Engineering Countermeasures to Mitigate Reckless Driving Behavior

Final Report

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PennState

WisDOT ID no. 0092-24-11
06/05/2025

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<table>
<tr><td>1. Report No.
0092-24-11</td><td>2. Government Accession No.</td><td>3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Engineering countermeasures to mitigate reckless driving behavior</td><td>5. Report Date
06/24/2025</td></tr>
<tr><td>6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Author(s)
S. Ilgin Guler, Vikash V. Gayah, Yiqi Zhang, Xiaohan Gu</td><td>8. Performing Organization Report No.
If applicable, enter any/all unique numbers assigned to the performing organization.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
The Pennsylvania State University
218 Engineering Collaborative Research and Education (ECoRE) Building
556 White Course Drive
University Park PA 16802</td><td>10. Work Unit No.</td></tr>
<tr><td>11. Contract or Grant No.
0092-24-11</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Wisconsin Department of Transportation
Research & Library Unit
4822 Madison Yards Way Room 911
Madison, WI 53705</td><td>13. Type of Report and Period Covered
Final Report
August 2024-July 2025.</td></tr>
<tr><td>14. Sponsoring Agency Code</td></tr>
<tr><td colspan="3">15. Supplementary Notes</td></tr>
<tr><td colspan="3">16. Abstract
This project aimed to enhance understanding of the role of reckless driving in traffic safety on Wisconsin roadways and to identify effective countermeasures to mitigate its impact. Reckless driving was defined as crashes involving the following four behaviors: speeding, distracted/drowsy driving, impaired, and aggressive driving. The research began with an extensive literature review focused on engineering-based strategies to address reckless driving, providing insight into their applicability by context and setting. Drawing from this review, the team identified specific countermeasures relevant to Wisconsin's roadway environment. Then, using crash, roadway, and public health data from across the state, the team developed negative binomial (NB) regression models to estimate the risk of the four types of reckless driving-related crashes on various roadway segments. Key findings indicate that average annual daily traffic (AADT) and segment length are positively associated with crash frequencies, while higher posted speed limits and wider shoulders are linked to reduced crash risk. These predictive models were integrated into a network screening tool designed to identify high-risk locations for reckless driving activity. The tool and associated findings offer a data-driven foundation for prioritizing safety interventions, improving resource allocation, and supporting targeted efforts to reduce reckless driving crashes in Wisconsin.</td></tr>
<tr><td colspan="2">17. Key Words
Reckless drivers, crash analysis, countermeasures, high risk locations</td><td>18. Distribution Statement
No restrictions. This document is available through the National Technical Information Service.
5285 Port Royal Road
Springfield, VA 22161</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages
107

22. Price</td></tr>
</table>

DISCLAIMER

This research was funded by the Wisconsin Department of Transportation and the Federal Highway Administration under Project 0092-24-11. The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Wisconsin Department of Transportation or the Federal Highway Administration at the time of publication.

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Executive Summary

Background

Despite great advancements in vehicle technology and infrastructure, reckless driving remains a significant risk to the safety of roadways. As defined by the National Highway Traffic Safety Administration (NHTSA), reckless, or risky, driving consists of ***speeding, drunk or drug- drowsy or distracted driving, impaired,*** and ***aggressive***. This project sought to enhance understanding of reckless driving, identify engineering-focused countermeasures to mitigate its impact, and identify locations most likely to experience reckless driving crashes in Wisconsin. The study was structured in three phases: an extensive literature review, stakeholder interviews, and the development of data-driven crash risk models.

The literature review synthesized national findings on countermeasures such as dynamic speed feedback signs, rumble strips, high-tension cable barriers, and infrastructure adjustments like road diets and traffic calming features. These interventions were evaluated using crash modification factors (CMFs), simulations, and empirical studies.

Interviews with stakeholders—including state department of transportations (DOTs), insurance companies, and vehicle manufacturers—provided insight into practical challenges and innovative solutions. These included automated speed enforcement systems, intelligent speed assistance (ISA), and in-vehicle drowsiness alerts. Notably, state DOTs reported success with variable speed limits, safety corridors, rumble strips, and public awareness campaigns.

The research team also developed statistical models using Wisconsin-specific crash, roadway, and public health data. These models predict the likelihood of reckless driving crashes on various roadway types and have been integrated into a network screening tool. This tool can enable Wisconsin DOT (WisDOT) to prioritize high-risk locations for targeted intervention.

Data and Methodology

The modeling framework uses crash data from Wisconsin between 2017 and 2021. Crashes flagged with contributing factors such as speeding, distracted/drowsy, impaired, and aggressive driving behavior influence were categorized as reckless. Data were enriched with roadway characteristics (e.g., number of lanes, shoulder width, posted speed). Negative Binomial (NB) regression models were employed to handle the count nature of crash data and to account for overdispersion present in crash data.

Key Findings

The relationships between roadway characteristics and reckless driving crash risks vary depending on roadway categories and reckless driving types. Across all roadway segments, factors that are generally associated with increased aggressive driving related crash risks include:

- Vehicular traffic volume (e.g., AADT)
- Roadway segment length

Factors that are generally associated with increased speeding-related crash risks include:

- Vehicular traffic volume (e.g., AADT)
- Roadway segment length
- Roadways with more lanes

Factors that are generally associated with reduced speeding-related crash risks include:

- Average shoulder width or the existence of shoulders
- Roadway segments with higher speed limits

Factors that are generally associated with increased distracted driving related crash risks include:

- Vehicular traffic volume (e.g., AADT)
- Roadway segment length
- Roadways with wide lane widths

Factors that are generally associated with reduced distracted driving related crash risks include:

- Average shoulder width or the existence of shoulders
- Roadway segments with higher speed limits

Factors that are generally associated with increased impaired driving related crash risks include:

- Vehicular traffic volume (e.g., AADT)
- Roadway segment length
- Roadways with more lanes

Factors that are generally associated with reduced impaired driving related crash risks include:

- Average shoulder width or the existence of shoulders
- Roadway segments with higher speed limits

Finally, factors that are generally associated with reduced aggressive driving related crash risks include:

- Average shoulder width or the existence of shoulders
- Roadway segments with higher speed limits

Implications

It is recommended that WisDOT prioritize network screening efforts at roadway segments with high crash risks, particularly those characterized by high traffic volumes, wide lanes, and a greater number of through lanes, which are often associated with increased reckless driving crash frequency. Targeted countermeasures should be considered at these locations, including the installation of medians, shoulder widening, and traffic calming treatments to help regulate speed and reduce aggressive maneuvers. These strategies can contribute to improving roadway safety and reducing reckless driving crash frequencies.

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INTRODUCTION

Despite great advancements in vehicle technology and infrastructure, reckless driving remains a significant risk to the safety of roadways. As defined by the National Highway Traffic Safety Administration (NHTSA), reckless, or risky, driving consists of ***speeding, drowsy or distracted driving*** or ***drunk or drug-impaired driving***. According to WisDOT 2022 year-end crash statistics, there were 17,895 speed-related crashes, 29,237 distracted driving related crashes, and 7,048 impaired driving related crashes, which accounted for 13.9%, 22.7% and 5.5% of all crashes in the state, respectively. These reckless driving behaviors place a significant burden on individuals, families and society.

The goals of this project were to provide an overall understanding of the role of reckless driving on the safety of Wisconsin roadways and identify safety-related countermeasures that can help reduce the impact of this safety risk in Wisconsin. First, detailed literature review on engineering-related countermeasures to provide more insight into how, when and where countermeasures to mitigate reckless driving behavior can be used was conducted. Then, specific countermeasures that were noted in the literature that could reduce reckless driving on Wisconsin roadways were identified. Finally, research team obtained roadway, crash and public health data from Wisconsin to support the development of statistical models to predict the occurrence of various types of reckless driving crashes on various roadway facilities throughout the state. These models were then integrated into a network screening tool that can be used to identify locations with the highest risk of reckless driving activity in the state. This report summarizes the findings of the project.

LITERATURE REVIEW

Distracted driving – defined as "the diversion of attention away from activities critical for safe driving toward a competing activity" (Lee et al., 2008) – was observed in nearly a quarter of all crashes and is the most common type of risky driving on Wisconsin roadways. This is not unique to Wisconsin: according to NHTSA, distracted driving generally accounts for 8-9% of all fatalities annually in the United States (U.S.). Beyond the fatal outcomes, distracted driving is also a highly prevalent behavior; e.g., a recent survey on distracted driving found that almost 60% of drivers use their cellphones while driving (Hill et al., 2018).

There are various countermeasures that can be used to mitigate risky driving behaviors. According to NHTSA's *Countermeasures That Work* (Venkatraman, 2021), engineering-related countermeasures aimed at reducing speeding and crashes caused by speeding include setting appropriate speed limits, using warning signs to alert drivers, and using appropriate geometric design to slow vehicles. Recommended countermeasures that aim at reducing distracted driving are general driver licensing requirements for beginner drivers and high-visibility cell phone/text messaging enforcement, which are not engineering-related and are not proven to be effective (Venkatraman, 2021). Similarly, general strategies that are used to reduce crashes involving impaired driving are not usually engineering-related, they are more focused on: deterrence, prevention, communications and outreach, and alcohol and drug treatment.

In general, the problem of reckless driving can be approached in two ways: 1) reduce the frequency of reckless driving behavior itself; or, 2) reduce the impacts of the reckless driving activities (e.g., even if a person is driving distracted, implementing measures to lower the likelihood of crashes or reduce injury severity when crashes occur). The literature review is broken into different sections for the different types of reckless driving behaviors, and both potential types of countermeasures are discussed. Note that while aggressive driving is also included in the general umbrella of reckless driving activities, specific countermeasures were not included for aggressive driving as it is typically defined as a combination of some of the other reckless driving-related activities.

After the literature review summary, interviews conducted with insurance companies, state department of transportations (DOTs) and vehicle manufacturers to identify countermeasures are discussed. Finally, a summary of the findings of the literature review and interviews is presented.

Speeding

<u>Definition of Speeding and Suggested Countermeasures</u>

NHTSA defines a crash to be speeding-related if any involved driver is charged with a speeding-related offense or the police report of the crash indicates that speeding is a contributing factor to the crash (e.g., the driver is either racing or driving too fast for the condition or driving faster than the posted speed limit) (Venkatraman et al., 2021). Though the percentages of fatal vehicular crashes caused by speeding started to decrease since 2009 in the US (31%), it has recently increased from 26% in 2018 to 29% in 2022 (NHTSA; Venkatraman et al., 2021). Younger male drivers, alcohol use, the lack of seat belt usage, drivers who are not properly licensed, and nighttime driving are the common risk factors identified by existing studies that are associated with speeding (Venkatraman et al., 2021).

FHWA's *Proven Safety Countermeasures* (2021) includes the following engineering-related countermeasures that can be considered for speed management: speed safety cameras, variable speed limits, and appropriate speed limits for all road users. *Countermeasures that Work* (2021) further identifies the following as effective engineering-related speeding countermeasures: enforced and obeyed speed limits and automated speed enforcement (speed cameras). Besides the countermeasures recommend by FHWA, some existing studies recommend speed management countermeasures such as dynamic speed feedback signs, roadside vegetations, speed limit change, portable plastic rumble strips, and peripheral transverse lines.

Some of the countermeasures, including speed limits and automated speed enforcement have reliable and high-quality crash modification factors (CMFs). Table 1 shows selected high-quality[1] CMFs for speeding countermeasures and speed management. Here, any countermeasure with a CMF star rating of 3 or above was considered high-quality. This table also shows the Crash Reduction Factor (CRF), the crash types that the countermeasure could target, the crash severity that the countermeasure would target (K: Fatal, A: Incapacitating, B: Non-incapacitating, C: Not visible but complains of point, O: Other), the area in which the countermeasure could be implemented, along with the star rating and ID from the CMF clearinghouse.

Countermeasures such as installing changeable speed warning signs and using speed restriction devices have higher CMFs for reducing vehicle operating speed, but do not have very high quality. Lowering speed limits has lower CMFs but they are of higher quality and are more suitable for urban roadways while installing dynamic speed feedback signs is a high quality but less effective countermeasure for speed management on rural roadways.

Table 1. CMFs of Selected Recommended Speeding Countermeasures

Category	CMF	CRF(%)	Crash Type	Crash Severity	Area Type	Rating	ID
Automated Speed Enforcement Related							
Implement automated speed enforcement cameras	0.878	12.18	All	K, A, B, C	All	4 star	10656
Implement mobile automated speed enforcement system	0.799	20.1	All	K, A, B, C	Urban	5 star	7582
Speed Limits Related							
Install changeable speed warning signs for individual drivers	0.540	46	All	All	NA	3 star	78
Presence of speed restriction devices (bike crashes)	0.280	71.92	Vehicle/Bicycle	All	NA	3 star	2198
Decreasing posted speed limit on expressways	0.855	14.4	All	All	NA	4 star	2928
Lower posted speed from 90 km/h to 70 km/h	0.670	33	All	K, A, B, C	Urban	5 star	4179
Lower posted speed limit from 50 kph to 40 kph	0.740	26	All	All	Urban	4 star	8076
Speed Management							
Install dynamic speed feedback sign	0.95	5	All	All	Rural	4 star	6885

1 The star quality rating was taken from CMF clearinghouse, they indicate the quality or confidence in the results of the studies that produced the CMFs. The star rating is based on a 1 to 5 scale, where a 5 indicates the relatively highest quality rating. See details from https://cmfclearinghouse.fhwa.dot.gov/sqr.php.

Methods and Models for Testing Effectiveness of Speeding Countermeasures

There are several other research studies that have considered speeding countermeasures that are not included in the CMF clearinghouse. These eleven reports and research papers on speeding-related countermeasures[2] were reviewed to understand whether and what countermeasures were effective in combating speeding. In general, studies that examined the effectiveness of speeding countermeasures usually observed the differences in speed changes or the number of crashes before and after the implementation of certain countermeasures in a real world or using simulated scenarios at different levels.

These studies considered several countermeasures that were implemented in the real-world: Perceptual Countermeasures (PCMs) (e.g., peripheral transverse lines) at selected curves and intersections (Fildes et al., 2005); portable plastic rumble strips (PPRS) on four-lane two-way rural and urban roadways (Yang et al., 2015); driver feedback signs (DFS) in several Canadian cities (Wu et al., 2020); statewide pavement projects for targeted speed management countermeasures (Gangireddy et al., 2024); and, speed limit changes (Anderson & Monsere, 2022; Gayah et al., 2018; Saleem & Srinivasan, 2023). Additionally, several countermeasures were evaluated in simulations: roadside vegetations in transition areas to mitigate speeding (Jiang et al., 2024); work zone specific speeding countermeasures (Sommers & McAvoy, 2013); two-step posted speed reduction in school zones (Valdés-Díaz et al., 2020). Others examined crash characteristics that are related to speeding driving behavior (Monsere et al., 2006). Table 18 in Appendix A summarizes the statistical methods used to study the effectiveness of speeding reduction countermeasures.

[2] The 11 papers included in this section do not contain any that examined the use of automated speeding cameras. A separate discussion for studies that considered automated speeding cameras is presented at the end of this section.

Data sources and variables employed

Depending on the scope of the projects and the examined countermeasures, existing studies usually included crash data (e.g., number of crashes and crash injury severity levels) and roadway characteristics (e.g., AADT, degree of curvature, lane width, presence of passing zone, median type, and speed limits) to examine under what circumstances and how effective countermeasures are at reducing speeding, the number of crashes related to speeding or lowering the injury severity level of crashes related to speeding. For smaller projects or projects that are specifically designed for a certain countermeasure, besides crash data and roadway characteristics, video data or recorded simulation results were used to assess the effectiveness of countermeasures. For the dependent variables, some of the studies used the number of crashes expected to be reduced after the implementation of certain countermeasures while others compared the before and after mean and 85th percentile speeds, vehicle braking distance, and lateral displacement. Several studies also used research specific variables to investigate the effectiveness of certain countermeasures.

Findings

This section describes the findings on the effectiveness of speed-related countermeasures from existing studies and reports reviewed for this study. Studies that examined the effects of changing posted speed limits have found that reducing speed limits at different levels has various impacts on the change in speed and speed compliance, as well as the reduction of crash frequencies and severity levels. Gayah et al. (2018) found that setting the posted speed limits 5mph lower than engineering recommended practices can help reduce crash frequencies of all injury severity levels and property damage only (PDO) crashes. This study also found that though heavy police enforcement is positively related to the reduction in the mean and 85th percentile operating speeds, the larger the differences between the engineering recommended and posted speed limits, the lower speed limit compliance (Gayah et al., 2018). Anderson & Monsere (2022) also found that highways and interstates with increased speed limits would result in more vehicles operating at higher speeds, higher percentages of high-speed vehicles that are usually involved in crashes of higher injury severities, as well as increased crash frequencies in total crashes and crashes with more serious injuries, with significantly higher crash frequencies on rural two-lane highways than interstates. Another study further confirms that when the posted speed limit increases (from 55mph to 60mph on two-lane, two-way roads), crash frequencies of total crashes and the mean operating speed increase, but it does not have statistically significant impacts on injury crashes or the 85th percentile operating speed (Saleem & Srinivasan 2023).

Other studies have examined non-speed limit-based countermeasure implementations and their effectiveness in reducing vehicle operating speeds. Using field data from Australia, Fildes et al. (2005) found that installing peripheral transverse lines at intersections does not have significant impacts on short- or long-term operating speed reduction; however, enhanced post-spacing with ascending heights at road curves can help reduce vehicle operating speed in the long term. In rural community speed transition zones, Yang et al. (2015) found that implementing portable plastic rumble strips (PPRS) can help reduce mean speed, 85th percentile speed, and increase the speed limit compliance rate on four-lane two-way rural and urban roadways. Various feedback signs have also been tested in different studies to examine their effectiveness on speed reduction. Driver feedback signs (DFS) in are found effective in reducing the number of crashes and the number of speed-related crashes with more severe injuries in Canada (Wu et al., 2020). When implementing low-cost pavement speed management countermeasures, Gangireddy et al. (2024) found that while pavement preservation projects appear to increase speed during and after, radar speed feedback signs (RSFS) can help reduce crash risk during pavement preservation construction on rural collectors.

Studies also examined the effectiveness of certain speed management countermeasures via driving simulations. Jiang et al. (2024) found that spacing bushes of different sizes and narrow lane widths can help reduce the average speed on arterial roadways while only small spacing bushes and narrow lane widths can help reduce the average speed on highway exit ramps. Sommers & McAvoy (2013) tested the effectiveness of countermeasures that help reduce the speed of vehicles when they travel through work zones and found that the most effective work zone speeding countermeasure is the presence of workers while the least effective one is 3 sets of 3 rumble strips. Lastly, Valdés-Díaz et al. (2020) tested two-step posted speed reduction (an initial reduction sign to prepare drivers for the upcoming speed limit change and a final reduction near schools with a lower target speed) and found reduced mean speed, 85th percentile speed, as well as increased speed compliance. Table 2 summarizes the relationships between crash frequencies, speeding related variables, and the related explanatory variables.

Table 2. Summary of Findings of Speed-related Countermeasure Studies[3]

Countermeasure	Variable	Impact	Reference
Peripheral transverse lines (at intersections)	Speed	Long term (NS) Short term (NS)	Fildes et al., 2005
	Vehicle braking distance	Long term (NS) Short term (NS)	Fildes et al., 2005
Enhanced post-spacing with ascending heights (at road curves)	Speed	Long term (-) Short term (NS)	Fildes et al., 2005
	Vehicle braking distance	Long term (NS) Short term (NS)	Fildes et al., 2005
Radar speed feedback signs (RSFS)	Number of crashes	During pavement projects and two years within project completion (-)	Gangireddy et al., 2024
Roadside vegetations on arterial roads	Average speed	Large spacing bush (-) Small spacing bush (-) Hedge (NS) Narrow lane width (-)	Jiang et al., 2024
	Brake pedal press	Large spacing bush (NS) Small spacing bush (NS) Hedge (NS) Narrow lane width (NS)	Jiang et al., 2024
	Lane position	Large spacing bush (NS) Small spacing bush (NS) Hedge (NS) Narrow lane width (NS)	Jiang et al., 2024
Roadside vegetations on highway exit ramps	Average speed	Large spacing bush (NS) Small spacing bush (-) Hedge (NS) Narrow lane width (-)	Jiang et al., 2024
	Brake pedal press	Large spacing bush (NS) Small spacing bush (NS) Hedge (NS) Narrow lane width (NS)	Jiang et al., 2024
	Lane position	Large spacing bush (NS) Small spacing bush (+) Hedge (NS)	Jiang et al., 2024

3 "-"denotes a negative relationship, "+" denotes a positive relationship, "NS" indicates that the relationship is not statistically significant, and "LE" means less or least effective.

