Establishing Crash Modification Factors and Their Use

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16. Abstract

A critical component in the Association of State Highway and Transportation Officials' (AASHTO) *Highway Safety Manual* (HSM) safety management process is the Crash Modification Factor (CMF). It is used to estimate the change in the expected (average) number of crashes at a site when a specific countermeasure is implemented. This project responds to a request from the Pennsylvania Department of Transportation (PennDOT) to help integrate the use of CMFs into the existing safety management process. The objectives of this project were to assemble a list of CMFs that are consistent with the HSM and are appropriate for use in Pennsylvania, and provide guidelines for their use. Two products were created to help achieve these objectives. The first product is a guidebook that describes the proper implementation procedures for CMFs and contains a complete list of CMFs that are appropriate for use in Pennsylvania. This guidebook is the *Pennsylvania CMF Guide*. The second product is a training presentation for PennDOT entitled *What are CMFs and how do you use them?* This presentation will be used to introduce engineers to CMFs, describe how to implement them, and provide guidance for how to use the *Pennsylvania CMF Guide*. This presentation is geared toward both internal and external training workshops.
The remainder of this report provides details on the development of these two products, which are included as appendices.

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Introduction

The American Association of State Highway and Transportation Officials' (AASHTO) *Highway Safety Manual* (HSM) is transforming the way state and local transportation agencies manage road safety. In addition to providing an overview of many aspects of road safety management, the HSM contains a process for evaluating the effectiveness of alternative safety countermeasures based on previous research.

A critical component in the HSM safety management process is the Crash Modification Factor (CMF). It is used to estimate the change in the expected (average) number of crashes at a site when a specific countermeasure is implemented. This project responds to a request from the Pennsylvania Department of Transportation (PennDOT) to help integrate the use of CMFs into the existing safety management process. The objectives of this project were to: (1) assemble a list of CMFs that are consistent with the HSM and are appropriate for use in Pennsylvania, and (2) provide guidelines for their use. Two products were created to help achieve these objectives. The first product is a guidebook that describes the proper implementation procedures for CMFs and contains a complete list of CMFs that are appropriate for use in Pennsylvania. This guidebook is entitled *Pennsylvania CMF Guide*. The second product is a training presentation for PennDOT, entitled *What are CMFs and how do you use them?* This presentation will be used to introduce engineers to CMFs, describe how to implement CMFs, and provide guidance for use of the *Pennsylvania CMF Guide*. This presentation is geared toward both internal and external training workshops.

The rest of this report provides details on the development of these two products. The next section describes the *Pennsylvania CMF Guide*, and the following section describes the training presentation.

Pennsylvania CMF Guide

The purpose of the *Pennsylvania CMF Guide* is to provide a list of CMFs that are appropriate for use when estimating the safety performance of changes to the highway and street network in Pennsylvania, and to demonstrate how to apply them appropriately. The list of CMFs was compiled by reviewing the relevant literature and identifying high-quality CMFs that might be applicable to Pennsylvania roadways. In compiling this list, the following sources were reviewed:

- Federal Highway Administration (FHWA) CMF Clearinghouse website;
- AASHTO *Highway Safety Manual*;

- FHWA *Desktop Reference for Crash Reduction Factors* (Report FHWA-SA-08-011);
- Governors Highway Safety Association (GHSA) *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices*;
- FHWA Office of Safety, *Proven Safety Countermeasures*;
- FHWA *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes*;
- FHWA *Roadway Departure Countermeasures*;
- *Crash Reduction Factors for Traffic Engineering and Intelligent Transportation Systems (ITS) Improvements: State-of-Knowledge Report* (NCHRP Research Results Digest 299); and,
- Recently published research literature.

Only "high-quality" CMFs are included in this guide and deemed appropriate for application within Pennsylvania. The quality of the CMFs was determined using the star quality rating system proposed by the FHWA CMF Clearinghouse and documented on its website (http://www.cmfclearinghouse.org/). This system assigns each CMF with a numerical value on a scale of 1 to 5, where 5 is the most reliable or highest-quality rating. The ratings are determined based on the following five properties of the CMF and the study used to estimate its value:

- Study Design,
- Sample Size,
- Standard Error,
- Potential Bias, and
- Data Source.

High-quality CMFs were determined to be those having a rating of three stars or higher. The threshold of three stars was selected for the following reasons: It provides a relatively large list of CMFs, since the majority of CMFs in the CMF Clearinghouse are rated three stars; it is consistent with the HSM, since the CMFs provided in the HSM are almost all rated three stars or higher; and it ensures that any CMF with a poor rating for one or more properties also has other properties with an excellent rating (especially for study design and sample size).

Although CMFs with a rating of one or two stars are not deemed appropriate for application within Pennsylvania, a list of these lower-quality CMFs is included in the *Pennsylvania CMF Guide* to provide documentation concerning their use. However, because these CMFs are based on either a small sample size or suffer from a low-quality methodological evaluation, these CMFs are not recommended for use in Pennsylvania.

The CMFs in the guide are presented in 19 different CMF tables that are organized using the categories adopted by the FHWA CMF Clearinghouse. Table 1 provides a description of these categories and the total number of CMFs included within each category.

Table 1. CMF categories and number of CMFs included in each

Category Name	Number of high-quality CMFs included in guide
Access Management	258
Advanced Technology and ITS	100
Alignment	47
Bicyclists	62
Delineation	114
Highway Lighting	52
Interchange Design	52
Intersection Geometry	186
Intersection Traffic Control	310
On-Street Parking	27
Pedestrians	17
Railroad Grade Crossings	13
Roadside Features	69
Roadway Features	331
Shoulder Treatments	567
Signs	88
Speed Management	69
Transit	15
Work Zones	73
TOTAL	2,450

Each of the CMF tables contains the following information:

- Description of the highway change or countermeasure;
- Conditions for which the CMF is applicable;
- Point estimate and standard error of the CMF;
- Star quality rating as determined from the FHWA CMF Clearinghouse methodology; and
- Location of crash data used to estimate the CMF.

The conditions for which each CMF is applicable include the area type, crash severity, crash type, range of traffic volumes (given as a range of average annual daily traffic or AADT), and other considerations. If multiple CMFs are available for a specific set of conditions, a recommended CMF was identified for application in Pennsylvania. This recommendation was made by considering the value of the point estimates, the standard errors, the star-quality ratings, and the location of the crash data used to estimate the CMF. CMFs that were estimated using Pennsylvania crash data were also identified in the CMF tables.

The guidebook also contains a detailed methodology for the application of CMFs that are consistent with those in the HSM. This includes procedures for applying multiple CMFs simultaneously and references for more information on this topic. Several example problems were developed to demonstrate the CMF application procedure. These examples are included in the guidebook. The training presentation is provided in this report as Appendix A. The example problems follow, as Appendix B. The *Pennsylvania CMF Guide* is incorporated as Appendix C.

Training Presentation - What are CMFs and how do you use them?

The purpose of the training presentation is to introduce practitioners to the concept of CMFs and to demonstrate how to use them properly. The presentation is designed to be used as part of a training workshop for both internal (PennDOT) employees and external consultants and practitioners in Pennsylvania. After completing the training workshop, attendees should be able to:

- Define a CMF;
- Apply a single CMF to a particular site to estimate the impact of a single countermeasure;
- Apply multiple CMFs to a particular site to estimate the impact of multiple countermeasures applied simultaneously;
- Use CMFs to compare multiple alternatives based on their expected safety performance; and
- Select an appropriate CMF for a given countermeasure from the *Pennsylvania CMF Guide*.

The presentation includes a total of 45 slides and a set of example problems that should be done concurrently with the presentation to demonstrate CMF principles. The presentation is provided in Microsoft PowerPoint format, and is included here as Appendix A. Instructor notes are included on each slide in the “Notes” section of the slide. These instructor notes provide a script that can be followed by the instructor leading the training workshop. However, we recommend that the instructor use these notes merely as a guide and integrate their own experiences and knowledge into the workshop presentation to supplement the material provided.

Five example problems are included as a part of the training materials in a separate handout. They are provided in Appendix B. These problems and their solutions are incorporated into the training presentation. The presentation instructor should allow attendees ample time to attempt the example problems on their own at the appropriate time during the presentation before providing the solution. These problems are designed to build in complexity during the presentation and to demonstrate the various steps that should be taken when applying CMFs to a real project. This includes the application of a single CMF, the application of multiple CMFs when a single countermeasure is applied, the application of multiple CMFs simultaneously, the determination of the appropriate CMF to apply for a given countermeasure (using the CMF guide), and the comparison of multiple alternatives using CMFs. Attendees of the training workshop should be provided a copy of the *Pennsylvania CMF Guide* (or the tables from the appropriate sections) to complete the example problems. The tables required are Table B, Table I, and Table O. It is recommended that the presentation instructor take time to solve these problems before leading the presentation. The *Pennsylvania CMF Guide* is included as Appendix C.

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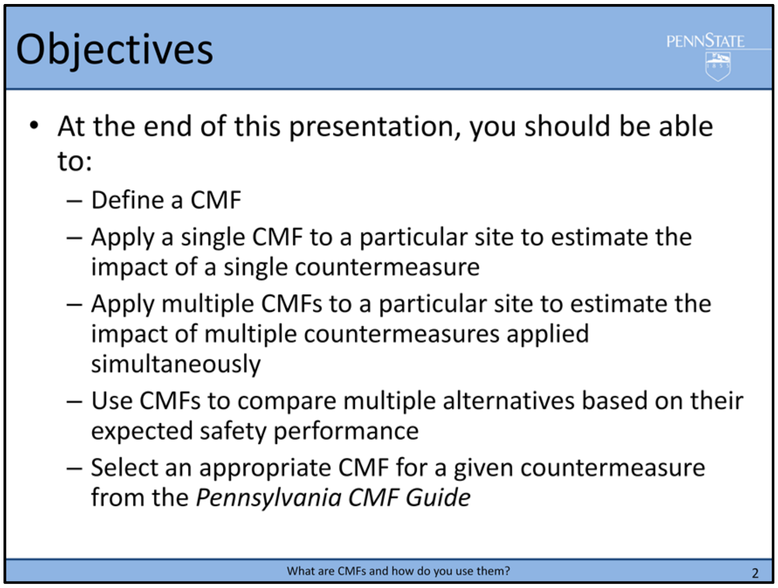
Appendix A: Presentation - What Are CMFs and How Do You Use Them?

What are CMFs and how do you use them?

Created by

Vikash V. Gayah & Eric T. Donnell
The Pennsylvania State University

The purpose of this presentation is to familiarize you with CMFs, make you comfortable using them and introduce you to the newly developed *Pennsylvania CMF Guide* that contains a collection of CMFs that have been deemed appropriate for application in Pennsylvania.



The objectives of this presentation are to prepare you to accomplish the following tasks:

- Define a CMF
- Apply a single CMF to a particular site to estimate the impact of a single countermeasure
- Apply multiple CMFs to a particular site to estimate the impact of multiple countermeasures applied simultaneously
- Use CMFs to compare multiple alternatives based on their expected safety performance
- Select an appropriate CMF for a given countermeasure from the *Pennsylvania CMF Guide*

Outline

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- What is a CMF?
- How are CMFs estimated?
- Errors in CMFs and confidence intervals
- Applying a single CMF
- Applying multiple CMFs
- The *Pennsylvania CMF Guide*

The following is a brief outline of the presentation

- First, we will describe what is a CMF is and how it can be used.
- Then, we will discuss how CMFs are estimated, which has a significant impact on how CMFs can be applied.
- This will lead to a discussion of errors that exist in CMFs and how we use confidence intervals to account for these errors.
- After this discussion, we will demonstrate how to apply CMFs with the help of a few examples. This will include applying a single CMF to a particular situation and applying multiple CMFs to a particular situation.
- Finally, we will end with an introduction to the *Pennsylvania CMF Guide* and how to use this guide.

What is a CMF?

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- A Crash Modification Factor (CMF) is “an **index of how much crash experience is expected to change following a modification** in design or traffic control” (Highway Safety Manual, 2010)

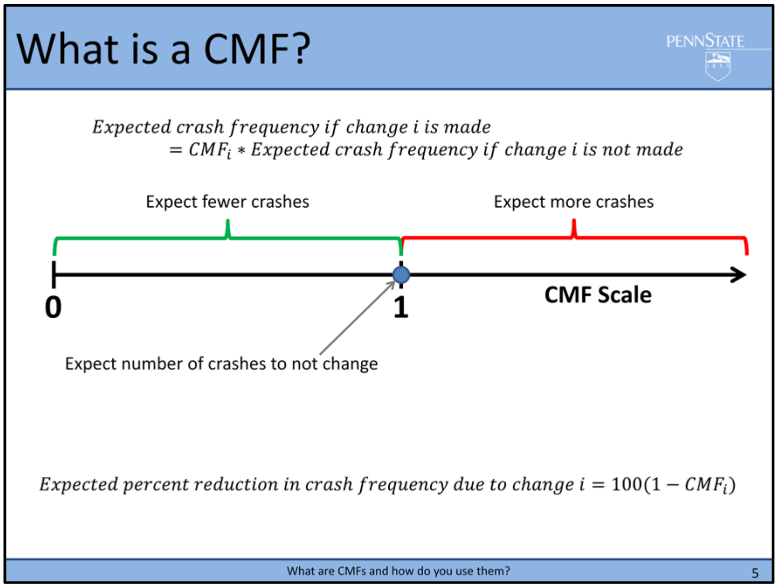
$$CMF_i = \frac{Expected\ crash\ frequency\ if\ change\ i\ is\ made}{Expected\ crash\ frequency\ if\ change\ i\ is\ not\ made}$$

What are CMFs and how do you use them? 4

So we start by asking the following question: what is a CMF?

CMF stands for crash modification factor. As defined by the Highway Safety Manual, it is “an index of how much crash experience is expected to change following a modification in design or traffic control”. Thus, it provides a numeric value that is used to assess how the safety performance of a facility will be impacted by a given countermeasure.

(click for animation) This impact is presented as the ratio of the expected number of crashes after the change is made to the expected number of crashes if the change is not made. Note that the expected crashes should be measured over the same time and spatial interval. What this means is that the “without” change and “with” change should apply to the same geographic location, and the crash counts should be for the same length of time (e.g., crashes/year or crashes/3 year period).



To understand a bit more about the numerical values of the CMF, we can rearrange the previous equation to express the expected number of crashes after the change is made in terms of the CMF and the expected number of crashes without the countermeasure. Thus, as shown here, the CMF is essentially a scaling factor that relates expected crashes without the change to with the change.

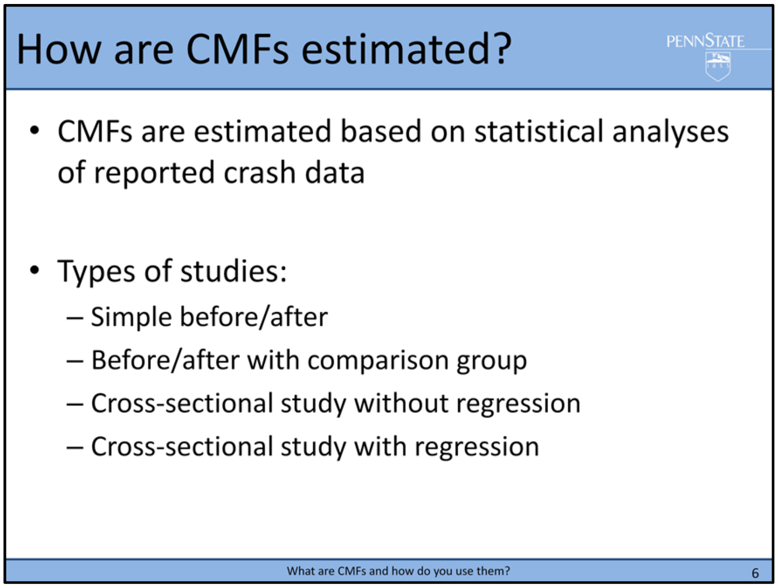
(click) A CMF value of 1 suggests that the expected number of crashes with the change is the same as the expected number of crashes without the change. Thus, countermeasures with a CMF of 1 are expected to have no impact on safety.

