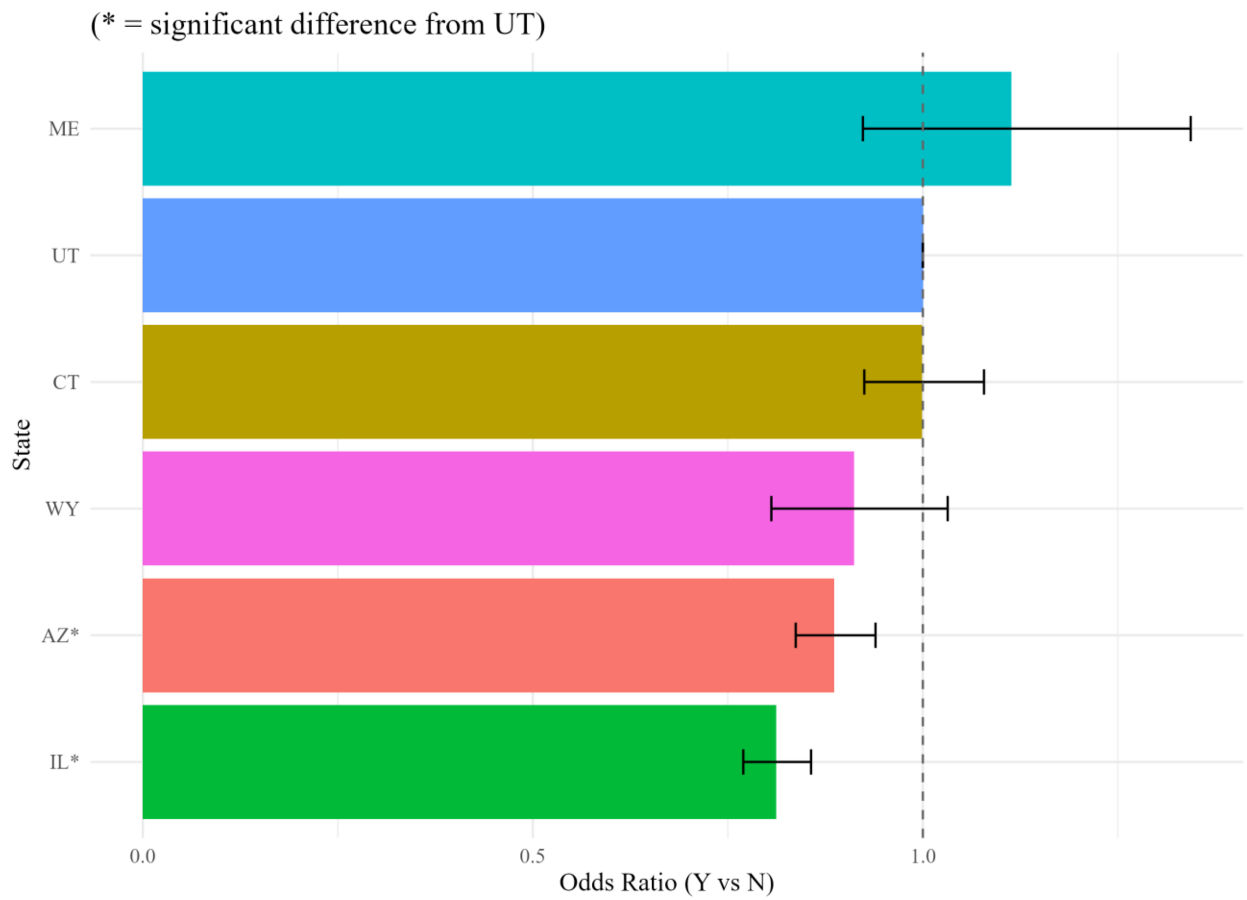


Figure 5.6 KAB Odds Ratio: Red-Light Running

5.4.2 Speed-Related

Figure 5.7 demonstrates a speed-related crash tree for different age groups. Speeding is a contributing factor in 6 percent of all crashes at signalized intersections in Utah. Although it is not a major contributing factor for all crashes, speeding is a contributing factor to 24 percent of fatalities and 12 percent of KA crashes in Utah. This highlights speeding as a notable factor in severe crashes and consequently an important concern in Utah. Speeding in Utah is most common in drivers aged 14 to 44, representing 38 percent of speed-related crashes in Utah for both the 14 to 24 and 25 to 44 age groups.

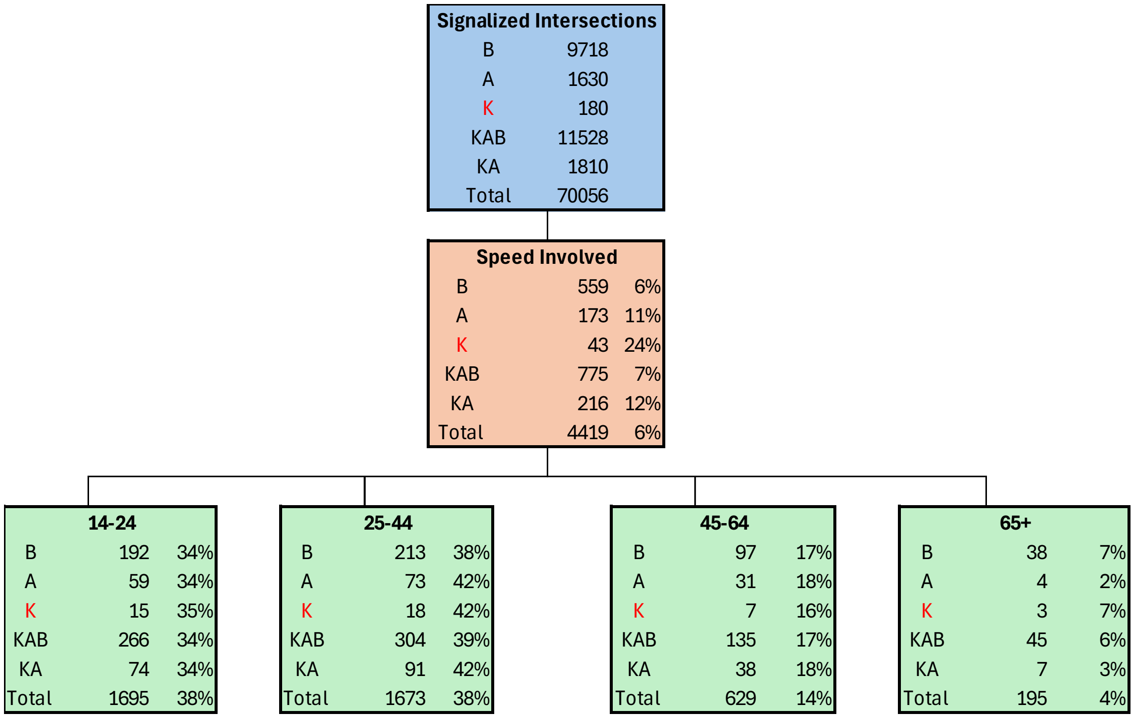


Figure 5.7 Crash Tree: Speed-Related

Table 5.4 shows the distribution of speed-related crashes in the person view data by state. Most of the states recorded their speed-related data in person view, but Idaho and Nebraska recorded it in vehicle view. Nebraska's vehicle view did not have a filter for severity level so percentages for KAB and KA crashes could not be computed. Georgia's speed data was originally recorded in the crash view with multiple entries as if it were person view. Since it was formatted as if it were person view data, the information was extracted to reflect person view crash percentages as seen from the other states. The proportion of speed-related crashes in Utah is 44 percent higher than the average of the other states for KABCO crashes, 72 percent higher for KAB crashes, and 55 percent higher for KA crashes. Nebraska and Georgia recorded the lowest percentage of speed-related crashes at 1 percent each. Arizona and Wyoming are the only states that have higher speed-related crashes than Utah in one or more of the severity categories.

Table 5.4 Comparison Table: Speed-Related

Speed Related	UT	AZ	WY	ME	ID*	NE*	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	6%	15%	7%	4%	2%	1%	1%	4%	2%	4%	44%
KAB	7%	13%	4%	2%	2%	-	2%	3%	3%	4%	72%
KA	12%	21%	13%	6%	3%	-	2%	4%	5%	8%	55%

*ID and NE recorded data in vehicle view while other states recorded data in person view

Figure 5.8 displays the odds ratio for KAB speed-related crashes. The odds of a KAB speed-related crash in Connecticut and Wyoming are higher than the odds in Utah. Additionally, the odds of a KAB speed-related crash in Maine, Arizona, and Illinois are lower than Utah. The results for Connecticut, Arizona, and Illinois are statistically significant, while the remaining results are inconclusive. Some states were not included in the odds ratio as their data were recorded in a different view. Idaho and Nebraska store speed-related crash data in vehicle view. Although Georgia's comparison table data is in person view, this data was also not included in the odds ratio because it is written in crash view as a list of each person involved.

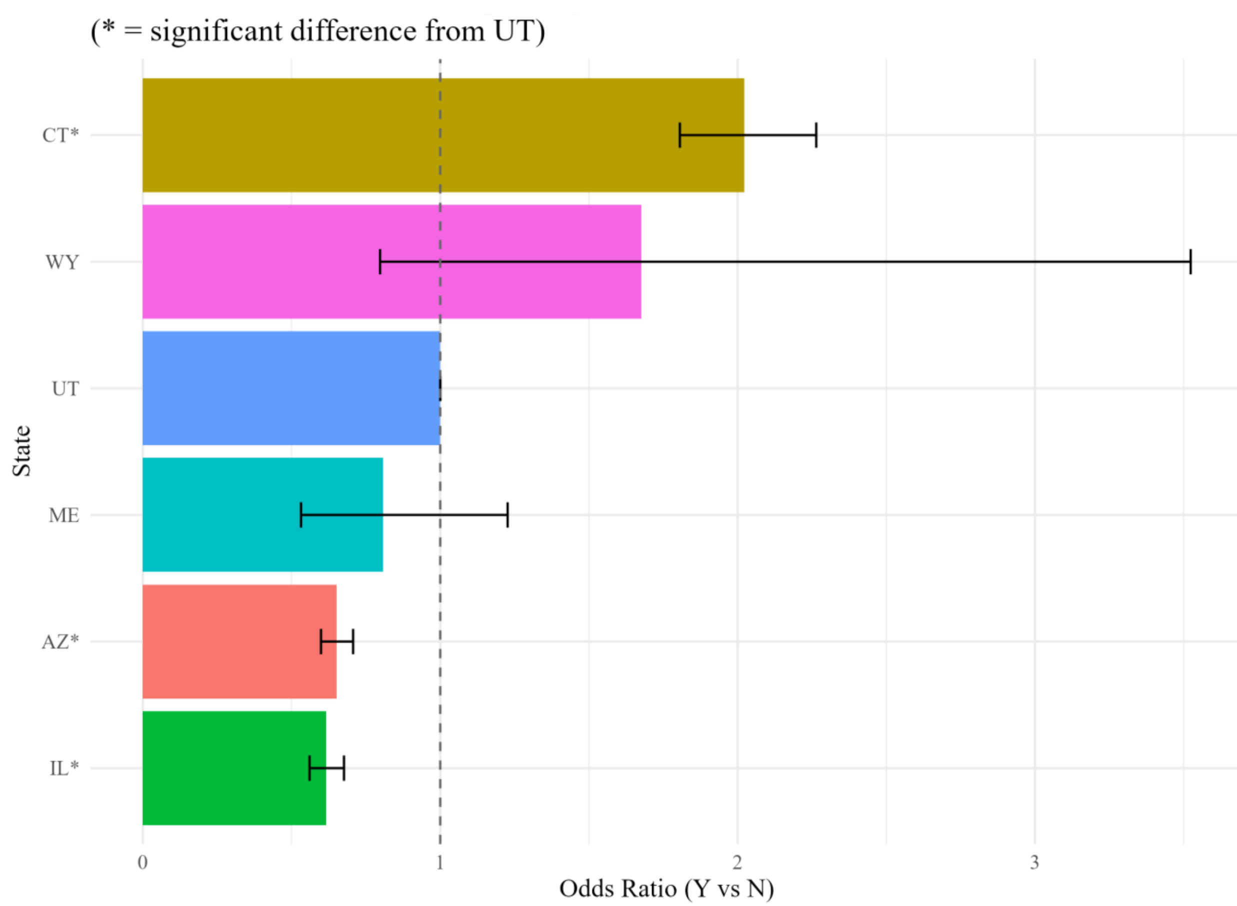


Figure 5.8 KAB Odds Ratio: Speed-Related

<u>5.4.3 Unrestrained Crashes</u>

In Utah, unrestrained crashes contribute to only 4 percent of KAB crashes in urban areas but 16 percent of fatal crashes. Unrestrained crashes also contribute to 12 percent of KAB crashes in rural areas and 50 percent of fatal crashes in rural areas as shown in Figure 5.9. KAB unrestrained crashes occurred most on principal arterials (57 percent), minor arterials (25 percent), and major collectors (10 percent), as shown in Figure 5.10. This dissuades the notion that unrestrained crashes only occur on lower-speed roads.

Table 5.5 shows the comparison table for unrestrained driving by state. Unrestrained crashes account for 1 percent of KABCO, 1 percent of KAB, and 3 percent of KA crashes in Utah. Wyoming has the highest percentage of KABCO and KA unrestrained crashes at 4 and 35 percent, respectively, and most other states are also substantially higher than Utah. This results in the averages without Utah being substantially higher than the Utah averages. Utah has one of the lowest percentages of unrestrained crashes of all the states analyzed.

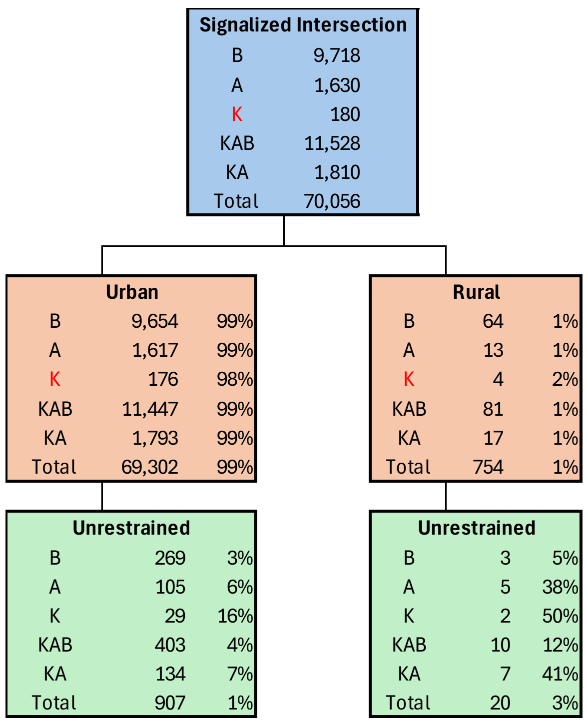


Figure 5.9 Crash Tree: Unrestrained Crashes by Urban Setting

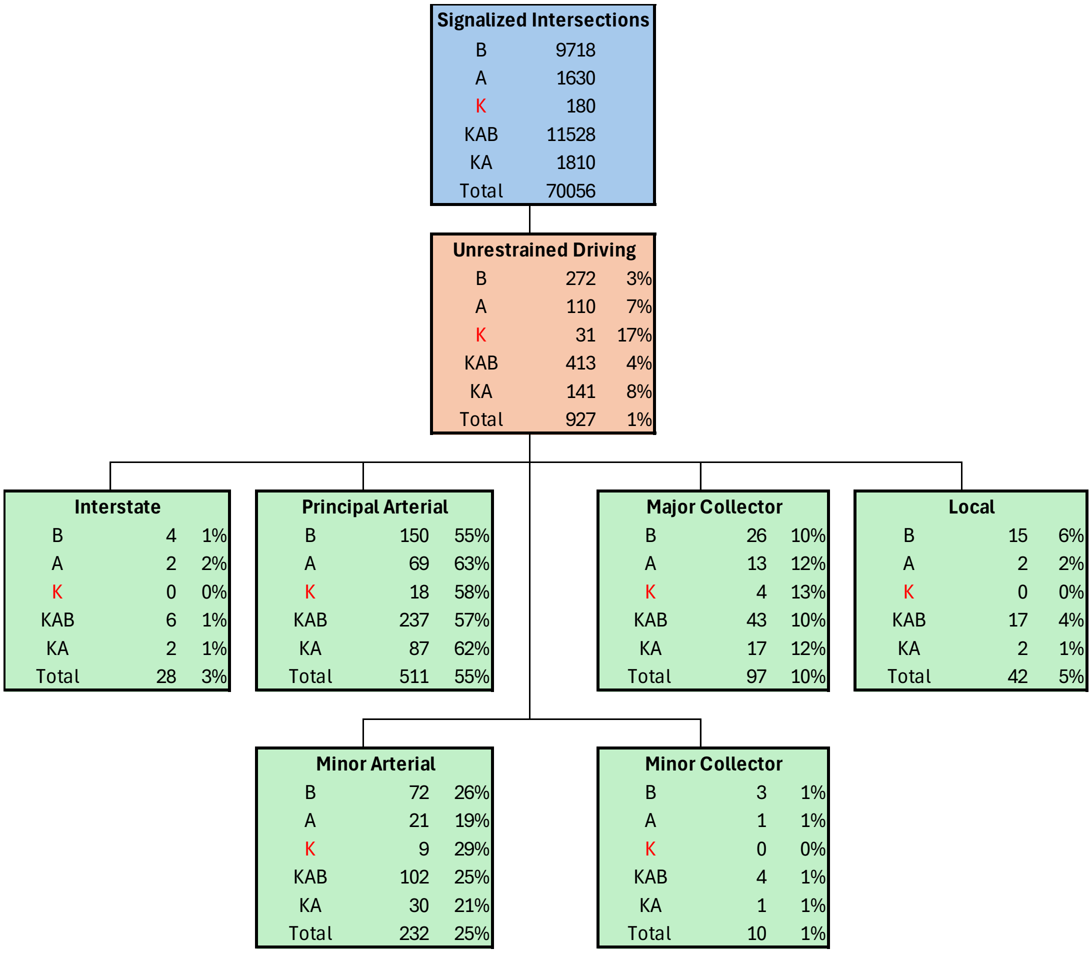


Figure 5.10 Crash Tree: Unrestrained Crashes by Functional Classification

Table 5.5 Comparison Table: Unrestrained Crashes

Unrestrained Crashes	UT	AZ	WY	ME	ID	NE	IL	CT	AVG. (w/o UT)	%Δ
KABCO	1%	1%	4%	1%	2%	2%	<1%	1%	2%	-72%
KAB	1%	7%	17%	4%	4%	8%	2%	3%	6%	-79%
KA	3%	19%	35%	10%	7%	23%	4%	11%	15%	-79%

Data are recorded in person view for all states

Figure 5.11 summarizes the odds ratio analysis for unrestrained KAB crashes. Maine, Arizona, and Wyoming have higher odds of an unrestrained KAB crash than Utah. Nebraska, Connecticut, Idaho, and Illinois have lower odds of an unrestrained KAB crash than Utah. The results from Maine, Arizona, Connecticut, Idaho, and Illinois are statistically significant. The results from Wyoming and Nebraska are inconclusive.

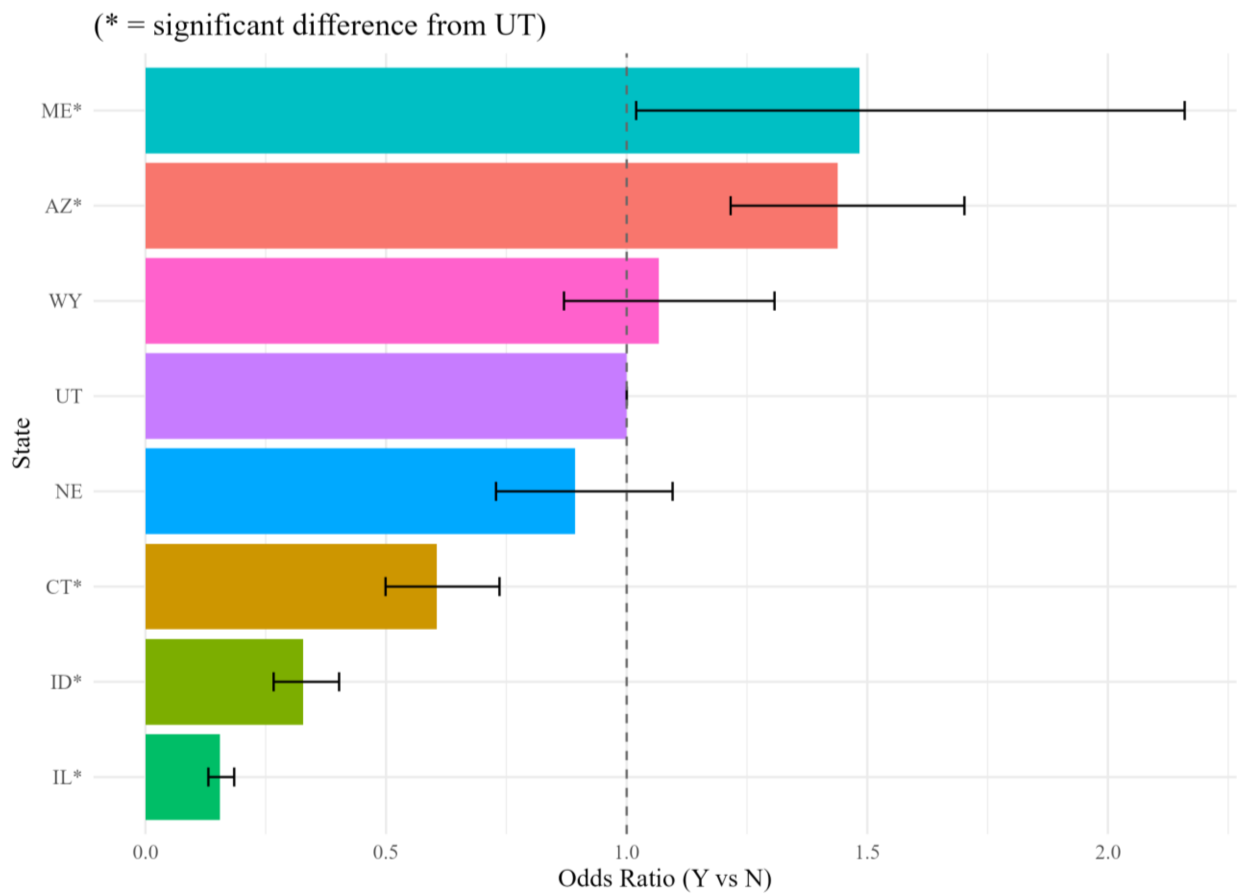


Figure 5.11 KAB Odds Ratio: Unrestrained Crashes

5.4.4 Angle Crashes

Angle crashes represent 43 percent of all signalized intersection crashes in Utah, 57 percent of all KAB crashes, and 58 percent of all KA crashes. With a higher likelihood of severity, these crashes are a major concern in the state. The research team investigated common contributing factors associated with angle crashes in Utah. Left-turn movements represent 61 percent of angle crashes at both the KABCO and KAB levels. RLR occurred at 38 percent of all angle crashes and 44 percent of KAB angle crashes. Additionally, teenage drivers contributed to 28 percent of all angle crashes and 27 percent of KAB angle crashes, while older drivers contributed 11 percent of all angle crashes and 12 percent of KAB angle crashes. This, and additional information regarding these crash attributes, is summarized in Figure 5.12.

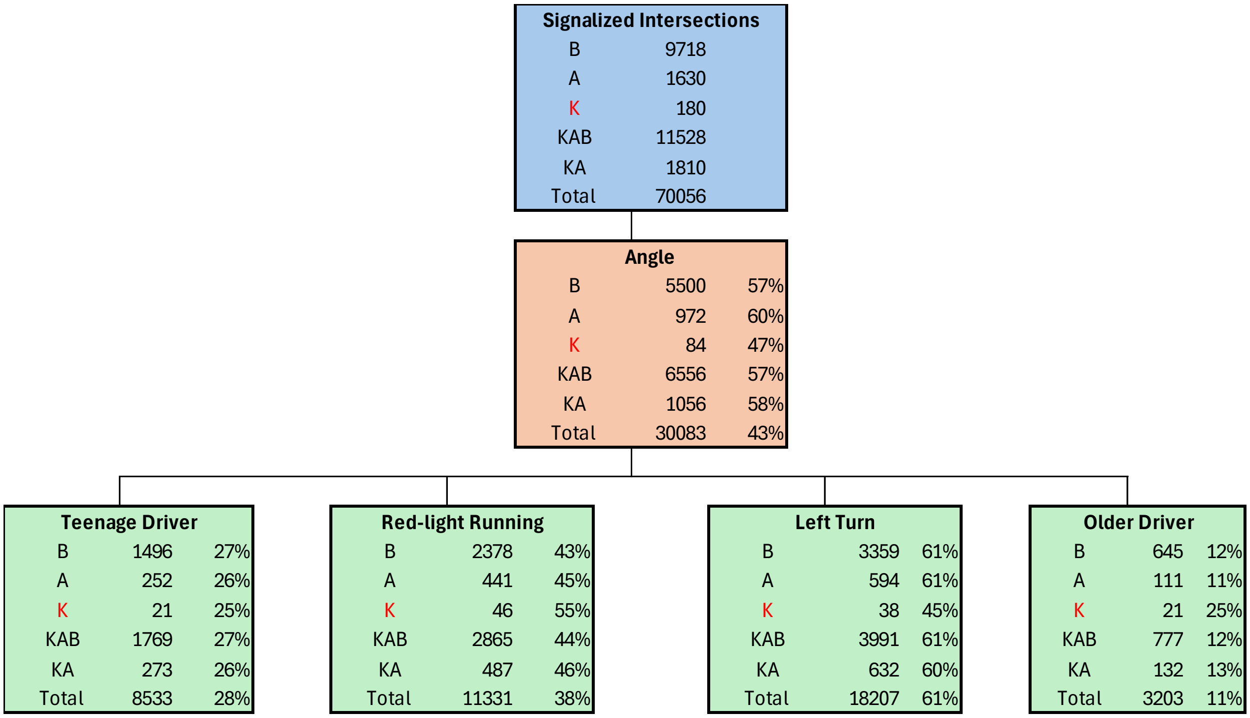


Figure 5.12 Crash Tree: Angle Crashes

Table 5.6 summarizes angle crashes at various severity levels. Most states recorded angle crash data in crash view, but Idaho recorded it in vehicle view. Nebraska, Illinois, and Wyoming are the states with the highest percentage of angle crashes on the KABCO level and have a higher percentage than Utah. Angle crashes in these states are 57 percent, 52 percent, and 50 percent, respectively. Connecticut and Georgia have the lowest percentage of KABCO angle crashes of the states represented in this table. Angle crashes represent 27 and 32 percent of signalized intersections crashes in Connecticut and Georgia, respectively. Excluding Utah, the average percent of angle crashes amongst states at the KABCO level is 43 percent, which exactly matches Utah's percentage.

Table 5.6 Comparison Table: Angle Crashes

Angle Crashes	UT	AZ	WY	ID*	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	43%	42%	50%	41%	57%	32%	52%	27%	43%	0%
KAB	57%	57%	62%	26%	68%	56%	62%	40%	53%	7%
KA	58%	59%	58%	53%	66%	53%	61%	42%	56%	4%

*ID crash data are reported in the vehicle view while other states reported crash view data

Figure 5.13 displays the odds ratio for KAB angle crashes. For many instances the odds were computed for attributes with yes/no fields where the probability of a 'no' would be used as the baseline or denominator for computing the odds. Since angle crashes were included as part of the manner of collision crash attribute that had multiple fields, and not a yes/no field, single-vehicle crashes were used as the denominator or baseline crash for comparison. The value for single-vehicle crashes will differ for each state which will ultimately affect the results of the odds ratio analysis. Angle crashes have significantly higher odds of severity KAB in Arizona, Georgia, Nebraska, and Connecticut than in Utah when compared to single-vehicle crashes. By contrast, angle crashes have lower odds of being severity KAB in Wyoming and Illinois. The results produced by Wyoming are inconclusive, and the results from Illinois are statistically significant. Idaho was not included as Idaho data are recorded in crash view unlike the other states which record their angle crash data in crash view

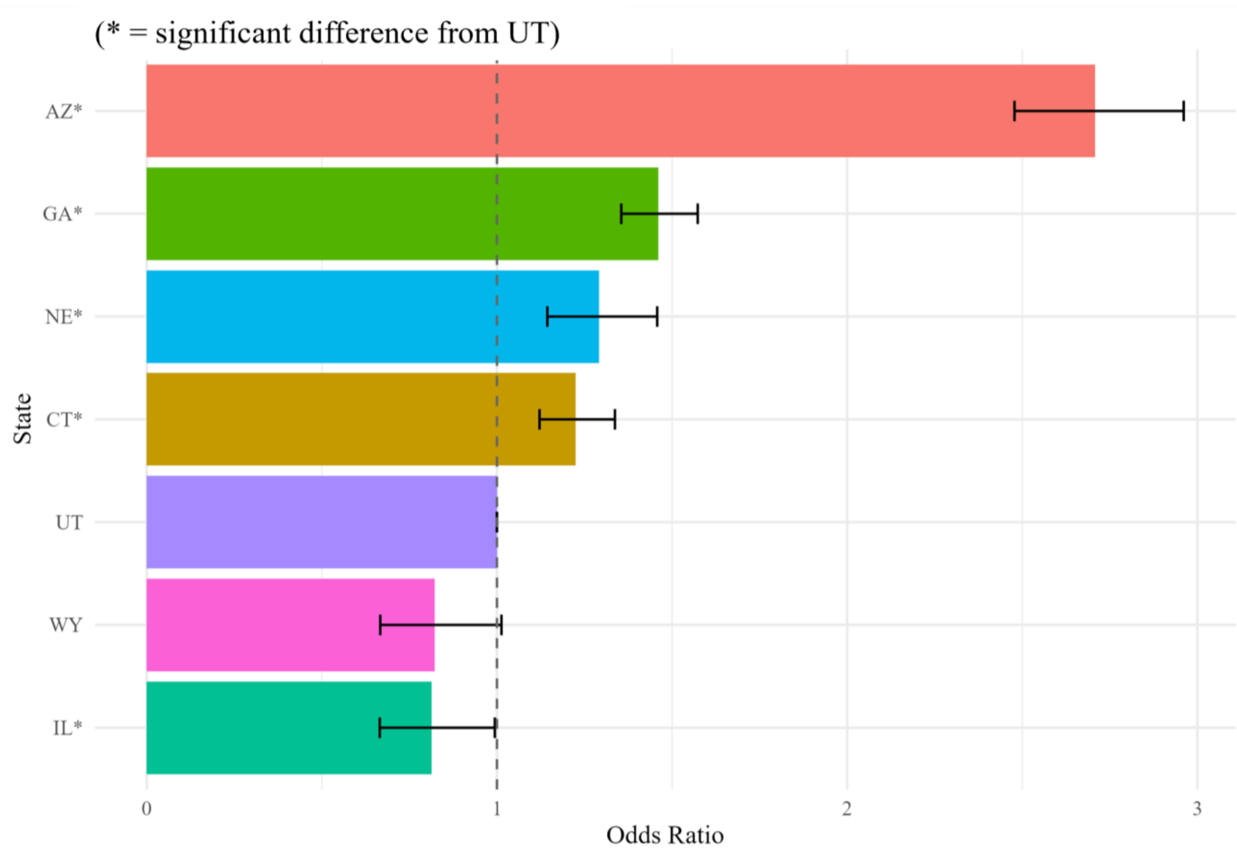


Figure 5.13 KAB Odds Ratio: Angle Crashes

5.4.5 Distracted Driving

Distracted driving contributes to 11 percent of all signalized intersection crashes, 10 percent of KAB crashes, and 7 percent of KA crashes in Utah. Using the NHTSA age categories, the data also suggests that drivers aged 14 to 24 and 25 to 44 contribute to 38 and 40 percent of distracted driving crashes at signalized intersections, respectively. This suggests that drivers ages 44 and under are more likely to be involved in a distracted driving crash. Rear-end and angle crashes make up 62 and 30 percent of all distracted driving crashes and 38 and 47 percent of KAB distracted driving crashes, respectively. This information is summarized in Figure 5.14.

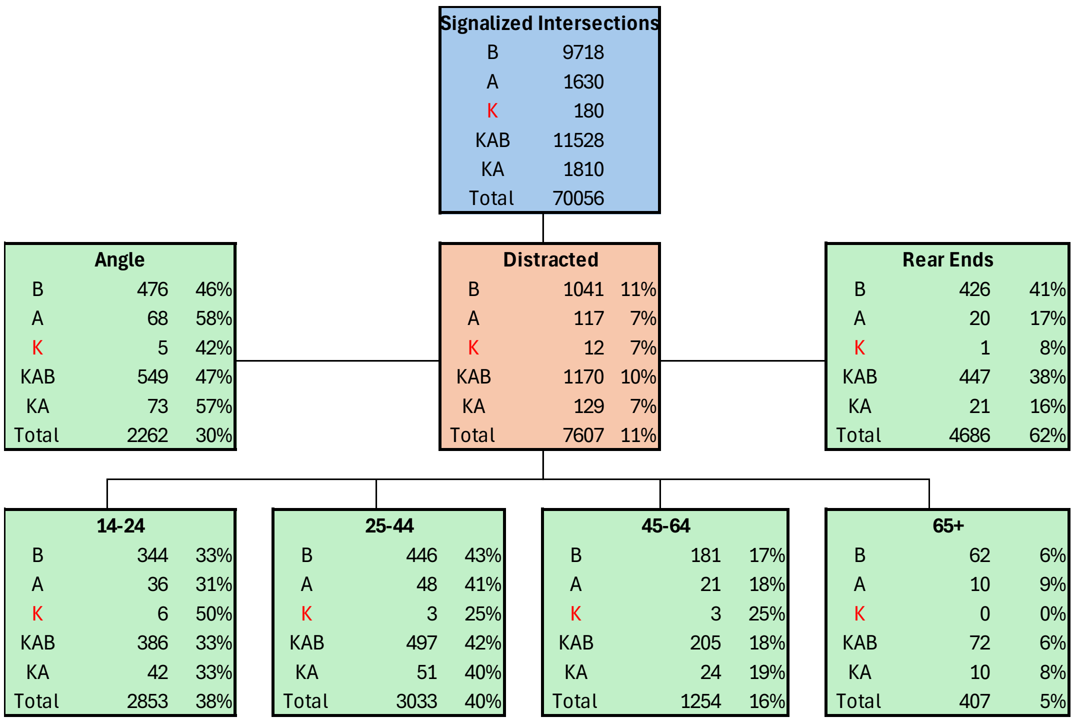


Figure 5.14 Crash Tree: Distracted Driving

Table 5.7 displays the comparison table for distracted driving crashes. Most states recorded distracted driving data in person view, but Idaho and Nebraska recorded it in vehicle view. Nebraska did not have data for KAB and KA crashes as its vehicle view does not include crash severity. Georgia's distracted driving data was originally recorded in the crash view with multiple entries as if it were person view. Since it was formatted as if it were person-view data, the information was extracted to reflect person-view crash percentages as seen from the other states. Several of the states analyzed have a lower percentage of distracted driving than Utah. Georgia reported 2 percent of signalized intersection crashes involved distracted driving. Idaho and Connecticut reported 3 percent. Illinois reported 24 percent of signalized intersection crashes as distracted driving. Differences in reporting methods among states may contribute to the wide distribution in the results reported.

Table 5.7 Comparison Table: Distracted Driving

Distracted Driving	UT	WY	ME	ID*	NE*	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	11%	6%	5%	3%	5%	2%	24%	3%	7%	64%
KAB	11%	8%	4%	3%	-	1%	27%	2%	8%	42%
KA	8%	1%	4%	2%	-	2%	26%	2%	6%	23%

*ID and NE recorded data in vehicle view while other states recorded data in person view

Figure 5.15 displays the odds ratio analysis for KAB distracted driving. The odds of a KAB distracted driving crash are higher in Wyoming and Illinois than in Utah. The odds of a KAB distracted driving crash are lower in Connecticut and Maine than in Utah. The results for Wyoming, Illinois, and Connecticut are statistically significant, while the results for Maine are inconclusive. Some states were not included in the odds ratio as their data were recorded in a different view. Idaho and Nebraska record distracted driving data in vehicle view. Although Georgia's comparison table data is in person view, this data was also not included in the odds ratio because it is written in crash view as a list of each person involved.

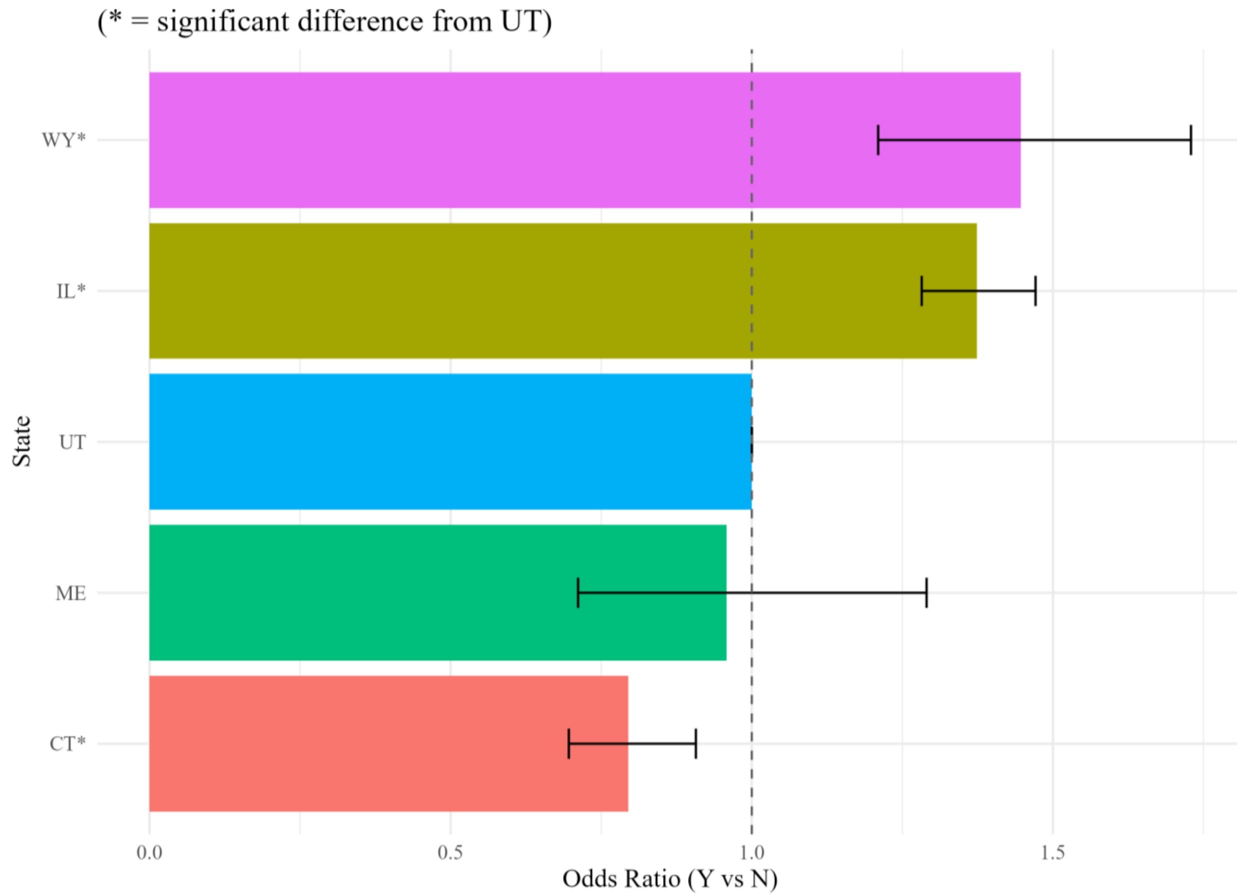


Figure 5.15 KAB Odds Ratio: Distracted Driving

5.4.6 Older Drivers

Figure 5.16 summarizes common crashes amongst older drivers. Drivers aged 65 and over are involved in 11 percent of the KAB crashes and 12 percent of the KA signalized intersection crashes in Utah. RLR and angle crashes represent 27 and 63 percent of KAB crashes, respectively, for ages 65 or older. Left-turn crashes, which are likely related to angle crashes, represent 53 percent of KAB crashes for this age group. This highlights crash types for which older drivers are most involved in signalized intersection crashes.

