Traffic Engineering, Operations & Safety Manual

Chapter 12 Safety

Section 1 Introduction

12-1-1 Introduction **April 2023**

INTRODUCTION

Transportation safety is a priority of the Wisconsin Department of Transportation (WisDOT) and is rooted within the Department's mission and policies to minimize the number of deaths, injuries and crashes on Wisconsin roadways. The WisDOT mission statement is: *"Provide leadership in the development and operation of a safe and efficient transportation system."* This is accomplished through a comprehensive approach which focuses on:

- Working with partners throughout Wisconsin to identify and resolve safety issues
- Gathering, analyzing, and reporting data on traffic crashes and injuries, and then using that data to inform policies, investments, and enforcement of safe operations on state highways and Interstates
- Managing state and federal funds to build safer infrastructure on our roads, rail system, and at our state's airports
- Conducting public outreach and education campaigns, including those focused on pedestrian and bicyclist safety

These tasks are supported by numerous programs, initiatives, and diverse workgroups across the State with the goal of improving safety for all users. Traffic safety involves all aspects of a transportation system and is not limited to just vehicle crashes. Maintenance items such as winter plowing operations, signing, and marking replacement, mowing operations, and roadside facility improvements are examples of focus areas which lead to a safe and efficient transportation system.

WisDOT takes a multifaceted approach to roadway safety by addressing issues through engineering, education, enforcement, and emergency medical services. These four areas are critical in the development of a safe and efficient roadway system but ultimately it is up to everyone to keep the Wisconsin transportation system safe.

This chapter provides guidance on safety initiatives within traffic safety planning as well as safety analysis methodologies and countermeasure information.

Traffic Engineering, Operations & Safety Manual

Chapter 12 Safety

Section 2 Traffic Safety Planning

12-2-1 Wisconsin Strategic Highway Safety Plan — August 2023

Wisconsin’s Strategic Highway Safety Plan (SHSP) is a statewide, comprehensive, and data-driven plan that implements the framework for supporting the safety goals. This plan identifies and examines a variety of issue areas and provides tasks with the most potential to reduce roadway crashes. By working with community partners such as law enforcement, emergency responders, health care providers, and local County Traffic Safety Commissions, WisDOT is committed to keep travelers safe on our roads. The SHSP examines a variety of factors that affect highway safety in Wisconsin. Goals of the SHSP include:

- Improve Safety Culture, Safety Data, and Safety Technology
- Reduce Driver Distraction/Improve Driver Alertness
- Reduce Alcohol and Drug-Impaired Driving
- Reduce the Incidence and Severity of Motorcycle Crashes
- Improve Driver Performance (Teens, Older and Competent)
- Improve Non-Motorist Safety
- Improve Safety of Intersections
- Increase Occupant Protection
- Curb Aggressive Driving/Reduce Speed-Related Crashes
- Reduce Lane Departure Crashes
- Improve Work Zone Safety

The SHSP provides direction for future safety programs and strategies that are implemented in Wisconsin. This document is a requirement by the Federal Highway Administration. Each plan is developed in a cooperative process with Local, State, Federal, Tribal, and other public and private sector stakeholders.

12-2-2 Zero in Wisconsin — April 2023

In pursuit of the goals identified in Wisconsin’s SHSP, WisDOT has advocated for *Zero in Wisconsin*, a program that advocates for safe driving practices and strives to eliminate all preventable traffic-related deaths on Wisconsin roadways. WisDOT does not tacitly accept deaths and injuries; its citizens and state policy makers work together towards achieving zero fatalities and serious injuries on our roadways.

The program provides information and resources about occupant protection, impaired driving, distracted driving, speeding, and aggressive driving, as well as pedestrian and bicycle safety.

Transportation safety involves a multifaceted approach to improve safety. Community Maps was developed to help support and enhance traffic safety planning, resource allocation, and decision support at the local level. This provides the public and local agencies a statewide map of all law enforcement reported motor vehicle crashes.

12-2-3 Safe System Approach — April 2023

The Safe System Approach aims to eliminate fatal and serious injuries for all roadway users. This is accomplished by minimizing the risks involved in using transportation systems. It is a holistic approach that accounts for human mistakes and human vulnerability with redundancies in place to protect users. The Safe System Approach is comprised of the following principles:

- Death and serious injury are unacceptable
- Humans make mistakes
- Humans are vulnerable
- Shared responsibility
- Safety must be proactive
- Redundancy is crucial

The Safe System Approach aims to design and operate our vehicles and infrastructure to anticipate human error to minimize the risk of fatal and serious injuries. This is accomplished by utilizing roadway design or having redundancies in place so that if a crash takes place the impact energy on the human body occurs at a tolerable level. It also seeks to expand the availability of vehicle systems and features that prevent and minimize the impact of crashes. The Safe System Approach also aims to enhance the survivability of crashes with prompt emergency medical care, while also facilitating a safe work environment for first responders via effective incident management practices.

There are five elements to the Safe System Approach that build on one another to create layers of protection for all road users. These are: safe road users, safe vehicles, safe speeds, safe roads, and post-crash care. With each of these elements in place, it creates a holistic approach to minimize fatal and serious injuries.

Figure 1: The Safe System Approach Principals and Elements

Safe Roads Measures: Systematic, Systemic and Spot Infrastructure Improvements, Design, Education, Training, Awareness, Technology, Legislation, Data

Safe Road Users Measures: Education, Training, Awareness, Enforcement, Technology, Data, Legislation

Safe Vehicles Measures: Technology, Legislation, Education

Safe Speeds Measures: Design/Target Speed, Education, Training, Awareness, Enforcement, Infrastructure Improvements, Technology, Data, Legislation

Post-Crash Care Measures: Quick Crash Scene Clearance, Quick Emergency Response, Crash Analysis, Education

12-3-1 Crash Reporting May 2024

INTRODUCTION

What is a Reportable Crash?

Crash reports are the primary source of data traffic safety engineers use to gauge the safety performance of roadways. Crashes are reported based on a set of criteria defined by s. 346.70(1).

When a reportable crash occurs, it is documented in a DT4000 form by the responsible law enforcement agency. Beginning on January 1, 2017, Wisconsin migrated to an electronic crash reporting system using a dynamic crash report form. Wisconsin has over 500 law enforcement agencies and most of them transmit crashes electronically to WisDOT using the TraCS (traffic and criminal) software. Examples of this report can be found here.

If the report is not filed by law enforcement, a similar report, the DT4002, is required to be filled out by one of the individuals involved in the crash. Due to the subjectivity and lack of uniformity, the DT4002 is not used for safety analyses.

What is Contained in a Crash Report?

The DT4000 form was created using the Model Minimum Uniform Crash Criteria (MMUCC) Guidelines. MMUCC is a standardized set of motor vehicle crash variables and is designed to generate information necessary to make data-driven decisions for improving highway safety. These elements and attributes include things such as the injury severity, spatial and temporal information, and a number of flags that indicate common or important contextual information. In Wisconsin, the severity of a crash is based on the KABCO injury severity scale. Having a robust and quality dataset provides engineers and analysts valuable information to determine where and if engineering countermeasures *should* be utilized.

How are Crash Reports used?

The information in crash reports is used by engineers to diagnose crashes and identify trends or crashes correctible by an engineering countermeasure. The number and type of crashes at a particular location, the flags, diagrams, and narratives of the crash reports can be used to determine if an engineering countermeasure *may* mitigate future crashes. For instance, if run-off-the-road crashes are observed on a curve in wet conditions, it is likely that location could benefit from a high friction surface treatment. The conditions and crash history at every location is unique and engineering judgement must be used when determining safety improvements.

Crash Report Resources

Crash reports submitted to WisDOT by law enforcement are validated for completeness and made available through the University of Wisconsin Traffic Operations and Safety (TOPS) Laboratory's WisTransPortal system. The WisTransPortal has been developed through ongoing collaboration between the TOPS Laboratory and WisDOT. It provides a central source of traffic operations, safety, and intelligent transportation systems data for Wisconsin highways. The TOPS lab has several videos to assist users in understanding and utilizing crash reports.

The crash data elements and attributes contained in the crash reports can be downloaded for analysis through the WisTransPortal's Crash Data Retrieval Facility.