(click) Countermeasures with CMFs less than one are expected to have a safety benefit because the expected number of crashes with the change will be less than the expected number of crashes without the change. The smaller the value, the more crash frequency is expected to reduce when the change is applied.

(click) Countermeasures with CMFs greater than one are expected to have a safety disbenefit because the expected number of crashes with the change will be greater than the expected number of crashes without the change. The larger the value, the more crash frequency is expected to increase when the change is applied.

CMFs must take positive values (otherwise, as you can see from this equation, we would expect negative crash frequencies when a change is made). Therefore, the lower limit of any CMF is zero. There is no upper limit for a CMF…this means that in theory CMFs can take values up to infinity. In practice, this is not very likely and the majority of CMFs that you will encounter will have values less than or equal to about 3.

(click) CMFs can be alternatively expressed as the expected percent change in crash frequency when a change is made using 100(1-CMF). Let's use the CMF scale to verify that the values obtained here makes sense. A CMF of 1 would be associated with a 0 percent change in crash frequency. A CMF of less than one (say 0.5) would be associated with a 50% reduction in crash frequency. A CMF greater than one (say 2) would be associated with a -100% reduction in crash frequency (or an increase in crash frequency by 100%).

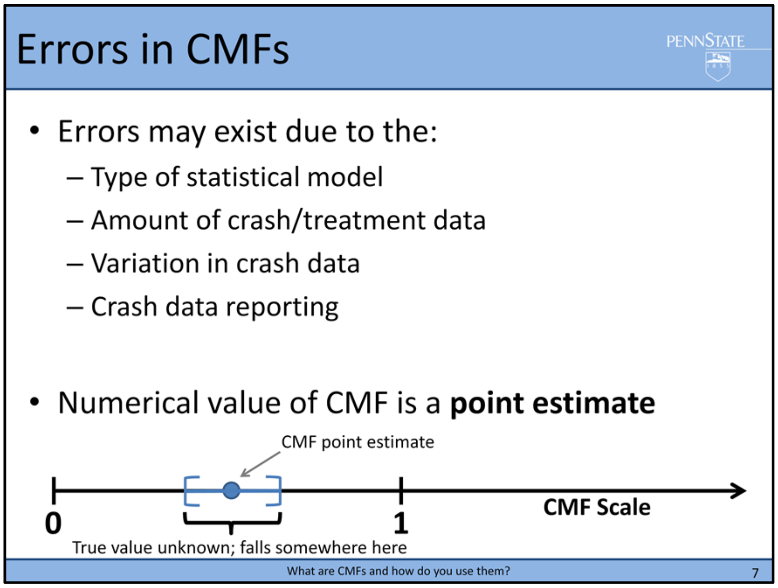


Before we can go into more detail about CMFs and how they can be applied, it is important to understand where CMFs come from.

Each CMF value is estimated as the result of a statistical analysis of reported crash data. To obtain a CMF, analysts use roadway inventory and other databases to identify locations and times in which a specific treatment and those that do not. This database is then populated with the set of reported crash data to compare the safety performance of those sites with the treatment to those without. This is not such a straightforward task and several types of statistical studies have been developed to help estimate these CMFs.

Some examples are:
- In before/after studies, the same set of sites are used and the CMF is estimated by examining safety performance before the treatment was implemented and after the treatment was implemented.
- In the second type, a comparison group of sites at which the treatment is not applied during the same timeframe is used to provide a baseline for how safety performance changes even when the treatment is not applied.
- Cross sectional studies identify sites both with and without treatment in the same time period to compare how the treatment impacts safety performance. Regression is often used to help control for the impacts of other factors that might simultaneously impact safety performance and provides a better estimate of the treatments true impact.

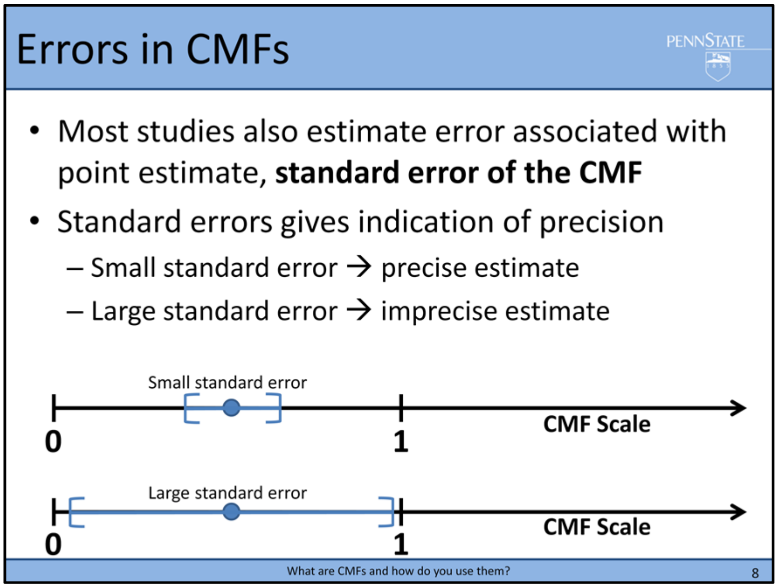
The type of study impacts the accuracy of the estimate. Those with poorer designs (at the top of this list) have higher potential to yield inaccurate estimates than those with better designs (at the bottom).



These estimation processes are NOT PERFECT. Because of variations in crash data and the fact that crashes are relatively infrequent events, the CMF values from the statistical models are usually associated with some error.

These errors may be due to:
- The type of statistical model (e.g., some modeling frameworks are more powerful and able to estimate the CMF more accurately than others)
- The amount of crash or treatment data used (e.g., a statistical study estimated from 2 years of crash data is often less accurate than a study estimated from 10 years of crash data. Likewise, CMFs estimated for a treatment that has only been implemented in a handful of locations is often less accurate than a treatment that has been implemented at many sites)
- Variation in the crash data used (e.g., crash data that has a lot of year-to-year or site-to-site variation is typically associated with more error than crash data with less variation).
- Crash data reporting (e.g., not all crashes are reported…therefore, only a subset of crash data are used to estimate the CMF)

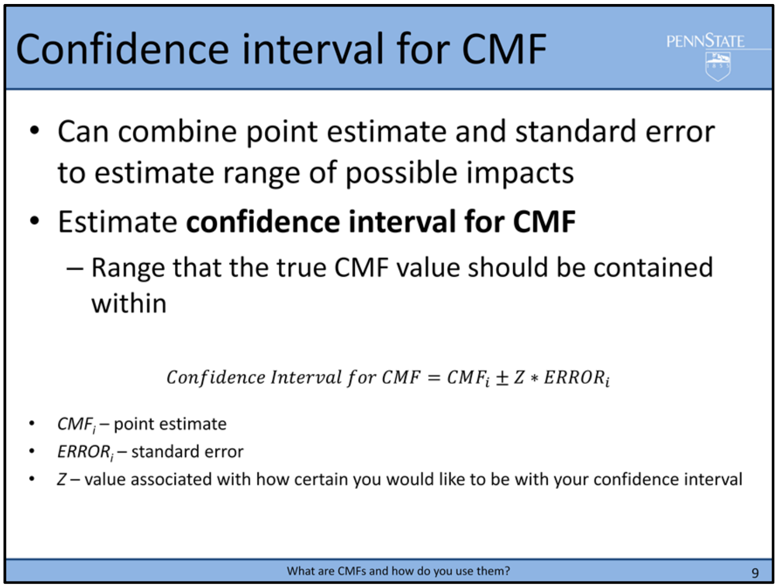
(click) Because of this error, the CMFs estimated from these studies are typically a **POINT ESTIMATE** of how a change or countermeasure will impact safety performance. However, this estimate is subject to some amount of uncertainty. The true impact of the change or countermeasure is unknown and exists within some range of the value estimated by the statistical model. So looking back at our line graph, the CMF point estimate is just one value, while the true value of the CMF lies within some range around it **(click)**.



To help account for this, most studies not only provide the point estimate of the CMF but they also provide an estimate of the amount of error associated with the point estimate. This estimate of error is based on the type of statistical model used, amount of variation in the crash data, and amount of data. However, this error cannot account for the fact that the sample of crash data used might not reflect the true population of data.

We call this estimate of the error the **standard error of the CMF**. The standard error provides an indication of the precision of the CMF point estimate. CMFs that have a smaller standard error are much more precise than those with a larger standard error. Therefore, we should trust more in the studies with lower standard errors because we have more confidence about the true impact of the change or countermeasure associated with that CMF.

(click) To illustrate this, let us again look at the CMF scale and consider two CMFs with the same point estimate but different values for standard error. The smaller standard error is associated with a smaller range of values that might contain the actual impact of the countermeasure, whereas the larger standard error is associated with a larger range of values. If we wanted to use one of these CMFs for planning and engineering purposes, which one would we prefer? There is no doubt that the one with the smaller standard error is preferred because the point estimate is more likely to reflect the actual impact of the CMF.



When applying CMFs in practice, we cannot ignore the potential errors that exist in the CMF point estimate.

The method we use to account for this error is to combine the point estimate and standard error together to estimate a range of possible impacts. This is done by estimating what is known as the **confidence interval for the CMF**. The confidence interval provides a range of values that contains the actual impact of the countermeasure subject to some probability. The more certain that we would like to be about the range of potential impacts, the larger the confidence interval becomes.

(click) The confidence interval is estimated using the following equation…

The value Z is associated with the level of certainty or confidence that we would like to have.

Confidence interval for CMF

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$$Confidence\ Interval\ for\ CMF = CMF_i \pm Z * ERROR_i$$

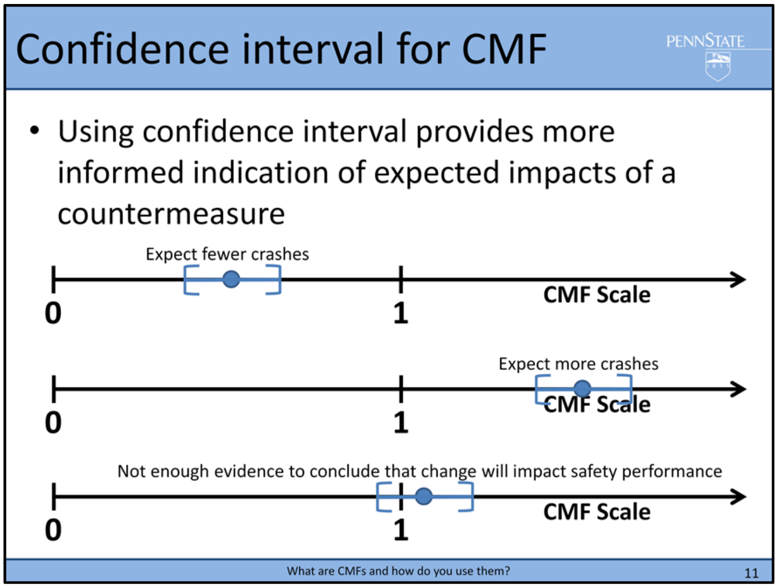
Type of confidence interval	Z value
90% confidence interval	1.64
95% confidence interval	**1.96**
99% confidence interval	2.58

What are CMFs and how do you use them? 10

Some Z values are provided here for typical confidence intervals used for safety applications. In general, the 95% confidence interval is the most widely used and accepted in practice. The others are provided as an example for how the Z value might change.

Let us consider the 95% confidence interval though, since it is the most common. When we create a 95% confidence interval, what we are saying is that we are 95% certain that the actual value of the CMF is obtained within the range specified. In this case, there is still a 5% chance that the true impacts is outside of this range so we are not 100% certain.

In general, we can never be 100% certain of the true impacts, which is why we do not list a Z value for the 100% confidence interval. If we wanted a 100% confidence interval, it would have to contain all possible values that the CMF can take (between 0 and infinity). This is because no matter how large our confidence interval is, there is always some chance (however small) that the true value is outside that range.

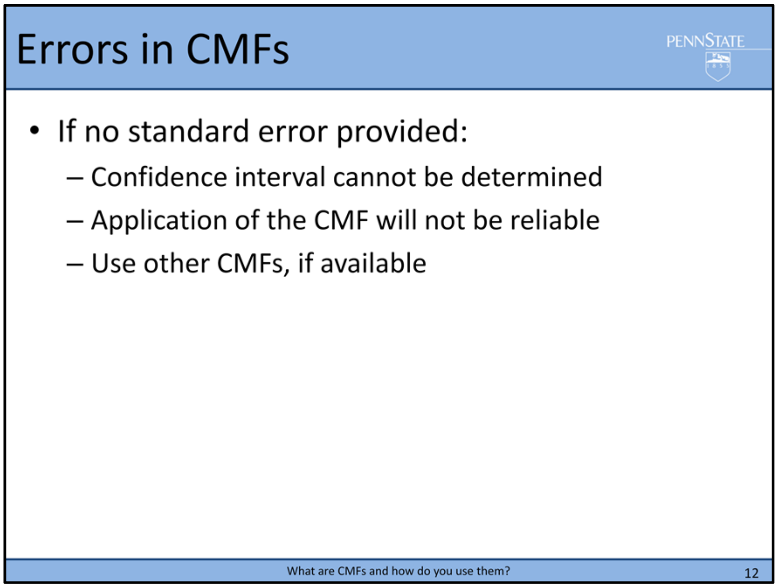


Using the confidence interval for the CMF helps to provide us with a better indication of how the change or countermeasure will impact crash frequency. When we were using only the point estimate, we compared that value to 1 to get an indication of the expected impact. When accounting for the errors that might exist, we compare the confidence interval to 1.

(click) If the CMF confidence interval is strictly less than one, we can be very confident that the change or countermeasure will reduce crash frequency. That is because even if the true value of the CMF is near the upper bound (UB) of the confidence interval, that value is still less than one.

(click) If the CMF confidence interval is strictly greater than one, we can be very confident that the change or countermeasure will increase crash frequency. That is because even if the true value of the CMF is near the lower bound (LB) of the confidence interval, the value is still greater than one.

(click) If the CMF confidence interval is includes one, then both possibilities exist: the countermeasure may reduce crash frequency or increase crash frequency. In this case, there is not enough evidence to conclude that the change or countermeasure will impact the safety performance. This is because the LB of the confidence interval is less than 1 (indicating that there is a significant chance the true value of the CMF is less than one) while the UB of the confidence interval is greater than one (indicating that there is a significant chance the true value of the CMF is greater than one).

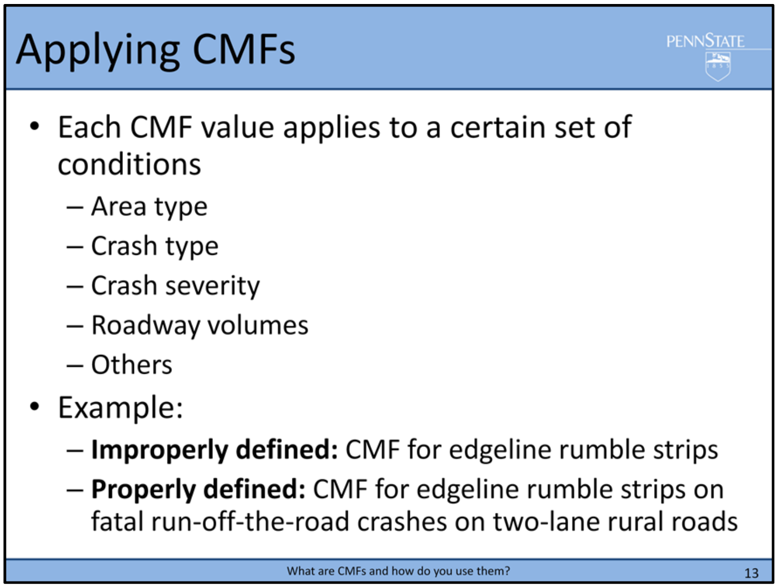


Unfortunately, there are many CMFs for which no standard error is provided. This could be due to the type of model used (and generally occurs when poorer study designs are used).

In these cases, confidence intervals for the CMFs cannot be determined and the analyst has no indication with the level of uncertainty associated with the CMF estimate.

These CMFs are not very reliable and should be avoided if at all possible. Instead, other CMFs should be used if they exist. If other CMFs do not exist, the point estimate can give a very naïve indication of the expected impacts but it should not be directly applied for modeling and estimation purposes since the analyst has no indication of the level of uncertainty involved.