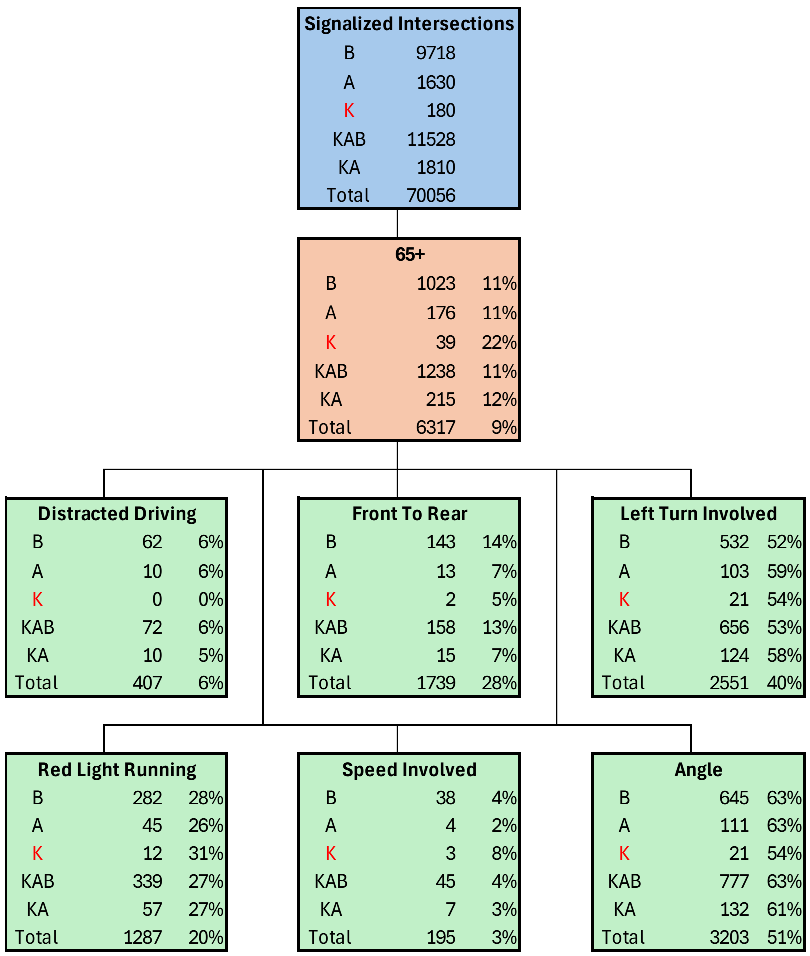


Figure 5.16 Crash Tree: Older Drivers

Table 5.8 displays the comparison table for crashes involving drivers aged 65 and above. Georgia's driver age data was originally recorded in the crash view with multiple entries as if it were person view. Since it was formatted as if it were person-view data, the information was extracted to reflect person-view crash percentages as seen from the other states. Utah has a lower percentage of crashes for this age group than the average of the states analyzed. Georgia, Wyoming, and Connecticut have lower percentages in either KABCO crashes or KA crashes than Utah. Other than those specific crash percentages, Utah has a lower percentage of crashes for this age group.

Table 5.8 Comparison Table: Ages 65 and Above

65+	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	9%	11%	12%	15%	12%	12%	8%	20%	12%	13%	-31%
KAB	10%	15%	14%	17%	13%	15%	11%	14%	11%	14%	-23%
KA	11%	17%	9%	22%	13%	15%	10%	16%	11%	14%	-15%

Data are recorded in person view for all states

Figure 5.17 displays the odds ratio for drivers ages 65 and over. Since this crash attribute had multiple fields, a baseline age group was needed to provide a one-to-one comparison between states. The 45 to 64 age group was used as the baseline crash attribute for the odds ratio results displayed. Arizona and Illinois have higher odds of a KAB crash for this age group with Arizona producing statistically significant results. Maine, Nebraska, Connecticut, Wyoming, and Idaho have lower odds of a KAB crash for this age group. Idaho has significantly lower odds of an older driver crash being severe. Although Georgia's comparison table data is in person view, this data was also not included in the odds ratio because it is written in crash view as a list of each person involved.

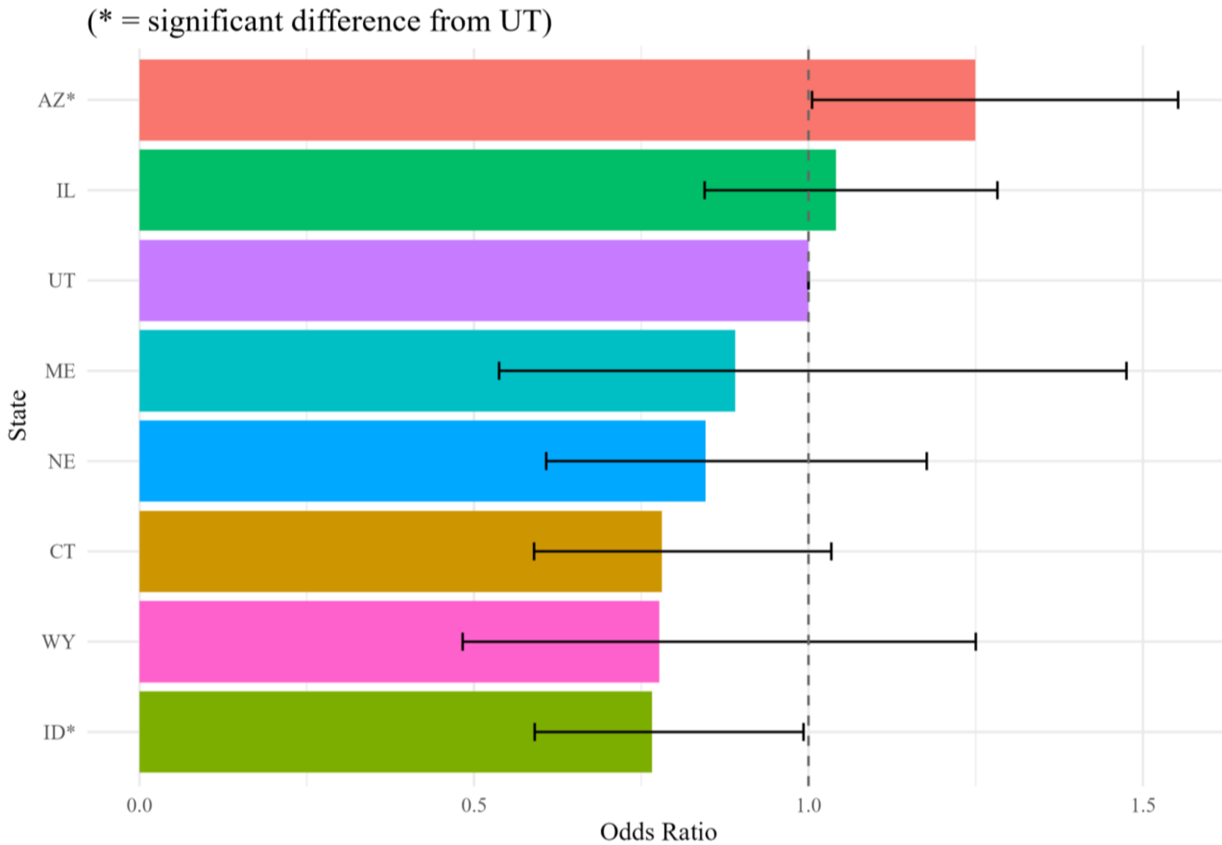


Figure 5.17 KAB Odds Ratio: Ages 65 and Above

5.5 Summary

Table 5.9 summarizes the comparison table and odds ratio analysis findings explored in this chapter for various crash attributes. States with a lower percentage of KAB crashes than both the average (excluding Utah) and Utah were added to the "Comparison Table" column. States with statistically significant lower odds of a specific crash attribute being severity KAB compared to Utah were added to the "Significantly Lower Odds" column. Connecticut, Georgia, Idaho, and Maine qualified for the "Comparison Table" column for at least one of the crash attributes of interest based on KAB crash percentage results. Arizona, Connecticut, Idaho, and Illinois qualified for the "Significantly Lower Odds" column based on results from the odds ratio analysis. This summary helps identify areas where further analysis will be conducted to understand why these states yield statistically lower odds. The survey data results reported in

Chapter 4 for these states will be used as a guide to explain why there may be differences in the results.

Table 5.9 Lower Comparison Table and Odds Ratio Results Summary

Crash Attribute	Comparison Table	Significantly Lower Odds
RLR	CT, GA	AZ, IL
Speeding	CT, ID, ME	AZ, IL
Unrestrained	-	CT, ID, IL
Angle	CT	IL
Distracted	CT, GA, ME	CT
Older	-	ID

5.6 Conclusion

Crash data from eight states were analyzed and compared to Utah to determine how specific crashes of interest compare in other states. Crash trees and random forest models were generated to identify other crash attributes that should be compared as part of the data analysis. Comparison tables were generated to compare the crash frequency of these attributes amongst states. Additionally, odds ratio analyses were conducted to compare the odds of a crash being severity KAB in Utah compared to other states. The results highlight how different states compare to Utah regarding RLR, speeding, unrestrained crashes, angle crashes, distracted driving, and older driver crashes at signalized intersections. This information will be used in conjunction with the survey data from Chapter 4 to explain why some states may be performing better than Utah in these specific areas of interest.

6.0 CONCLUSIONS

6.1 Summary

The purpose of this research was to quantify and evaluate the apparent safety rates and crash frequencies at signalized intersections in Utah compared to other states. This required collecting crash data from various states, including Utah, to understand in-depth crash trends. Once the crashes have been quantified, the secondary purpose was to determine why there may or may not be differences. This required an understanding of the different policies, procedures, and countermeasures that each state uses and how those compare to Utah. The results of the research may allow UDOT to identify policies, procedures, and countermeasures that may reduce signalized intersection crashes in the state.

To meet the purposes of the research, a survey was sent to all 50 states to understand different policies, procedures, and countermeasures implemented across the United States. Crash data were also collected from those willing to share statewide crash data to compare signalized intersection crashes in Utah to other states. Using that data, the percentages of specific crash attributes were compared for signalized intersections across different states. Additional statistical analysis was also conducted to compare how the odds of a KAB crash in Utah compared to other states.

This chapter first summarizes the methodology used to conduct the research, then presents findings from the data-driven investigation and analysis and finally presents limitations of the research.

6.2 Methodology

To understand how signalized intersection crashes in Utah compare to other states, a survey was sent to members of the AASHTO CTE to collect information on how states analyze, prioritize, and implement safety at signalized intersections. Survey questions were categorized based on their relation to different crash trends, contributing factors, policies, procedures, and countermeasures. Questions were influenced by information found in the literature review as well as other UDOT interests identified by the research team and the TAC. These categories were selected to encompass the planning, policy, and engineering aspects related to signalized intersection safety and data analysis.

An analysis of state crash data was also conducted for Utah as well as those states for which respondents indicated they were willing to share crash data. Crash trees were generated to determine which crash attributes were of highest concern in Utah. Crash trees were later generated for all states to determine crash frequency trends for each state. This information was used to create comparison tables that provided a quick glance of how crash frequency trends for a specific crash attribute compared across different states. This included a severity grouping on the KABCO scale to identify both severity as well as frequency. Those states that showed lower percentages than Utah, along with the average of the states, were highlighted for cross comparison with the survey results.

A random forest model was generated to identify which crash attributes were most influential in determining whether a crash was a KAB (injury) crash. Once these crash attributes were identified, a KAB odds ratio analysis was conducted to compare the odds of a crash being an injury crash in Utah compared to other states. Those states that had significantly lower odds of a KAB crash when compared to Utah were highlighted for cross comparison with survey results.

In conjunction with the TAC, the research team selected six emphasis areas from the crash analysis to compare with survey results: RLR, speed-related, unrestrained crashes, angle crashes, distracted driving, and older drivers. After identifying those states that had either a lower percentage of a crash attribute or lower odds of a crash attribute producing severity KAB crashes, the survey results from those states were studied to identify relevant information connecting survey responses to the observed differences in crash data as potential factors related to the differences.

6.3 Findings

A survey to understand how signalized intersection crashes in Utah compare to other states was sent to members of the AASHTO CTE. Of the 23 states (as well as Puerto Rico and District of Columbia) which submitted complete survey responses, 12 states, including Utah, were willing to share crash data. Eight of these states had comparable data to Utah that were used to further compare safety rates in Utah to other states. Based on the results of the comparison tables as well as the odds ratio analyses, seven states were identified that experienced a lower percentage of crash types of interest or statistically lower odds of a KAB crash in comparison to Utah. These states included Arizona, Connecticut, Georgia, Idaho, Illinois, Maine, and Wyoming. The survey responses were further analyzed to identify possible explanations for the differences in crashes between states.

The findings presented in this section will focus on the emphasis areas identified by the TAC and the research team: RLR, speed-related, unrestrained crashes, angle crashes, and distracted driving. Additional policies, procedures, or countermeasures from the literature that address older driver crashes will be presented. The full results were presented in Chapter 4 and Chapter 5 of this report.

6.3.1 Red-Light Running

Connecticut and Georgia had a lower percentage of RLR crashes than Utah and were also lower than the average of the states excluding Utah. Additionally, Arizona and Illinois had significantly lower odds of a KAB RLR crash in comparison to Utah. Based on the survey, Arizona implements advanced warning flashers on the first signal of rural roads where limited visibility is present. Georgia and Illinois implement red-light cameras at signalized intersections. Illinois implements these red-light cameras where RLR violations and crashes are common and where a minimum of three signal heads exist for through movements and two for left-turn movements (IDOT, 2007). These differences are potential factors related to the difference in KAB crashes observed between states.

6.3.2 Speed-Related

Connecticut, Idaho, and Maine had a lower percentage of speed-related crashes than Utah and were also lower than the average of the states excluding Utah. Additionally, Arizona and Illinois had significantly lower odds of a KAB speed-related crash in comparison to Utah. The survey respondent in Connecticut ranked speed crashes as the highest crash of concern at signalized intersections. This suggests that Connecticut DOT may focus their efforts on reducing these crashes, which could explain the lower percentage of speed-related crashes. Respondents from Maine and Arizona indicated the use of curb extensions at signalized intersections, but they also indicated no formal threshold has been established for their installation. Although Georgia did not report a lower percentage than the average excluding Utah or lower odds of KAB speed-related crashes, the state does have an established threshold for installing curb extensions. Georgia has implemented curb extensions on roads with speeds up to 40 mph where on-street parking exists and larger vehicle turning movements are not frequent (GDOT, 2021). These differences are potential factors related to the difference in KAB crashes observed between states.

6.3.3 Unrestrained Crashes

Connecticut, Idaho, and Illinois had lower odds of KAB unrestrained crashes in comparison to Utah and were also lower than the average of the states excluding Utah. The survey results did not highlight information related to unrestrained crashes. Since unrestrained crashes are a result of human response and have no engineering alternative, education and enforcement solutions are often presented. Connecticut relies heavily on education to ensure that drivers are wearing their seatbelts. This includes notification of seatbelt enforcement through television, radio, bus panels, gas stations, social media, outreach at sports events, and other forms of media to increase the perception that unrestrained occupants will be penalized (CTDOT, 2026). In Illinois, education is most unique in the school system where state police will perform a rollover demonstration simulating the effects of unrestrained crashes (Illinois State Police, 2026).

Idaho has invested in reducing unrestrained driving crashes and has a goal to have 89 or fewer unrestrained fatalities in 2026 (ITD, 2025). The state provides funding for child passenger safety seats and distributes them to those most in need, especially families that have kids with special needs. Idaho provides training for child passenger safety technicians and instructors. The state also funds educational events and engages with the public. This educational outreach is provided to high-risk demographic groups including rural residents, pickup truck drivers, Native Americans, and young people. Idaho also encourages seatbelt use in the media and uses high visibility enforcement campaigns to enforce seatbelt laws. These differences are potential factors related to the difference in lower odds of KAB crashes observed between states.

6.3.4 Angle Crashes

Connecticut had a lower percentage of angle crashes than Utah and was also lower than the average of the states excluding Utah, and Illinois had lower odds of a KAB crash in comparison to Utah. Wyoming had lower odds of a KAB crash in comparison to Utah with an upper confidence level just over 1.0. Since the confidence interval was close, and the odds are lower than Utah, Wyoming was also considered as part of the conclusions. Wyoming ranked angle crashes as the primary crash of concern, and Connecticut and Illinois ranked angle crashes as the second highest concern at signalized intersections. This suggests that the traffic and safety discussions in these states may focus on reducing angle crashes. Connecticut reported the use of split phasing when the intersection geometry inhibits sharing left-turn space for opposing through movements. Connecticut and Illinois indicated the use of protected/permissive left-turn phasing but also noted that there are no formal guidelines for implementation. Additionally, Illinois noted the use of a delayed permissive left-turn phase as well as an ICE policy guidance designed to determine the safest intersection configuration.

Although Georgia did not report a lower percentage than the average excluding Utah or lower odds of KAB angle crashes, they do have a formal threshold for the use of different signal phasing options. Georgia uses protected/permissive phasing at signalized intersections where left-turn volumes exceed 125 vehicles per hour for a leading left-turn phase. Other criteria such as storage length, speed of opposing through traffic, the number of opposing through lanes, and the angle of the left turn are also considered. When there are more than five left-turn and opposing-through crashes within a 2-year period, or when roadway geometry or other obstructions limit sight distance, protected-only left-turn phasing is recommended (GDOT, 2020). These differences are potential factors related to the difference in KAB crashes observed between states.

6.3.5 Distracted Driving

Connecticut, Georgia, and Maine had a lower percentage of distracted driving crashes than Utah and were also lower than the average of the states excluding Utah. Additionally, Connecticut also had significantly lower odds of a KAB distracted driving crash in comparison to Utah. In 2026, Connecticut is increasing enforcement by challenging officers to better identify distracted driving on the roadway. The state also has fines ranging from $200 to $625 for distracted driving offenses depending on the number of offenses (Rowan, 2026). Georgia and Maine have set distracted driving legislation, but this does not differ much when compared to other states (Georgia Governor's Office of Highway Safety, 2026; Maine State Legislature, n.d.). These differences are potential factors related to the difference in KAB crashes observed between states.

6.3.6 Older Driver

Idaho has significantly lower odds of older driver crashes being KAB in comparison to Utah. Idaho has a goal of having 53 or fewer older driver crashes and provides countermeasures to achieve this goal in their Strategic Highway Safety Plan (ITD, 2021). Idaho uses programs such as American Automobile Association (AAA) Roadwise Review to provide older drivers information about alternatives to driving. Idaho is also working to develop a process to collect data on the number of crashes that result from visual or cognitive impairment. They are also working to make roadway features more visible.

6.4 Limitations and Challenges

Data collection efforts experienced limitations due to the number of responses received and the available data for comparison. Those states identified in Chapter 3 as comparable states were intended to be the focus of the statistical analysis. Since only three peer states sent comparable data to Utah, the crash data analysis was extended to all states willing to share crash data. This means that the crash analysis conducted includes states with different climates, geographies, and levels of urbanization that may affect the analysis results. Twelve states sent crash data for analysis, but only eight had a filter for signalized intersections. Those datasets without a signalized intersection filter were deemed incomparable to Utah and could not be used for this research. These crash data collection results limit the amount of analysis that could be performed and consequently limit the conclusions that could be drawn for this research. Data collection efforts and reporting methods also vary between states as police reports and areas of emphasis differ. This might explain some of the differences observed between states for certain crash attributes such as distracted driving.

There were also limitations in the analysis of crash data. Some of the states collected the same data in different views. For instance, Idaho and Nebraska collected contributing factor data in the vehicle view while other states collected it in the person view. This inhibited making a one-to-one comparison of how the states compared to each other. In addition, seven of the eight states did not include severity level in their vehicle view sheet which limited the data that could be compared across severity levels for categories such as turning movements and motorcycle involved. Additionally, not all the crash attributes of interest for this research were measured by each of the states. For example, Arizona, Wyoming, and Nebraska did not include a field for functional classification, and Maine did not include the manner of collision attribute. These limitations inhibited the one-to-one comparison available for both the comparison table and odds ratio analyses.

7.0 RECOMMENDATIONS AND IMPLEMENTATION

7.1 Recommendations

This chapter includes data-driven recommendations on policies, procedures, countermeasures, and future research for UDOT to implement to improve safety at signalized intersections. Each subsection will follow the crash attributes of interest highlighted in Chapter 5: RLR, speed-related, unrestrained crashes, angle crashes, distracted driving, and older drivers. The recommendations reflect conclusions made comparing the crash data analysis to the survey results as identified in Chapter 6 as well as alternatives individually found in the survey and existing literature.

7.1.1 Red-Light Running

Based on the research results, the use of red-light cameras should be studied to determine their effectiveness in Utah. Policies related to the use of advanced warning flashers in the state should also be reviewed to determine additional locations where this countermeasure may be implemented. Survey results and additional research also highlight countermeasures that are not specific to the research findings, including adjustments to the yellow change interval, red clearance interval including the DARE mentioned in Chapter 2, and dual red-light displays. These countermeasures should also be studied to determine their effectiveness in Utah.

7.1.2 Speed-Related

The use of curb extensions, specifically on wide local roads and collectors where driver speeds tend to exceed the limit, should be studied for implementation in Utah. A formal threshold should be determined to ensure proper implementation. Survey results and additional research also highlight countermeasures that are not specific to the research findings, including advanced warning flashers, variable speed limits, and changes to the yellow change interval. Speed cameras and raised intersections were also recommended by Schultz et al. (2024) and should be considered for future research.

7.1.3 Unrestrained Crashes

Education and enforcement alternatives that persuade drivers to wear seatbelts should be studied further in the state. Utah should consider providing car seats to those in need and prioritizing education and outreach efforts for high-risk demographics. Future research with Connecticut, Idaho, and Illinois, who demonstrated lower odds of KAB unrestrained crashes, would be beneficial to identify pursuits that could be effective in Utah. NHTSA also highlights countermeasures that are not specific to the research findings, including short-term, high-visibility seat belt enforcement; nighttime, high-visibility seat belt enforcement; increased fines for seat belt violations; and employer incentive programs (NHTSA, 2026a). These countermeasures should also be studied to determine their effectiveness in Utah.

7.1.4 Angle Crashes

Prioritizing angle crashes in safety discussions and in intersection design is an important practice to effectively reduce these crashes. This includes determining effective criteria for installing various left-turn signal phasing options in the appropriate context of the intersection. Survey results and additional research also highlight countermeasures that are not specific to the research findings, including adjustments to the yellow change interval, continuing the use of signal backplates with retroreflective borders, and determining guidelines for protected left-turn phasing (Schultz et al., 2024).

7.1.5 Distracted Driving

Education and enforcement alternatives that persuade drivers to eliminate distractions should be studied further in the state. Future research may include identifying specific promotional activities that effectively reduce distracted driving crashes in Utah. NHTSA also highlights countermeasures that are not specific to the research findings, including passenger limits for young drivers, high-visibility cell phone enforcement, and employer incentive programs (NHTSA 2026b). These countermeasures should also be studied to determine their effectiveness in Utah.

7.1.6 Older Drivers

To address older driver crashes at signalized intersections, maintaining and improving roadway viability, such as increasing the size of signage, is recommended in Idaho (ITD, 2021). Educational efforts that help to inform older drivers of alternatives to driving would also be beneficial. NHTSA highlights countermeasures in the literature that are not specific to the research, including license screening and restrictions, license referrals, and formal courses for older drivers (NHTSA, 2026c). These countermeasures should be considered in future research aimed at reducing older driver crashes.

7.2 Implementation Plan

UDOT has already implemented innovative policies, procedures, and countermeasures to improve safety at signalized intersections. In addressing speed-related crashes, UDOT assesses speed limits using the 85th percentile as well as context-based settings to recommend a safer driving speed. In addressing angle crashes, UDOT uses light detection and ranging (LiDAR) where FYAs are installed to delay the permissive left movement when conflicting pedestrians are present. UDOT also uses LiDAR technology to improve volume counts and identify near misses which can be applied to multiple emphasis areas identified in this research.

Other innovative policies, procedures, and countermeasures are focused on reducing pedestrian crashes, including protected-only left-turn phasing in school zones, audible pedestrian signals with a supplemental app, using LiDAR data to enhance pedestrian and cyclist counts, using LiDAR to enhance performance measure analysis for jaywalking, using LiDAR to extend the pedestrian phase when needed, and pedestrian-sensing technology in vehicles. The emphasis on implementing innovative policies, procedures, and countermeasures for pedestrian safety explains why the odds ratio for KAB pedestrian crashes is low in Utah when compared to other states.

The recommendations presented in this research emphasize specific alternatives that may reduce signalized intersection crashes as well as areas of future research. The survey results and crash data analysis will serve as a guide for UDOT in developing and implementing policies, procedures, and countermeasures related to safety at signalized intersections for future crash attributes of interest. The implementation of these recommendations, including the future research listed, should be conducted by UDOT according to crash attributes of interest.

Table 7.1 outlines an implementation plan that includes the proposed action, the responsible department within UDOT, and an estimated timeline for the implementation to be conducted. Actionable items include evaluating DARE for intersections with high-angle crashes, testing the feasibility of curb extensions on local and collector roads with speeding issues, investigating the legal feasibility of red-light cameras, and revising the UDOT crash data dashboard to include crash tree logic. These assessments aim to identify candidate locations, strategies, and policy considerations for pilot implementation and further evaluation.

Table 7.1 UDOT Implementation Plan

Step	Action	Responsibility	Timeline
Audit	Verify if Utah's high RLR is a reporting difference in Numetric versus other states.	Traffic & Safety	Q3 2026
Policy	Evaluate DARE for intersections with high angle crash scores	Traffic Ops	Q4 2026
Engineering	Set up pilot spots for curb extensions on local roads and collectors with speeding issues	Region Engineers	Q1 2027
Research	Investigate the legal feasibility of red-light cameras in Utah	Research Division	Q2 2027
Tools	Put the Crash Tree logic into our dashboards so engineers can check their own site	Data Team	Q2 2027

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APPENDIX A: DATA ATTRIBUTES

A.1 Crash Data Attributes

- Crash Date Time
- Year
- Functional Class
- Roadway Type
- Urban/Rural
- Area Type
- Manner of Collision
- Crash Severity
- Intersection Major AADT
- Intersection Minor AADT
- Light Condition
- Weather Condition
- Roadway Surface Condition
- Number of Vehicles Involved
- Route Type
- Intersection Involved
- Crash Attributes
- Milepoint
- Age Group
- Sex
- Left or U-Turn Involved
- Left vs. Straight Opposing Movement Crashes T/F
- Aggressive Driving Involved
- Animal Involved
- Bicycle Involved
- Commercial Vehicle Involved
- Disregard Traffic Control Device Involved
- Distracted Driving Involved
- Domestic Animal Involved
- Drowsy Driving Involved
- DUI Involved
- Heavy Truck Involved
- Motorcycle Involved
- Older Driver Involved
- Pedestrian Involved
- Right Turn Involved
- Roadway Departure Involved
- Roadway Geometry Involved
- Speed Involved
- Teenage Driver Involved
- Train Involved
- Transit Vehicle Involved
- Unrestrained Involved
- Wild Animal Involved
- Work Zone Involved
- Wrong-Way Driving Involved
- Overturn/Rollover Involved
- Geopoint
- Crash Verified
- Vehicle 1 Driver 1 Age

- Adverse Roadway Surf Condition
- Divided Highway
- Estimated Travel Speed
- Highest Vehicle Over Speed Limit
- Total K&A Crashes
- V1 Movement and Direction
- V2 Movement and Direction

A.2 Intersection Data Attributes

- Traffic Control Device
- Roadway Junction Type
- Traffic Control
- Crosswalk Width

APPENDIX B: SURVEY RESPONSES

Intersection Safety

Survey Flow

Block: 1. General Information (4 Questions)
Standard: 1. Defining Safety (5 Questions)
Standard: 2. Crash Data and Trends (9 Questions)
Standard: 3. Safety Evaluation and Programs (2 Questions)
Standard: 4. Countermeasures and Practices (10 Questions)
Standard: 5. Signal Installation and Policy (8 Questions)
Standard: 6. Other Considerations (5 Questions)
Standard: 7. Feedback and Participation (4 Questions)

Page Break

Start of Block: 1. General Information

The Utah Department of Transportation (UDOT) is looking for ways to improve safety at signalized intersections. We want to know how your state is improving safety so we can make Utah intersections safer. Please complete the following survey. It should take about 10 minutes to complete. UDOT appreciates your responses to help improve intersection safety.

Q1 Which state do you represent?

____

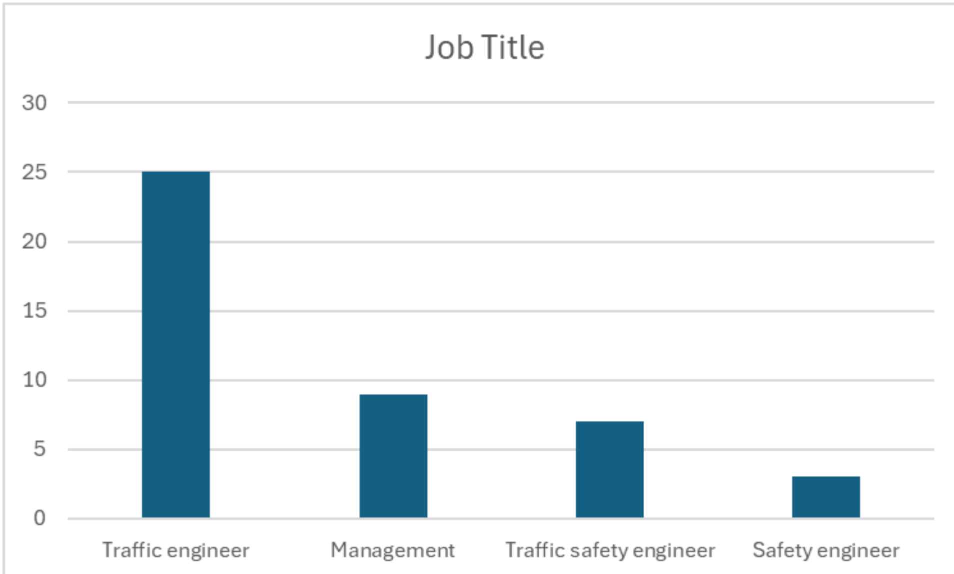
____

____

____

____

Q2 Your role/title:



Q3 Agency/Department Name:

End of Block: 1. General Information

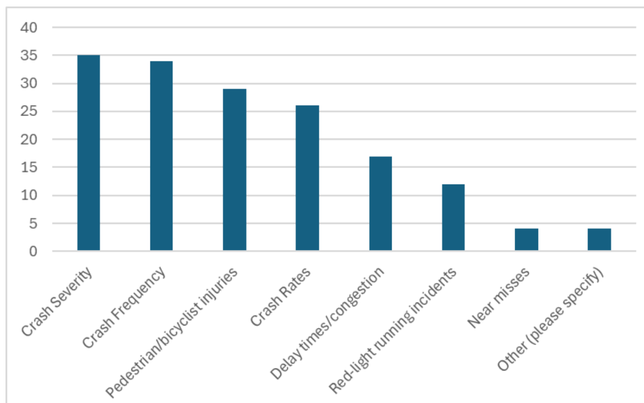
Start of Block: 2. Defining Safety

Q4 In your opinion, what makes a signalized intersection safe?

Category	Number of Responses
Good visibility/signal visibility	10
Accommodate all mode users	8
Signal timing	7
Slower speeds	7
Attentive drivers	4
Efficient traffic flow	4
Law enforcement	3
LPIs	3
Protected turns	3
Adequate lighting	3
One signal head per lane	2
Good lane markings	2
Inherently not safe	2
No crashes	2
Few fatal and severe crashes	2
Reduce conflict angles	2
Short crossings	2

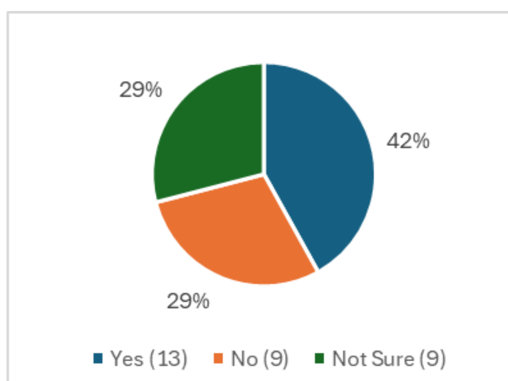
Q5 Which metrics does your agency use to measure safety at signalized intersections? Check all that apply.

- ❑ Crash frequency (1)
- ❑ Crash severity (2)
- ❑ Crash rates (3)
- ❑ Red-light running incidents (4)
- ❑ Pedestrian/bicyclist injuries (5)
- ❑ Near misses (6)
- ❑ Delay times/congestion (7)
- ❑ Other (please specify) (8)



Q6 Does your state use the 13 Highway Safety Manual (HSM) performance measures when analyzing safety at signalized intersections?

- ○ Yes (1)
- ○ No (2)
- ○ Not sure (3)

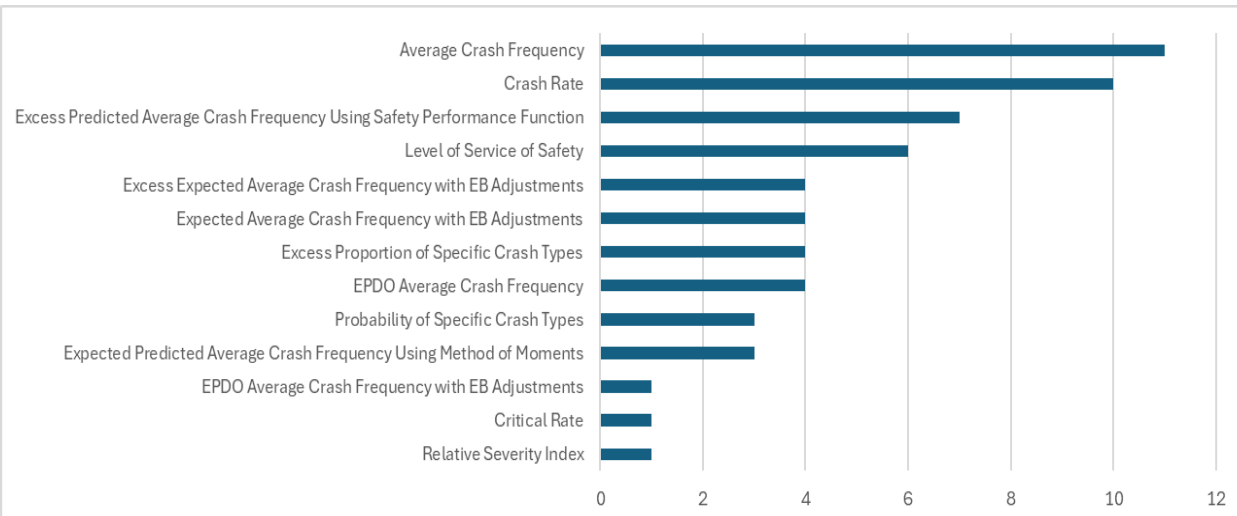


Display this question:

If Does your state use the 13 Highway Safety Manual (HSM) performance measures when analyzing safety... = Yes

Q7 What performance measures does your state use when analyzing safety at signalized intersections. Check all that apply.

- ☐ Average Crash Frequency (1)
- ☐ Crash Rate (2)
- ☐ Equivalent Property Damage Only (EPDO) Average Crash Frequency (3)
- ☐ Relative Severity Index (4)
- ☐ Critical Rate (5)
- ☐ Expected Predicted Average Crash Frequency Using Method of Moments (6)
- ☐ Level of Service of Safety (7)
- ☐ Excess Predicted Average Crash Frequency Using Safety Performance Functions (8)
- ☐ Probability of Specific Crash Types (9)
- ☐ Excess Proportion of Specific Crash Types (10)
- ☐ Expected Average Crash Frequency with Empirical Bayes (EB) Adjustments (11)
- ☐ EPDO Average Crash Frequency with EB Adjustments (12)
- ☐ Excess Expected Average Crash Frequency with EB Adjustments



Display this question:

If Does your state use the 13 Highway Safety Manual (HSM) performance measures when analyzing safety... = Yes

Q8 Describe how your state uses the HSM when analyzing safety at signalized intersections. For example, if your state primarily follows one performance measure, but deviates from it slightly, please describe below.

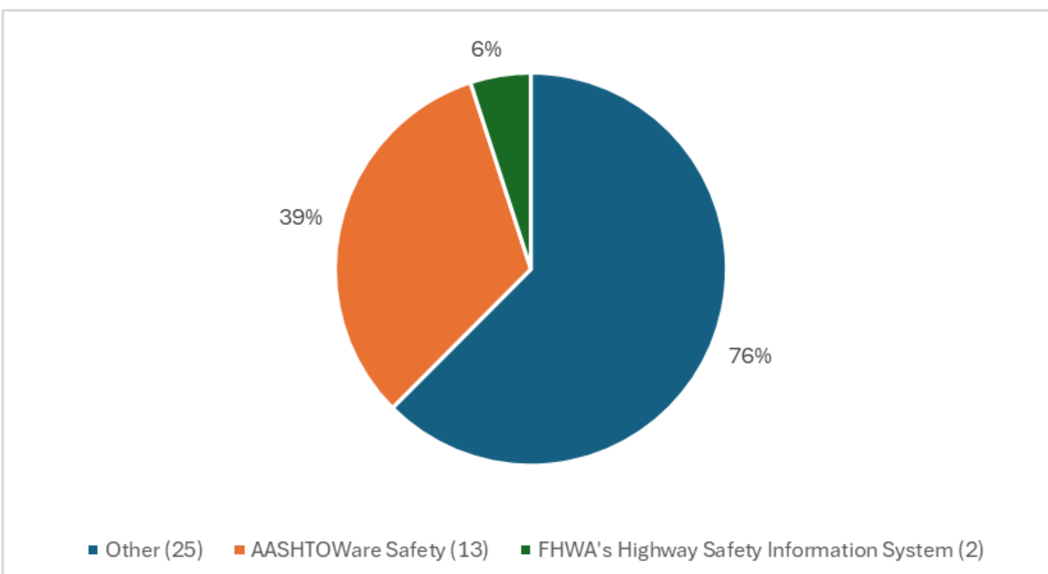
Category	Number of Responses
HSM methodology	5
CMF's/SPF's	4
Limited safety analysis due to poor communication	1
Compare similar intersections	1
LOSS with EB adjustment	1

End of Block: 2. Defining Safety

Start of Block: 3. Crash Data and Trends

Q9 How does your state gather and maintain crash data (e.g., AASHTOWare Safety, FHWA's Highway Safety Information System, etc.)?

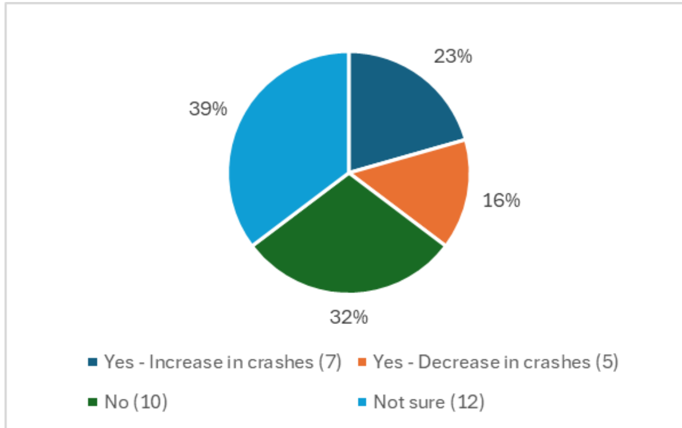
- ❑ AASHTOWare Safety (1)
- ❑ FHWA's Highway Safety Information System (2)
- ❑ Other (please specify) (3) ____



Category	Number of Responses
State manual/system/database	19
Police department	3
ArcGIS	1
Accident analysis office	1

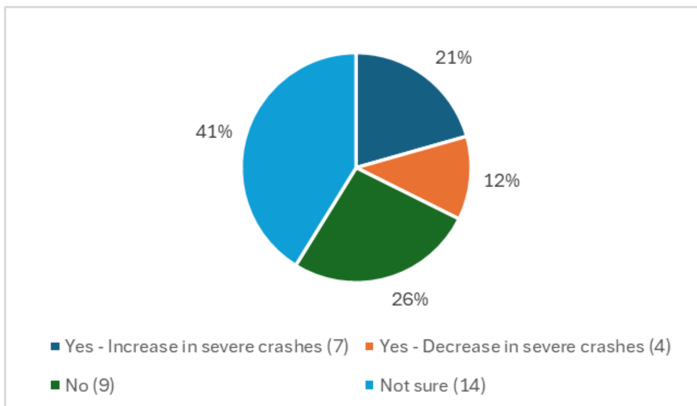
Q10 Has your state observed any specific crash frequency trends (increases or decreases) at signalized intersections over the past 5 years?

