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

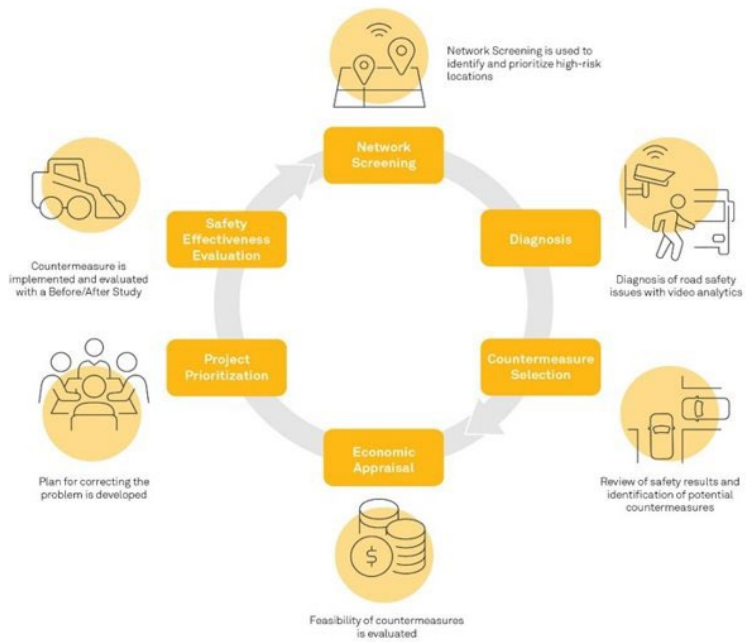


Figure 1: HSM 6-Step Roadway Safety Management Process, AASHTO (2010)

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.

