

Crash Modification Factors (CMFs)

Introduction

Local and rural road owners often have limited financial resources available to implement highway safety improvements. Therefore, it is important that safety improvements return the highest level of benefit for each dollar invested. A primary benefit of safety improvements is to reduce crashes and fatalities, so it is useful for local and rural road owners to understand how much a particular safety improvement, or set of safety improvements, can reduce crashes. Published resources are available to assist local and rural road owners in understanding the crash reduction potential associated with specific safety improvements. This briefing sheet describes these resources and provides an example of how a crash modification factor can be used to assess the safety impact of a set of improvements.

Developing CMFs

Highway safety professionals have conducted numerous studies measuring the crash reduction potential of various types of safety improvements. Many of these estimates have been developed by comparing crashes “before” implementation of a safety improvement against crashes “after” implementation. The measured change in crashes is used to develop a “crash modification factor,” or CMF. A CMF is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site.

While some experience and judgment is required to develop and apply CMFs, the information derived from their proper application can benefit local and rural road owners in selecting safety improvements or “countermeasures” by providing a basis to understand how crashes are affected by a particular safety improvement or set of improvements.

Resources

Application of CMFs requires an appreciation of their sources and limitations. The CMF Clearinghouse¹ contains over 3,000 CMFs, each developed through one or more safety studies. The Clearinghouse provides a searchable database for CMFs and accompanying background information on each. The practitioner can use the search tools available with the Clearinghouse to find the CMFs that match the facility where they have a safety need; e.g., intersections or roadway segments. Each CMF has a “star rating” indicating the quality or confidence in the results of the study producing the CMF. A higher number of stars indicate a better rating, with five stars representing the best quality of research for the CMF. Each CMF will have an accompanying study along with the countermeasure’s impact on crash severity, crash types, and where the countermeasure was deployed (e.g., rural or urban area).

The *Highway Safety Manual* (HSM), published in 2010, provides practitioners with information and tools to consider safety when making decisions concerning the design and operation of roadways. The CMFs used in the HSM are considered the “best of the best” at the time of publication. This tool can help practitioners evaluate alternatives and determine expected impacts on roadway safety. Two chapters in Part C Predictive Method are specific to rural roadways. Chapter 10 provides a methodology to analyze rural two-lane roadways, and chapter 11 is about rural multilane highways. It is important to note the current HSM pertains to only paved roadways.



Estimating Countermeasure Benefits

The *Highway Safety Manual* and CMF Clearinghouse also provide directions for how to calculate the combined effects of applying multiple safety improvements. In these cases, the CMFs are typically multiplied to estimate the combined effect of independent countermeasures such as adding pedestrian signals and left-turn lane at a signalized intersection. The HSM recommends that practitioners multiply no more than 3 CMFs to estimate the combined effect of multiple safety improvements. Practitioners are cautioned about multiplying CMFs for countermeasures targeting the same crash type, such as using chevrons and widened shoulders at a curve to reduce roadway departure crashes. This practice can overestimate the benefits of combined treatments. In this case, caution and engineering judgment should be exercised.²

While the number of CMFs for newer or more innovative safety improvements is limited, the CMF Clearinghouse can provide local and rural road managers with a good start in compiling benefits and comparing the relative effectiveness of potential improvements.

Local and rural road operators can gain an understanding of safety treatment effectiveness by comparing CMFs for countermeasures that reduce the occurrence of the same crash type. For example, the table below presents a series of safety countermeasures to treat run-off-the-road crashes, a frequent challenge on two-lane local and rural roads, by increasing cost.

CMFs for Selected Run-Off-The-Road Crash Countermeasures

Countermeasure	CMF	Cost	Reference
Install Advance Curve Warning Signs	0.70	Low	R. Elvik, and T. Vaa, "Handbook of Road Safety Measures," Oxford, United Kingdom, Elsevier (2004).
Provide Road Delineation Signing	0.65	Low	A. Montella, "Safety Evaluation of Curve Delineation Improvements An Empirical Bayes Observational Before-After Study," TRB 88th Annual Meeting Compendium of Papers CD-ROM, Washington, DC: TRB, 2009).
Install Edge Line Striping	0.62 to 0.56	Low to Moderate	X. Sun and S. Das, "Safety Improvement from Edge Lines on Rural Two-Lane Highways," Louisiana Department of Transportation and Development, Report No. FHWA/LA.11/487, (Baton Rouge: 2011).
Install Edge Line Rumble Strips	0.90 to 0.78	Low to Moderate	D.J. Torbic, J.M. Hutton, C.D. Bokenkroger, et al. <i>NCHRP Report 641: Guidance for the Design and Application of Shoulder and Centerline Rumble Strips</i> , National Cooperative Highway Research Program (Washington DC: TRB, 2009).
Widen Shoulders	0.98	Low to Moderate	K. Haleem, A. Gan, and J. Lu. "Using multivariate adaptive regression splines (MARS) to develop crash modification factors for urban freeway interchange influence areas," <i>Accident Analysis and Prevention</i> 55 (2013): 12-21.