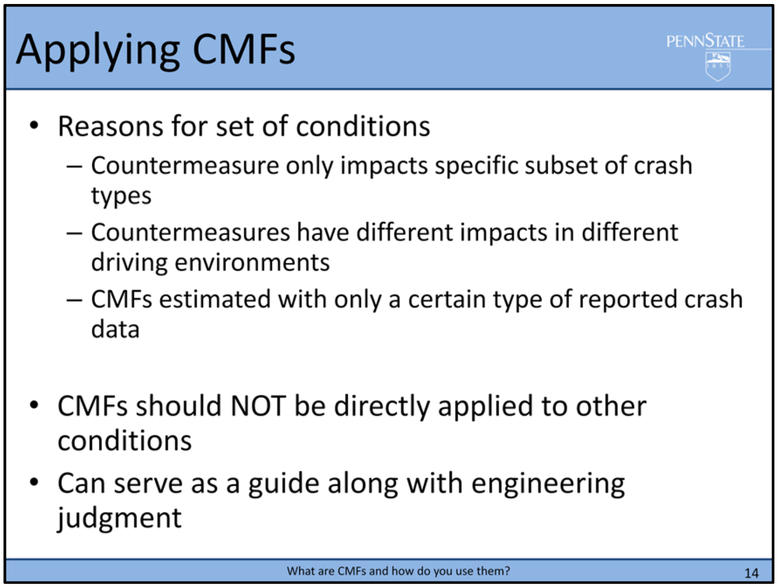
(refer back to plot on slide 7)



Because CMFs are estimated using reported crash data, each only applies to a very specific set of conditions based on the type of data used in the estimation. These conditions can include the following:

- Area type: urban, suburban, rural
- Crash type: all, rear-end only, angle-only, etc
- Crash severity: all, fatality, major injury, minor injury, PDO
- Roadway volumes: typically measured in AADT
- Others: these include roadway geometry (e.g., number of lanes or number of legs at an intersection), traffic control (e.g., speed limit or type of intersection control), etc.

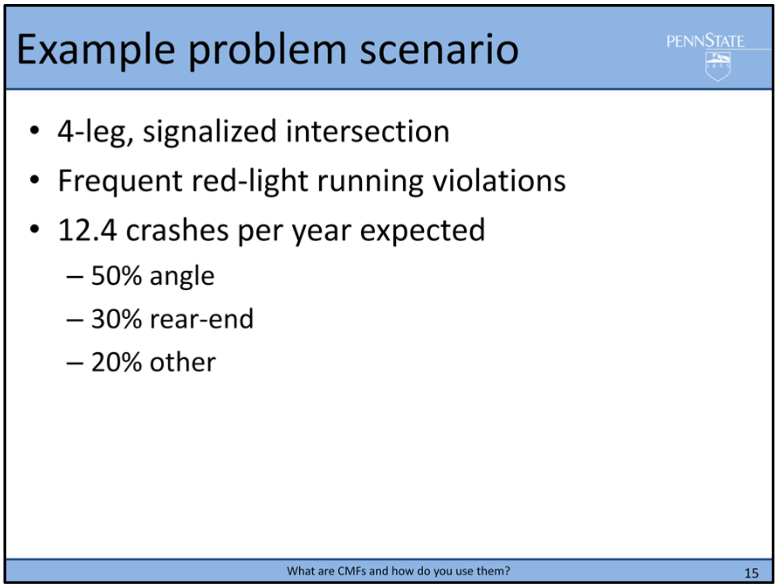
Therefore, the CMFs provided are usually very specific. **(click)** two examples are provided that show a properly defined CMF and an improperly defined CMF. In the former, the analyst has no idea on what types of crashes are affected and other conditions for which the CMF can be applied. The latter is more appropriate, because it outlines the limitations and domain of application for the CMF. The example for the properly defined CMF includes all possible attributes that might be considered in a CMF…crash type, crash severity, area type. Often some of the attributes are missing…e.g., CMF for edgeline run-off-the-road crashes for edgeline rumble strips on two-lane rural roads. In this case, we can either 1) try be more specific about the crash severity; or 2) assume that the CMF refers to all crash severities.



There are several reasons that CMFs are defined for a narrow set of conditions.

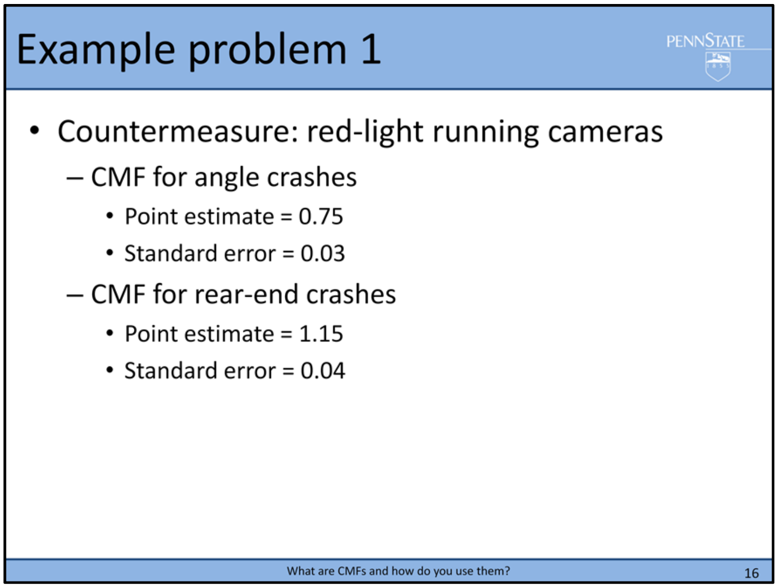
- Often, specific countermeasures are only intended to impact a subset of crashes. For example, edgeline rumble strips are primarily used to reduce run-off-the-road crashes in rural areas. However, this countermeasure is not expected to reduce other types of crashes, like rear-end crashes. Therefore, the CMF is typically defined for this crash type alone and when it is defined in this way it should only be applied to run-off-the-road crashes.
- The effect of some countermeasures changes depending on the environment in which it is applied. For example, intersection treatments can have vastly different impacts depending on the intersection configuration and type of control at the intersection.
- Sometimes only a specific subset of crash data are available. For example, fatal crashes are more consistently and carefully reported than other crash types and might often be the only type of crash information available. CMFs estimated using fatal crash data alone, however, should not be applied to different crash severities like PDO.

Therefore, CMFs should only be applied to the conditions that are specified and should NOT be applied directly to other conditions!
In cases where CMFs do not exist for a specific set of conditions, CMFs for similar conditions can serve only as GUIDE for the potential impacts. However, proper engineering judgment should also be applied in these cases.



We will now use an example problem to demonstrate how to apply CMFs.

Our example will focus on a four-leg, signalized intersection located in a downtown region. Historical and anecdotal evidence suggests this location experiences frequent red-light running violations and about 50% of all crashes are angle crashes within the intersection footprint associated with these events. The remaining crashes are rear-end crashes on the intersection approaches (30%) and crashes of unknown type (20%). It is expected that crash frequency at this location will be 12.4 crashes per year if no countermeasures are applied.



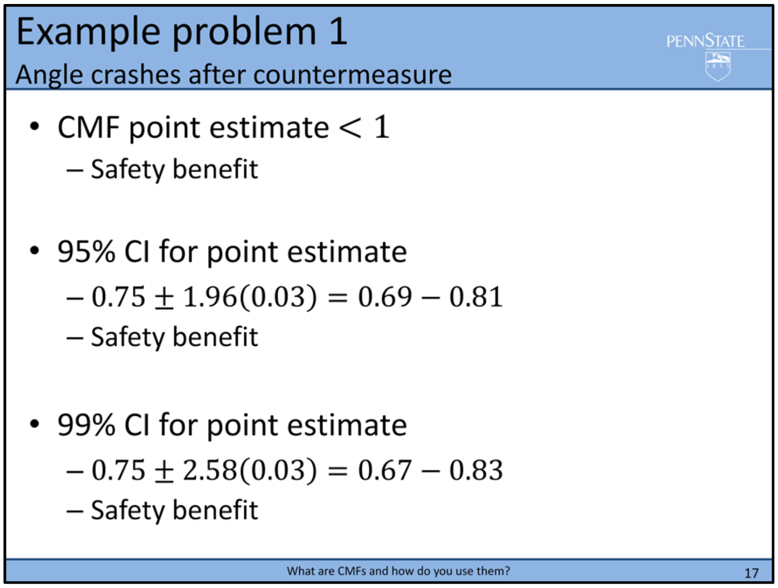
Our first problem considers the implementation of red-light running cameras as a countermeasure. Two CMFs are available for red-light running cameras…one for angle crashes and the other for rear-end crashes. Both apply to all crash severities. Since the severities are not specified in our problem, we will assume that the previous crash values represent all crash severities.

The point estimates and standard errors for the crash types are provided here.

We would like to know the following:

How many angle crashes are expected after the implementation of the red-light running cameras?

How many rear-end crashes are expected after the implementation of the red-light running cameras?



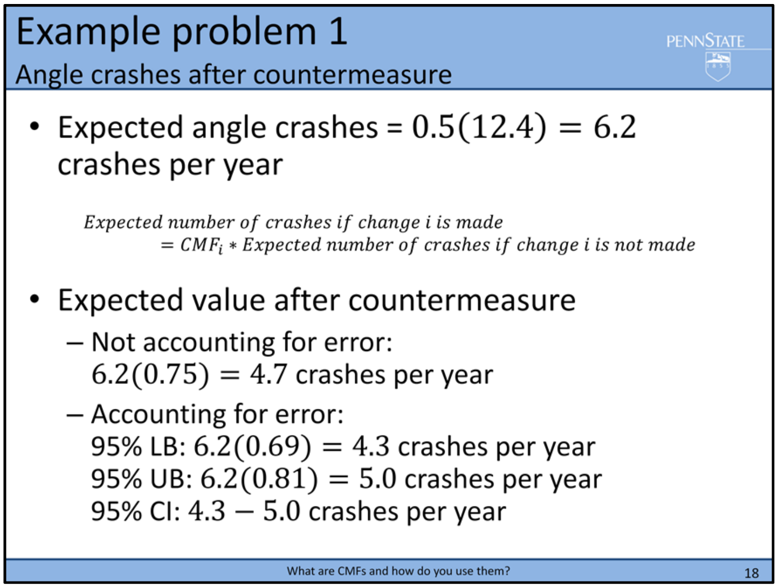
Let’s start with angle crashes.

(click) We first note that we expect some sort of safety benefit from angle crashes since the point estimate is < 1. But to be really sure, we first need to compute the confidence interval for the CMF point estimate.

(click) The 95% confidence interval is computed first.

(click) If we wanted, we can compute other confidence intervals. For example, the 99% confidence interval is provided here. Note, however, that the 95% CI is the most prevalent for practical applications.

Both suggest that there should be a safety benefit for angle crashes when implementing red-light running cameras in urban regions since the CIs are strictly less than one.



We now use these values to calculate the number of crashes expected.

Since the CMF applies to angle crashes only, we need to calculate the number of angle crashes expected.

(click) Then, we calculate the number of angle crashes expected after the implementation of the countermeasure.

(click) First, we do so without accounting for the error associated with the CMF point estimate.

However, this is not as informative as calculating the expected number of crashes while accounting for the error that might exist.

(click) To do this, we calculate the LB and UB for expected number of crashes based on the LB and UB of the CMF point estimate provided by the CI.

This provides a CI for the expected number of angle crashes after the implementation of the countermeasure. In practice, we should always report the confidence interval for expected crash frequency whenever possible to give an indication of the level of uncertainty associated with it.

Example problem 1
Rear-end crashes after countermeasure

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- CMF point estimate > 1
  - Safety disbenefit
- 95% CI for point estimate
  - $1.15 \pm 1.96(0.04) = 1.07 - 1.23$
  - Safety disbenefit

What are CMFs and how do you use them? 19

To reinforce these concepts, let us repeat the process for rear-end crashes.

(click) Notice that the CMF point estimate and CI are both greater than one. This suggests that the countermeasure is expected to *increase* crashes after implementation and provides an overall safety disbenefit.

(click) Is this reasonable? Given the countermeasure, yes we can expect that rear-end crashes would increase when implementing red-light running cameras! Why? Vehicles will be more likely to stop during the yellow period and this might not be expected by following vehicles.

Example problem 1

Rear-end crashes after countermeasure

- Expected rear-end crashes = $0.3(12.4) = 3.7$ crashes per year

$$Expected\ crash\ frequency\ if\ change\ i\ is\ made = CMF_i * Expected\ crash\ frequency\ if\ change\ i\ is\ not\ made$$

- Expected value after countermeasure
  - Not accounting for error:
    $3.7(1.15) = 4.3$ crashes per year
  - Accounting for error:
    95% LB: $3.7(1.07) = 4.0$ crashes per year
    95% UB: $3.7(1.23) = 4.6$ crashes per year
    95% CI: $4.0 - 4.6$ crashes per year

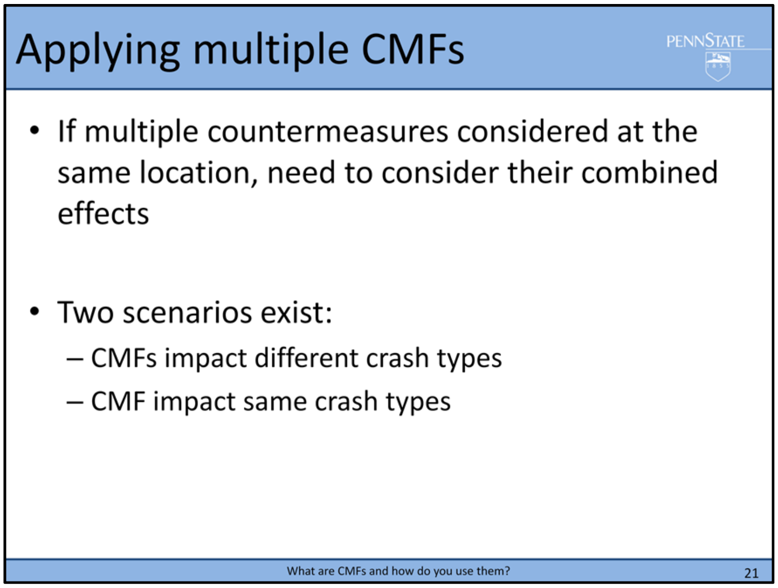
What are CMFs and how do you use them? 20

The same logic as before can be used to estimate the number of rear-end crashes expected.

First, calculate the number of rear-end crashes expected before the implementation of the countermeasure.
(click) Then calculate the expected number of crashes using the CMF point estimate.

(click) The LB and UB of the confidence interval can then be used to estimate a confidence interval for the number of crashes as well.

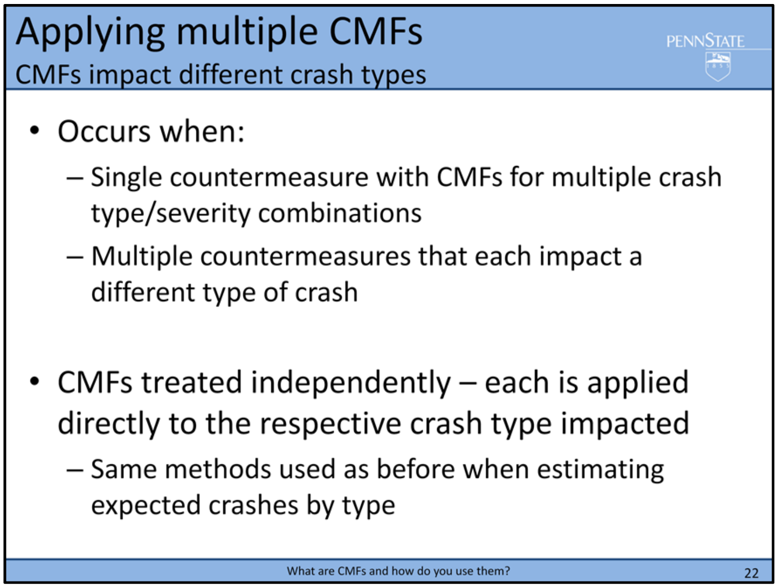
Again, remember we report the confidence interval for the crash frequency when we can calculate it.