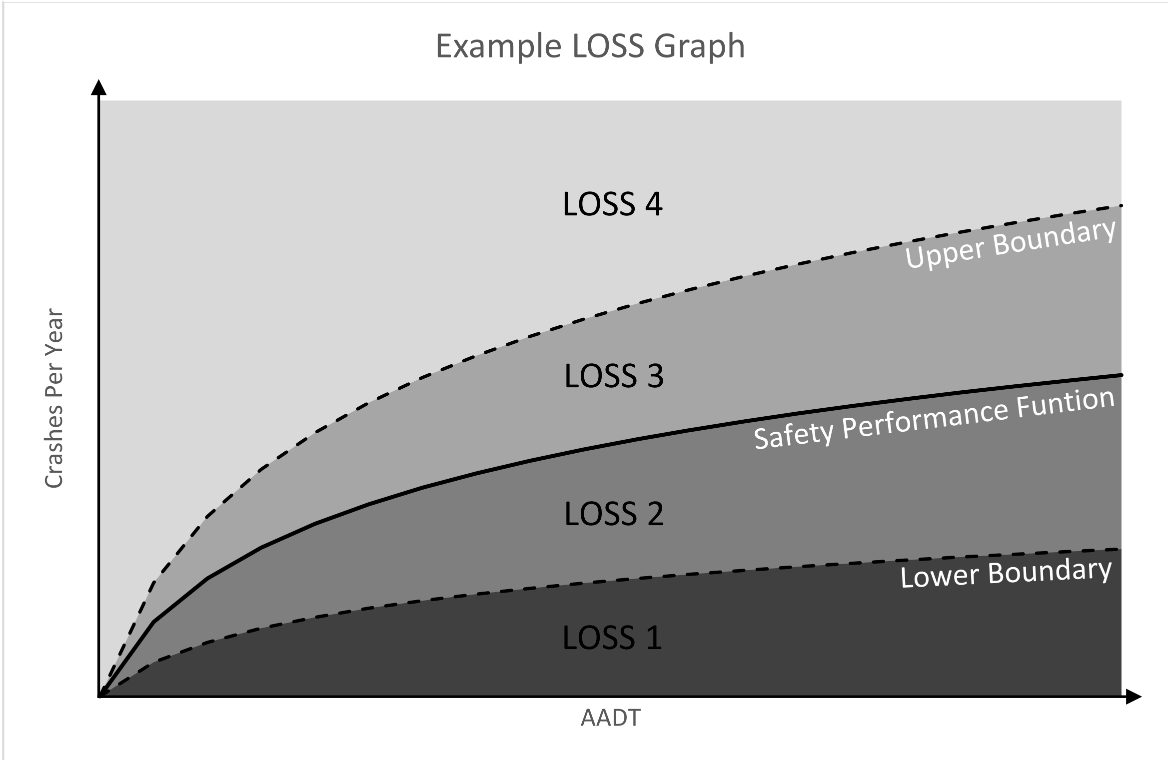
Expected Crash Frequency

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

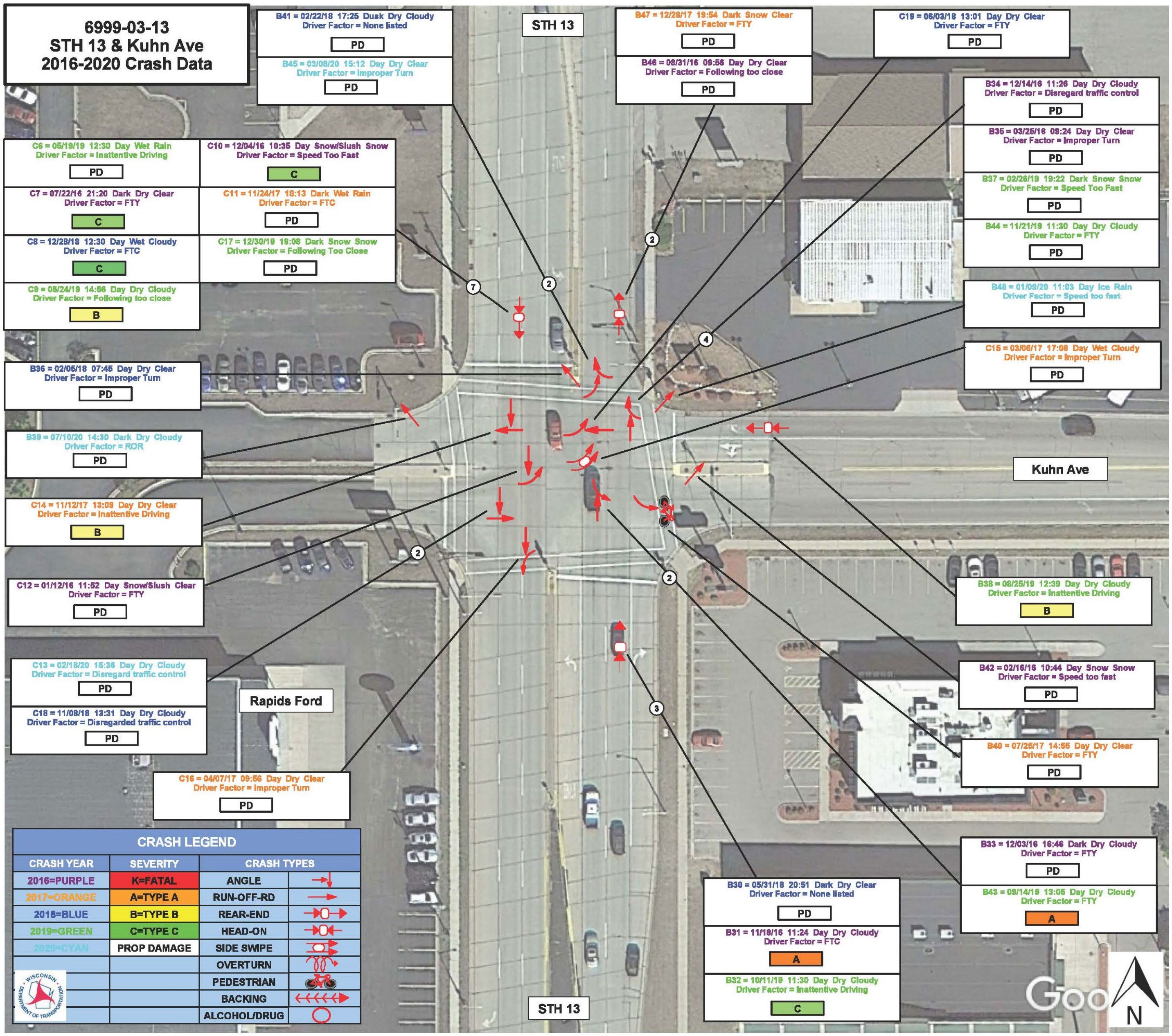


