Guidance for Using Crash Modification Factors (CMF)

What is a CMF?

A Crash Modification Factor (CMF) is a value that quantifies the expected change in crash frequency at a site as a result of implementing a specific countermeasure or treatment.

$$CMF = \frac{\text{Expected crashes with treatment}}{\text{Expected crashes without treatment}}$$

Where,

CMF > 1 - expected to increase crashes

CMF < 1 - expected to decrease crashes

CMF = 1 - no effect on crash frequency

CMFs can be used in the transportation project development process to:

- Estimate the expected change in crash frequency associated with various countermeasures.
- Select among alternative countermeasures.
- Estimate safety benefits (crash savings) associated with a particular countermeasure.
- Identify cost-effective safety strategies.

The following table illustrates a CMF (HSM Table 13-21) for increasing the distance to roadside features for rural two-lane roads and freeways.

CMF Resources

Treatment	Setting (Road Type)	Traffic Volume	Crash Type (Severity)	CMF	Standard Error
Increase distance to roadside features from 3.3 feet to 16.7 feet	Rural two-lane roads and freeways	Unspecified	All Types (All Severities)	0.78	0.02
Increase distance to roadside features from 16.7 feet to 30.0 feet				0.56	0.01
Base condition: Distance to roadside features of 3.3 feet or 16.7 feet depending on geometry.					

CMFs can be found in several different resources, but two of the main resources include the FHWA CMF Clearinghouse (www.cmfclearinghouse.com) and the AASHTO Highway Safety Manual (HSM). While the HSM provides only the best available research-based CMFs, the CMF Clearinghouse is a comprehensive database of available CMFs, including all of the CMFs listed in the HSM. The CMF Clearinghouse is updated regularly, with new CMFs from researchers and state agencies.

Key Considerations in Selecting CMFs

When selecting CMFs it is imperative to consider the evaluation study method used to develop the CMF, the quality of the CMF, and the applicability to the site of interest.

Evaluation Study Design

The evaluation study design (i.e., how the study was conducted to calculate the CMF) plays a critical role in the quality of the CMF and should be considered when evaluating CMFs. Depending on the evaluation study design used to develop a CMF, the CMF could over or underestimate the effectiveness of a safety treatment. When a period with a comparatively high crash frequency is observed, it is statistically probable that the following period will have a comparatively low crash frequency. This statistical phenomenon is known as regression to the mean and also applies to the converse situation; a low crash frequency period will probably be followed by a high crash frequency period. The most reliable CMFs are those developed using statistical methods that account for regression to the mean.

Most agencies currently use the simple (or naïve) before-after study to estimate changes in crash frequency due to a specific change (safety treatment) at a site. However, this method doesn't account for regression to the mean or other changes (e.g., traffic volumes, weather, or driver behavior) that may have impacted the site. The HSM presents methods for estimating changes in crash frequency using statistical methods that address these issues. The methods are observational

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before-after study using a comparison group, observational before-after study using the Empirical Bayes (EB) method, cross-sectional studies. See Chapter 9 of the HSM to learn more about these methods. When selecting a CMF, it is most desirable to use one developed using the observational before and after study with either a comparison group or the EB method followed by a cross-sectional study.

Treatment	Setting (Road Type)	Traffic Volume	Crash Type (Severity)	CMF	Standard Error
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Base condition: Distance to roadside features of 3.3 feet or 16.7 feet depending on geometry.					

CMF Quality

The quality of a CMF should always be considered when selecting a CMF to use. Both the CMF Clearinghouse and HSM provide measures to evaluate the quality of the CMF.

The CMFs in the FHWA CMF Clearinghouse are given a star quality rating based on the quality or confidence in the results of the study using a scale of one to five stars (five indicates the highest or most reliable rating). The star rating of the CMFs is judged based on study design, sample size, standard error, potential bias, and data source and judged according to its performance in each area, as illustrated in the following table.

Relative Rating	Excellent	Fair	Poor
Study Design	Statistically rigorous study design with reference group or randomized experiment and control	Cross sectional study or other coefficient based analysis	Simple before/after study
Sample Size	Large sample, multiple years, diversity of sites	Moderate sample size, limited years, and limited diversity of sites	Limited homogeneous sample
Standard Error (SE)	Small compared to CMF	Relatively large SE, but confidence interval does not include zero	Large SE and confidence interval includes zero
Potential Bias	Controls for all sources of known potential bias	Controls for some sources of potential bias	No consideration of potential bias
Data Source	Diversity in states representing different geographies	Limited to one state, but diversity in geography within state (e.g., California)	Limited to one jurisdiction in one state

Points are assigned to each CMF characteristic based on the relative rating (excellent = 2 points, fair = 1 point, poor = 0 points) and assigned a weighted score using the following equation:

Score = 2*(Study Design) + 2*(Sample Size) + Standard Error + Potential Bias + Data Source

The star rating is then assigned based on the score as illustrated in the table to the right.

