Purpose

This policy outlines the use of WisDOT's crash modification factor (CMF) table for evaluating safety treatments/countermeasures on the Wisconsin state trunk highway system. The purpose of the WisDOT CMF table is to provide acceptable CMFs for use on WisDOT projects to ensure consistent application statewide and reduce the amount of time needed to find an applicable CMF. As more applicable research becomes available, 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 expected average crash frequency as a result of a particular treatment or design element. CMFs are used to quantify the effectiveness of a safety countermeasure.

$$CMF = \frac{Expected\ Crash\ Frequency\ WITH\ Countermeasure}{Expected\ Crash\ Frequency\ WITHOUT\ Countermeasure}$$

- 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. The true value of the CMF for any treatment is unknown. Many CMFs include a standard error which serves as a measure of the reliability of that estimate. A lower standard error 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. Additional information about CMFs can be found in chapter 3 of the 1st Edition of the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM).

How Are CMFs Used?

CMFs are used to estimate the safety performance of a variety of different safety countermeasures. CMFs are typically applied:

1. By multiplying the CMF with the observed[1] crash frequency of an existing site to estimate the crash frequency after installation of a treatment. This is done when a site-specific safety performance function (SPF[2]) is not available for the treated site. See application example 1 below.
2. By multiplying a SPF's crash frequency values with one or more CMFs to obtain a site specific predicted[3] crash frequency. This is done to account for differences between the base conditions and actual site conditions. See application example 2 below.

Policy

Applying CMFs on WisDOT Projects

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. The crash type associated with a CMF defines the crashes for which the related CMF is applicable. 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 countermeasure *may* reduce certain crash types or severities while increasing other crash types or severities. If a CMF is available for a specific crash type, it *should* be used instead of the CMF for 'All' crash types.

Applying Multiple CMFs

Many projects propose several different safety treatments. Currently, limited research is available documenting the combined effect of multiple countermeasures so there **shall** be a maximum of two CMFs applied to a particular location. Implementing several countermeasures might be more effective than just one, however, it is unlikely that the full effect of each countermeasure would be realized when they are implemented concurrently. Unless the countermeasures act independently, multiplying several CMFs together can lead to overestimation of the safety benefit.

[1] Observed crash frequency is the number of crashes that have occurred within the limits of the site being investigated 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.

If multiple safety treatments are proposed for a project, include the CMFs that provide the most benefit to the existing crash trends at the location. If two non-independent CMFs are used for a location, the following methodology **shall** be used to determine the estimated combined effect of both countermeasures. Engineering judgement *should* be applied in these situations.

Systematic Reduction of Subsequent CMFs[4]

With this method the effect of the second countermeasure is systematically diminished. First identify the more effective of the two countermeasures (CMF with the lower value). Then reduce the second CMF using the equation below:

$$CMF_{2,Reduced} = \frac{1-\mathrm{CMF}_2}{2} + CMF_2$$

After the value of $CMF_{2,Reduced}$ is determined, multiply the first CMF by the reduced second CMF to get the combined CMF for the location.

$$CMF_{combined} = CMF_1 * CMF_{2,Reduced}$$

WisDOT CMF Table

There are a large number of CMFs available in the HSM, CMF Clearinghouse, and many other sources. In many cases, several CMFs exist for a given treatment, making it challenging for engineers to determine the most appropriate CMF to apply on a project. Most of the CMFs included in the table are for treatments commonly used in Wisconsin. Therefore, the WisDOT CMF table *should* be used unless a CMF is not available for the countermeasure in question or the CMF in the table does not apply to the location in question. The WisDOT CMF table can be found here: http://wisconsindot.gov/dtsdManuals/traffic-ops/manuals-and-standards/tgm/12/cmf-table.xlsm

Selection Process

The CMF selection process involves several considerations, including the availability, applicability, and quality of the CMF, along with the location of the sites used to develop the CMF. CMFs in the WisDOT CMF table were selected based on the following factors in order of importance:

1. Location of sites in study *(Preference given to sites near Wisconsin with similar climates, driver behavior, design standards, etc.)*
2. Star rating *(Preference given to higher star ratings from CMF Clearinghouse)*
    - For more information about star ratings: http://www.cmfclearinghouse.org/sqr.cfm
3. CMF provided in HSM (*unless better data has been published since the HSM*)

[4] For more information: http://www.cmfclearinghouse.org/collateral/Combining_Multiple_CMFs_Final.pdf

4. General applicability determined upon review of available CMFs

WisDOT CMF Table Features

The table is separated into 4 different categories:

1. Countermeasure Identification
2. Countermeasure Characteristics and Filtering Tools
3. CMF by Crash Severity
4. Countermeasure Source and Other Information

1. Countermeasure Identification

This section provides the name of the countermeasure and a unique CMF number. This number *should* be used when referencing the CMF in WisDOT documents.

2. Countermeasure Characteristics and Filtering Tools

For each CMF, information is provided about the characteristics of the sites used to generate the CMF. To identify an applicable CMF, select the characteristics that best match the characteristics of the site being evaluated.

Area Type is broken down into urban, rural, and all classifications. Definitions for urban and rural are defined by the study in which the CMF was developed. A link to the source of the CMF can be found in the table under the Countermeasure Source and Other Information category. Review of the study and engineering judgement *should* be used to determine what area type *should* be used for a particular location.