- Yes - Increase in crashes (1)
- Yes - Decrease in crashes (2)
- No (3)
- Not sure (4)



Q11 Has your state observed any crash severity trends (increases or decreases) at signalized intersections over the past 5 years?

- Yes - Increase in severe crashes (1)
- Yes - Decrease in severe crashes (2)
- No (3)
- Not sure (4)



Display this question:

If Has your state observed any specific crash frequency trends (increases or decreases) at signalize... = Yes - Increase in crashes

Q12 What factors have led to an increase in crashes at signalized intersections in your state?

Category	Number of Responses
Distracted driving (especially cell phones)	4
Speeding	2
Roadway/weather conditions	2
Aggressive driving	1
Increased traffic volumes	1
DUI	1

Display this question:

If Has your state observed any specific crash frequency trends (increases or decreases) at signalize... = Yes - Decrease in crashes

Q13 What factors have led to a decrease in crashes at signalized intersections in your state?

Response
Optimistically, I would like to think better timing plans, better detection.
Serious crashes are down across the state including signalized intersections. Possibly due to lower speeds brought about by higher congestion
Systemic flashing yellow arrow and high-visibility traffic signal backplate projects that were completed recently
Safe system approach. High visibility signal back plates, no turn on red at 70% of intersections, leading pedestrian intervals at nearly 85%, high visibility crossings, intersection daylighting etc.

Display this question:

If Has your state observed any crash severity trends (increases or decreases) at signalized intersec... = Yes - Increase in severe crashes

Q14 What factors have led to an increase in crash severity at signalized intersections in your state?

Category	Number of Responses
Pandemic related speeding	3
Red-light running	2
Reckless driving	1
Data or reporting changes	1
Mopeds	1

Display this question:

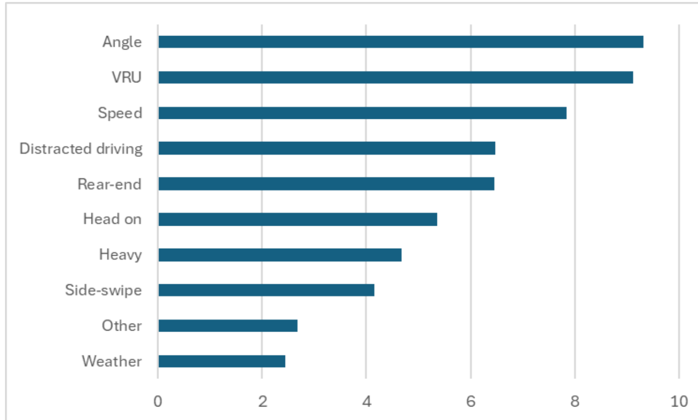
If Has your state observed any crash severity trends (increases or decreases) at signalized intersec... = Yes - Decrease in severe crashes

Q15 What factors have led to a decrease in crash severity at signalized intersections in your state?

Response
Optimistically, I would like to think better timing plans, better detection, and using updated clearance intervals, along with other limited strategies of Red Light Extension and more Flashing Yellow arrows. Outside of signals, added congestion, post-Covid, is likely a strong factor, along with better car technology for collision avoidance.
In Colorado, a decrease in crash severity at signalized intersections is due to improved signal timing, intersection design enhancements, safety features like pedestrian signals, and traffic safety technologies such as adaptive signals and red-light cameras.
Behavior factors (DUI, distracted, speed)
Updating signals with FYA's, backplates, and reviewing signal timings.

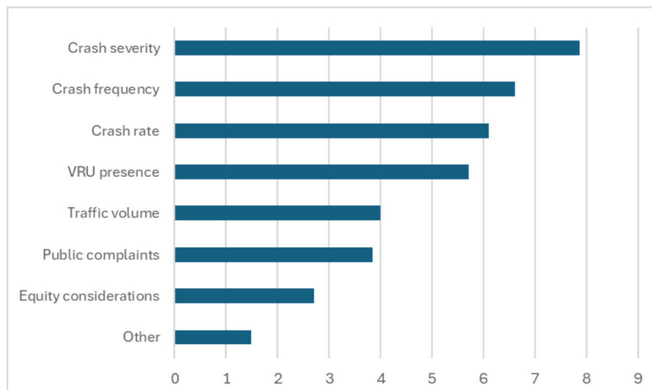
Q16 Rank your state's top crashes of concern at signalized intersections. Click and drag the items in order from most concerning to least concerning with most concerning at the top.

_______ Pedestrian/bicyclist crashes (1)
_______ Rear-end crashes (2)
_______ Head on crashes (3)
_______ Angle crashes (4)
_______ Side-swipe crashes (5)
_______ Speed related (6)
_______ Heavy vehicle related (7)
_______ Distracted driving related (8)
_______ Weather related (9)
_______ Other (please specify) (10)



Q17 Rank the importance of the following measures in determining safety improvements at signalized intersections. Click and drag the items in order from most important to least important with the most important measure at the top.

_______ Crash frequency (1)
_______ Crash rate (2)
_______ Crash severity (3)
_______ Public complaints (4)
_______ Traffic volume (5)
_______ Vulnerable road user presence (6)
_______ Equity considerations (7)
_______ Other: (8)



End of Block: 3. Crash Data and Trends

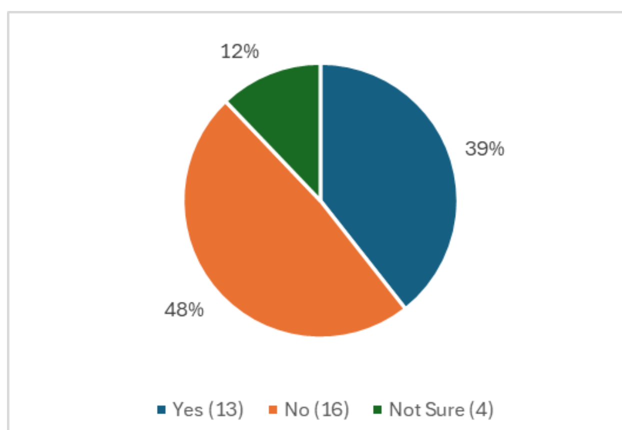
Start of Block: 4. Safety Evaluation and Programs

Q18 Does your state have a systemic safety analysis or signalized intersection safety audit program? If yes, please describe below.

○ Yes–please describe (1) ________________

○ No (2)

○ Not Sure (3)



Response
Arizona Annual Network Screening
We currently are using a GIS-based tool to convey intersection alternatives based on volume, configuration, and calibrated SPF's (initially developed by BYU)
Intersection safety implementation plan with systemic approach for prioritizing intersection safety needs
Not quite sure what this is asking. We have a Systemic Safety program that focuses on Roadway Departure and Bike/Ped (not specific to signalized intersection safety).
Risk Based, combined with crash history.
We conduct RSA for all high crash locations per MPO and we have systemic analysis including focus on VRU.
CDOT conducts systemic safety analysis and signalized intersection safety audits.
We have systemic safety analysis
State specific screening system of all crash locations using crash frequency, crash severity and crash rates
Under development now
Systemic safety analysis for intersections
Hazard Elimination Program is utilized.

Q19 Describe other methods your state uses to measure safety performance at signalized intersections.

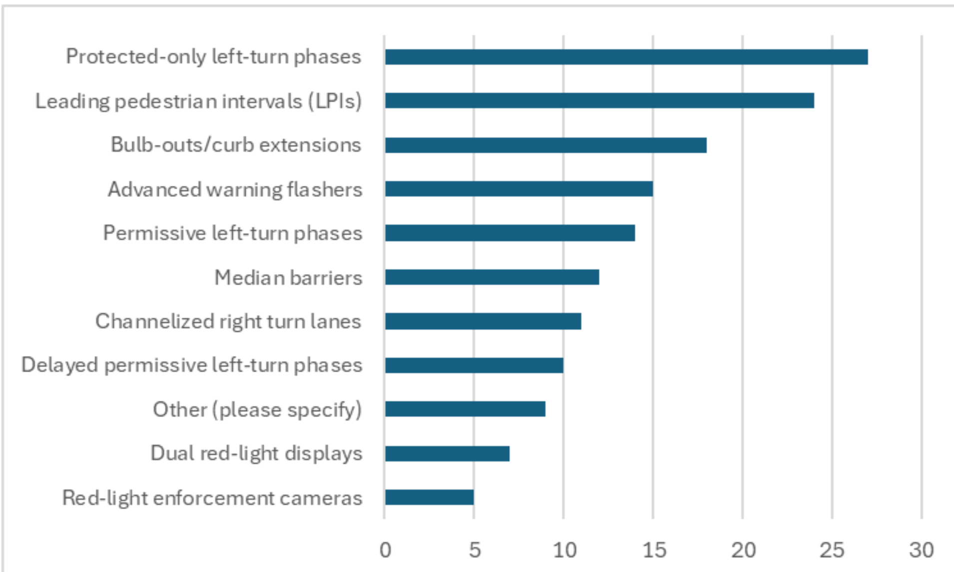
Response
Traffic signal control is typically the "safety" improvement for an intersection. We rarely look back at locations with existing traffic signals, though some have advocated for identifying unwarranted, or marginally warranted traffic signals for replacement with roundabouts, or even all-way stop control.
Currently evaluating crash rate and predictive crash likelihood
Illinois has an ICE Policy guidance to determine the best possible intersection configuration for safety
There are no methods for measuring safety performance at signalized intersections
Equivalent PDOs and ratio of intersection crash rate compared to the statewide average intersection crash rate
We do have a road safety office. But the only work with specific cases and situations.
A pilot study (altogether 10 signalized intersections statewide) was also conducted to collect near missing data to evaluate the safety improvement needs and identify potential safety improvements.
Mostly described in previous questions. We use AASHTOWare Safety to perform Network Screening to identify study and project locations and to identify crash trends. We use HSM Methodology and spreadsheet tools to analyze specific locations and compare design alternatives.
Crash Rates, namely fatal and serious injury crashes. Recently, MnDOT has been focusing on corridor wide improvements along high risk roads.
Crash rate and severity are the primary factors used to measure safety performance.
We use EPDO ranking as well as network screening. All high-crash locations undergo intersection control evaluation when intersection is being reconstructed.
CDOT uses signalized intersection safety audits, Empirical Bayes (EB) adjustments, and predictive safety models to assess safety. The Crash Data Repository is used for analyzing crash frequency and severity, and AASHTOWare Safety helps in performing data-driven evaluations to identify high-risk locations. Additionally, CDOT applies the Vision Zero suite program for crash/safety screening and analysis.
ATSPM performance measures, SSI, Speed, VRU probe data, event probe data (harsh braking, etc.)
Compliance with laws and regulations through observations on Road Safety Audits.

End of Block: 4. Safety Evaluation and Programs

Start of Block: 5. Countermeasures and Practices

Q20 Which countermeasures has your state found effective at signalized intersections? Check all that apply.

- ❑ Protected-only left-turn phases (1)
- ❑ Permissive left-turn phases (2)
- ❑ Delayed permissive left-turn phases (3)
- ❑ Dual red-light displays (4)
- ❑ Red-light enforcement cameras (5)
- ❑ Advanced warning flashers (6)
- ❑ Leading pedestrian intervals (LPIs) (7)
- ❑ Bulb-outs/curb extensions (9)
- ❑ Median barriers (10)
- ❑ Channelized right turn lanes (11)
- ❑ Other (please specify) (8) ____



Category	Number of Responses
FYA	4
Reflective backplates	3
More signal heads	2
Working equipment/maintenance	2
Dual left-turn lanes	1
Right-turn lanes	1
Paint markings	1
Narrow left-turn lanes	1
All-red phase	1
Confirmation lights	1
LPI	1
Enforcement initiatives	1

Display this question:

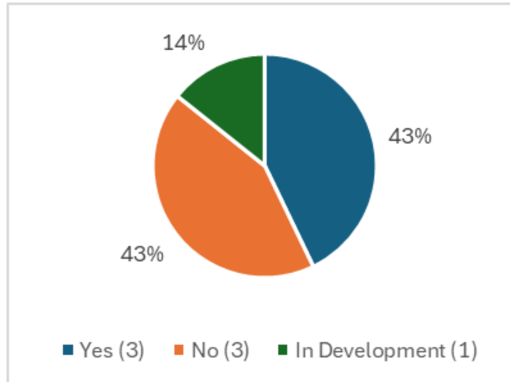
If Which countermeasures has your state found effective at signalized intersections? Check all that... = Dual red-light displays

Q21 Does your state have a formal threshold or guideline for using dual red-light displays?

○ Yes–please describe (1) ____

○ No (2)

○ In development (3)



Response
CDOT uses dual red-light displays to improve visibility and reduce conflicts at signalized intersections, especially in areas with heavy left-turn volumes or complex lane configurations.
Used for single lane protected phasing

Display this question:

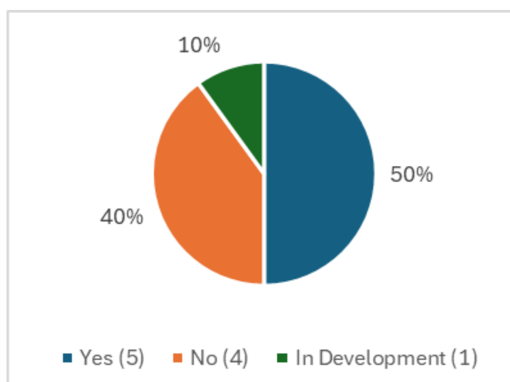
If Which countermeasures has your state found effective at signalized intersections? Check all that... = Delayed permissive left-turn phases

Q22 Does your state have a formal threshold or guideline for implementing a delayed permissive left-turn phase?

○ Yes–please describe (1) ____

○ No (2)

○ In development (3)



Response
3 seconds after LPI ends
It's the standard practice
CDOT implements delayed permissive left-turn phases to reduce conflicts with pedestrians, cyclists, and opposing traffic, based on factors like traffic volume and intersection design.
Provided in Delaware's Traffic Design Manual

Display this question:

If Which countermeasures has your state found effective at signalized intersections? Check all that... = Protected-only left-turn phases

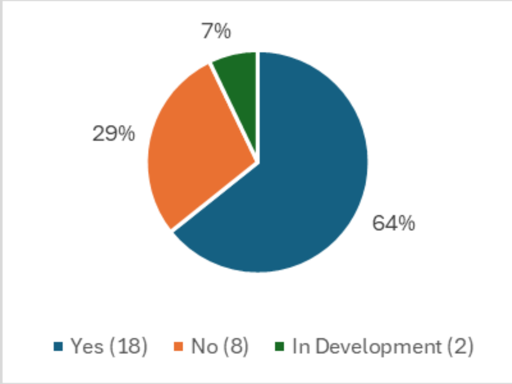
Or Which countermeasures has your state found effective at signalized intersections? Check all that... = Permissive left-turn phases

Q23 Does your state have a formal threshold or guideline for using protected/permissive left-turn phasing?

○ Yes–please describe (1) ____

○ No (2)

○ In development (3)



Category	Number of Responses
Listed in state guidelines	6
Left turn volumes	5
Traffic volumes	4
Crash frequency	2
Crash severity	1
Left turn crashes	1
Pedestrian presence	1

Display this question:

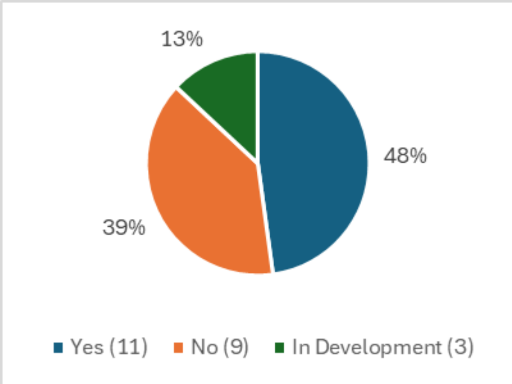
If Which countermeasures has your state found effective at signalized intersections? Check all that... = Leading pedestrian intervals (LPIs)

Q24 Does your state have a formal threshold or guideline for using LPIs?

○ Yes–please describe (1) ____

○ No (2)

○ In development (3)



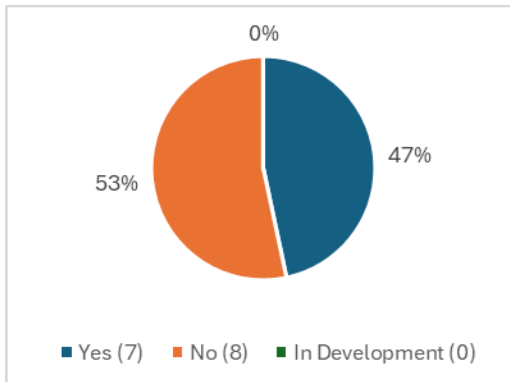
Response
Default condition for all concurrent and most exclusive pedestrian phases.
RTE discretion based on pedestrian volume
See TEM Guidance 404-4.
https://www.transportation.ohio.gov/working/engineering/roadway/manuals-standards/tem
Install wherever possible
All intersections with crosswalks
Practitioners are encouraged to implement LPI where APS exist and there is crash history, poor visibility of peds, large radii corner geometry or minimal operational impact (undersized ped split)
CDOT implements Leading Pedestrian Intervals (LPIs) at intersections with high pedestrian volumes to reduce conflicts by giving pedestrians a head start before vehicles. Guidelines consider pedestrian safety and intersection complexity.
We seek to put them everywhere they can be placed and are appropriate

Display this question:

If Which countermeasures has your state found effective at signalized intersections? Check all that... = Advanced warning flashers

Q25 Does your state have a formal threshold or guideline for using advanced warning flashers at signalized intersections?

- Yes–please describe (1) ________________
- No (2)
- In development (3)



Category	Number of Responses
Limited visibility	4
Speed	2
Volume	2
Rural to urban transition	1
Crash history	1

Display this question:

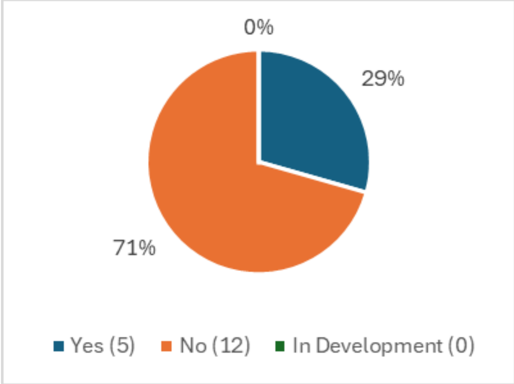
If Which countermeasures has your state found effective at signalized intersections? Check all that... Bulb-outs/curb extensions

Q26 Does your state have a formal threshold or guideline for using bulb-outs/curb extensions at signalized intersections?

○ Yes–please describe (1) ________________

○ No (2)

○ In development (3)



Response
Yes, es – CDOT does use guidelines for bulb-outs and curb extensions at signalized intersections. Yes, in our PSG:https://www.dot.ga.gov/DriveSmart/Travel/BikePed/PSG.pdf Every intersection 25' back from crossings by law

Display this question:

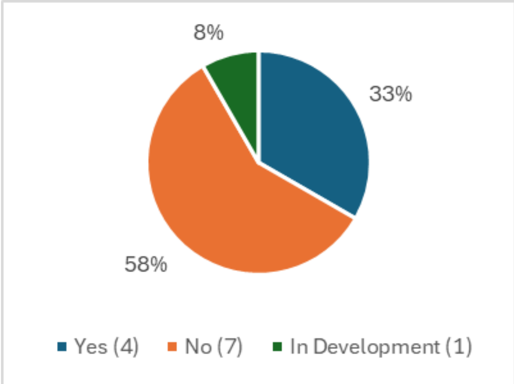
If Which countermeasures has your state found effective at signalized intersections? Check all that... = Median barriers

Q27 Does your state have a formal threshold or guideline for using median barriers at signalized intersections?

○ Yes–please describe (2) ________________

○ No (3)

○ In development (4)



Response
We do have a tool that was developed, but it is not a standard and as such is sometimes not implemented due to political or public will Front to front collisions Es – CDOT has guidelines for implementing median barriers at signalized intersections.

Display this question:

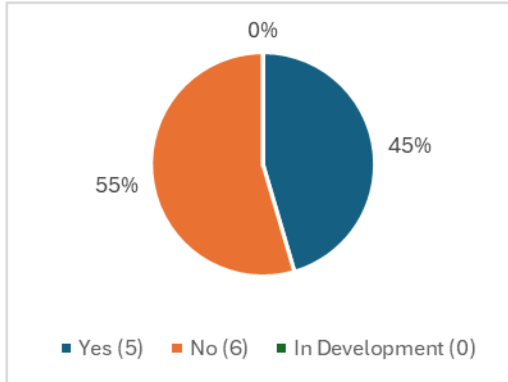
If Which countermeasures has your state found effective at signalized intersections? Check all that... = Channelized right turn lanes

Q28 Does your state have a formal threshold or guideline for using channelized right turn lanes at signalized intersections?

○ Yes–please describe (1) ________________

○ No (2)

○ In development (3)



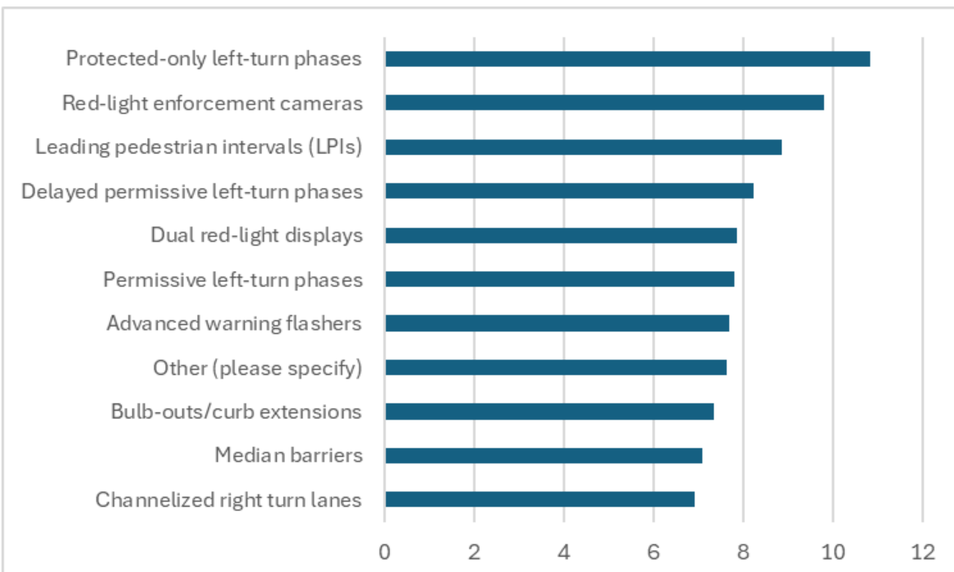
Response
See 401-6.3. https://www.transportation.ohio.gov/working/engineering/roadway/manuals-standards/location-design-vol-1/0400/0400
Right turn counts
Not truly formal in terms of volume, but where there is higher volumes expected
Yes – CDOT has guidelines for using channelized right-turn lanes at signalized intersections.
Yes, in our PSG: https://www.dot.ga.gov/DriveSmart/Travel/BikePed/PSG.pdf

Carry Forward Selected Choices from "Which countermeasures has your state found effective at signalized intersections? Check all that apply."

X→

Q29 Rank the countermeasures your state has implemented based on their order of effectiveness. Click and drag the items in order from most important to least important with the most important measure at the top.

_______ Protected-only left-turn phases (1)
_______ Permissive left-turn phases (2)
_______ Delayed permissive left-turn phases (3)
_______ Dual red-light displays (4)
_______ Red-light enforcement cameras (5)
_______ Advanced warning flashers (6)
_______ Leading pedestrian intervals (LPIs) (7)
_______ Bulb-outs/curb extensions (8)
_______ Median barriers (9)
_______ Channelized right turn lanes (10)
_______ Other (please specify) (11)



Response
Dual left turns
FYAs, retroreflective backplates, signal head per lane
Working detection equipment
Signal operation adjustments, increased sign reflectivity, and enforcement

End of Block: 5. Countermeasures and Practices

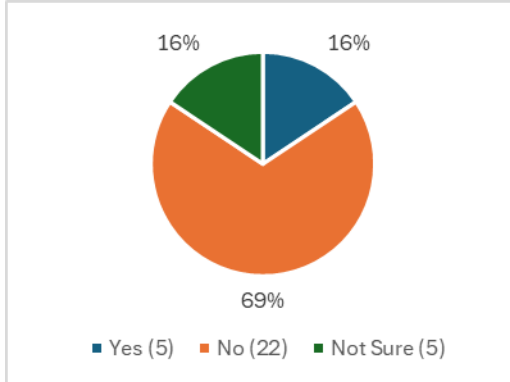
Start of Block: 6. Signal Installation and Policy

Q30 Are there speed thresholds for installing new traffic signals in your state?

○ Yes–please specify (1) ________________________

○ No (2)

○ Not sure (3)



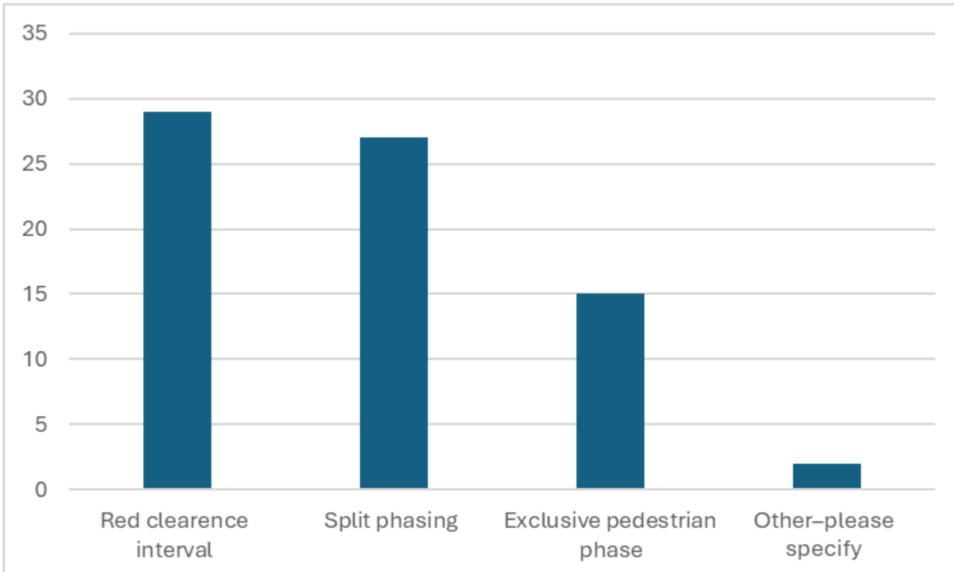
Response
Speed limits and actual speeds evaluated during decision and signalization set up.
Shouldn't be above 55 MPH

Q31 Describe your state's standards for lighting at signalized intersections?

Category	Number of Responses
Light signalized intersections	14
FHWA/state lighting manual	5
Light crosswalk	4
Traffic volumes	1
RP8 lighting levels	1
Nighttime crash volumes	1

Q32 Which of the following signal phasing does your state use? Check all that apply.

- ❑ Red clearance interval (4)
- ❑ Exclusive pedestrian phase (5)
- ❑ Split phasing (6)
- ❑ Other–please specify (7) ____



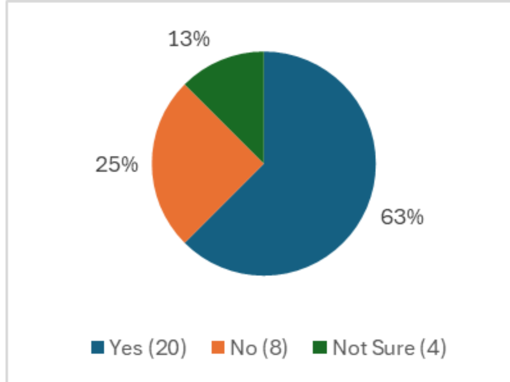
Response
Leading Bike Interval
CDOT also uses leading pedestrian intervals (LPIs) at many high-pedestrian-volume intersections. This phase gives pedestrians a head start before vehicles move, enhancing safety.

Q33 How do you determine the length of the yellow interval? Is there a standard you use?

Category	Number of Responses
ITE method/kinematic equation	13
MUTCD	5
State manual	5
4 seconds	1
Speed and size of intersection	1

Q34 Are detectors used to extend the green interval if a car is in the dilemma zone?

- Yes (1)
- No (2)
- Not sure (3)



Display this question:

If Which of the following signal phasing does your state use? Check all that apply. = Red clearance interval

Q35 How do you determine the red clearance interval? How long is it? Is there a standard you use?

Category	Number of Responses
ITE method/kinematic equation	6
State manual	3
Speed	3
Intersection geometry	2
MUTCD	2
Engineer's discretion	1
2 seconds	3
1 second minimum	2
1-2 seconds	1
0.5 to 1 second	1

Display this question:

If Which of the following signal phasing does your state use? Check all that apply. = Exclusive pedestrian phase

Q36 How do you determine when to use an exclusive pedestrian interval? How long is it? Is there a standard you use?

Category	Number of Responses
Pedestrian volumes	4
Moving to concurrent phasing	2
Any signal with crosswalk	1
Safety concerns	1
Crash trends	1
Traffic study	1
Based on crossing length	1
3 seconds	1
7 second min	1
7 to 10 sec	1

Display this question:

If Which of the following signal phasing does your state use? Check all that apply. = Split phasing

Q37 What guidelines does your state have for split phasing?

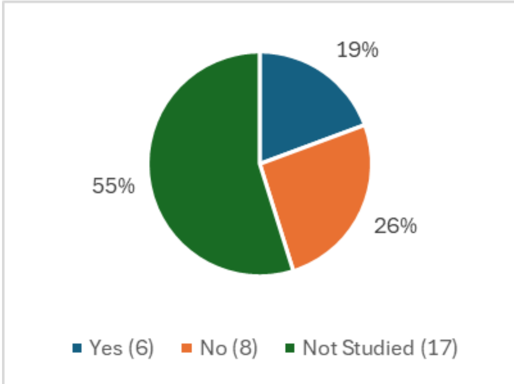
Category	Number of Responses
Intersection geometry	9
Imbalance in traffic volumes	3
Traffic volumes	3
MUTCD	2
Split bicycle and ped movements first	1
Lane utilization	1
Capacity	1
Avoid it	1
Safety evaluation	1
Left turn conflicts	1
Traffic study	1

End of Block: 6. Signal Installation and Policy

Start of Block: 7. Other Considerations

Q38 Have you observed a relationship between sunlight glare and safety at signalized intersections?

- Yes–please describe (1) ____
- No (2)
- Not studied (3)



Category	Number of Responses
Signal not visible	2
East-west corridor glare	2
Intersection not visible	1
Pedestrian not visible	1
Contributing factor in crash report	1

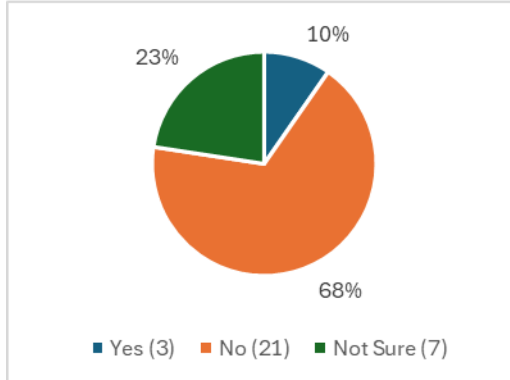
Q39 Does your state collect roadway width data in connection with signalized intersection crashes?

○ Yes–please describe any observed crash trends to roadway width (if known) (1)

____

○ No (2)

○ Not sure (3)



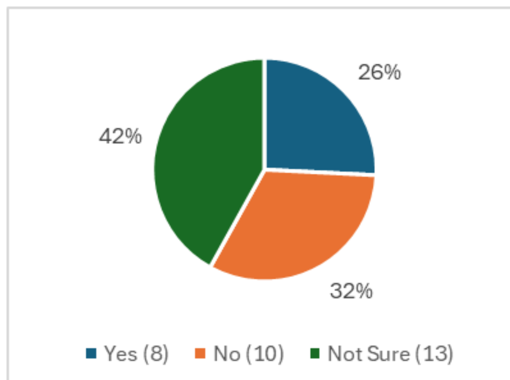
Response
Higher crashes typically found at wider intersections
We've seen that multilane streets tend to have more severe crashes, especially off-peak when people can pass and it feels like a highway. If possible we use curb extensions to narrow the approach.

Q40 Is your state aware of a correlation between crash rates and other intersection geometry (e.g. curve, grade, etc.)?

○ Yes–please explain (1) ________________________

○ No (2)

○ Not sure (3)



Response
Lane width
Presence of curve, intersection as a skew, high speeds
We have observed correlations, but are still formalizing the correlations to extract usable insights.
We are aware of that possibility and we avoid to install traffic signals under those conditions. But sometimes, there are no alternative, so it is taken into account in the design of the traffic signal systems to include additional safety measures..
Part of risk assessment
Yes – CDOT recognizes correlations between crash rates and intersection geometry, such as curves, grades, and lane configurations. These factors help prioritize safety improvements at high-risk intersections.
We use established CMFs and SPFs.. We also do correlations ourselves.
Curves, grades, sight lines with old buildings or trees

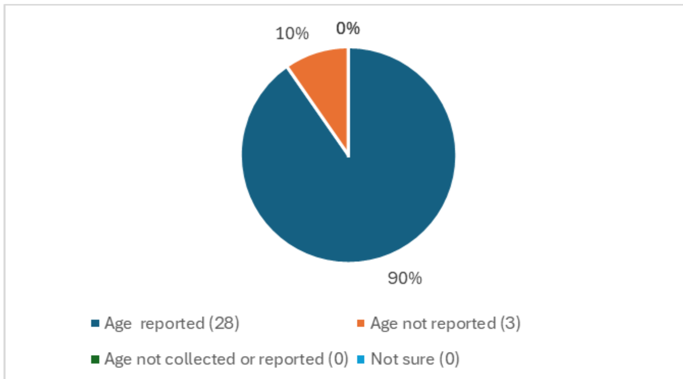
Q41 Does your state collect and report data on the ages of drivers involved in intersection-related crashes?"

○ Age data is collected and reported (1)

○ Age data is collected but not reported (2)

○ Age data is neither collected nor reported (3)

○ Not sure (4)



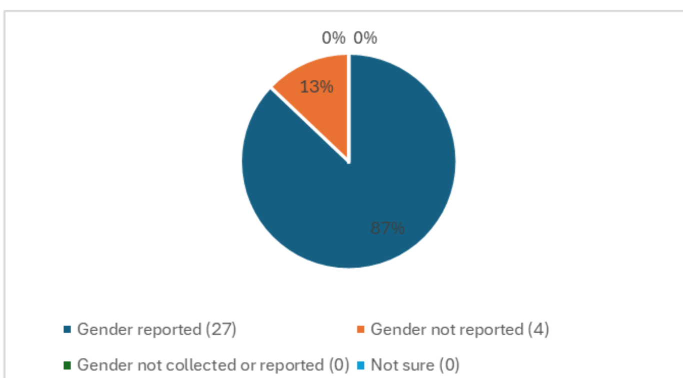
Q42 Does your state collect and report data on the gender of drivers involved in intersection-related crashes?

○ Gender data is collected and reported (1)

○ Gender data is collected but not reported (2)

○ Gender data is neither collected nor reported (3)

○ Not sure (4)

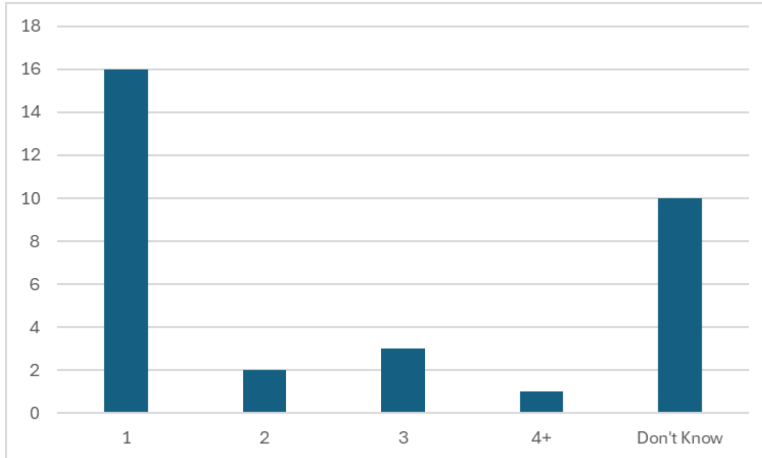


End of Block: 7. Other Considerations

Start of Block: 8. Feedback and Participation

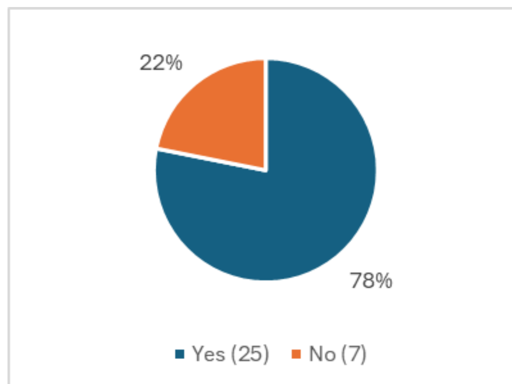
Q43 How many people from your state agency are completing this survey?

- 1 (1)
- 2 (2)
- 3 (3)
- 4+ (4)
- Don't know (5)



Q44 Would you be willing to participate in a follow-up discussion?

- Yes–provide contact (1) ________________________
- No (2)



Q45 Any other comments, ideas, or concerns related to signalized intersection safety?

Response
When in doubt, roundabout.
State currently developing intersection control evaluation program
My responses were primarily focused on ODOT signals, where we own/maintain 1600 signals. Statewide, there are roughly 11k signals, and we are a Home Rule state.
TDOT does not own or maintain signals. Once installed, they are turned over to local agencies. We do evaluate high crash locations for improvement and these may or may not be signalized locations.
Flashing yellow arrows were popular several years ago, but BSPE no longer favors them based on some studies that show they lose their effectiveness over time
On-going issue
We are in the process of determining how to use the large amounts of data we collect to provide implementable actions, beyond just knowing the problems exist.
We often compare signalize intersection safety with roundabouts, RCUTS, and two-way stop controlled intersections.
We have begun using bimodal blank-out signs to further warn drivers when peds are crossing
Other ideas we have been implementing: Red light running protection. Not using video with high % trucks and higher speed roadways (radar instead). Wide back plates where sun glare could be an issue (yellow back plates on all signals however). Reliable advanced detection. Supplemental far left signal heads
I think there could be potential enhancements to safety in the future using V2X tech to warn drivers of a potential conflict before they enter an intersection
NMDOT is just beginning to develop screening criteria for signalized intersections. Many of the signals in the state marginally met signal requirements and there is interest in determining if some of these intersections could be candidates for other types of intersection control such as a 4-way stop.
CDOT is continuously working to improve signalized intersection safety, particularly for pedestrians and cyclists. There is an increasing focus on Vision Zero initiatives to reduce fatalities and severe injuries. Ongoing safety audits and the use of advanced technology like adaptive signal systems help improve intersection operations and safety.

Q46 Please provide contact information to whom we may contact to access your state's crash data.

____

____

____

End of Block: 8. Feedback and Participation

APPENDIX C: CRASH TREE RESULTS

C.1 Overview

Crash trees are visual representations of crash data trends for a given dataset. Each level of a crash tree represents a crash attribute, and each branch of a tree represents a collection of specific data attributes. The percentages displayed compare the number for each category to the total of each severity level. The data displayed in the crash trees was found by using 'COUNTIFS' functions in Excel. Data for the crash trees came from three datasets for each level which are crash view, vehicle view, and person view. Crash view contains one data point for each crash, vehicle view contains one data point for each vehicle involved in a crash and person view contains a data point for each person. Each crash tree states the sheet that the data came from. More detailed information about the use of crash trees can be found in Chapter 5.

The following sections provide a summary of the crash trees for Utah, Arizona, Connecticut, Georgia, Idaho, Illinois, Maine, Nebraska, and Wyoming. The crash trees are used to measure several crash attributes including manner of collision, weather condition, functional classification, light condition, urban/rural, age, sex, vehicle movements, contributing factors, and VRUs.

C.2 Utah

This section summarizes crash trees for Utah. Table C.1 provides a summary of the crash trees provided by the crash attributes observed as seen in this appendix. The table outlines 11 figures with crash trees by manner of collision, functional classification, weather condition, light condition, urban/rural, driver age, driver sex, vehicle movement, contributing factors, DUI, and VRU.