The previous slides describe how to apply a single CMF at a time.
Often, however, we must apply multiple CMFs simultaneously at the same location. Now we will discuss the factors that must be considered when applying multiple CMFs simultaneously and how to apply them.

When multiple CMFs are considered, there are two scenarios that might exist.

- The first is that the CMFs impact different crash types
- The second is that the CMFs impact the same crash types.



Let's first consider the simpler case in which the CMFs impact different crash types. This could occur if:

- one countermeasure is implemented that has multiple CMFs for different crash types or
- if multiple countermeasures exist and each influences a different crash type.

In this case, each CMF is treated independently and applied directly to the respective crash type that it impacts. This is done using the same methods as before, assuming the other CMFs did not exist, to generate estimates of expected crash frequency by individual crash type.

Our previous problem was actually an example of this. We estimated the number of angle crashes and rear-end crashes using two CMFs for the same intersection. The estimates are correct because there was no overlap in the crash type that was impacted by each CMF.

Applying multiple CMFs

CMFs impact different crash types

- Cannot sum individual CIs to get CI for total crashes
  - Randomness reduces as we aggregate crash counts
- Confidence interval for total crashes is:

$$\sum_i N_i CMF_i \pm Z * \sqrt{\sum_i (N_i ERROR_i)^2}$$

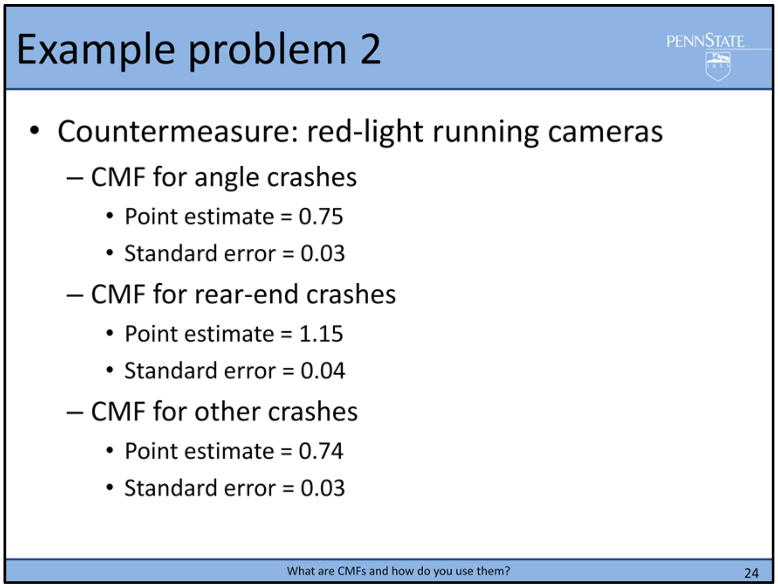
- CMF_i – point estimate of CMF for crash type *i*
- $ERROR_i$ – standard error of CMF for crash type *i*
- N_i – expected number of crashes (before countermeasure) for crash type *i*
- Z – value associated with how certain you would like to be with your confidence interval

What are CMFs and how do you use them? 23

However, an interesting question that we might ask is: using these estimates for the individual crash frequencies, how do we get an estimate of the total crash frequency?

One might think that we can simply add together the multiple individual confidence intervals—i.e., add the different LBs to get an overall LB, and add the different UBs to get an overall UB. However, this turns out to greatly overestimate the CI for total crashes. The reason is simple: when we aggregate random variables, the overall variation reduces. Another way to look at it is that the randomness in estimates of individual crash type estimates might cancel each other out when we start adding them together to estimate the total number of crashes.

(click) To account for this, we estimate the CI for the total number of crashes using the simple formula provided here.
This formula accounts for the reduction in variation that is achieved when aggregating the different confidence intervals together.



Let's now expand our example slightly and try this methodology for applying multiple CMFs simultaneously.

(click) Suppose now that we have found a third CMF for the "other" crash type. This takes care of the three crash types expected at our hypothetical intersection.

Now the question we want to ask is, how many TOTAL crashes are expected at this intersection.

Example problem 2

Total crashes after countermeasure

- Since a single countermeasure with CMFs for multiple crash types
  - Treat all impacts as independent

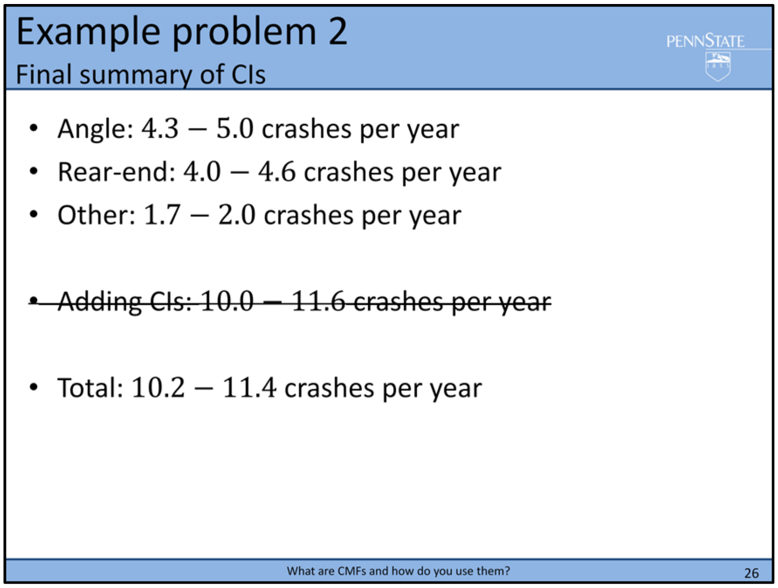
$$95\%\ \mathrm{CI} = \sum_i N_i CMF_i \pm Z * \sqrt{\sum_i (N_i ERROR_i)^2}$$

- 95% CI: $6.2(0.75) + 3.7(1.15) + 2.5(0.74)$
  $\pm 1.96 * \sqrt{(6.2 * 0.04)^2 + (3.7 * 0.03)^2 + (2.5 * 0.03)^2}$
  $= 10.8 \pm 0.6 = 10.2 - 11.4$ crashes per year

What are CMFs and how do you use them? 25

We know that the formula just presented is valid because we have a single countermeasure that has CMFs for multiple crash types. Therefore, we can treat these all independently and apply the formula…

(click) The result stems exactly from the equation.



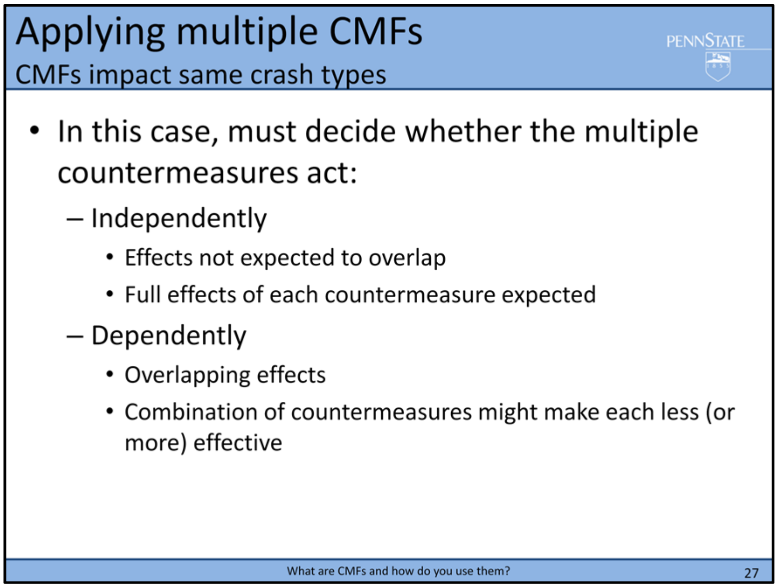
Let’s take a look at the results for the individual crash types and the total number of crashes.

We didn’t do the “other” crash type together but I have left that for each of you to do on your own to verify the results….

(click) Now what happens when we add the CIs . Notice it is crossed out because it is wrong!

(click) Compare to the previously calculated CI.

Notice though that the CI obtained from the equation is smaller than obtained by adding the individual CIs. This is not a calculation/rounding error either, this is a consistent result that will be obtained whenever this equation is used and is the correct way to perform this calculation.

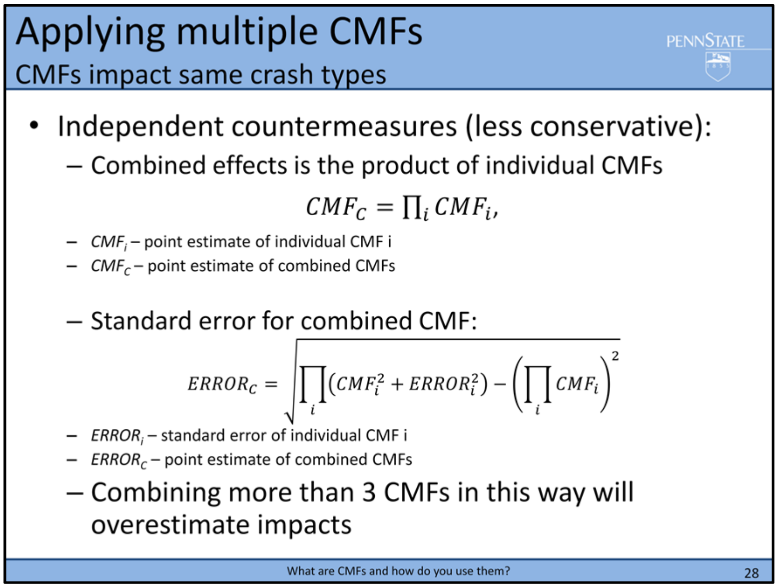


Now let's consider the more complicated case in which the CMFs impact the same crash types. This can only occur when multiple countermeasures are applied simultaneously at the same location.

There are two sub-cases to consider in this situation.
- the countermeasures act independently
- The countermeasures act non-independently

We select independent if we assume that the effects of each countermeasure do not overlap (i.e., the presence of one of the countermeasures does not make the impacts of the other better or worse than if it were applied by itself). In this case, the full effects of each countermeasure (implemented independently) are expected when applied simultaneously.

We select dependent if we assume that there are some overlapping effects (so if the presence of one countermeasure might enhance or diminish the impacts of the other). In this case, the combined effects might be less (or more) effective than if applied separately. We now examine how to deal with these two cases.

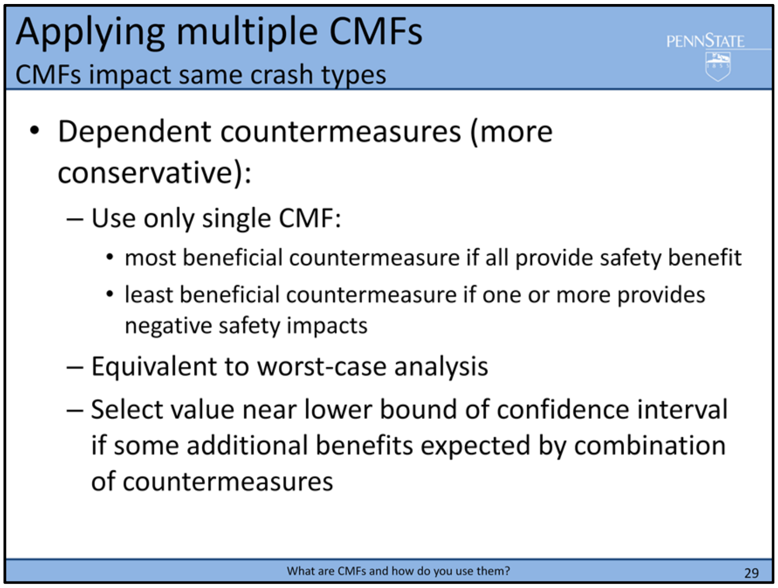


If the two countermeasures are treated as independent, the full effects of each should be observed. This is the less conservative approach since we expect the full impacts of each.

(click) In this case, the combined impact of the application of these multiple countermeasures simultaneously is given by the product of the individual CMFs.

(click) The standard error of the combination of multiple CMFs is not so straightforward. For some of the reasons previously mentioned, the errors of the individual CMFs become smaller than the sum of the individual errors when aggregated. This combined error can be calculated using the following formula.

(click) Note that in general one should be very conservative when applying multiple CMFs in this way since countermeasures are not likely to be independent in practice. Combining more than 3 CMFs in this way is expected to overestimate their impacts. Therefore, this methodology should not be used when 3 or more CMFs are required. Instead, a more conservative approach might be considered (such as just selecting three of CMFs to apply). Note that this does NOT mean more than 3 COUNTERMEASURES should be applied simultaneously. It only applies to how we estimate their effects.



If the two countermeasures are treated as dependent, then the effects would be enhanced or diminished by being applied in combination.

Unfortunately, not much work has been done on this topic so little is known about the combined impact of dependent countermeasures. Therefore, the best practice is to be as conservative as possible. In this case, the conservative approach is to do one of the following…either:

- Use the single CMF for the most effective countermeasure if both provide a benefit
- Use the single CMF of the least beneficial countermeasure if one or more provides a disbenefit (is expected to increase crash frequency)

These conservative assumptions ensure that we do not overstate the combined impacts and underpredict the crash frequency by actually examining the worst-case scenario.

If the combination of the countermeasures is expected to provide some benefit over the use of just the single countermeasure, then a value near the lower bound of the confidence interval could be selected to account for these combined effects. However, this requires that the analyst exercise careful engineering judgment.

Example problem 3

- Original countermeasure: red-light running cameras
  - CMF for rear-end crashes
    - Point estimate = 1.15
    - Standard error = 0.04
- Second countermeasure: replace incandescent signal bulbs with LEDs
  - CMF for rear-end crashes
    - Point estimate = 0.827
    - Standard error = 0.036

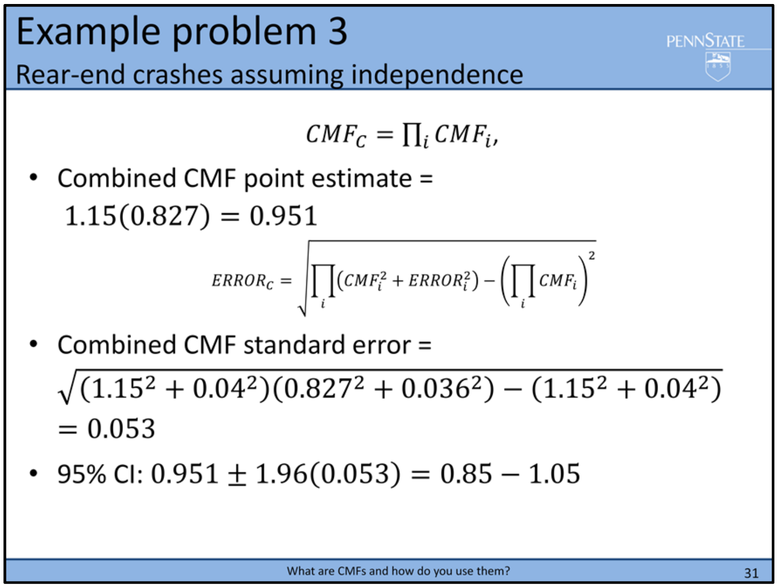
Let us now apply this to our example problem.

We previously saw that the implementation of red-light running cameras would increase the expected rear-end crash frequency at our hypothetical intersection. **(click)** In an effort to alleviate this, another countermeasure is considered: the replacement of traditional incandescent bulbs at the signal with LEDs. A CMF exists with the properties shown for rear-end crashes in urban areas for this countermeasure.

Assuming that red-light running cameras and the installation of LED traffic signals are independent, how many rear-end crashes should be expected after their implementation?

Assuming that the two countermeasures are dependent, how many rear-end crashes should be expected after their implementation?

What is the most appropriate estimate to use?