Community Maps is another WisTransPortal tool to help visualize crashes spatially over a period of time. This mapping tool was developed to provide accessible and timely crash data to aid local agencies in traffic safety planning and help support County Traffic Safety Commissions.

12-3-2 Roadway Safety Management Process May 2024

PURPOSE

WisDOT has integrated the Roadway Safety Management Process (RSMP) from the American Association of State Highway and Transportation Official's (AASHTO) Highway Safety Manual (HSM) into the Department's safety processes. This process implements a continuous approach to roadway safety. WisDOT has adapted the RSMP within its safety process. See TEOpS 12-4-1 for information on the Safety Certification Process.

The RSMP has several steps which are outlined below:

Network Screening

Network screening is the step of identifying sites for further investigation and potential treatment across a transportation network. Treatment and countermeasure are used interchangeably throughout this policy and are intended to mean a roadway improvement that could be implemented to reduce the crash frequency or severity, or both, at a site. Those sites identified are analyzed in more detail in the diagnosis step.

Diagnosis

Diagnosis is the second step in the RSMP. Sites identified in the Network Screening step are analyzed in more detail to identify crash patterns and contributing factors. The intended outcome of the diagnosis step is to identify the factors that contributed to the crashes. Diagnosing the underlying safety issues is critical for identifying appropriate countermeasures.

Countermeasure Selection

Once the contributing factors have been identified in the diagnosis step, safety engineers select countermeasures to directly target the correctible crashes or trends and contributing factors. Safety analysts review crash modification factors and other research to identify potential countermeasures. Crash modification factors indicate the expected change in crashes after a particular countermeasure is implemented.

Economic Appraisal

Once potential countermeasures are selected, an economic appraisal is performed to compare their crash reduction benefits to their implementation costs. There are two types of economic appraisal which address projects in different ways: benefit-cost analysis and cost-effectiveness analysis. Both types begin quantifying the benefits of a proposed project, expressed as the estimated change in crash frequency or severity of crashes, as a result of implementing a countermeasure. In benefit-cost analysis, the expected change in average crash frequency or severity is converted to monetary values, summed, and compared to the cost of implementing the countermeasure. In cost-effectiveness analysis, the change in crash frequency is compared directly to the cost of implementing the countermeasure.

WisDOT has selected the benefit-cost analysis (i.e., benefit-cost ratio) method as its primary metric for economic appraisal.

Project Prioritization

Project prioritization refers to the step of developing an ordered list of recommended projects or safety countermeasures that are expected to achieve a certain objective. Prioritization of projects uses optimization methods to balance project benefits compared to the budget and other constraints.

WisDOT has several different roadway improvement programs, and each have specific goals and objectives. Improving safety is one of the goals that is consistent in all of WisDOT’s programs.

Safety Effectiveness Evaluation

Safety effectiveness evaluation is the process of evaluating how a treatment, project, or a group of projects has affected crash frequencies or severities. The effectiveness estimate for a project or treatment is a valuable piece of information for future safety decision making and policy development. Safety effectiveness evaluation *may* include:

- Evaluating a single project at a specific site to document the safety effectiveness of that specific project,
- Evaluating a group of similar projects to document the safety effectiveness of those projects,
- Evaluating a group of similar projects for the specific purpose of quantifying a Crash Modification Factor (CMF) for a countermeasure, and
- Assessing the overall safety effectiveness of specific types of projects or countermeasures in comparison to their costs.

The RSMP is depicted in Figure 3.1:

Figure 3.1 Highway Safety Manual Road Safety Management Process

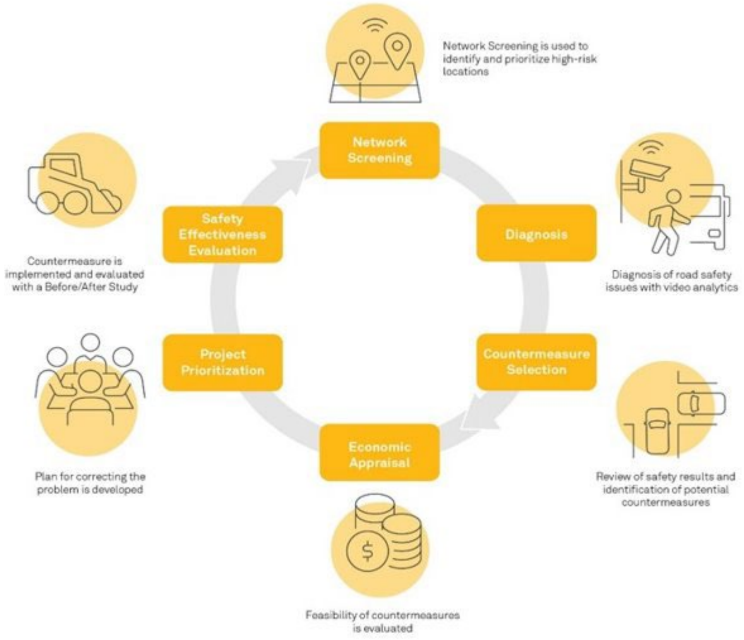


Figure 1: HSM 6-Step Roadway Safety Management Process, AASHTO (2010)

12-3-3 Network Screening May 2024

INTRODUCTION

WisDOT utilizes several different network screening metrics that express the safety performance of a roadway as defined in the Highway Safety Manual (HSM), 1st Edition. Key considerations in selecting appropriate performance measures rely on data availability, regression-to-the-mean bias and how the performance measure is established.

Crash Rate

A crash rate expresses the safety performance of a segment of roadway. This performance measure normalizes the frequency of crashes with the exposure, measured by traffic volume. Crash rates are unique for each particular location and are expressed in terms of crashes per hundred million vehicle miles traveled (HMVMT). A crash rate is calculated by the following equation.

$$Crash\ Rate = \frac{C * 100{,}000{,}000}{AADT * L * Y * 365}$$

Where,

Crash Rate = Frequency of crashes (crashes per HMVMT)

C = Number of crashes that occurred within analysis limits (total or severe injury (KAB))

AADT = Annual Average Daily Traffic through segment (vehicles/day)

L = Length of segment (miles)

Y = Years analyzed (typically 5)

Critical Crash Rates

The critical crash rate is a threshold value that allows for a relative comparison among sites with similar characteristics. The critical crash rate depends on the average crash rate at similar sites, traffic volume, and a statistical constant that determines the thresholds which flag locations for consideration of safety improvements. Critical crash rates, commonly referred to as “statewide average crash rates” at WisDOT, are used to flag locations that have worse safety performance than similar sites statewide. Critical crash rates are developed using data collected from similar sites in Wisconsin (e.g., 4-lane freeways, 6-lane freeways with AADT > 90,300 vehicles per day, etc.) to determine the expected level of performance for a given site type. The following equation is an example of how the critical crash rate is determined.

$$Critical\ Crash\ Rate = Crash\ Rate_{Average} + Statistical\ Constant * \sqrt{\frac{Crash\ Rate_{Average}}{AADT * L * Y}}$$

Where:

Critical Crash Rate = Upper control limit (threshold value) for a set of similar facilities (crashes per HMVMT)

Crash $\text{Rate}_{\text{Average}}$ = the average crash rate for a set of similar facilities (crashes per HMVMT)

AADT = Annual Average Daily Traffic through segment (vehicles/day)

L = Length of segment (miles)

Y = Years analyzed (typically 5)

Crash Terms

Three terms are used to express the number of crashes:

Observed Crash History

The total number of crashes that were reported over a period of time, typically 5 years, and are usually summarized by crash severity and crash type. Shown as $N_{observed}$ in equations.

Predicted Crash Frequency

The result from a crash prediction model (CPM) used to calculate a predicted number of crashes at a given site based on the site's parameters. Shown as $N_{predicted}$ in equations. See TEOpS 12-3-5 for more information regarding CPMs.