Table C.1 Utah Crash Tree Figure Summary

Utah	
Crash Attribute	**Figure**
Manner of Collision	C.1
Functional Classification	C.2
Weather Condition	C.3
Light Condition	C.4
Urban/Rural	C.5
Driver Age	C.6
Driver Sex	C.7
Movement	C.8
Contributing Factors	C.9
DUI	C.10
VRU	C.11

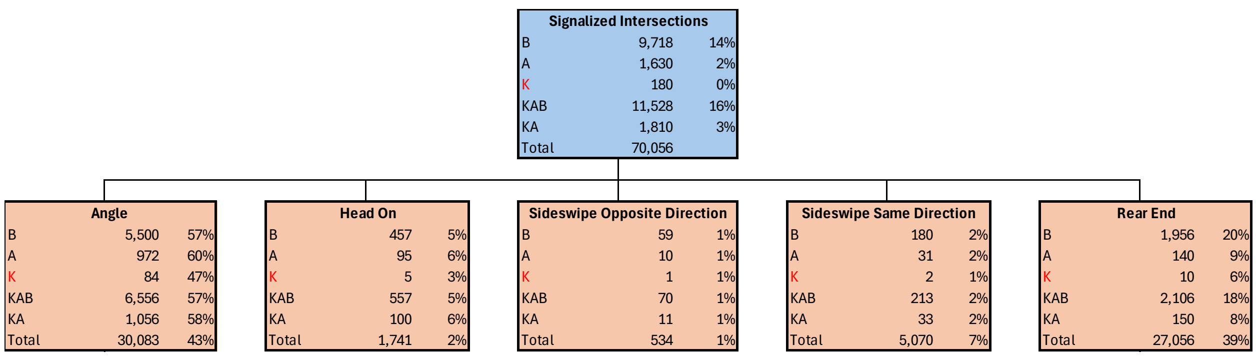


Figure C.1 UT Crash View: Manner of Collision

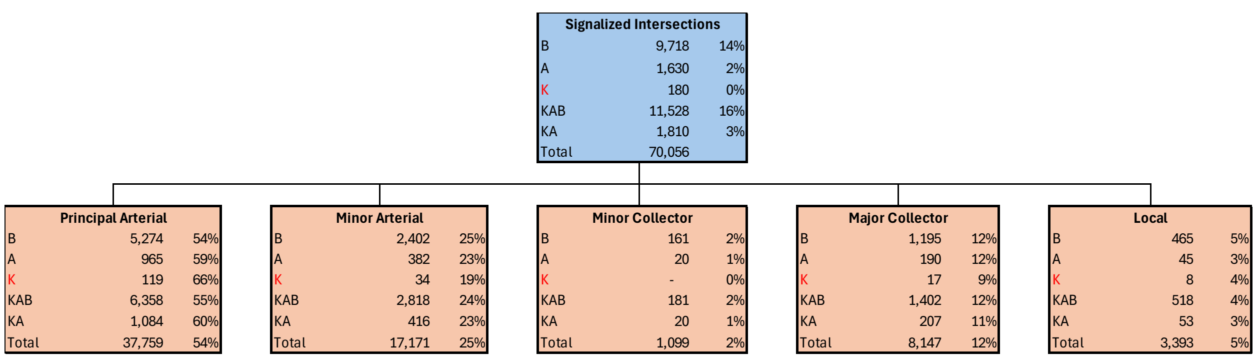


Figure C.2 UT Crash View: Functional Classification

Signalized Intersection		
B	9,718	14%
A	1,630	2%
K	180	0%
KAB	11,528	16%
KA	1,810	3%
Total	70,056	

Clear		
B	7,571	78%
A	1,305	80%
K	144	80%
KAB	9,020	78%
KA	1,449	80%
Total	52,439	75%

Cloudy		
B	1,440	15%
A	218	13%
K	27	15%
KAB	1,685	15%
KA	245	14%
Total	10,848	15%

Fog		
B	14	0%
A	5	0%
K	-	0%
KAB	19	0%
KA	5	0%
Total	106	0%

Rain		
B	418	4%
A	67	4%
K	8	4%
KAB	493	4%
KA	75	4%
Total	3,153	5%

Severe Winds		
B	4	0%
A	1	0%
K	-	0%
KAB	5	0%
KA	1	0%
Total	26	0%

Snow		
B	232	2%
A	26	2%
K	-	0%
KAB	258	2%
KA	26	1%
Total	3,136	4%

Figure C.3 UT Crash View: Weather Condition

Signalized Intersections		
B	9,718	14%
A	1,630	2%
K	180	0%
KAB	11,528	16%
KA	1,810	3%
Total	70,056	

Daylight		
B	7,023	72%
A	1,102	68%
K	98	54%
KAB	8,223	71%
KA	1,200	66%
Total	51,631	74%

Dark-Lighted		
B	2,041	21%
A	410	25%
K	57	32%
KAB	2,508	22%
KA	467	26%
Total	13,810	20%

Dark		
B	219	2%
A	46	3%
K	12	7%
KAB	277	2%
KA	58	3%
Total	1,690	2%

Figure C.4 UT Crash View: Light Condition

Signalized Intersection		
B	9,718	14%
A	1,630	2%
K	180	0%
KAB	11,528	16%
KA	1,810	3%
Total	70,056	

Urban		
B	9,654	99%
A	1,617	99%
K	176	98%
KAB	11,447	99%
KA	1,793	99%
Total	69,302	99%

Rural		
B	64	1%
A	13	1%
K	4	2%
KAB	81	1%
KA	17	1%
Total	754	1%

Figure C.5 UT: Crash View: Urban/Rural

Drivers		
B	18,838	14%
A	3,111	2%
K	325	0%
KAB	22,274	17%
KA	3,436	3%
Total	133,330	

14-24		
B	5,096	27%
A	789	25%
K	66	20%
KAB	5,951	27%
KA	855	25%
Total	38,212	29%

25-44		
B	7,573	40%
A	1,266	41%
K	122	38%
KAB	8,961	40%
KA	1,388	40%
Total	53,726	40%

45-64		
B	4,309	23%
A	737	24%
K	86	26%
KAB	5,132	23%
KA	823	24%
Total	29,383	22%

65+		
B	1,856	10%
A	318	10%
K	51	16%
KAB	2,225	10%
KA	369	11%
Total	11,979	9%

Figure C.6 UT Person View: Driver Age

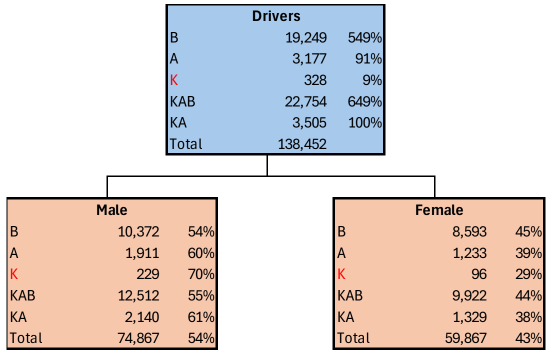


Figure C.7 UT Person View: Driver Sex

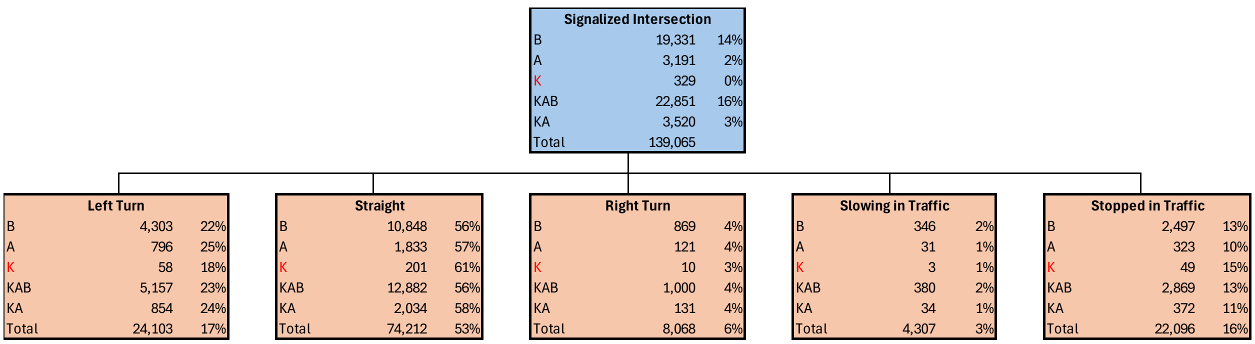


Figure C.8 UT Vehicle View: Movement

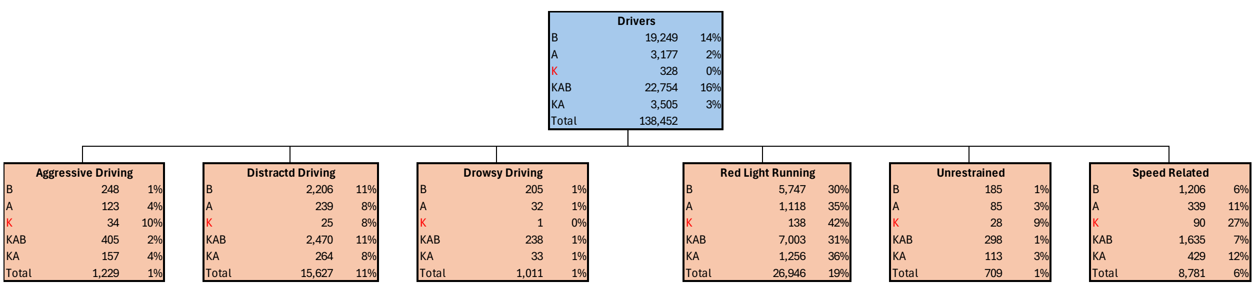


Figure C.9 UT Person View: Contributing Factors

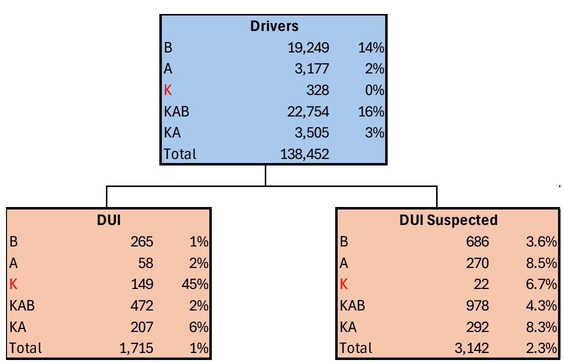


Figure C.10 UT Person View: DUI

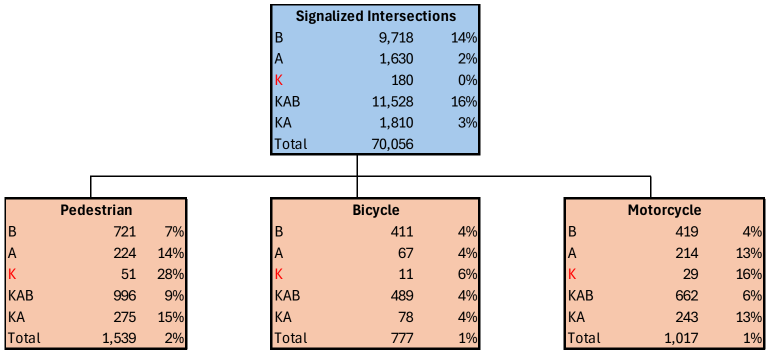


Figure C.11 UT Crash View: VRU

C.3 Arizona

This section summarizes crash trees for Arizona. Table C.2 provides a summary of the crash trees provided by the crash attributes observed as seen in this appendix. The table outlines 10 figures with crash trees by manner of collision, weather condition, light condition, driver age, driver sex, vehicle movement, contributing factors, speeding, DUI, and VRU.

Table C.2 Arizona Crash Tree Summary

Arizona	
Crash Attribute	**Figure**
Manner of Collision	C.12
Weather Condition	C.13
Light Condition	C.14
Driver Age	C.15
Driver Sex	C.16
Movement	C.17
Contributing Factors	C.18
Speeding	C.19
DUI	C.20
VRU	C.21

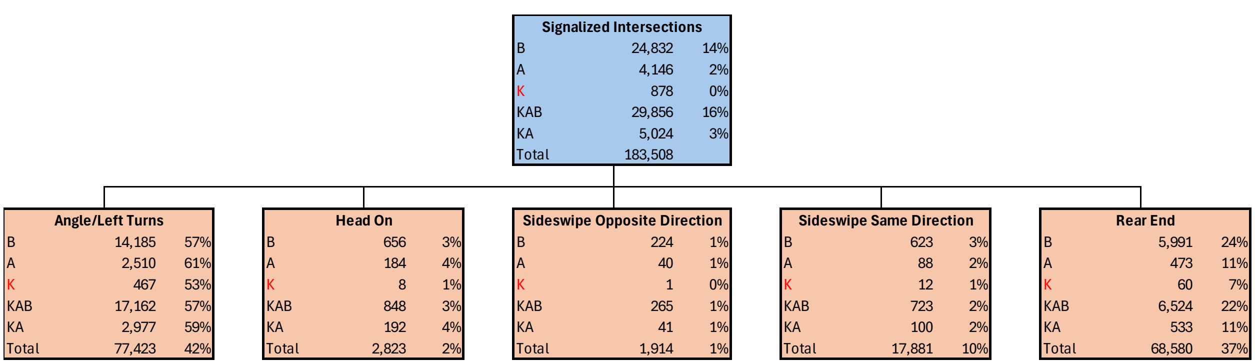


Figure C.12 AZ Crash View: Manner of Collision

Signalized Intersections		
B	24,832	14%
A	4,146	2%
K	878	0%
KAB	29,856	16%
KA	5,024	3%
Total	183,508	

	Clear		Cloudy		Rain		Snow	
B	22,194	89%	1,817	7%	651	3%	20	0%
A	3,742	90%	286	7%	86	2%	1	0%
K	760	87%	76	9%	23	3%	-	0%
KAB	26,696	89%	2,179	7%	760	3%	21	0%
KA	4,502	90%	362	7%	109	2%	1	0%
Total	163,286	89%	13,412	7%	5,220	3%	282	0%

Figure C.13 AZ Crash View: Weather Condition

Signalized Intersections		
B	24,832	14%
A	4,146	2%
K	878	0%
KAB	29,856	16%
KA	5,024	3%
Total	183,508	

	Daylight		Dark-Lighted		Dark	
B	17,184	69%	6,227	25%	179	1%
A	2,481	60%	1,409	34%	52	1%
K	410	47%	395	45%	14	2%
KAB	20,075	67%	8,031	27%	245	1%
KA	2,891	58%	1,804	36%	66	1%
Total	130,025	71%	43,296	24%	1,471	1%

Figure C.14 AZ Crash View: Light Condition

Driver		
B	24,404	7%
A	3,090	1%
K	498	0%
KAB	27,992	8%
KA	3,588	1%
Total	359,532	

	14-24		25-44		45-64		65 +	
B	5,395	22%	9,258	38%	6,292	26%	3,458	14%
A	603	20%	1,211	39%	801	26%	475	15%
K	83	17%	155	31%	133	27%	126	25%
KAB	6,081	22%	10,624	38%	7,226	26%	4,059	15%
KA	686	19%	1,366	38%	934	26%	601	17%
Total	84,922	24%	141,097	39%	92,547	26%	40,948	11%

Figure C.15 AZ Person View: Driver Age Group

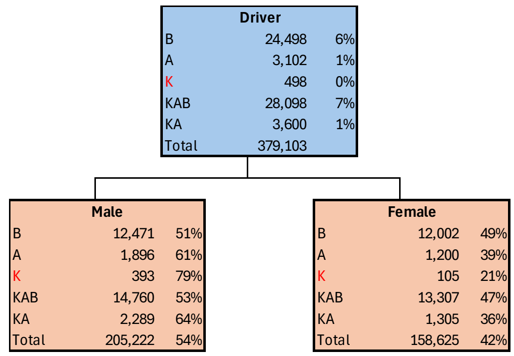
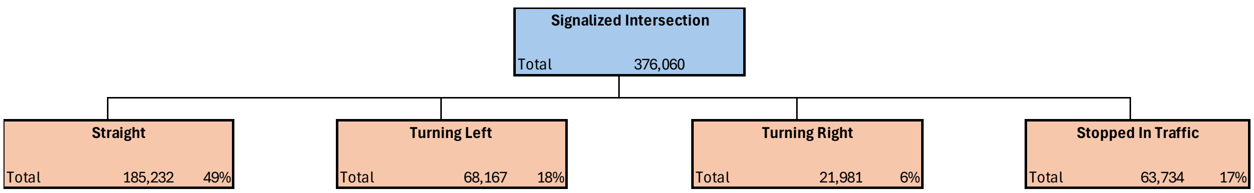


Figure C.16 AZ Person View: Driver Sex



Crashes could not be filtered by severity level
Only total crashes are analyzed

Figure C.17 AZ Vehicle View: Movement

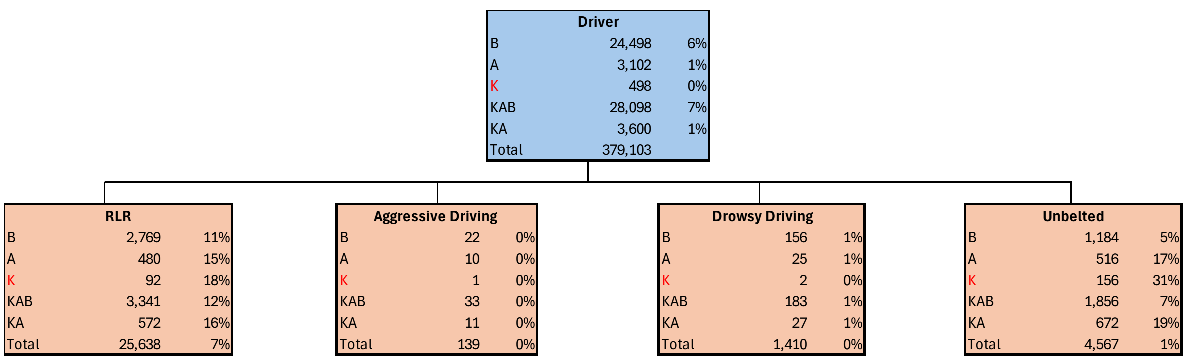


Figure C.18 AZ Person View: Contributing factors

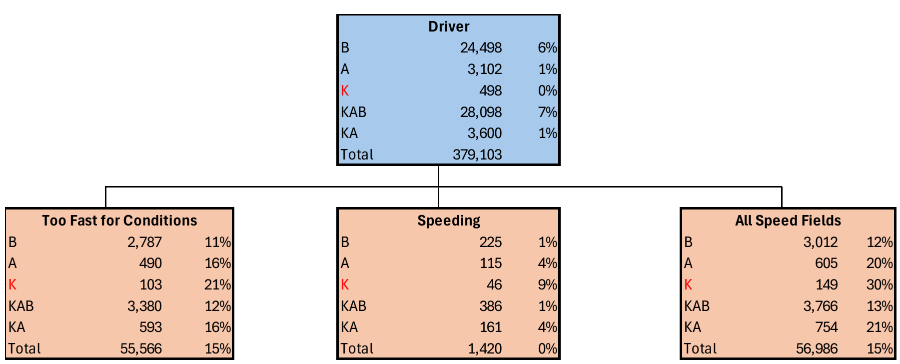


Figure C.19 AZ Person View: Speeding

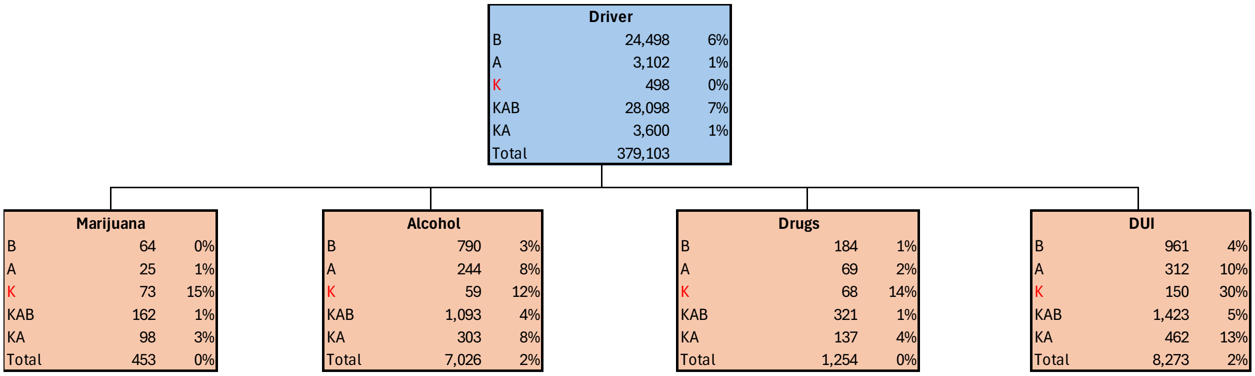
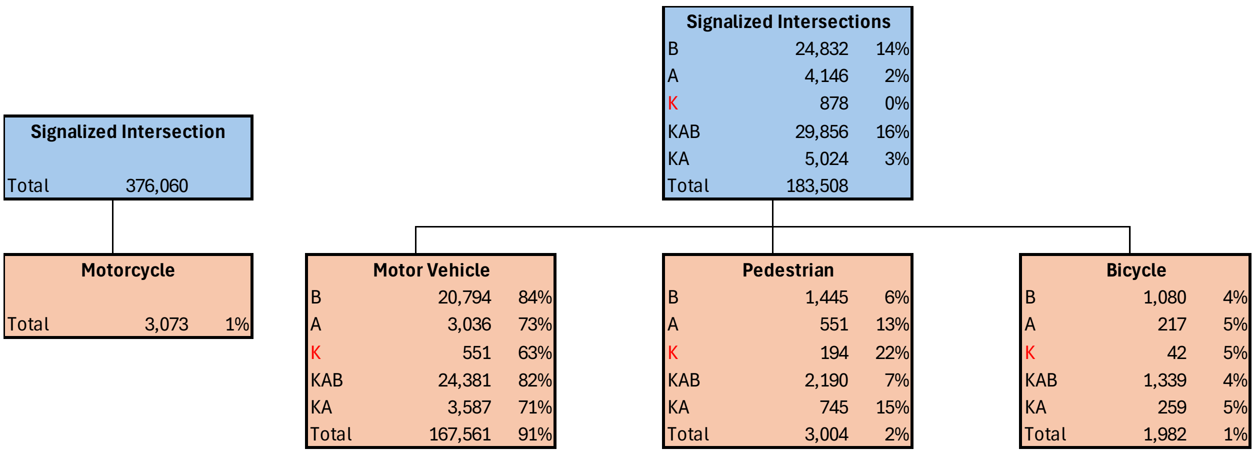


Figure C.20 AZ Person View: DUI



Pedestrians and bicycles come from person view
Motorcycles come from vehicle view

Figure C.21 AZ: VRU

C.4 Connecticut

This section summarizes crash trees for Connecticut. Table C.3 provides a summary of the crash trees provided by the crash attributes observed as seen in this appendix. The table outlines 11 figures with crash trees by manner of collision, functional classification, weather condition, light condition, urban/rural, driver age, driver sex, vehicle movement, contributing factors, speeding, and VRU.

Table C.3 Connecticut Crash Tree Summary

Connecticut	
Crash Attribute	**Figure**
Manner of Collision	C.22
Functional Classification	C.23
Weather Condition	C.24
Light Condition	C.25
Urban/Rural	C.26
Driver Age	C.27
Driver Sex	C.28
Movement	C.29
Contributing Factors	C.30
Speeding	C.31
VRU	C.32

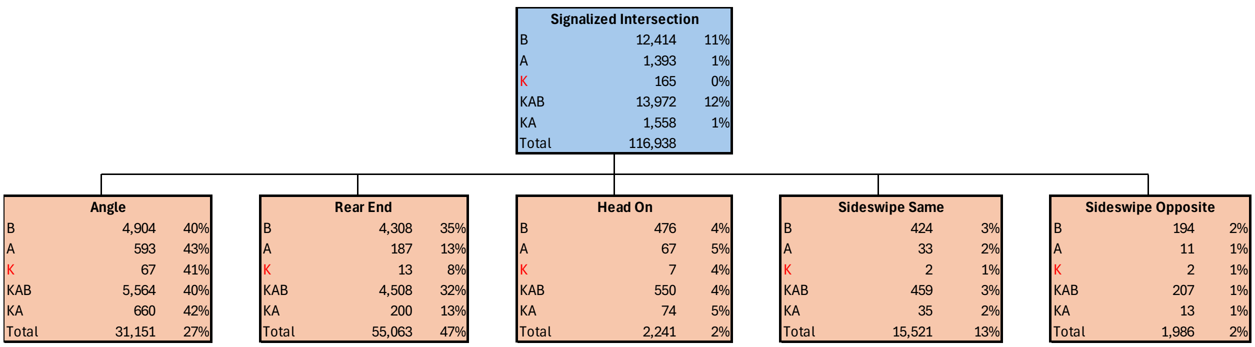


Figure C.22 CT Crash View: Manner of Collision

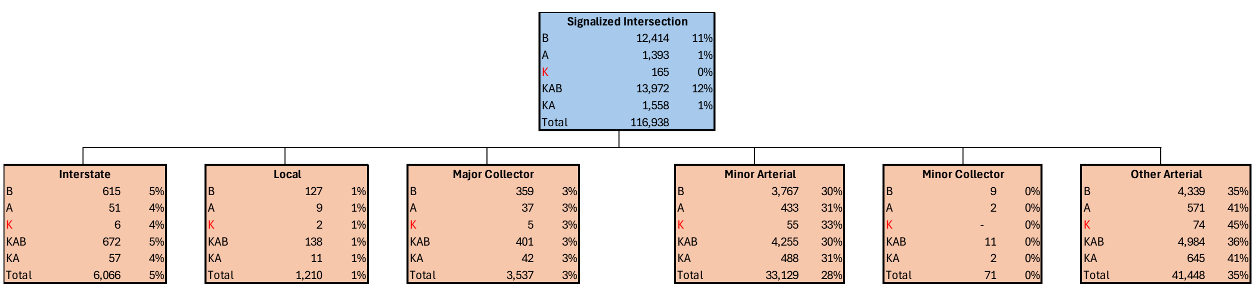


Figure C.23 CT Crash View: Functional Classification

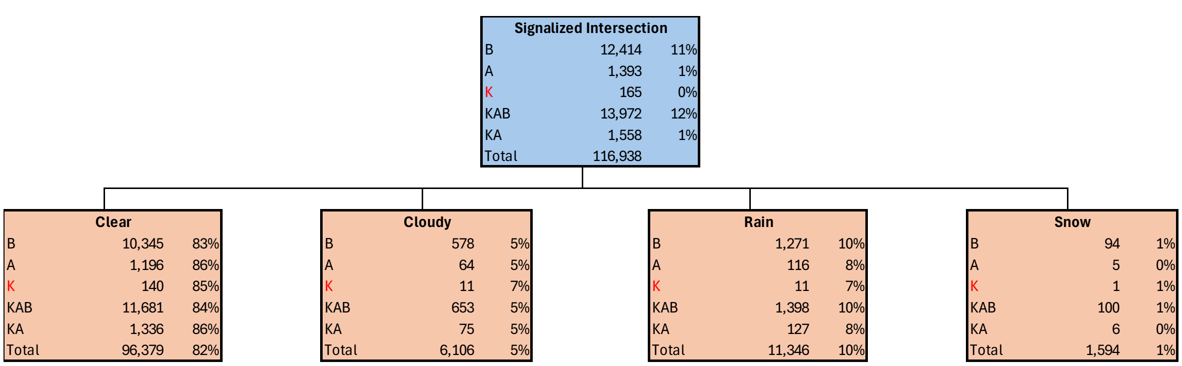


Figure C.24 CT Crash View: Weather Condition

Signalized Intersection

B	12,414	11%
A	1,393	1%
K	165	0%
KAB	13,972	12%
KA	1,558	1%
Total	116,938	

Light

B	10,345	83%
A	1,196	86%
K	140	85%
KAB	11,681	84%
KA	1,336	86%
Total	96,379	82%

Dark-Lighted

B	1,271	10%
A	116	8%
K	11	7%
KAB	1,398	10%
KA	127	8%
Total	11,346	10%

Dark

B	2	0%
A	1	0%
K	-	0%
KAB	3	0%
KA	1	0%
Total	61	0%

Figure C.25 CT Crash View: Light Condition

Urban/Rural

B	9,367	11%
A	1,122	1%
K	146	0%
KAB	10,635	12%
KA	1,268	1%
Total	86,702	

Urban

B	7,886	84%
A	997	89%
K	131	90%
KAB	9,014	85%
KA	1,128	89%
Total	73,309	85%

Rural

B	1,352	14%
A	110	10%
K	11	8%
KAB	1,473	14%
KA	121	10%
Total	12,301	14%

Figure C.26 CT Crash View: Urban/Rural

Driver

B	11,737	5%
A	1,061	0%
K	91	0%
KAB	12,889	6%
KA	1,152	1%
Total	218,545	

14-24

B	2,047	17%
A	174	16%
K	13	14%
KAB	2,234	17%
KA	187	16%
Total	37,726	17%

25-44

B	4,937	42%
A	469	44%
K	31	34%
KAB	5,437	42%
KA	500	43%
Total	87,987	40%

45-64

B	3,419	29%
A	315	30%
K	24	26%
KAB	3,758	29%
KA	339	29%
Total	66,125	30%

65 +

B	1,334	11%
A	102	10%
K	23	25%
KAB	1,459	11%
KA	125	11%
Total	26,689	12%

Figure C.27 CT Person View: Driver Age Group

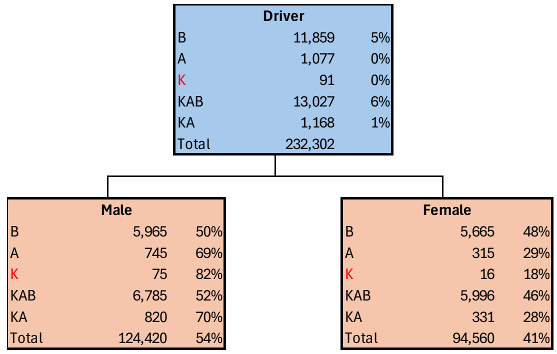
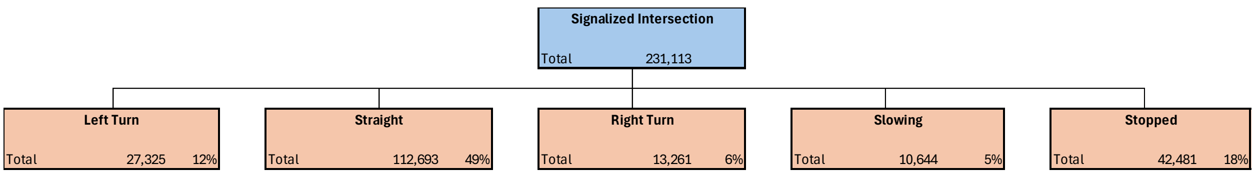


Figure C.28 CT Person View: Driver Sex



Crashes could not be filtered by severity level
Only total crashes are analyzed

Figure C.29 CT Vehicle View: Movement

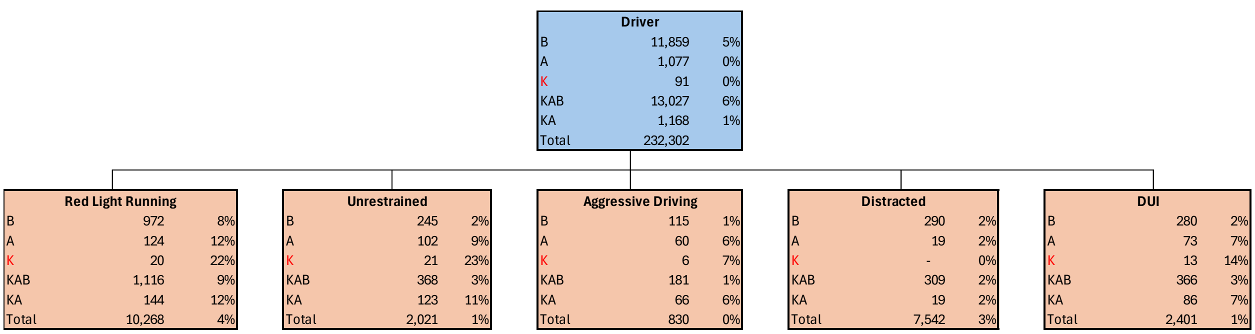


Figure C.30 CT Person View: Contributing Factor

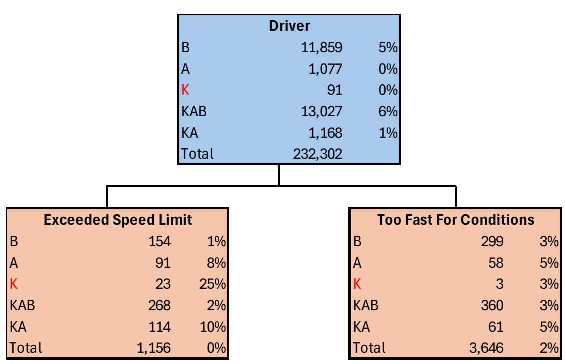


Figure C.31 CT Person View: Speeding

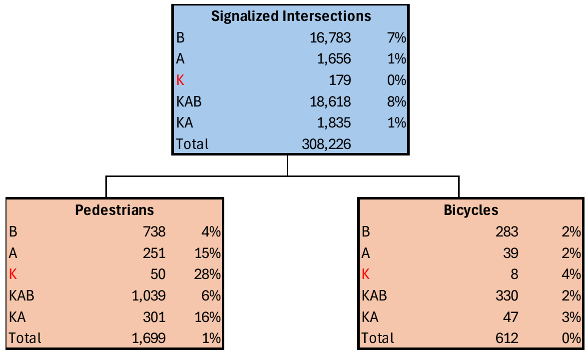


Figure C.32 CT Person View: VRU

C.5 Georgia

This section summarizes crash trees for Georgia. Table C.4 provides a summary of the crash trees provided by the crash attributes observed as seen in this appendix. The table outlines 10 figures with crash trees by manner of collision, functional classification, weather condition, light condition, urban/rural, driver age, driver sex, contributing factors, and VRU.

Table C.4 Georgia Crash Tree Summary

Georgia	
Crash Attribute	**Figure**
Manner of Collision	C.33
Functional Classification	C.34
Weather Condition	C.35
Light Condition	C.36
Urban/Rural	C.37
Driver Age	C.38
Driver Sex	C.39
Contributing Factors 1	C.40
Contributing Factors 2	C.41
VRU	C.42

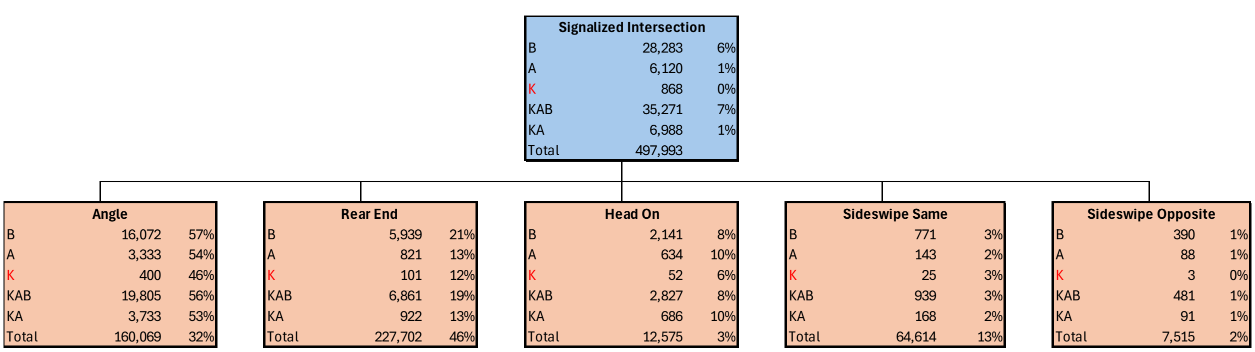


Figure C.33 GA Crash View: Manner of Collision

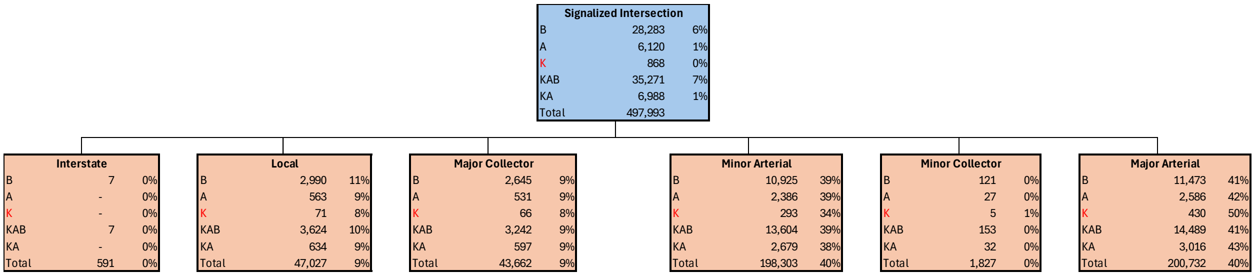


Figure C.34 GA Crash View: Functional Classification

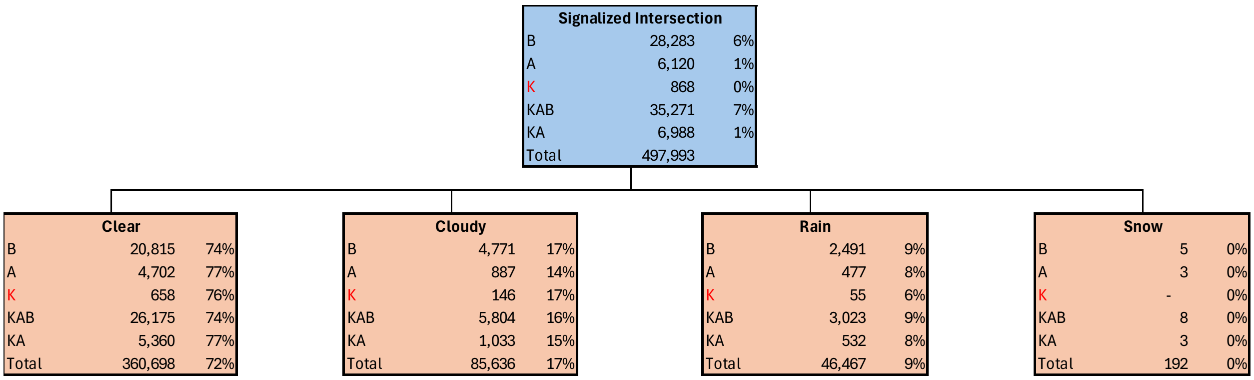


Figure C.35 GA Crash View: Weather Condition

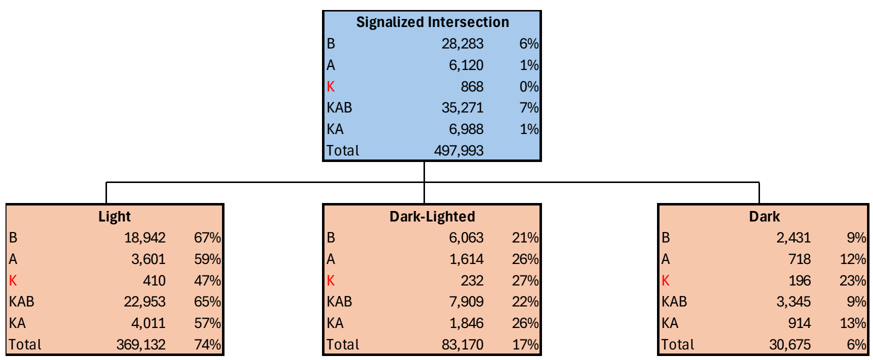


Figure C.36 GA Crash View: Light Condition

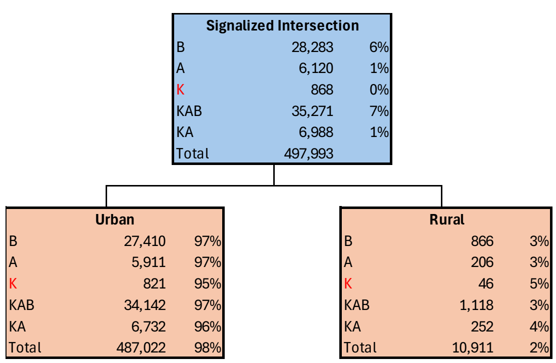


Figure C.37 GA Crash View: Urban/Rural

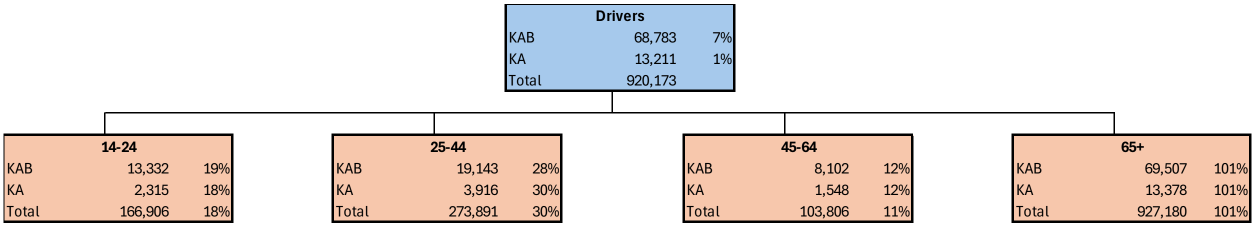


Figure C.38 GA Person View: Driver Age Group

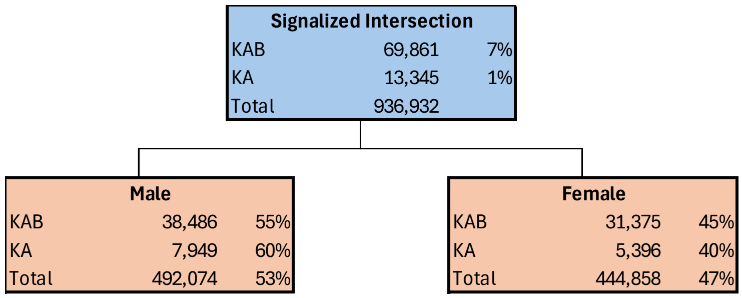


Figure C.39 GA Person View: Driver Sex

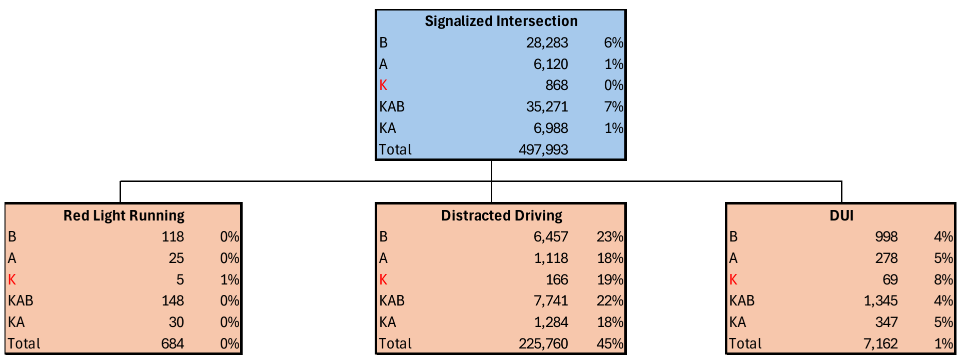


Figure C.40 GA Crash View: Contributing Factors

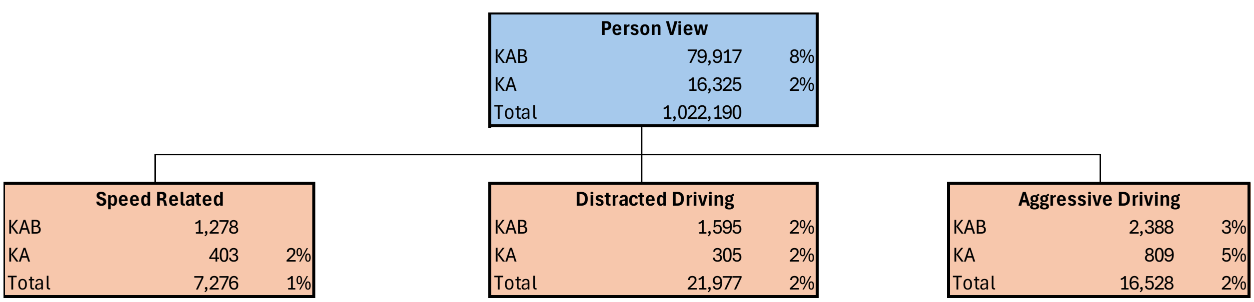


Figure C.41 GA Crash Person View: Contributing Factors

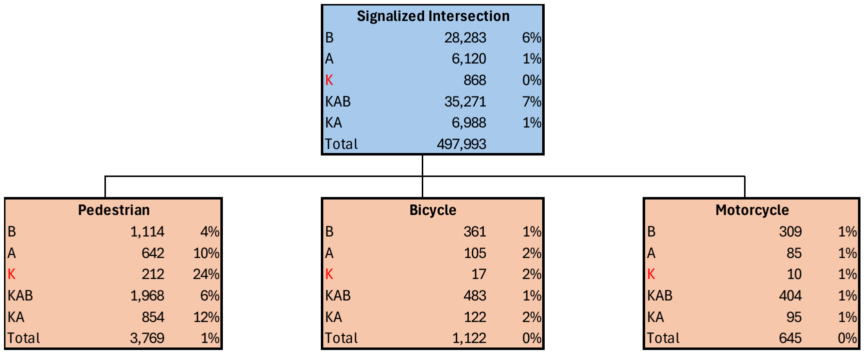


Figure C.42 GA Crash View: VRU

C.6 Idaho

This section summarizes crash trees for Idaho. Table C.5 provides a summary of the crash trees provided by the crash attributes observed as seen in this appendix. The table outlines 12 figures with crash trees by manner of collision, functional classification, weather condition, light condition, urban/rural, driver age, driver sex, vehicle movement, contributing factors, unrestrained, and VRU.