Figure 3.1b. Example Crash Diagram

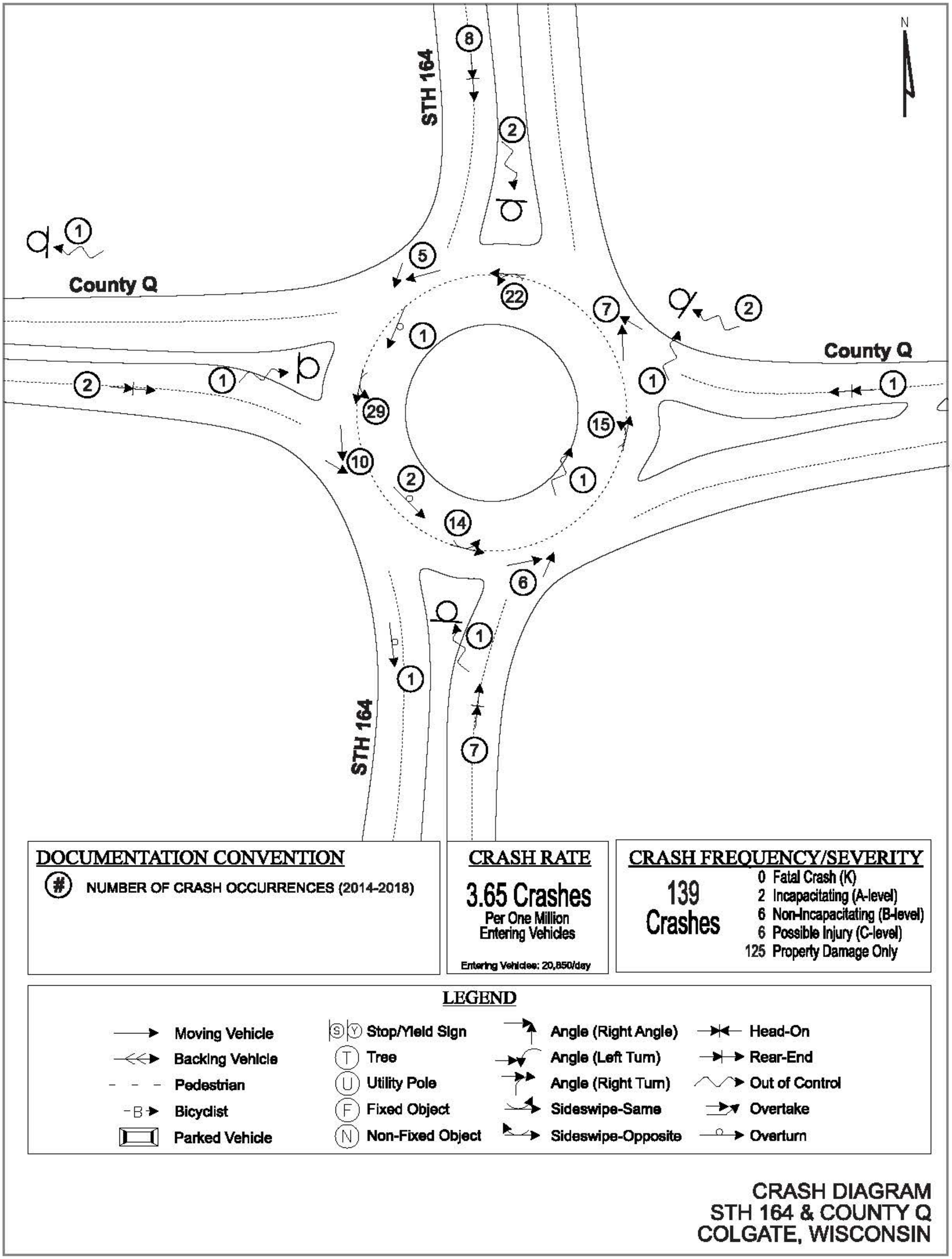


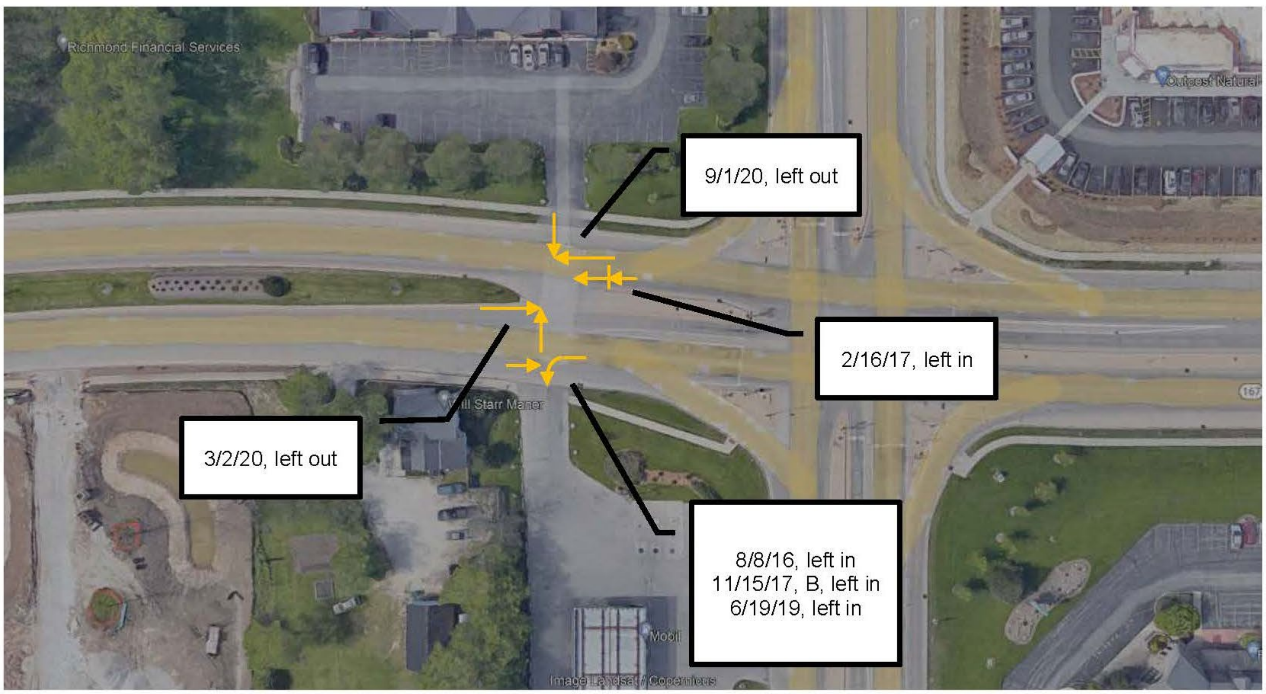
Figure 3.1c. Example Crash Diagram

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	C = POS. INJURY
Parked Vehicle	Moving Vehicle	Sideswipe-Opp.	Overturn	OR DRUG USE	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.