Countermeasure	Variable	Impact	Reference
		Narrow lane width (NS)	
Portable plastic rumble strips	Mean speed and 85th percentile speed	(-)	Yang et al., 2015
	Braking Rate	(+)	Yang et al., 2015
	Speed limit compliance rate	(+)	Yang et al., 2015
Driver feedback signs (DFS)	Number of Crashes and number of severe speed-related crashes	(-)	Wu et al., 2020
Two step speed reduction combination	Mean speed and 85th percentile speed	(-)	Valdés-Díaz et al., 2020
	Speed compliance	(+)	Valdés-Díaz et al., 2020
Higher speed limits	Average speed change	(+)	Anderson & Monsere, 2022
	Number of crashes and number of crashes with higher severity	(+)	Anderson & Monsere, 2022; Saleem & Srinivasan, 2023
	Mean speed	(+)	Saleem & Srinivasan, 2023
Lower speed limits than engineering recommendations	Number of crashes	(-)	Gayah et al., 2018
Differences in posted speed limits and engineering recommended speed limit	Speed compliance	(-)	Gayah et al., 2018
At work zone: Speed photo enforcement Highway work zone billboard Sequential flashing lights Dynamic message signs Optical speed bars Emergency flasher traffic control device Lane reduction Speed trailer Rumble strips Variable speed limit sign Changeable message sign Concrete barriers	Speed	(-)	Sommers & McAvoy, 2013

The effectiveness of automated speed enforcement (ASE) has been investigated and examined in different states. Chan & Lee (2010) found that through field experiments in California, ASE can help reduce vehicle operating speed, but their performances vary between different types of devices and locations. Cunningham et al. (2008) examined the ASE performances in Charlotte, North Carolina and found that ASE are to reduce vehicle operating speed and crashes in corridors. Researchers in Canada also investigated the effectiveness of ASEs and found that ASEs can help reduce crashes of all severity levels, especially crashes with higher injury severities (Li et al., 2016).

Distracted and Drowsy Driving

Definition of Distracted and Drowsy Driving and Suggested Countermeasures

NHTSA defines distracted driving as things that divert the driver's attention from the primary tasks of navigating the vehicle and responding to critical events (e.g., visual distraction, cognitive distraction, and manual distraction) (Venkatraman et al., 2021). In the US, distracted driving is a serious traffic safety issue that endangers both the driver and users of the road (NHTSA; Venkatraman et al., 2021).

Drowsy driving is usually related to impaired cognition and performance that may lead to motor vehicle crashes or traffic accidents and is typically related to fatigued driving (NHTSA). Distracted and drowsy driving are difficult to observe and hence difficult to enforce. However, many drivers admit they would frequently engage in these behaviors when they are behind the wheel (Venkatraman et al.;2021).

FHWA's *Proven Safety Countermeasures* (2021) identifies and recommends longitudinal rumble strips and stripes and SafetyEdge[4] as effective engineering-related countermeasures that alert distracted or drowsy drivers about lane departure and potentially reduce the impact of crashes caused by distracted or drowsy drivers.

Countermeasures that Work (2021) does not have engineering-related countermeasures that can be implemented for reducing distracted driving behavior; however, they do mention the following laws and enforcement countermeasures that are relatively effective: GDL[5] requirements for beginner drivers and high-visibility cellphone/text messaging enforcement.

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4 SafetyEdge is a technology that shapes the edge of the pavement at approximately 30 degrees from the pavement cross slope during the paving process. By doing so, it can help give drivers the opportunity to safely return to their travel lane while maintaining control of their vehicle when they are off the travel lane. See https://highways.dot.gov/safety/proven-safety-countermeasures/safetyedgesm.

5 Graduated driver licensing, a three-phase system for beginner drivers consisting of a learner's permit, a provisional license, and a full license. See Venkatraman, V., Richard, C. M., Magee, K., & Johnson, K. (2021). *Countermeasures that work: A highway safety countermeasure guide for state highway safety offices*. https://doi.org/10.21949/1526021.

Existing research studies also examined vehicle-related measures that can help alert distracted drivers; examples include truck rear signaling and motorcycles with higher visibility. Most in-vehicle alert technologies aim at reducing drowsy driving by detecting drivers' levels of drowsiness and alerting them about taking a break after driving for a long time. Table 3 shows the recommended high-quality CMFs for distracted and drowsy driving. In most cases, different types of rumble strips are moderately effective and high-quality countermeasures in rural areas that can reduce run off road crashes. Installing centerline rumble strips on roadways with existing should rumble strips can be more effective at reducing run off road crashes, but the quality of this CMF is relatively low.

Table 3. CMFs of Recommended Distracted and Drowsy Driving Countermeasures

Category	CMF	CRF(%)	Crash Type	Crash Severity	Area Type	Rating	ID
Roadway rumble strips and stripes							
Install centerline and shoulder rumble strips	0.702	29.8	Run off road	All	Rural	5 star	6974
Install centerline rumble strips	0.831	16.9	All	All	Rural	5 star	10372
Install centerline rumble strips on roads with existing shoulder rumble strips	0.554	44.6	Head on, Run off road, Sideswipe	All	Rural	2 star	5300
Install edgeline rumble strips	0.670	33	Run off road	K, A, B, C	Rural	5 star	3394
SafetyEdge							
Install safety edge treatment	0.591	40.9	All	K, A, B, C	Rural	5 star	4322

Note: CRF (%) is the crash reduction factor which equals to 1-CMF.

<u>Methods and Models for Testing Effectiveness of Distracted and Drowsy Driving Countermeasures</u>

Reports and research papers on distracted and drowsy driving countermeasures that are not included in the CMF clearinghouse were also reviewed. In general, studies that examined the effectiveness of distracted and drowsy driving countermeasures considered crash types that are caused by distracted or drowsy driving and how related countermeasures can reduce the crash frequency of these types of crashes using statistical methods. Others tested how specific infrastructure and vehicle-related countermeasures can help reduce the distracted or drowsy driving behavior itself. Countermeasures studied in the literature include centerline rumble strips (Ahmed et al., 2022), driving distracted advisory (DDA) (Rahman & Kang, 2020), rest areas (Kang et al., 2015)), rear signaling to reduce distracted truck following (Schaudt et al., 2013), detecting in-vehicle driving fatigue (Hickman et al., 2016), the effectiveness of in-vehicle detection and alerting (Gaspar et al., 2017, 2023), and ways to improve motorcycle visibility to distracted drivers (Jenness et al., 2011).

Surveys and literature reviews were also conducted to understand and review how different road users and stakeholders perceive the effectiveness of such countermeasures, as well as how they were evaluated by different studies (Ahmed et al., 2015). Others have examined how the duration of distraction is related to crashes (Ahmad et al., 2023). Table 19 in Appendix A summarizes the statistical methods used to study the effectiveness of countermeasures that target distracted and/or drowsy driving behavior.

Data sources and variables employed

Depending on the scope of the projects and the examined countermeasures, existing studies usually included crash data (e.g., number of crashes and crash injury severity levels) and roadway characteristics (e.g., presence of rest areas, presence of signage with warning messages, presence of lanes, median presence, and road surface condition) to examine under what circumstances and how effective countermeasures are at reducing distracted driving, the number of distracted and/or drowsy driving crashes or lowering the injury severity level of these crashes. For vehicle-related or in-vehicle countermeasures that are specifically designed for detecting or warning distracted or drowsy driving behavior, besides crash data and roadway characteristics, video data or recorded simulation results were used. For the dependent variables, some of the studies used the number of crashes expected to be reduced after the implementation of certain countermeasures while others used research specific variables to investigate the effectiveness of certain countermeasures or interventions. Studies that did not test the effectiveness of related countermeasures usually engaged surveys and conducted literature reviews to understand how different road users perceive distracted and drowsy driving behavior, and how they can be effectively reduced.

Findings

This section describes the findings on the effectiveness of distracted and drowsy driving countermeasures from existing studies and reports reviewed for this study. Ahmad et al. (2023) found that longer distraction is positively related to higher driving instability, which would lead to higher chances of causing near-crash and crash events. Sun & Rahman (2018) found that higher speed limits, curved roads, and head-on crashes are positively related to distracted driving.

Studies mostly tested the effectiveness of rumble strips on alerting distracted drivers to go back to their travel lanes. Ahmed et al. (2015) found rumble strips are the most used distracted driving countermeasure nationwide, shoulder rumble strips (SRS) are more widely used than centerline rumble strips (CLRS) or edgeline rumble stripes (ELRS). This study also found that state DOTs mostly install rumble strips on rural roadways due to fewer installation criteria constraints (Ahmed et al., 2015).

Ahmed et al. (2022) further found that the installing CLRS on the centerline for two-lane two-way highways has the potential to reduce 25% to 68% expected crashes; though the performance of CLRS can be negatively affected by heavy snow, increased winter maintenance level operation can help quickly restore the performance of CLRS. Additionally, Schaudt et al. (2013) found that for heavy trunks, enhanced rear signaling (ERS) would help detect rear-end crash threats by drawing the attention of the distracted following driver back to the forward roadway and reduce the severity of unintended consequences. Besides in-vehicle countermeasures, Jenness et al. (2011) also tested various frontal light treatment of motorcycles and found that better front light treatment would help drivers notice them and reduce daytime crashes involving right-of-way violations.

Studies focused on engineering-related infrastructure countermeasures mainly examined presence of rest areas, Drowsy Driving Advisory (DDA), and warning signage on reducing drowsy driving behavior. Kang et al. (2015) found that rates of crashes caused by drowsy driving are higher at rural interstate roadways than urban interstate roadways, crash rates are also higher upstream of a rest area when compared to downstream. Their survey results also indicate that a lot of participants expressed their willingness to stop and rest in rest areas if they see safety messaging signage on the road (Kang et al., 2015). Rahman & Kang (2020) further examined the effectiveness of DDA on reducing drowsy driving related crashes, they found that combined with rest areas, DDA can better help reduce broadly defined drowsy driving related crashes by 49% to 64%; they also found that without the presence of rest areas, drowsy driving related crashes would increase by 5% to 45%. Other studies examined in-vehicle countermeasures that are aimed at alerting drowsy drivers. Gaspar et al. (2017) tested different interface types and alerts to alert drowsy drivers, lane departure frequencies and standard deviation in lateral position (SDLP) were both lower with in-vehicle countermeasures than without. Gaspar et al. (2023) found that drowsiness notification with lane departure warning would help alert drowsy drivers and reduce lane departure frequency and percentage of eye closure (PERCLOS) during lane departures. Hickman et al. (2016) monitored and observed truck drivers' driving patterns and found that drowsy driving threats for truck drivers are usually in the forward view of the driver, and thus interventions to increase their awareness of forward field events would have more potential to reduce drowsiness related near-crash and crashes. Table 4 summarizes the relationships between crash frequencies, distracted and drowsy driving related variables, and the related explanatory variables countermeasures (highlighted texts indicate the type of targeted driving behavior tested in the papers or reports).

Table 4. Summary of Findings of Distracted and Drowsy Driving Countermeasure Studies[6]

Countermeasure	Variable	Impact	Reference
Presence of centerline rumble strips (CLRS)	Number of Crashes	(-)	Ahmed et al. (2022)
Shoulder width	Number of Crashes	(-)	Ahmed et al. (2022)
High speed limit	Number of Crashes	(-) (NS) in lane departure crashes (-) in all of crashes	Ahmed et al. (2022)
	Crash Injury Severity	(+)	Sun & Rahman, (2018)

6 "-"denotes a negative relationship, "+" denotes a positive relationship, "NS" indicates that the relationship is not statistically significant, and "LE" means less or least effective.

Drowsy driving advisory (DDA) presence	Number of Crashes	(-)	Rahman & Kang, (2020)
	Number of expanded definition of drowsy driving crashes	(-)	
Enhanced rear signaling (ERS)	Following-vehicle unintended consequences	(-)	Schaudt et al., (2013)
	Eye-drawing capability	(+)	
	Decreased following distance	(effectiveness not clear, can cause false alarms)	
Curved roads	Number of crashes	(+)	Sun & Rahman, (2018)
In-vehicle alert system	Lane departures	(-)	Gaspar et al., (2017)
	standard deviation in lateral position	(-)	Gaspar et al., (2017)
Lane departure warning (LDW)	Lane departure frequency, severity, response time; Percentage of Eye Closure during lane departure	(NS)	Gaspar et al., (2023)
Drowsiness notification with LDW	Lane departure frequency	(-)	Gaspar et al., (2023)
	Percentage of Eye Closure during lane departure	(-)	
Motorcycle forward lighting treatments: • Modulated high beam headlamp • Low beam headlamp plus pairs of low-mounted auxiliary lamps • High-mounted auxiliary lamps • Both high- and low-mounted auxiliary lamps • Low-mounted LED lamps	Indicator of when it would be safe (and not safe) to initiate a left turn across the opposing lanes when viewed the approaching traffic stream on an active roadway	More helpful than baseline	Jenness et al., (2011)
Roadside rest areas presence	Number of crashes	(-)	Kang et al., (2015)

Impaired Driving

Definition of Impaired Driving and Suggested Countermeasures

NHTSA defines alcohol-impaired driving as drivers or motorcycle riders with blood alcohol concentrations of >.08 g/dL (Venkatraman et al., 2021). Less research is done on drug-impaired driving compared to alcohol-impaired driving, and the definition of drug-impaired is trickier as a driver testing positive for drugs does not necessarily mean they are drug-impaired (Venkatraman et al., 2021). However, in the US, alcohol- and drug-impaired driving are still considered as safety threats that would cause harm to other road users' lives (NHTSA; Venkatraman et al., 2021).

FHWA's *Proven Safety Countermeasures* (2021) also does not have recommended engineering-related countermeasures that help reduce impaired driving behavior. However, existing studies found that median cable barriers and high-tension cable barriers can help reduce the number and the injury severity of median crossover crashes and rollover crashes, which can be related to impaired driving (Savolainen et al., 2014, 2018). *Countermeasures that Work* (2021) does not have engineering-related countermeasures that can be implemented for reducing impaired driving. The most effective countermeasures are in laws, enforcement, prosecution and adjudication, as well as DWI offender treatment, monitoring, and control: open container laws, publicized sobriety checkpoints, DWI courts, and alcohol ignition interlocks.

Table 5 shows the recommended high-quality CMFs that are related to cable barriers, which can reduce crash types that occur as a result of impaired driving. Cable median barriers installation is a less effective and lower quality countermeasure that reduce injury crashes in rural areas while high tension cable median barrier installation is a more effective and high-quality countermeasure that target at cross median crashes.

Table 5. CMFs of Suggested Impaired Driving Countermeasures

Category	CMF	CRF(%)	Crash Type	Crash Severity	Area Type	Rating	ID
Install cable median barrier	0.710	29	All	A, B, C	Rural	3 star	47
Install cable median barrier (high tension)	0.209	79.1	Cross median	All	All	5 star	11455

Note: CRF (%) is the crash reduction factor which equals to 1-CMF.

Methods and Models for Testing Effectiveness of Impaired Driving Countermeasures

Due to the lack of engineering-related countermeasures that directly tackle impaired driving, most studies examined how well alcohol ignition laws are enforced. Other studies using statistical methods found that median cable barriers are related to impaired driving crash frequencies (Savolainen et al., 2014, 2018). Scholars also investigated how the heights of mounted signage can impact impaired drivers' reaction times (Seitzinger et al., 2016). Table 20 in Appendix A summarizes the statistical methods used to study the effectiveness of countermeasures that can reduce impaired driving related crashes.

Data sources and variables employed

Depending on the scope of the projects and the examined countermeasures, existing studies usually included crash data (e.g., number of crashes and crash injury severity levels) and roadway characteristics (e.g., median type and median width, shoulder type and should width, number of lanes and lane width, AADT, and road segment length) to examine under what circumstances and how effective different type of cable median barriers are at reducing the number of impaired driving crashes or lowering the injury severity level of such crashes (Savolainen et al., 2014, 2018). Others tested how mounting heights of signs can reduce impaired wrong way driving (DDW) (Seitzinger et al. 2016). Studies that did not test the effectiveness of related countermeasures usually studied the enforcement of alcohol ignition interlock laws.

Findings

This section describes the findings on the effectiveness of impaired driving countermeasures from existing studies and reports reviewed for this study. DeYoung (2002) found that alcohol ignition interlock enforcement is very ineffective in California. Marques & McKnight (2017) also found that the installation of alcohol ignition interlocks poses a higher risk to driving for offenders who rode motorcycles. A couple of related works found that installing high-tension cable barriers can reduce fatal and severe injury crashes (K, A and B), while increasing lower injury severity crashes (C and PDO), for impaired driving since this behavior can result in median-crossover crashes (Savolainen et al., 2014, 2018), and that installation of cable barriers can reduce cross median crashes by over 85% and rollover crashes by over 50% (Savolainen et al., 2014). Seitzinger et al. (2016) investigated how signage mounting heights impacted impaired drivers' reaction time and distance when they are at intersections. That work found that impaired drivers reacted faster to lower mounted (3 foot) signage, and that they were also less likely to miss lower mounted signage. Table 6 summarizes the relationship between crash frequencies, impaired driving related variables, and the related explanatory variables.

Table 6. Summary of Findings of Impaired Driving Countermeasure Studies[7]

Countermeasure	Variable	Impact	Reference
Presence of high-tension cable barriers	Number of fatal and severe crashes	(-)	Savolainen et al. (2014)
	Number of less severe and PDO crashes	(+)	Savolainen et al. (2014)
Median-related crashes with cable barrier presence	Number of fatal and severe crashes	(-)	Savolainen et al. (2018)
	Number of less severe and PDO crashes	(+)	Savolainen et al. (2018)
Mounted signs	Reaction time	3-foot (-) 7-foot (NS)	Seitzinger et al. (2016)
	Reaction distance	3-foot (NS) 7-foot (NS)	Seitzinger et al. (2016)

Interviews

In addition to reviewing the existing research literature on reckless driving countermeasures, the research team also conducted interviews with stakeholders from an insurance company, a vehicle manufacturer, and state DOTs to further understand effective engineering-related countermeasures, emerging technologies that help reduce reckless driving behavior or reduce the impact of reckless driving activities, as well as the challenge they face implementing related countermeasures. Interviewees included in this study are from AAA Foundation for Traffic Safety (AAA FTS)[8], DOT representatives from Ohio, Pennsylvania, and South Dakota, and General Motors (GM).

Insurance Companies

AAA FTS

The interviewee from AAA FTS mentioned several studies from AAA FTS's 2024 Safe Mobility Conference that shed light on how to reduce speeding behavior. A pilot program in New York retrofitted a fleet of city-owned vehicles with active Intelligent Speed Assistance (ISA) to prevent drivers from exceeding speed limits during the drive (AAA FTS, 2024). They found that over 99%

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7 "-"denotes a negative relationship, "+" denotes a positive relationship, "NS" indicates that the relationship is not statistically significant, and "LE" means less or least effective.

8 AAA FTS focuses its research on traffic safety, mainly on driver behavior and performance, emerging technologies, roadway systems and drivers, and vulnerable road users. See AAA Foundation for Traffic Safety. (2024, May 16). https://aaafoundation.org/about/

of more than 1.7 million miles driven by vehicles participating in the pilot program were within the set speed limits, and there was an observed nearly 40% reduction in hard braking with ISA (AAA FTS, 2024). Another speed management pilot program in Bishopville, Maryland used widened centerlines and edge lines (visually narrowing the travel lanes) and speed feedback signs on a rural two-lane undivided corridor in 2021, they found reduced speeds and reduced number of speeding instances after countermeasure implementation. (AAA FTS, 2024).

Researchers at AAA FTS also examined existing studies on countermeasures that could reduce drowsy or distracted driving. Some in-vehicle technologies like advanced driver assistance systems (ADAS), drowsy driver detection and alerting systems, fitness to drive assessment technologies, and biometric devices can help reduce drivers' drowsiness and increase their alertness to varying degrees and have the potential to reduce the probability of certain crashes (Bayne et al., 2022). Bayne et al. (2022) also reported the effectiveness of shoulder and centerline rumble strips, rest areas, road signs, and roadway markings existing studies, and they found that these countermeasures usually address drowsy driving in the late stages of drowsiness to prevent drowsy driving crashes or mitigate the severity of these crashes.

Molnar et al. (2024) found that distracted driving behavior is difficult to measure and detect, stakeholders consider new technological approaches (reduce smartphone usage and alert drivers about roadway conditions), strict enforcement, as well as communication and education as potential effective countermeasures to curb distracted driving. The interviewee from AAA FTS also mentioned studies funded by Progressive Causality Insurance Company that examined the effectiveness of using monetary incentives to discourage handheld phone usage through monitoring smartphone applications. Their findings suggest that push notifications combined with monetary incentives from auto insures can help reduce distracted driving and potential crashes (Delgado et al., 2024; Ebert et al., 2024).

State DOTs

We interviewed three DOT representatives from three states on the effectiveness of implemented engineering-related countermeasures that target reckless driving behavior, countermeasures that they are going to implement to mitigate reckless driving behavior.