Table C.5 Idaho Crash Tree Summary

Idaho	
Crash Attribute	**Figure**
Manner of Collision	C.43
Functional Classification	C.44
Weather Condition	C.45
Light Condition	C.46
Urban/Rural	C.47
Driver Age	C.48
Driver Sex	C.49
Movement	C.50
Contributing Factors	C.51
Unrestrained	C.52
VRU by Vehicle Type	C.53
VRU by Most Harmful Event	C.54

Driver		
B	6,257	13%
A	1,261	3%
K	106	0%
KAB	7,624	16%
KA	1,367	3%
Total	47,191	

Angle		
B	2,941	47%
A	662	52%
K	45	42%
KAB	3,648	48%
KA	707	52%
Total	17,754	38%

Rear End		
B	2,304	37%
A	265	21%
K	11	10%
KAB	2,580	34%
KA	276	20%
Total	21,748	46%

Head On		
B	60	1%
A	26	2%
K	3	3%
KAB	89	1%
KA	29	2%
Total	235	0%

Sidswipe Same Direction		
B	136	2%
A	31	2%
K	4	4%
KAB	171	2%
KA	35	3%
Total	3,539	7%

Sideswipe Opposite Direction		
B	56	1%
A	28	2%
K	-	0%
KAB	84	1%
KA	28	2%
Total	414	1%

Figure C.43 ID Vehicle View: Manner of Collision

Signalized Intersections		
B	2,845	13%
A	576	3%
K	49	0%
KAB	3,470	16%
KA	625	3%
Total	22,342	

Principal Arterial		
B	1,578	55%
A	311	54%
K	32	65%
KAB	1,921	55%
KA	343	55%
Total	12,456	56%

Minor Arterial		
B	868	31%
A	178	31%
K	9	18%
KAB	1,055	30%
KA	187	30%
Total	6,817	31%

Minor Collector		
B	1	0%
A	-	0%
K	-	0%
KAB	1	0%
KA	-	0%
Total	17	0%

Major Collector		
B	313	11%
A	65	11%
K	7	14%
KAB	385	11%
KA	72	12%
Total	2,230	10%

Local		
B	23	1%
A	6	1%
K	-	0%
KAB	29	1%
KA	6	1%
Total	270	1%

Interstate		
B	62	2%
A	16	3%
K	1	2%
KAB	79	2%
KA	17	3%
Total	551	2%

Figure C.44 ID Crash View: Functional Classification

Signalized Intersections		
B	2,845	13%
A	576	3%
K	49	0%
KAB	3,470	16%
KA	625	3%
Total	22,342	

Clear		
B	2,210	78%
A	456	79%
K	37	76%
KAB	2,703	78%
KA	493	79%
Total	16,885	76%

Cloudy		
B	430	15%
A	83	14%
K	9	18%
KAB	522	15%
KA	92	15%
Total	3,570	16%

Rain		
B	114	4%
A	20	3%
K	3	6%
KAB	137	4%
KA	23	4%
Total	903	4%

Snow		
B	51	2%
A	10	2%
K	-	0%
KAB	61	2%
KA	10	2%
Total	646	3%

Figure C.45 ID Crash View: Weather Condition

Signalized Intersections

B	2,845	13%
A	576	3%
K	49	0%
KAB	3,470	16%
KA	625	3%
Total	22,342	

Daylight

B	2,075	73%
A	365	63%
K	26	53%
KAB	2,466	71%
KA	391	63%
Total	16,977	76%

Dark Lighted

B	593	21%
A	159	28%
K	22	45%
KAB	774	22%
KA	181	29%
Total	4,110	18%

Dark

B	52	2%
A	12	2%
K	1	2%
KAB	65	2%
KA	13	2%
Total	362	2%

Figure C.46 ID Crash View: Light Condition

Signalized Intersections

B	2,845	13%
A	576	3%
K	49	0%
KAB	3,470	16%
KA	625	3%
Total	22,342	

Urban

B	2,707	95%
A	546	95%
K	42	86%
KAB	3,295	95%
KA	588	94%
Total	21,275	95%

Rural

B	138	5%
A	30	5%
K	7	14%
KAB	175	5%
KA	37	6%
Total	1,067	5%

Figure C.47 ID Crash View: Urban/Rural

Driver

B	6,131	13%
A	1,210	3%
K	105	0%
KAB	7,446	16%
KA	1,315	3%
Total	46,023	

14-24

B	1,504	25%
A	253	21%
K	21	20%
KAB	1,778	24%
KA	274	21%
Total	11,944	26%

25-44

B	2,285	37%
A	466	39%
K	29	28%
KAB	2,780	37%
KA	495	38%
Total	17,209	37%

45-64

B	1,502	24%
A	344	28%
K	30	29%
KAB	1,876	25%
KA	374	28%
Total	11,112	24%

65 +

B	819	13%
A	144	12%
K	22	21%
KAB	985	13%
KA	166	13%
Total	5,728	12%

Figure C.48 ID Person View: Driver Age Group

	Driver	
B	6,208	13%
A	1,241	3%
K	105	0%
KAB	7,554	16%
KA	1,346	3%
Total	46,812	

	Male			Female	
B	3,360	54%	B	2,814	45%
A	732	59%	A	494	40%
K	78	74%	K	27	26%
KAB	4,170	55%	KAB	3,335	44%
KA	810	60%	KA	521	39%
Total	25,474	54%	Total	20,964	45%

Figure C.49 ID Person View: Driver Sex

	Driver	
B	6,257	13%
A	1,261	3%
K	106	0%
KAB	7,624	16%
KA	1,367	3%
Total	47,191	

	Slowing in Traffic		Straight		Turning Left		Turning Right		Stopped in Traffic	
B	203	3%	3,015	48%	1,048	17%	213	3%	1,234	20%
A	23	2%	623	49%	264	21%	32	3%	177	14%
K	1	1%	56	53%	16	15%	5	5%	8	8%
KAB	227	3%	3,694	48%	1,328	17%	250	3%	1,419	19%
KA	24	2%	679	50%	280	20%	37	3%	185	14%
Total	2,029	4%	21,843	46%	6,852	15%	2,160	5%	10,065	21%

Figure C.50 ID Vehicle View: Movement

	Driver	
B	6,257	13%
A	1,261	3%
K	106	0%
KAB	7,624	16%
KA	1,367	3%
Total	47,191	

	Red Light Running		Speeding		Distracted		Drowsy		DUI	
B	745	12%	27	0%	221	4%	37	1%	199	3%
A	178	14%	16	1%	30	2%	8	1%	94	7%
K	18	17%	8	8%	-	0%	-	0%	23	22%
KAB	941	12%	51	1%	251	3%	45	1%	316	4%
KA	196	14%	24	2%	30	2%	8	1%	117	9%
Total	4,333	9%	107	0%	1,526	3%	177	0%	972	2%

Figure C.51 ID Vehicle View: Contributing Factor

	Driver	
B	6,208	13%
A	1,241	3%
K	105	0%
KAB	7,554	16%
KA	1,346	3%
Total	46,812	

	Unrestrained	
B	215	3%
A	86	7%
K	6	6%
KAB	307	4%
KA	92	7%
Total	1,088	2%

Figure C.52 ID Person View: Unrestrained

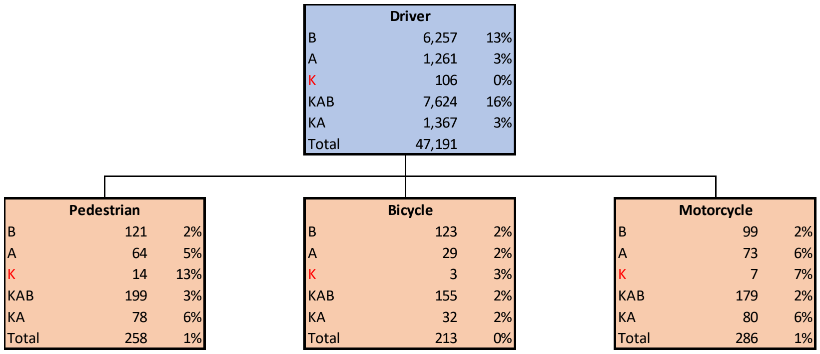


Figure C.53 ID Vehicle View: VRU by Vehicle Type

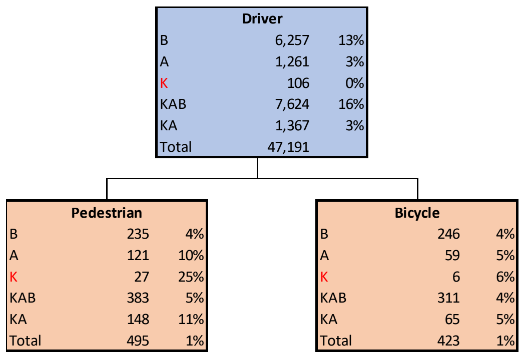


Figure C.54 ID Vehicle View: VRU by Most Harmful Event

C.7 Illinois

This section summarizes crash trees for Illinois. Table C.6 provides a summary of the crash trees provided by the crash attributes observed as seen in this appendix. The table outlines 11 figures with crash trees by manner of collision, functional classification, weather condition, light condition, urban/rural, driver age, driver sex, vehicle movement, DUI, contributing factors, and VRU.

Table C.6 Illinois Crash Tree Summary

Illinois	
Crash Attribute	**Figure**
Manner of Collision	C.55
Functional Classification	C.56
Weather Condition	C.57
Light Condition	C.58
Urban/Rural	C.59
Driver Age	C.60
Driver Sex	C.61
Movement	C.62
DUI	C.63
Contributing Factors	C.64
VRU	C.65

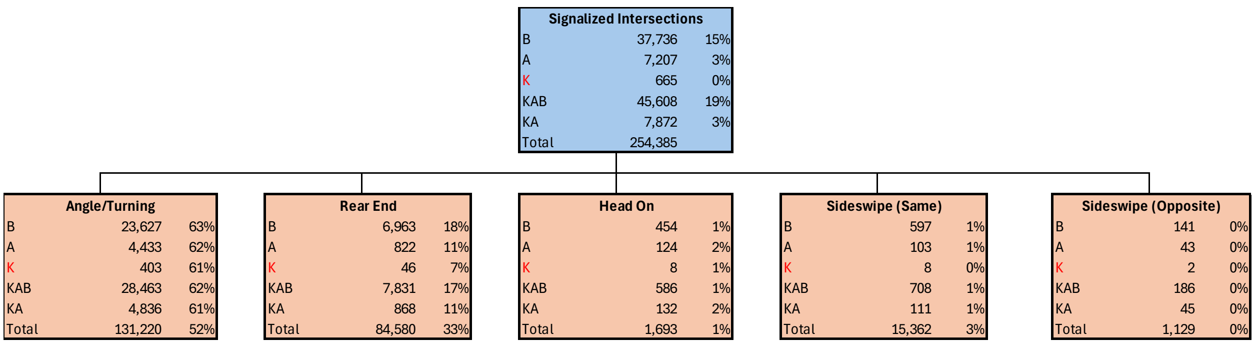


Figure C.55 IL Crash View: Manner of Collision

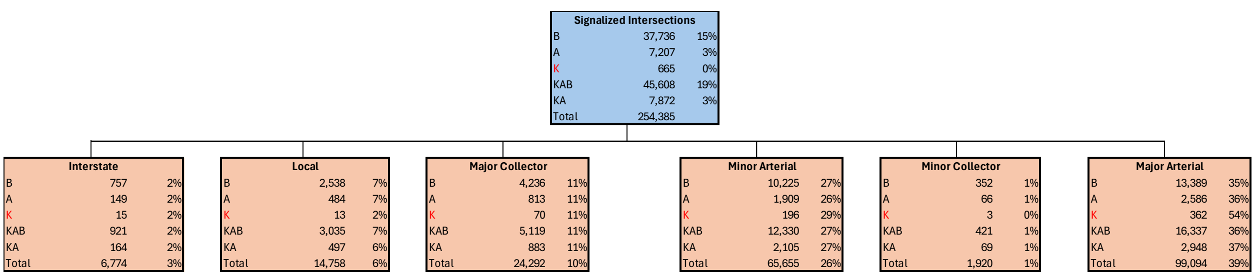


Figure C.56 IL Crash View: Functional Classification

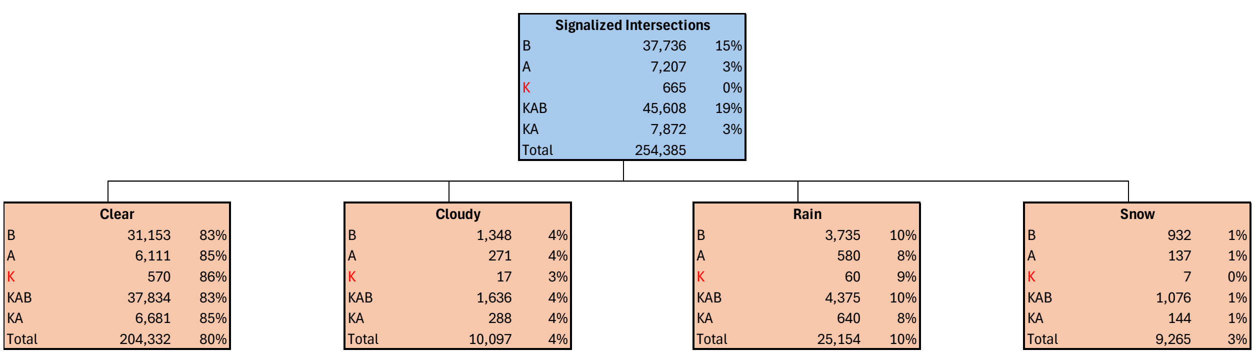


Figure C.57 IL Crash View: Weather Condition

Signalized Intersections		
B	37,736	15%
A	7,207	3%
K	665	0%
KAB	45,608	19%
KA	7,872	3%
Total	254,385	

Daylight		
B	24,933	66%
A	4,406	61%
K	314	47%
KAB	29,653	65%
KA	4,720	60%
Total	176,206	69%

Dark Lighted		
B	9,430	25%
A	2,067	29%
K	274	41%
KAB	11,771	26%
KA	2,341	30%
Total	55,275	22%

Dark		
B	1,677	4%
A	406	6%
K	56	8%
KAB	2,139	5%
KA	462	6%
Total	11,121	4%

Figure C.58 IL Crash View: Light Condition

Signalized Intersections		
B	37,736	15%
A	7,207	3%
K	665	0%
KAB	45,608	19%
KA	7,872	3%
Total	254,385	

Urban		
B	31,497	83%
A	6,011	83%
K	657	99%
KAB	38,165	84%
KA	6,668	85%
Total	212,611	84%

Rural		
B	5,269	14%
A	989	14%
K	8	1%
KAB	6,266	14%
KA	997	13%
Total	35,635	14%

Figure C.59 IL Crash View: Urban/Rural

Drivers		
B	36,264	8%
A	5,576	1%
K	388	0%
KAB	42,228	19%
KA	5,964	3%
Total	471,624	

14-24		
B	7,312	20%
A	976	18%
K	72	19%
KAB	8,360	20%
KA	1,048	18%
Total	98,512	21%

25-44		
B	14,744	41%
A	2,283	41%
K	133	34%
KAB	17,160	41%
KA	2,416	41%
Total	190,053	40%

45-64		
B	9,648	27%
A	1,572	28%
K	92	24%
KAB	11,312	27%
KA	1,664	28%
Total	129,473	27%

65+		
B	5,048	14%
A	843	15%
K	95	24%
KAB	5,986	14%
KA	938	16%
Total	96,511	20%

Figure C.60 IL Person View: Driver Age Group

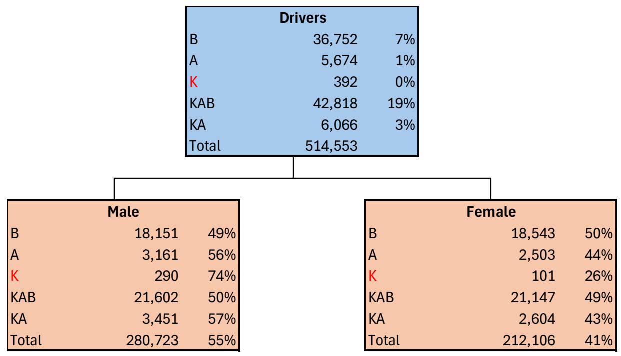
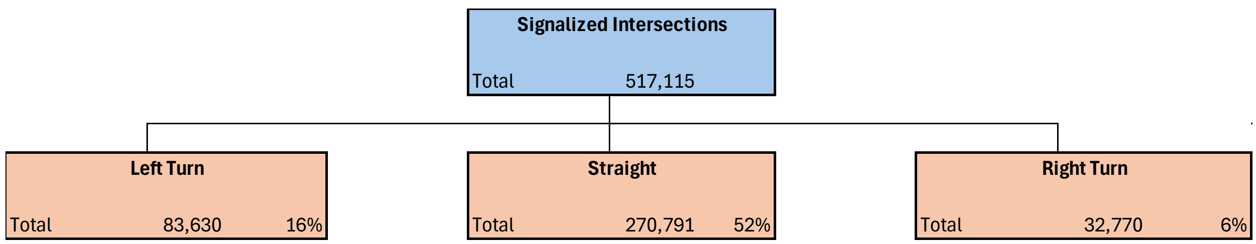


Figure C.61 IL Person View: Driver Sex



Crashes could not be filtered by severity level
Only total crashes are analyzed

Figure C.62 IL Vehicle View: Movement

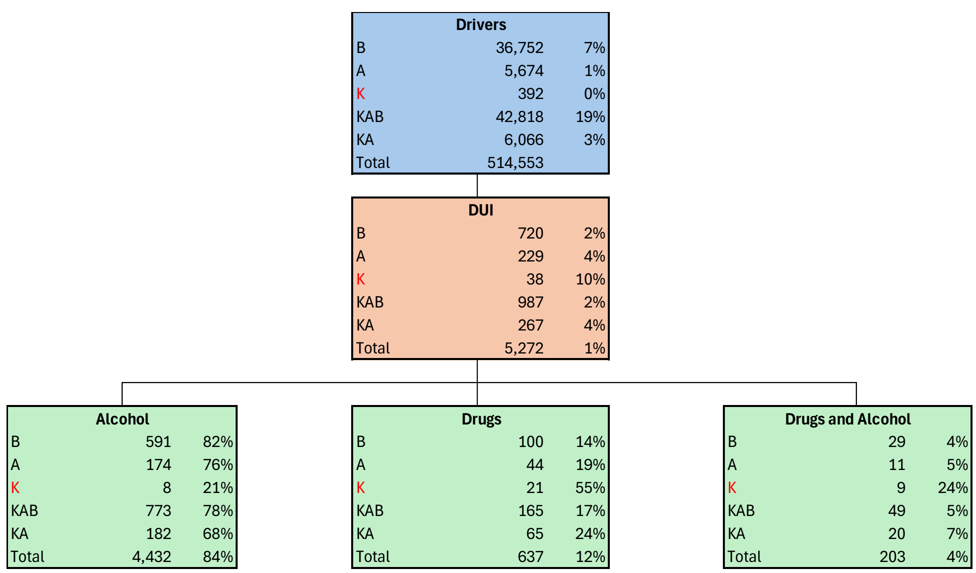


Figure C.63 IL Person View: DUI

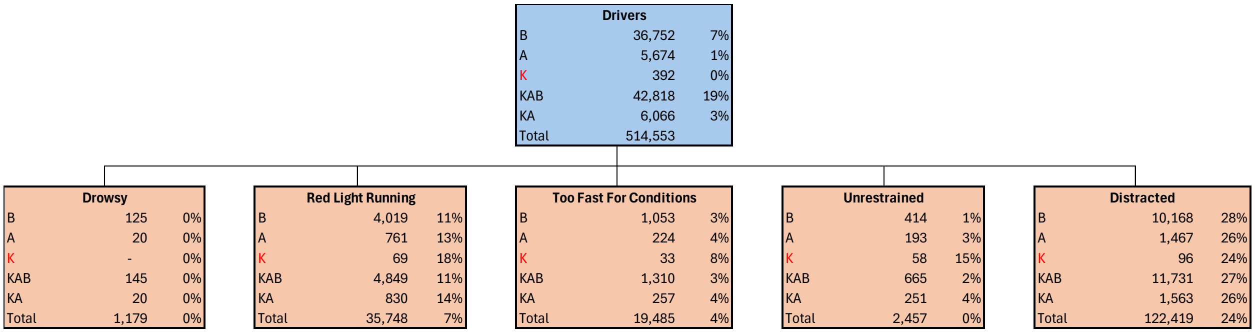
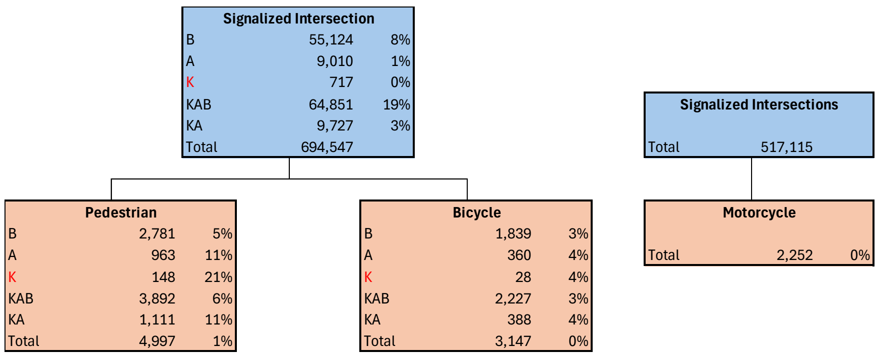


Figure C.64 Person View: Contributing Factors



Pedestrians and bicycles come from person view
Motorcycles come from vehicle view

Figure C.65 IL: VRU

C.8 Maine

This section summarizes crash trees for Maine. Table C.7 provides a summary of the crash trees provided by the crash attributes observed as seen in this appendix. The table outlines nine figures with crash trees by functional classification, weather condition, light condition, urban/rural, driver age, driver sex, vehicle movement, contributing factors, and VRU.

Table C.7 Maine Crash Tree Summary

Maine	
Crash Attribute	**Figure**
Functional Classification	C.66
Weather Condition	C.67
Light Condition	C.68
Urban/Rural	C.69
Driver Age	C.70
Driver Sex	C.71
Movement	C.72
Contributing Factors	C.73
VRU	C.74

Signalized Intersections		
B	1,150	6%
A	167	1%
K	21	0%
KAB	1,338	7%
KA	188	1%
Total	18,286	

Principal Arterial		
B	456	40%
A	62	37%
K	9	43%
KAB	527	39%
KA	71	38%
Total	7,505	41%

Minor Arterial		
B	451	39%
A	76	46%
K	7	33%
KAB	534	40%
KA	83	44%
Total	7,604	42%

Minor Collector		
B	5	0%
A	1	1%
K	-	0%
KAB	6	0%
KA	1	1%
Total	64	0%

Major Collector		
B	143	12%
A	21	13%
K	5	24%
KAB	169	13%
KA	26	14%
Total	1,823	10%

Local		
B	7	1%
A	-	0%
K	-	0%
KAB	7	1%
KA	-	0%
Total	51	0%

Interstate		
B	24	2%
A	3	2%
K	-	0%
KAB	27	2%
KA	3	2%
Total	380	2%

Figure C.66 ME Crash View: Functional Classification

Signalized Intersections		
B	1,150	6%
A	167	1%
K	21	0%
KAB	1,338	7%
KA	188	1%
Total	18,286	

Clear		
B	873	76%
A	131	78%
K	13	62%
KAB	1,017	76%
KA	144	77%
Total	13,586	74%

Cloudy		
B	150	13%
A	13	8%
K	4	19%
KAB	167	12%
KA	17	9%
Total	2,229	12%

Rain		
B	88	8%
A	19	11%
K	4	19%
KAB	111	8%
KA	23	12%
Total	1,457	8%

Snow		
B	26	2%
A	1	1%
K	-	0%
KAB	27	2%
KA	1	1%
Total	792	4%

Figure C.67 ME Crash View: Weather Condition

Signalized Intersections		
B	1,150	6%
A	167	1%
K	21	0%
KAB	1,338	7%
KA	188	1%
Total	18,286	

Daylight		
B	822	71%
A	120	72%
K	12	57%
KAB	954	71%
KA	132	70%
Total	14,260	78%

Dark-Lighted		
B	250	22%
A	35	21%
K	8	38%
KAB	293	22%
KA	43	23%
Total	3,100	17%

Dark		
B	22	2%
A	4	2%
K	-	0%
KAB	26	2%
KA	4	2%
Total	269	1%

Figure C.68 ME Crash View: Light Condition

Signalized Intersection

B	1,150	6%
A	167	1%
K	21	0%
KAB	1,338	7%
KA	188	1%
Total	18,286	

Urban

B	981	85%
A	146	87%
K	18	86%
KAB	1,145	86%
KA	164	87%
Total	15,937	87%

Rural

B	169	15%
A	21	13%
K	3	14%
KAB	193	14%
KA	24	13%
Total	2,349	13%

Figure C.69 ME Crash View: Urban/Rural

Driver

B	979	3%
A	115	0%
K	9	0%
KAB	1,103	3%
KA	124	0%
Total	35,781	

14-24

B	171	17%
A	12	10%
K	-	0%
KAB	183	17%
KA	12	10%
Total	6,480	18%

25-44

B	339	35%
A	32	28%
K	4	44%
KAB	375	34%
KA	36	29%
Total	12,898	36%

45-64

B	291	30%
A	45	39%
K	3	33%
KAB	339	31%
KA	48	39%
Total	10,483	29%

65 +

B	177	18%
A	26	23%
K	2	22%
KAB	205	19%
KA	28	23%
Total	5,877	16%

Figure C.70 ME Person View: Driver Age Group

Drivers

B	979	3%
A	115	0%
K	9	0%
KAB	1,103	3%
KA	124	0%
Total	35,781	

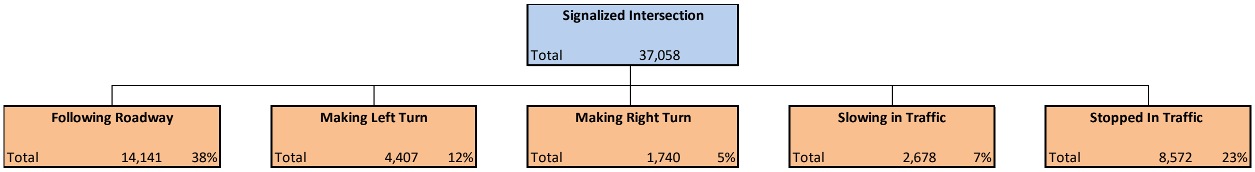
Male

B	465	47%
A	75	65%
K	9	100%
KAB	549	50%
KA	84	68%
Total	19,439	54%

Female

B	514	53%
A	40	35%
K	-	0%
KAB	554	50%
KA	40	32%
Total	16,329	46%

Figure C.71 ME Person View: Driver Sex



Crashes could not be filtered by severity level
Only total crashes are analyzed

Figure C.72 ME Vehicle View: Movement

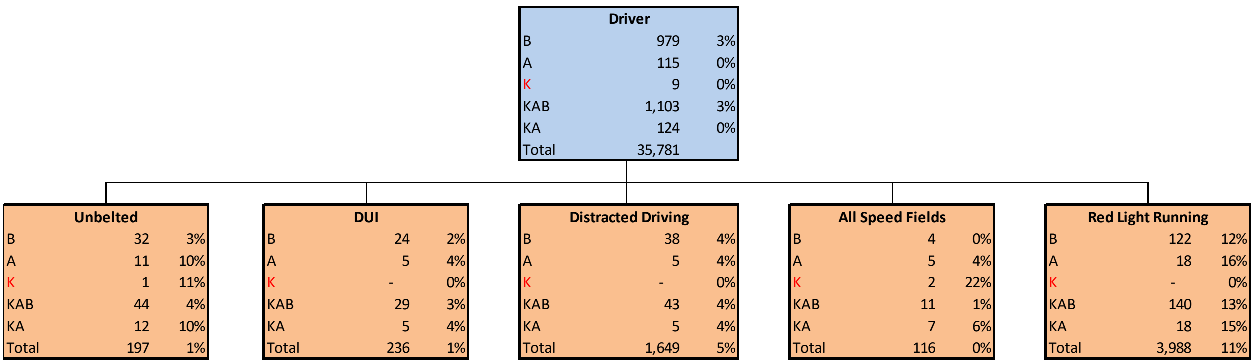
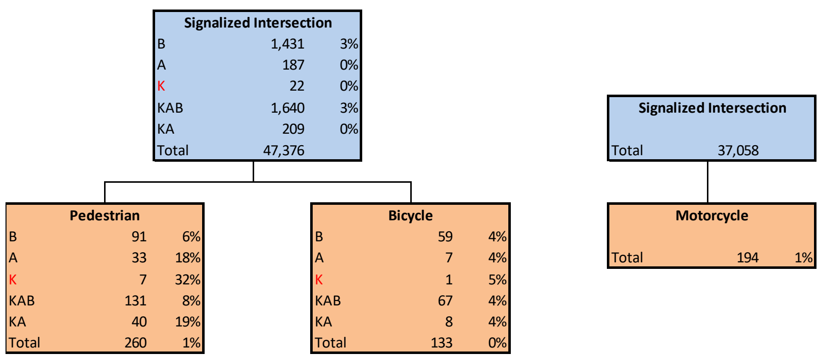


Figure C.73 ME Person View: Contributing Factors



Pedestrians and bicycles come from person view
Motorcycles come from vehicle view

Figure C.74 ME: VRU

C.9 Nebraska

This section summarizes crash trees for Nebraska. Table C.8 provides a summary of the crash trees provided by the crash attributes observed as seen in this appendix. The table outlines nine figures with crash trees by manner of collision, weather condition, light condition, driver age, driver sex, vehicle movement, speeding, contributing factors, and motorcycle related.

Table C.8 Nebraska Crash Tree Summary

Nebraska	
Crash Attribute	**Figure**
Manner of Collision	C.75
Weather Condition	C.76
Light Condition	C.77
Driver Age	C.78
Driver Sex	C.79
Movement	C.80
Speeding	C.81
Contributing Factors	C.82
VRU	C.83

Signalized Intersections

B	4,246	16%
A	664	3%
K	88	0%
KAB	4,998	19%
KA	752	3%
Total	26,327	

Angle

B	2,881	68%
A	440	66%
K	57	65%
KAB	3,378	68%
KA	497	66%
Total	15,023	57%

Rear End

B	549	13%
A	53	8%
K	5	6%
KAB	607	12%
KA	58	8%
Total	6,721	26%

Head On

B	237	6%
A	27	4%
K	2	2%
KAB	266	5%
KA	29	4%
Total	785	3%

Sideswipe (Same)

B	25	1%
A	6	1%
K	-	0%
KAB	31	1%
KA	6	1%
Total	727	3%

Sideswipe (Opposite)

B	1	0%
A	-	0%
K	-	0%
KAB	1	0%
KA	-	0%
Total	40	0%

Figure C.75 NE Crash View: Manner of Collision

Signalized Intersections

B	4,246	16%
A	664	3%
K	88	0%
KAB	4,998	19%
KA	752	3%
Total	26,327	

Clear

B	3,276	77%
A	509	77%
K	70	80%
KAB	3,855	77%
KA	579	77%
Total	19,658	75%

Cloudy

B	675	16%
A	107	16%
K	13	15%
KAB	795	16%
KA	120	16%
Total	3,917	15%

Rain

B	163	4%
A	36	5%
K	2	2%
KAB	201	4%
KA	38	5%
Total	1,208	5%

Snow

B	34	1%
A	4	1%
K	-	0%
KAB	38	1%
KA	4	1%
Total	397	2%

Figure C.76 NE Crash View: Weather Condition

Signalized Intersections

B	4,246	16%
A	664	3%
K	88	0%
KAB	4,998	19%
KA	752	3%
Total	26,327	

Daylight

B	2,925	69%
A	382	58%
K	43	49%
KAB	3,350	67%
KA	425	57%
Total	18,064	69%

Dark Lighted

B	992	23%
A	213	32%
K	37	42%
KAB	1,242	25%
KA	250	33%
Total	5,995	23%

Dark

B	26	1%
A	10	2%
K	-	0%
KAB	36	1%
KA	10	1%
Total	146	1%

Figure C.77 NE Crash View: Light Condition

Driver

B	4,467	8%
A	563	1%
K	67	0%
KAB	5,097	9%
KA	630	1%
Total	54,861	

14-24

B	1,140	26%
A	128	23%
K	19	28%
KAB	1,287	25%
KA	147	23%
Total	14,491	26%

25-44

B	1,604	36%
A	195	35%
K	19	28%
KAB	1,818	36%
KA	214	34%
Total	20,822	38%

45-64

B	1,042	23%
A	159	28%
K	14	21%
KAB	1,215	24%
KA	173	27%
Total	12,896	24%

65+

B	681	15%
A	81	14%
K	15	22%
KAB	777	15%
KA	96	15%
Total	6,642	12%

Figure C.78 NE Person View: Driver Age Group

Drivers with Know Sex

B	3,683	8%
A	502	1%
K	60	0%
KAB	4,245	9%
KA	562	1%
Total	48,821	

Male

B	1,756	48%
A	334	67%
K	46	77%
KAB	2,136	50%
KA	380	68%
Total	27,227	56%

Female

B	1,927	52%
A	168	33%
K	14	23%
KAB	2,109	50%
KA	182	32%
Total	21,594	44%

Figure C.79 NE Person View: Driver Sex

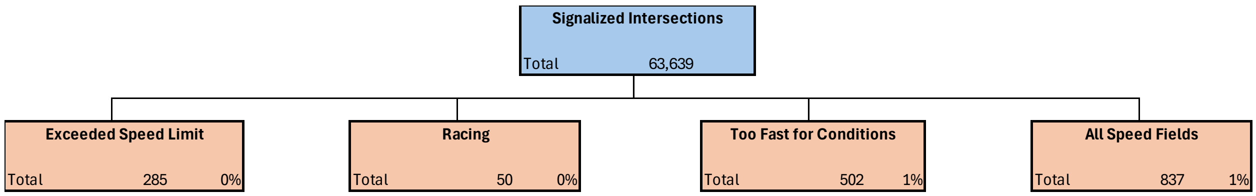
Signalized Intersection

Total	64,705	

	Slowing in Traffic		Straight		Turning Left		Turning Right		Stopped in Traffic	
Total	4,130	6%	33,113	51%	9,590	15%	2,940	5%	7,678	12%

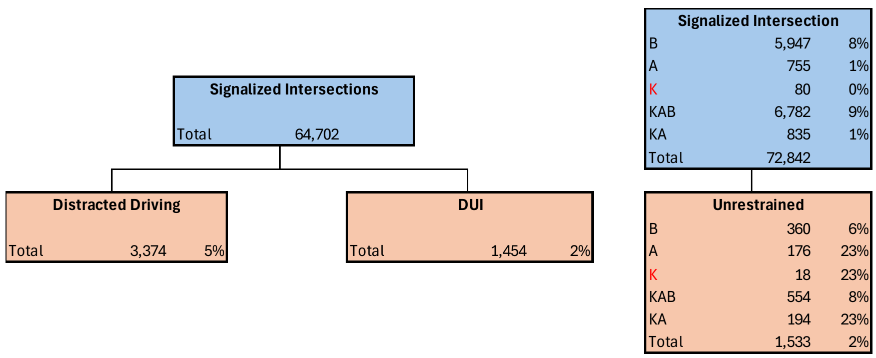
Crashes could not be filtered by severity level
Only total crashes are analyzed

Figure C.80 NE Vehicle View: Movement



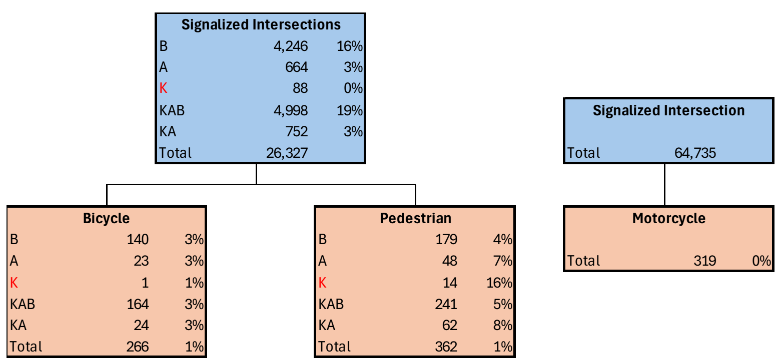
Crashes could not be filtered by severity level
Only total crashes are analyzed

Figure C.81 NE Vehicle View: Speeding



Distracted driving and DUI come from vehicle view
Unrestrained comes from person view

Figure C.82 NE Contributing Factors



Pedestrians and bicycles come from crash view
Motorcycles come from vehicle view

Figure C.83 NE Vehicle View: Motorcycle

C.10 Wyoming

This section summarizes crash trees for Wyoming. Table C.9 provides a summary of the crash trees provided by the crash attributes observed as seen in this appendix. The table outlines nine figures with crash trees by manner of collision, weather condition, light condition, driver age, driver sex, vehicle movement, contributing factors, speeding, and VRU.