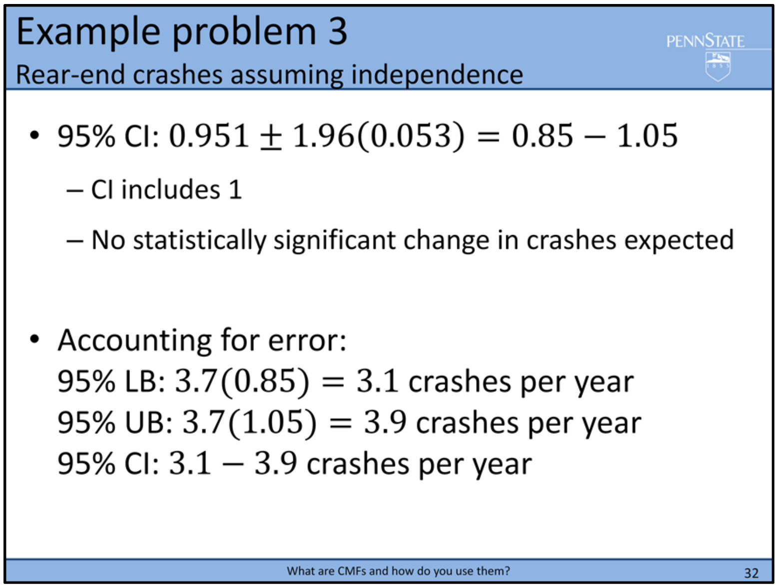


First, let’s assume that the two countermeasures are independent and that the full effects of each are experienced.

In this case, we can apply the formulas to predict the combined impact on rear-end crashes…

(click) First calculate the combined CMF point estimate.

(click) Then the combined standard error.
(click) Finally, use this to get the CI for the combined CMF.



Note that the CI includes 1. Therefore, there is not enough evidence to suggest the combined impacts of the two countermeasures will affect safety performance.

(click) Using the CI for the CMF, we can also get a CI for the expected crashes.

Example problem 3
Rear-end crashes assuming dependence

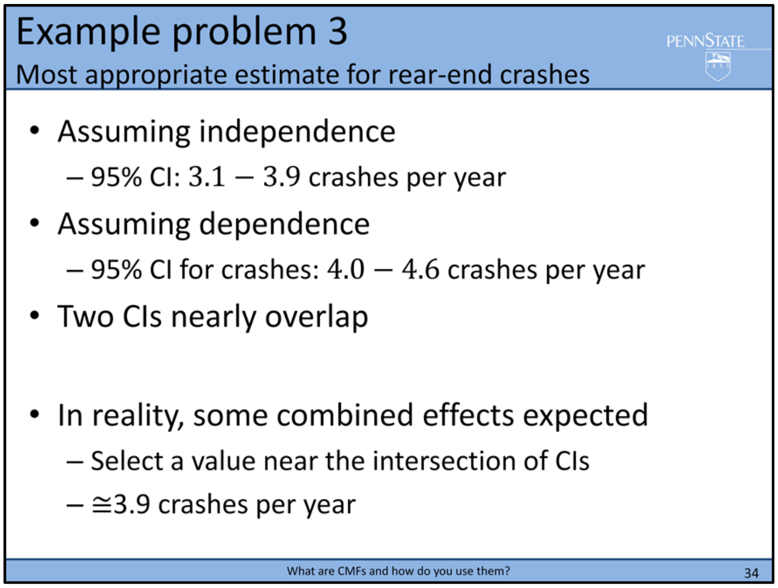
- Since one countermeasure increases crashes, apply only that value
- 95% CI for point estimate
  - $1.15 \pm 1.96(0.04) = 1.07 - 1.23$
- 95% CI for crashes: $1.07(3.7) - 1.23(3.7) = 4.0 - 4.6$ crashes per year
- Since combination of countermeasures should provide some benefit, value near the LB would be appropriate

What are CMFs and how do you use them? 33

Let's now repeat assuming there is some dependence. In this case, we will make the most conservative assumption that only one CMF should be applied. Since one CMF suggests a safety disbenefit (red-light enforcement cameras), we apply that CMF.

Note that we already found the CI for this CMF and the expected crashes using this CMF.

Since in reality we would expect SOME positive benefit from applying the two, we should expect a number of crashes closer to the LB.



So a question we might ask in practice is: what is the most appropriate estimate for rear-end crashes?

Let’s compare the two solutions. In general, an analyst should present both cases and then suggest a value that he/she finds most reasonable. In this case, we see that the two methods provide nearly overlapping CIs for rear-end crashes.

To determine the most appropriate value, we need to think about these countermeasures being applied. Red-light running cameras will make vehicles in the dilemma zone more likely to stop at the signal, which we expect to increase crash frequency. Installing LED traffic signals would improve the visibility of the signal and might make drivers more aware of the downstream signal. This would make them more likely to stop when the signal is changing intervals. However, this latter countermeasure is typically used in areas with poor visibility. Since we know nothing about the visibility here, we cannot really expect the full effects of this countermeasure to occur, especially in conjunction with the red-light enforcement cameras. Therefore, the assumption of independence might be too liberal and we should go with the more conservative approach.

Therefore, a value near the LB of the conservative (dependent) approach might be appropriate.

Pennsylvania CMF Guide

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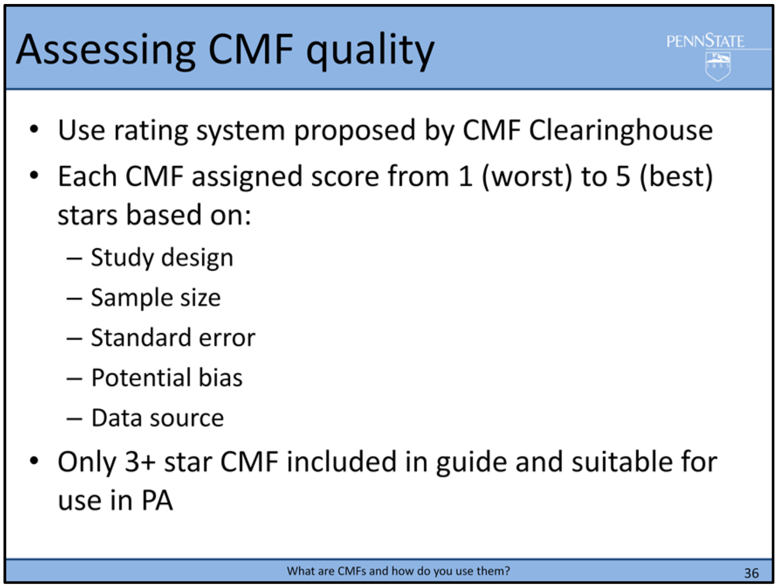
- The *Pennsylvania CMF Guide* provides list of high-quality Crash Modification Factors appropriate for use in Pennsylvania
- Obtained mainly from FHWA CMF Clearinghouse website, www.cmfclearinghouse.com

What are CMFs and how do you use them? 35

So now that we know how to apply CMFs once we have them, we would like to introduce the *Pennsylvania CMF Guide*

This guide provides a list of high-quality CMFs that have been estimated in the literature and are deemed as appropriate for use in PA.

These CMFs were obtained from previous studies that have been documented in the research literature. The team that developed this guide examined multiple sources, although most of the CMFs came from the FHWA CMF Clearinghouse. Other sources include: AASHTO Highway Safety Manual, FHWA Toolboxes for Safety Countermeasures, and research studies.



We mentioned that the guide contains only high-quality CMFs. To determine the quality of each CMF, we employed the rating system developed by the CMF Clearinghouse. In this system, each CMF is given a star rating between 1 and 5, where 1 is the worst and 5 is the best. This rating is based on five characteristics of the CMFs:

- Study design (which we talked about earlier)
- Sample size (number of crashes / locations considered)
- Standard error of the CMF (lower is better)
- Potential for bias in the estimates (perhaps due to data collection or other factors that might yield an inaccurate measure)
- Data source (small geographic region vs. large geographic region)

Only CMFs rated a 3-star or higher are included in the guide. However, the guide contains a list of low quality CMFs and their sources for countermeasures that did not have higher-quality CMFs. This can provide an analyst with a reference if they are interested in these particular countermeasures. However, we do not recommend that these lower-quality CMFs be applied for safety applications in PA.

Using the CMF Tables

- CMFs categorized into 19 tables
  - Access Management
  - Advanced Technology and ITS
  - Alignment
  - Bicyclists
  - Delineation
  - Highway Lighting
  - Interchange Design
  - Intersection Geometry
  - Intersection Traffic Control
  - On-Street Parking
  - Pedestrians
  - Railroad Grade Crossings
  - Roadside Features
  - Roadway Features
  - Shoulder Treatments
  - Signs
  - Speed Management
  - Transit
  - Work Zones

The CMF guide is split into 19 tables…the categorization used here is the same as provided by the FHWA CMF Clearinghouse. This was done for consistency and to help an analyst look up the CMF in the clearinghouse if more detailed information is desired (e.g., if the analyst wants to find the exact reference that the CMF came from).

Note that individual countermeasures are not duplicated across tables and an analyst might have to check multiple tables to find a specific countermeasure. For example, CMFs for countermeasures at intersections with rail crossings can be found in both the table for Intersection Traffic Control and Railroad Grade Crossings.

Using the CMF Tables

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- Each table provides information on the conditions for which the CMF applies, which include:
  - Roadway/area type
  - Crash type
  - Crash severity
  - Level of traffic (AADT)
  - Other implementation notes
- CMFs should only be directly applied to the **same conditions**
- CMFs might serve as a guide for other conditions

What are CMFs and how do you use them? 38

The CMF tables are organized as follows:
They contain the name of the countermeasure, the conditions for which it applies, the point estimate and standard error, the star-rating and finally the states for which crash data were obtained to estimate the CMF.

The conditions are broken into five categories as shown here. The only one that might not be self explanatory is "Other implementation notes". This contains countermeasure specific information that might influence where the CMF could be applied. Examples include: intersection types, number of lanes, speed limits, etc.

As discussed previously, the CMFs should only be applied to the SAME CONDITIONS as listed in the table.

Using the CMF Tables

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Countermeasures	Area Type	Crash Severity	Crash Type
Install shoulder rumble strips	Urban	All	Run-off-road
		Fatal and injury	Run-off-road
Install continuous milled-in shoulder rumble strips	All	All	Run-off-road,Single vehicle
		Injury	Run-off-road,Single vehicle
	Rural	All	All
			Run-off-road,Single vehicle
		Injury	All
			Run-off-road,Single vehicle

AADT	Note	CMF		Star Quality Rating	State
		Value	Std. Err		
		0.82		3	notusa
180 - 92757		**1**	**0.0556**	**3**	**MN,MO,PA**
		0.82	0.12	3	
		0.21	0.07	4	
		0.87	0.21	3	
2000 - 50000		0.84	0.13	3	
2000 - 50000		0.9	0.25	3	
		0.79	0.18	3	
2000 - 50000		0.83	0.19	3	
2000 - 50000		0.78	0.33	3	
		0.93	0.28	3	

- Highlighted: recommended values
- **Bolded**: values estimated using PA data

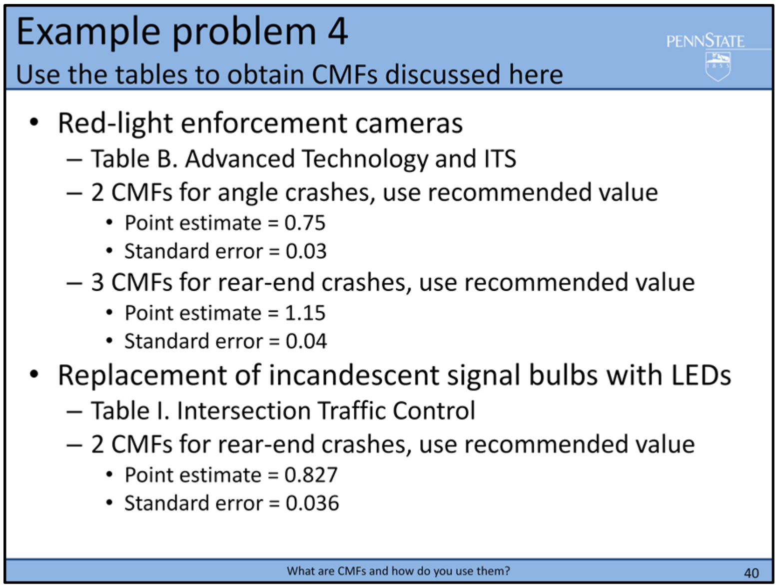
What are CMFs and how do you use them? 39

Shown here is a portion of the CMF table. Note that it is broken to fit on the slide.

Notice the organization is as mentioned previously. For these CMFs, there are no “notes”.

(click) The highlighted values are provided whenever multiple CMFs exist for the same conditions. These highlighted values are the values that are recommended for use in PA. The other values are provided to show the range of potential values as another indication of the uncertainty associated with the CMF.

(click) You might also notice that some values are bolded (the one with AADT 180-92757). These bolded values represent that the CMF was estimated using PA data. Note that the ones estimated with PA data are not always the “best” values as CMFs estimated from a larger geographic region and from more crash data might be more precise. However, this is provided in case the analyst would prefer to use a PA-specific CMF.



We will now use the tables to look up the values obtained here.

(click) Red-light enforcement cameras is in Table B.
We have the following conditions: urban areas, all severities.
(click) For angle crashes, two CMFs exist. We should use the recommended value.
(click) For rear-end crashes, three CMFs exist. We should use the recommended value.

(click) Replacement of incandescent signal bulbs is in Table I.
We have the following conditions: urban areas, all severities, rear-end crashes and 4-leg intersections.
Two CMFs exist. We should use the recommended value.

Note that none of these recommended values are estimated using PA crash data. In fact, for these two countermeasures CMFs from PA-specific data has never been estimated.

Example problem 5
Using CMFs to compare alternatives

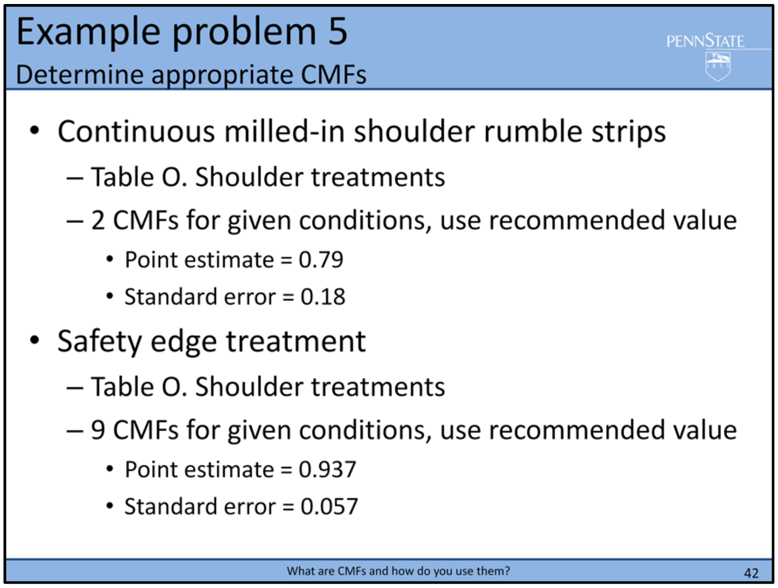
- Two-lane rural roadway segment
- Run-off-the-road crashes of all severities considered
- Potential treatments:
  - Continuous milled-in shoulder rumble strips
  - Safety edge treatment

What are CMFs and how do you use them? 41

Last problem…

Consider the following conditions:
Two-lane rural roadway segment
Run-off-the-road crashes of all severities (since severity is not specifically mentioned)

Two treatments for consideration:
- Continuous milled-in shoulder rumble strips
- Safety edge treatment



To obtain the appropriate CMFs, we must use the CMF tables…

(click) For continuous milled-in shoulder rumble strips, use that specific countermeasure (note: shoulder rumble strips exist but the type isnt specified so let’s use the type that we were specifically given)
Two CMFs exist, use the recommended value

(click) For safety edge, 9 CMFs given. Use the recommended value.