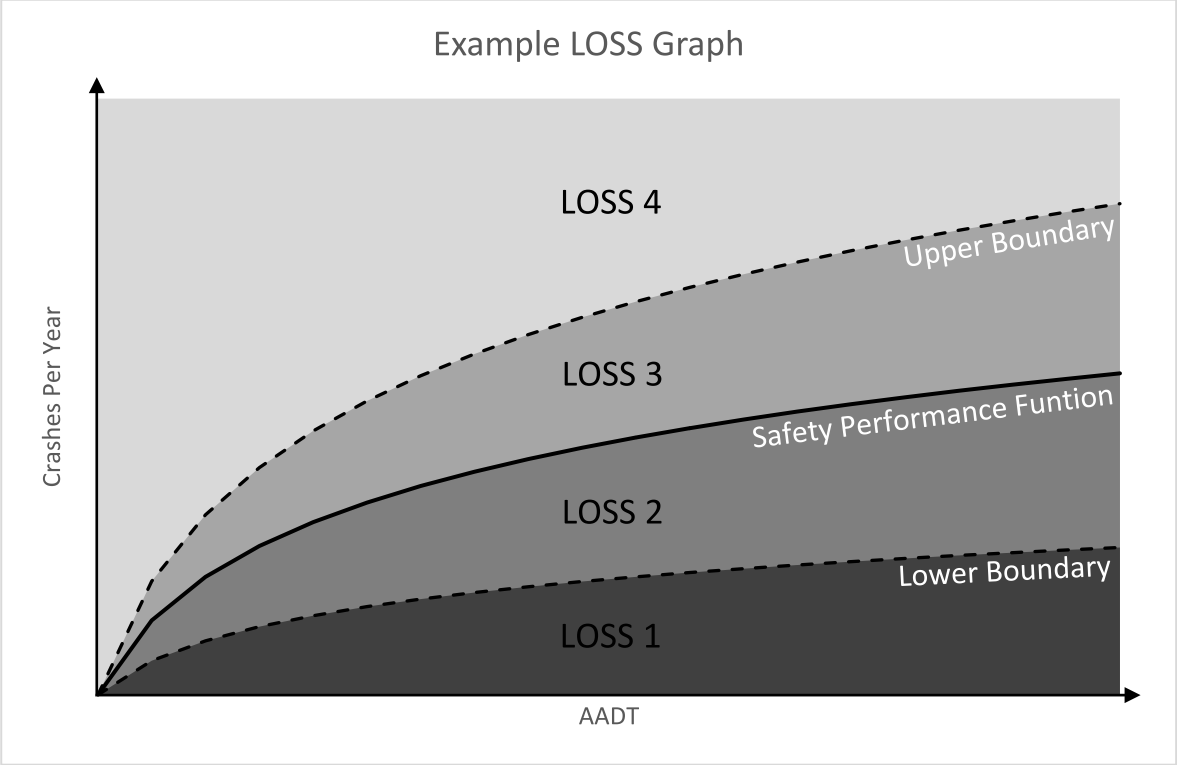
Expected Crash Frequency

The result of using the Empirical Bayes (EB) method to combine the observed crash history and the predicted crash frequency together. This typically yields more robust results than either observed crash history or predicted crash frequency alone. Shown as $N_{expected}$ in equations.

Level of Service of Safety (LOSS) with Empirical Bayes Adjustment

Level of Service of Safety (LOSS) is a performance measure used by WisDOT to separate sites into one of four safety performance classifications. A safety performance function (SPF) calibrated to local conditions is used to predict the average number of crashes for a set of similar sites. This average crash prediction defines the boundary between LOSS classifications 2 and 3, where LOSS 1 & LOSS 2 are classifications with fewer crashes than the average crash prediction and LOSS 3 & LOSS 4 are classifications with more crashes than the average crash prediction. The upper and lower boundaries are determined using an inverse gamma distribution. Figure 3.2 shows an example of the LOSS graph. The specific site is placed into one of the four LOSS classifications based on the expected crash frequency.

Figure 3.2 Level of Service Safety Thresholds



Potential for Safety Improvement (PSI)

The potential for safety improvement (PSI) is also known as *excess expected average crash frequency with empirical bayes adjustment* in the HSM, 1st Edition. It's calculated by subtracting the predicted crash frequency from the expected crash frequency. A positive result indicates there is the potential for safety improvement at that given location. Using the LOSS classifications, LOSS 3 & LOSS 4 will always yield a positive PSI and LOSS 1 & LOSS 2 will always yield a negative PSI. This means LOSS 3 & LOSS 4 locations have the potential for improvement when compared to an average site of the same type. Sites with LOSS 1 or 2 *may* still have clear crash trends that can be targeted with an effective safety countermeasure.

12-3-4 Diagnosis May 2024

Crash Diagrams

Crash Diagrams are used in safety analyses to visualize the crash history and easily identify trends. Key components of crash diagrams are the date, time, severity, manner of collision, location, environmental condition as well as any extenuating circumstances. All of these data fields are required to understand the factors contributing to crashes at the site. It is common to use aerial imagery for crash diagrams, but a generic intersection layout is acceptable to convey the intersection geometry. Example crash diagrams are provided in Figures 3.1a-c.

Road Safety Audits

A Road Safety Audit (RSA) is a formal examination of safety performance of an existing or future roadway or intersection by an independent, multi-disciplinary team. RSAs help to promote road safety during any phase of a project such as planning, preliminary engineering, design, and construction. RSAs can also be used to identify potential issues with temporary traffic control. This process promotes awareness of safe design practices, while integrating multimodal safety concerns, and considering human factors. The goal is to identify any safety concerns and document how those concerns can be mitigated.

