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.

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 Modification Factor Policy **October 2018**

PURPOSE

This policy outlines the selection and application of crash modification factors (CMF) for estimating the change in crashes associated with a specific safety treatment / countermeasure. Thousands of CMFs are available in the 1st Edition of the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM), CMF Clearinghouse, and other sources. In many cases, several CMFs exist for a given treatment, making it difficult to determine the most appropriate CMF to apply on a project. The WisDOT CMF Table was developed to provide a list of acceptable CMFs for use in WisDOT safety analyses to ensure consistent application statewide and reduce the amount of time needed to find an applicable CMF. As additional research is completed, the WisDOT CMF Table will be updated accordingly.

BACKGROUND

<u>What is a CMF?</u>

Definition

A 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.

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

- 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%

Standard Error

The CMF value is only an estimate of the expected average crash frequency based on a statistical analysis of crash data, safety performance functions (SPF), traffic volumes, etc. The true value of the CMF for any treatment is unknown. Most CMFs include a standard error which is the estimated standard deviation of the sampling distribution of the CMF. The standard error is critical to understanding the statistical significance of the CMF and is one factor related to the quality of the CMF. A lower standard error generally means a more reliable estimate. This standard error can be used to calculate a confidence interval which provides a range that the true value of the CMF *should* fall within. To calculate the confidence interval, use the following equation:

Equation 1

$$C.I. = CMF \pm (SE) * (SM)$$

C.I. = Confidence Interval for the desired level of significance
CMF = Crash Modification Factor
SE = Standard Error
SM = Statistical Multiplier, which is a variable based on the desired level of significance

Table 1: Level of Significance for Confidence Intervals

α	Level of Significance	Statistical Multiplier
0.01	99%	2.576
0.05	95%	1.960
0.10	90%	1.645

If the confidence interval does not include the value of 1.0, then the CMF is significant at that level. Additional information about CMFs can be found in Chapter 3 and Part D of the HSM.

How Are CMFs Used?

CMFs are used to estimate the change in crashes after a safety treatment is installed. There are two common applications for CMFs.

Application 1: Multiply the CMF(s) and the observed[1] crashes from an existing site to estimate the crash frequency after installation of a safety treatment. This is done when a safety performance function[2] (SPF) is not available for the treated site. This method is less reliable than Application 2. Application 1 is demonstrated in Example 1.

Application 2: Multiply the CMF(s) and the predicted[3] 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. Application 2 is demonstrated in Example 2.

POLICY

CMFs used in WisDOT safety analyses **shall** come from the WisDOT CMF Table unless a CMF is not available for the identified treatment or the CMF in the table does not match the site's crash and roadway characteristics.

Applying Multiple CMFs for a Single Treatment

In some cases, there is more than one CMF associated with a single safety treatment. CMFs for different crash types and/or severities **shall** be applied to the respective crashes.

Applying CMFs for Multiple Treatments

Implementing several safety treatments might be more effective than just one; however, there is limited research on the effects of combining many CMFs. The interactions between safety treatments are complicated and as a result, it is difficult to determine the effectiveness of multiple treatments when used together. Therefore, no more than two unique treatments **shall** be used and each treatment *may* have more than one CMF for different crash types and/or severities.

If two treatments are used at one location, the following methodology **shall** be used to estimate the combined effect of both treatments.

1. If both CMFs are less than 1.0, combine the CMFs using the *Dominant Common Residuals Method*
2. If one or both CMFs are greater than 1.0, use the *Dominant Effect Method*

Dominant Common Residuals Method

The dominant common residuals method provides a more conservative estimate of the combined effect of multiple treatments than simply multiplying the CMFs together. In this method, the CMFs (i.e., common residuals) are raised to the power of the most effective CMF (i.e., dominant common residual). The combined effect of multiple treatments is estimated as shown in Equation 2. The primary limitation is when either of the individual CMFs are greater than 1.0, particularly the most effective treatments. In these cases, the combined CMFs are raised to a power greater than 1.0, which intensifies the effect rather than dampening. As such, this method is not appropriate for CMFs greater than 1.0. Example 3 demonstrates the *Dominant Common Residuals Method*. Additional examples can be found in the Highway Safety Benefit-Cost Analysis Guide.

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[1] Observed crash frequency is the number of crashes that have occurred within the investigated site limits over one or more years.

[2] A Safety Performance Function (SPF) is a statistically derived equation used to predict the expected average crash frequency of a site based on specific traffic volumes and roadway or intersection characteristics. Refer to Chapter 3.5.2 of the HSM for more information regarding SPFs and how they are used.