Example problem 5
Largest expected reduction in crashes

- Continuous milled-in shoulder rumble strips
  - Point estimate = 0.79
  - Expected percent reduction in crashes: $100(1-0.79)$ =21%
- Safety edge treatment
  - Point estimate = 0.937
  - Expected percent reduction in crashes: $100(1-0.937) =$ 6.3%

What are CMFs and how do you use them? 43

For the expected change in crash frequency, we can use the point estimate and convert the CMF to the percent reduction in crashes

(click) first for rumble strips
(click) then for safety edge

Shoulder rumble strips provide a much larger expected reduction in crash frequency than safety edge. Thus, if we were only focused on expected reduction in crash frequency we would choose the continuous milled-in shoulder rumble strips

Example problem 5

Largest expected reduction in crashes

- Continuous milled-in shoulder rumble strips
  - Point estimate = 0.79
  - Standard error = 0.18
  - 95% CI for CMF point estimate: $0.44 - 1.14$
  - Worst-case percent reduction in crashes: $100(1 - 1.14) =$ -14%
- Safety edge treatment
  - Point estimate = 0.937
  - Standard error = 0.057
  - 95% CI for CMF point estimate: $0.83 - 1.05$
  - Expected percent reduction in crashes: $100(1 - 1.05) =$ -5%

Now, we are concerned with the worst case scenario. To examine the worst case, we would need to also consider the errors associated with these point estimates.

(click) first for rumble strips. We calculate the 95% CI for the CMF. Which value would provide the “worst-case”? The higher value since larger numbers are associated with more crashes. Then, we examine the percent reduction in crashes associated with this value. **(click)** Repeat the same for the safety edge. From this, we can see that the safety edge provides a best “worst-case” than the continuous milled-in shoulder rumble strips. Therefore, if we were only focused on the worst-case performance and wanted to minimize crash frequency for this case, we might consider the safety edge treatment.

Questions?

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Appendix B: Example Problems Demonstrating the CMF Procedure

Scenario:

Our first four examples focus on a four-leg, signalized intersection located in a downtown region. Historical and anecdotal evidence suggests this location experiences frequent red-light running violations and about 50% of all crashes are angle crashes within the intersection footprint associated with these events. The remaining crashes are rear-end crashes on the intersection approaches (30%) and crashes of unknown type. It is expected that crash frequency at this location will be 12.4 crashes per year if no countermeasures are applied.

Problem 1:

Red-light enforcement cameras are being considered to reduce total crash frequency at this location. Two CMFs are available for red-light enforcement cameras in urban areas. The CMF for angle crashes has a point estimate of 0.75 and a standard error of 0.03, while the CMF for rear-end crashes has a point estimate of 1.15 and a standard error of 0.04.

a) *How many angle crashes are expected after the implementation of the red-light enforcement cameras?*
b) *How many rear-end crashes are expected after the implementation of the red-light enforcement cameras?*

Problem 2:

A third CMF exists for other crash types, which has a point estimate of 0.74 and a standard error of 0.03.

How many total crashes are expected after the implementation of red-light enforcement cameras?

Problem 3:

Signal bulb replacement is also being considered to reduce the additional rear-end crashes that will occur with the implementation of red-light enforcement cameras. The countermeasure would replace existing incandescent traffic signal bulbs with LEDs. A CMF for applying this strategy in urban environments for rear-end crashes has a point estimate of 0.827 and a standard error of 0.036.

a) *Assuming that red-light enforcement cameras and the installation of LED traffic signals are independent, how many rear-end crashes should be expected after their implementation?*
b) *Assuming that the two countermeasures are dependent, how many rear-end crashes should conservatively be expected after their implementation?*
c) *What is the most appropriate estimate to use?*

Problem 4:

Use the CMF tables to obtain the CMF point estimate and standard error for the installation of red-light enforcement cameras and the replacement of incandescent signal bulbs with LEDs for rear-end, angle and other crashes in urban areas for all crash severities.

Problem 5:

Two countermeasures are being considered to reduce run-off-the-road crashes of all severities on a two-lane rural roadway segment. The first is the installation of continuous milled-in shoulder rumble strips. The second is the installation of a safety edge treatment.

a) *What are the appropriate CMFs to use for each of these two treatments?*
b) *Which treatment is expected to provide the largest reduction in crashes?*
c) *For which treatment is the worst-case performance expected to be the worst?*

Appendix C: *Pennsylvania CMF Guide*

PENNSYLVANIA CMF GUIDE

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Introduction

The American Association of State Highway and Transportation Officials' (AASHTO) *Highway Safety Manual* (HSM) is transforming the way state and local transportation agencies manage road safety. In addition to providing an overview of many aspects of road safety management, the manual contains a process for evaluating the effectiveness of alternative safety countermeasures based on previous research.

A critical factor in the use of the HSM safety management process is the Crash Modification Factor (CMF). It is used to estimate the change in the expected (average) number of crashes at a site when a specific countermeasure is implemented. This guidebook responds to a request from the Pennsylvania Department of Transportation (PennDOT) to review the existing CMF literature and make recommendations concerning their use in Pennsylvania. The purpose of this guide is to provide a list of CMFs that are appropriate for use when estimating the safety performance of changes on the highway and street network in Pennsylvania, and to demonstrate how to apply them appropriately. The list of CMFs was compiled by reviewing the relevant literature and identifying high-quality CMFs that might be applicable to Pennsylvania roadways. In compiling this list, the following sources were reviewed:

- Federal Highway Administration (FHWA), CMF Clearinghouse website;
- AASHTO *Highway Safety Manual*;
- FHWA *Desktop Reference for Crash Reduction Factors* (Report FHWA-SA-08-011);
- Governors Highway Safety Association (GHSA), *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices*;
- FHWA Office of Safety, *Proven Safety Countermeasures*;
- FHWA *Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes*;
- FHWA *Roadway Departure Countermeasures*;
- *Crash Reduction Factors for Traffic Engineering and Intelligent Transportation Systems (ITS) Improvements: State-of-Knowledge Report* (NCHRP Research Results Digest 299); and
- Recently published research literature.

The complete list of CMFs is summarized in a set of tables provided at the end of this document. For countermeasures not provided in these tables, or that were added to the FHWA CMF Clearinghouse after publication of this document, the reader can refer to the FHWA CMF Clearinghouse website (http://www.cmfclearinghouse.org/), which contains the most up-to-date database of CMFs. It is important to note that the FHWA CMF Clearinghouse contains both high- and low-quality CMFs; however, only high-quality CMFs are recommended for application within Pennsylvania. The determination of high-quality CMFs is discussed in the section of this guide titled "Assessing the Quality of a CMF." A list of low-quality CMFs and their values are also provided at the conclusion of this guide to provide documentation concerning their use. However, because these CMFs are based on either a small sample size, or suffer from a low-quality methodological evaluation, these CMFs are not recommended for use in Pennsylvania.

The rest of this document is organized into five sections. The first section describes what a CMF is and how it is estimated. The next section includes information about how to apply a single CMF to estimate the expected safety performance from a highway improvement or implementation of a countermeasure. Next, a methodology to apply multiple CMFs at a single location is described. The process used to determine the quality of a CMF is described in the subsequent section. The last section of this report includes a description of the CMF tables, which are provided at the end of the guide.

What is a CMF?

As defined by the *Highway Safety Manual*, a CMF is "an index of how much crash experience is expected to change following a modification in design or traffic control" at a particular location. Each CMF is a numerical value that provides the ratio of the expected number of crashes over some unit of time after a change is made to the expected number of crashes for the same time period had the change not been made. Equation 1 shows how the ratio is applied to develop a CMF for a particular countermeasure i:

$$CMF_i = \frac{Expected\ number\ of\ crashes\ if\ change\ i\ is\ made}{Expected\ number\ of\ crashes\ if\ change\ i\ is\ not\ made}. \qquad \text{(Equation 1)}$$

The percent crash reduction associated with countermeasure i is $(1 - CMF_i) * 100\%$.

The true value of the CMF for any countermeasure will always be unknown. The reported value is only an estimate of the true value obtained from a statistical analysis of reported crash data. This reported value (referred to as a **point estimate**) provides an estimate of the effectiveness of the potential change or countermeasure on crash frequency. CMF values less than 1.0 indicate that the change should reduce crash frequency, while CMF values greater than 1.0 indicate that the change should increase crash frequency. CMF values equal to 1.0 indicate that the change is expected to have no impact on crash frequency.

Since the true CMF value is unknown, there is always some error associated with the point estimate of the CMF. The size of this error provides an indication of the precision of the point estimate. Small errors indicate that the point estimate is precise and the CMF is known with a high degree of certainty, while larger errors suggest that the true CMF may differ significantly from the point estimate. The magnitude of this error depends on several factors, such as the:

- type of study performed,
- analysis method used to obtain the estimate,
- amount of data used to estimate the CMF, and
- variation in the actual crash data used to estimate the CMF.

Various methods exist to estimate CMFs. Rigorous statistical methods to account for variation in the crash data produce less error in the CMF estimates. Studies with more crash data (either from more sites or over a longer period of time) and more geographic variation in the data also provide estimates with smaller errors than those that use little data or data constrained to a smaller geographic area.

Most research studies that estimate a CMF also include an estimate of the amount of error associated with the point estimate. The magnitude of this error is reported as the standard deviation of the error in the point estimate, and this value is referred to as the **standard error** of the CMF. Careful consideration of the standard error is critical to understanding the range of possible impacts that a highway modification or countermeasure may have on expected crash frequency. One way to quantify this range is by calculating the confidence interval for the true value of the CMF. The confidence interval is calculated using the following equation:

$$Confidence\ Interval\ for\ CMF_i = CMF_i \pm Z * ERROR_i, \qquad \text{(Equation 2)}$$

where CMF_i is the point estimate of the CMF for countermeasure i as defined in Equation 1, $ERROR_i$ is the standard error associated with that point estimate, and Z is a value associated with the statistical significance of the confidence interval. A 95% confidence interval is sufficient for most typical applications; in this case, $Z = 1.96$. Other common Z values are provided in Table 1.

Table 1. Common Z values to obtain confidence intervals

Type of confidence interval	Z value
90% confidence interval	1.64
95% confidence interval	1.96
99% confidence interval	2.58

The confidence interval provides a range that the true value of the CMF should fall within with some degree of certainty. For example, when using a 95% confidence interval, the analyst can claim with 95% confidence that the true value of the CMF falls within this range.

Using the confidence interval for the CMF can provide a more informed indication of the impact of a potential change or countermeasure on crash frequency. If the confidence interval contains the value 1.0, then there is not enough statistical evidence to conclude that applying the change will impact safety performance. If the confidence interval is strictly less than 1.0, the change or countermeasure is expected to reduce crash frequency. If the confidence interval is strictly greater than 1.0, the change or countermeasure is expected to increase crash frequency.

Unfortunately, some sources do not provide estimates of the standard errors associated with CMF point estimates. The point estimates of these CMFs provide a general indication of the expected change in crash frequency. However, if no standard error is provided, the true effects of these countermeasures could vary greatly from the point estimates and the analyst has no indication of the level of uncertainty associated with these estimates. These CMFs should be avoided if at all possible, since their application is unreliable. Instead, the analyst should seek to use CMFs that also provide standard errors, if they are available.

Each CMF is provided for a specific set of conditions (e.g., traffic volumes, roadway types, crash types and severity). These CMFs are only applicable to these specific conditions and should not be applied directly to other situations. There are several reasons for this. Many countermeasures only influence a subset of crash types and/or severities (e.g., shoulder rumble strips will likely reduce run-off-the-road crashes but should not significantly influence rear-end crashes). Therefore, the CMFs for these countermeasures are typically limited in their application to the set of crashes associated with that specific countermeasure. Other countermeasures may have different impacts in different driving environments (e.g., the effectiveness of intersection treatments often varies with the type of control and configuration of the intersection). In addition, CMFs are often only estimated with a subset of crash data (e.g., only using crash records that involve a fatality) and are therefore only useful to describe the influence of a countermeasure for these crash types. Nevertheless, in this case, CMF values can still serve as a guide that, along with engineering judgment, provides some indication of the expected change in crash frequency under alternative conditions, even if no CMFs are available for the specific alternative conditions.

Applying a Single CMF

An example is used to illustrate how to apply a single CMF to a particular site and how to interpret the results.

Example Problem: Consider a freeway segment in which the expected crash frequency is 10 crashes per year and 50% of these crashes are expected to involve a major injury. A highway engineer is considering installing shoulder rumble strips as a countermeasure to reduce total crash frequency. A CMF for major injury crashes is available for the installation of shoulder rumble strips on freeways. The CMF point estimate is 0.80 and the standard error is 0.08. The engineer would like to know the following: (1) would installing shoulder rumble strips help to reduce the number of crashes expected at this facility? And (2) how many total crashes should be expected after shoulder rumble strips are installed?

1) Would installing shoulder rumble strips help to reduce the number of crashes expected at this facility?

Since the point estimate of the CMF is less than 1.0, the engineer could conclude that the countermeasure is effective at reducing major crash frequency. However, the standard error of the estimate should be considered to make a more informed decision. The 95% confidence interval for the point estimate is equal to: $0.80 \pm 1.96 * 0.08$. Therefore, the engineer can be 95% confident that the true point estimate lies between 0.643 and 0.957. Since this entire confidence interval is below 1.0, the engineer could be 95% confident that the countermeasure should reduce crash frequency on this roadway by between $(1 - 0.957) * 100 = 4.3$ and $(1 - 0.643) * 100 = 35.7$ percent based on Equation 1.

Note that if a 99% confidence interval was used, the point estimate would fall between 0.594 and 1.01. In this case, the confidence interval contains the value 1.0, so the engineer could not be confident that the countermeasure would reduce the crash frequency on this roadway segment. However, for most practical purposes the 95% confidence interval is the most common confidence interval used in traffic safety analyses.

2) How many total crashes should be expected after shoulder rumble strips are installed?

The engineer could apply just the point estimate of the CMF to estimate the number of crashes after installing the countermeasure. Since the CMF applies only to all major injury crashes, it would only affect this specific subset of total crashes. In this case, there are only 5 expected major injury crashes (10 total * 50 percent major injury crashes) per year expected without the countermeasure. Therefore, the expected number of major injury crashes with the countermeasure is: $0.8 * 5 = 4$ major injury crashes. The total number of crashes expected for this segment when the countermeasure is applied would then be 9 crashes per year, which includes the 5 non-major injury crashes expected per year.

A more informed answer would also report the confidence interval for total number of crashes, which takes into account the error associated with the CMF. The answer to Question 1 indicates that the 95% confidence interval of the CMF estimate is between 0.643 and 0.957. This suggests that when the countermeasure is applied, the expected number of major injury crashes is between 3.22 and 4.79 crashes per year. Therefore, the total number of crashes expected should fall between 8.22 and 9.79 crashes per year when the 5 non-major injury crashes expected per year are included.

Applying Multiple CMFs

Special consideration must be given when applying multiple CMFs simultaneously at the same location. There are two scenarios that might exist when applying multiple CMFs:

- The CMFs impact different crash types
- The CMFs impact the same crash types

Each of the scenarios is discussed below.

<u>CMFs impacting different crash types</u>

This scenario can occur when multiple countermeasures are implemented simultaneously that impact different crash types or when a single countermeasure is implemented that has unique CMFs for different crash types. In this case, the CMFs are treated independently, since the effects of each are not likely to overlap and the full effects of the countermeasures are expected. Each CMF is then applied directly to the set of crashes that it influences in the manner discussed previously. Confidence intervals for the expected crash frequencies of the individual crash types created in this way are valid.

If the confidence interval for the total number of crashes is desired, the CMFs for the different crash types can be combined using the following formula, which relies on the fact that each crash type is treated independently:

CI for total crashes: $\sum_i N_i CMF_i \pm Z * \sqrt{\sum_i (N_i ERROR_i)^2}$, (Equation 3)

where N_i is the expected number of crashes (before the implementation of a countermeasure) for crash type i, CMF_i is the CMF applied to crash type i, $ERROR_i$ is the standard error of the CMF applied to crash type i, and Z is the value associated with the statistical significance of the confidence interval.

An example is used to demonstrate how to apply multiple CMFs for countermeasures that influence different crash types.

Example Problem: Consider the implementation of shoulder rumble strips and a median barrier at a particular site with a predicted crash frequency of 5 run-off-the-road crashes and 6 cross-median crashes (per year). A CMF is available for shoulder rumble strips, which applies to run-off-the-road crashes. The point estimate is 0.84 and the standard error is 0.08. Another CMF is available for median barriers, which applies to cross-median crashes. The point estimate is 0.35 and the standard error is 0.04. How many of each crash type should be expected if both countermeasures are installed? How many total crashes should be expected?

How many of each type of crash should be expected if both countermeasures are installed?