Table C.9 Wyoming Crash Tree Summary

Wyoming	
Crash Attribute	**Figure**
Manner of Collision	C.84
Weather Condition	C.85
Light Condition	C.86
Driver Age	C.87
Driver Sex	C.88
Movement	C.89
Contributing Factors	C.90
Speeding	C.91
VRU	C.92

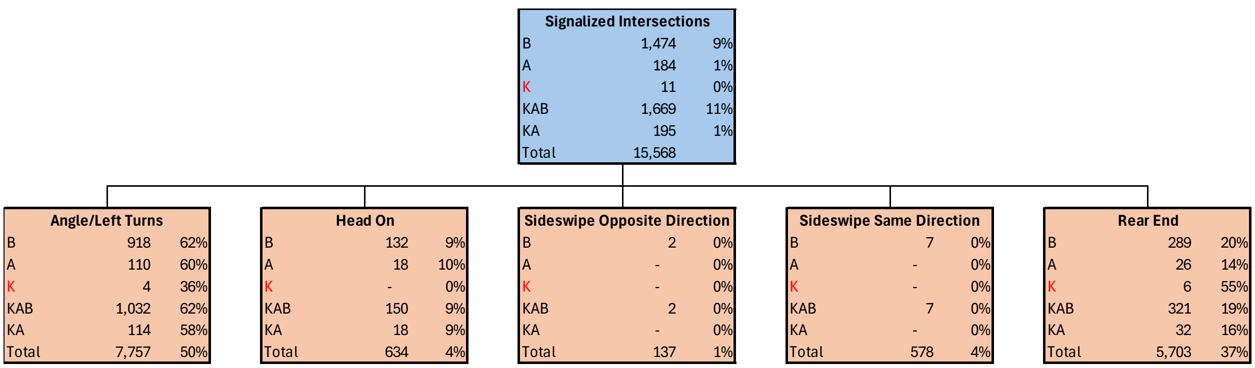


Figure C.84 WY Crash View: Manner of Collision

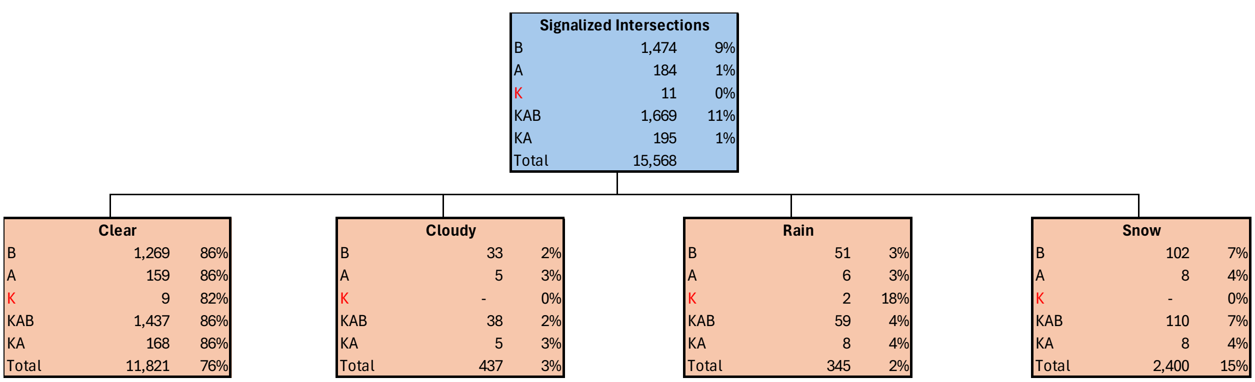


Figure C.85 WY Crash View: Weather Condition

	Signalized Intersections		Daylight		Dark-Lighted		Dark	
B	1,474	9%	1,097	74%	269	18%	21	1%
A	184	1%	114	62%	52	28%	3	2%
K	11	0%	8	73%	1	9%	-	0%
KAB	1,669	11%	1,219	73%	322	19%	24	1%
KA	195	1%	122	63%	53	27%	3	2%
Total	15,568		12,186	78%	2,487	16%	208	1%

Figure C.86 WY Crash View: Light Condition

	Drivers		14-24		25-44		45-64		65 +	
B	1,816	5%	422	23%	767	42%	351	19%	276	15%
A	306	1%	35	11%	185	60%	64	21%	22	7%
K	12	0%	-	0%	4	33%	-	0%	8	67%
KAB	2,134	6%	457	21%	956	45%	415	19%	306	14%
KA	318	1%	35	11%	189	59%	64	20%	30	9%
Total	36,382		8,858	24%	13,685	38%	8,551	24%	4,407	12%

Figure C.87 WY Person View: Driver Age Group

	Drivers		Male		Female	
B	1,816	5%	973	54%	843	46%
A	306	1%	178	58%	128	42%
K	12	0%	12	100%	-	0%
KAB	2,134	6%	1,163	54%	971	46%
KA	318	1%	190	60%	128	40%
Total	36,382		21,167	58%	14,354	39%

Figure C.88 WY Person View: Driver Sex

	Signalized Intersections		Straight Ahead		Turnign Left		Turning Right		Slowing in Traffic		Stopped in Traffic	
Total	14,524		7,731	53%	2,261	16%	807	6%	568	4%	2,261	16%

Crashes could not be filtered by severity level
Only total crashes are analyzed

Figure C.89 WY Vehicle View: Movements

Drivers

B	1,816	5%
A	306	1%
K	12	0%
KAB	2,134	6%
KA	318	1%
Total	36,382	

Distracted Driving

B	158	9%
A	4	1%
K	-	0%
KAB	162	8%
KA	4	1%
Total	2,203	6%

Aggresive Driving

B	128	7%
A	53	17%
K	-	0%
KAB	181	8%
KA	53	17%
Total	1,204	3%

Unrestrained

B	247	14%
A	104	34%
K	6	50%
KAB	357	17%
KA	110	35%
Total	1,349	4%

Red Light Running

B	353	19%
A	30	10%
K	2	17%
KAB	385	18%
KA	32	10%
Total	3,712	10%

DUI

B	312	17%
A	141	46%
K	-	0%
KAB	453	21%
KA	141	44%
Total	2,575	7%

Figure C.90 WY Person View: Contributing Factor

Drivers

B	1,816	5%
A	306	1%
K	12	0%
KAB	2,134	6%
KA	318	1%
Total	36,382	

Too Fast For Conditions

B	26	1%
A	4	1%
K	-	0%
KAB	30	1%
KA	4	1%
Total	2,102	6%

All Speed Fields

B	48	3%
A	41	13%
K	-	0%
KAB	89	4%
KA	41	13%
Total	2,505	7%

Speeding

B	22	1%
A	37	12%
K	-	0%
KAB	59	3%
KA	37	12%
Total	403	1%

Figure C.91 WY Person View: Speeding

Signalized Intersections

B	1,474
A	184
K	11
KAB	1,669
KA	195
Total	15,568

Pedestrian

B	59	4%
A	16	9%
K	1	9%
KAB	76	5%
KA	17	9%
Total	111	1%

Bicycle

B	27	2%
A	3	2%
K	0	0%
KAB	30	2%
KA	3	2%
Total	47	0%

Vehicle

B	1,350	92%
A	154	84%
K	10	91%
KAB	1,514	91%
KA	164	84%
Total	14,966	96%

Figure C.92 WY Crash View: VRU

APPENDIX D: COMPARISON TABLE RESULTS

D.1 Overview

Comparison tables were created for a variety of factors with Utah as the baseline. The states compared to Utah include Arizona, Wyoming, Maine, Idaho, Nebraska, Georgia, Illinois, and Connecticut. Data were extracted from three types of data sheets: crash view, person view, and vehicle view. Each view presents different information representing a crash, a person involved in a crash, or a vehicle involved in a crash, respectively.

The column "AVG. (w/o UT)" included in each comparison table is the average percentage of every state but Utah. The percent change "**%Δ**" column was calculated by subtracting the average excluding Utah from Utah's percentage and dividing that result by the average excluding Utah.

The following sections include a series of comparison tables that use the data from the crash trees for each attribute so data can be compared between the states. Comparison tables were made for KABCO, KAB and KA severity levels. Not all the states found in the KABCO comparison tables can be found in the KAB and KA comparison tables because some states did not include crash severity with their vehicle view data for some crash attributes.

D.2 KABCO Severity Level

This section displays the KABCO severity comparison tables by crash attribute. Table D.1 displays the crash attributes described for each of the 11 comparison tables included in this section. Crash attributes observed include manner of collision, crash severity, weather condition, functional classification, light condition, urban/rural, driver age, movement, driver sex, contributing factors, and VRU.

Table D.1 KABCO Comparison Table List

KABCO Crashes Crash Attribute	Table
Manner of Collision	D.2
Crash Severity	D.3
Weather Condition	D.4
Functional Classification	D.5
Light Condition	D.6
Urban/Rural	D.7
Driver Age	D.8
Movement	D.9
Driver Sex	D.10
Contributing Factors	D.11
VRU	D.12

Table D.2 KABCO Comparison Table: Manner of Collision

Manner of Collision	UT	AZ	WY	ID*	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Angle	43%	42%	50%	41%	57%	32%	52%	27%	43%	>-1%
Front to Rear	39%	37%	37%	45%	26%	46%	33%	47%	39%	<1%
Head On	3%	2%	4%	1%	3%	3%	1%	2%	2%	23%
Sideswipe Same	7%	10%	4%	8%	3%	13%	3%	13%	8%	-4%
Sideswipe Opposite	1%	1%	1%	1%	<1%	2%	<1%	2%	1%	-16%

ID recorded data in vehicle view while the other states recorded data in crash view

Table D.3 KABCO Comparison Table: Crash Severity

Crash Severity	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
K	0.3%	0.5%	0.1%	0.1%	0.2%	0.4%	0.2%	0.3%	0.1%	0.2%	9.8%
A	2.3%	2.3%	1.2%	0.9%	2.6%	3.1%	1.2%	2.8%	1.2%	1.9%	21.7%
B	13.9%	13.5%	9.5%	6.3%	12.7%	19.9%	5.7%	14.8%	10.6%	11.6%	19.3%
C	20.9%	16.4%	12.9%	19.9%	20.3%	13.3%	19.2%	11.7%	15.3%	16.1%	29.5%
O	62.7%	66.0%	76.0%	72.8%	64.2%	60.2%	72.6%	70.4%	72.7%	69.4%	-9.7%

Data are recorded in crash view for all states

Table D.4 KABCO Comparison Table: Weather Condition

Weather Condition	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Clear	74.9%	89.0%	75.9%	74.3%	75.6%	74.7%	72.4%	80.3%	82.4%	78.1%	-4.1%
Cloudy	15.5%	7.3%	2.8%	12.2%	16.0%	14.9%	17.2%	4.0%	5.2%	9.9%	55.7%
Rain	4.5%	2.8%	2.2%	8.0%	4.0%	4.6%	9.3%	9.9%	9.7%	6.3%	-28.8%
Snow	4.5%	0.2%	15.4%	4.3%	2.9%	1.5%	0.0%	2.8%	1.4%	3.6%	25.8%

Data are recorded in crash view for all states

Table D.5 KABCO Comparison Table: Functional Classification

Functional Classification	UT	ME	ID	GA	IL	CT	AVG. (w/o UT)	%Δ
Interstate	3.2%	2.1%	2.5%	0.1%	2.7%	5.2%	2.5%	27.3%
Local	4.8%	0.3%	1.2%	9.4%	5.8%	1.0%	3.6%	36.3%
Major Collector	11.6%	10.0%	10.0%	8.8%	9.5%	3.0%	8.3%	40.8%
Minor Arterial	24.5%	41.6%	30.5%	39.8%	25.8%	28.3%	33.2%	-26.2%
Minor Collector	1.6%	0.3%	0.1%	0.4%	0.8%	0.1%	0.3%	387.7%
Other Arterial	53.9%	41.0%	55.8%	40.3%	39.0%	35.4%	42.3%	27.4%

Data are recorded in crash view for all states

Table D.6 KABCO Comparison Table: Light Condition

Light Condition	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Daylight	73.7%	70.9%	78.3%	78.0%	76.0%	68.6%	74.1%	69.3%	82.4%	74.7%	-1.3%
Dark-Light	19.7%	23.6%	16.0%	17.0%	18.4%	22.8%	16.7%	21.7%	9.7%	18.2%	8.1%
Dark	2.4%	0.8%	1.3%	1.5%	1.6%	0.6%	6.2%	4.4%	0.1%	2.0%	17.9%

Data are recorded in crash view for all states

Table D.7 KABCO Comparison Table: Urban/Rural

Urban/Rural	UT	ME	ID	GA	IL	CT	AVG. (w/o UT)	%Δ
Urban	98.9%	87.2%	95.2%	97.8%	83.6%	84.6%	89.7%	10.3%
Rural	1.1%	12.8%	4.8%	2.2%	14.0%	14.2%	9.6%	88.8%

Data are recorded in crash view for all states

Table D.8 KABCO Comparison Table: Driver Age Group

Age Group (Driver)	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
<20	13.6%	10.0%	13.1%	7.6%	12.9%	12.5%	7.7%	8.5%	6.2%	9.8%	39.3%
20-29	26.8%	25.4%	21.9%	20.1%	24.0%	24.6%	25.3%	24.2%	22.2%	23.4%	14.2%
30-39	19.7%	19.4%	18.5%	18.5%	18.4%	19.0%	21.0%	20.0%	20.5%	19.4%	1.5%
40-49	15.7%	15.4%	14.9%	15.0%	14.8%	14.6%	16.6%	16.1%	16.5%	15.5%	1.6%
50-59	10.6%	13.1%	11.6%	15.2%	12.0%	11.7%	14.3%	14.0%	15.9%	13.4%	-20.9%
60-69	7.9%	9.4%	10.3%	13.0%	10.0%	9.9%	9.4%	10.2%	11.2%	10.4%	-24.0%
>70	5.6%	7.3%	7.4%	10.6%	8.0%	7.7%	5.8%	7.0%	7.6%	7.7%	-27.2%

Data are recorded in person view for all states

Table D.9 KABCO Comparison Table: Movements

Movements	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Left Turn	17.3%	18.1%	15.6%	11.9%	14.5%	14.8%	12.0%	16%	12%	14.3%	20.8%
Straight	53.4%	49.3%	53.2%	38.2%	46.3%	51.2%	38.0%	52%	49%	47.1%	13.3%
Right Turn	5.8%	5.8%	5.6%	4.7%	4.6%	4.5%	5.0%	6%	6%	5.2%	10.6%
Slowing in Traffic	3.1%	3.8%	3.9%	7.2%	4.3%	6.4%	7.0%	-	5%	5.3%	-41.7%
Stopped in Traffic	15.9%	16.9%	18.6%	23.1%	21.3%	11.9%	23.0%	-	18%	19.0%	-16.5%

Data are recorded in vehicle view for all states

Table D.10 KABCO Comparison Table: Driver Sex

Sex (Driver)	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Male	54.1%	54.1%	58.2%	54.3%	54.4%	55.8%	52.5%	54.6%	53.6%	54.7%	-1.1%
Female	43.2%	41.8%	39.5%	45.6%	44.8%	44.8%	47.5%	41.2%	40.7%	43.2%	0.0%

Data are recorded in person view for all states

Table D.11 KABCO Comparison Table: Contributing factors

Contributing Factors	UT	AZ	WY	ME	ID*	NE*	GA	IL	CT	AVG. (w/o UT)	%Δ
Aggressive Driving	0.9%	0.0%	3.3%	-	-	-	1.6%	-	0.4%	1.3%	-33.3%
Distracted Driving	11.3%	-	6.1%	3.5%	3.2%	5.2%	2.1%	23.8%	3.2%	6.7%	67.5%
Drowsy Driving	0.7%	0.4%	-	-	0.4%	-	<1%	0.2%	-	0.3%	124.4%
DUI (suspected)	2.3%	2.2%	7.1%	0.5%	2.1%	2.2%	0.0%	1.0%	-	2.2%	5.0%
RLR	19.5%	6.8%	10.2%	8.4%	9.2%	-	<1%	6.9%	4.4%	7.7%	154.1%
Speeding (exceeded limit)	-	0.4%	1.1%	0.2%	0.2%	0.4%	1.6%	-	0.5%	0.6%	-
All Speed Fields	6.3%	15.0%	6.9%	3.7%	2.3%	1.3%	0.7%	3.8%	1.6%	4.4%	44.0%
Unrestrained	0.5%	1.2%	3.7%	0.7%	2.3%	2.1%	3.2%	0.5%	0.9%	1.8%	-71.9%

UT, AZ, WY, ME, GA, IL, and CT data are recorded in person view
ID and NE data are recorded in vehicle view for all fields except unrestrained, which are recorded in person view

Table D.12 KABCO Comparison Table: VRU

VRU	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Peds	2.2%	1.6%	0.7%	0.5%	0.5%	-	0.8%	0.7%	0.6%	0.8%	181.0%
Bicycle	1.1%	1.1%	0.3%	0.3%	0.5%	-	0.2%	0.5%	0.2%	0.4%	159.6%
Motorcycle	1.5%	0.8%	-	0.5%	0.6%	0.5%	0.1%	0.4%	0.5%	0.5%	187.9%

UT, AZ, WY, and GA pedestrian and bicycle data are recorded in crash view
ME, IL, and CT pedestrian and bicycle data are recorded in person view
ID pedestrian and bicycle data are recorded in vehicle view
Motorcycle data are recorded in vehicle view for all states

D.3 KAB Severity Level

This section displays the KAB severity comparison tables by crash attribute. Table D.13 displays the crash attributes described for each of the 10 comparison tables included in this section. Crash attributes observed include manner of collision, weather condition, functional classification, light condition, urban/rural, driver age, movement, driver sex, contributing factors, and VRU.

Table D.13 KAB Comparison Table List

KAB Crashes Crash Attribute	Table
Manner of Collision	D.14
Weather Condition	D.15
Functional Classification	D.16
Light Condition	D.17
Urban/Rural	D.18
Driver Age	D.19
Movement	D.20
Driver Sex	D.21
Contributing Factors	D.22
VRU	D.23

Table D.14 KAB Comparison Table: Manner of Collision

Manner of Collision	UT	AZ	WY	ID*	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Angle	56.9%	57.5%	61.8%	47.8%	67.6%	56.2%	62.4%	39.8%	56.2%	1.3%
Front to Rear	18.3%	21.9%	19.2%	33.8%	12.1%	19.5%	17.2%	32.3%	22.3%	-18.0%
Head On	4.8%	2.8%	9.0%	1.2%	5.3%	8.0%	1.3%	3.9%	4.5%	7.2%
Sideswipe Same	1.8%	2.4%	0.4%	2.2%	0.6%	2.7%	0.6%	3.3%	1.8%	5.4%
Sideswipe Opposite	0.6%	0.9%	0.1%	1.1%	0.0%	1.4%	0.0%	1.5%	0.7%	-14.9%

ID recorded data in vehicle view while the other states recorded data in crash view

Table D.15 KAB Comparison Table: Weather Condition

Weather Condition	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Clear	78.2%	89.4%	86.1%	76.0%	77.9%	77.1%	74.2%	83.0%	83.6%	80.9%	-3.3%
Cloudy	14.6%	7.3%	2.3%	12.5%	15.0%	15.9%	16.5%	3.6%	4.7%	9.7%	50.4%
Rain	4.3%	2.5%	3.5%	8.3%	3.9%	4.0%	8.6%	9.6%	10.0%	6.3%	-32.3%
Snow	2.2%	0.1%	6.6%	2.0%	1.8%	0.8%	0.0%	0.6%	0.7%	1.6%	42.6%

Data are recorded in crash view for all states

Table D.16 KAB Comparison Table: Functional Classification

Functional Classification	UT	ME	ID	GA	IL	CT	AVG. (w/o UT)	%Δ
Interstate	2.0%	2.0%	2.3%	0.0%	2.0%	4.8%	2.2%	-12.4%
Local	4.5%	0.5%	0.8%	10.3%	6.7%	1.0%	3.9%	16.6%
Major Collector	12.2%	12.6%	11.1%	9.2%	11.2%	2.9%	9.4%	29.3%
Minor Arterial	24.4%	39.9%	30.4%	38.6%	27.0%	30.5%	33.3%	-26.5%
Minor Collector	1.6%	0.4%	0.0%	0.4%	0.9%	0.1%	0.4%	310.4%
Other Arterial	55.2%	39.4%	55.4%	41.1%	35.8%	35.7%	41.5%	33.0%

Data are recorded in crash view for all states

Table D.17 KAB Comparison Table: Light Condition

Light Condition	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Daylight	71.3%	67.2%	73.0%	71.3%	71.1%	67.0%	65.1%	65.0%	83.6%	70.4%	1.3%
Dark-Light	21.8%	26.9%	19.3%	21.9%	22.3%	24.8%	22.4%	25.8%	10.0%	21.7%	0.3%
Dark	2.4%	0.8%	1.4%	1.9%	1.9%	0.7%	9.5%	4.7%	0.0%	2.6%	-8.4%

Data are recorded in crash view for all states

Table D.18 KAB Comparison Table: Urban/Rural

Urban/Rural	UT	ME	ID	GA	IL	CT	AVG. (w/o UT)	%Δ
Urban	99.3%	85.6%	95.0%	96.8%	83.7%	84.8%	89.2%	11.4%
Rural	0.7%	14.4%	5.0%	3.2%	13.7%	13.9%	10.0%	-93.0%

Data are recorded in crash view for all states

Table D.19 KAB Comparison Table: Age Group

Age Group (Driver)	UT	AZ	WY	ME	ID	NE	IL	CT	AVG. (w/o UT)	%Δ
<20	12.6%	8.7%	10.4%	11.6%	11.9%	12.1%	7.1%	5.6%	9.7%	30.0%
20-29	25.7%	24.6%	25.1%	17.4%	23.1%	23.2%	25.1%	23.8%	23.2%	11.0%
30-39	19.6%	18.8%	19.7%	16.9%	18.4%	18.2%	20.1%	21.2%	19.1%	3.1%
40-49	16.1%	14.4%	16.4%	14.7%	15.0%	13.6%	15.2%	16.5%	15.1%	6.4%
50-59	11.3%	13.1%	8.5%	15.4%	12.4%	11.7%	13.8%	15.8%	13.0%	-12.8%
60-69	8.5%	10.5%	10.2%	12.1%	10.6%	10.4%	10.4%	10.0%	10.6%	-19.8%
>70	6.2%	9.9%	9.6%	11.5%	8.5%	10.7%	8.3%	7.1%	9.4%	-34.0%

Data are recorded in person view for all states

Table D.20 KAB Comparison Table: Movements

Movements	UT	ID*
Left Turn	22.6%	17.4%
Straight	56.4%	48.5%
Right Turn	4.4%	3.3%
Slowing in Traffic	1.7%	3.0%
Stopped in Traffic	12.6%	18.6%

Data are recorded in vehicle view for both states
*ID was the only state with comparable data

Table D.21 KAB Comparison Table: Driver Sex

Sex (Driver)	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Male	55.0%	52.5%	54.5%	49.8%	55.2%	50.3%	50.5%	50.5%	52.1%	52.5%	4.8%
Female	43.6%	47.4%	45.5%	50.2%	44.1%	49.7%	49.4%	49.4%	46.0%	47.2%	-7.5%

Data are recorded in person view for all states

Table D.22 KAB Comparison Table: Contributing Factors

Contributing Factors	UT	AZ	WY	ME	ID*	NE*	GA	IL	CT	AVG. (w/o UT)	%Δ
Aggressive Driving	1.8%	0.1%	8.5%	-	-	-	1.1%	-	1.4%	2.8%	-36.1%
Distracted Driving	10.9%	-	7.6%	2.6%	3.3%	-	1.4%	27.4%	2.4%	7.4%	45.9%
Drowsy Driving	1.0%	0.7%	-	-	0.6%	-	-	0.3%	-	0.5%	98.6%
DUI (suspected)	4.3%	5.1%	21.2%	2.0%	4.1%	-	-	2.3%	-	7.0%	-38.2%
RLR	30.8%	11.9%	18.0%	8.5%	12.3%	-	5.6%	11.3%	8.6%	10.9%	182.4%
Speeding (over limit)	-	1.4%	2.8%	0.7%	0.7%	-	-	-	2.1%	-	-
All Speed Fields	7.2%	13.4%	4.2%	2.4%	1.9%	-	1.6%	3.1%	2.8%	4.2%	71.9%
Unrestrained	1.3%	6.6%	16.7%	5.1%	4.1%	36.1%	-	1.6%	2.8%	10.3%	-87.4%

UT, AZ, WY, ME, GA, IL, and CT data are recorded in person view
*ID and NE data are recorded in vehicle view for all fields except unrestrained, which is in person view

Table D.23 KAB Comparison Table: VRU

VRU	UT	AZ	WY	ME	ID	IL	CT	AVG. (w/o UT)	%Δ
Peds	8.6%	7.3%	4.6%	8.0%	2.6%	6.0%	5.6%	5.7%	52.2%
Bicycle	4.2%	4.5%	1.8%	4.1%	2.0%	3.4%	1.8%	2.9%	44.5%
Motorcycle	5.7%	-	-	-	2.3%	-	-	2.3%	144.6%

UT, AZ, WY, and GA pedestrian and bicycle data are recorded in crash view
ME, IL, and CT pedestrian and bicycle data are recorded in person view
ID pedestrian and bicycle data are recorded in vehicle view
Motorcycle data are recorded in vehicle view for all states

D.4 KA Severity Level

This section displays the KA severity comparison tables by crash attribute. Table D.24 displays the crash attributes described for each of the 10 comparison tables included in this section. Crash attributes observed include manner of collision, weather condition, functional classification, light condition, urban/rural, driver age, movement, driver sex, contributing factors, and VRU.

Table D.24 KA Comparison Table List

KA Crashes Crash Attribute	Table
Manner of Collision	D.25
Weather Condition	D.26
Functional Classification	D.27
Light Condition	D.28
Urban/Rural	D.29
Driver Age	D.30
Movement	D.31
Driver Sex	D.32
Contributing Factors	D.33
VRU	D.34

Table D.25 KA Comparison Table: Manner of Collision

Manner of Collision	UT	AZ	WY	ID*	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Angle	58.3%	59.3%	58.5%	52.7%	66.1%	53.4%	61.4%	42.4%	56.3%	3.7%
Front to Rear	8.3%	10.6%	16.4%	19.5%	7.7%	13.2%	11.0%	12.8%	13.0%	-36.5%
Head On	5.5%	3.8%	9.2%	2.1%	3.9%	9.8%	1.7%	4.7%	5.0%	9.6%
Sideswipe Same	1.8%	2.0%	0.0%	2.6%	0.8%	2.4%	0.8%	2.2%	1.5%	18.2%
Sideswipe Opposite	0.7%	0.8%	0.0%	2.0%	0.0%	1.3%	0.0%	0.8%	0.7%	-7.2%

ID recorded data in vehicle view while the other states recorded data in crash view

Table D.26 KA Comparison Table: Weather Condition

Weather Condition	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Clear	80.1%	89.6%	86.2%	76.6%	78.9%	77.0%	76.7%	84.9%	85.8%	81.9%	-2.3%
Cloudy	13.5%	7.2%	2.6%	9.0%	14.7%	16.0%	14.8%	3.7%	4.8%	9.1%	48.9%
Rain	4.1%	2.2%	4.1%	12.2%	3.7%	5.1%	7.6%	8.1%	8.2%	6.4%	-35.2%
Snow	1.4%	0.0%	4.1%	0.5%	1.6%	0.5%	0.0%	0.8%	0.4%	1.0%	43.4%

Data are recorded in crash view for all states

Table D.27 KA Comparison Table: Functional Classification

Functional Classification	UT	ME	ID	GA	IL	CT	AVG. (w/o UT)	%Δ
Interstate	1.4%	1.6%	2.7%	0.0%	2.1%	3.7%	2.0%	-31.3%
Local	2.9%	0.0%	1.0%	9.1%	6.3%	0.7%	3.4%	-14.1%
Major Collector	11.4%	13.8%	11.5%	8.5%	11.2%	2.7%	9.6%	19.6%
Minor Arterial	23.0%	44.1%	29.9%	38.3%	26.7%	31.3%	34.1%	-32.6%
Minor Collector	1.1%	0.5%	0.0%	0.5%	0.9%	0.1%	0.4%	177.0%
Other Arterial	59.9%	37.8%	54.9%	43.2%	37.4%	41.4%	42.9%	39.5%

Data are recorded in crash view for all states

Table D.28 KA Comparison Table: Light Condition

Light Condition	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Daylight	66.3%	57.5%	62.6%	70.2%	62.6%	56.5%	57.4%	60.0%	85.8%	64.1%	3.5%
Dark-Light	25.8%	35.9%	27.2%	22.9%	29.0%	33.2%	26.4%	29.7%	8.2%	26.6%	-2.9%
Dark	3.2%	1.3%	1.5%	2.1%	2.1%	1.3%	13.1%	5.9%	0.1%	3.4%	-6.4%

Data are recorded in crash view for all states

Table D.29 KA Comparison Table: Urban/Rural

Urban/Rural	UT	ME	ID	GA	IL	CT	AVG. (w/o UT)	%Δ
Urban	97.8%	87.2%	94.1%	96.3%	84.7%	89.0%	90.3%	8.3%
Rural	2.2%	12.8%	5.9%	3.6%	12.7%	9.5%	8.9%	-75.0%

Data are recorded in crash view for all states

Table D.30 KA Comparison Table: Driver Age Group

Age Group (Driver)	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
<20	11.5%	7.1%	5.3%	4.0%	9.4%	9.0%	7.0%	5.5%	4.8%	6.5%	75.7%
20-29	25.3%	24.1%	20.4%	11.3%	22.4%	25.2%	25.8%	24.1%	23.7%	22.1%	14.3%
30-39	18.9%	18.6%	18.9%	15.3%	18.2%	15.4%	20.7%	20.4%	22.7%	18.8%	0.8%
40-49	16.9%	14.8%	27.0%	18.5%	17.0%	14.0%	16.2%	14.8%	16.5%	17.4%	-2.6%
50-59	12.0%	12.2%	13.2%	21.0%	13.2%	12.2%	14.1%	15.2%	15.4%	14.6%	-17.7%
60-69	8.8%	11.6%	9.4%	15.3%	11.6%	13.3%	9.6%	10.6%	9.6%	11.4%	-22.3%
>70	6.6%	11.6%	5.7%	14.5%	8.2%	10.8%	6.7%	9.3%	7.3%	9.3%	-29.0%

Data are recorded in person view for all states

Table D.31 KA Comparison Table: Movements

Movements	UT	ID*
Left Turn	24.3%	20.5%
Straight	57.8%	49.7%
Right Turn	3.7%	2.7%
Slowing in Traffic	1.0%	1.8%
Stopped in Traffic	10.6%	13.5%

Data are recorded in vehicle view for all states
*ID was the only state with comparable data

Table D.32 KA Comparison Table: Driver Sex

Sex (Driver)	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Male	61.1%	63.6%	59.7%	67.7%	60.2%	67.6%	59.6%	56.9%	70.2%	63.2%	-3.4%
Female	37.9%	36.3%	40.3%	32.3%	38.7%	32.4%	40.4%	42.9%	28.3%	36.4%	4.0%

Data are recorded in person view for all states

Table D.33 KA Comparison Table: Contributing Factors

Contributing Factors	UT	AZ	WY	ME	ID*	NE*	GA	IL	CT	AVG. (w/o UT)	%Δ
Aggressive Driving	4.5%	0.3%	16.7%	-	-	-	5.0%	-	5.7%	6.9%	-35%
Distracted Driving	7.5%	-	1.3%	4.0%	2.2%	-	1.9%	25.8%	1.6%	6.1%	23%
Drowsy Driving	0.9%	0.8%	-	-	0.6%	-	-	0.3%	-	0.6%	70%
DUI (suspected)	8.3%	12.8%	44.3%	4.0%	8.6%	-	0.5%	4.4%	-	12.4%	-32%
RLR	35.8%	15.9%	10.1%	14.5	14.3%	-	12.2%	13.7%	12.3%	13.3%	170%
Speeding (over limit)	-	4.5%	11.6%	5.6%	1.8%	-	-	-	9.8%	-	-
All Speed Fields	12.2%	20.9%	12.9%	6.5%	2.9%	-	2.5%	4.2%	5.2%	7.9%	40%
Unrestrained	3.2%	18.7%	34.6%	9.7%	6.8%	12.7%	-	4.1%	10.5%	13.9%	-77%

UT, AZ, WY, ME, GA, IL, and CT data are recorded in person view
*ID and NE data are recorded in vehicle view for all fields except unrestrained, which is in person view

Table D.34 KA Comparison Table: VRU

VRU	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
Peds	15.2%	14.8%	8.7%	19.1%	5.7%	-	12.2%	11.4%	16.4%	12.6%	20.3%
Bicycle	4.3%	5.2%	1.5%	3.8%	2.3%	-	1.7%	4.0%	2.6%	3.0%	42.6%
Motorcycle	13.4%	-	-	-	5.9%	-	1.4%	-	-	3.6%	272.3%

UT, AZ, WY, and GA pedestrian and bicycle data are recorded in crash view
ME, IL, and CT pedestrian and bicycle data are recorded in person view
ID pedestrian and bicycle data are recorded in vehicle view
Motorcycle data are recorded in vehicle view for all states

APPENDIX E: ADDITIONAL DATA ANALYSIS

E.1 Overview

This appendix displays the results of the odds ratio and additional analysis for those factors not mentioned in Chapter 5. The data from each state comes from three levels: crash view, person view, and vehicle view. Some of the states collect certain data in a different level than other states. For example, Idaho records contributing factors in vehicle view while the other states include them in person view. Most vehicle view datasets did not include crash severity, which is required to compute the odds of a crash being severe. For this reason, not all the states available in the comparison table could be compared in the odds ratio. As another example, Idaho and Nebraska are not displayed in the odds ratio for DUI despite being in the comparison table as their data came from vehicle view while the other states' data came from person view.

This section will discuss the data analysis conducted for the following: age of driver, functional classification, left-turn crashes, pedestrian-involved crashes, rear-end crashes, and other manners of collision and contributing factors.

E.2 Age of Driver

Drivers of different ages have different levels of roadway experience, perception times, reaction times, and other factors that contribute to safe driving. For this research, ages are categorized into four categories based on the NHTSA age categories (NHTSA, 2025). The age categories are 14 to 24, 25 to 44, 45 to 64, and 65 and above. Table E.1 displays the distribution of crashes by age group for the State of Utah. Drivers ages 14 to 34 contribute to 32 percent of all signalized intersection crashes, 30 percent of KAB crashes, and 27 percent of KA crashes. Drivers ages 25 to 44 contribute to 35 percent of all signalized intersection crashes, 36 percent of KAB crashes, and 37 percent of KA crashes. The following subsections will present additional information for each driver age group, including a comparison table and statistical analyses performed for each group.

Table E.1 Utah Crashes by Age Group

Age Group	14-24	25-44	45-64	65+
KABCO	32%	35%	18%	9%
KAB	30%	36%	19%	11%
KA	27%	37%	21%	12%

Data are recorded in person view

E.2.1 Ages 14 to 24

Table E.2 displays the comparison table for crashes with drivers ages 14 to 24. Every state, except Georgia, recorded driver age data in person view. Georgia's driver age data was originally recorded in the crash view with multiple entries as if it were person view. Since it was formatted as if it were person view data, the information was extracted to reflect person view crash percentages as seen from the other states. Utah has the highest percentage of signalized intersection crashes on all severity levels of the states analyzed in this age group. Excluding Utah, the average percentage of KA crashes for this age group is 17 percent, which is a 10 percent decrease of the value recorded in Utah. Connecticut has the lowest percentage of crashes for the 14 to 24 age group on the KABCO and KAB levels, followed by Maine and Georgia.

Table E.2 Comparison Table: Ages 14-24

14-24	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	32%	24%	24%	20%	26%	26%	18%	21%	17%	22%	46%
KAB	30%	22%	21%	18%	24%	25%	19%	20%	17%	21%	44%
KA	27%	19%	11%	13%	21%	23%	18%	18%	16%	17%	58%

Data are recorded in person view for all states

Figure E.1 demonstrates the KAB odds ratio for ages 14 to 24 for each state. The baseline for this comparison is the 45 to 64 age group. Connecticut and Illinois have significantly higher odds of a KAB crash for this age group than Utah. Arizona and Nebraska also have higher odds, but the results are inconclusive. Idaho, Wyoming, and Maine have lower odds of a KAB crash for drivers aged 14 to 24, but the results are inconclusive. Although Georgia's comparison table data is in person view, this data was also not included in the odds ratio because it is written in crash view as a list of each person involved.