In some cases, safety countermeasures target wet-weather crashes so CMFs are developed accordingly. It is important that the driving conditions of the site or crashes in question match the driving conditions of the CMF when applicable.

In most cases, safety countermeasures target specific crash types so CMFs are developed accordingly. If a CMF is available for a specific crash type, it *should* be used instead of the CMF for 'All' crash types.

The expected service life of the countermeasure can be used in calculating benefit to cost (B/C) ratios. Service life values will be included in future versions of the table.

3. CMF by Crash Severity

The CMF table breaks down crash severity terms differently than the standard KABCO scale. The following *should* be used for comparison purposes:

- Fatal (Ftl) = K
- Serious Injury (SI) = A-level & B-level
- Minor Injury (MI) = C-level
- Property Damage Only (PDO) = O

More information on crash severity can be found in the FAQ's of the *CMF Clearinghouse*.

4. Countermeasure Source and Other Information

Information about the source of each countermeasure can be found here. Reading the research that generated the CMF can provide additional information about where the CMF *should* be applied. This section also has a comment area which provides additional information.

Applying CMFs from Other Resources

As mentioned above, the purpose of the WisDOT CMF table is to ensure consistent application of CMFs on WisDOT projects; therefore, the WisDOT CMF table *should* be used unless a CMF is not available for the countermeasure in question or the CMF in the table does not apply to the location in question. In these cases, explanation **shall** be provided to justify use of a CMF from another source. The following resources and guidelines *should* be used in these cases:

CMF Resources

- HSM (1st Edition)
  - Provided in Volume 3 of the HSM
  - CMFs provided went under a literature review process, an inclusion process, and a series of expert panels before being accepted into the manual
- CMF Clearinghouse
  - Web-based source of CMFs, which is updated regularly
  - Includes CMFs compiled in the first edition of the HSM along with many other available CMFs published since the release of the HSM
  - Includes a star rating system to indicate the quality or confidence in the results of the study producing the CMF
  - Provides supporting documentation to help users identify the most appropriate countermeasures for their safety needs

Guidelines for Using Other Resources

- Use the HSM or CMF Clearinghouse:
  - CMFs *should* have a minimum of a 3 star rating
  - Choose the CMF that most closely matches the characteristics of the site being analyzed.
- If no CMF is Available:
  - When there are no CMF's available, evaluate other sources and studies to see if any information is available regarding the specific safety treatment. This *may* include research from other states or countries that have applied the same countermeasure.

Application Examples

Example 1

Problem:

A rural two-lane undivided highway segment has experienced an average of 9 crashes/year. To reduce crashes, the shoulder will be widened from 3 ft. to 6 ft. and shoulder rumble strips will be installed. Determine the estimated crash frequency for this segment with the proposed treatments.

Solution:

From the WisDOT CMF table, the CMF for increasing shoulder width from 3 ft. to 6 ft. is 0.82 and adding shoulder rumble strips is 0.87. Since the CMF for both of these treatments apply to similar crash types (Run Off Road), we can combine the two CMFs to determine the estimated crash frequency. Based on the CMFs for both countermeasures, the less effective CMF is shoulder rumble strips and will be reduced accordingly.

$$CMF_{2,Reduced} = \frac{1-\mathrm{CMF}_2}{2} + CMF_2$$

$$CMF_{2,Reduced} = \frac{1-0.87}{2} + 0.87$$

$$CMF_{2,Reduced} = 0.935$$

The combined effect of the two CMFs is:

$$CMF_{combined} = CMF_1 * CMF_{2,Reduced}$$

$$CMF_{combined} = 0.82 * 0.935$$

$$CMF_{combined} = 0.77$$

Estimated crash frequency = 9 x 0.77 = 6.9 crashes/year.

Example 2

Problem:

An urban 4-legged signalized intersection has a predicted average crash frequency of 20 crashes/year determined with an SPF. 10 of the 20 crashes are related to left-turning vehicles, 3 of the 20 crashes involve a pedestrian, and the remaining 7 crashes are other crash types. Improvements are being considered at this intersection, including changing the left-turn phasing from permissive to protected/permissive and adding pedestrian countdown timers. Determine the crash frequency for this signalized intersection with the proposed treatments.

Solution:

From the WisDOT CMF table, the CMF for changing from permissive left-turn phasing to protected/permissive phasing is 0.862 and the CMF for installing pedestrian countdown timers is 0.3. Since these two treatments impact different crash types, the two treatments and CMFs are treated independently.

Predicted left-turn crashes = 10 x 0.862 = 8.62 crashes/year.

Predicted pedestrian crashes = 3 x 0.3 = 0.9 crashes/year.

Overall predicted crash frequency with both treatments is 8.62 + 0.9 + 7 = 16.52 crashes/year

Helpful Links

- WisDOT CMF table: (http://wisconsindot.gov/dtsdManuals/traffic-ops/manuals-and-standards/tgm/12/cmf-table.xlsm/)
- CMF Clearinghouse: (http://www.cmfclearinghouse.org/)
- CMF Clearinghouse User Guide: (http://www.cmfclearinghouse.org/userguide.cfm)
- CMFs in Practice: (http://safety.fhwa.dot.gov/tools/crf/resources/cmfs/)
- CMF Clearinghouse FAQ's: (http://www.cmfclearinghouse.org/faqs.cfm)