[3] Predicted crash frequency is the estimated number of crashes determined with a SPF.

Equation 2

$$CMF_{comb} = (CMF_1 * CMF_2)^{CMF_1}$$

CMF_{comb} = the combined effectiveness of the two treatments selected
CMF_1 = the CMF with the lowest value (i.e., the most effective treatment selected)
CMF_2 = the CMF for the other treatment selected

Dominant Effect Method

The dominant effect method applies the CMF for only the most effective treatment (i.e., lowest CMF value). This method is a simplified and conservative approach to estimating the combined effect of multiple treatments. By only applying a single CMF, this method avoids the issue of independence. The primary limitation of this method is that it is likely to underestimate the combined treatment effect if subsequent treatments improve safety.

Applying CMFs from Other Sources

If a CMF is not available for the identified treatment or the CMF in the WisDOT CMF Table does not match the site's crash and roadway characteristics, a CMF *may* be used from another source. When a CMF is used from outside the WisDOT CMF Table, the following documentation **shall** be provided:

1. The CMF study citation, with links to the study when possible
2. CMF value and standard error
3. Roadway and crash characteristics associated with the CMF

Before selecting a CMF, confirm that the following attributes match those of the site being evaluated:

- Area Type
- Roadway Type
- Crash Type
- Crash Severity
- Other Site Conditions – such as number of intersection legs or location of application (e.g., shoulder, curve, etc.)

Also check the quality of the study by:

- Reviewing the number of crashes in the sample
- Identifying the number of sites in the sample and where those sites were located (i.e., in just one state or in many states)
- Considering the statistical methodology that was used and what biases may be present

GUIDANCE

WisDOT CMF Table

The WisDOT CMF Table can be found here:

http://wisconsindot.gov/dtsdManuals/traffic-ops/manuals-and-standards/teops/cmf-table.xlsm

There are two types of CMFs in the HSM; Part C CMFs and Part D CMFs. Part C CMFs are often referred to as 'SPF adjustment factors' because they are used to adjust the base conditions of the SPFs used in conjunction with the HSM predictive methods. Most WisDOT safety analyses should utilize the predictive methods found in Part C of the HSM. The WisDOT CMF Table does not include those CMFs found in Part C. The WisDOT CMF Table includes CMFs that are used to account for differences between the geometric conditions within the SPF's and actual site conditions. (i.e., Application 2 described above).

Selection Process

CMFs in the table were chosen based on the following factors:

1. **Availability**: Included treatments commonly used in Wisconsin

2. **Quality**: Many factors influence the quality of a CMF including: study design and statistical methodology, sample size, standard error, potential bias, and data source.
3. **Applicability**: Location of the sites in the study and the crash types and severities for which the CMF was developed. Preference was given to studies with sites near Wisconsin or with similar climates, driver behavior, design standards, etc.

For each CMF in the table, multiple studies were reviewed and the factors described above were documented. A WisDOT committee reviews and approves which CMFs are included in the WisDOT CMF Table.

Selecting a CMF from the WisDOT CMF Table

CMFs can be applied to total crashes or to target crash types and severities. It is often useful to estimate the change in crashes by type and severity but this should only be done when there are CMFs available for the specific crash types and severities in question. Crash severity is defined by the most severe outcome of those involved in the crash. It is not appropriate to apply a CMF for a specific crash type or severity to other crash types and severities because a treatment may reduce certain crash types or severities while increasing others.

The first step is to identify the treatment being evaluated. Each row in the WisDOT CMF Table corresponds to a specific treatment and has an associated CMF or group of CMFs. In a few cases, there is more than one row in the table that has the same treatment name with different CMF values due to the applicability of the CMF.

Next, select the most appropriate CMF(s) by matching the CMF characteristics to the roadway and crash characteristics of the site being evaluated. If the crash and roadway characteristics are different, it *may* be necessary to find a CMF from another source, which is described in the section "Applying CMFs from Other Resources".

APPLICATION EXAMPLES

Example 1: Applying a CMF to Observed Crash History

Problem:

At a midblock crossing on a 4-lane, undivided urban road, there have been 4 pedestrian crashes in 5 years.

Analysis:

One potential treatment is to install a pedestrian hybrid beacon (PHB) to warn drivers when pedestrians are crossing the street.