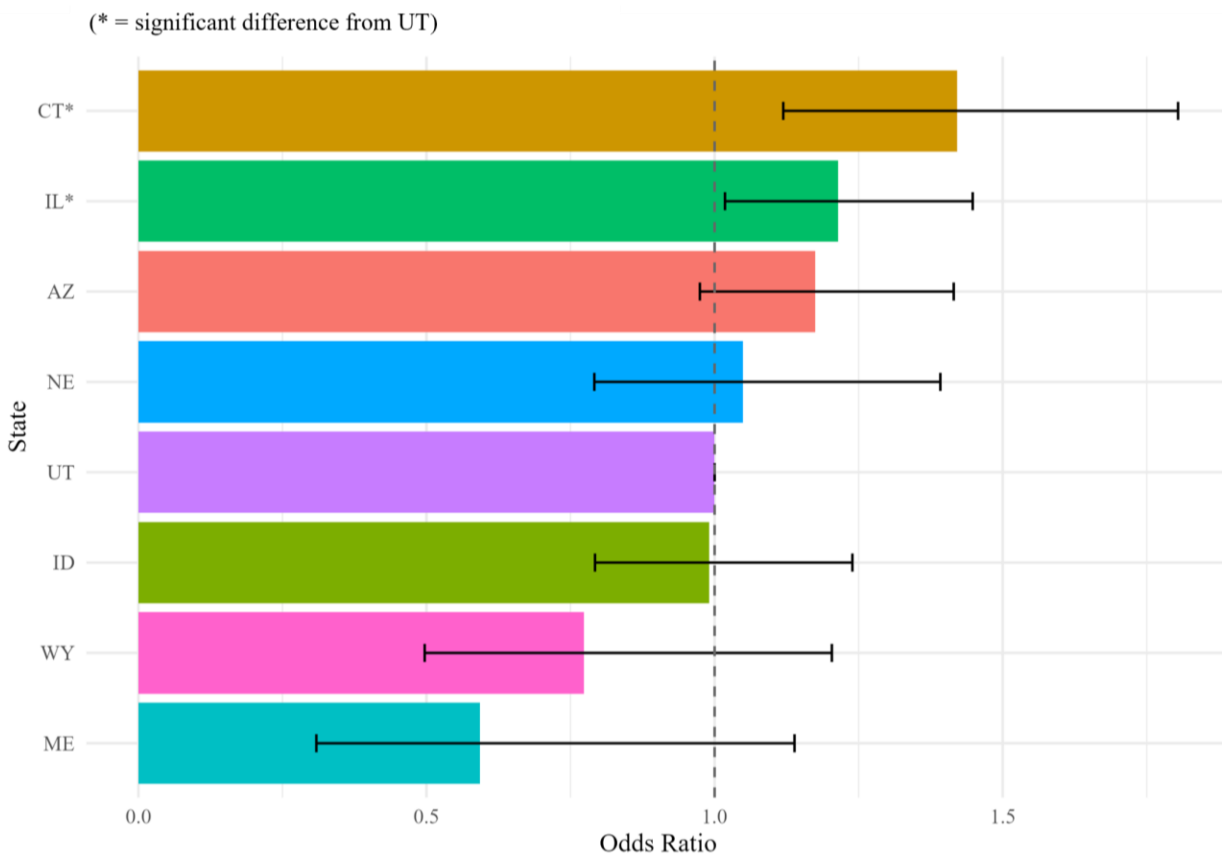


Figure E.1 KAB Odds Ratio: Ages 14-24

<u>E.2.2 Ages 25 to 44</u>

Table E.3 displays the comparison table for crashes involving drivers ages 25 to 44. Georgia's driver age data was originally recorded in the crash view with multiple entries as if it were person view. Since it was formatted as if it were person-view data, the information was extracted to reflect person-view crash percentages as seen from the other states. Of the states analyzed, crashes in this age group ranged from 30 to 40 percent. Utah has a slightly lower percentage of crashes from this age group than the average of the other states analyzed. Wyoming's data shows a high percentage of KAB and KA crashes, however, inconsistencies were found in their state's data so these percentages might not be accurate.

Table E.3 Comparison Table: Ages 25-44

25-44	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	35%	39%	38%	33%	37%	38%	30%	40%	40%	37%	-6%
KAB	36%	38%	45%	32%	37%	36%	28%	41%	42%	37%	-4%
KA	37%	38%	59%	28%	38%	34%	30%	41%	43%	39%	-6%

Data are recorded in person view for all states

Figure E.2 displays the KAB odds ratio for ages 25 to 44 for each state. The baseline for this comparison is the 45 to 64 age group. Although Georgia's comparison table data is in person view, this data was also not included in the odds ratio because it is written in crash view as a list of each person involved. Wyoming and Connecticut have significantly higher odds of a KAB crash for this age group than Utah. It should again be noted that Wyoming's crash data might not be reliable as the ages recorded for each crash appear to be rounded. Illinois and Arizona also have higher odds of a KAB crash for this age group, but the results are inconclusive. Idaho, Nebraska, and Maine had lower odds of a KAB crash for the 25 to 44 age group, but these results are all inconclusive.

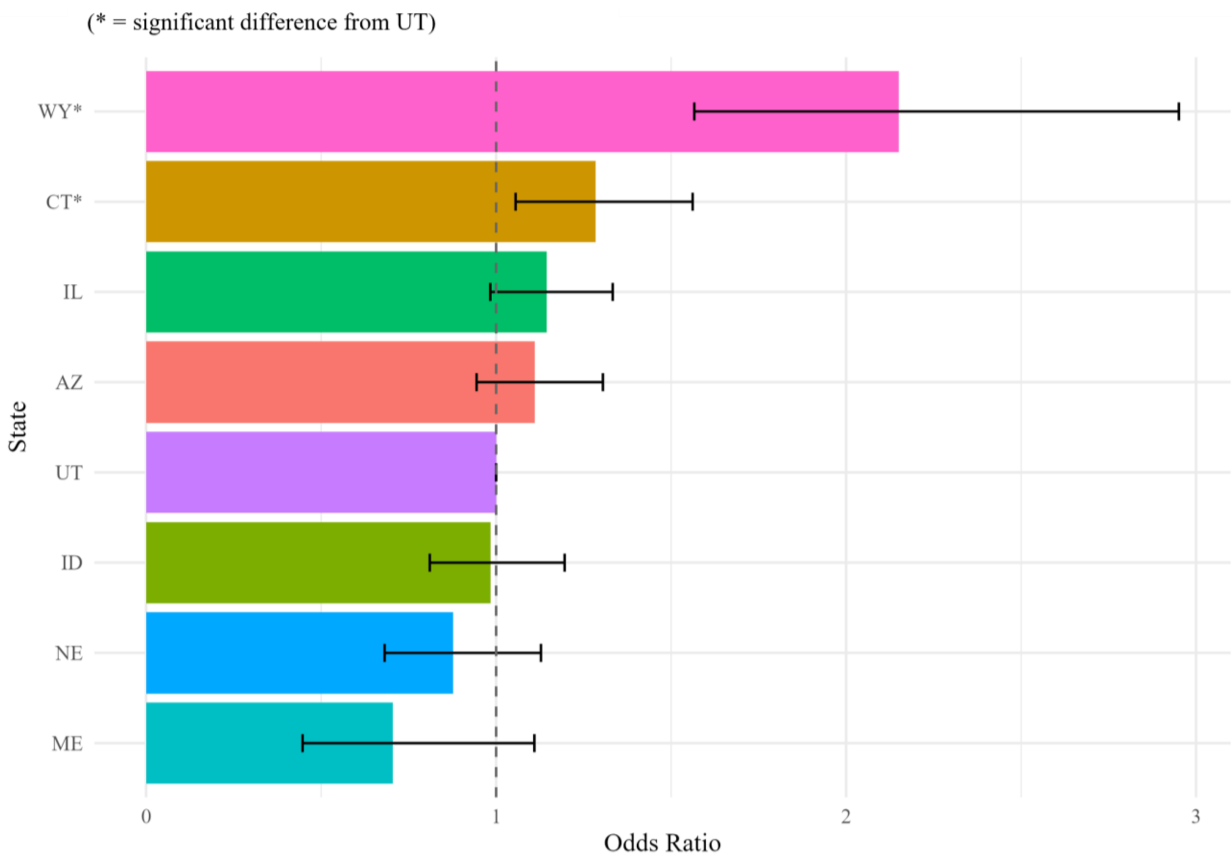


Figure E.2 KAB Odds Ratio: Ages 25-44

E.2.3 Ages 45 to 64

Table E.4 displays the comparison table for crashes involving drivers ages 45 to 64. Georgia's driver age data was originally recorded in the crash view with multiple entries as if it were person view. Since it was formatted as if it were person-view data, the information was extracted to reflect person-view crash percentages as seen from the other states. Utah has the lowest percentage of crashes from drivers of this age group than the other states analyzed. Excluding Utah, the average percentage of crashes involving drivers ages 45 to 64 is 24 percent for KABCO and KAB crashes and 26 percent for KA crashes. In Utah, drivers ages 45 to 64 comprise 18 percent of KABCO crashes, 19 percent of KAB crashes, and 21 percent of KA crashes.

Table E.4 Comparison Table: Ages 45-64

45-64	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	18%	26%	24%	26%	24%	24%	11%	27%	30%	24%	-26%
KAB	19%	26%	19%	28%	25%	24%	12%	27%	29%	24%	-19%
KA	21%	26%	20%	36%	28%	27%	12%	28%	29%	26%	-20%

Data are recorded in person view for all states

Figure E.3 presents the KAB odds ratio for drivers ages 45 to 64. The baseline for this odds ratio is the 25 to 44 age group. Although Georgia's comparison table data is in person view, this data was also not included in the odds ratio because it is written in crash view as a list of each person involved. Utah has the highest odds of a KAB crash for drivers ages 45 to 64. Of the states analyzed, Arizona, Illinois, Connecticut, and Wyoming have statistically significant lower odds of a KAB crash for drivers in this age group. Maine, Nebraska, and Idaho also have lower odds of a KAB crash for drivers ages 45 to 64, but these results are inconclusive.

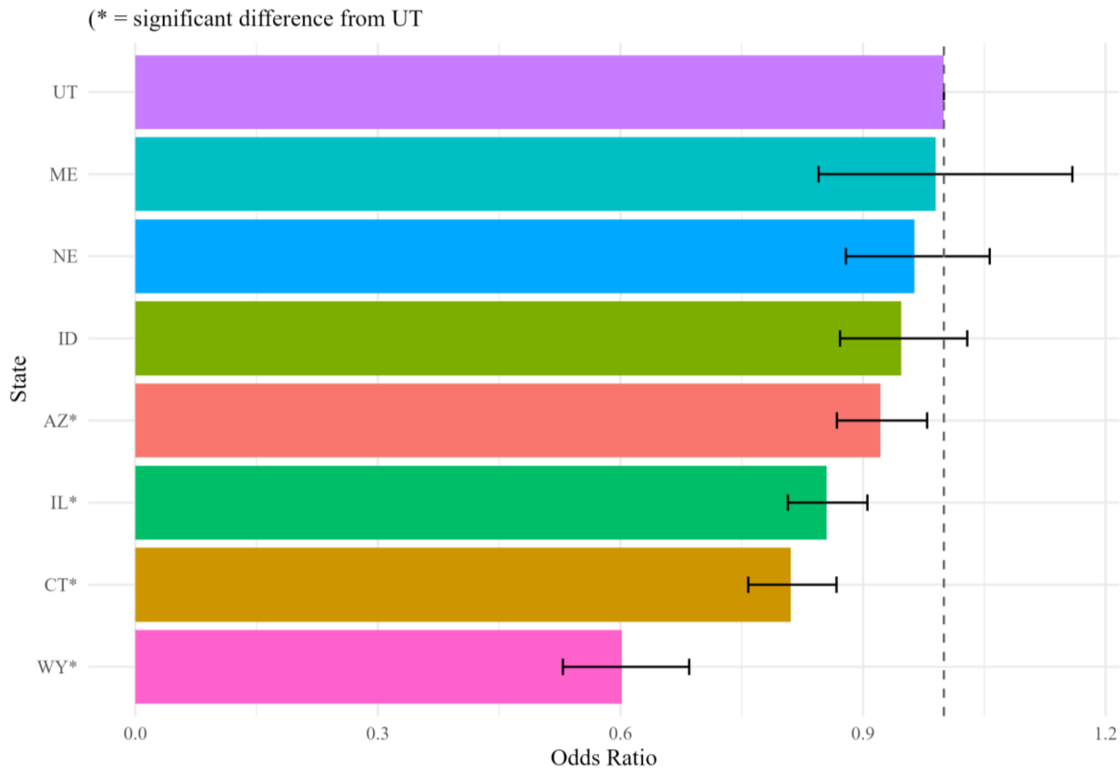


Figure E.3 KAB Odds Ratio: Ages 45-64

E.3 Functional Classification

Roadways are grouped into different classifications based on mobility and accessibility that the road provides. This grouping is referred to as a roadway's functional classification. Arterials are generally higher-speed, high-mobility, lower-access roadways. Collector roadways exhibit a combination of mobility and access. Local roads are generally lower-speed, low-mobility, high-access roadways. The research team was interested in observing trends in crashes at signalized intersections based on functional classification. Figure E.4 shows that in Utah, 78 percent of signalized intersection crashes happen on arterials with 80 percent of KAB crashes occurring on arterials. Collectors account for 13 percent of all signalized intersection crashes and 14 percent of KAB crashes. This percentage most heavily weighs on major collectors as they are more likely to warrant a signal. Local roads account for 5 percent of signalized intersection crashes in Utah and only 4 percent of its KAB crashes.

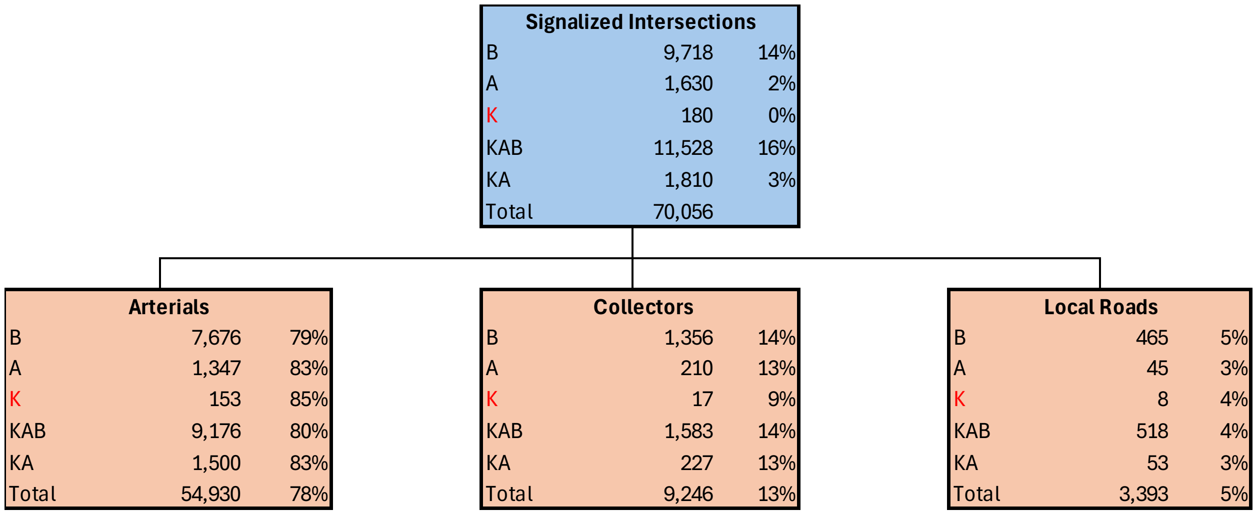


Figure E.4 Crash Tree: Functional Class

Additional research was conducted to determine how functional classification affects the distribution of contributing factors. Contributing factors investigated include, but are not limited to, distracted driving, drowsy driving, pedestrian involved, RLR, and speeding. Results demonstrated little variation amongst the different functional classifications, suggesting that the type of roadway has minimal influence on the contributing factors present.

E.4 Left-Turn Crashes

Left-turn crashes represent 34 percent of all signalized intersection crashes in Utah as shown in Figure E.5. Additionally, they contribute to 46 percent of KAB crashes and 50 percent of KA crashes, making these turning movements a concern for UDOT. The research team further investigated the movements related to these crashes by analyzing the unit level, or vehicle level, for these crashes. Of the left-turn crashes in Utah, 51 percent of the vehicles were making left turns, 42 percent were going straight, 3 percent were stopped in traffic, and 2 percent were making right turns.

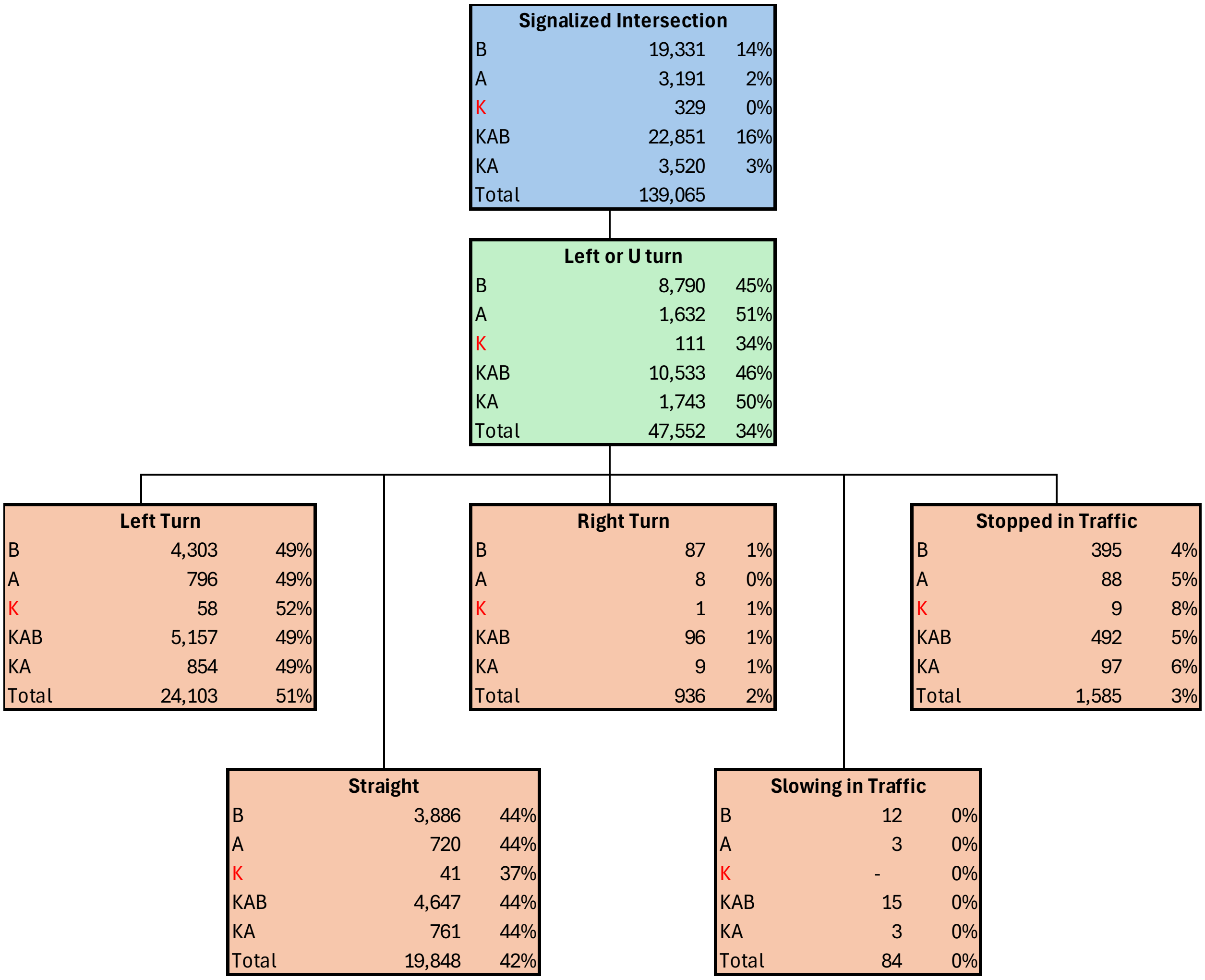


Figure E.5 Crash Tree: Left or U-Turn

RLR also contributes to 20 percent of left-turn crashes at signalized intersections in Utah. Unlike the other states analyzed, Utah collects left-turn crash data on the crash level and vehicle level. This allows the analysis for left-turn crash data to be more elaborate in Utah than in other states. Utah also included crash severity levels with its vehicle data, which is not true of most other states. For this reason, a comparison table was not generated comparing left-turn crash trends to other states. Additionally, no statistical analyses were performed for this section.

E.5 Vulnerable Road User Crashes

Addressing VRU crashes is a focus area for UDOT as these users are more likely to be seriously injured. Figure E.6 displays the severity levels for VRUs in Utah. The figure shows that

51 percent of K crashes and 31 percent of A crashes involved either a pedestrian, cyclist, or motorcyclist. Since a high percentage of all KA crashes involve a pedestrian, cyclist, or motorcyclist, addressing VRU crashes is an important topic in Utah. The following subsections will present the comparison tables and statistical analyses performed for pedestrian-, bicycle-, and motorcycle-involved crashes for Utah and other states.

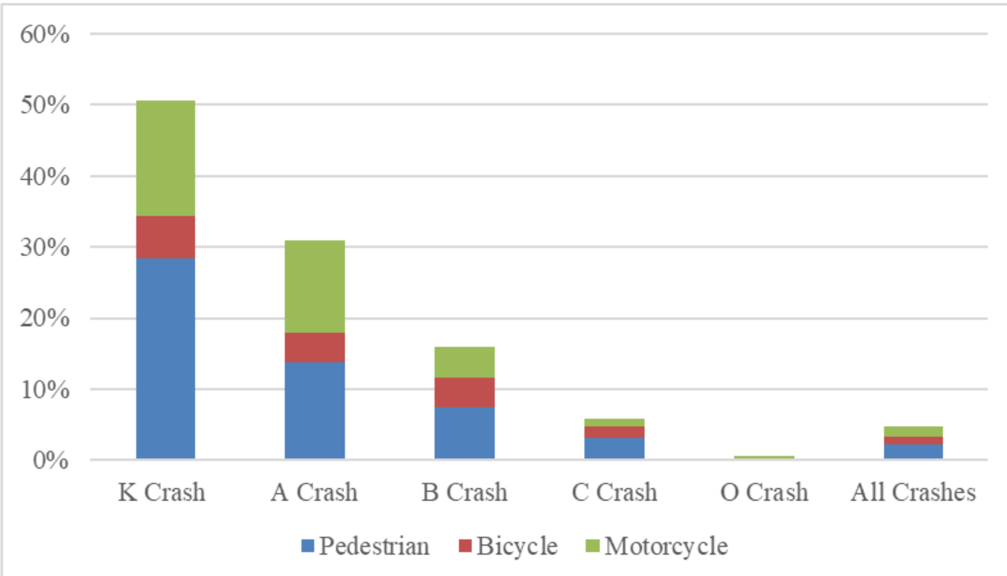


Figure E.6 VRU Crashes in Utah

<u>E.5.1 Pedestrian Involved</u>

Table E.5 displays the comparison table for pedestrian-involved crashes. Idaho has the lowest recorded percentage of KAB and KA pedestrian crashes of the states analyzed. The percentage of KAB crashes in Idaho is 3 percent, which is 6 percent lower than Utah. Additionally, the percentage of KA crashes is 6 percent, which is 9 percent lower than Utah. Wyoming, Georgia, and Illinois also have lower percentages of severe pedestrian-involved crashes than Utah.

Figure E.7 displays the odds ratio for KAB pedestrian crashes. Several states have higher odds of KAB pedestrian-related crashes in comparison to Utah. In order from highest to lowest odds, Connecticut, Illinois, Wyoming, Arizona, and Georgia all have higher odds of KAB pedestrian-related crashes compared to Utah, all of which are statistically significant. Results from Nebraska are also similar to Utah with odds just lower than that of Utah, but inconclusive.

Table E.5 Comparison Table: Pedestrian-Involved Crashes

Pedestrian Involved*	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	157%
KAB	9%	7%	5%	8%	3%	5%	6%	6%	6%	6%	55%
KA	15%	15%	9%	19%	6%	8%	12%	11%	16%	12%	26%

UT, AZ, WY, NE, and GA recorded data in the crash view
ID recorded data in the vehicle view
ME, IL, and CT recorded data in the person view

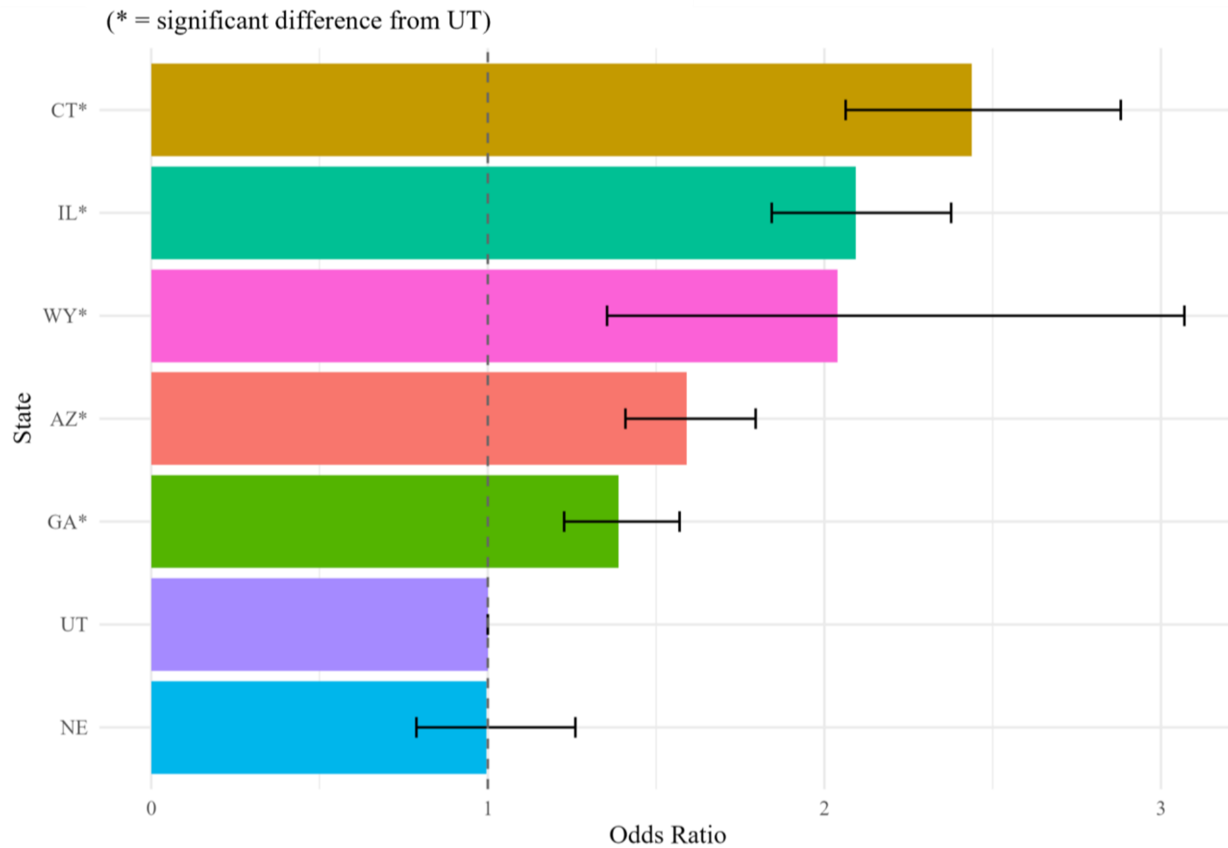


Figure E.7 KAB Odds Ratio: Pedestrian Involved

E.5.2 Bicycle Involved

Table E.6 displays the comparison table for bicycle-involved crashes. Connecticut and Georgia recorded the lowest percentage of bicycle-involved crashes, though Wyoming and Georgia have the lowest percentage of KA bicycle-involved crashes. Utah has a higher percentage of bicycle-involved crashes than any state but Arizona for all severity levels with a bicycle-involved percentage 122 percent higher than the average of the other states.

Table E.6 Comparison Table: Bicycle Involved

Bicycle Involved*	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	1%	1%	0%	0%	0%	1%	0%	0%	0%	1%	122%
KAB	4%	4%	2%	4%	2%	3%	1%	3%	2%	3%	53%
KA	4%	5%	2%	4%	2%	3%	2%	4%	3%	3%	41%

UT, AZ, WY, NE, and GA reported data in crash view
ID reported data in vehicle level
ME, IL, and CT reported data in person view

Figure E.8 displays the odds ratio for KAB bicycle crashes. Wyoming, Arizona and Georgia have higher odds of KAB bicycle-related crashes in comparison to Utah. Nebraska has lower odds of a KAB bicycle-related crash. Arizona is the only state in which the odds are significant. Maine, Illinois, and Connecticut were not included in this analysis as bicycle crash information was stored in a different view than Utah.

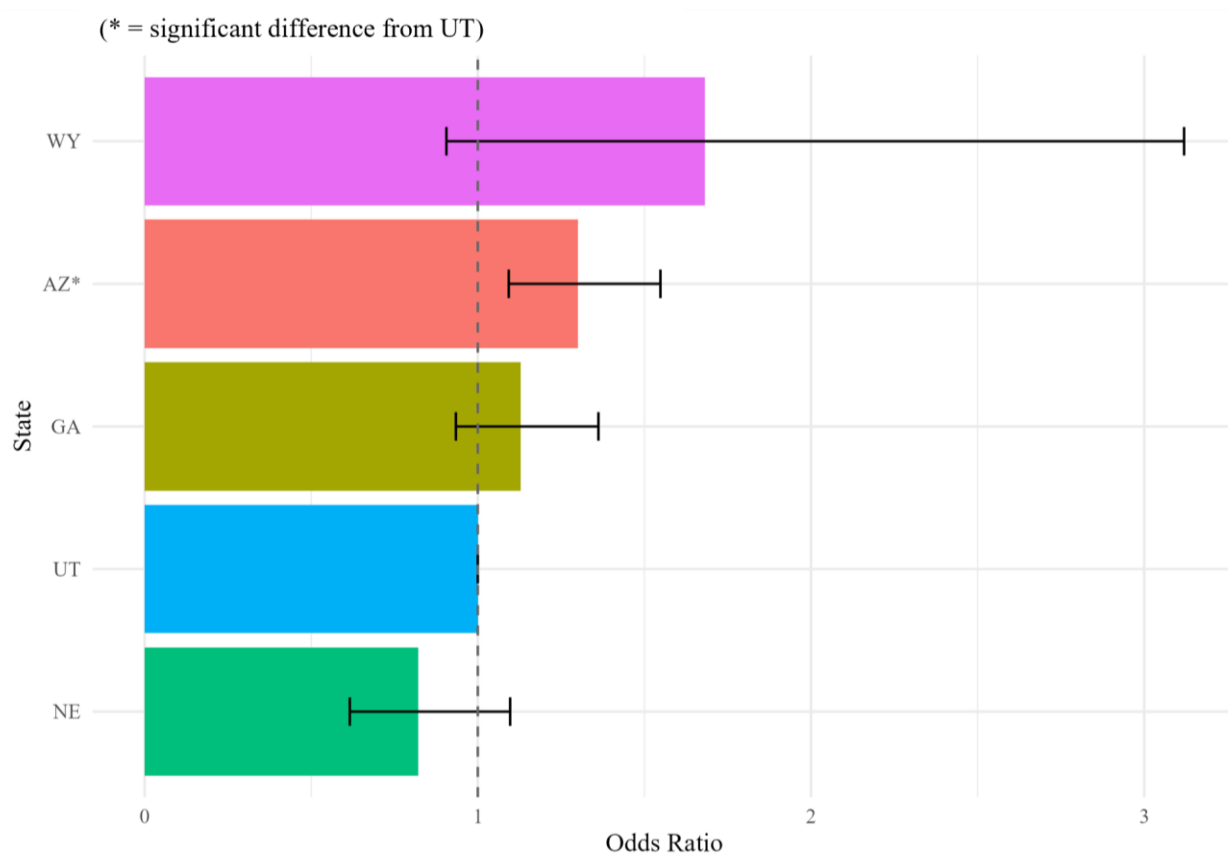


Figure E.8 KAB Odds Ratio: Bicycle Involved

E.5.3 Motorcycle Involved

Table E.7 displays the comparison table for motorcycle-involved crashes. Most states did not have data on KA and KAB motorcycle-involved crashes, but the data from the states that do suggest that motorcycle-involved crashes are more likely to be severe than other crash types. Utah has the highest percentage of motorcycle-involved crashes of all the states analyzed with their motorcycle crashes being 188 percent higher than the average of the other states. Georgia has the lowest percentage of motorcycle crashes, which is true for all severity levels.

Table E.7 Comparison Table: Motorcycle-Involved Crashes

Motorcycle Involved	UT*	AZ	WY	ME	ID	NE	GA*	IL	CT	AVG. (w/o UT)	%Δ
KABCO	1%	1%	-	1%	1%	0%	0%	0%	1%	1%	188%
KAB	6%	-	-	-	2%	-	1%	-	-	2%	229%
KA	13%	-	-	-	6%	-	1%	-	-	4%	272%

*UT and GA reported data in crash view
The other states reported data in vehicle view

E.6 Rear-End Crashes

Rear-end crashes, also labeled as front-to-rear crashes in some states, represent 39 percent of all signalized intersection crashes in Utah, 18 percent of KAB crashes, and 8 percent of KA crashes as shown in Figure E.9. Although not often severe, the frequency of rear-end crashes makes them a concern at signalized intersections. The research team investigated common factors associated with rear-end crashes in Utah. Teenage drivers were involved in 23 percent of all rear-end crashes at signalized intersections. Factors such as distracted driving, roadway geometry, and older drivers contributed to 17, 15, and 14 percent of all rear-end crashes at signalized intersections, respectively.

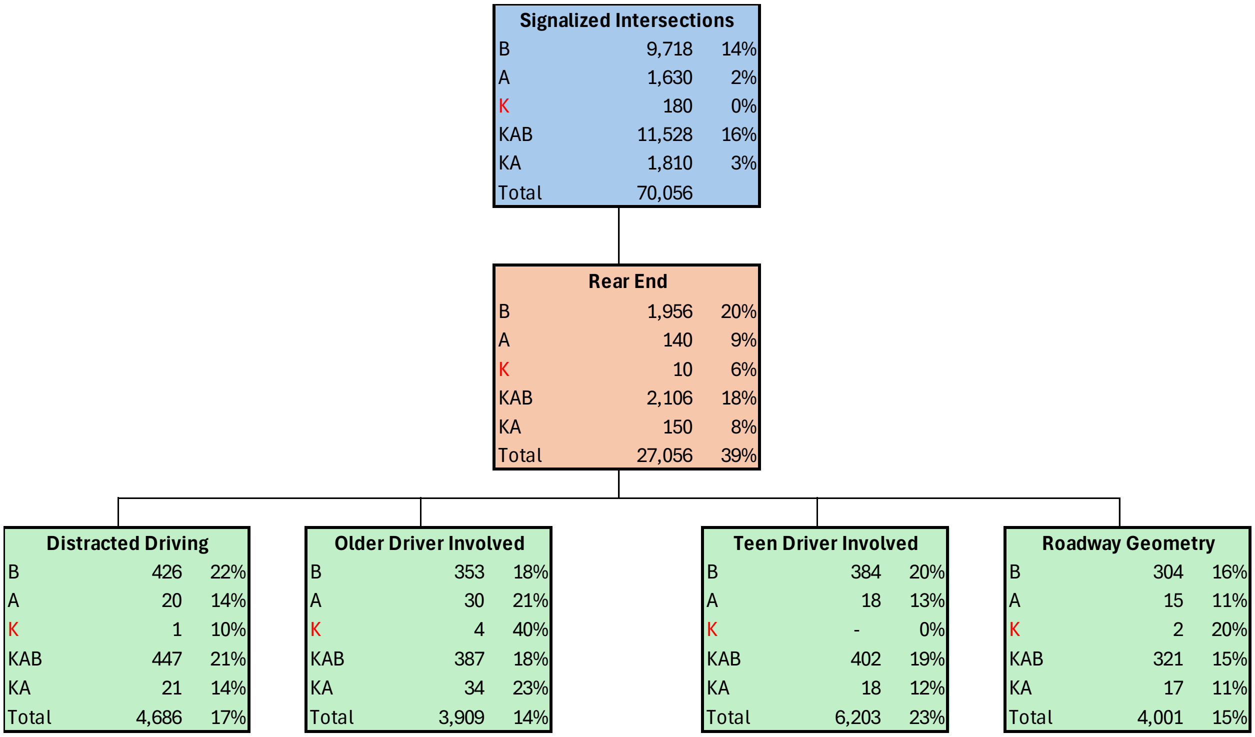


Figure E.9 Crash Tree: Rear-End Collisions

Table E.8 demonstrates the comparison table for rear-end crashes at various severity levels. Connecticut, Georgia, and Idaho have the highest percentage of rear-end crashes of the states analyzed at 47, 46, and 45 percent, respectively. Nebraska has the lowest percentage of rear-end crashes of the states analyzed at 26 percent. Excluding Utah, the average percentage of rear-end crashes at signalized intersections is 39 percent, which aligns with Utah crash data. The average percentage of KAB and KA rear-end crashes are 22 and 13 percent, respectively. This average is higher than the crash data from Utah, suggesting that Utah exceeds average performance in the context of severe rear-end crashes.

Table E.8 Comparison Table: Rear-End Crashes

Rear Ends	UT	AZ	WY	ID*	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	39%	37%	37%	45%	26%	46%	33%	47%	39%	0%
KAB	18%	22%	19%	34%	12%	19%	17%	32%	22%	-18%
KA	8%	11%	16%	20%	8%	13%	11%	13%	13%	-36%

*ID reported data in vehicle view while other states reported data in crash view

Figure E.10 demonstrates the odds ratio for KAB rear-end crashes. The odds of a KAB rear-end crash in Arizona, Connecticut, and Nebraska are higher than Utah and statistically significant. The odds for Georgia and Wyoming were also higher than Utah while Illinois was lower. Given the confidence bounds for those states, there is no conclusive evidence on how the odds of rear-end crashes compare to Utah.

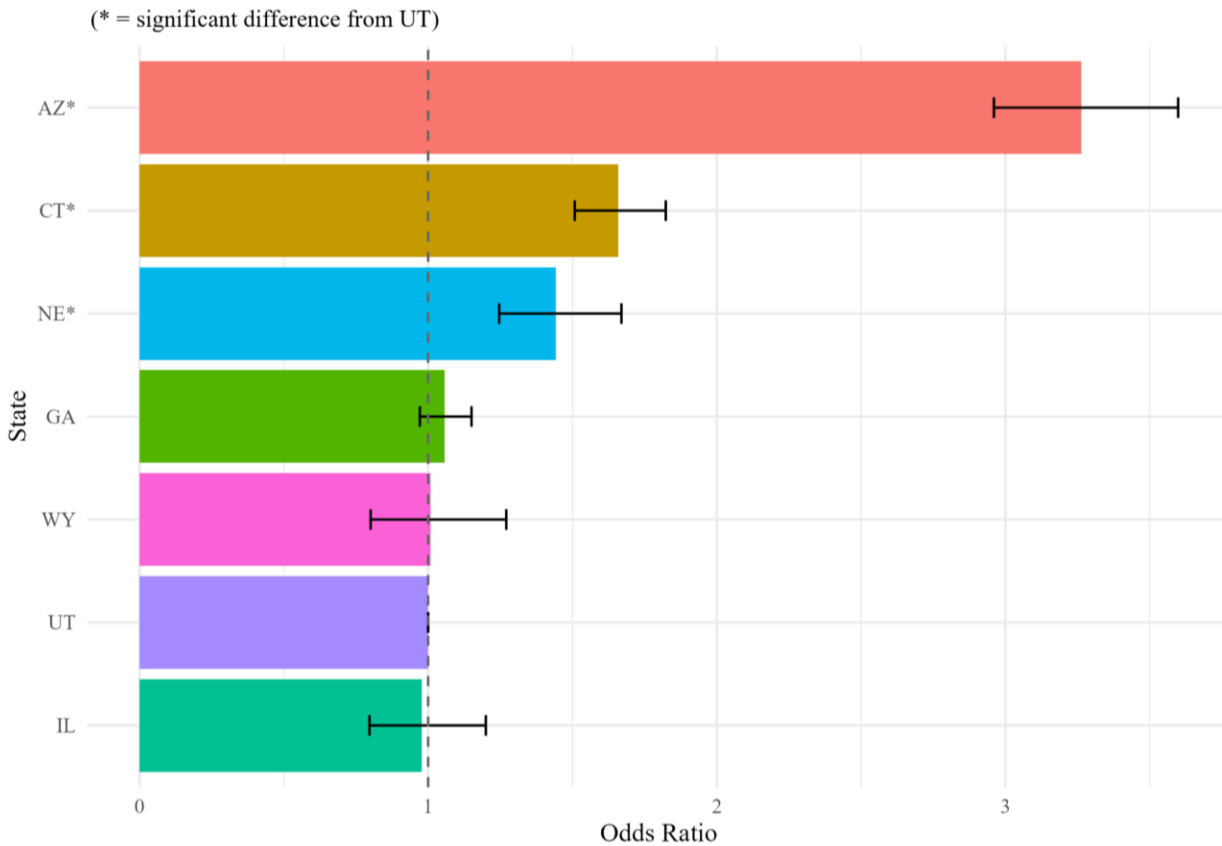


Figure E.10 KAB Odds Ratio: Rear End

E.7 Weather Conditions

The Utah police crash report categorizes weather conditions into multiple categories, the most common of which are clear, cloudy, rain, and snow. These conditions describe the current atmosphere and precipitation and not the conditions of the roadway surface. In Utah, 75 percent of all signalized intersection crashes occur in clear weather conditions. Additionally, 78 percent of KAB crashes and 80 percent of KA crashes occur in clear weather conditions. Although adverse weather conditions do not contribute to crashes in Utah, a comparison was made to determine how adverse weather affects other states. The following subsections will present the comparison tables and statistical analyses performed in cloudy, rainy, and snowy weather conditions.