Figure 3.1a. Example Crash Diagram

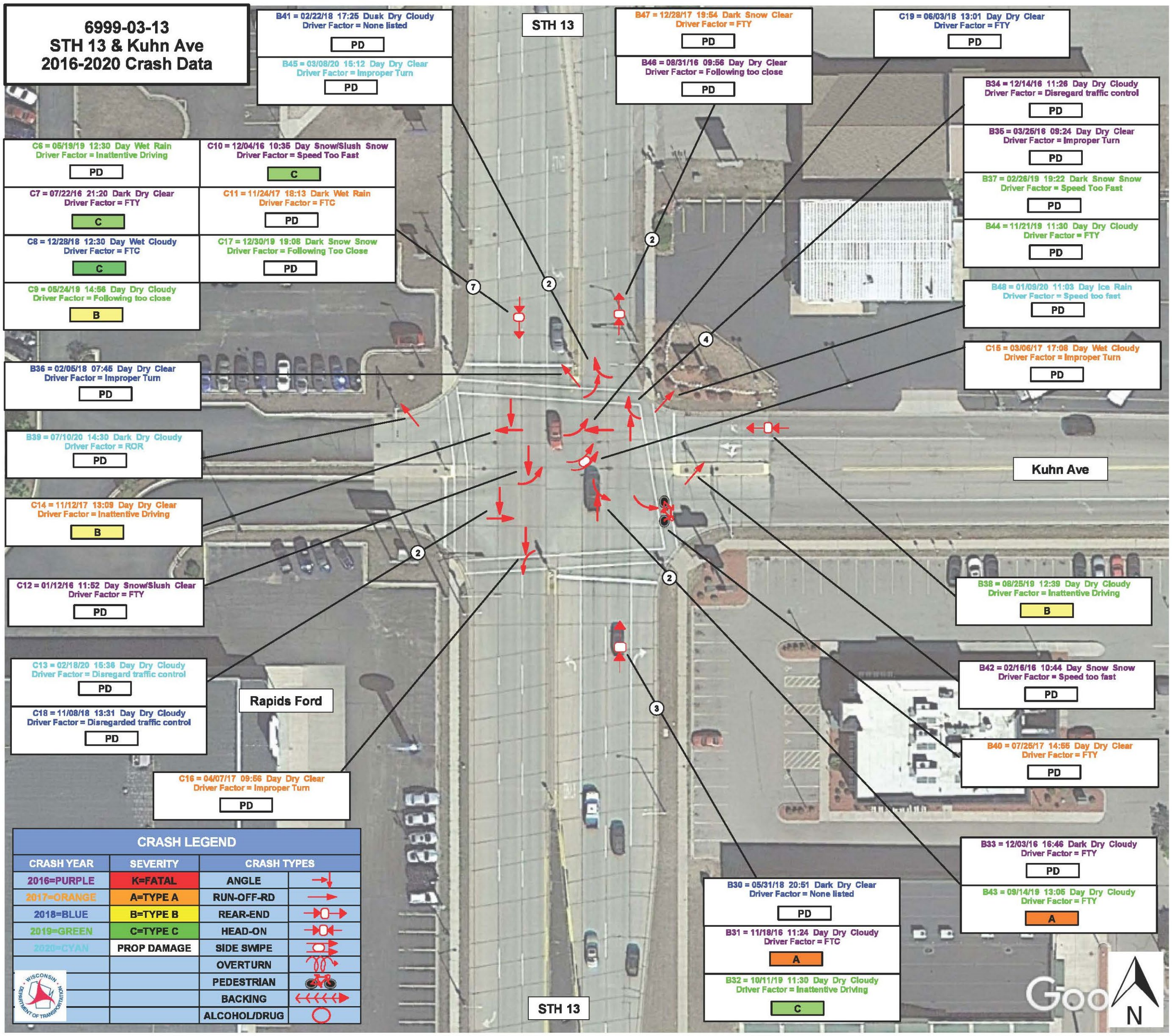
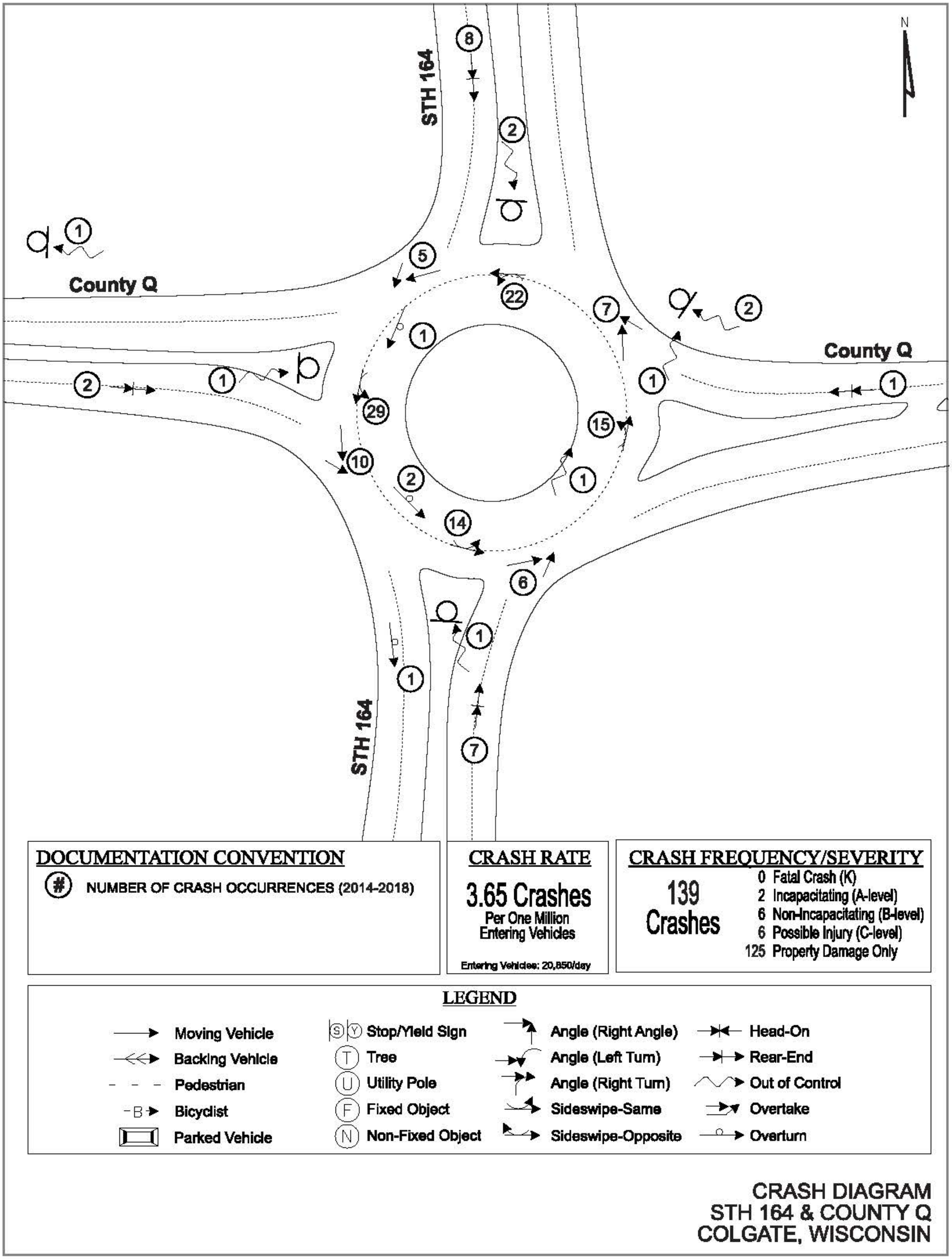


Figure 3.1b. Example Crash Diagram



DOCUMENTATION CONVENTION

(#) NUMBER OF CRASH OCCURRENCES (2014-2018)

CRASH RATE

3.65 Crashes
Per One Million
Entering Vehicles

Entering Vehicles: 20,850/day

CRASH FREQUENCY/SEVERITY

139 Crashes

0 Fatal Crash (K)
2 Incapacitating (A-level)
6 Non-Incapacitating (B-level)
6 Possible Injury (C-level)
125 Property Damage Only

CRASH DIAGRAM
STH 164 & COUNTY Q
COLGATE, WISCONSIN

Figure 3.1c. Example Crash Diagram

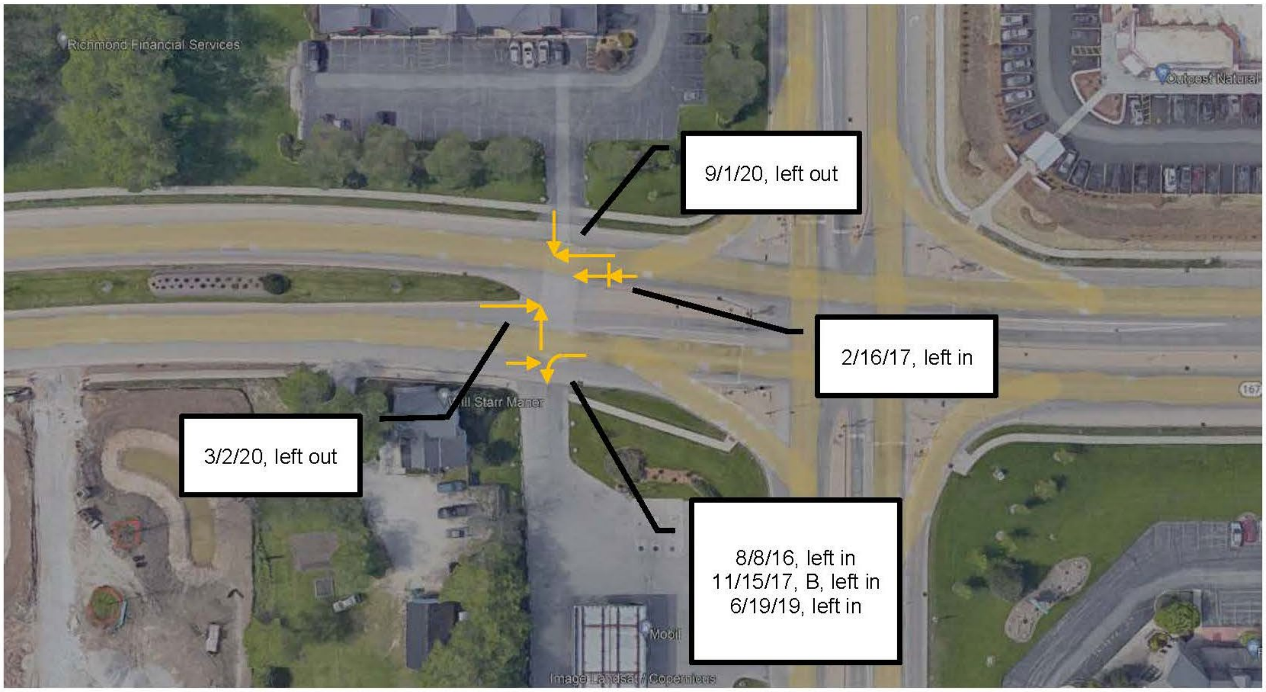
DTSD – SE Region

Intersection Safety Evaluation

Median opening W of STHs 167 & 181

Ozaukee County

January 2016-December 2020



LEGEND

○	Signal/Sign Post	▪▪▪▪▪	Bicycle		Right Angle		Out of Control	(S) = SNOW-ICE	K = FATAL
●	Tree/Utility Pole	◆- - -	Pedestrian		Left Turn		Rear-End	(W) = WET	A = SUS. SERIOUS INJURY
□	Non-Fixed Object	← - - -	Non-Contact Vehicle		Right Turn		Head-On	(F) = FOG-MIST	B = SUS. MINOR INJURY
■	Fixed Object	↔	Backing Vehicle		Sideswipe-Same		Overtake	(DUI) = ALCOHOL OR DRUG USE	C = POS. INJURY
▨	Parked Vehicle	←	Moving Vehicle		Sideswipe-Opp.		Overturn		BLANK = PROPERTY