Crash History

Type	Fatal	Injury A	Injury B	Injury C	PDO	TOTAL
Pedestrian		1	2	1		4
Rear End				1	1	2
Other						0
TOTAL		1	2	2	1	6

Solution:

The CMF value for "Install a Pedestrian Hybrid Beacon" in the WisDOT CMF Table is 0.309. This CMF is for "Pedestrian" crashes of "All" severities. To determine the potential benefit of installing a PHB, multiply the CMF and the observed pedestrian crashes together.

$N_{Ped} = \text{Observed}_{Ped} * \text{CMF}_{Ped}$
$N_{Ped} = 4 * 0.309$
$N_{Ped} = 1.24$ crashes in 5 years

Using the point estimate of the CMF, the estimated number of crashes in a 5 year period is 1.24, compared to 4 pedestrian crashes in a 5 year period without the PHB.

If desired, a confidence interval (C.I.) can be calculated using the standard error (SE) as well as the point estimate. For example, to be 95% confident of the estimated crash value, a statistical multiplier (SM) of 1.96 (shown in Table 1) is used with the standard error.

C.I. = CMF ± (SE * SM)
95% C.I. = 0.309 ± (0.156 * 1.96)
95% C.I. = 0.0 to 0.615
N_{Ped} = (0.0 * 4) to (0.615 * 4)
N_{Ped} = 0 to 2.46 crashes in 5 years

This means there is 95% confidence that the estimated number of crashes in a 5 year period ranges from 0 crashes to 2.46 crashes.

<u>Example 2</u>: Applying a CMF to a SPF Prediction

Problem:

In a rural area, there is a 4-leg, two-way stop-controlled (TWSC) intersection on a multilane, divided highway with a history of right angle crashes (17 in 5 years).

Analysis:

The improvement being considered is to convert the two-way stop controlled intersection to a single lane roundabout (RAB). The analysis will use safety performance functions instead of the observed crash history.

Crash History

Type	Fatal	Injury A	Injury B	Injury C	PDO	TOTAL
Right Angle		2	3	5	7	17
Left Turn			1	1	3	5
Rear End			3	1	7	11
Other			1		1	2
TOTAL		2	8	7	18	35

Traffic Volumes

Road	Approach 1	Approach 2	TOTAL
Major	5,550	3,500	9,050
Minor	1,800	500	2,300

Solution:

1. Get CMF(s) from the WisDOT Table for “Convert Two-Way Stop Control (TWSC) to Roundabout (RAB)”
    a. CMF = 0.5 for “All” crash types and “KABC” crash severities
    b. CMF = 1.16 for “All” crash types and “PDO” crash severity.

2. Next, use the Rural, 4-Lane, Two-Way Stop Controlled SPFs for Total Crashes and Fatal & Injury Crashes to predict the crashes in the analysis period
    a. *<u>Predicted Total Crashes before Treatment:</u>*

$N_{Total} = e^{(-10.008+(0.848* \ln(Major\ Total\ AADT))+(0.448*\ln(\ Minor\ Total\ AADT)))}$

$N_{Total} = e^{(-10.008+(0.848* \ln(9050))+(0.448*\ln(2300)))}$

N_{Total} = 3.27 crashes per year

b. *Predicted Fatal and Injury Crashes before Treatment:*

$N_{F\&I} = e^{(-11.554+(0.888* \ln(Major\ Total\ AADT))+(0.525*\ln(\ Minor\ Total\ AADT)))}$

$N_{F\&I} = e^{(-11.554+(0.888* \ln(9050))+(0.525*\ln(2300)))}$

$N_{F\&I}$= 1.82 crashes per year

c. *Predicted Property Damage Only Crashes before Treatment:*

$N_{PDO} = N_{Total} - N_{F\&I}$

N_{PDO} = 3.27 – 1.82

N_{PDO}= 1.45 crashes per year

3. Next, multiply the CMFs with the corresponding predictions.

a. *Predicted Fatal and Injury Crashes after Treatment:*

$N_{F\&I} = N_{F\&I} * CMF_{KABC}$

$N_{F\&I}$ = 1.82 * 0.5

$N_{F\&I}$= 0.91 crashes per year

b. *Predicted Property Damage Only Crashes after Treatment:*

$N_{PDO} = N_{PDO} * CMF_{PDO}$

N_{PDO} = 1.45 * 1.16

N_{PDO}= 1.68 crashes per year

c. *Predicted Total Crashes after Treatment:*

$N_{Total} = N_{F\&I} + N_{PDO}$

N_{Total} = 0.91 + 1.68

N_{Total} = 2.59 crashes per year

The safety performance functions predict the intersection would have 3.27 crashes per year with two-way stop control. Of the 3.27 predicted crashes, 1.82 crashes would be a fatal or injury crash and the other 1.45 would be property damage only crashes.