E.7.1 Cloudy Weather Conditions

Table E.9 displays the percentage of crashes that occurred in cloudy conditions for each state analyzed. Crashes during cloudy weather comprise 15 percent of all signalized intersection crashes, 15 percent KAB crashes, and 14 percent KA crashes in Utah. Excluding Utah, the average percentage of crashes during cloudy conditions is 10 percent. This average is lower than the 15 percent of crashes that occurred in cloudy conditions in Utah. Georgia has the highest percentage of crashes during cloudy conditions at 17 percent, and Wyoming has the lowest at 3 percent.

Table E.9 Comparison Table: Cloudy Weather Conditions

Cloudy	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	15%	7%	3%	12%	16%	15%	17%	4%	5%	10%	56%
KAB	15%	7%	2%	12%	15%	16%	16%	4%	5%	10%	50%
KA	14%	7%	3%	9%	15%	16%	15%	4%	5%	9%	49%

Data are recorded in crash view for all states

Figure E.11 displays the odds ratio comparing KAB crashes in cloudy weather amongst the various states. In cloudy weather, the odds of a KAB crash are higher and statistically significant in Nebraska, Connecticut, and Arizona than in Utah. The odds of a KAB crash in cloudy weather are also higher in Maine, Georgia, and Idaho but the results are not statistically significant, and thus, are inconclusive. Illinois and Wyoming have lower odds of KAB crashes in cloudy weather conditions, but the results are inconclusive.

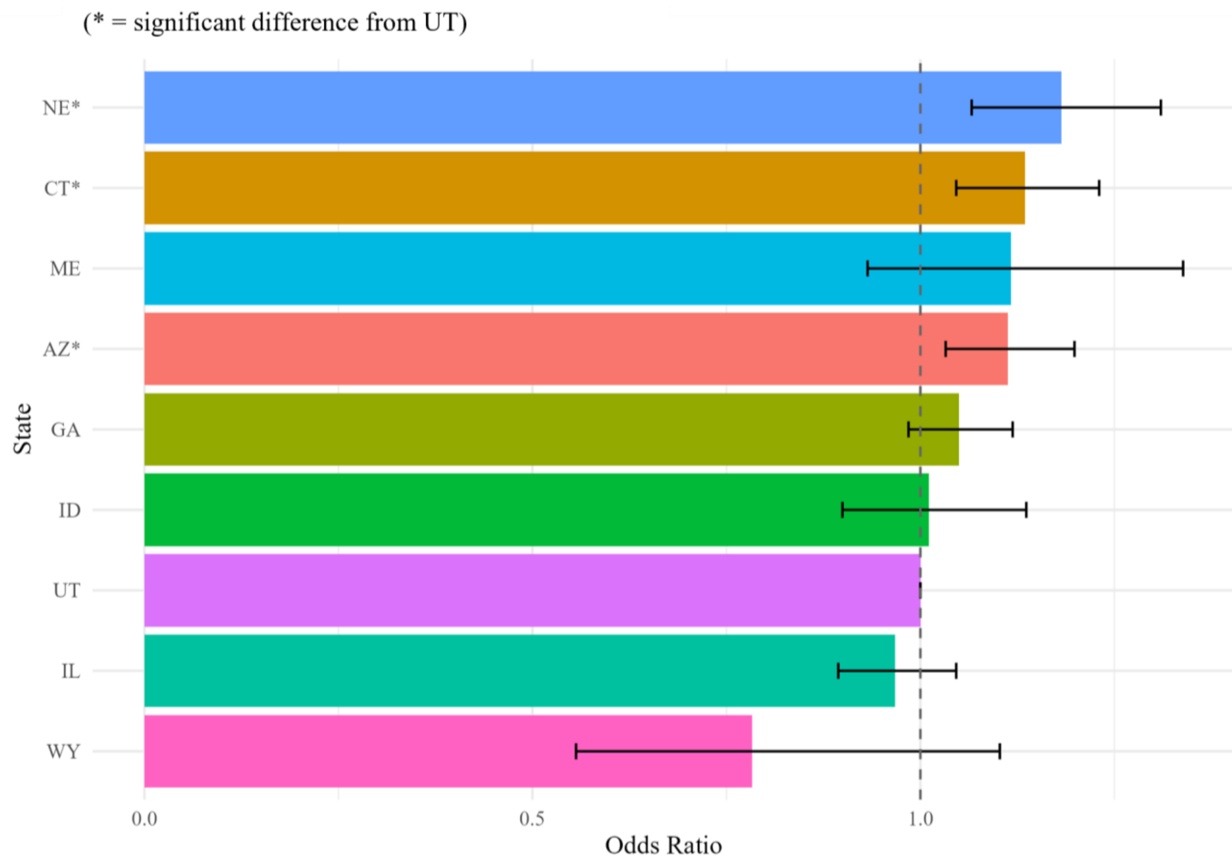


Figure E.11 KAB Odds Ratio: Cloudy Weather Conditions

<u>E.7.2 Rainy Weather Conditions</u>

Table E.10 displays the crashes that occurred in rainy conditions. Utah crashes that occur in rainy weather comprise 5 percent of all signalized intersection crashes, and 4 percent of both KAB and KA crashes. Illinois and Connecticut have the highest percentage at 10 percent, and Wyoming has the lowest percentage at 2 percent. The average percentage of all crashes in the rain amongst states is 6 percent, which is similar to the Utah data.

Table E.10 Comparison Table: Rainy Weather Conditions

Rain	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	5%	3%	2%	8%	4%	5%	9%	10%	10%	6%	-29%
KAB	4%	3%	4%	8%	4%	4%	9%	10%	10%	6%	-32%
KA	4%	2%	4%	12%	4%	5%	8%	8%	8%	6%	-35%

Data are recorded in crash view for all states

Figure E.12 displays the odds ratio for KAB crashes in rainy weather. Wyoming and Connecticut have higher odds of a KAB crash in rainy weather than in Utah and are statistically significant. Maine, Idaho, and Illinois also have higher odds of a KAB crash in rainy weather, but the results are inconclusive. Georgia, Arizona, and Nebraska have lower odds of a KAB crash in rainy weather, but the results are inconclusive.

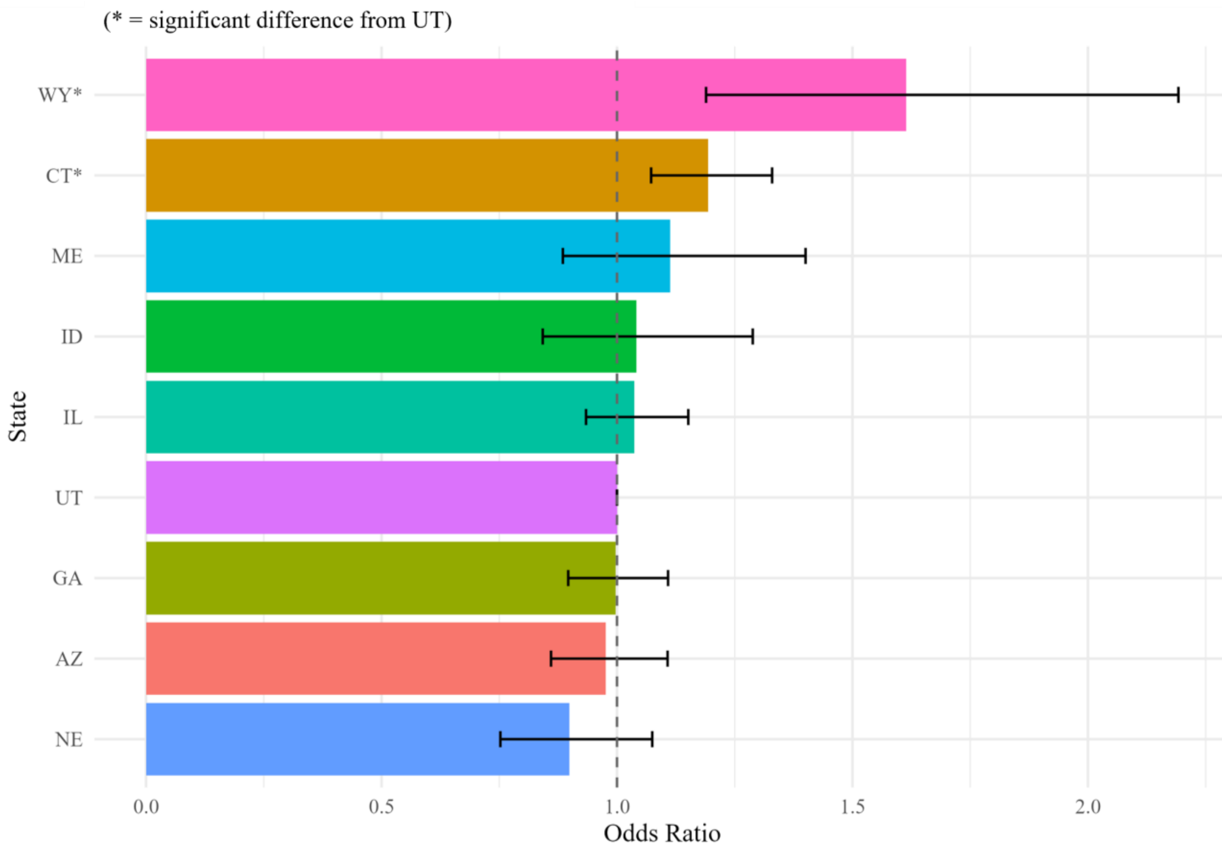


Figure E.12 KAB Odds Ratio: Rainy Weather Condition

E.7.3 Snowy Weather Conditions

Table E.11 displays the percentage of crashes that occurred in snowy conditions at signalized intersections. Utah crashes that occur in the snow comprise 4 percent of all signalized intersection crashes, 2 percent KAB crashes, and 1 percent KA crashes. Wyoming has the highest percentage at 15 percent, which is much higher than Utah. Arizona and Georgia naturally have the lowest percentage of crashes in snowy conditions as these states do not receive much snow. The average percentage of all crashes in snow is comparable to Utah data at 4 percent.

Table E.11 Comparison Table: Snowy Weather Conditions

Snow	UT	AZ	WY	ME	ID	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	4%	0%	15%	4%	3%	2%	0%	3%	1%	4%	26%
KAB	2%	0%	7%	2%	2%	1%	0%	1%	1%	2%	43%
KA	1%	0%	4%	1%	2%	1%	0%	1%	0%	1%	43%

Data are recorded in crash view for all states

Figure E.13 represents the odds ratios of KAB crashes that occurred in snowy weather for the different states. Of those observed, Connecticut and Illinois have higher odds of a KAB crash in snowy weather. Similarly, Wyoming has lower odds of a KAB crash in snowy weather. These states have statistically significant results while all other states' results are inconclusive.

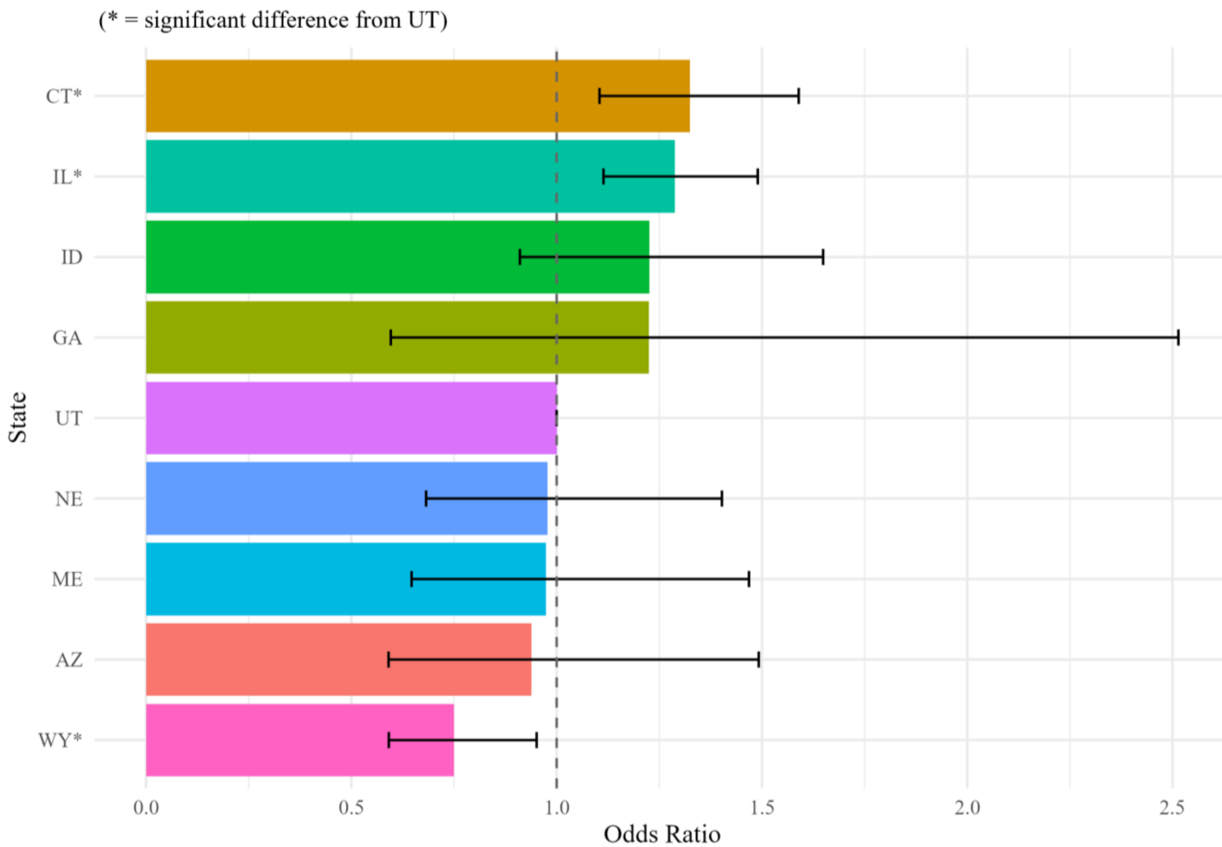


Figure E.13 KAB Odds Ratio: Snowy Weather Conditions

E.8 Other Manners of Collision

Other collisions such as sideswipe and head-on collisions are not common at signalized intersections in Utah. Although these collision manners do not contribute to many crashes in

Utah, a comparison was made to determine how these, and other, manners of collision affect other states. The following subsections will present the comparison tables and statistical analyses performed for sideswipe and head-on collisions. A heatmap displaying the proportion of KAB crashes for each manner of collision by state will also be presented to show how Utah compares to other states.

E.8.1 Sideswipe Collisions

Table E.12 displays the comparison table for same-direction sideswipe collisions. Sideswipe collisions in the same direction contribute to 7 percent of signalized intersection crashes and 2 percent of both KAB and KA crashes in Utah. Georgia and Connecticut recorded that 13 percent of signalized intersection crashes were same-direction sideswipe collisions. Nebraska and Wyoming recorded 3 and 4 percent, respectively. Excluding Utah, the average percentage of sideswipe collisions in the same direction amongst states is 8 percent, which is slightly higher than what is observed in Utah.

Table E.12 Comparison Table: Sideswipe Same Direction

Sideswipe Same Direction	**UT**	**AZ**	**WY**	**ID***	**NE**	**GA**	**IL**	**CT**	**AVG. (w/o UT)**	**%Δ**
KABCO	7%	10%	4%	7%	3%	13%	3%	13%	8%	-4%
KAB	2%	2%	0%	2%	1%	3%	1%	3%	2%	5%
KA	2%	2%	0%	3%	1%	2%	1%	2%	2%	18%

*ID reported data in vehicle view

Figure E.14 displays the odds ratio for KAB sideswipe crashes in the same direction. Since this field had multiple crash attributes, single-vehicle crashes were used as a baseline for the odds ratio analysis. Arizona, Nebraska, and Connecticut have higher odds that a sideswipe, same-direction crash will be KAB than Utah. Georgia, Illinois, and Wyoming have lower odds that this crash will be severity KAB compared to Utah. The results from Arizona and Wyoming are statistically significant.

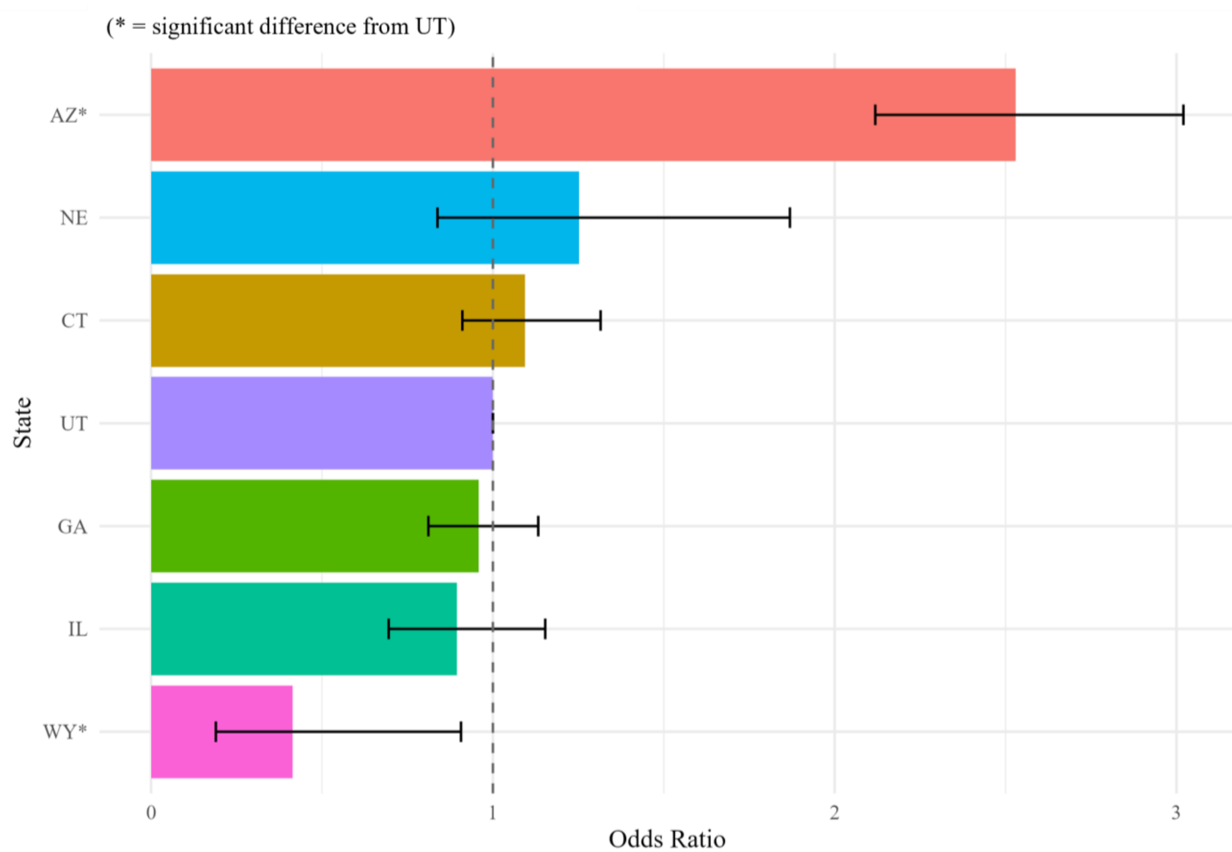


Figure E.14 KAB Odds Ratio: Sideswipe Same Direction

Table E.13 displays the comparison table for sideswipe opposite direction collisions. Sideswipe opposite direction collisions contribute to 1 percent of signalized intersection crashes on all levels analyzed in Utah. All the states analyzed observed between 0 and 2 percent of crashes were opposing-direction sideswipe collisions. This observation affirms that these crash types are not common amongst states and that they are not an area of concern.

Table E.13 Comparison Table: Sideswipe Opposite Direction

Sideswipe Opposite Direction	UT	AZ	WY	ID*	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	1%	1%	1%	1%	0%	2%	0%	2%	1%	-15%
KAB	1%	1%	0%	1%	0%	1%	0%	1%	1%	-15%
KA	1%	1%	0%	2%	0%	1%	0%	1%	1%	-7%

*ID reported data in vehicle view

Figure E.15 displays the odds ratio results for KAB sideswipe opposite direction collisions. Since this field had multiple crash attributes, single-vehicle crashes were used as a baseline for the odds ratio analysis. Arizona, Georgia, Connecticut, and Illinois have higher odds that a sideswipe, opposite-direction crash will be severity KAB compared to Utah. Nebraska and Wyoming have lower odds that a sideswipe, opposite-direction crash will be severity KAB when compared to Utah. The results from Arizona, Georgia, and Wyoming are statistically significant.

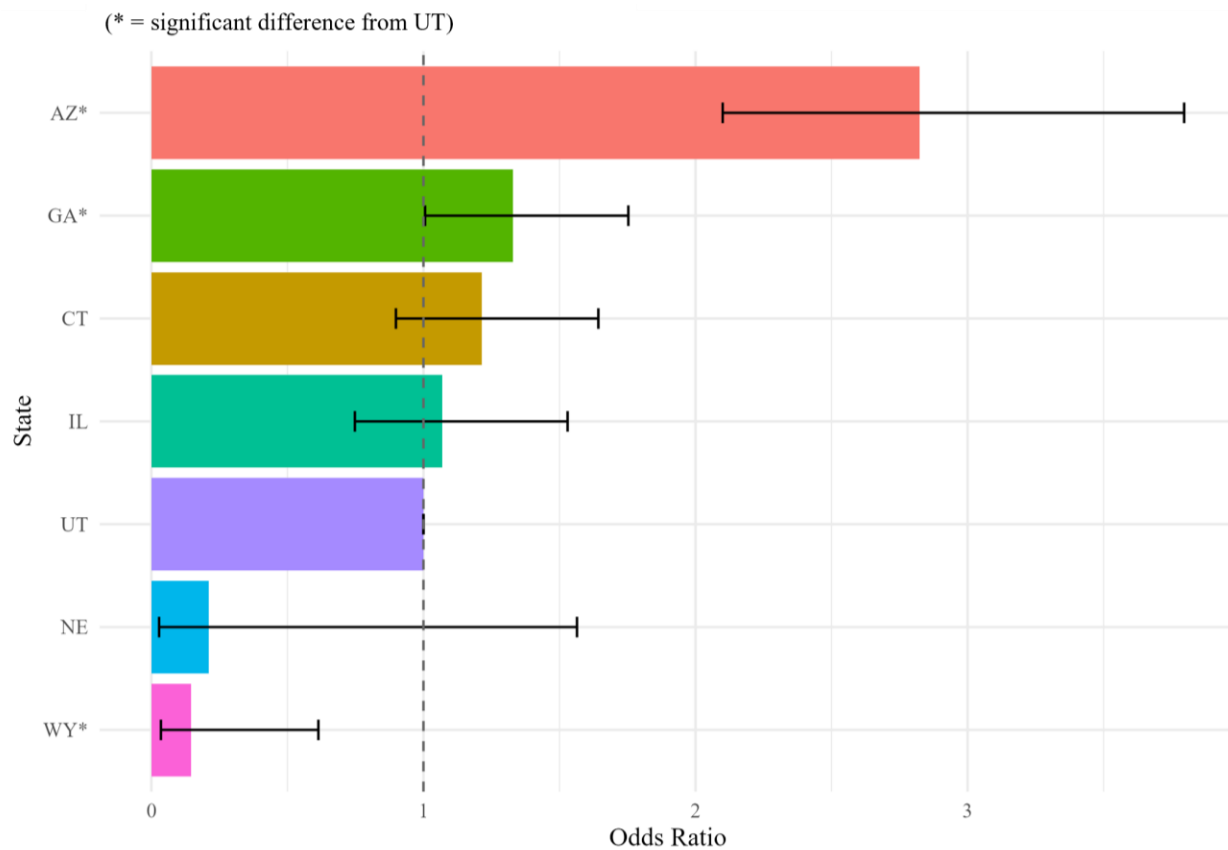


Figure E.15 KAB Odds Ratio: Sideswipe Opposite Direction

<u>E.8.2 Head-On Collisions</u>

Table E.14 displays the comparison table for head-on collisions. Head-on collisions contribute to 2 percent of signalized intersection crashes, 5 percent of KAB crashes, and 6 percent of KA crashes in Utah. None of the states observed more than 5 percent head-on collisions at signalized intersections. Wyoming observed the highest percentage of head-on collisions at 4 percent. Idaho observed the lowest percentage of head-on collisions at less than 1 percent on the KABCO level.

Table E.14 Comparison Table: Head-On Collisions

Head On	UT	AZ	WY	ID*	NE	GA	IL	CT	AVG. (w/o UT)	%Δ
KABCO	2%	2%	4%	0%	3%	3%	1%	2%	2%	23%
KAB	5%	3%	9%	1%	5%	8%	1%	4%	8%	-36%
KA	6%	4%	9%	2%	4%	10%	2%	5%	5%	10%

*ID recorded data in vehicle view while other states recorded data in crash view

Figure E.16 displays the odds ratio for KAB head-on collisions. Since this crash attribute had multiple fields, single-vehicle crashes were selected as the baseline for the odds ratio analysis. Arizona, Georgia, and Nebraska have statistically higher odds of a KAB head-on collision. Wyoming and Illinois had lower odds of a KAB head-on crash, but the results are inconclusive.

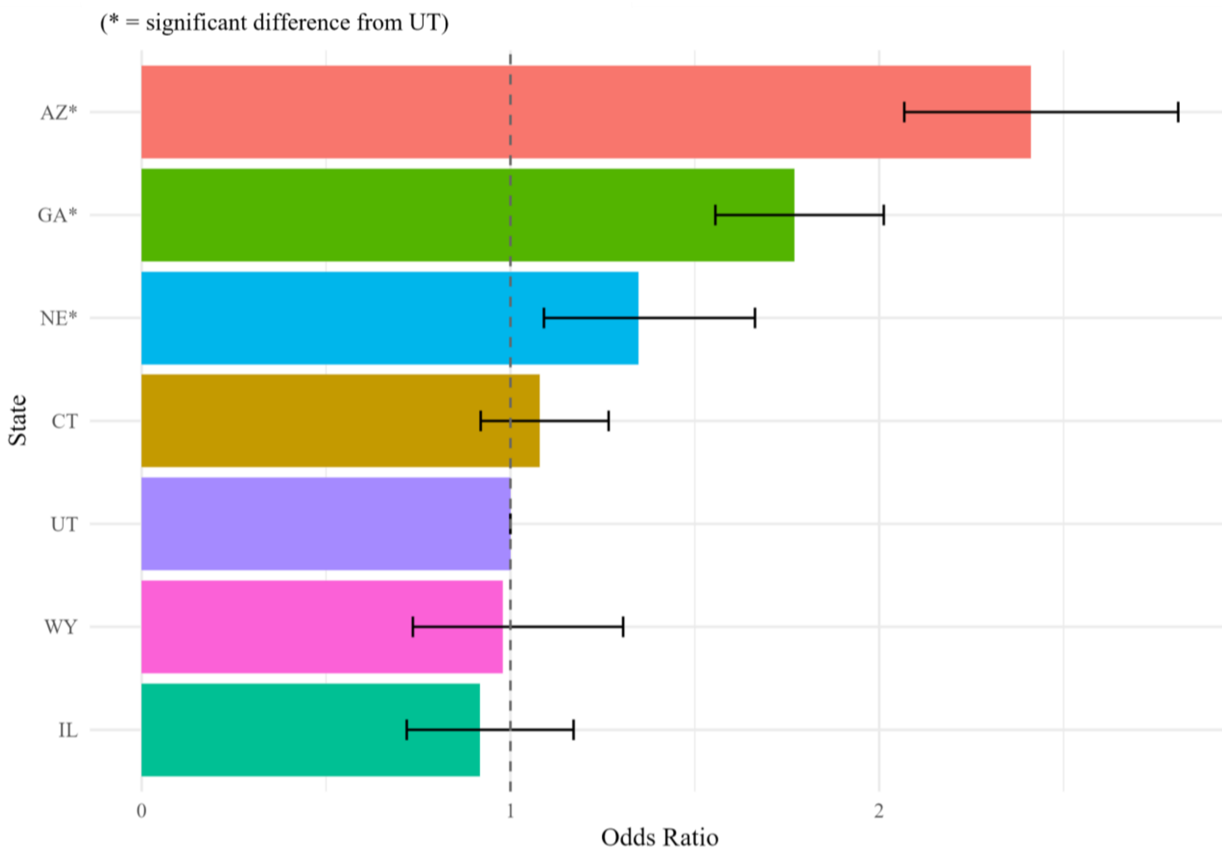


Figure E.16 KAB Odds Ratio: Head-On Collisions

E.8.3 Collision Manner Heatmap

Figure E.17 displays the heatmap comparing the proportion of KAB crashes for all the manners of collision fields amongst different states. This includes additional manner of collision fields not previously identified in this report, namely “Unknown,” “Other*,” “Rear to Rear,” “Rear to Side,” and “Not Applicable/Single Vehicle.” This information helps identify states that have a low proportion of severe crashes for a given manner of collision. Having this information helps identify which states to analyze more fully to determine best practices.

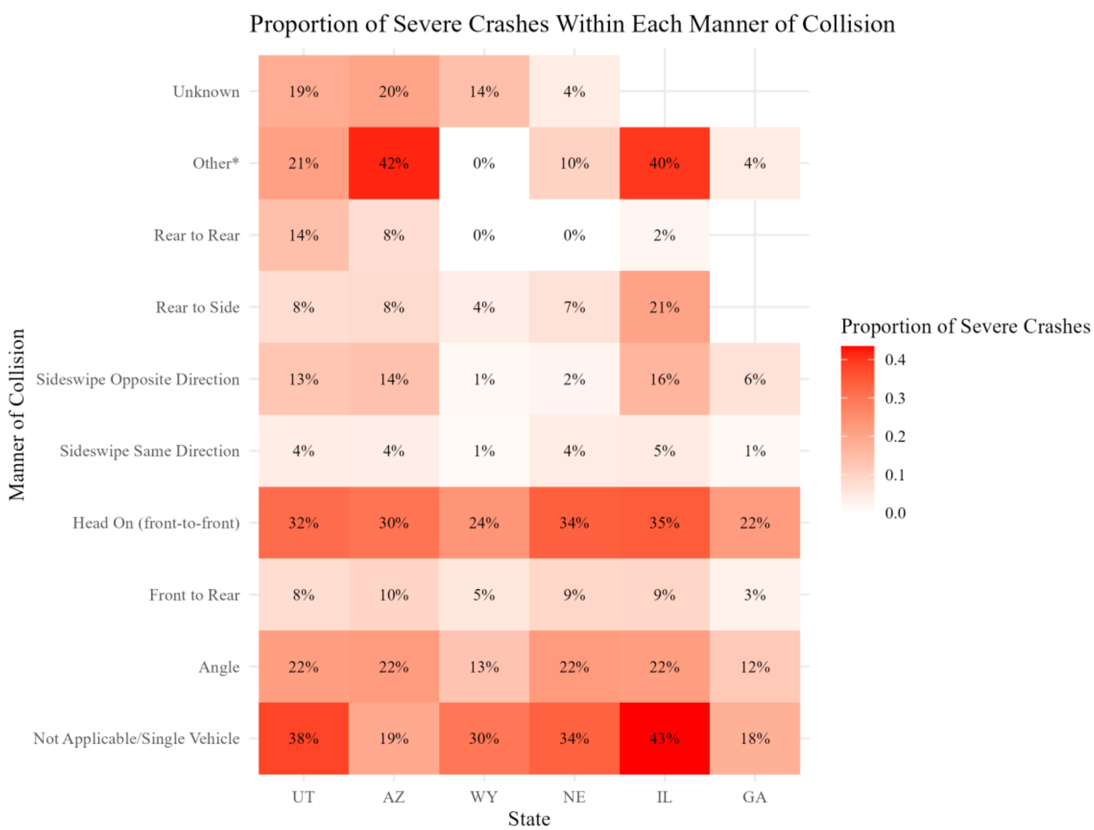


Figure E.17 Manner of Collision Heatmap

E.9 Other Contributing Factors

There are many factors that contribute to crashes at signalized intersections. Aggressive driving and DUIs were other factors of interest for this research. Aggressive driving represents about 1 percent of all signalized intersection crashes in Utah, but 11 percent of fatalities. DUIs represent 44 percent of Utah's fatal crashes at signalized intersections. The analysis for each of these factors will be presented in this section.

E.9.1 Aggressive Driving

Table E.15 summarizes the comparison table for aggressive driving. Georgia's aggressive driving data was originally recorded in the crash view with multiple entries as if it were person view. Since it was formatted as if it were person-view data, the information was extracted to reflect person-view crash percentages as seen from the other states. Excluding Utah, the average percentage of KABCO, KAB and KA crashes involving aggressive driving are 1 percent, 3 percent, and 7 percent, respectively. Utah falls beneath the average of the states for each severity analyzed. Wyoming has the highest reported aggressive driving for each of the states analyzed. Arizona had almost no reports of aggressive driving crashes.

Table E.15 Comparison Table: Aggressive Driving

Aggressive Driving	UT	AZ	WY	GA	CT	AVG. (w/o UT)	%Δ
KABCO	1%	<1%	3%	2%	<1%	1%	-33%
KAB	2%	<1%	8%	1%	1%	3%	-36%
KA	4%	<1%	17%	5%	6%	7%	-35%

Data are recorded in person view for all states

Figure E.18 presents the odds ratio for KAB aggressive driving crashes. Connecticut and Wyoming have higher odds of an aggressive driving crash being severity KAB compared to Utah. These results are statistically significant for both states. Arizona has lower odds, but the results are inconclusive. Although Georgia's comparison table data is in person view, this data was also not included in the odds ratio because it is written in crash view as a list of each person involved.

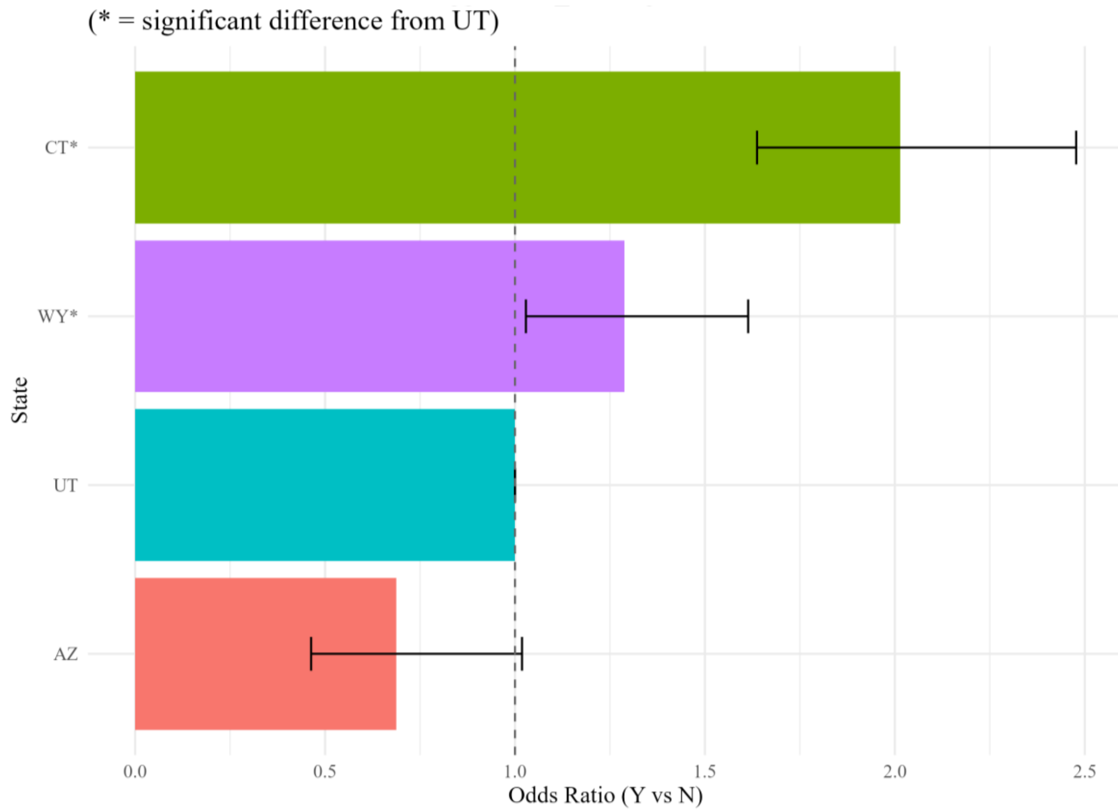


Figure E.18 KAB Odds Ratio: Aggressive Driving

E.9.2 Driving Under the Influence

Table E.16 displays the DUI comparison table. Georgia's DUI crash data was originally recorded in the crash view with multiple entries as if it were person view. Since it was formatted as if it were person-view data, the information was extracted to reflect person-view crash percentages as seen from the other states. DUI crashes represent 2 percent of all signalized intersection crashes in Utah. These numbers are higher when additional severity levels are considered, with DUI crashes representing 4 percent of KAB crashes and 8 percent of KA crashes.

Table E.16 Comparison Table: DUI

DUI	UT	AZ	WY	ME	ID*	NE*	GA	IL	AVG. (w/o UT)	%Δ
KABCO	2%	2%	7%	1%	2%	2%	1%	1%	2%	2%
KAB	4%	5%	21%	3%	4%	-	4%	2%	6%	-28%
KA	8%	13%	44%	4%	9%	-	5%	4%	12%	-33%

*ID and NE recorded data in vehicle view while other states recorded data in person view

Figure E.19 displays the odds ratio results for KAB DUI crashes. Based on the results, all states analyzed have higher odds of a DUI crash being severity KAB compared to Utah. Of those states, Wyoming and Connecticut have statistically significant results while the other states do not. Although Georgia's comparison table data is in person view, this data was also not included in the odds ratio because it is written in crash view as a list of each person involved.

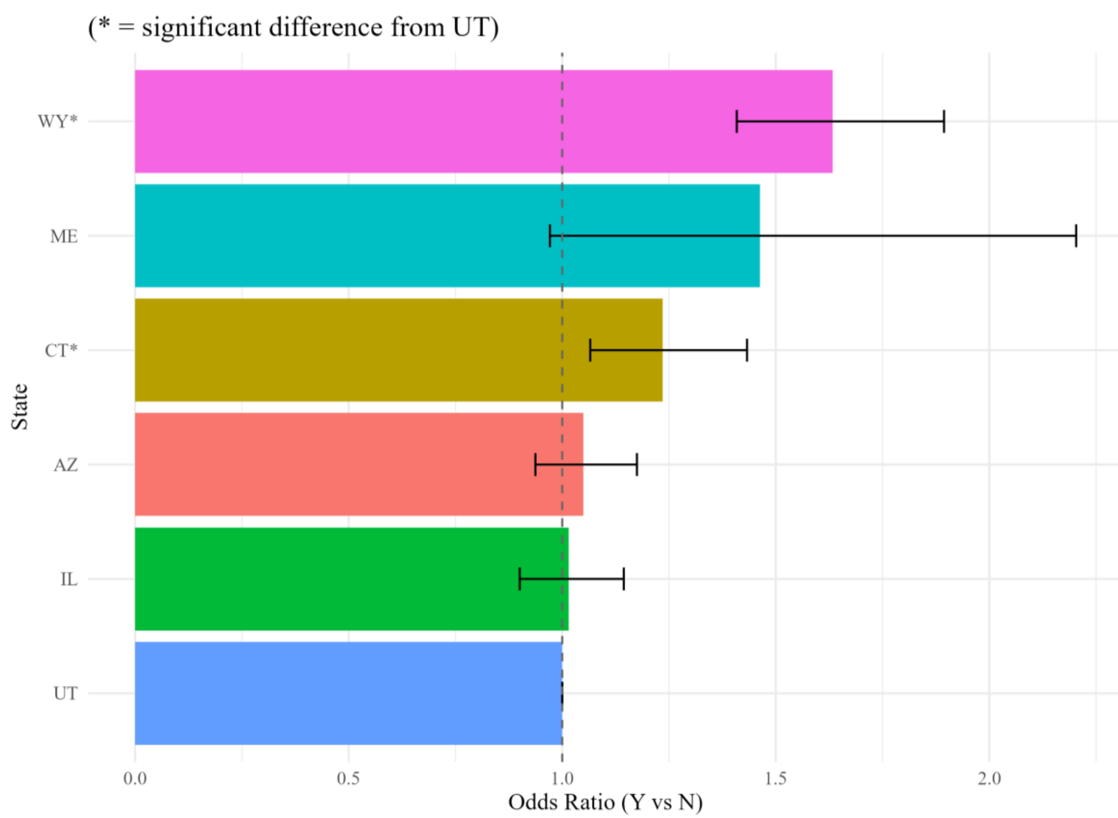


Figure E.19 KAB Odds Ratio: Driving Under the Influence