12-3-5 Crash Prediction Models **May 2024**

INTRODUCTION

Crash Prediction Models

Crash prediction models (CPMs) are used to calculate the safety performance of existing or proposed roadways and have the following form:

$CPM_x = SPF_x * (AF_1 * AF_2 * \ldots * AF_N)$

Where:

CPM_x = The crash prediction model for site type *x*

SPF_x = The results from the safety performance function (SPF) for site type *x*. This can either be predicted crash frequency or expected crash frequency.

$AF_1 \ldots AF_N$ = Adjustment factors for treatment *n*

There are two different types of CPMs:

1. Network Screening CPMs (HSM Part B)
2. Alternative Analysis CPMs (HSM Part C)

Network Screening CPMs

Network Screening CPMs contain fewer parameters and offer a high-level analysis of a given location. Traffic volume is the primary indicator of crashes and is the primary parameter. These CPMs are used when computing the LOSS and PSI (TEOpS 12-3-3).

Alternative Analysis CPMs

Alternative Analysis CPMs are more detailed models that incorporate crash modification factors for specific design features or elements that are proven to influence crashes at a particular site or facility (e.g., presence of left or right turn lanes at a rural, two-way stop-controlled intersection). These models are used to compare different project-level alternatives. If the models are uncalibrated, only the relative difference between results can be used.

Safety Performance Functions

Safety performance functions (SPFs) are equations that predict the average number of crashes for a given location. Each facility type will have a different equation and will use adjustment factors to adapt a location from the base conditions to site specific conditions. Calibration factors are used in the equations to reflect local influences. WisDOT has calibrated the national models to statewide conditions. If additional crash modification factors are not used, the CPM is the same as the SPF, which is why it is common for people to interchange the terms crash prediction model and safety performance function. These equations have the following form:

$N_{predicted} = (N_{SPFx} * AF_{SPFx1} * AF_{SPFx2} * \ldots * AF_{SPFxN}) * C_x$

Where:

$N_{predicted}$ = The predicted crash frequency for site type *x*

N_{SPFx} = The predicted crash frequency for site type *x* for the base conditions

$AF_{SPFx1} \ldots AF_{SPFxN}$ = Adjustment factors for site type *x*

C_x = Calibration factor for site type *x*

If the Empirical Bayes (EB) method is used, then the SPF changes from predicted crash frequency to expected crash frequency. This is done by weighting the observed crash history and predicted crash frequency together.

$N_{expected} = (w * N_{predicted}) + ((1 – w) * N_{observed})$

Where:

$N_{expected}$ = the expected crash frequency for site type *x*

w = the weighted adjustment

$N_{predicted}$ = the predicted crash frequency for site type *x*

$N_{observed}$ = the observed crash history for the location

The weighted adjustment is calculated as follows:

$$w = \frac{1}{1 + \mathrm{k} * N_{predicted}}$$

Where:

w = the weighted adjustment

k = the overdispersion parameter for site type *x*

$N_{predicted}$ = the predicted crash frequency for site type *x*

The Empirical Bayes method requires at least two years of observed crash history without significant changes occurring at the location. This method is typically the most robust crash analysis method.

Crash Modification Factors

A crash modification factor (CMF) is an estimate of the change in crash frequency as a result of a particular safety treatment or design element. CMFs are used to quantify the effectiveness of a safety treatment.

$$CMF = \frac{Crash\ Frequency\ WITH\ Treatment}{Crash\ Frequency\ WITHOUT\ Treatment}$$

The value of a CMF determines whether the treatment has the potential to increase or reduce crashes.

- A CMF < 1.0 indicates that a treatment has the potential to reduce crashes.
- A CMF > 1.0 indicates that a treatment has the potential to increase crashes.
- The percent crash reduction is (1 – CMF) * 100%

CMFs are only a point estimate but do have an associated confidence interval. WisDOT uses the point estimates and not the confidence interval when incorporating CMFs into calculations. There are two common applications for CMFs.

Application 1: Multiply the CMF(s) and the observed crashes to estimate the crash frequency after installation of a safety treatment. This is done when a safety performance function (SPF) is not available for the treated site.

Application 2: Multiply the CMF(s) and the predicted crashes obtained from a SPF. This is done to account for differences between the SPF’s conditions and actual site conditions (e.g., proposed safety treatment). This *should* only be done after verifying that the CMF conditions are consistent with the conditions represented by the SPF. This type of CMF would supplement the adjustment factors associated with the SPFs found in Part C of the HSM.

Calibration

Calibrating the SPFs (and CPMs) to Wisconsin conditions is important to predict the most accurate results. Like the aphorism states: “all models are wrong, but some are useful”. In this context, the number of crashes predicted is not definitive, but rather informative to help make the best decision possible. Since the models/equations were developed with national data (data from different states), it is important to calibrate the models to Wisconsin to account for our specific climate, driver population and driving behaviors, animal populations, and crash reporting practices.

Calibration Factor

A calibration factor is the ratio of observed crashes to expected crashes for the same time period of the same sites. In this way, a calibration factor is like a CMF, where:

- A calibration factor > 1 indicates the number of predicted crashes is greater for the local jurisdiction compared to the model.
- A calibration factor < 1 indicates the number of predicted crashes is lesser for the local jurisdiction compared to the model.

The calibration factor adjusts the total number of crashes predicted.

Crash Distributions

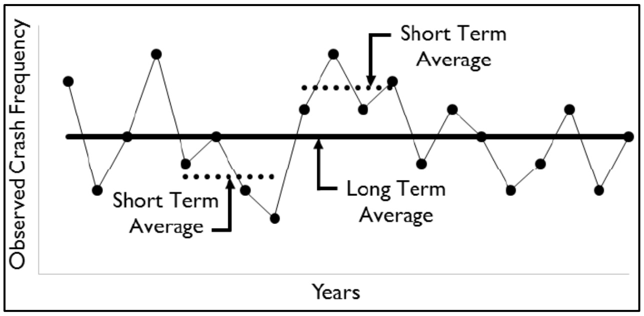
In addition to accounting for the total number of crashes, it is important to calibrate the types and severities of crashes. Calibration for crash types and severities use crash distribution/proportion tables that are then applied to the predicted number of crashes.

12-4-1 Safety Certification Process April 2023

PURPOSE

Quantifying safety early in the project development process is key to determining safety improvement impacts to projects. Proposed safety improvements in a project must be balanced with other competing fiscal needs such as operational, environmental, and pavement factors. Historically, safety benefits have been assumed inherent, or “built-in”, to design policies and practices. The safety treatments were proposed at locations that were identified using the existing (observed) short-term crash data. This method was not representative of the long-term conditions of the subject location as it did not account for the Regression to the Mean (RTM) of crash data. RTM is defined as the natural variation of crash data. A location that was being reviewed could be analyzed when it was seeing a randomly high fluctuation of crashes, but the long-term period saw the location operating within typical safety norms. Likewise, a location could be overlooked from review due to it having a randomly low fluctuation of crashes. Figure 1 displays RTM bias.