With the improvement of a roundabout, the number of fatal and injury crashes per year would drop to 0.91 while the property damage only crashes would increase to 1.68 crashes per year. This is equal to a total of 2.59 crashes per year.

Example 3: *Dominant Common Residuals Method* for Combining CMFs for Multiple Treatments

Problem:

An urban signalized intersection is experiencing left turn and rear end crash issues.

Analysis:

For this intersection, two safety improvements are being evaluated; changing the signal heads to include a flashing yellow arrow (FYA) and adding retroreflective backplates to the signal heads. Since the two treatments both apply to “All” crash types and “All” severities, they need to be combined using the *Dominant Common Residuals Method*.

Solution:

1. Get CMF from the WisDOT Table for “Install Flashing Yellow Arrow: Maintain Protected/Permissive Phasing”
    a. CMF = 0.922 for “All” crash types and “All” crash severities

2. Get CMF from the WisDOT Table for “Install Retroreflective Signal Backplates”
    a. CMF = 0.85 for “All” crash types and “All” crash severities

3. Combined CMFs using the *Dominant Common Residuals Method*

$$CMF_e = (CMF_1 * CMF_2)^{CMF_1}$$

$$CMF_{comb} = (0.85 * 0.922)^{0.85}$$

$$CMF_{comb} = 0.81$$

Therefore, the combined CMF = 0.81.

HELPFUL LINKS

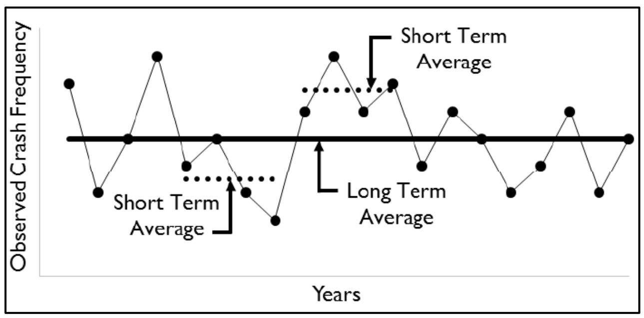
- WisDOT CMF Table: (http://wisconsindot.gov/dtsdManuals/traffic-ops/manuals-and-standards/teops/cmf-table.xlsm)
- CMF Clearinghouse: (http://www.cmfclearinghouse.org/)
    - CMF Clearinghouse User Guide: (http://www.cmfclearinghouse.org/userguide.cfm)
- CMF Clearinghouse FAQ’s: (http://www.cmfclearinghouse.org/faqs.cfm
- CMFs in Practice: (http://safety.fhwa.dot.gov/tools/crf/resources/cmfs/)

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.

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.)

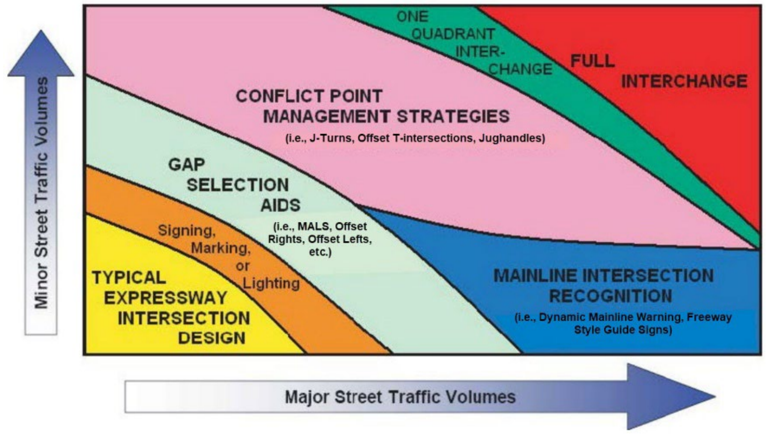
THROUGH ROUTE ACTIVATED WARNING SYSTEMS

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.