Ohio

Ohio DOT (ODOT) developed a 2021-2025 Strategic Highway Safety Plan (SHSP) in collaboration with stakeholders at different levels in 2020 to address traffic safety issues and to reduce related crash frequency and lower crash injury severity (ODOT, 2020). Most crashes involving reckless driving behavior (alcohol and drug impaired, speeding, distracted drivers) in Ohio occurred on urban roads. Out of the crashes that involved reckless driving, speeding had the highest rate of fatal and serious injury crashes (24.3%), followed by 16.4% for alcohol impaired crashes, 9.3% for drug impaired crashes, and 7.9% for distracted driving crashes (ODOT, 2020).

Speed-related fatal crashes in Ohio rank higher than national average, causing nearly 31% fatal crashes and 23% crashes involving serious injury annually in Ohio (ODOT, 2020). To combat speeding, ODOT developed a specific Speed Action Plan that identified roadways with more speed-related crashes and aimed at increasing speed enforcement visibility on these safety corridors (ODOT, 2020). Other countermeasures included a lower speed limit of 25 mph for certain corridors as well as using driver feedback signs to reduce speed-related driving behavior on such corridors. ODOT is also planning on implementing an urban-focused speed pilot program that encourages slower speeds through various traffic calming designs. Traffic calming design countermeasures ODOT considers include lane repurposing (narrower lane width), use of roundabouts, adding curb bump outs, using speed bumps, as well as installing raised crosswalks to lower vehicles' operating speed. Moreover, ODOT also aims to establish expanded context-based road classifications for setting more context appropriate speed limits for better speed management.

Similar efforts were made (or are considered) to also reduce distracted driving. Besides strict law enforcement on using electronics while driving in Ohio, ODOT also identified roadways with high rates of distracted driving crashes as Distracted Driving Safety Corridors and installed signs alerting motorists about strict enforcement on distracted driving on these corridors. Through working with telematics service provider, ODOT found sustained decline in cellphone usage a year after more strict enforcement, which had a positive impact on reducing distracted driving (ODOT, 2024). Their early efforts on improving enforcement and signage on Distracted Driving Safety Corridors have helped reduce 6% crash frequency and 13% fatal and serious injury crashes (ODOT, 2023a). ODOT found rumble strips as an effective way to prevent roadway departure, which is one of leading causes of Ohio's fatal crashes.

Alcohol and drug related fatal crashes and serious injury crashes are a significant concern for ODOT. However, impaired driving is very difficult to detect, measure, and target through specific countermeasures. Therefore, besides safety campaigns and using rumble strips to alert drivers and prevent roadway departure, ODOT also adopted Wrong Way Detection Systems (WWDS) at certain locations to better inform, document, and help prevent incidents caused by wrong way driving vehicles (which is more likely for drowsy or impaired drivers). WWDS in Ohio successfully detected wrong way driving vehicles, and over one third of them in 2023 were impaired by alcohol, over 5% of them were impaired by drugs (ODOT, 2023b). While ODOT did not have specific countermeasures that focus on drowsy driving, they examined high-demand truck parking clusters and related rest areas to understand the demand of truck parking to better provide truck drivers with safe rest areas.

Pennsylvania

Pennsylvania DOT (PennDOT) uses variable speed limits and speed feedback signs to reduce speeding. PennDOT also developed a highway safety program guide, providing guidelines for safety countermeasures based on crash types (PennDOT, 2024a). To reduce speeding and aggressive driving behavior, PennDOT (2012, 2024a) recommends the following cost-effective traffic calming countermeasures for urban collectors and local roads (Bold text indicates speed-related countermeasures that are also effective at intersections):

- **Bulb out/curb extension**
- Chicane
- On-street parking
- **Raised median island/pedestrian refuge**
- **Mini-Roundabout**
- **Roundabout**
- Speed hump
- **Raised crosswalk**
- **Raised intersection**
- **Speed limit signing**
- **Multi-way stop control**
- **Commercial vehicle prohibition**
- Roadway narrowing through edge lines
- Transverse pavement markings

In the meantime, PennDOT also developed Pennsylvania-specific contextual design guidance on roadway design speed. Specifically, based on the context, they recommend narrower travel lanes, physical measures to narrow roadway, on-street parking, superelevation elimination, shoulder elimination, smaller curb radii, channelized right-turn lane elimination, as well as use paving materials with texture to reduce vehicle operating speed (PennDOT, 2024b). PennDOT developed a five-year pilot program in 2020, termed the Automated Work Zone Speed Enforcement (AWZSE) program to reduce speeding in active work zones by using portable automated speed enforcement systems (PennDOT, 2024c). Travel speeds, speeding, and excessive speeding in work zones have reduced since the adoption of automated speed enforcement (PennDOT, 2024c). In Philadelphia, the Speed Camera Program has helped reduce speeding even when traffic volume increased (PennDOT, 2024d); and their Red Light Camera Program also helped reduce fatal and injury crashes (PennDOT, 2024e).

PennDOT does not have specific countermeasures that target crashes caused by distracted or drowsy driving, however, PennDOT did find that using rumble strips can help alert drivers who depart travel lanes. Moreover, rumble strips and barriers are found to be helpful in reducing the number of fatal and serious head-on and sideswipe crashes that are caused by speeding or impaired drivers in Pennsylvania. Drivers who drive under the influence of alcohol or controlled substances (DUI) in Pennsylvania are required by law to have ignition interlock installed in their vehicle for one year from the restoration of their driving privileges (PennDOT, 2023). From 2019 to 2023, PennDOT has ordered over 10,000 DUI ignition interlocks annually, and prevented an average of 85,000 vehicles starts each year.

South Dakota

South Dakota DOT (SDDOT) uses road diets and traffic calming measures to reduce speeding. By turning 5-lanes roads into 4-lane roads and adding raised medians, SDDOT has successfully reduced speeding-related crashes in some urban areas. Radar speed feedback signs have also been implemented and have been effective in some communities. Implementing speed-related countermeasures in rural areas has been challenging in South Dakota as local municipalities do not always welcome changes made to the roads. SDDOT is waiting for the required legislative approval to implement variable speed limits to reduce speeding driving behavior.

SDDOT recently issued its 2024 5-year South Dakota Strategic Highway Safety Plan (SHSP) focusing on reducing fatal and serious crash injuries. Nearly 25% of fatal and serious injury crashes in South Dakota involved aggressive and speed-related driving. SDDOT is considering implementing advisory warning signs (e.g., curve signs, vertical grade signs), using dynamic speed display/feedback signs, and enhanced road designs (e.g., designated left turn lanes, physical barriers between opposing lanes of traffic, and slower posted speed limits) to lower the injury levels of such crashes (SDDOT, 2024).

SDDOT finds rumble strips and median cable barriers effective in alerting distracted or drowsy drivers about lane departures and lowering the injury severity levels of related crashes. Additionally, SDDOT considers several other countermeasures that could be effective for lane departures to combat reckless driving (SDDOT, 2024). The list of countermeasures and the associated CMFs are:

- Provide lighting on curves (CMF: 0.721)
- Install climbing/passing lanes on high-risk head-on collision locations with high traffic volumes (CMF: 0.66 to 0.751)
- Install centerline and edge line pavement markings (CMF: 0.6)
- Provide enhanced curve delineation (CMF: 0.78 to 0.94)
- Utilize high friction surface treatment to increase traction for winter road conditions (CMF: 0.6)
- Remove or relocate roadside fixed objects, or replace with guardrail (CMF: 0.71)
- Deploy enhanced pavement markings (CMF: 0.7 to 0.89)
- Replace and enhance pavement markings by embedding wet reflective materials (CMF: 0.7 to 0.892, rural)
- Install centerline buffer area (CMF: 0.10 to 0.65)

While most strategies SDDOT employ to reduce impaired driving focus on education and enforcement, there are other countermeasures that can help alert impaired drivers, such as wrong way driving signage and rumble strips, particularly on partial cloverleaf interchanges. SDDOT also tries to implement rumble strips on all state-owned routes and lower the traffic volume threshold for centerline rumble strips. South Dakota was the first state to implement a 24/7 Sobriety Program for DUI offenders, which involved installing ignition interlocks on DUI offenders' vehicles, monitoring their sobriety through ankle monitors and courthouse breathalyzer tests. The SDDOT interviewee believes that vehicle lane assist and adaptive cruise control systems could be effective in alerting drivers, but currently SDDOT has no partnerships or collaborations with any vehicle manufacturers on testing the effectiveness of such in-vehicle countermeasures.

<u>Vehicle Manufacturer</u>

GM

GM partners with a third-party technology provider Samsara to allow GM commercial vehicles owners to better connect with their vehicles, and in the meantime, detect distracted driving behavior (e.g., using cell phones while driving) with AI cameras and provide warnings and instructions through driver coaching when distracted or speeding driving is detected (Samsara, 2023). GM develops a Super Cruise System with Adaptive Cruise Control combined with automatic lane-centering control that allows hands-free driving on certain roads and helps reduce lane departure, it does not have significant impact on reducing the number of lane departure crashes (Leslie et al., 2022).

Summary of Engineering-Related Countermeasures

After examining engineering-related countermeasures that aim at reducing reckless driving behavior and/or crashes caused by reckless driving, Table 7 summarizes the countermeasures for risky driving proposed in the literature and selects ones that were identified through interviews.

Table 7. Summary of the Tested Effectiveness of Selected Engineering-related Countermeasures[9]

Countermeasure	Status
Speeding	
Implement automated speed enforcement cameras	CMF exists
Implement mobile automated speed enforcement system	CMF exists
Install changeable speed warning signs for individual drivers	CMF exists
Individual changeable speed warning signs	CMF exists
Presence of speed restriction devices (bike crashes)	CMF exists
Decreasing posted speed limit on expressways	Research exists with no CMF established
Lower posted speed from 90 km/h to 70 km/h	CMF exists
Lower posted speed limit from 50 kph to 40 kph	CMF exists
Install dynamic speed feedback sign (DSFS)	CMF exists
Perceptual Countermeasures (PCMs) • Peripheral transverse lines • Enhanced post-spacing with ascending heights	Research exists with no CMF established
Install Radar speed feedback signs (RSFS)	Research exists with no CMF established
Roadside vegetation on arterial roads and highway exit ramps	Research exists with no CMF established
Install portable plastic rumble strips	Research exists with no CMF established
Install Driver feedback signs (DFS)	Research exists with no CMF established
Two step speed reduction combination	Research exists with no CMF established
Higher speed limits	CMF exists
Lower speed limits than engineering recommendations	Research exists with no CMF established
Speed management countermeasures at work zone: Speed photo enforcement	CMF exists

9 The status of a countermeasure indicates whether CMFs has been developed to show its safety effect. "CMF exists" denotes CMFs for a certain countermeasure can be found from the CMF Clearing house; "Research exists with no CMF established" denotes that there is not a developed CMF for that countermeasure that can be found from the CMF Clearinghouse yet, but related research has tested the countermeasure's safety effect; while "Countermeasures without specific research" denotes that these are countermeasures suggested or have been used but with little dedicated research for their safety effects.

Countermeasure	Status
Highway work zone billboard	Research exists with no CMF established
Sequential flashing lights	Research exists with no CMF established
Dynamic message signs	Research exists with no CMF established
Optical speed bars	Research exists with no CMF established
Emergency flasher traffic control device	Research exists with no CMF established
Lane reduction	Research exists with no CMF established
Speed trailer (also with law enforcement)	Research exists with no CMF established
Rumble strips	CMF exists
Variable speed limit sign	CMF exists
Changeable message sign	Research exists with no CMF established
Concrete barriers	CMF exists
Context-based road classifications	Countermeasures without specific research
Distracted and/or Drowsy Driving	
Install centerline and shoulder rumble strips	CMF exists
Install centerline rumble strips	CMF exists
Install centerline rumble strips on roads with existing shoulder rumble strips	CMF exists
Install edgeline rumble strips	CMF exists
Install safety edge treatment	CMF exists
Drowsy driving advisory (DDA) presence	Research exists with no CMF established
Enhanced rear signaling (ERS)	Research exists with no CMF established
In-vehicle alert system	Research exists with no CMF established
Lane departure warning	Research exists with no CMF established
Drowsiness notification with LDW	Research exists with no CMF established
Motorcycle forward lighting treatments	Research exists with no CMF established
Roadside rest areas presence	Research exists with no CMF established
Signs warning distracted drivers	Countermeasures without specific research
Impaired Driving	
Install cable median barrier	CMF exists
Install cable median barrier (high tension)	CMF exists
Mounted signs	Research exists with no CMF established
Wrong way detection systems (WWDS)	Research exists with no CMF established
Wrong way driving signage	CMF exists
Ignition interlock	Countermeasures without specific research
Vehicle lane assist	Countermeasures without specific research
Adaptive cruise control systems	Countermeasures without specific research

LIST OF APPLICABLE COUNTERMEASURES

Specific countermeasures that were noted in the literature that could reduce reckless driving on Wisconsin roadways were identified. A list of specific engineering-related countermeasures as being applicable in Wisconsin to reduce reckless driving activity and the harmful impacts of reckless driving is provided. This focused on three major reckless driving activities:

- Speeding
- Distracted/drowsy driving
- Impaired driving

The format of *Countermeasures that Work* (2021) to show selected countermeasures' effectiveness, cost, use, time of implementation, as well as related CMF information was adopted. For countermeasures that are not listed in *Countermeasures that Work,* their evaluations were based on information from existing literature, the CMF clearinghouse, and the research team's expertise.

The research team used four indices to evaluate the countermeasures for reckless driving: effectiveness, cost, use, time, and status. Effectiveness refers to the proven effectiveness of the countermeasure at either reducing reckless driving activity, reckless driving-related crashes, or other harmful outcomes. Cost refers to the cost of implementation. Use refers to how widely this countermeasure has been applied across the United States. Time refers to the timeline for implementation of this specific countermeasure. The status indicates whether crash modifications factors (CMFs) to demonstrate the safety impact of a countermeasure has been developed. The detailed explanation can be found in Appendix B. The remainder of the document provides tabular summaries of the identified countermeasures.

Countermeasures targeting speeding

Table 8. Summary of Speeding Engineering-related Countermeasure Evaluation

Countermeasure	Effectiveness	Cost	Use	Time	Status
General infrastructure-related countermeasures					
Dynamic speed feedback sign (DSFS)	★★★★★	$	High	Short	CMF exists
Changeable speed warning signs for individual drivers	★★★☆☆	$	Unknown	Short	CMF exists
Presence of speed restriction devices, including red light cameras and speed humps	★★★☆☆	$	Unknown	Short	CMF exists
Decreasing posted speed limit on expressways	★★★★☆	$	Unknown	Short	CMF exists
Perceptual Countermeasures (PCMs) • Peripheral transverse lines • Enhanced post-spacing with ascending heights	★★☆☆☆	$	Unknown	Unknown	Research exists with no CMF established
Roadside vegetation on arterial roads and highway exit ramps	★★☆☆☆	$	Unknown	Medium	Research exists with no CMF established
Portable plastic rumble strips	★★☆☆☆	$	Unknown	Medium	Research exists with no CMF established
Two-step speed reduction combination	★★☆☆☆	$	Unknown	Short	Research exists with no CMF established
Higher speed limits	★★★★★ [10]	$	Unknown	Short	CMF exists
Context-based road classifications	★☆☆☆☆	$	Unknown	Long	Countermeasures without specific research
Speed management countermeasures at work zone					
Rumble strips	★★★★★	$	Unknown	Short	CMF exists
Variable speed limit sign	★★★★☆	$	Unknown	Short	CMF exists
Speed photo enforcement	★★★★★	$$	Unknown	Short	CMF exists
Highway work zone billboard	★★☆☆☆	$	Unknown	Short	Research exists with no CMF established
Sequential flashing lights	★★☆☆☆	$	Unknown	Short	Research exists with no CMF established
Dynamic/changeable message signs	★★☆☆☆	$	Unknown	Short	Research exists with no CMF established
Optical speed bars	★★☆☆☆	$	Unknown	Short	Research exists with no CMF established
Emergency flasher traffic control device	★★☆☆☆	$	Unknown	Short	Research exists with no CMF established
Lane reduction	★★☆☆☆	$$$	Unknown	Long	Research exists with no CMF established
Speed trailer (also with law enforcement)	★★☆☆☆	$	Unknown	Short	Research exists with no CMF established
Concrete barriers	★★☆☆☆	$	Unknown	Short	CMF exists

Countermeasures targeting distracted and drowsy driving activities

Table 9. Summary of Distracted and Drowsy Driving Engineering-related Countermeasure Evaluation

Countermeasure	Effectiveness	Cost	Use	Time	Status
General infrastructure-related countermeasures					
Install centerline and shoulder rumble strips	★★★★★	$	High	Short	CMF exists
Install edgeline rumble strips	★★★★★	$	High	Short	CMF exists

Install safety edge treatment	★★★★★	$	Unknown	Short	CMF exists
Drowsy driving advisory (DDA) presence	★★☆☆☆	$	Unknown	Short	Research exists with no CMF established
Roadside rest areas presence	★★☆☆☆	$$	Unknown	Long	Research exists with no CMF established
Signs warning distracted drivers	★☆☆☆☆	$	Unknown	Short	Countermeasures without specific research
Vehicle-based countermeasures					
Enhanced rear signaling (ERS)	★★☆☆☆	$$	Unknown	Short	Research exists with no CMF established
In-vehicle alert system	★★☆☆☆	$$	Unknown	Short	Research exists with no CMF established
Lane departure warning (LDW)	★★☆☆☆	$$	Low	Short	Research exists with no CMF established
Drowsiness notification with LDW	★★☆☆☆	$$	Unknown	Short	Research exists with no CMF established
Motorcycle forward lighting treatments	★★☆☆☆	$	Unknown	Short	Research exists with no CMF established

Countermeasures targeting impaired driving

Table 10. Summary of Impaired Driving Engineering-related Countermeasure Evaluation

Countermeasure	Effectiveness	Cost	Use	Time	Status
General infrastructure-related countermeasures					
Install cable median barrier (high tension)	★★★★★	$$	Unknown	Medium	CMF exists
Mounted signs	★★☆☆☆	$	Unknown	Short	Research exists with no CMF established
Wrong way detection systems (WWDS)	★★☆☆☆	$$	Unknown	Short	Research exists with no CMF established
Wrong way driving signage	★★★★★	$	Unknown	Short	CMF exists
Vehicle-based countermeasures					
Ignition interlock	★★★★★	$$	Medium	Medium	Countermeasures without specific research
Vehicle lane assist	★☆☆☆☆	$$	Unknown	Unknown	Countermeasures without specific research
Adaptive cruise control systems	★☆☆☆☆	$$	Unknown	Unknown	Countermeasures without specific research

10 Depending on the base speed limit and the magnitude of the increase in speed limit, the quality rating of related CMFs varies from 4 stars to 5 stars.

MODELING CRASH RISK

The research team obtained roadway, crash and public health data from Wisconsin to support the development of statistical models to predict the occurrence of various types of reckless driving crashes on various roadway facilities throughout the state. The remainder of this section describes the data collection and analysis process that was followed as a part of this task.

Data Collection

A wide range of variables contribute to reckless driving related crash frequencies and injury severity levels. The data was collected for the Wisconsin State Trunk Highway Network (STHN), and county trunk highways were not included in the data collection. This section summarizes the data elements that were included for the model development process. Table 11 provides a summary of the relevant data items used for this project, along with their sources.

Table 11. Summary of data collection status

Data category	Data element	Collected? (Y/N)	Source (if collected)	Version
Crash	Reckless driving crashes	Y	Wisconsin Traffic Operations and Safety Laboratory (TOPS Lab)	2017-2021
Roadway data	Traffic volume	Y	WisDOT	2017-2021
	Median width and presence	N	n/a	n/a
	Number of lanes	Y	WisDOT	2023
	Divided road status	Y	WisDOT	2023
	Travel lane width	Y	WisDOT	2023
	Shoulder width and presence	Y	WisDOT	2023
	Posted speed limit	Y	WisDOT	2023
	Highway Capacity Manual facility type	Y	WisDOT	2023
	Horizontal curvature	Y	WisDOT	n/a
	Urban or rural location	N	n/a	n/a
	Segment length	Y	WisDOT	2023
Public Health Index[11]	Socioeconomic status	Y	US Census Bureau	2017-2021 ACS 5-Year estimates
	Household characteristics	Y	US Census Bureau	2017-2021 ACS 5-Year estimates
	Racial and ethnic minority status	Y	US Census Bureau	2017-2021 ACS 5-Year estimates

[11] The public health indices used in this project is based on the Social Vulnerability Index (SVI) framework developed by the Centers for Disease Control and Prevention and Agency for Toxic Substances and Disease Registry (CDC/ATSDR). See details from https://www.atsdr.cdc.gov/place-health/php/svi/index.html.