Since the two countermeasures influence different crash types, the two can be treated independently. The CMF for shoulder rumble strips will be applied to only the run-off-the-road crashes, while the CMF for median barriers will be applied to cross-median crashes. The 95% confidence interval for the rumble strips CMF is $0.84 \pm 1.96 * 0.08$ or 0.683 to 0.997. This is applied only to the run-off-the-road crashes. Therefore, the expected number of run-off-the-road crashes should fall somewhere between 3.42 and 4.99 run-off-the-road crashes per year after the shoulder rumble strips are applied to the site. Similarly, the 95% confidence interval for the CMF for median barriers is $0.35 \pm 1.96 * 0.04$ or 0.272 to 0.428, and the expected number of cross-median crashes should fall somewhere between 1.63 and 2.59 cross-median crashes per year after median barrier is installed to the site.

How many total crashes should be expected?

To determine the 95% confidence interval for the total expected number of crashes, Equation 3 can be directly applied. The confidence interval is $[5(0.84) + 6(0.35)] \pm 1.96 * \sqrt{(5 * 0.08)^2 + (6 * 0.04)^2} = 6.3 \pm 1.96 * 0.466$. This implies that the number of total crashes expected at this location should fall between 5.38 and 7.22 crashes per year after both countermeasures are installed. Notice that this confidence interval is not simply the sum of the confidence intervals for each crash type. This is because when aggregating multiple (independent) confidence intervals, the variability of the final sum decreases due to aggregation.

<u>CMFs impacting the same crash types</u>

This scenario occurs when multiple countermeasures are applied simultaneously at the same location that targets the same crash types. In this case, the analyst must first decide whether to treat the associated countermeasures as if they were independent or dependent.

Independent countermeasures are those with effects that are not expected to overlap and for which the full effects of each countermeasure should be expected. This is the less conservative assumption, since countermeasures that influence the same crash type would generally have overlapping effects. For these independent countermeasures, the current practice suggests that the CMFs be treated multiplicatively. That is, the combined effect is estimated as the product of the individual CMF point estimates, as shown in Equation 4:

$$CMF_C = \prod_i CMF_i, \qquad \text{(Equation 4)}$$

where CMF_i is the point estimate of each individual CMF i and CMF_C is the combined impact of the combination of multiple independent CMFs. In this case, the standard error of the individual CMFs cannot be directly used when applying multiple independent CMFs at a single location. Instead, a combined standard error must be estimated using the point estimates and standard errors of each individual CMF. As described in Lord (2008), this combined standard error is:

$$ERROR_C = \sqrt{\prod_i \left(CMF_i^2 + ERROR_i^2\right) - \left(\prod_i CMF_i\right)^2}, \qquad \text{(Equation 5)}$$

where CMF_i is the point estimate of each individual CMF i, $ERROR_i$ is the standard error of each individual CMF i, and $ERROR_C$ is the combined error of the product of the independent CMFs.

In general, conservative estimates and assumptions should be used when applying multiple independent CMFs simultaneously. Combining three or more CMFs using the above method is likely to significantly overestimate the true safety effects that can be expected from applying the respective countermeasures. Therefore, this methodology should be discouraged when three or more CMFs are required and another, more conservative method like the one described below, should be used instead.

Dependent countermeasures are those expected to have overlapping effects such that the combination of the multiple countermeasures may have different impacts than if the CMFs were applied in a multiplicative fashion. In this case, the true impacts of the combined countermeasures may be greater than, less than, or equal to the product of the CMFs. Since the combined effect of multiple dependent CMFs has not been thoroughly studied, it is usually best practice to assume that the combined effect is not as beneficial as would be expected if the countermeasures were independent. A conservative way to treat these dependent countermeasures is to identify a single CMF for application. The CMF selected should be either:

- the most effective CMF (i.e., the CMF with the lower point estimate) if all CMFs are expected to provide safety benefits, or
- the least effective CMF (i.e., the CMF with the highest point estimate) if one or more CMFs are expected to provide an increase in crash frequency.

In this case, the standard error of the selected CMF is used as the error of the combined treatment. This method is conservative because it is the equivalent of a worst-case analysis of the safety effects of the combined countermeasures and should not overestimate the safety benefits of combined countermeasures. If the combination of countermeasures is expected to provide additional benefits beyond the application of a single CMF, a value near the lower bound of the confidence interval for the single select CMF can be selected to account for the additional benefits. Other methods to estimate the combined CMF for multiple dependent countermeasures can be found in Gross et al. (2012).

In cases for which the analyst is unsure whether the countermeasures are independent or dependent, the combined influence of the multiple CMFs should be determined using both methods to provide a range of potential effects. The independent method would provide an upper bound for the expected safety benefits of the combined countermeasures, while the dependent analysis would provide a lower bound. Engineering judgment can then be used to select the most appropriate value from this range.

An example is used to illustrate how to apply multiple CMFs for countermeasures that influence the same crash types, including how to interpret the results.

Example Problem: Consider a two-lane rural roadway segment in which the crash frequency is expected to be 10 crashes per year. A highway engineer is considering installing edgeline rumble strips and paved shoulders as countermeasures to reduce crash frequency. CMFs are available for both countermeasures: the CMF for edgeline rumble strips (total crashes) is 0.80 with a standard error of 0.08 and the CMF for paved shoulders (total crashes) is 0.58 with a standard error of 0.054. The engineer would like to know how many crashes should be expected if these two countermeasures are applied simultaneously: (1) assuming they are independent countermeasures, and (2) assuming they are dependent countermeasures. If the engineer is not sure of the combined effects, what is the most appropriate estimate to use?

How many crashes should be expected if both countermeasures are applied simultaneously, assuming the countermeasures are independent?

Equation 3 can be used to determine the point estimate for the combination of these countermeasures assuming independence. The point estimate of the combined effect of both countermeasures will be a product of the two CMFs and equal to $0.80 * 0.58 = 0.464$. The error associated with this point estimate can be estimated using Equation 4: $\sqrt{(0.80^2 + 0.08^2) * (0.58^2 + 0.054^2) - (0.80 * 0.58)^2} = 0.064$. Therefore, the 95% confidence interval for the combined effect of the two countermeasures is: $0.464 \pm 1.96 * 0.064$, which implies that the estimate of the combined countermeasures lies between 0.339 and 0.589. The estimate of total number crashes per year would then be between 3.39 and 5.89 after installing both countermeasures at the site.

How many crashes should be expected if both countermeasures are applied simultaneously, assuming the countermeasures are dependent?

If these two countermeasures are dependent, the conservative approach would be to apply only the CMF associated with the most effective countermeasure, since both are expected to provide safety benefits. In this case, paved shoulders is the most effective countermeasure, since the point estimate of the CMF of paved shoulders is lower than the point estimate for the CMF of edgeline rumble strips. Therefore, the point estimate applied will be 0.58. The standard error of 0.054 for this point estimate is also used. The 95% confidence interval for this combined treatment, using a conservative approach, is $0.58 \pm 1.96 * 0.054$, which implies that the estimate of the combined countermeasures conservatively lies between 0.474 and 0.686. The estimate of total number of crashes per year is between 4.74 and 6.86. This range is higher than the range obtained when assuming the two countermeasures are independent because the independence assumption is generally not conservative.

What is the most appropriate estimate to use?

To determine the most appropriate estimate of crashes after the combined implementation of both countermeasures, the countermeasures being applied must be considered. Both edgeline rumble strips and paved shoulders are typically implemented to prevent run-off-the-road crashes and are likely to have dependent effects. For example, implementing edgeline rumble strips on a roadway segment that already has a paved shoulder might not be as effective as implementing edgeline rumble strips on a roadway segment without a shoulder, since the shoulder would already mitigate some of the run-off-the-road crashes. However, the combined effects of both countermeasures should be more than just paved shoulders alone, because edgeline rumble strips can alert a driver that the driven vehicle is departing the travel lane while the shoulder provides additional space and time for the vehicle to recover. Thus, it might be appropriate to use the conservative approach, but select an estimate of the number of crashes closer to the lower bound to capture the additional benefit of combining the countermeasure. In this case, a value near 5 crashes per year may be appropriate if the combined effects are expected to be significant.

Assessing the Quality of a CMF

Only "high-quality" CMFs are included in this guide for application within the Commonwealth of Pennsylvania. The star quality rating system proposed by the FHWA CMF Clearinghouse and documented on its website (http://www.cmfclearinghouse.org/) was used to assess the quality of each of the CMFs identified. This system assigns each CMF with a numerical value on a scale of 1 to 5, where 5 is the most reliable or highest-quality rating. The ratings are determined based on five properties of the CMF and the study used to estimate its value, including the:

- Study design,
- Sample size,
- Standard error,
- Potential bias, and
- Data source.

Each of these properties is assigned a point value based on the level of rigor. Table 2 (modified slightly from the CMF Clearinghouse website) provides a guideline for assigning point values for each of these properties. These points are then used to assign each CMF an aggregate score using the following equation:

$$\begin{aligned} &Aggregate\ CMF\ Score \\ &\quad = (2 * Study\ Design\ Score) + (2 * Sample\ Size\ Score) + Standard\ Error\ Score \\ &\quad + Potential\ Bias\ Score + Data\ Source\ Score \end{aligned}$$

(Equation 5)

Table 2. Guidelines for assigning points in the CMF star quality rating system

Property	Excellent (2 points)	Fair (1 point)	Poor (0 points)
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	Small (when compared to 1-CMF value)	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., CA)	Limited to one jurisdiction in one state

The final star rating is assigned based on the aggregate CMF score using Table 3.

Table 3. CMF score to star rating conversion

Aggregate CMF Score	Star Rating
14 (max possible)	5 Stars
11 – 13	4 Stars
7 – 10	3 Stars
3 – 6	2 Stars
1 – 2	1 Star
0	0 Stars

High-quality CMFs were determined to be those having a star rating of 3 or higher. The threshold of 3 stars was selected for the following reasons: it provides a relatively large list of CMFs, since the majority of CMFs in the CMF Clearinghouse are rated 3 stars; it is consistent with the HSM, since the CMFs provided in the HSM are almost all rated 3 stars or higher; and it ensures that any CMF with a poor rating for one or more properties also has other properties with an excellent rating (especially for study design and sample size).

Using the CMF Guide

In this guide, CMFs are categorized by the CMF type used in the FHWA CMF Clearinghouse website. This categorization was chosen for consistency so that a user can easily identify additional CMF details using the website (http://www.cmfclearinghouse.org/).

The categories used are:

- Access Management
- Advanced Technology and ITS
- Alignment
- Bicyclists
- Delineation
- Highway Lighting
- Interchange Design
- Intersection Geometry
- Intersection Traffic Control
- On-Street Parking
- Pedestrians
- Railroad Grade Crossings
- Roadside Features
- Roadway Features
- Shoulder Treatments
- Signs
- Speed Management
- Transit
- Work Zones

A separate CMF table is provided for each of the categories listed above; see Tables A through S at the end of this guide. Note that individual countermeasures are not duplicated across tables and an analyst might have to check multiple tables to find a specific countermeasure. For example, CMFs for countermeasures at intersections with rail crossings can be found in both Tables I (Intersection Traffic Control) and L (Railroad Grade Crossings).

Each of these tables contains the following information:

- Description of the highway change or countermeasure,
- Conditions for which the CMF is applicable,
- Point estimate and standard error of the CMF,
- Star quality rating as determined from the FHWA CMF Clearinghouse methodology, and
- Location of crash data used to estimate the CMF.

The "Countermeasure" column provides a brief description of the change or countermeasure considered. Most countermeasures contain multiple CMF point estimates and standard errors, each associated with a different set of conditions provided in the "Area Type," "Severity," "Crash Type," "AADT Range," and "Implementation Notes" columns. A description of common abbreviations used in the CMF tables for Area Type, Severity and Crash Type is provided in Tables 4 through 6. The Implementation Notes column includes additional factors depending on the nature of the countermeasure (e.g., number of lanes or speed limit). CMFs can only be confidently applied to the set of conditions for which they are associated. Blank cells in Tables A through S for Area Type, Severity, Crash Type, and AADT Range indicate that this information was not specified or readily available. These CMFs should be applied more cautiously than those for which the conditions are provided. CMFs with different conditions than desired might serve as a guide for applying a CMF to the situation of interest. However, an analyst should use conservative and careful engineering judgment when applying these estimates under different conditions.

Table 4. Description of common Area Type abbreviations

Abbreviation	Description
Urban	Urban roadways only
Urban/Suburban	Urban and suburban roadways only
Rural	Rural roadways only

Table 5. Description of common Severity abbreviations

Abbreviation	Description
All	All crash severities
Fatal	Fatal crashes
Incapacitating Injury	Fatal and serious injury crashes
Fatal and Injury	Fatal, serious injury, and minor injury crashes
Injury	Serious injury and minor injury crashes
Serious Injury	Serious injury crashes
Minor Injury	Minor injury crashes
Injury and PDO	Serious injury, minor injury, and property damage only crashes
Minor and PDO	Minor injury and property damage only crashes
PDO	Property damage only crashes

Table 6. Description of common Crash Type abbreviations

Abbreviation	Description
All	All crash types
Angle	Angle crashes only
Cross median	Cross median crashes only
Daytime	Daytime crashes only
Fixed object	Fixed object crashes only
Head-on	Head-on crashes only
Intersection	Intersection related crashes only
Left-turn	Left-turn crashes only
Motorcycle	Motorcycle related crashes only
Multiple vehicle	Multiple vehicle crashes only
Nighttime	Nighttime crashes only
Non-intersection	Non-intersection crashes only
Non-summer	Non-summer period crashes only
Non-winter	Non-winter period crashes only
Parking related	Parking related crashes only
Rear-end	Rear-end crashes only
Right-turn	Right-turn crashes only
Run-off-road	Run-off-road crashes only
Shoulder	Shoulder related crashes only
Sideswipe	Sideswipe crashes only
Single vehicle	Single vehicle crashes only
Speed	Speed related crashes only
Summer	Summer period crashes only
Truck related	Truck related crashes only
Vehicle/bicycle	Vehicle/bicycle crashes only
Vehicle/pedestrian	Vehicle/pedestrian crashes only
Wet road	Wet road crashes only
Winter	Winter period crashes only

The "CMF" column contains the point estimate and standard error of the CMF. In some cases, multiple CMFs are provided for the same set of conditions. In such cases, the CMF highlighted in green is the most appropriate estimate to use. This value was selected by considering the star rating, point estimate, standard error, and study methodology. The other estimates are still provided to give the user of this guide an indication of the range of potential impacts that this highway change or countermeasure may have. One of these other CMFs may be applied only if sufficient justification is provided for its use.

The “Point Estimate” column generally provides the numerical value of the point estimate of the CMF for that countermeasure. However, in some instances an equation or formula is used to estimate the point estimate of the CMF. The equations are designated in the tables as “EQN X,” and the functional form of the equations are provided in Table T at the end of this guide. The information in Table T provides the relevant variables that should be used to estimate the numerical value of the CMF.

The next column of each table contains a value indicating the quality of the CMF using the star quality rating system developed by the FHWA CMF Clearinghouse. As previously described, only CMFs with a 3-star rating or higher are included in this guide. Of these, CMFs with star quality ratings of 4 and 5 are generally those that were estimated using a better study design, include a larger sample size of sites/crashes, have a lower standard error of the point estimate, have less potential bias in the estimate, and contain data from a wider range of sources. In general, these CMFs should be trusted more than CMFs with star quality ratings of 3.

The final column labeled “State” lists the set of states (when reported) from which crash data were obtained to estimate the CMF. The bolded CMFs in each table represent those for which Pennsylvania crash data were used to estimate the point estimate and standard error of the CMF. These CMFs might be more appropriate for application in Pennsylvania, especially in cases where significant variation exists for multiple CMFs provided for the same set of conditions.

The low-quality CMFs are provided in the same basic format at the conclusion of this report. However, these CMFs are not recommended for use in Pennsylvania due to their low quality.

A series of examples are used to demonstrate how to use this guide.

Example Problem 1: A raised median is being considered on a 4-lane road in a suburban region. What change in property damage only (PDO) crashes are expected after this countermeasure is implemented?