Score	Star Rating
14 (maximum)	★★★★★
11-13	★★★★☆
7-10	★★★☆☆
3-6	★★☆☆☆
1-2	★☆☆☆☆
0	—

An extensive review of the high-quality transportation research was conducted to identify CMFs to include in the HSM. The CMFs study design and resulting standard error were evaluated. The standard error indicates the anticipated variation in the results of the CMF. A smaller standard error indicates more

Standard Error	Font
0.10	**BOLD**
0.10 < Standard Error ≤ 0.20	NORMAL
0.20 < Standard Error ≤ 0.30	*ITALIC*

stable and reliable results. The most reliable and stable CMFs, with a standard error less than 0.1, are identified in the HSM through the use of bold text. The table on the right summarizes the formatting used in the HSM to indicate the standard error of a CMF and the table below (HSM Table 13-46) illustrates the standard error (and formatting) for different crash types/severities for installing centerline rumble strips on rural two-lane roads.

Road Type	AADT	**Crash Type** (Severity)	CMF	Standard Error
Rural (Two-Lane)	5,000 to 22,000	All Types (All Severities)	**0.86**	**0.05**
		All Types (Injury)	**0.85**	**0.08**
		Head-On and Opposing-Direction Sideswipe (All Severities)	**0.79**	**0.10**
		Head-On and Opposing-Direction Sideswipe (Injury)	*0.75*	*0.20*
Base condition: Absense of centerline rumble strips.				

CMF Applicability

When selecting CMFs, it is important to make sure the CMF is applicable to the site of interest. For example, the same countermeasure used on different road types may have different effects. Therefore, applying a CMF at a location that does not correspond to the setting identified in the study may provide an erroneous estimate of the expected change in crash frequency. This could result in infrastructure investments that may not be as beneficial as expected. In addition to roadway type, other factors to consider include: area type (rural versus urban), study location (differences in driver characteristics), traffic volumes, speed limit, and traffic control. It is ideal to review the evaluation study from which the CMF was developed.

Applying CMFs

CMFs are applied to total crashes or some subset of crashes defined by crash type or circumstances (i.e., run-off-the-road or rear-end collisions). In this situation, the same countermeasure can have different impacts on various crash types. As an example, consider Table 13-46 from the HSM shown below. Notice the CMF for all crash types and all severities is equal to 0.86 plus or minus a standard error of 0.05, but for head-on and opposing direction injury crashes, the CMF is equal to 0.75 plus or minus a standard error of 0.2.

Road Type	AADT	**Crash Type** (Severity)	CMF	Standard Error
Rural (Two-Lane)	5,000 to 22,000	All Types (All Severities)	**0.86**	**0.05**
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		Head-On and Opposing-Direction Sideswipe (All Severities)	**0.79**	**0.10**
		Head-On and Opposing-Direction Sideswipe (Injury)	*0.75*	*0.20*
Base condition: Absense of centerline rumble strips.				

Accounting for the standard error, the effectiveness of the CMFs could be:

CMF All Types, All Severities = (0.86 + 2(0.05)) = 0.96 or (0.86 - 2(0.05)) = 0.76

CMF Head-On, Opposing Direction, Injury = (0.75 + 2(0.20)) = 1.16 or (0.75 - 2(0.20)) = 0.36

The CMF for adding centerline rumble strips on rural two-lane highways could be between 0.76 and 0.96 for all crash types and all severities. For head-on, opposing-direction or sideswipe injury crashes, the CMF could be between 0.36 and 1.16. Note the impact of the standard error to the estimated range of benefit to head-on, opposing-direction or sideswipe injury crashes.

It also is important to realize that since every location is different, variations in the actual performance of a treatment can be expected if implemented at several different sites. When the standard error is available, it should be accounted for when CMFs are applied to reduce the potential of over or underestimating the effects of a particular countermeasure.

Finally, there are times when multiple countermeasures may be applied at a particular site. Some CMFs exist that account for multiple countermeasures; otherwise, the process for estimating the combined effects of multiple countermeasures is to multiply the CMFs. However, the HSM only recommends multiplying individual CMFs that apply to the same set or subset of crashes at the site. This requires the crash data to first be segmented (e.g., using severity or collision type distribution data), and then apply the applicable CMF for each treatment to its respective subset of crash data. It is important to note this approach basically assumes that CMFs function independently of each other and the magnitude of the expected crash reduction of implementing each of the countermeasures is the same as if implemented individually. This assumption needs more research; therefore, one should be cautious in applying a large number of CMFs for various countermeasures or treatments at any one location. It is recommended to compare the estimated combined effects resulting from multiplying multiple CMFs to CMFs developed based on multiple countermeasures when determining the appropriate value to use.