Figure 1. Variation in short-term observed crash frequency to illustrate RTM bias



There are methods and tools available to quantify safety benefits in the development and analysis of alternatives in projects while accounting for RTM. This allows WisDOT to employ a PBPD approach. Within the safety evaluation of a project, to facilitate the safety comparison of alternatives, predictive crash modeling and an economic appraisal is used to compare the cost of crashes to the cost of roadway improvements. Predictive crash modeling is used to estimate crash frequencies and severities for alternatives on a project. Economic appraisal techniques are then used to assign average costs to the crashes for each alternative to monetize safety benefits. In this way, safety can be compared with other costs (construction, real estate) to evaluate alternatives. For a discussion on alternative viability, see FDM 11-38-15.1.

The Safety Certification Process (SCP) follows the Highway Safety Manual’s (HSM’s) Road Safety Management Process (RSMP). This is a step-by-step process of determining whether safety improvements should be included on a project by quantifying alternatives, monetizing the resulting safety benefits, completing benefit-cost comparisons of the alternatives, and documenting decisions and judgements throughout the process.

This requires the analyst to use and document sound engineering judgement and experience based on specific project conditions, context, and modal priorities.

The Safety Certification Process is detailed in FDM 11-38.

12-4-2 Highway Safety Improvement Program April 2023

The Highway Safety Improvement Program (HSIP) is a core Federal-aid program with the purpose of achieving a significant reduction in fatalities and serious injuries on all public roads. Projects are identified by statewide screenings and WisDOT regional safety engineers on the state-owned system and by local agencies on the local system. All candidate projects must compile crash data and develop a proposed treatment strategy as part of a competitive application process. The applications are considered through a peer review process that involves statewide and regional safety engineering staff, as well as HSIP program management staff.

Federal HSIP guidance can be found on the FHWA HSIP website. Wisconsin-specific HSIP information can be found on the Wisconsin HSIP website. WisDOT HSIP program guidelines are available for internal use only.

Traffic Engineering, Operations & Safety Manual

Chapter 12 Safety

Section 5 Countermeasures

12-5-1 General — April 2023

Safety countermeasures are facility improvements that have been proven to reduce the severity of crashes. Countermeasures range from additional signage to complete reconfiguration of roadways. This section does not detail all available countermeasures that WisDOT implements. Many other countermeasures are detailed in WisDOT's Facilities Development Manual (FDM) and throughout the Traffic Engineering, Operations & Safety (TEOpS) manual.

12-5-3 Intersection Conflict Warning Systems — August 2021

BACKGROUND

Intelligent Transportation System (ITS) technologies can be used to provide enhanced warning information to drivers approaching intersections compared to static signing and marking applications. One type of ITS installation that *may* reduce crashes at intersections is an Intersection Conflict Warning System (ICWS). An ICWS is an actuated system which provides advance warning of a condition that may require a vehicle to stop but the condition is not always present. These systems have a broad spectrum of types and applications but are all categorized as ICWSs. An ICWS is a countermeasure intended to address locations that are experiencing crash issues, have unusual geometry, or restricted sight distances. An ICWS *should* only be used where other countermeasures have failed or *may* not be feasible.

GUIDELINES

Three criteria are to be considered when reviewing a location for an ICWS. These criteria are as follows:

1. Demonstrated crash issue
2. Visibility restrictions
3. Unusual geometrics

Due to the long-term maintenance of these systems, other countermeasures *should* be considered first to address safety concerns prior to the installation of an ICWS. These include:

- Improving sight distance (clearing vegetation, obstructions, or brush)
- Installing an advance intersection warning sign (W2 series)
- Increasing sign sizes
- Double-marking signs
- Installing advanced crossroad name signs (D series), if applicable. See TEOpS 2-4-50.
- Installing permanent flags on signs
- Electrical countermeasures (beacons, etc.)

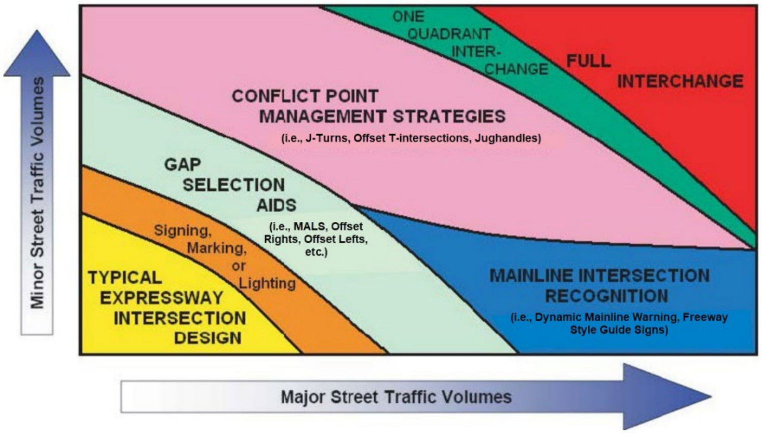
THROUGH ROUTE ACTIVATED WARNING SYSTEMS

Introduction

The frequency of crashes at two-way stop-controlled (TWSC) intersections is typically lower than at signalized intersections; however, the crashes are often more severe. The most common crash type at TWSC intersections is a multi-vehicle angle crash where a vehicle stopped on the minor road enters the intersection without an acceptable gap, resulting in a collision with a through vehicle on the major road. On higher speed roadways, these crashes are often severe because of the nature of the impact. In many cases, a primary factor in these crashes is misjudgment of approaching traffic on the major road by the minor road vehicle, not failure to stop at the minor road approach.

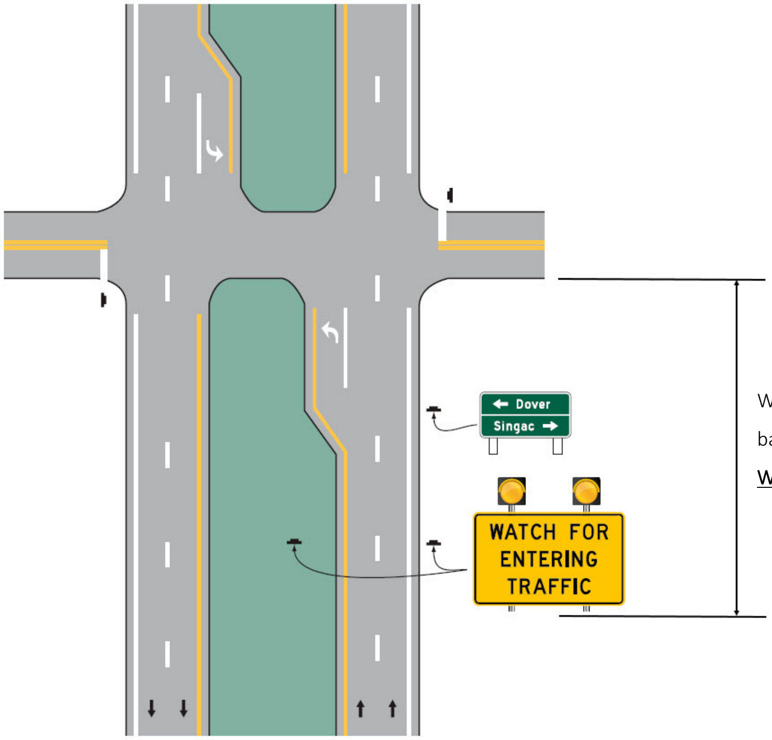
Several countermeasures are available to mitigate these angle crashes with varying costs and effectiveness. Figure 1 shows several categories of countermeasures for reducing crashes at TWSC intersections. Some countermeasures are more appropriate for divided highways and some are more appropriate for undivided highways. The most appropriate countermeasure *should* be based on the crash trends and contributing factors of those crashes at the intersection in question.

Figure 1. TWSC Rural Expressway Intersection Countermeasure Categories



One type of ICWS which has been implemented in several states is a Through Route Activated Warning System (TRAWS). A TRAWS detects vehicles on the minor road of a TWSC intersection to warn traffic on the major road. Detected vehicles activate flashing beacons that are attached to static warning signs. The flashing beacons are activated to warn major road traffic that vehicles on the minor road *may* enter the intersection. An evaluation by FHWA showed that a TRAWS has the ability to reduce right angle crashes at TWSC intersections. Figure 2 shows a conceptual layout of a TRAWS.

Figure 2. Typical Installation of a TRAWS on a multi-lane highway



Warning sign placement distance based on speed limit. See <u>WisMUTCD</u> Table 2C-4.