Data category	Data element	Collected? (Y/N)	Source (if collected)	Version
	Housing type and transportation	Y	US Census Bureau	2017-2021 ACS 5-Year estimates

Reckless driving crashes

Reckless driving crash information was obtained through the WisTransPortal maintained by the TOPS Lab[12]. This database contains information on crashes on Wisconsin state roads including the location of each crash, vehicles involved, and general crash attributes. The research team discussed with the Project Oversight Committee (POC) and identified four categories of reckless driving crashes that occurred between 2017 and 2021, and Table 12 summarizes the variables used for identifying reckless driving behavior in Wisconsin for this analysis.

Table 12. Variables Indicating Reckless Driving Behavior from the Wisconsin DT4000 Crash Report

Reckless Driving Behavior Category	Variables Indicating Reckless Driving Behavior	Description
Speeding	SPEEDFLAG	Flag indicating whether speed was a factor in a crash
Distracted	DISTFLAG	Flag indicating whether a crash involved distracting or inattentive driving
	DNMFTR[1,2][A,B]: • SLEEP - Asleep or Fatigued	Any relevant condition of the individual (motorist or non-motorist) that is directly related to the crash
Impaired	DRUGLFAG	Indicates whether law enforcement suspected that at least one driver or non-motorist involved in the crash had used drugs
	ALCFLAG	Indicates whether law enforcement suspected that at least one driver or non-motorist involved in the crash had used alcohol. This includes both alcohol use under the legal limit and at or over the legal limit
	DNMFTR[1,2][A,B]: • UI MDA - Under the Influence of Medication/Drugs/Alcohol • PHY IMP - Physically Impaired • SICK - Ill (Sick), Fainted • CONF - Confused or Disoriented (Non Lucid)	Any relevant condition of the individual (motorist or non-motorist) that is directly related to the crash

[12] Wisconsin crash database is managed by Wisconsin Traffic Operations and Safety Laboratory (TOPS Lab). TOPS Lab contains a complete database of Wisconsin police reported crash data since 1994. See details from https://transportal.cee.wisc.edu/services/crash-data/

Reckless Driving Behavior Category	Variables Indicating Reckless Driving Behavior	Description
Aggressive[1]	TRUE if for any person, DRVRPC[1,2][A,B,C,D]: has one or more occurrences from Tier 1, two or more occurrences from Tier 2, or three or more occurrences from Tiers 2 or 3, where: Tier 1: • AR - Operated Motor Vehicle in Aggressive/Reckless Manner • RAC – Racing Tier 2: • SPD - Exceed Speed Limit • TFC - Speed Too Fast/Cond • FTC - Following Too Close • IOR - Improper Overtaking / Passing Right • IOL - Improper Overtaking / Passing Left • ID - Operated Motor Vehicle in Inattentive, Careless or Erratic Manner Tier 3: • FTY - Failed to Yield Right-Of-Way • FVC - Failure to Control • DRED - Disregarded Red Light • DSS - Disregarded Stop Sign • DTC - Disregarded Other Traffic Control • DRM - Disregarded Other Road Markings	The actions by the driver that may have contributed to the crash, based on the judgment of the law enforcement officer investigating the crash

Note:
This information is extracted from Wisconsin crash DT4000 data dictionary for year 2017-2021
1. Queried using community maps crash flag for aggressive driver (AGGRFLAG) with an addition of DRVRPC[1,2][A,B,C,D] that is RAC to Tier 1. See details from: https://transportal.cee.wisc.edu/partners/community-maps/docs/CM_Crash_Flags_Technical.pdf

Each crash has a unique identifier and contains information on the location of the crash, injury severity level, and other general attributes. Five unique severity levels are present in the data:

- K – Fatal injury;
- A – Incapacitating injury;
- B – Non-incapacitating injury);
- C – Possible injury; and,
- O – No apparent injury.

The research team used the unique CRASH identifier to link qualifying reckless driving crashes from 2017 to 2023 to quantify the magnitude of reckless driving occurrence along the Wisconsin STHN. Table 13 summarizes the statistics of different reckless driving related crashes by injury level included in the project.

Table 13. Summary of reckless driving crashes by injury level[13]

Type	K	A	B	C	O	KABC	KABCO
Speeding	322	1,483	4,879	4,197	25,358	10,881	36,239
Distracted	161	915	4,084	4,238	17,083	9,398	26,481
Impaired	384	1,144	2,169	1,265	5,751	4,962	10,713
Aggressive	172	584	1,558	1,480	5,956	3,794	9,750
Total	**1,039**	**4,126**	**12,690**	**11,180**	**54,148**	**29,035**	**83,183**

Roadway characteristics

Roadway characteristics information was provided directly by WisDOT. For this project, the research team identified and used highways within the Wisconsin STHN. The Wisconsin STHN database contained a wide variety of roadway characteristics that can be linked to the roadway segment base file with unique roadway segment IDs. Specific data elements associated with each roadway segment included number of lanes, travel lane width, should width and presence, posted speed limit, horizontal curvature, and segment length. Due to incomplete information on median width and presence, this research team used DIVUND (a variable indicating whether a roadway segment is one-way, divided, or undivided) as an indicator of roadway separation types. Given the missing urban and rural code definitions from the Wisconsin STHN database, the research team used the existing HCMTYPE (Highway Capacity Manual facility type) variable to classify roadway segments. The following categories were available in this variable:

1. FRE: Basic freeway segments
2. MLT: Multilane highway segments that have 4 or 6 lanes, and posted speed limits > 40 mph and signal spacing > 2 miles apart.
3. TWO: Two-Lane highway segments that have a 2-lane undivided rural cross section.
4. URB: Highway segments that have an urban cross section, or segments that have signal spacing of less than 2 miles apart and are within city or village limits.

[13] Note that crashes occurred on roadways segments are one-way two-lane segments or are with incomplete data were not included in this summary. Note that some crashes might be counted in more than one reckless driving categories, thus, the total number of crashes are not mutually exclusive.

Urban highway segments were further categorized as divided or undivided using the DIVUND variable for analysis purposes based on differences in safety performance of reckless driving crashes that were observed. Hence, overall, five categories of roadway type are considered.

Average Annual Daily Traffic (AADT) data from 2017 to 2021 was obtained directly from WisDOT. Since the AADT volumes are provided for both directions, the directional or adjusted AADT was obtained for divided road segments by dividing the reported AADT by two. This adjusted AADT value is used for modeling reckless driving crash risk. Table 14 summarizes the data by roadway categories. The summary statistics for data that is used in the analysis can be found in Appendix D: Table 23. This summary reveals that over 70% of roadway segments do not have documented median type or presence information, therefore these variables were removed from the analysis dataset.

Lastly, the research team also generated two new variables using existing roadway characteristic information:

- Average shoulder width: obtained by summing the right shoulder width with the left shoulder width divided by two; and
- Average lane width: obtained by dividing the total traveled way width by the number of lanes.

Table 14. Summary of risk data by roadway categories

Roadway Category	Total Segments (#)	Relative Frequency by Segment	Total Mileage (mi)	Relative Frequency by Mileage	Total Crashes (#)[14]	Relative Frequency by Segment
Basic freeway	3,071	13.9%	2,557	17.6%	26,564	30.0%
Multilane highway	2,476	11.2%	1,874	12.9%	7,873	8.9%
Two-lane highway	10,404	47.0%	8,435	58.0%	22,595	25.5%
Undivided urban highway	1,990	9.0%	574	3.9%	10,447	11.8%
Divided urban highway	3,065	13.8%	901	6.2%	18,060	20.4%
One-way urban highway	371	1.7%	49	0.3%	1,309	1.5%
NA	772	3.5%	163	1.1%	1,684	1.9%
Total	22,149	100.0%	14,554	100.0%	88,532	100.0%

[14] The total crash numbers in this table reflects all crashes occurred on all highway segments that are within the Wisconsin STHN, including one-way two-lane roadway segments and roadway segments with incomplete data.

Public Health Indices (PHIs)

The research team adopted the Social Vulnerability Index (SVI) framework developed by the Centers for Disease Control and Prevention and Agency for Toxic Substances and Disease Registry (CDC/ATSDR) for developing public health indices that were intended to be included in the project. CDC/ATSDR's SVI has four indices using selected American Community Survey (ACS) 5-year estimates variables (CDC/ATSDR, 2022):

- **Theme 1: Socioeconomic Status**
  - Below 150% Poverty
  - Unemployed
  - Housing Cost Burden
  - No High School Diploma
  - No Health Insurance
- **Theme 2: Household Characteristics**
  - Aged 65 & Older
  - Aged 17 & Younger
  - Civilian with a Disability
  - Single-Parent Households
  - English Language Proficiency
- **Theme 3: Racial & Ethnic Minority Status**
  - Hispanic or Latino (of any race);
  - Black and African American, Not Hispanic or Latino;
  - American Indian and Alaska Native, Not Hispanic or Latino;
  - Asian, Not Hispanic or Latino;
  - Native Hawaiian and Other Pacific Islander, Not Hispanic or Latino;
  - Two or More Races, Not Hispanic or Latino;
  - Other Races, Not Hispanic or Latino
- **Theme 4: Housing Type & Transportation**
  - Multi-Unit Structures
  - Mobile Homes
  - Crowding
  - No Vehicle
  - Group Quarters

CDC/ATSDR develops SVIs at the census tract level and has been using ACS 5-year estimates for SVI calculation since 2010. CDC/ATSDR used 2016-2020 ACS 5-year estimates for their 2020 SVI calculation and 2018-2022 ACS 5-year estimates for their 2022 SVI calculation.[15] Since the existing SVIs developed and published by CDC/ATSDR do not cover the time period intended for this project (2017-2021), the research team obtained 2017-2021 ACS 5-year estimates and developed project-specific SVIs using the method published by CDC/ATSDR. The geographic unit of SVIs is at the census tract level, so the research team created a 5-foot buffer of highways included in this project and used the overlap percentage of roadway segments over census tracts for generating a weighted average value of related variables for each roadway segment. The detailed calculations are provided in the appendix of this report.

Model Development

This section outlines the model development process used to identify and quantify risk factors associated with reckless driving crashes in Wisconsin, categorized into four types:

- Speeding;
- Impaired;
- Distracted; and,
- Aggressive.

The first subsection defines the scope of the analysis. This is followed by a detailed description of the statistical methodology employed in the study. Next, risk factor estimates are presented for aggressive driving. Additional models for other reckless driving types are provided in the appendix of this report.

Scope

The first step in the risk factor identification process was to determine the scope of the model development. As a part of this, the research team focused on two key aspects:

1. Roadway categorization of roadway segments in Wisconsin STHN, and
2. Reckless driving crash categorization on Wisconsin STHN.

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[15] See details from https://www.atsdr.cdc.gov/place-health/php/svi/index.html

The first aspect was necessary to determine how roadway segments would be categorized for risk factor development. The Highway Capacity Manual facility types from the Wisconsin STHN database were readily available for categorizing roadway segments. The research team further broke down urban highway segments into divided and undivided.[16] Thus, unique models were developed for the following roadway types:

- Basic freeway segments
- Multilane highway segments with 4 or 6 lanes, posted speed limit over 40 mph, and with signal spacing greater than 2 miles apart
- Two-lane highway segments with a 2-lane undivided rural cross section
- Undivided urban highway segments with an urban cross section, or segments with signal spacing of less than 2 miles apart and are within city or village limits
- Divided urban highway segments with an urban cross section, or segments with signal spacing of less than 2 miles apart and are within city or village limits

The research team assessed the distribution of the number and mileage of roadway segments of each roadway category, traffic volume data, the availability of variables that are going to be included in the modeling process, and the observed crash frequencies over 2017-2021 (inclusive) to determine the road categories to be used for modeling. Table 15 summarizes the roadway segment characteristics by roadway categories. The most incomplete risk data are in AADT, posted speed limit, and horizontal curvature.

As a result, the number of roadway segments with complete data included in the final modeling process was 20,004 (90.3% of all 22,149 Wisconsin STHN roadway segments):

- 2,864 basic freeway segments (representing 2406.66 total miles)
- 2,351 multilane highway segments (representing 1803.89 total miles)
- 10,216 two-lane highway segments (representing 8407.3 total miles)
- 1,742 undivided urban highway segments (representing 531.74 total miles)

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[16] Note that there are three types of roadway segments in the Wisconsin STHN: one-way roadway segments, divided roadway segments, and undivided roadway segments. One-way roadway segments were not included for the divided and undivided two-lane highway categories.

- 2,841 divided urban highway segments (representing 856.75 total miles)

Table 15. Distribution of roadway segment characteristics by roadway category

Roadway characteristics	Basic freeway (3,071 segments)		Multilane highway (2,476 segments)		Two-lane highway (10,404 segments)		Undivided urban highway (1,990 segments)		Divided urban highway (3,065 segments)	
	Non-NA	NA	Non-NA	NA	Non-NA	NA	Non-NA	NA	Non-NA	NA
Average AADT	3,031	40	2,452	24	10,388	16	1,982	8	3,038	27
Adjusted average AADT	3,031	40	2,452	24	10,388	16	1,982	8	3,038	27
Number of lanes	3,071	0	2,476	0	10,403	1	1,990	0	3,065	0
Travel lane width	3,071	0	2,476	0	10,403	1	1,990	0	3,065	0
Left shoulder width	3,071	0	2,476	0	10,403	1	1,990	0	3,065	0
Right shoulder width	3,071	0	2,476	0	10,403	1	1,990	0	3,065	0
Posted speed limit	3,057	14	2,459	17	10,392	12	1,988	2	3,050	15
Horizontal curvature (Curves/mile posted speed limit 40 mph or less)	2,901	170	2,363	113	10,364	40	1,746	244	2,864	201
Horizontal curvature (Curves/mile posted speed limit more than 40 mph)	2,864	170	2,363	113	10,364	40	1,746	244	2,864	201
Segment Length	3,071	0	2,476	0	10,404	0	1,990	0	3,065	0

The second aspect was necessary to determine how to group the injury severity levels of crashes for risk factor development. The research team found that the median number of fatal crashes and crashes with serious injuries (KAB) are always zeros. Table 24 through Table 28 in Appendix D provide summary statistics for the number of crashes by different injury severity level groupings for each of the five roadway types and reckless driving categories. To generate more reliable reckless driving crash risk model results, and upon consultation with the POC, the research team decided to develop reckless driving crash risk models for each reckless driving category at the two following injury severity grouping levels:

- KABCO: all crash injury severity levels, and
- KABC: all crash injury severity levels except for property damage only crashes

A total of 40 unique models are developed that represent each combination of the three categories below:

1) Reckless driving (4 levels: speeding, distracted, impaired, aggressive)

2) Roadway type (5 levels: freeway, multilane highway, two-lane highway, undivided urban highway, divided urban highway), and
3) Injury severity level (2 levels: KABC and KABCO).

Statistical modeling methodology

All statistical models in this study were developed using Negative Binomial (NB) regression, which is a widely used and appropriate method for analyzing crash data. NB regression is a count-based modeling technique suited for dependent variables that take on non-negative integer values (Shankar et al., 1998). It is especially effective for crash modeling because it accounts for overdispersion—a common condition in crash datasets where the variance exceeds the mean (Geedipally et al., 2012; Hilbe, 2011).

The general form of the crash frequency models estimated for roadway segments is shown in Equation 1. These models were used to quantify the influence of traffic and various roadway characteristics on the risk of crashes within each of the four reckless driving categories:

$$N_{i,risk} = AADT^{\beta_{AADT}} \times L^{\beta_{Length}} \times e^{\beta_0} \times e^{\sum x_{ij}\beta_j}$$

$$= AADT^{\beta_{AADT}} \times L^{\beta_{Length}} \times e^{\beta_0} \times e^{x_{i1}\beta_1} \times e^{x_{i2}\beta_2} \times \ldots \times e^{x_{iJ}\beta_J} \quad (1)$$

where:

- $N_{i,risk}^{k}$: Predicted frequency of a reckless driving crash type k driving crashes on segment i (crashes/year)
- AADT: Annual average daily traffic on segment i (veh/day)
- β_{AADT}: Estimated coefficient for traffic volume
- β_{Length}: Estimated coefficient for segment length
- L: Length of segment (miles)
- β_0: Regression intercept
- x_{ij}, β_j: Explanatory variables and corresponding coefficients related to roadway design and traffic characteristics

Variables considered in the model included those known to be associated with reckless driving behavior—such as posted speed limit, lane width, shoulder width, and others. Note that segment length L is not treated as a proportional constant in the risk model. While treating segment length as a proportional constant facilitates that the output can be interpreted in terms of crash frequency per mile by dividing the result by L, the model specifications showed that crash frequency was not proportional to segment length in any of the models. This suggests that segment length is likely correlated with unobserved features that cannot be captured in the model. Not treating segment length as a proportional constant and instead estimating a unique coefficient for segment length would then lead to more accurate predictions and better overall model fit.

To interpret the influence of independent variables on reckless driving crash frequency, elasticities can be used. These represent the responsiveness of the predicted crash frequency to a marginal change in an explanatory variable. For continuous variables the elasticity is defined as:

$$E_{X_{ijk}}^{\lambda_{ij}} = \frac{\partial\lambda_{ij}/\lambda_{ij}}{\partial X_{ijk}/X_{ijk}} = \frac{\partial\lambda_{ij}}{\partial X_{ijk}} \times \frac{X_{ijk}}{\lambda_{ij}} \quad (2)$$

Depending on how the variable is modeled (log-log or log-linear), elasticity simplifies as follows:

- Log-log form (e.g., AADT):

$$E_{X_{ijk}}^{\lambda_{ij}} = \beta_k \quad (3)$$

- Log-linear form (e.g., average shoulder width):

$$E_{X_{ijk}}^{\lambda_{ij}} = \beta_k X_{ijk} \quad (4)$$

For indicator (binary) variables—such as the posted speed limit being greater than some threshold value—pseudo-elasticity was used to estimate the percentage change in crash frequency when the variable switches from 0 to 1:

$$E_{X_{ijk}}^{\lambda_{ij}} = \exp(\beta_k) - 1 \quad (5)$$

These elasticities allow for meaningful interpretation of the risk associated with individual roadway or environmental features in relation to different types of reckless driving crashes.

Reckless Driving Crash Risk Model Estimation

This section describes the models and risk factors for reckless driving obtained for each roadway type. To reduce redundancy, two models (one at KABCO level and one at KABC level) for only aggressive driving behavior are included for each roadway type. However, the results of all of reckless driving crash risk models and risk factors developed for this project (40 models in total) are included in Appendix D.

Models were initially developed including PHIs; however, while the PHIs were sometimes statistically significant, their inclusion did not significantly improve the practical predictive power of the models. PHIs could be used to understand the impact of different socioeconomic variables on reckless driving crashes, but were not found necessary for modeling crash risk. Therefore, after careful consultation with the POC, the research team decided not to include PHIs in the final models. An example model developed using PHIs is shown in Appendix G to illustrate the lack of significance and practical impact in the models.

During a discussion with the POC, members of the POC noted that the lane width information provided by WisDOT was subject to a fair degree of error and might not be very precise. To facilitate their inclusion in the models, the research team suggested breaking this variable into binary categories (e.g., greater than or equal to 12 ft) as this would allow some knowledge of lane width (essentially, wider or narrower lanes) into the safety models while acknowledging the lack of precision. The POC agreed and the inclusion of lane width in a binary form was considered in the safety models developed. A similar approach was also considered for shoulder width, although shoulder width was also considered in a continuous form if it improved the overall model fit.

Table 16 provides a summary of the aggressive crash frequency model developed for roadway segments categorized as basic freeway. Models were developed using both KABCO aggressive crash frequency and only KABC aggressive crash frequency as the dependent variable and both models are summarized in Table 16. The table provides both the coefficient estimates and the associated p-value, along with the overdispersion parameter and the log-likelihood value for the model.

Table 16. Summary of aggressive crash frequency models developed for basic freeways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-12.3242*	*<0.001*	*-11.8381*	*<0.001*
Natural log of adjusted average AADT	1.3282	<0.001	1.169	<0.001
Natural log of segment length (in mile)	0.8404	<0.001	0.8682	<0.001
Average shoulder width	-0.0671	<0.001	-0.062	<0.001
Posted speed limit 65 mph or above	-0.3342	<0.001	-0.3331	0.002
Number of lanes 3 or above	0.2851	<0.001	0.4189	<0.001
Inverse of overdispersion parameter	*2.059*		*1.998*	
2xlog-likelihood value	*-6582.624*		*-3809.531*	

The coefficient estimate for a given variable provides the relationship between that variable and aggressive crash frequency: values greater than 0 represent factors associated with increased aggressive crash risk, while values less than 0 represent factors associated with decreased aggressive crash risk. As shown, factors associated with increased risk include:

- Vehicular traffic volume (e.g., AADT)
- Roadway segment length
- Roadway segments with three or more lanes

Factors associated with reduced risk include:

- Average shoulder width
- Roadway segments with higher speed limits (e.g., higher than 65 mph)

These coefficient estimates generally align with expectations. Crash frequencies are generally expected to increase with exposure, and both traffic volume (number of vehicles that travel on the segment) and segment length (the amount of travel on the segment) increase exposure. The number of lanes is associated with increased aggressive driving crashes, which seems reasonable as more lanes typically means more interactions with other vehicles and opportunities to perform aggressive driving maneuvers. On the other hand, shoulder width is negatively correlated with aggressive driving activities; this is likely due to larger shoulder widths providing more space for vehicles to recover from an event when they leave the travel path. Roadway segments with higher speed limits are also expected to have fewer aggressive driving crashes; while this might seem counterintuitive, roads with higher speed limits typically have more conservative design criteria. Additionally, higher speed limits typically mean that vehicles travel faster, reducing opportunities for aggressive driving maneuvers.