Example Application

Problem: Given a two-lane rural highway segment with 12-foot travel lanes, 4-foot paved shoulder, and AADT of 8,000 vehicles per day; evaluate the expected difference in crash frequency if the roadway cross-section is altered to an 11-foot lane width with 5-foot paved shoulders. The average total crash frequency on the segment is equal to 20 crashes per year. The average crash frequency of run-off-the road, head-on, and side-swipe crashes is equal to 11 crashes a year, which comprises 55 percent of the total observed crashes.

Solution: The first step is to identify the appropriate CMFs for lane width. Table 13-2 of the HSM provides CMFs for lane width on rural two-lane roadway segments. Based on the AADT, the CMF corresponding to the existing condition is 1.00 (base condition) and the proposed condition is 1.05 based on an AADT of 8,000 vehicles per day. Note that these CMFs only apply to single-vehicle run-off-road and multiple-vehicle head-on, opposite-direction side-swipe, and same-direction side-swipe crashes.

	Average Annual Daily Traffic (vehicle/day)		
Lane Width	< 400	400 to 2,000	> 2,000
≤ 9 feet	1.05	1.05 + 2.81 x 10-4 x (AADT – 400)	1.50
10 feet	1.02	1.02 + 1.75 x 10-4 x (AADT – 400)	1.30
11 feet	1.01	1.01 + 2.5 x 10-5 x (AADT – 400)	1.05
≥ 12 feet	1.00	1.00	1.00

Note: The collision types related to lane width to which these CMFs apply are single-vehicle run-off-road and multiple-vehicle head-on, opposite-direction side-swipe, and same-direction side-swipe crashes.

The next step is to identify the appropriate CMF for shoulder width using Table 13-7 of the HSM. The CMF for the existing conditions with a 4-foot paved shoulder is equal to 1.15, and the CMF for the proposed 5-foot paved shoulder is interpolated as approximately 1.075. Once again, these CMFs only apply to single-vehicle run-off-road and multiple-vehicle head-on, opposite-direction side-swipe, and same-direction side-swipe crashes.

	Average Annual Daily Traffic (vehicle/day)		
Lane Width	< 400	400 to 2,000	> 2,000
0 feet	1.10	1.10 + 2.5 x 10-4 x (AADT – 400)	1.50
2 feet	1.07	1.07 + 1.43 x 10-4 x (AADT – 400)	1.30
4 feet	1.02	1.02 + 8.125 x 10-5 x (AADT – 400)	1.15
6 feet	1.00	1.00	1.00
≥ 8 feet	0.98	0.98 – 6.875 x 10-5 x (AADT – 400)	0.87

Note: The collision types related to shoulder width to which this CMF applies include single-vehicle run-off-road and multiple-vehicle head-on, opposite-direction side-swipe, and same-direction side-swipe crashes.

Since the CMF values identified for lane width and shoulder width only apply to a particular subset of crash types, these CMFs must be converted to total crashes, using HSM Equation 13-3:

$$CMF = ((CMF_{ra} - 1.0) \times p_{ra}) + 1.0$$

Where,

CMF_{ra} = crash modification for related crashes

P_{ra} = related crashes expressed as a proportion of total crashes.

No adjustment is necessary for the 12-foot lane width. The CMF for the 11-foot lane width is calculated as follows:

$$CMF = ((1.05-1.0)\times0.55) + 1.0 = 1.0275$$

The same process is used to convert the CMF for shoulder width to total crashes.

4-foot shoulder: $CMF = ((1.15-1.0)\times0.55) + 1.0 = 1.0825$

5-foot shoulder: $CMF=((1.075-1.0)\times0.55)+1.0=1.0413$

Finally, the combined influence of the lane and shoulder width is determined by multiplying the respective CMFs.

Existing condition (12-foot lane, 4-foot shoulder): $CMF = 1.0 \times 1.0825 = 1.0825$

Proposed condition (11-foot lane, 5-foot shoulder): $CMF = 1.0275 \times 1.0413 = 1.0699$

Based on the results, the proposed condition is expected to perform slightly better than the current condition with approximately 1.26 percent fewer total crashes (1.0825-1.0699). It would be necessary to perform a benefit cost analysis to determine if the required investment for the proposed configuration provides enough benefit to justify the change.