<u>Policy</u>

This policy contains provisions for proper site selection, application, design, and installation of a TRAWS on the State Trunk Highway (STH) system.

Site Selection Criteria

A TRAWS *should* be considered at an existing TWSC intersection if it meets all the following conditions:

1. Enhanced signing and marking treatments have failed to mitigate crashes
2. Conflict point management strategies such as Restricted Crossing U-Turn (RCUT) intersections or other access restrictions are not appropriate or are too costly to implement
3. Improving sight distance is too costly to implement, if applicable
4. The intersection experienced three or more angle crashes in the previous five years or since the most recent safety improvement, if one was installed, within the previous five years
5. The posted speed limit for the through route is greater than 45 mph

As traffic volumes on the side road increase, the amount of time the beacons are activated increases respectively. The total activation time per vehicle is dependent on several factors. Minor road Average Annual Daily Traffic (AADT) volumes of more than 3,000 vehicles per day *may* cause near continuous activation of the system which can lead to drivers ignoring the dynamic warning and diminish the effectiveness of the system. Average activation times **shall** be considered based on the site conditions and engineering judgement used to confirm the system will activate dynamically for drivers on the major road. To optimize the effectiveness of a TRAWS, the following maximum AADT volumes *should* be considered:

- Major Road AADT typically does not exceed 12,000
- Minor Road AADT typically does not exceed 3,000

Design and Installation

The following provisions pertain to the design and installation of the signing components for a TRAWS on the STH system:

1. Installations **shall** be in compliance with the requirements established in the Wisconsin MUTCD (WisMUTCD)
2. The sign legend **shall** follow WisDOT sign plate W8-75. Sign size varies by facility type. For sizing information, see TEOpS 2-1-35.
3. Number of signs, beacon details and sign installation
    a. The sign and beacon assembly **shall** be ground mounted in the lateral and vertical location as specified in the WisMUTCD
        i. The sign **shall** be located in accordance to WisMUTCD Table 2C-4
        ii. See WisDOT sign plate A4-4 for information on roadway offsets, number of posts and post spacing required
        iii. Warning beacons **shall** be mounted on the same support as the warning sign. See WisMUTCD 4L.01 and 4L.03 for information. The beacon **shall** be mounted, at minimum, one foot above the sign with a maximum of two feet.
    b. The number of signs depends on the facility type and site condition. See Figure 2 for an illustration of a typical installation on a divided, multi-lane highway.
        i. For two-lane undivided highways, one sign **shall** be installed for each direction of travel
        ii. For four-lane divided highways, one sign **shall** be installed on each side of the highway for each direction of travel
    c. Two flashing beacons **shall** be used on all signs. When activated, the beacons **shall** operate with an alternating flashing, "wig-wag", signal indication.

The following provisions pertain to the design and installation of the detection and electrical service for a TRAWS on the STH system:

1. Detection
    a. All stop approaches *should* have advance and stop bar detection. The type of detection *should* be controlled through radar detection. The equipment **shall** be furnished by the Department.
    b. Detection of a vehicle on the stop approaches **shall** be transmitted through a hard-wired connection from a detector to activate the beacons on the system
    c. Any poles needed for mounting detection equipment **shall** be in conformance with the standards in FDM 11-15-1
    d. System timing *should* be based on the operating speeds on the major and minor roads, major road sign placement, major road vehicle perception-reaction time, intersection geometrics, traffic volumes, vehicle mix and type of detection at each site
    e. The need to detect vehicles in the median who are making two-stage crossing maneuvers **shall** be evaluated during design

2. Electrical service
    a. Service **shall** be installed underground. The conduit **shall** run up and be attached to the control cabinet. The control cabinet **shall** be mounted on the pole at least three feet from the ground.
    b. Solar-powered installations **shall** not be allowed on the STH system

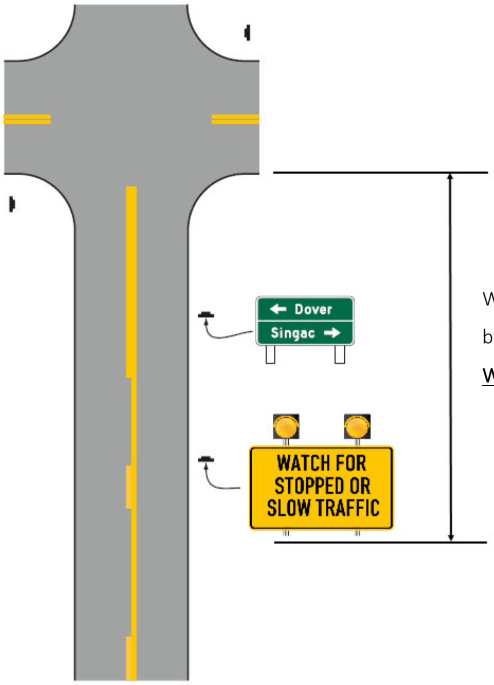
STOPPED OR SLOW TRAFFIC AHEAD WARNING SYSTEM

Introduction

A common crash type at a TWSC intersection where a separated left turn lane doesn't exist is when a vehicle on the mainline slows to perform a turn or is stopped within a queue of vehicles due to turning traffic and is rear-ended by another vehicle. Several factors that could contribute to these types of crashes are restricted sight distance, unusual geometry, and roadway curvature.

A Stopped or Slow Traffic Ahead Warning System is a type of ICWS that detects vehicles on the major road to warn subsequent vehicles of a stopped/slowed vehicle ahead. A vehicle that is slowing prior to the intersection to perform a turn activates flashing beacons that are attached to a static warning sign. Figure 3 displays a typical installation on a two-lane undivided facility.

Figure 3. Typical Installation of a Stopped or Slow Traffic Ahead Warning System on a two-lane highway



Warning sign placement distance based on speed limit. See WisMUTCD Table 2C-4.

Policy

This policy contains provisions for proper site selection, application, design, and installation of a Stopped or Slow Traffic Ahead Warning System on the STH system.

Site Selection Criteria

A Stopped or Slow Traffic Ahead Warning System *should* be considered at an existing TWSC intersection if it meets all the following conditions:

1. Enhanced signing and marking treatments have failed to mitigate crashes
2. The Stopping Sight Distance (SSD) does not meet minimum standards for a category 1 sight distance requirement or the intersection experienced three or more correctable crashes (mainline rear-ends relating to left-turning movements) in the previous five years or since the most recent safety improvement, if one was installed, within the previous five years. See FDM 11-10-5.1.1 for SSD requirements.
3. Installing geometric alternatives (turn lanes, bypass lanes, paved shoulders) is not feasible due to unusual geometrics, existing roadway features, or other factors
4. The posted speed limit for the through route is greater than 45 mph

Design and Installation

The following provisions pertain to the design and installation of the signing components for a Stopped or Slow Traffic Ahead Warning System on the STH system:

1. Installations **shall** be in compliance with the requirements established in the Wisconsin MUTCD (WisMUTCD)
2. The sign legend **shall** follow WisDOT sign plate W8-77. Sign size varies by facility type. For sizing information, see TEOpS 2-1-35.
3. Number of signs, beacon details and sign installation
    a. The sign and beacon assembly **shall** be ground mounted in the lateral and vertical location as specified in the WisMUTCD
        i. The sign **shall** be located in accordance to WisMUTCD Table 2C-4
        ii. See WisDOT sign plate A4-4 for information on roadway offsets, number of posts and post spacing required
        iii. Warning beacons **shall** be mounted on the same support as the warning sign. See WisMUTCD 4L.01 and 4L.03 for information. The beacon **shall** be mounted, at minimum, one foot above the sign with a maximum of two feet.

   b. This system *should* only be used for two-lane undivided highways. One sign **shall** be installed for each direction of travel
   c. Two flashing beacons **shall** be used on all signs. When activated, the beacons **shall** operate with an alternating flashing, “wig-wag”, signal indication.

The following provisions pertain to the design and installation of the detection and electrical service for a Stopped or Slow Traffic Ahead Warning System on the STH system:

1. Detection
   a. Detection *should* be camera-based in order to detect mainline vehicles slowing to perform a turn. The type of detection *should* be evaluated at each location. The equipment **shall** be furnished by the Department.
   b. Detection of a vehicle **shall** be transmitted through a hard-wired connection from a detector to activate the beacons on the system
   c. Any poles needed for mounting detection equipment **shall** be in conformance with the standards in FDM 11-15-1
   d. Considerations for system timing and system delays *should* be based on conditions at the site such as traffic volumes, vehicle type, vehicle speeds, major road vehicle perception-reaction time, intersection geometrics, and major road sign placement.