The p-values associated with each coefficient are used to assess the statistical significance of the variable included in the model. Smaller values indicate stronger statistical significance; p-values less than 0.05 indicate variables that are statistically significant to the 95% confidence level. Note that most of the risk factors are statistically significant to the 95% confidence level. Those that are not (e.g., the number of lanes is 3 or above in the KABCO model) are still included since the coefficient estimate is in line with expectation, its inclusion improves the overall model fit and keeping the variable would improve the use of the model in identifying high-risk locations.

Table 17 provides the elasticities for all variables associated with the models in Table 16, computed using Equations 1 to 5. These elasticities quantify the amount of "risk" associated with each risk factor included in the model. Specifically, each value represents the relevant increase in crash frequency associated with a change in a given variable, referred to hereafter as crash risk. Values greater than 0 represent an increase in crash risk associated with an increase in that variable (e.g., positive correlation), whereas values less than 0 represent a decline in crash risk associated with an increase in that variable (e.g., negative correlation). Continuous variables that are not in a log form are assessed at the median value observed in the dataset (provided in the table). The elasticity values would differ for other values of these continuous variables; however, these estimates provide a good indication of the strength of the relationship between that variable and reckless driving crash frequency. Despite being continuous variables, the AADT and segment length are entered in the log form and hence the elasticity values provided in this table would hold for all AADT and segment length values (the elasticity values would be the model coefficients for these two variables). For binary (indicator) variables, the elasticity shows the expected crash frequency changes when the variable goes from 0 to 1.

Table 17. Elasticity values for aggressive crash frequency models developed for basic freeways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.3282	1.169	NA
Natural log of segment length (in mile)	Log	0.8404	0.8682	NA
Average shoulder width	C	-0.4697	-0.4339	7
Posted speed limit 65 mph or above	I	-0.2841	-0.2833	NA
Number of lanes 3 or above	I	0.3299	0.5203	NA

Values in Table 17 can be interpreted as follows. AADT and segment length are variables included in the model in a log form. The elasticities suggest that a one percent change in AADT along a basic freeway segment is associated with a 1.33 percent increase in KABCO aggressive crash frequency and 1.17 percent increase in KABC aggressive crash frequency along that segment, respectively. For the continuous variable average shoulder width, the elasticity is provided at the median value observed in the data. For example, a one percent change in average shoulder width —for the "average" roadway segment with average shoulder width of 7ft— would be associated with a 0.4697 percent decrease in KABCO aggressive crash frequency and a 0.4399 percent decrease in KABC aggressive crash frequency along that segment, respectively. Finally, indicator variables provide the percentage change associated with the indicator being used. For example, the presence of 3 or more travel lanes is associated with a 33.0 percent increase in KABCO aggressive crash frequency and 52.0 percent increase in KABC aggressive crash frequency along that segment, respectively. Other variables can be interpreted similarly.

Roadway network screening criteria tool

The risk factors estimated by the models from the previous section can be used to model the expected crash risk at individual roadway segments within Wisconsin STHN. These crash risk values can be used to "rank" individual sites to identify those that have the highest crash risk of different reckless driving behaviors included in this project. These high-risk locations can then be considered for additional scrutiny or the application of systemic safety treatments. The research team has performed these calculations and developed an excel-based screening tool that identifies the riskiest roadway segments within Wisconsin. The NB model coefficients are applied within the excel-based screening tool to estimate predicted crash frequencies for individual sites at KABCO and KABC injury severity levels. The tool is organized by roadway types to provide the predicted number of KABCO and KABC crashes for individual sites for each roadway type, allowing for efficient safety screening and prioritization. Additionally, a data dictionary, results of each model, and model elasticities are provided in the screening tool separately. Examples of the screening tool are shown in Appendix F.

Roadway network screening criteria map

To support visual interpretation of these results, the predicted crash risks and observed crashes were mapped across the statewide network, enabling spatial identification of high-risk roadway segments. The maps provide a clear and intuitive way to highlight locations where specific reckless driving behaviors are more likely to result in crashes, helping agencies focus safety efforts geographically. Maps are organized by roadway type and injury severity level (KABCO and KABC), allowing for targeted screening based on segment classification and crash impact.

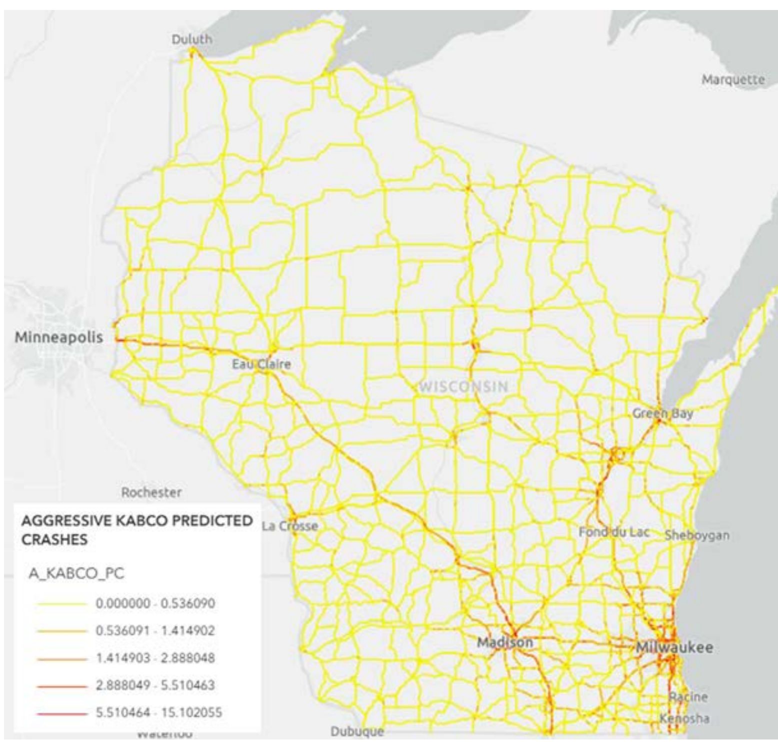

Figure 1. Map showing Predicted KABCO Aggressive Driving Related Crashes by Segment

These visualizations also support network-level planning by illustrating how crash risk varies across different regions and corridor types. Figure 1 shows the mapped predicted KABCO aggressive driving related crashes by segment. As expected, the crash risk is higher near major cities and appears to be the highest along I-94 and I-90.

CONCLUSIONS

The research team conducted a literature review to identify countermeasures for reckless driving, and determined a set of countermeasures that would be applicable to the Wisconsin highways. Next, the team developed risk factors to quantify the relationship between crash frequencies and key roadway and traffic variables across different roadway types. The Excel-based screening tool applies these model results to predict site-specific crash frequencies with an accessible method for identifying high-risk locations. Based on the model findings, sites with higher predicted crashes are often associated with factors such as higher AADT, longer segment lengths, and undivided or relatively wide roadways. On the other hand, sites with lower predicted crashes are often associated with relatively higher posted speed limits and the presence of wider shoulders. Additionally, speeding was identified as having a relatively higher risk of resulting in crashes.

Based on these findings, it is recommended that WisDOT prioritize network screening at sites with higher risks and consider targeted countermeasures such as median installation, shoulder widening, and traffic calming treatments. At sites where speeding contributes significantly to crash risk, it is recommended that WisDOT consider implementing speed management strategies, such as speed feedback signs or geometric modifications. To maintain the effectiveness of the tool, regular model updates and validation with the most recent crash data are encouraged, alongside ongoing training for users to correctly interpret outputs and implement appropriate safety improvements.

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Appendix A: Methods Used Testing Countermeasures from Existing Studies

Table 18. Methods Used Testing Speeding Countermeasures from Exiting Studies

Category	Type of Comparison	Statistical Methods	Location and Time Period
Real World Implementation			
Fildes et al., 2005 PCM countermeasures (n=6 sites) • Peripheral transverse lines (Intersections) • Enhanced post-spacing with ascending heights (Curves)	• Before and After • Short term vs. Long term • Between sites	• ANOVA • Linear Regression	Location: Australia • Victoria • New South Wales Time: • Short term: 1-2 months after implementation • Long term: 12 months after implementation
Gangireddy et al., 2024 145 pavement preservation projects • 103 in rural areas • 42 in urban areas	• Before and After	• Paired t-tests • Multiple Linear Regression	Location: Louisiana Time: 2018 to 2020
Wu et al., 2020 The effectiveness of DFS on urban road segments	• Before and After	• Negative Binomial (NB) model • Empirical Bayes (EB) methods	Location: Alberta, Canada Time: January 2009 to December 2018
Yang et al., 2015 The effectiveness of DFS on four-lane two-way roadways in suburban/urban area	• Before and After	• F-test • Two-sample t-test • Two-sample Kolmogorov–Smirnov (KS) test • Fisher's exact test	Location: New Jersey Time: NA
Anderson & Monsere, 2022 Speed and crash analysis of speed limit changes on interstates and highways	• Before and After • Between different speed limit settings	• Poisson and Negative Binomial pooled models • Zero-inflated Poisson and Negative Binomial models • Traditional Poisson and Negative Binomial models based on cross-sectional data • Empirical Bayes (EB) methods	Location: East Oregon Time: March 2013 to April 2019
Gayah et al., 2018 Safety impacts of setting speed limits below engineering recommendations	• Before and After • Between different speed limit settings	• Linear Regression • Quantile Regression • Binary Logistic Regression • Negative Binomial models • Empirical Bayes (EB) methods	Location: Montana Time: • Speed: July 20–23, 2015, August 10–13, 2015, October 26–29, 2015

Category	Type of Comparison	Statistical Methods	Location and Time Period
Saleem & Srinivasan, 2023 Safety impacts of changing speed limit from 55mph to 60mph on two-lane, two-way road segments	• Before and After	• Negative Binomial models • Empirical Bayes (EB) methods	Location: Minnesota Time: • Crash data: 2012 to 2018 • Speed: 2015, 2016, and 2017, 2018, 2019
Simulated Scenarios			
Jiang et al., 2024 Roadside vegetations as countermeasures in transition areas	• Between different arterial roads • Between different highway exit ramps	• ANOVA • Paired t-tests	Location: Lab simulation • State road of US 24 running through Goodland, Indiana • Exit 29B of I-469 to Maple Crest Road near Fort Wayne Time: mid-July to late September 2023
Sommers & McAvoy, 2013 The effectiveness of 20 countermeasures that could reduce speed in work zones	• Between different roads • Between different scenarios	• ANOVA • Post-hoc tests (Tukey and Games-Howell)	Location: Lab simulation with drivers from Southeast Ohio Time: NA
Valdés-Díaz et al., 2020 The effectiveness of two-step posted speed reduction	• Between different scenarios	• T-tests of mean and 85th percentile speed	Location: Lab simulation with school zone selected from Puerto Rico Time: NA
Trends			
Monsere et al., 2006 Association between speed and crashes, light conditions, and surface conditions	• Speed-related crash analysis	• Wilcoxon Signed Rank Test	Location: Oregon Time: 2000-2002

Table 19. Methods Used Testing Distracted and Drowsy Driving Countermeasures from Exiting Studies

Reckless Driving Category and Countermeasure Tested	Type of Studies Comparison	Methods	Location and Time Period
Ahmad et al. (2023) (Distracted) Distraction and safety–critical events	Baseline vs Near-Crash vs Crash	Tobit model Ordered probit model Path analysis via joint estimation	Location: US
Ahmed et al. (2022) (Distracted and Drowsy) The effectiveness of centerline rumble strips	Before and After Between different weather conditions	Negative Binomial (NB) model (SPFs) Empirical Bayes (EB) methods	Location: Wyoming Time: Overall summer (April 15–October 14) winter (October 15–April 14)
Rahman & Kang, (2020) (Drowsy) Drowsy driving advisory presence	Before and After	Negative Binomial (NB) model (SPFs) Empirical Bayes (EB) methods	Location: Alabama Time: Crash data 2011-2018

Schaudt et al., (2013) (Distracted) Enhanced rear signaling system	Between baseline and treatment	Fisher's exact test	Location: Virginia Time: NA
Gaspar et al., (2017) (Drowsy) In-vehicle alert system	Between different countermeasures	ANOVA Cohen's d	Location: Iowa Time: NA
Gaspar et al., (2023) (Drowsy) Lane departure warning Drowsiness notification with lane departure warning	Between different in-vehicles countermeasures	ANOVA Dunnett's post-hoc tests.	Location: Iowa Time: NA
Jenness et al., (2011) (Distracted) Different types of motorcycle forward lighting treatment	Between different forward light treatments	Logistic regression model	Location: Gaithersburg, Maryland. Time: 11:30 AM and 2:00 PM
Kang et al., (2015) (Drowsy) Roadside rest areas Signage for driver education and safety messages	Between different engineering-related countermeasures	Shapiro–Wilk test One-tailed T-test Survey	Location: Alabama Time: NA
Hickman et al., (2016) (Distracted and Drowsy) Detection of drowsiness Warnings when driver drowsiness exceeds predetermined levels	Control and experimental	Descriptive data analysis	Location: US
Surveys and Literature Review			
Ahmed et al. (2015) (Distracted) Polices on shoulder and centerline rumble strips/stripes	Between stakeholders and different road users	Survey questionnaires	Location: Wyoming Time: NA

Table 20. Methods Used Testing Impaired Driving Countermeasures from Exiting Studies

Category	Type of Studies Comparison	Methods	Location and Time Period
Savolainen et al. (2014) High-tension cable barriers	• Before and After	• Negative Binomial (NB) model (SPFs) • Empirical Bayes (EB) methods	Location: Michigan Time: Crash data • 2004 through 2013 Cable barrier installation: after 2012
Savolainen et al. (2018) In-Service performance evaluation of median cable barriers	• Before and After	• Negative Binomial (NB) model	Location: Iowa Time: Crash data • 2007 through 2015
Seitzinger et al. (2016)	• Between different scenarios	• T-tests • Chi-squared test	Location: Lab Time: 2014

Traffic sign mounting height for preventing wrong-way driving			

APPENDIX B: COUNTERMEASURE EVALUATION METRICS

Table 21. Countermeasure Evaluation Metrics

	Explanation
Effectiveness	
★★★★★	Demonstrated to be effective by several high-quality evaluations with consistent results.
★★★★☆	Demonstrated to be effective in certain situations.
★★★☆☆	Likely to be effective based on balance of evidence from high-quality evaluations.
★★☆☆☆	Limited evaluation evidence, but adheres to principles of human behavior and may be effective if implemented well.
★☆☆☆☆	No evaluation evidence, but adheres to principles of human behavior and may be effective if implemented well.
Cost	
$$$	Requires extensive new facilities, staff, equipment, or publicity, or makes heavy demands on current resources.
$$	Requires some additional staff time, equipment, facilities, and/or publicity.
$	Can be implemented with current staff, perhaps with training; limited costs for equipment or facilities.
Use	
High	More than two-thirds of the States, or a substantial majority of communities.
Medium	One-third to two-thirds of the States or communities.
Low	Less than one-third of the States or communities.
Unknown	Data not available.
Time	
Long	More than 1 year.
Medium	More than 3 months but less than 1 year.
Short	3 months or less.
Unknown	Data not available.
Status	
CMF Exists	CMFs can be found from the CMF Clearing house
Research exists with no CMF established	There is not a developed CMF that can be found from the CMF Clearinghouse yet, but related research has tested the countermeasure's safety effect
Countermeasures without specific research	Countermeasures that have been suggested used but with little dedicated research on their safety effects

APPENDIX C: SEGMENT RISK DATA DICTIONARY.

Table 36 provides a data dictionary for the variables used in the models. Note that the last column represents the variables from the 2017-2021 ACS 5-year estimates data and the related calculations (if any) needed for generating the public health indices. The variable names provided in this column are short codes that represent specific data points from the survey.

Table 22. Segment risk data dictionary

Variable Name	Variable Definition	Source	SVI Original Calculations
PDP_ID	Meta-Manager Segment ID Number	WisDOT	
TRAF_SEG_ID	Traffic Segment ID Number	WisDOT	
DIVUND	Divided/Undivided/1-Way Highway Segment (D / U / 1)	WisDOT	
HWY&DIR	Highway and Direction	WisDOT	
TRWAYWD	Traveled way width	WisDOT	
HCURLE40	Curves/mile posted 40 mph or less	WisDOT	
HCURGT40	Curves/mile posted more than 40 mph	WisDOT	
NUMLANES	Number of lanes (Directional when roadway is divided)	WisDOT	
WI_CNTY_NM	County Name	WisDOT	
RSH1WD	Width of Right shoulder (first shoulder)	WisDOT	
RSH1TYP	Right shoulder type (first shoulder)		
LSH1TYP	Left shoulder type (first shoulder)	WisDOT	
LSH1WD	Width of Left shoulder (first shoulder)	WisDOT	
AVERAGESHOULDER	The average shoulder width on a specific segment: (LSH1WD+RSH1WD)/2	Calculated	
AVERAGELANEWIDTH	The average lane width of a specific segment: TRWAYWD/NUMLANES	Calculated	
MEDNTYP	Median Type	WisDOT	
MEDNWD	Median Width	WisDOT	
AADT_EST_2017	2017 AADT on a specific segment	WisDOT	
AADT_EST_2018	2018 AADT on a specific segment	WisDOT	

AADT_EST_2019	2019 AADT on a specific segment	WisDOT	
AADT_EST_2020	2020 AADT on a specific segment	WisDOT	
AADT_EST_2021	2021 AADT on a specific segment	WisDOT	
Avg_AADT_1721	The average AADT from 2017-2021 on a specific segment	Calculated	
Avg_AADT_1721_adjusted	The adjusted average AADT from 2017-2021 on a specific segment (The average AADT is divided by 2 if a segment is Divided (using DIVUND)	Calculated	
HCMTYPE	Highway Capacity Manual facility type **FRE**: Basic Freeway Section analyses are applied to freeway segments **MLT**: Multilane Highway analyses are applied to segments that have 4 or 6 lanes, and posted speed limits > 40 mph and signal spacing > 2 mi. apart. **TWO**: Two-Lane Highway analyses are applied to segments that have a 2-lane undivided rural cross section. **URB**: Urban analyses are applied to segments that have an urban cross section, or segments that have signal spacing of less than 2 miles apart and are within city or village limits.	WisDOT	
PTDSPEED	Posted speed limit	WisDOT	
Speed_K	Number of K level crashes that caused by speeding	Calculated from crash data	
Speed_A	Number of A level crashes that caused by speeding	Calculated from crash data	
Speed_B	Number of B level crashes that caused by speeding	Calculated from crash data	
Speed_C	Number of C level crashes that caused by speeding	Calculated from crash data	

Speed_O	Number of O level crashes that caused by speeding	Calculated from crash data	
Speed_KABCO	Number of all crashes that caused by speeding	Calculated from crash data	
Speed_KABC	Number of all crashes except for property damage only crashes that caused by speeding	Calculated from crash data	
Distracted_K	Number of K level crashes caused by distracted/drowsy driving	Calculated from crash data	
Distracted_A	Number of A level crashes caused by distracted/drowsy driving	Calculated from crash data	
Distracted_B	Number of B level crashes caused by distracted/drowsy driving	Calculated from crash data	
Distracted_C	Number of C level crashes caused by distracted/drowsy driving	Calculated from crash data	
Distracted_O	Number of O level crashes caused by distracted/drowsy driving	Calculated from crash data	
Distracted_KABCO	Number of all crashes that caused by distracted/drowsy driving	Calculated from crash data	
Distracted_KABC	Number of all crashes except for property damage only crashes that caused by distracted/drowsy driving	Calculated from crash data	
Impaired_K	Number of K level crashes caused by impaired driving	Calculated from crash data	
Impaired_A	Number of A level crashes caused by impaired driving	Calculated from crash data	
Impaired_B	Number of B level crashes caused by impaired driving	Calculated from crash data	
Impaired_C	Number of C level crashes caused by impaired driving	Calculated from crash data	
Impaired_O	Number of O level crashes caused by impaired driving	Calculated from crash data	
Impaired_KABCO	Number of all crashes that caused by impaired driving	Calculated from crash data	
Impaired_KABC	Number of all crashes except for property	Calculated from crash data	

	damage only crashes that caused by impaired driving		
Aggressive_K	Number of K level crashes caused by aggressive driving	Calculated from crash data	
Aggressive_A	Number of A level crashes caused by aggressive driving	Calculated from crash data	
Aggressive_B	Number of B level crashes caused by aggressive driving	Calculated from crash data	
Aggressive_C	Number of C level crashes caused by aggressive driving	Calculated from crash data	
Aggressive_O	Number of O level crashes caused by aggressive driving	Calculated from crash data	
Aggressive_KABCO	Number of all crashes that caused by aggressive driving	Calculated from crash data	
Aggressive_KABC	Number of all crashes except for property damage only crashes that caused by aggressive driving	Calculated from crash data	
E_TOTPOP_weighted	Population estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S0601_C01_001E
M_TOTPOP_weighted	Population estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S0601_C01_001M
E_HU_weighted	Housing units estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0001E
M_HU_weighted	Housing units estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data.	DP04_0001M

		Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	
E_HH_weighted	Households estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP02_0001E
M_HH_weighted	Households estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP02_0001M
E_POV150_weighted	Persons below 150% poverty estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S1701_C01_040E
M_POV150_weighted	Persons below 150% poverty estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S1701_C01_040M
E_UNEMP_weighted	Civilian (age 16+) unemployed estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP03_0005E
M_UNEMP_weighted	Civilian (age 16+) unemployed estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment	DP03_0005M

		overlaying intersecting census tracts.	
E_HBURD_weighted	Housing cost-burdened occupied housing units with annual income less than $75,000 (30%+ of income spent on housing costs) estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S2503_C01_028E + S2503_C01_032E + S2503_C01_036E + S2503_C01_040E
M_HBURD_weighted	Housing cost-burdened occupied housing units with annual income less than $75,000 (30%+ of income spent on housing costs) estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	SQRT(S2503_C01_028M ^2 + S2503_C01_032M ^2 + S2503_C01_036M ^2 + S2503_C01_040M ^2)
E_NOHSDP_weighted	Persons (age 25+) with no high school diploma estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	B06009_002E
M_NOHSDP_weighted	Persons (age 25+) with no high school diploma estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	B06009_002M
E_UNINSUR_weighted	Uninsured in the total civilian noninstitutionalized population estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S2701_C04_001E
M_UNINSUR_weighted	Uninsured in the total civilian noninstitutionalized population estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S2701_C04_001M
E_AGE65_weighted	Persons aged 65 and older estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data.	S0101_C01_030E

		Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	
M_AGE65_weighted	Persons aged 65 and older estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S0101_C01_030M
E_AGE17_weighted	Persons aged 17 and younger estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0019E
M_AGE17_weighted	Persons aged 17 and younger estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0019M
E_DISABL_weighted	Civilian noninstitutionalized population with a disability estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP02_0072E
M_DISABL_weighted	Civilian noninstitutionalized population with a disability estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP02_0072M
E_SNGPNT_weighted	Single-parent household with children under 18 estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment	DP02_0007E + DP02_0011E

		overlaying intersecting census tracts.	
M_SNGPNT_weighted	Single-parent household with children under 18 estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	SQRT(DP02_0007M ^2 + DP02_0011M^2)
E_LIMENG_weighted	Persons (age 5+) who speak English "less than well" estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	B16005_007E + B16005_008E + B16005_012E + B16005_013E + B16005_017E + B16005_018E + B16005_022E + B16005_023E + B16005_029E + B16005_030E + B16005_034E + B16005_035E + B16005_039E + B16005_040E + B16005_044E + B16005_045E
M_LIMENG_weighted	Persons (age 5+) who speak English "less than well" estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	
E_MINRTY_weighted	Minority estimate (Hispanic or Latino (of any race); Black and African American, Not Hispanic or Latino; American Indian and Alaska Native, Not Hispanic or Latino; Asian, Not Hispanic or Latino; Native Hawaiian and Other Pacific Islander, Not Hispanic or Latino; Two or More Races, Not Hispanic or Latino; Other Races, Not Hispanic or Latino) estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	SQRT(B16005_007M^2 + B16005_008M^2 + B16005_012M^2 + B16005_013M^2 + B16005_017M^2 + B16005_018M^2 + B16005_022M^2 + B16005_023M^2 + B16005_029M^2 + B16005_030M^2 + B16005_034M^2 + B16005_035M^2 + B16005_039M^2 + B16005_040M^2 + B16005_044M^2 + B16005_045M^2)

M_MINRTY_weighted	Minority estimate MOE, 2017-2021 ACS (Hispanic or Latino (of any race); Black and African American, Not Hispanic or Latino; American Indian and Alaska Native, Not Hispanic or Latino; Asian, Not Hispanic or Latino; Native Hawaiian and Other Pacific Islander, Not Hispanic or Latino; Two or More Races, Not Hispanic or Latino; Other Races, Not Hispanic or Latino)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0001E - DP05_0079E
E_MUNIT_weighted	Housing in structures with 10 or more units estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	SQRT(M_TOTPOP^2 + DP05_0079M^2)
M_MUNIT_weighted	Housing in structures with 10 or more units estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0012E + DP04_0013E
E_MOBILE_weighted	Mobile homes estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	SQRT(DP04_0012M^2 + DP04_0013M^2)
M_MOBILE_weighted	Mobile homes estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0014E
E_CROWD_weighted	At household level (occupied housing units), more people than rooms estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the	DP04_0014M

		percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	
M_CROWD_weighted	At household level (occupied housing units), more people than rooms estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0078E + DP04_0079E
E_NOVEH_weighted	Households with no vehicle available estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	SQRT(DP04_0078M^2 + DP04_0079M^2)
M_NOVEH_weighted	Households with no vehicle available estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0058E
E_GROUPQ_weighted	Persons in group quarters estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0058M
M_GROUPQ_weighted	Persons in group quarters estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	B26001_001E
EP_POV150_weighted	Percentage of persons below 150% poverty estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	B26001_001M

MP_POV150_weighted	Percentage of persons below 150% poverty estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	(E_POV150 / S1701_C01_001E) * 100
EP_UNEMP_weighted	Unemployment Rate estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	((SQRT(M_POV150^2 - ((EP_POV150 / 100)^2 * S1701_C01_001M^2))) / S1701_C01_001E) * 100
MP_UNEMP_weighted	Unemployment Rate estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP03_0009PE
EP_HBURD_weighted	Percentage of housing cost-burdened occupied housing units with annual income less than $75,000 (30%+ of income spent on housing costs) estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP03_0009PM
MP_HBURD_weighted	Percentage of housing cost-burdened occupied housing units with annual income less than $75,000 (30%+ of income spent on housing costs) estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	(E_HBURD / S2503_C01_001E) * 100
EP_NOHSDP_weighted	Percentage of persons with no high school diploma (age 25+) estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	((SQRT(M_HBURD^2 - ((EP_HBURD / 100)^2 * S2503_C01_001M^2))) / S2503_C01_001E) * 100
MP_NOHSDP_weighted	Percentage of persons with no high school diploma (age 25+)	Calculated from SVI and Census Tract data. Weighted average calculated using the	S0601_C01_033E

	estimate MOE, 2017-2021 ACS	percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	
EP_UNINSUR_weighted	Percentage uninsured in the total civilian noninstitutionalized population estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S0601_C01_033M
MP_UNINSUR_weighted	Percentage uninsured in the total civilian noninstitutionalized population estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S2701_C05_001E
EP_AGE65_weighted	Percentage of persons aged 65 and older estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S2701_C05_001M
MP_AGE65_weighted	Percentage of persons aged 65 and older estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S0101_C02_030E
EP_AGE17_weighted	Percentage of persons aged 17 and younger estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S0101_C02_030M
MP_AGE17_weighted	Percentage of persons aged 17 and younger estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0019PE

EP_DISABL_weighted	Percentage of civilian noninstitutionalized population with a disability estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0019PM
MP_DISABL_weighted	Percentage of civilian noninstitutionalized population with a disability estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP02_0072PE
EP_SNGPNT_weighted	Percentage of single-parent households with children under 18 estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP02_0072PM
MP_SNGPNT_weighted	Percentage of single-parent households with children under 18 estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP02_0007PE + DP02_0011PE
EP_LIMENG_weighted	Percentage of persons (age 5+) who speak English "less than well" estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	((SQRT(M_SNGPNT^2 - ((EP_SNGPNT / 100)^2 * M_HH^2))) / E_HH) * 100
MP_LIMENG_weighted	Percentage of persons (age 5+) who speak English "less than well" estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	(E_LIMENG / B16005_001E) * 100
EP_MINRTY_weighted	Percentage minority (Hispanic or Latino (of any race); Black and African American, Not	Calculated from SVI and Census Tract data. Weighted average calculated using the	((SQRT(M_LIMENG^2 - ((EP_LIMENG / 100)^2 *

	Hispanic or Latino; American Indian and Alaska Native, Not Hispanic or Latino; Asian, Not Hispanic or Latino; Native Hawaiian and Other Pacific Islander, Not Hispanic or Latino; Two or More Races, Not Hispanic or Latino; Other Races, Not Hispanic or Latino) estimate, 2017-2021 ACS	percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	B16005_001M^2))) / B16005_001E) * 100
MP_MINRTY_weighted	Percentage minority (Hispanic or Latino (of any race); Black and African American, Not Hispanic or Latino; American Indian and Alaska Native, Not Hispanic or Latino; Asian, Not Hispanic or Latino; Native Hawaiian and Other Pacific Islander, Not Hispanic or Latino; Two or More Races, Not Hispanic or Latino; Other Races, Not Hispanic or Latino) estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	100.0 - DP05_0019PE
EP_MUNIT_weighted	Percentage of housing in structures with 10 or more units estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	((SQRT(M_MINRTY^2 - ((EP_MINRTY / 100)^2 * M_TOTPOP^2))) / E_TOTPOP) * 100
MP_MUNIT_weighted	Percentage of housing in structures with 10 or more units estimate MOE	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0012PE + DP04_0013PE
EP_MOBILE_weighted	Percentage of mobile homes estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment	((SQRT(M_MUNIT^2 - ((EP_MUNIT / 100)^2 * M_HU^2))) / E_HU) * 100

		overlaying intersecting census tracts.	
MP_MOBILE_weighted	Percentage of mobile homes estimate MOE	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0014PE
EP_CROWD_weighted	Percentage of occupied housing units with more people than rooms estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0014PM
MP_CROWD_weighted	Percentage of occupied housing units with more people than rooms estimate MOE	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0078PE + DP04_0079PE
EP_NOVEH_weighted	Percentage of households with no vehicle available estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	((SQRT(M_CROWD^2 - ((EP_CROWD / 100)^2 * DP04_0002M^2))) / DP04_0002E) * 100
MP_NOVEH_weighted	Percentage of households with no vehicle available estimate MOE	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0058PE
EP_GROUPQ_weighted	Percentage of persons in group quarters estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP04_0058PM

MP_GROUPQ_weighted	Percentage of persons in group quarters estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	(E_GROUPQ / E_TOTPOP) * 100
EPL_POV150_weighted	Percentile percentage of persons below 150% poverty estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	((SQRT(M_GROUPQ^2 - ((EP_GROUPQ / 100)^2 * M_TOTPOP^2))) / E_TOTPOP) * 100
EPL_UNEMP_weighted	Percentile percentage of civilian (age 16+) unemployed estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_POV150 with 4 significant digits
EPL_HBURD_weighted	Percentile percentage of housing cost-burdened occupied housing units estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_UNEMP with 4 significant digits
EPL_NOHSDP_weighted	Percentile percentage of persons with no high school diploma (age 25+) estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_HBURD with 4 significant digits
EPL_UNINSUR_weighted	Percentile percentage of uninsured estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_NOHSDP with 4 significant digits
SPL_THEME1_weighted	Sum of series for Socioeconomic Status theme	Calculated from SVI and Census Tract data. Weighted average calculated using the	Percent rank EP_UNINSUR with 4 significant digits

		percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	
RPL_THEME1_weighted	Percentile ranking for Socioeconomic Status theme summary	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_POV150 + EPL_UNEMP + EPL_HBURD + EPL_NOHSDP + EPL_UNINSUR
EPL_AGE65_weighted	Percentile percentage of persons aged 65 and older estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank SPL_THEME1 with 4 significant digits
EPL_AGE17_weighted	Percentile percentage of persons aged 17 and younger estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_AGE65 with 4 significant digits
EPL_DISABL_weighted	Percentile percentage of civilian noninstitutionalized population with a disability estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_AGE17 with 4 significant digits
EPL_SNGPNT_weighted	Percentile percentage of single-parent households with children under 18 estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_DISABL with 4 significant digits
EPL_LIMENG_weighted	Percentile percentage of persons (age 5+) who speak English "less than well" estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_SNGPNT with 4 significant digits

SPL_THEME2_weighted	Sum of series for Household Characteristics theme	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_LIMENG with 4 significant digits
RPL_THEME2_weighted	Percentile ranking for Household Characteristics theme summary	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_AGE65 + EPL_AGE17 + EPL_DISABL + EPL_SNGPNT + EPL_LIMENG
EPL_MINRTY_weighted	Percentile percentage minority (Hispanic or Latino of any race; Black and African American, Not Hispanic or Latino; American Indian and Alaska Native, Not Hispanic or Latino; Asian, Not Hispanic or Latino; Native Hawaiian and Other Pacific Islander, Not Hispanic or Latino; Two or More Races, Not Hispanic or Latino; Other Races, Not Hispanic or Latino) estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank SPL_THEME2 with 4 significant digits
SPL_THEME3_weighted	Sum of series for Racial and Ethnic Minority Status theme	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_MINRTY with 4 significant digits
RPL_THEME3_weighted	Percentile ranking for Racial and Ethnic Minority Status theme	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_MINRTY
EPL_MUNIT_weighted	Percentile percentage housing in structures with 10 or more units estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the	Percent rank SPL_THEME3 with 4 significant digits

		percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	
EPL_MOBILE_weighted	Percentile percentage of mobile homes estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_MUNIT with 4 significant digits
EPL_CROWD_weighted	Percentile percentage of households with more people than rooms estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_MOBILE with 4 significant digits
EPL_NOVEH_weighted	Percentile percentage of households with no vehicle available estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_CROWD with 4 significant digits
EPL_GROUPQ_weighted	Percentile percentage of persons in group quarters estimate	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_NOVEH with 4 significant digits
SPL_THEME4_weighted	Sum of series for Housing Type/Transportation theme	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank EP_GROUPQ with 4 significant digits
RPL_THEME4_weighted	Percentile ranking for Housing Type/Transportation theme	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_MUNIT + EPL_MOBILE + EPL_CROWD + EPL_NOVEH + EPL_GROUPQ

SPL_THEMES_weighted	Sum of series themes	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank SPL_THEME4 with 4 significant digits
RPL_THEMES_weighted	Overall percentile ranking	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	SPL_THEME1 + SPL_THEME2 + SPL_THEME3 + SPL_THEME4
F_POV150_weighted	Flag - the percentage of persons below 150% poverty is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	Percent rank SPL_THEMES with 4 significant digits
F_UNEMP_weighted	Flag - the percentage of civilian unemployed is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_POV150 >= 0.90
F_HBURD_weighted	Flag - the percentage of housing cost-burdened occupied housing units is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_UNEMP >= 0.90
F_NOHSDP_weighted	Flag - the percentage of persons with no high school diploma is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_HBURD >= 0.90
F_UNINSUR_weighted	Flag - the percentage of uninsured is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the	EPL_NOHSDP >= 0.90

		percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	
F_THEME1_weighted	Sum of flags for Socioeconomic Status theme	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_UNINSUR >= 0.90
F_AGE65_weighted	Flag - the percentage of persons aged 65 and older is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	F_POV150 + F_UNEMP + F_HBURD + F_NOHSDP + F_UNINSUR
F_AGE17_weighted	Flag - the percentage of persons aged 17 and younger is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_AGE65 >= 0.90
F_DISABL_weighted	Flag - the percentage of persons with a disability is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_AGE17 >= 0.90
F_SNGPNT_weighted	Flag - the percentage of single-parent households is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_DISABL >= 0.90
F_LIMENG_weighted	Flag - the percentage of those with limited English is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_SNGPNT >= 0.90

F_THEME2_weighted	Sum of flags for Household Characteristics theme	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_LIMENG >= 0.90
F_MINRTY_weighted	Flag - the percentage of minority is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	F_AGE65 + F_AGE17 + F_DISABL + F_SNGPNT + F_LIMENG
F_THEME3_weighted	Sum of flags for Racial and Ethnic Minority Status theme	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_MINRTY >= 0.90
F_MUNIT_weighted	Flag - the percentage of households in multi-unit housing is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	F_MINRTY
F_MOBILE_weighted	Flag - the percentage of mobile homes is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_MUNIT >= 0.90
F_CROWD_weighted	Flag - the percentage of crowded households is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_MOBILE >= 0.90
F_NOVEH_weighted	Flag - the percentage of households with no vehicles is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the	EPL_CROWD >= 0.90

		percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	
F_GROUPQ_weighted	Flag - the percentage of persons in group quarters is in the 90th percentile (1 = yes, 0 = no)	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_NOVEH >= 0.90
F_THEME4_weighted	Sum of flags for Housing Type/Transportation theme	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	EPL_GROUPQ >= 0.90
F_TOTAL_weighted	Sum of flags for the four themes	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	F_MUNIT + F_MOBILE + F_CROWD + F_NOVEH + F_GROUPQ
E_NOINT_weighted	Adjunct variable - Estimated daytime population, LandScan 2021**	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	F_THEME1 + F_THEME2 + F_THEME3 + F_THEME4
M_NOINT_weighted	Adjunct variable - Households without an internet subscription estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S2801_C01_019E
E_AFAM_weighted	Adjunct variable - Households without an internet subscription estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	S2801_C01_019M

M_AFAM_weighted	Adjunct variable - Black/African American, not Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0080E
E_HISP_weighted	Adjunct variable - Black/African American, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0080M
M_HISP_weighted	Adjunct variable – Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0073E
E_ASIAN_weighted	Adjunct variable – Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0073M
M_ASIAN_weighted	Adjunct variable – Asian, not Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0082E
E_AIAN_weighted	Adjunct variable – Asian, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0082M
M_AIAN_weighted	Adjunct variable - American Indian or Alaska Native, not Hispanic or Latino	Calculated from SVI and Census Tract data. Weighted average calculated using the	DP05_0081E

	persons estimate, 2017-2021 ACS	percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	
E_NHPI_weighted	Adjunct variable - American Indian or Alaska Native, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0081M
M_NHPI_weighted	Adjunct variable - Native Hawaiian or Other Pacific Islander, not Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0083E
E_TWOMORE_weighted	Adjunct variable - Native Hawaiian or Other Pacific Islander, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0083M
M_TWOMORE_weighted	Adjunct variable - Two or more races, not Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0085E
E_OTHERRACE_weighted	Adjunct variable - Two or more races, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0085M
M_OTHERRACE_weighted	Adjunct variable - Some other race, not Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0084E

EP_NOINT_weighted	Adjunct variable - Some other race, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0084M
MP_NOINT_weighted	Adjunct variable - Percentage of households without an internet subscription estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	(E_NOINT / S2801_C01_001E) * 100
EP_AFAM_weighted	Adjunct variable - Percentage of households without an internet subscription estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	((SQRT (M_NOINT^2 - ((EP_NOINT / 100)^2 * S2801_C01_001M^2))) / S2801_C01_001E) * 100
MP_AFAM_weighted	Adjunct variable - Percentage of Black/African American, not Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0080PE
EP_HISP_weighted	Adjunct variable - Percentage of Black/African American, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0080PM
MP_HISP_weighted	Adjunct variable - Percentage of Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0073PE
EP_ASIAN_weighted	Adjunct variable - Percentage of Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the	DP05_0073PM

		percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	
MP_ASIAN_weighted	Adjunct variable - Percentage of Asian, not Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0082PE
EP_AIAN_weighted	Adjunct variable - Percentage of Asian, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0082PM
MP_AIAN_weighted	Adjunct variable - Percentage of American Indian or Alaska Native, not Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0081PE
EP_NHPI_weighted	Adjunct variable - Percentage of American Indian or Alaska Native, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0081PM
MP_NHPI_weighted	Adjunct variable - Percentage of Native Hawaiian or Other Pacific Islander, not Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0083PE
EP_TWOMORE_weighted	Adjunct variable - Percentage of Native Hawaiian or Other Pacific Islander, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0083PM