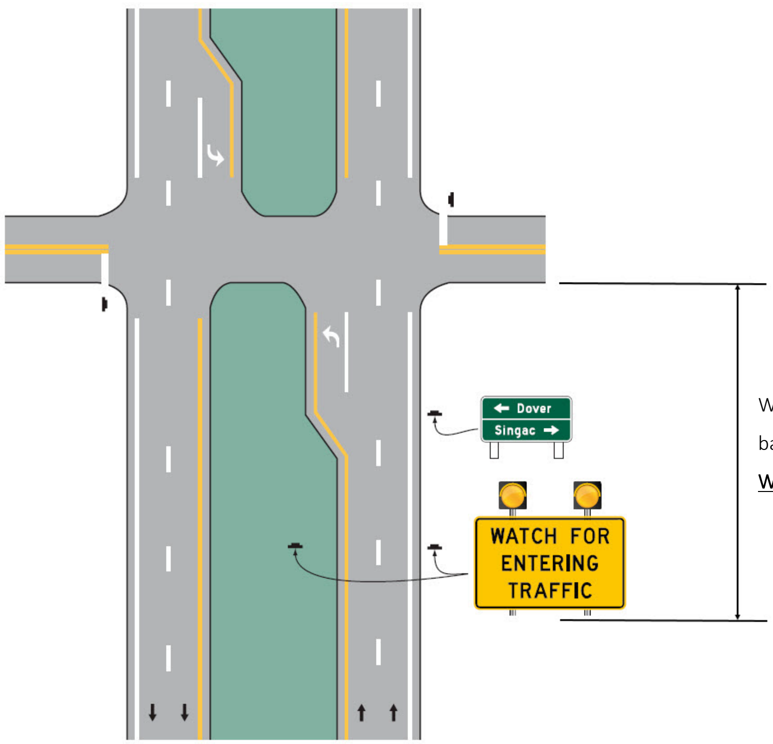
Several countermeasures are available to mitigate these angle crashes with varying costs and effectiveness. Figure 1 shows several categories of countermeasures for reducing crashes at TWSC intersections. Some countermeasures are more appropriate for divided highways and some are more appropriate for 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



Policy

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

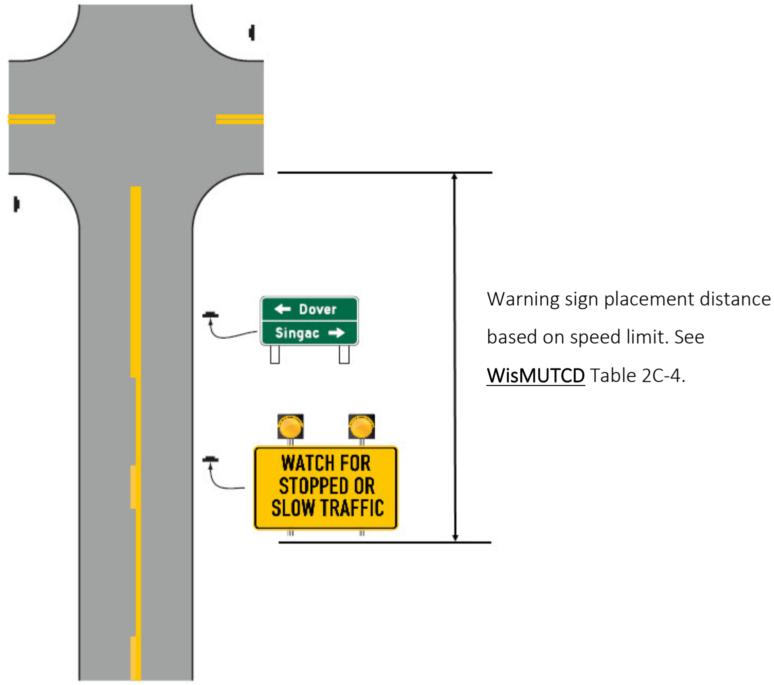
STOPPED OR SLOW TRAFFIC AHEAD WARNING SYSTEM

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



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.

REFERENCES

1. Amjadi, R. (2015). TechBrief: Safety Evaluation of Intersection Conflict Warning Systems (ICWS). *Report No. FHWA-HRT-15-076.* Federal Highway Administration, Washington, D.C.
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).
6. Vaughan, I., & Jackson, S. (2016). Intersection Conflict Warning Systems Human Factors: Final Report*.* *Report No. FHWA-HRT-16-061*. Federal Highway Administration, Washington, D.C.

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.

<u>Placement and application</u>

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.
2. "High Friction Surface Treatments" (2018, February). Federal Highway Administration, Washington, D.C. Retrieved from https://www.fhwa.dot.gov/innovation/everydaycounts/edc-2/hfst.cfm. Accessed August 9, 2021.
3. "Horizontal Curve Safety" (2021, February). Federal Highway Administration, Washington, D.C. Retrieved from https://safety.fhwa.dot.gov/roadway_dept/countermeasures/horicurves/. Accessed August 9, 2021.
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