2. Electrical service
   a. Service **shall** be installed underground. The conduit **shall** run up and be attached to the control cabinet. The control cabinet **shall** be mounted on the pole at least three feet from the ground.
   b. Solar-powered installations **shall** not be allowed on the STH system

PERMITTING OF INTERSECTION CONFLICT WARNING SYSTEMS

See TEOpS 4-5-1 for provisions on permitting ICWSs.

MAINTENANCE AND RELIABILITY OF INTERSECTION CONFLICT WARNING SYSTEMS

Reliability of an ICWS is critical for public acceptance and successful crash mitigation. The provisions described in this policy have been developed to provide a high level of system reliability commensurate with other ITS devices deployed by the Department. Design of the detection system, electrical service and data transmission, and sign messaging all play a role in how drivers perceive and react to an ICWS during normal and fail-safe conditions. Once a system has been installed, the Region operations section **shall** be the primary caretaker of the system to provide any needed maintenance and repairs that keep the system functional on the STH system. Coordination with local maintenance forces, law enforcement and local stakeholders is needed to identify any system malfunctions so the appropriate personnel can promptly respond to any issues.

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2. Bryer, T. (2011). Stop-Controlled Intersection Safety: Through Route Activated Warning Systems. *Report No. FHWA-SA-11-015*. Federal Highway Administration, Washington, D.C.
3. Crowson, G., & Jackels, J. (2011). Design and Evaluation Guidance for Intersection Conflict Warning Systems (ICWS). *Report No. ENT-2011-1.* ENTERPRISE Transportation Pooled Fund Study TPF-5 (231).
4. Himes, S., Gross, F., Eccles, K., Persaud, B. (2016). Safety Evaluation of Intersection Conflict Warning Systems*. Report No. FHWA- HRT-16-035*. Federal Highway Administration, Washington, D.C.
5. “Planning Guidance for Intelligent Transportation Systems (ITS) Devices. Version 3.1” (2015). ENTERPRISE Transportation Pooled Fund Study TPF-5 (231).
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12-5-4 Friction Surface Treatment August 2021

BACKGROUND

Maintaining pavement friction is a critical component of vehicles safely navigating a roadway. Almost 20% of all traffic fatalities result from lane departure crashes, while they only account for less than 5% of all traffic crashes. A “lane departure” crash is a “non-intersection crash which occurs after a vehicle crosses an edge line or a center line, or otherwise leaves the travel way.”

One of the primary causes for lane departure crashes is related to poor weather conditions, particularly snow/ice and wet weather conditions.

One method to address lane departure crashes is to provide friction enhancements to the pavement. Wisconsin has several types of surface treatments that are considered friction enhancements to existing roadway or bridge surfaces.

High Friction Surface Treatments (HFST) use a calcined bauxite aggregate with resin binder, which is an aggregate that maintains frictional resistance over time by resisting polishing and wear. A resin binder is applied to the roadway or bridge surface prior to the aggregate application. HFSTs are a proven low-cost countermeasure to reduce lane departure crashes in areas that have an observed crash history related to poor, especially wet, weather conditions.

Enhanced Friction Surface Treatments (EFST) include all other types of friction enhancements to roadway and bridge surfaces.

GUIDANCE

Areas that have vehicles changing lanes or braking excessively *may* experience pavement surfaces becoming prematurely polished which reduces pavement friction. These locations commonly are located on interchange ramps and horizontal or vertical curves. Locations that experience a high number of lane departure crashes that can be considered for friction treatment installation include:

- Interchange Ramps
- Horizontal or vertical curves
- Structures
- Roundabouts

A HFST **shall** be the preferred friction enhancement to mitigate lane departure crashes. Friction surface treatments **shall** be installed as spot treatments or on short segments to mitigate crashes related to pavement friction deficiencies. These treatments are not intended to be applied as a corridor treatment and *should* only be considered when warranted.

Placement and application

Crashes are likely to occur in the area where a driver recognizes an upcoming change of condition and applies the brakes to navigate the roadway feature. These crashes *may* be prevented by providing a HFST prior to the change of condition. Placement of a HFST *should* be based on the characteristics of the roadway and other indications that are specific to each site. These factors *may* include:

- Crash locations
- Presence of skid marks
- Damaged roadside barriers or other objects
- Presence and condition of previous low-cost countermeasures
- Superelevation
- Driver speeds
- Advisory speeds
- Driver behavior
- Point of curvature and point of tangent
- Horizontal and vertical sight distances
- Intersections near or within a curve
- Heavy vehicle use
- Speed differentials
- Presence of horizontal curves, vertical curves, or weaving areas
- Friction levels (if existing pavement will remain)

When applying a HFST to the roadway surface it **shall** be installed in a single layer unless it is being applied to a bridge deck. When applying either a Thin Polymer Overlay (TPO) or a HFST to the bridge deck it **shall** require a two-layer application for deck preservation against chloride infiltration. Additionally, the standard two-layer application provides protection against snowplow and snowmobile operations.

For bridge applications, the standard two-layer TPO consists of a two-component system of epoxy polymer and aggregates for a ¼-inch minimum total thickness. This TPO system does not require use of calcined bauxite aggregates and is considered an EFST. When a HFST is warranted, a two-layer TPO with calcined bauxite aggregates **shall** be applied. The bridge deck (driving lanes and shoulders) *should* be the only feature that receives the treatment. Other considerations *should* be evaluated to determine if the approach slabs or travel lanes prior to the bridge deck need to be treated such as the presence of a curve or areas where heavy weaving may occur. Use of a HFST on bridge decks will require additional coordination and prior approval from the Bureau of Structures. For additional information on friction treatments for bridge decks, refer to the thin polymer overlay section in Chapter 40 of the WisDOT Bridge Manual.

For applications prior to vertical curves and roundabouts, the above factors *should* be taken into consideration at each situation due to the unique properties of the site.

For horizontal curves, the braking distance can be used to provide an approximate location of where to begin placement of a HFST. Table 1 provides general placement guidance for horizontal curves prior to the point of curvature (PC).

Table 1. Recommended HFST placement distances prior to the point of curvature (PC)

Approach Speed (mph)	Curve Advisory Speed (mph)											
	15	20	25	30	35	40	45	50	55	60	65	70
25	100	75	50	-	-	-	-	-	-	-	-	-
30	125	125	100	50	-	-	-	-	-	-	-	-
35	175	150	125	100	50	-	-	-	-	-	-	-
40	200	200	175	150	100	50	-	-	-	-	-	-
45	250	225	225	175	150	100	50	-	-	-	-	-
50	300	300	275	225	200	150	125	50	-	-	-	-
55	375	350	325	300	250	225	175	125	50	-	-	-
60	425	400	375	350	325	275	225	175	125	50	-	-
65	500	475	450	425	375	350	300	250	200	125	50	-
70	575	550	525	500	450	425	375	325	275	200	125	50
75	650	625	600	575	525	500	450	400	350	275	225	150

Note: Recommended values are based on the braking distance with a conservative deceleration rate of 10 ft/s^2*.*
All values include an added 50 feet and are rounded to the nearest 25 feet.

REFERENCES

1. "Frequently Asked Questions – High Friction Surface Treatments (HFST) – 2017" (2018, February). Federal Highway Administration, Washington, D.C. Retrieved from https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/faqs_links_other/hfst_faqs/. Accessed August 9, 2021.
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4. "Wisconsin Strategic Highway Safety Plan 2017-2020" (2017, November). Wisconsin Department of Transportation, Madison, WI. Retrieved from https://wisconsindot.gov/Documents/safety/education/frms-pubs/strategichwy-17-20.pdf. Accessed August 9, 2021.

WISDOT SPECIAL PROVISIONS AND REFERENCES

1. Wisconsin Resin Binder High Friction Surface Treatment
2. WisDOT Bridge Manual: Chapter 40 – Bridge Rehabilitation, 40.5.1.1 Thin Polymer Overlay