MP_TWOMORE_weighted	Adjunct variable - Percentage of two or more races, not Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0085PE
EP_OTHERRACE_weighted	Adjunct variable - Percentage of two or more races, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0085PM
MP_OTHERRACE_weighted	Adjunct variable - Percentage of some other race, not Hispanic or Latino persons estimate, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0084PE
E_DAYPOP_weighted	Adjunct variable - Percentage of some other race, not Hispanic or Latino persons estimate MOE, 2017-2021 ACS	Calculated from SVI and Census Tract data. Weighted average calculated using the percentages of a 5ft buffer of road segment overlaying intersecting census tracts.	DP05_0084PM

APPENDIX D: CRASH SUMMARY STATISTICS

Table 23. Summary statistics for risk data

Variable	Missing Values		Mean	Median	Min.	Max.	SD
	Number	Percent					
Average AADT (2017-2021)	374	1.69	12,510	6,600	60	175,880	0.13
Adjusted average AADT (2017-2021)[17]	374	1.69	7,454	4,992	60	84,957	0.13
Median Type	16,345	73.80	n/a	n/a	n/a	n/a	n/a
Median Width	16,401	74.05	41.47	28	1	830	48.84
Number of lanes (Directional when roadway is divided)	1	0.00	2.02	2	1	5	0.55
Divided road status	0	0.00	n/a	n/a	n/a	n/a	n/a
Traveled way width (through lanes only)	1	0.00	24.97	24	10	70	6.75
Left shoulder type (first shoulder)	1	0.00	n/a	n/a	n/a	n/a	n/a
Width of left shoulder (first shoulder)	1	0.00	2.84	3	0	30	2.66
Right shoulder type (first shoulder)	294	1.32	n/a	n/a	n/a	n/a	n/a
Width of right shoulder (first shoulder)	1	0.00	3.75	3	0	34	3.40
Posted speed limit	411	1.86	51.08	55	25	70	0.13
Highway capacity manual facility type (roadway category)	772	3.49	n/a	n/a	n/a	n/a	n/a
Curves/mile posted more than 40 mph	1,269	5.73	n/a	n/a	n/a	n/a	n/a
Curves/mile posted 40 mph or less	1,269	5.73	n/a	n/a	n/a	n/a	n/a
Segment length (mile)	0	0.00	0.66	0.59	0.01	2.92	0.49
Speeding KABCO crashes	0	0.00	1.75	1	0	254	4.23
Speeding KABC crashes	0	0.00	0.52	0	0	59	1.36
Distracted KABCO crashes	0	0.00	1.27	0	0	43	2.47
Distracted KABC crashes	0	0.00	0.45	0	0	18	0.99
Impaired KABCO crashes	0	0.00	0.51	0	0	22	1.05
Impaired KABC crashes	0	0.00	0.24	0	0	14	0.60
Aggressive KABCO crashes	0	0.00	0.47	0	0	40	1.25
Aggressive KABC crashes	0	0.00	0.18	0	0	13	0.58

Table 24. Summary statistics of basic freeway crashes by injury severity groupings

Crash Category	Basic freeway			
	Mean	Median	Min	Max
Speeding				
KAB	0.83	0.00	0.00	17.00
KABC	1.43	1.00	0.00	38.00
KABCO	5.17	3.00	0.00	109.00
Distracted				
KAB	0.33	0.00	0.00	5.00
KABC	0.58	0.00	0.00	10.00
KABCO	1.74	1.00	0.00	43.00

[17] The adjusted average AADT from 2017-2021 on a specific segment (The average AADT is divided by two if a segment is Divided (using the DIVUND variable).

Impaired				
KAB	0.25	0.00	0.00	6.00
KABC	0.35	0.00	0.00	13.00
KABCO	0.82	0.00	0.00	19.00
Aggressive				
KAB	0.22	0.00	0.00	7.00
KABC	0.37	0.00	0.00	13.00
KABCO	1.06	0.00	0.00	40.00

Table 25. Summary statistics of multilane highway crashes by injury severity groupings

Crash Category	Multilane highway			
	Mean	**Median**	**Min**	**Max**
Speeding				
KAB	0.28	0.00	0.00	6.00
KABC	0.43	0.00	0.00	9.00
KABCO	1.47	1.00	0.00	26.00
Distracted				
KAB	0.23	0.00	0.00	6.00
KABC	0.39	0.00	0.00	9.00
KABCO	1.08	0.00	0.00	25.00
Impaired				
KAB	0.14	0.00	0.00	6.00
KABC	0.18	0.00	0.00	6.00
KABCO	0.41	0.00	0.00	9.00
Aggressive				
KAB	0.09	0.00	0.00	3.00
KABC	0.14	0.00	0.00	4.00
KABCO	0.34	0.00	0.00	7.00

Table 26. Summary statistics of two-lane highway crashes by injury severity groupings

Crash Category	Two-lane highway			
	Mean	Median	Min	Max
Speeding				
KAB	0.22	0.00	0.00	5.00
KABC	0.31	0.00	0.00	7.00
KABCO	0.90	0.00	0.00	17.00
Distracted				
KAB	0.21	0.00	0.00	8.00
KABC	0.30	0.00	0.00	10.00
KABCO	0.70	0.00	0.00	21.00
Impaired				
KAB	0.16	0.00	0.00	4.00
KABC	0.20	0.00	0.00	6.00
KABCO	0.38	0.00	0.00	7.00
Aggressive				
KAB	0.07	0.00	0.00	6.00
KABC	0.10	0.00	0.00	6.00
KABCO	0.22	0.00	0.00	8.00

Table 27. Summary statistics of undivided urban highway crashes by injury severity groupings

Crash Category	Undivided urban highway			
	Mean	Median	Min	Max
Speeding				
KAB	0.25	0.00	0.00	9.00
KABC	0.43	0.00	0.00	18.00
KABCO	1.47	1.00	0.00	42.00
Distracted				
KAB	0.37	0.00	0.00	9.00
KABC	0.74	0.00	0.00	14.00
KABCO	2.39	1.00	0.00	29.00
Impaired				
KAB	0.25	0.00	0.00	8.00
KABC	0.35	0.00	0.00	14.00
KABCO	0.80	0.00	0.00	22.00
Aggressive				
KAB	0.14	0.00	0.00	10.00
KABC	0.24	0.00	0.00	13.00
KABCO	0.63	0.00	0.00	23.00

Table 28. Summary statistics of divided urban highway crashes by injury severity groupings

Crash Category	Divided urban highway			
	Mean	Median	Min	Max
Speeding				
KAB	0.32	0.00	0.00	9.00
KABC	0.62	0.00	0.00	14.00
KABCO	2.07	1.00	0.00	29.00
Distracted				
KAB	0.31	0.00	0.00	12.00
KABC	0.82	0.00	0.00	18.00
KABCO	2.50	1.00	0.00	39.00
Impaired				
KAB	0.20	0.00	0.00	4.00
KABC	0.30	0.00	0.00	6.00
KABCO	0.69	0.00	0.00	15.00
Aggressive				
KAB	0.17	0.00	0.00	5.00
KABC	0.33	0.00	0.00	9.00
KABCO	0.87	0.00	0.00	16.00

APPENDIX E: RISK FACTORS MODELING[18]

Basic freeway risk factors modeling

Table 29. Summary of aggressive crash frequency models developed for basic freeways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-12.3242*	*<0.001*	*-11.8381*	*<0.001*
Natural log of adjusted average AADT	1.3282	<0.001	1.169	<0.001
Natural log of segment length (in mile)	0.8404	<0.001	0.8682	<0.001
Average shoulder width	-0.0671	<0.001	-0.062	<0.001
Posted speed 65 mph or above	-0.3342	<0.001	-0.3331	0.002
Number of lanes 3 or above	0.2851	<0.001	0.4189	<0.001
Inverse of overdispersion parameter	*2.059*		*1.998*	
2xlog-likelihood value	*-6582.624*		*-3809.531*	

Table 30. Elasticity values for aggressive crash frequency models developed for basic freeways

	Variable type	**Elasticity for KABCO crash frequency**	**Elasticity for KABC crash frequency**	**Median value (if applicable)**
Natural log of adjusted average AADT	Log	1.3282	1.169	NA
Natural log of segment length (in mile)	Log	0.8404	0.8682	NA
Average shoulder width	C	-0.4697	-0.4339	7
Posted speed 65 mph or above	I	-0.2841	-0.2833	NA
Number of lanes 3 or above	I	0.3299	0.5203	NA

[18] Aggressive driving related crash modeling results were also included in this section for consistency.

Table 31. Summary of speeding crash frequency models developed for basic freeways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-6.4598*	*<0.001*	*-6.9485*	*<0.001*
Natural log of adjusted average AADT	0.8983	<0.001	0.8166	<0.001
Natural log of segment length (in mile)	0.8447	<0.001	0.8292	<0.001
Posted speed 65 mph	-0.5402	<0.001	---	---
Posted speed 65 mph or above	---	---	-0.7516	<0.001
Posted speed 70 mph	-0.6567	<0.001	---	---
Average shoulder width greater than or equal to 4ft	-0.1933	<0.001	-0.1647	0.007
Number of lanes 3 or above	0.2868	<0.001	0.4659	<0.001
Inverse of overdispersion parameter	*2.341*		*2.186*	
2xlog-likelihood value	*-13264.784*		*-7835.036*	

Table 32. Elasticity values for speeding crash frequency models developed for basic freeways

	Variable type	**Elasticity for KABCO crash frequency**	**Elasticity for KABC crash frequency**	**Median value (if applicable)**
Natural log of adjusted average AADT	Log	0.8983	0.8166	NA
Natural log of segment length (in mile)	Log	0.8447	0.8292	NA
Posted speed 65 mph	I	-0.4174	---	NA
Posted speed 65 mph or above	I	---	-0.5284	NA
Posted speed 70 mph	I	-0.4814	---	NA
Average shoulder width greater than or equal to 4ft	I	-0.1758	-0.1518	NA
Number of lanes 3 or above	I	0.3322	0.5934	NA

Table 33. Summary of distracted crash frequency models developed for basic freeways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-9.8407*	*<0.001*	*-9.6469*	*<0.001*
Natural log of adjusted average AADT	1.1574	<0.001	1.0170	<0.001
Natural log of segment length (in mile)	0.8490	<0.001	0.8529	<0.001
Average shoulder width	-0.0472	<0.001	-0.0430	<0.001
Posted speed 65 mph or above	-0.7049	<0.001	-0.5407	<0.001
Inverse of overdispersion parameter	*2.827*		*2.688*	
2xlog-likelihood value	*-8427.866*		*-5120.047*	

Table 34. Elasticity values for distracted crash frequency models developed for basic freeways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.1574	1.0170	NA
Natural log of segment length (in mile)	Log	0.8490	0.8529	NA
Average shoulder width	C	-0.3302	-0.3012	7
Posted speed 65 mph or above	I	-0.5058	-0.4213	NA

Table 35. Summary of impaired crash frequency models developed for basic freeways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-7.3969*	*<0.001*	*-5.9711*	*<0.001*
Natural log of adjusted average AADT	0.8159	<0.001	0.5806	<0.001
Natural log of segment length (in mile)	0.7921	<0.001	0.7964	<0.001
Average shoulder width	-0.0211	0.054	-0.0069	0.652
Posted speed 65 mph or above	-0.7861	<0.001	-0.8776	<0.001
Number of lanes 3 or above	0.3171	<0.001	0.4423	<0.001
Inverse of overdispersion parameter	*2.644*		*2.179*	
2xlog-likelihood value	*-6061.827*		*-3840.989*	

Table 36. Elasticity values for impaired crash frequency models developed for basic freeways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	0.8159	0.5806	NA
Natural log of segment length (in mile)	Log	0.7921	0.7964	NA
Average shoulder width	C	-0.1476	-0.0485	7
Posted speed 65 mph or above	I	-0.5444	-0.5842	NA
Number of lanes 3 or above	I	0.3732	0.5562	NA

Multilane highway risk factors modeling

Table 37. Summary of aggressive crash frequency models developed for multilane highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-12.3383*	*<0.001*	*-13.544*	*<0.001*
Natural log of adjusted average AADT	1.3321	<0.001	1.3509	<0.001
Natural log of segment length (in mile)	0.5829	<0.001	0.7158	<0.001
Average lane width greater than or equal to 12.5ft	0.6064	<0.001	0.6000	0.002
Posted speed 65 mph or above	-0.6791	<0.001	-0.4623	0.001
Average shoulder width greater than or equal to 3ft	-0.2170	0.012	---	---
Inverse of overdispersion parameter	*1.326*		*1.009*	
2xlog-likelihood value	*-3169.147*		*-1802.631*	

Table 38. Elasticity values for aggressive crash frequency models developed for multilane highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.3321	1.3509	NA
Natural log of segment length (in mile)	Log	0.5829	0.7158	NA
Average lane width greater than or equal to 12.5ft	I	0.8338	0.8222	NA
Posted speed 65 mph or above	I	-0.4929	-0.3702	NA
Average shoulder width greater than or equal to 3ft	I	-0.1951	---	NA

Table 39. Summary of speeding crash frequency models developed for multilane highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-8.5294*	*<0.001*	*-11.332*	*<0.001*
Natural log of adjusted average AADT	1.0546	<0.001	1.2161	<0.001
Natural log of segment length (in mile)	0.5973	<0.001	0.7007	<0.001
Average lane width greater than or equal to 13ft	0.2827	0.003	0.2345	0.121
Average shoulder width greater than or equal to 5.5ft	-0.1825	0.001	---	---
Posted speed 55 mph	-0.1493	0.037	---	---
Posted speed 65 mph or above	-0.2040	0.004	-0.0569	0.473
Inverse of overdispersion parameter	*1.999*		*1.671*	
2xlog-likelihood value	*-7235.261*		*-3783.925*	

Table 40. Elasticity values for speeding crash frequency models developed for multilane highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.0546	1.2161	NA
Natural log of segment length (in mile)	Log	0.5973	0.7007	NA
Average lane width greater than or equal to 13ft	I	0.3266	0.2642	NA
Average shoulder width greater than or equal to 5.5ft	I	-0.1668	---	NA
Posted speed 55 mph	I	-0.1387	---	NA
Posted speed 65 mph or above	I	-0.1845	-0.0553	NA

Table 41. Summary of distracted crash frequency models developed for multilane highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-11.2491*	*<0.001*	*-12.1958*	*<0.001*
Natural log of adjusted average AADT	1.3546	<0.001	1.3435	<0.001
Natural log of segment length (in mile)	0.4915	<0.001	0.5849	<0.001
Average shoulder width	-0.0453	0.004	-0.0532	0.013
Posted speed 65 mph or above	-0.9476	<0.001	-0.6774	<0.001
Average lane width greater than or equal to 12.5ft	0.4127	<0.001	0.4009	0.003
Inverse of overdispersion parameter	*1.114*		*1.178*	
2xlog-likelihood value	*-5950.145*		*-3458.821*	

Table 42. Elasticity values for distracted crash frequency models developed for multilane highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.3546	1.3435	NA
Natural log of segment length (in mile)	Log	0.4915	0.5849	NA
Average shoulder width	C	-0.1360	-0.1597	3
Posted speed 65 mph or above	I	-0.6123	-0.4921	NA
Average lane width greater than or equal to 12.5ft	I	0.5110	0.4932	NA

Table 43. Summary of impaired crash frequency models developed for multilane highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-9.4192*	*<0.001*	*-10.0193*	*<0.001*
Natural log of adjusted average AADT	1.0242	<0.001	0.9950	<0.001
Natural log of segment length (in mile)	0.5404	<0.001	0.5712	<0.001
Posted speed 65 mph or above	-0.7315	<0.001	-0.5688	<0.001
Inverse of overdispersion parameter	*1.778*		*1.751*	
2xlog-likelihood value	*-3662.986*		*-2224.664*	

Table 44. Elasticity values for impaired crash frequency models developed for multilane highways

	Varia ble type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.0242	0.9950	NA
Natural log of segment length (in mile)	Log	0.5404	0.5712	NA
Posted speed 65 mph or above	I	-0.5188	-0.4338	NA

Urban divided highway risk factors modeling

Table 45. Summary of aggressive crash frequency models developed for urban divided highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-12.1688*	*<0.001*	*-14.7673*	*<0.001*
Natural log of adjusted average AADT	1.4357	<0.001	1.6253	<0.001
Natural log of segment length (in mile)	0.6540	<0.001	0.7327	<0.001
Posted speed 40 mph or above	-0.3423	<0.001	-0.4641	<0.001
Average shoulder width is not zero	-0.3053	<0.001	-0.3307	0.001
Inverse of overdispersion parameter	*1.624*		*1.480*	
2xlog-likelihood value	*-6239.595*		*-3547.454*	

Table 46. Elasticity values for aggressive crash frequency models developed for urban divided highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.4357	1.6253	NA
Natural log of segment length (in mile)	Log	0.6540	0.7327	NA
Posted speed 40 mph or above	I	-0.2899	-0.3713	NA
Average shoulder width is not zero	I	-0.2631	-0.2816	NA

Table 47. Summary of speeding crash frequency models developed for urban divided highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-8.4497*	*<0.001*	*-12.1074*	*<0.001*
Natural log of adjusted average AADT	1.1062	<0.001	1.3920	<0.001
Natural log of segment length (in mile)	0.5992	<0.001	0.6934	<0.001
Average shoulder width is not zero	-0.1972	<0.001	-0.2713	<0.001
Posted speed 25 mph or below	-0.2025	0.008	-0.3710	0.006
Posted speed 45 mph or above	-0.1166	0.020	-0.4135	<0.001
Inverse of overdispersion parameter	*1.960*		*1.684*	
2xlog-likelihood value	*-9573.94*		*-5143.050*	

Table 48. Elasticity values for speeding crash frequency models developed for urban divided highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.1062	1.3920	NA
Natural log of segment length (in mile)	Log	0.5992	0.6934	NA
Average shoulder width is not zero	I	-0.1790	-0.2376	NA
Posted speed 25 mph or below	I	-0.1833	-0.3100	NA
Posted speed 45 mph or above	I	-0.1101	-0.3386	NA

Table 49. Summary of distracted crash frequency models developed for urban divided highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-9.2316*	*<0.001*	*-12.499*	*<0.001*
Natural log of adjusted average AADT	1.2352	<0.001	1.4774	<0.001
Natural log of segment length (in mile)	0.6057	<0.001	0.6631	<0.001
Posted speed 30 mph or above	-0.3157	<0.001	-0.3523	<0.001
Inverse of overdispersion parameter	*1.504*		*1.193*	
2xlog-likelihood value	*-10439.221*		*-6007.791*	

Table 50. Elasticity values for distracted crash frequency models developed for urban divided highways

	Varia ble type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.2352	1.4774	NA
Natural log of segment length (in mile)	Log	0.6057	0.6631	NA
Posted speed 30 mph or above	I	-0.2707	-0.2969	NA

Table 51. Summary of impaired crash frequency models developed for urban divided highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	p-value	Coefficient	p-value
Constant	*-7.3085*	*<0.001*	*-9.2732*	*<0.001*
Natural log of adjusted average AADT	0.8739	<0.001	0.9971	<0.001
Natural log of segment length (in mile)	0.6118	<0.001	0.6514	<0.001
Average shoulder width is not zero	-0.2396	<0.001	---	---
Posted speed 45 mph or above	-0.5293	<0.001	-0.4984	<0.001
Inverse of overdispersion parameter	*2.012*		*2.102*	
2xlog-likelihood value	*-5817.777*		*-3612.821*	

Table 52. Elasticity values for impaired crash frequency models developed for urban divided highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	0.8739	0.9971	NA
Natural log of segment length (in mile)	Log	0.6118	0.6514	NA
Average shoulder width is not zero	I	-0.2131	---	NA
Posted speed 45 mph or above	I	-0.4110	-0.3925	NA

Urban undivided highway risk factors modeling

Table 53. Summary of aggressive crash frequency models developed for urban undivided highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	p-value	Coefficient	p-value
Constant	*-11.9371*	*<0.001*	*-13.9500*	*<0.001*
Natural log of adjusted average AADT	1.3924	<0.001	1.5025	<0.001
Natural log of segment length (in mile)	0.7191	<0.001	0.7201	<0.001
Posted speed 35 mph or above	-0.2842	0.005	-0.1418	0.330
Average shoulder width is not zero	-0.4959	<0.001	-0.5759	0.002
Inverse of overdispersion parameter	*1.233*		*0.952*	
2xlog-likelihood value	*-3212.564*		*-1802.207*	

Table 54. Elasticity values for aggressive crash frequency models developed for urban undivided highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.3924	1.5025	NA
Natural log of segment length (in mile)	Log	0.7191	0.7201	NA
Posted speed 35 mph or above	I	-0.2474	-0.1322	NA
Average shoulder width is not zero	I	-0.3910	-0.4378	NA