Countermeasure	CMF	Cost	Reference
Remove or Shield Roadside Obstacles	0.62	Low to Moderate	P.W. Hovey and M. Chowdhury, <i>Development of Crash Reduction Factors</i> , 14801(0), Ohio Department of Transportation, (2005).
Flatten Horizontal Curve	0.33	High	Pitale, J.T., Shankwitz, C., Preston, H., and Barry, M., <i>Benefit-Cost Analysis of In-Vehicle Technologies and Infrastructure Modifications as a Means to Prevent Crashes Along Curves and Shoulders</i> , Minnesota Department of Transportation, (2009).

Source: Federal Highway Administration, "Crash Modification Factors (CMF) Clearinghouse." Available online at: www.cmfclearinghouse.org.

As presented in this table, the installation of advance curve warning signs has a CMF of 0.70. By applying this treatment to horizontal curves along a two-lane rural road experiencing an average of ten horizontal curve/run-off-the-road crashes per year, one can expect seven horizontal curve/run-off-the-road crashes per year following the implementation of the countermeasure ($10 \times 0.70 = 7$). In other words, crashes can be reduced by 30 percent. Conversely, widening shoulders, a more costly countermeasure, would result in a more modest reduction in crashes. Based on this knowledge, and supplemented with experienced application of CMFs, local and rural road agencies can quickly understand the potential safety benefits from applying a range of safety treatments.

Crash Modification Factor Example:

$$\frac{\text{Average Crashes (after CM implementation)} - (\text{CMF} \times \text{Avg. Crashes (Before CM Implementation)})}{\text{Average Crashes (Before CM Implementation)}} = \text{Crash Reduction}$$

Adding Advance Warning Signs at Curves

$$10 - (0.7 \times 10 \text{ crashes/year}) = 3 \text{ crashes per year reduced}$$

Some CMFs apply to the average of all crashes on a roadway segment or intersection, while others may apply to crashes based on severity, such as fatal or injury crashes. This allows agencies to rank the benefits of countermeasures based on the severity of the crashes that can be prevented and to target more severe crashes in a road safety strategy.

Local and rural road owners are sometimes able to fund highly effective, lower-cost projects using local funds more quickly than they can fund more effective but perhaps considerably more costly projects. Reviewing CMFs, along with implementation costs, provides local and rural road owners with an opportunity to understand the benefit/cost (B/C) ratio of different countermeasures before undertaking a more detailed assessment. As shown in the table above, a local road owner could choose to implement a lower cost option, such as signing or striping, as a first step in improvement while perhaps waiting for State or Federal funding for more costly strategies that may have greater long-term effectiveness.

Resources



American Association of State Highway and Transportation Officials, *Highway Safety Manual*. Available at: <http://www.highwaysafetymanual.org/>



Federal Highway Administration, *Introduction to Crash Modification Factors*, FHWA-SA-13-015 (Washington, DC: 2013). Available at: <http://safety.fhwa.dot.gov/tools/crf/resources/cmfs/intro.cfm>



Federal Highway Administration, “Crash Modification Factors (CMF) Clearinghouse” web page. Available at: www.cmfclearinghouse.org



Federal Highway Administration, “Crash Modification Factors in Practice” web page. Available at: <http://safety.fhwa.dot.gov/tools/crf/resources/cmfs/>



F. Gross and K. Yunk, “Using CRFs to Improve Highway Safety,” *Public Roads*, May/June (2009): 26-31. Available at: <http://www.fhwa.dot.gov/publications/publicroads/09june/04.cfm>

¹ Federal Highway Administration, “Crash Modification Factors (CMF) Clearinghouse” web page. Available online at: www.cmfclearinghouse.org

² Ibid.