Table 55. Summary of speeding crash frequency models developed for urban undivided highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-8.6997*	*<0.001*	*-11.0937*	*<0.001*
Natural log of adjusted average AADT	1.1337	<0.001	1.2703	<0.001
Natural log of segment length (in mile)	0.7589	<0.001	0.8647	<0.001
Average shoulder width is not zero	-0.2585	0.002	-0.2032	0.128
Posted speed 35 mph or below	-0.3063	<0.001	-0.2944	0.012
Inverse of overdispersion parameter	*1.403*		*1.085*	
2xlog-likelihood value	*-5048.715*		*-2586.673*	

Table 56. Elasticity values for speeding crash frequency models developed for urban undivided highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.1337	1.2703	NA
Natural log of segment length (in mile)	Log	0.7589	0.8647	NA
Average shoulder width is not zero	I	-0.2278	-0.1839	NA
Posted speed 35 mph or below	I	-0.2638	-0.2550	NA

Table 57. Summary of distracted crash frequency models developed for urban undivided highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-8.5613*	*<0.001*	*-11.9038*	*<0.001*
Natural log of adjusted average AADT	1.1783	<0.001	1.4288	<0.001
Natural log of segment length (in mile)	0.7594	<0.001	0.9118	<0.001
Average shoulder width is not zero	-0.4309	<0.001	-0.2971	0.003
Posted speed 30 mph or above	-0.3419	<0.001	-0.3086	<0.001
Inverse of overdispersion parameter	*1.928*		*2.443*	
2xlog-likelihood value	*-6163.827*		*-3393.049*	

Table 58. Elasticity values for distracted crash frequency models developed for urban undivided highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.1783	1.4288	NA
Natural log of segment length (in mile)	Log	0.7594	0.9118	NA
Average shoulder width is not zero	I	-0.3501	-0.2570	NA
Posted speed 30 mph or above	I	-0.2896	-0.2655	NA

Table 59. Summary of impaired crash frequency models developed for urban undivided highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	-8.0825	<0.001	-10.1008	<0.001
Natural log of adjusted average AADT	1.0118	<0.001	1.1472	<0.001
Natural log of segment length (in mile)	0.802	<0.001	0.8581	<0.001
Average shoulder width is not zero	-0.4669	<0.001	-0.5134	0.001
Posted speed 35 mph or above	-0.3905	<0.001	-0.326	0.010
Inverse of overdispersion parameter	*1.438*		*1.093*	
2xlog-likelihood value	*-3759.088*		*-2324.914*	

Table 60. Elasticity values for impaired crash frequency models developed for urban undivided highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.0118	1.1472	NA
Natural log of segment length (in mile)	Log	0.8020	0.8581	NA
Average shoulder width is not zero	I	-0.3731	-0.4015	NA
Posted speed 35 mph or above	I	-0.3233	-0.2782	NA

Two-lane highway risk factors modeling

Table 61. Summary of aggressive crash frequency models developed for two-lane highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-8.3694*	*<0.001*	*-9.7572*	*<0.001*
Natural log of adjusted average AADT	0.9172	<0.001	0.9302	<0.001
Natural log of segment length (in mile)	0.5236	<0.001	0.5433	<0.001
Roadway is undivided	0.0337	0.766	0.6426	0.001
Posted speed above 45mph	---	---	-0.2702	0.021
Posted speed above 50 mph	-0.2479	0.002	---	---
Average shoulder width is greater than or equal to 3ft	-0.2170	0.006	-0.2670	0.020
Inverse of overdispersion parameter	*1.592*		*1.463*	
2xlog-likelihood value	*-10761.923*		*-6332.844*	

Table 62. Elasticity values for aggressive crash frequency models developed for two-lane highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	0.9172	0.9302	NA
Natural log of segment length (in mile)	Log	0.5236	0.5433	NA
Roadway is undivided	I	0.0343	0.9013	NA
Posted speed above 45mph	I	---	-0.2368	NA
Posted speed above 50 mph	I	-0.2196	---	NA
Average shoulder width is greater than or equal to 3ft	I	-0.1951	-0.2344	NA

Table 63. Summary of speeding crash frequency models developed for two-lane highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-5.0120*	*<0.001*	*-6.1055*	*<0.001*
Natural log of adjusted average AADT	0.7370	<0.001	0.7519	<0.001
Natural log of segment length (in mile)	0.6177	<0.001	0.7843	<0.001
Average shoulder width is greater than or equal to 5ft	-0.0722	0.018	-0.1202	0.007
No curves on roadway with posted speed 40 mph or below	-0.5064	<0.001	-0.5431	<0.001
Roadway is undivided	---	---	0.2126	0.075
Posted speed 55 mph or below	-0.1361	0.004	-0.1649	0.023
Average lane width is greater than or equal to 11.5ft	-0.2275	<0.001	-0.4336	<0.001
Inverse of overdispersion parameter	*1.39*		*2.400*	
2xlog-likelihood value	*-24658.456*		*-13439.428*	

Table 64. Elasticity values for speeding crash frequency models developed for two-lane highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	0.7370	0.7519	NA
Natural log of segment length (in mile)	Log	0.6177	0.7843	NA
Average shoulder width is greater than or equal to 5ft	I	-0.0697	-0.1132	NA
No curves on roadway with posted speed 40 mph or below	I	-0.3973	-0.4190	NA
Roadway is undivided	I	---	0.2369	NA
Posted speed 55 mph or below	I	-0.1272	-0.1520	NA
Average lane width is greater than or equal to 11.5ft	I	-0.2035	-0.3518	NA

Table 65. Summary of distracted crash frequency models developed for two-lane highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-7.4201*	*<0.001*	*-9.6766*	*<0.001*
Natural log of adjusted average AADT	1.0063	<0.001	1.0318	<0.001
Natural log of segment length (in mile)	0.5572	<0.001	0.5284	<0.001
Average shoulder width is not zero	-0.6150	<0.001	---	---
Roadway is undivided	0.0310	0.635	0.5003	<0.001
No curves on roadway with posted speed over 40 mph	-0.0982	0.046	---	---
Posted speed 55 mph or above	-0.2719	<0.001	-0.1968	0.003
Inverse of overdispersion parameter	*2.433*		*2.596*	
2xlog-likelihood value	*-20916.021*		*-12820.624*	

Table 66. Elasticity values for distracted crash frequency models developed for two-lane highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.0063	1.0318	NA
Natural log of segment length (in mile)	Log	0.5572	0.5284	NA
Average shoulder width is not zero	I	-0.4594	---	NA
Roadway is undivided	I	0.0314	0.6492	NA
No curves on roadway with posted speed over 40 mph	I	-0.0935	---	NA
Posted speed 55 mph or above	I	-0.2381	-0.1787	NA

Table 67. Summary of impaired crash frequency models developed for two-lane highways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-4.9082*	*<0.001*	*-6.3627*	*<0.001*
Natural log of adjusted average AADT	0.6553	<0.001	0.6236	<0.001
Natural log of segment length (in mile)	0.7350	<0.001	0.7523	<0.001
Average shoulder width is not zero	-0.3635	<0.001	---	---
Roadway is undivided	---	---	0.6363	<0.001
No curves on roadway with posted speed over 40 mph	-0.1982	<0.001	---	---
Posted speed 55 mph or above	-0.2974	<0.001	-0.2597	0.003
Average lane width is greater than or equal to 11.5ft	-0.3201	<0.001	-0.4611	<0.001
Inverse of overdispersion parameter	*2.950*		*2.432*	
2xlog-likelihood value	*-15332.017*		*-10183.795*	

Table 68. Elasticity values for impaired crash frequency models developed for two-lane highways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	0.6553	0.6236	NA
Natural log of segment length (in mile)	Log	0.7350	0.7523	NA
Average shoulder width is not zero	I	-0.3048	---	NA
Roadway is undivided	I	---	0.8894	NA
No curves on roadway with posted speed over 40 mph	I	-0.1798	---	NA
Posted speed 55 mph or above	I	-0.2573	-0.2287	NA
Average lane width is greater than or equal to 11.5ft	I	-0.2739	-0.3694	NA

APPENDIX F: SCREENING CRITERIA TOOL

Variable Name	Variable Definition	Source	SVI Original Calculations
PDP_ID	Meta-Manager Segment ID Number	WisDOT	
TRAF_SEG_ID	Traffic Segment ID Number	WisDOT	
DIVUND	Divided/Undivided/1-Way Highway Segment (D / U / 1)	WisDOT	
HWY&DIR	Highway and Direction	WisDOT	
FCLASS	Federal Functional class	WisDOT	
TRWAYWD	Traveled way width	WisDOT	
RSHTOTWD	Right shoulder total width	WisDOT	
RSHPAVWD	Right shoulder paved width	WisDOT	
HCURLE40	Curves/mile posted 40 mph or less	WisDOT	
HCURGT40	Curves/mile posted more than 40 mph	WisDOT	
NUMLANES	Number of lanes (Directional when roadway is divided)	WisDOT	
WI_CNTY_NM	County Name	WisDOT	
RSH1WD	Width of Right shoulder (first shoulder)	WisDOT	
LSHPAVWD	Left shoulder paved width	WisDOT	
LSH1TYP	Left shoulder type (first shoulder)	WisDOT	
LSH1WD	Width of Left shoulder (first shoulder)	WisDOT	
MEDNTYP	Median Type	WisDOT	
MEDNWD	Median Width	WisDOT	
AADT_EST_2017	2017 AADT on a specific segment	WisDOT	
AADT_EST_2018	2018 AADT on a specific segment	WisDOT	
AADT_EST_2019	2019 AADT on a specific segment	WisDOT	
AADT_EST_2020	2020 AADT on a specific segment	WisDOT	
AADT_EST_2021	2021 AADT on a specific segment	WisDOT	
Avg_AADT_1721	The average AADT from 2017-2021 on a specific segment	Calculated	
Avg_AADT_1721_adjusted	The adjusted average AADT from 2017-2021 on a specific segment (The av	Calculated	
HCMTYPE	Highway Capacity Manual facility type **FRE**: Basic Freeway Section analys	WisDOT	
PTDSPEED	Posted speed	WisDOT	
Speed_K	Number of K level crashes that caused by speeding	Calculated from crash data	
Speed_A	Number of A level crashes that caused by speeding	Calculated from crash data	
Speed_B	Number of B level crashes that caused by speeding	Calculated from crash data	
Speed_C	Number of C level crashes that caused by speeding	Calculated from crash data	
Speed_O	Number of O level crashes that caused by speeding	Calculated from crash data	
Speed_KA	Number of K and A level crashes that caused by speeding	Calculated from crash data	
Distracted_K	Number of K level crashes caused by distracted/drowsy driving	Calculated from crash data	
Distracted_A	Number of A level crashes caused by distracted/drowsy driving	Calculated from crash data	
Distracted_B	Number of B level crashes caused by distracted/drowsy driving	Calculated from crash data	

Figure 2. Screenshot of the Data Dictionary Included in the Screening Tool

BASIC FREEWAY

		Aggressive																
		KABCO									KABC							
		Crashes		Coefficients							Crashes		Coefficients					
pdp_id	traf_seg_id	Predicted Crashes	Observed Crashes	Intercept	log(avg_aadt_1721_adjusted)	log(pdp_mile)	averageshoulder	ptdspeed >= 65		numlanes >= 3	Predicted Crashes	Observed Crashes	Intercept	log(avg_aadt_1721_adjusted)	log(pdp_mile)	averageshoulder	ptdspeed >= 65	numlanes >= 3
854	25073	0.27	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.12	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
855	20176	0.04	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.02	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
856	20176	0.15	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.07	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
857	20176	0.15	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.07	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
858	20176	0.16	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.07	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
859	20176	0.18	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.08	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
860	5805	0.02	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.01	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
861	5805	0.15	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.07	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
862	5805	0.13	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.06	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
863	5805	0.11	1	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.05	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
864	5805	0.16	1	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.07	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
865	1161	0.01	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.01	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
876	15000	0.62	1	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.25	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
877	15000	0.15	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.06	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
878	8922	0.41	2	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.17	1	-11.84	1.17	0.87	-0.06	-0.33	0.42
879	8921	0.57	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.24	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
880	6690	0.62	2	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.26	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
881	6690	0.36	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.15	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
890	8283	0.66	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.25	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
891	8284	0.66	1	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.25	1	-11.84	1.17	0.87	-0.06	-0.33	0.42
892	8284	0.18	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.07	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
893	1837	0.47	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.18	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
894	1837	0.14	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.05	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
895	1837	0.18	1	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.07	1	-11.84	1.17	0.87	-0.06	-0.33	0.42
896	1837	0.16	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.06	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
908	8714	0.05	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.02	0	-11.84	1.17	0.87	-0.06	-0.33	0.42
909	8714	0.06	0	-12.32	1.33	0.84	-0.07	-0.33		0.29	0.02	0	-11.84	1.17	0.87	-0.06	-0.33	0.42

Figure 3. Screenshot of Calculation of Predicted Crashes (KABCO and KABC) Aggressive Driving Related Crashes on Basic Highways

AGGRESSIVE MODEL RESULTS			
Term	Estimate	P_Value	Over-dispersion
aggressive - KABCO - FRE			2.059
(Intercept)	-12.3242	0.000	2 x log-likelihood
log(avg_aadt_1721_adjusted)	1.3282	0.000	-6582.624
log(pdp_mile)	0.8404	0.000	
averageshoulder	-0.0671	0.000	
as.factor(ptdspeed >= 65)TRUE	-0.3342	0.000	
as.factor(numlanes >= 3)TRUE	0.2851	0.000	
aggressive - KABC - FRE			Over-dispersion
(Intercept)	-11.8381	0.000	1.998
log(avg_aadt_1721_adjusted)	1.169	0.000	2 x log-likelihood
log(pdp_mile)	0.8682	0.000	-3809.531
averageshoulder	-0.062	0.000	
as.factor(ptdspeed >= 65)TRUE	-0.3331	0.002	
as.factor(numlanes >= 3)TRUE	0.4189	0.000	
aggressive - KABCO - MLT			Over-dispersion
(Intercept)	-12.3383	0.000	1.326
log(avg_aadt_1721_adjusted)	1.3321	0.000	2 x log-likelihood
log(pdp_mile)	0.5829	0.000	-3169.147
as.factor(averagelanewidth >= 12.5)TRUE	0.6064	0.000	
as.factor(ptdspeed >= 65)TRUE	-0.6791	0.000	
as.factor(averageshoulder >= 3)TRUE	-0.217	0.012	
aggressive - KABC - MLT			Over-dispersion
(Intercept)	-13.544	0.000	1.009
log(avg_aadt_1721_adjusted)	1.3509	0.000	2 x log-likelihood
log(pdp_mile)	0.7158	0.000	-1802.631
as.factor(averagelanewidth >= 12.5)TRUE	0.6	0.002	
as.factor(ptdspeed >= 65)TRUE	-0.4623	0.001	

Figure 4. Screenshot of Model Results of Predicted Crashes (KABCO and KABC) Aggressive Driving Related Crashes on Basic Multilane Highways

MULTILANE HIGHWAY

		Speeding															
		KABCO									KABC						
		Crashes		Coefficients							Crashes		Coefficients				
pdp_id	traf_seg_id	Predicted Crashes	Observed Crashes	Intercept	log(avg_aadt_1721_adjusted)	log(pdp_mile)	averagelanewidth >= 13	averageshoulder >= 5.5	ptdspeed == 55	ptdspeed >= 65	Predicted Crashes	Observed Crashes	Intercept	log(avg_aadt_1721_adjusted)	log(pdp_mile)	averagelanewidth >= 13	ptdspeed >= 65
467	4099	1.43	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.33	0.00	-11.28	1.21	0.71	0.25	-0.08
468	8276	1.25	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.29	0.00	-11.28	1.21	0.71	0.25	-0.08
469	8276	0.55	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.11	0.00	-11.28	1.21	0.71	0.25	-0.08
590	8276	0.55	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.11	0.00	-11.28	1.21	0.71	0.25	-0.08
591	8276	1.24	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.28	0.00	-11.28	1.21	0.71	0.25	-0.08
592	4099	1.44	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.34	0.00	-11.28	1.21	0.71	0.25	-0.08
834	4262	0.06	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.01	0.00	-11.28	1.21	0.71	0.25	-0.08
835	4262	0.19	1.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.03	0.00	-11.28	1.21	0.71	0.25	-0.08
836	4262	0.73	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.19	0.00	-11.28	1.21	0.71	0.25	-0.08
837	4262	0.67	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.17	0.00	-11.28	1.21	0.71	0.25	-0.08
838	25064	0.48	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.12	0.00	-11.28	1.21	0.71	0.25	-0.08
839	25064	0.41	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.10	0.00	-11.28	1.21	0.71	0.25	-0.08
840	25068	0.58	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.14	0.00	-11.28	1.21	0.71	0.25	-0.08
841	25068	2.02	1.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.61	1.00	-11.28	1.21	0.71	0.25	-0.08
842	10518	1.32	1.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.37	0.00	-11.28	1.21	0.71	0.25	-0.08
843	10518	1.83	1.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.54	1.00	-11.28	1.21	0.71	0.25	-0.08
844	10518	1.38	3.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.39	2.00	-11.28	1.21	0.71	0.25	-0.08
845	25069	1.07	1.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.29	1.00	-11.28	1.21	0.71	0.25	-0.08
846	25069	1.06	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.29	0.00	-11.28	1.21	0.71	0.25	-0.08
847	25071	1.46	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.42	0.00	-11.28	1.21	0.71	0.25	-0.08
848	25071	0.90	1.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.24	0.00	-11.28	1.21	0.71	0.25	-0.08
849	25071	0.82	4.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.21	0.00	-11.28	1.21	0.71	0.25	-0.08
850	25072	1.23	1.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.35	0.00	-11.28	1.21	0.71	0.25	-0.08
851	25072	0.97	1.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.26	0.00	-11.28	1.21	0.71	0.25	-0.08
852	25072	1.03	1.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.28	0.00	-11.28	1.21	0.71	0.25	-0.08
853	25072	0.14	0.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.03	0.00	-11.28	1.21	0.71	0.25	-0.08
867	27089	2.34	6.00	-8.58	1.06	0.61	0.30	-0.20	-0.15	-0.23	0.64	0.00	-11.28	1.21	0.71	0.25	-0.08

Figure 5. Screenshot of Calculation of Predicted Crashes (KABCO and KABC) Aggressive Driving Related Crashes on Multilane Highways

APPENDIX G: RISK FACTORS MODELING WITH PHIS EXAMPLE

Models for predicting KABC and KABCO aggressive crash frequencies for basic freeways are shown in Tables 77 and 78, with and without the PHI, respectively[19]. As can be seen, the PHI variables, weighted PHI themes, and Weighted PHI flags. As can be seen, these variables indicate that larger PHIs (e.g., more vulnerable regions) are associated with higher crash frequencies. However, the variables have low statistical significance in predicting crash frequencies indicating a lack of meaningful contribution to the model accuracy. In this case, though the PHIs yielded relatively higher over-dispersion parameters, they did not enhance the overall model fit significantly, and their inclusion may even reduce predictive power due to issues like multicollinearity with other more relevant factors (e.g., traffic volume, road type). Additionally, socioeconomic data at the local or segment level can be sparse or inconsistent, making it difficult to incorporate reliably into the model. As a result, and after discussing with the POC, the research team prioritized roadway characteristics and traffic-related variables, which have a more direct and actionable impact on crash risk, leading to simpler, more robust models that are easier to interpret and apply.

Table 69. Summary of aggressive crash frequency models with PHIs developed for basic freeways

	KABCO crash frequency		KABC crash frequency	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Constant	*-12.905*	*<0.001*	*-12.321*	*<0.001*
Natural log of adjusted average AADT	1.328	<0.001	1.176	<0.001
Natural log of segment length (in mile)	0.844	<0.001	0.868	<0.001
Average shoulder width	-0.067	<0.001	-0.060	<0.001
Posted speed 65 mph or above	-0.333	<0.001	-0.297	0.010
Number of lanes 3 or above	0.282	<0.001	0.407	<0.001
Weighted PHI themes	<0.001	0.599	<0.001	0.495
Weighted PHI flags	0.057	0.110	0.024	0.640
Inverse of overdispersion parameter	*2.069*		*2.011*	
2xlog-likelihood value	*-6572.155*		*-3806.342*	

[19] Weighted PHI themes represents the sum of all four themes included in the PHIs. Weighted PHI flags represents the sum of flags for the four themes. Please see Appendix A for the detailed descriptions and calculations.

Table 70. Elasticity values for aggressive crash frequency models with PHIs developed for basic freeways

	Variable type	Elasticity for KABCO crash frequency	Elasticity for KABC crash frequency	Median value (if applicable)
Natural log of adjusted average AADT	Log	1.3282	1.1757	NA
Natural log of segment length (in mile)	Log	0.844	0.8681	NA
Average shoulder width	C	-0.4099	-1.0507	7
Posted speed 65 mph or above	I	-0.2833	-0.2566	NA
Number of lanes 3 or above	I	0.3258	0.5026	NA
Weighted PHI themes	C	-0.0558	0.2938	479.2863
Weighted PHI flags	C	0.6008	0.7208	11