To determine the expected change in crashes, the CMF for this scenario needs to be determined. The countermeasure “Provide a raised median” is included in Table A: Access Management. In this table, nearly 60 CMF estimates are included for this countermeasure. However, the “Area Type” and “Crash Severity” columns can be used to identify only those that influence suburban roadway segments and PDO crashes. This narrows the list of CMFs to 7 values. Since the crash type is not specified in the problem, only the CMFs provided for all crash types should be considered, which further narrows the list to 4 CMFs. Each of these has different implementation conditions under the “Implementation Notes” column. Of these four, only one CMF is applicable to 4-lane roadway segments. This CMF should be used. Therefore, the CMF selected should have a point estimate of 0.742 and standard error of 0.034. The 95% confidence interval is $0.742 \pm 1.96 * 0.034$, or between 0.675 and 0.809. This suggests a reduction in PDO crashes of between 19.1% and 32.5%.

Example Problem 2: Centerline rumble strips are being considered on a rural roadway segment in Pennsylvania. What is the most appropriate CMF to use in this scenario to estimate the impact on the total number of crashes?

The countermeasure “Install centerline rumble strips” is included in Table N: Roadway Features. 32 CMFs are provided for this countermeasure, and 28 of them pertain to rural roadway segments. Since total crashes are of interest, all crash types and crash severities should be considered. This reduces the list to 6 CMFs. However, there are no other differentiating characteristics of these 6 CMF estimates. Since no other information is provided, the most appropriate choice is to select the recommended value that has been highlighted. This CMF has a point estimate of 0.91 and a standard error of 0.02. Since the CMF is also bolded, the data used to estimate the CMF came from Pennsylvania, which further validates this selection.

If the analyst has a strong suspicion that centerline rumble strips would be less effective than average at this particular location, then the following two options are available: the analyst can either elect to use a point estimate closer to the upper bound of the confidence interval provided by the CMF chosen above or choose another CMF with a slightly higher point estimate.

Example Problem 3: A CMF is desired to estimate the effect of increasing the retroreflectivity of white edgelines from 100 to 200 mcd/m^2/lux. The effect on all crash types is desired. What is the most appropriate point estimate to use?

The countermeasure “Increase pavement marking retroreflectivity of white edgelines from X to Y mcd/m^2/lux” is included in Table E: Delineation. The point estimate is obtained using Equation 5-6 from the set of equations following this table. The equation has the following functional form:

$CMF = e^{-0.001(Y-X)}$,

where X and Y are the before and after retroreflectivity of the white edgelines in units of mcd/m^2/lux. In this particular case, $X = 100$ mcd/m^2/lux and $Y = 200$ mcd/m^2/lux. Therefore, the CMF point estimate is:

$CMF = e^{-0.001(200-100)} = 0.905.$

Unfortunately, standard errors are not available in cases in which equations are used to obtain the point estimate. Therefore, the CMF point estimate of 0.905 should be used with caution, as there is no indication of the level of uncertainty associated with this value.

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Table A. Access Management

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Provide a raised median		All	All	10000 - 55000		0.61		4	UT
		Incapacitating injury	All	10000 - 55000		0.56		4	UT
	Urban	Fatal and injury	All			0.61	0.06	4	
		Injury	All			0.78	0.02	5	
		PDO	All			1.09	0.01	5	
		All	All	1390 - 51200		0.29	0.184	3	UT
					2 lanes, less than 45 mph speed limit	0.86		3	NJ
			Angle	1390 - 51200		0.45	0.125	3	UT
	Urban/Suburban	Fatal and injury	All	10500 - 57000	2, 4, 6 lanes	0.66	0.028	3	FL
				26224 - 57000	6 lanes	0.582	0.029	3	FL
					35, 40 mph speed limit	0.654	0.086	3	FL
					45, 50, 55 mph speed limit	0.695	0.031	3	FL
			Angle	10500 - 57000		0.641	0.07	3	FL
			Left-turn	10500 - 57000		0.294	0.035	3	FL
			Rear-end	10500 - 57000		0.776	0.051	3	FL
		Injury	All	10500 - 57000	2, 4, 6 lanes	0.659	0.028	3	FL
				26224 - 57000	6 lanes	0.58	0.029	3	FL
					35, 40 mph speed limit	0.643	0.085	3	FL
					45, 50, 55 mph speed limit	0.695	0.031	3	FL
			Angle	10500 - 57000		0.64	0.07	3	FL
			Left-turn	10500 - 57000		0.295	0.035	3	FL
			Rear-end	10500 - 57000		0.777	0.051	3	FL
		PDO	All	10500 - 57000	2, 4, 6 lanes	0.742	0.034	3	FL
				26224 - 57000	6 lanes	0.684	0.036	3	FL
					35, 40 mph speed limit	0.712	0.094	3	FL
					45, 50, 55 mph speed limit	0.783	0.037	3	FL
			Angle	10500 - 57000		0.544	0.065	3	FL
			Left-turn	10500 - 57000		0.397	0.058	3	FL
			Rear-end	10500 - 57000		0.896	0.063	3	FL
		All	All	10500 - 57000	2, 4, 6 lanes	0.697	0.022	3	FL
				26224 - 57000	6 lanes	0.628	0.022	3	FL
					35, 40 mph speed limit	0.682	0.064	3	FL
					45, 50, 55 mph speed limit	0.735	0.024	3	FL
			Angle	10500 - 57000	2, 4, 6 lanes	0.595	0.048	3	FL
				18340 - 50925	6 lanes	0.732	0.124	3	FL
				26224 - 57000	35, 40 mph speed limit	0.558	0.051	3	FL
					45, 50, 55 mph speed limit	0.647	0.054	3	FL
			Daytime	26224 - 57000	6 lanes	0.564	0.025	3	FL
					35, 40 mph speed limit	0.639	0.072	3	FL
					45, 50, 55 mph speed limit	0.684	0.027	3	FL
			Left-turn	10500 - 57000	2, 4, 6 lanes	0.329	0.03	3	FL
				18340 - 50925	6 lanes	0.664	0.126	3	FL
				26224 - 57000	35, 40 mph speed limit	0.262	0.029	3	FL
					45, 50, 55 mph speed limit	0.348	0.033	3	FL
			Nighttime	26224 - 57000		0.859	0.061	3	FL
					45, 50, 55 mph speed limit	0.625	0.119	3	FL
			Other	26224 - 57000		0.827	0.081	3	FL
			Rear-end	10500 - 57000	2, 4, 6 lanes	0.83	0.04	3	FL
				26224 - 57000	6 lanes	0.742	0.041	3	FL
					35, 40 mph speed limit	0.756	0.1	3	FL
					45, 50, 55 mph speed limit	0.881	0.045	3	FL
			Right-turn	10500 - 57000	2, 4, 6 lanes	0.661	0.119	3	FL
					45, 50, 55 mph speed limit	0.663	0.125	3	FL
			Sideswipe	10500 - 57000	2, 4, 6 lanes	0.83	0.101	3	FL
					45, 50, 55 mph speed limit	0.818	0.106	3	FL
			Vehicle/pedestrian	10500 - 57000		0.711	0.139	3	FL
	Rural	Injury	All			0.88	0.03	5	
		PDO	All			0.82	0.02	5	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Replace TWLTL with raised median	Urban	All	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 96080		0.77	0.0616	3	NV
			Angle	4883 - 96080		0.65	0.0728	3	NV
			Rear-end	4883 - 96080		0.81	0.0684	3	NV
			Sideswipe	4883 - 96080		0.79	0.0822	3	NV
			Head-on	4883 - 96080		0.53	0.1473	3	NV
		Injury	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 96080		0.79	0.0721	3	NV
		PDO	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 96080		0.67	0.0692	3	NV
Increase intersection median width by 3 ft increments	Rural	Fatal and injury	Multiple vehicle			0.96	0.02	5	
		All	Multiple vehicle			0.96	0.02	5	
	Urban/Suburban	Fatal and injury	Multiple vehicle		Stop-controlled	1.05	0.01	5	
					Signalized	1.03	0.01	5	
		All	Multiple vehicle		4-leg, Stop-controlled	1.06	0.01	5	
					3-leg, Stop-controlled	1.03	0.01	5	
					4-leg, Signalized	1.03	0.18	5	
Convert a 10-ft traversable median to a 20-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.86	0.02	5	
				1000 - 90000	Partial access control	0.84	0.03	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.89	0.04	5	
				2600 - 282000	5 lanes or more, Full access control	0.89	0.04	5	
				1900 - 150000	4 lanes, Partial access control	0.87	0.04	5	
		All	Multiple vehicle			0.91		4	CA,KY,MN
Convert a 10-ft traversable median to a 30-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.74	0.04	5	
				1000 - 90000	Partial access control	0.71	0.06	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.8	0.07	5	
				2600 - 282000	5 lanes or more, Full access control	0.79	0.07	5	
				1900 - 150000	4 lanes, Partial access control	0.76	0.06	5	
		All	Multiple vehicle			0.83		4	CA,KY,MN
Convert a 10-ft traversable median to a 40-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.63	0.05	5	
				1000 - 90000	Partial access control	0.6	0.07	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.71	0.09	5	
				2600 - 282000	5 lanes or more, Full access control	0.71	0.1	5	
				1900 - 150000	4 lanes, Partial access control	0.67	0.08	5	
		All	Multiple vehicle			0.75		4	CA,KY,MN
Convert a 10-ft traversable median to a 50-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.54	0.06	5	
			Cross median	1000 - 90000	Partial access control	0.51	0.08	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.64	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.63	0.1	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.59	0.1	5	
		All	Multiple vehicle			0.68		4	CA,KY,MN
Convert a 10-ft traversable median to a 60-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.46	0.07	5	
			Cross median	1000 - 90000	Partial access control	0.43	0.09	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.57	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.56	0.1	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.51	0.1	5	
		All	Multiple vehicle			0.62		4	CA,KY,MN

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality	State
						Value	Std. Err	Rating	
Convert a 10-ft traversable median to a 70-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.4	0.07	5	
			Cross median	1000 - 90000	Partial access control	0.36	0.09	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.51	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.5	0.1	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.45	0.1	5	
		All	Multiple vehicle			0.57		4	CA,KY,MN
Convert a 10-ft traversable median to a 80-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.34	0.07	5	
			Cross median	1000 - 90000	Partial access control	0.31	0.09	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.46	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.45	0.1	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.39	0.1	5	
		All	Multiple vehicle			0.51		4	CA,KY,MN
Convert a 10-ft traversable median to a 90-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.29	0.07	5	
			Cross median	1000 - 90000	Partial access control	0.26	0.08	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.41	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.4	0.2	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.34	0.1	5	
Convert a 10-ft traversable median to a 100-ft traversable median	Rural		Cross median	2400 - 119000	Full access control	0.25	0.06	5	
			Cross median	1000 - 90000	Partial access control	0.22	0.08	5	
	Urban		Cross median	4400 - 131000	4 lanes, Full access control	0.36	0.1	5	
			Cross median	2600 - 282000	5 lanes or more, Full access control	0.35	0.2	5	
			Cross median	1900 - 150000	4 lanes, Partial access control	0.3	0.1	5	
Decrease freeway ramp spacing from infinity to S (ft) with or without auxiliary lane		All		5134 - 153500		Eqn. 1- 55		4	CA,WA
			Multiple vehicle	5134 - 153500		Eqn. 1- 56		4	CA,WA
		Fatal and injury		5134 - 153500		Eqn. 1- 57		4	CA,WA
Decrease median width from 64 ft to 22 ft	Urban	All	All	5700 - 309000		3.629	0.404	3	FL
			Rear-end	5700 - 309000		5.732	0.673	3	FL
			Sideswipe	5700 - 309000		4.184	0.434	3	FL
		Fatal and injury	All	5700 - 309000		3.227	0.329	3	FL
Decrease median width from 64 ft to 40 ft	Urban	All	All	5700 - 309000		1.071	0.126	3	FL
			Rear-end	5700 - 309000		1.43	0.222	3	FL
			Sideswipe	5700 - 309000		1.151	0.14	3	FL
		Fatal and injury	All	5700 - 309000		1.073	0.099	3	FL
Replace direct left-turn with right-turn/U-turn		Fatal and injury	All	0 - 34000	4, 6, 8 lanes	0.64	0.39	3	
				0 - 34000		0.38	0.21	3	
				0 - 34000	6 lanes	0.69	0.17	3	
				0 - 34000	4, 6, 8 lanes	0.89	0.37	3	
		PDO		0 - 34000		0.56	0.2	3	
				0 - 34000	6 lanes	0.95	0.13	3	
		All		0 - 34000	4, 6, 8 lanes	0.8	0.28	4	
				0 - 34000	4, 6, 8 lanes	0.49	0.15	3	
				0 - 34000	6 lanes	0.86	0.21	3	
			Angle	0 - 34000	4, 6, 8 lanes	0.64	0.25	3	
				0 - 34000	6 lanes	0.67	0.22	3	
			Rear-end	0 - 34000	4, 6, 8 lanes	0.84	0.25	3	
				0 - 34000	6 lanes	0.91	0.05	3	
Restrict left or right-turns	Urban	All	Transit-related			0.72	0.113	3	notusa
			Transit-serviced locations			0.96	0.01	3	notusa
						0.87	0.02	3	notusa
Increase separation distance between driveway exit and downstream U-turn by 10% (m)		All	All	18200 - 86300		0.967	0.0118	3	FL
			Related to in-direct left-turns	18200 - 86300		0.955	0.013	3	FL

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Change in driveway density from X to Y driveways per mile	Rural	All	All		2 lanes	Eqn. 1- 1		3	TX
		Fatal and injury				Eqn. 1- 2		3	TX
	Urban	All	Angle	29320 - 96080	Divided with median	Eqn. 1- 3		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 4		3	NV
			Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 5		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 6		3	NV
			Fixed object,Run off road,Single vehicle	4883 - 71280	Divided with TWLTL	Eqn. 1- 7		3	NV
			Rear-end	29320 - 96080	Divided with median	Eqn. 1- 8		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 9		3	NV
			Sideswipe	4883 - 71280	Divided with TWLTL	Eqn. 1- 10		3	NV
		PDO	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 11		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 12		3	NV
		Injury	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 13		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 14		3	NV
Change in driveway density from 48 to 26-48 driveways per mile	Urban/Suburban	Injury	All			0.71	0.02	5	
Change in driveway density from 26-48 to 10-24 driveways per mile	Urban/Suburban	Injury	All			0.69	0.03	5	
Change in driveway density from 10-24 to <10 driveways per mile	Urban/Suburban	Injury	All			0.75	0.02	5	
Increase freeway on-ramp density from 0 to 1 ramps per mile (total in both directions)	Urban	Fatal and injury	All		8 lanes	1.05	0.02	3	TX
					4 lanes	1.047	0.027	3	TX
	All	Fatal and injury	All			1.033	0.012	3	TX
						1.04	0.016	3	TX
						1.023	0.018	3	TX
Increase freeway on-ramp density from 0 to 5 ramps per mile (total in both directions)	Urban	Fatal and injury	All		8 lanes	1.279	0.12	3	TX
					4 lanes	1.256	0.164	3	TX
	All	Fatal and injury	All			1.174	0.069	3	TX
						1.217	0.094	3	TX
						1.12	0.098	3	TX
Increase freeway on-ramp density from 0 to 10 ramps per mile (total in both directions)	Urban	Fatal and injury	All		8 lanes	1.636	0.31	3	TX
					4 lanes	1.578	0.415	3	TX
	All	Fatal and injury	All			1.379	0.1617	3	TN
						1.48	0.229	3	TX
						1.25	0.22	3	TX
Increase freeway on-ramp density from X to Y ramps per mile (total in both directions)	Urban	Fatal and injury	All		8 lanes	Eqn. 1- 15		3	TX
					4 lanes	Eqn. 1- 16		3	TX
	All	Fatal and injury	All			Eqn. 1- 17		3	TX
Increase freeway on-ramp density from X to Y ramps per mile (total in both directions) (curve sections)	All	Fatal and injury	All			Eqn. 1- 18		3	TX
Increase freeway on-ramp density from X to Y ramps per mile (total in both directions) (tangents)	All	Fatal and injury	All			Eqn. 1- 19		3	TX
Change in signal spacing from X 1000's feet to Y 1000's feet	Urban	All	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 20		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 21		3	NV
			Fixed object,Run off road,Single vehicle	4883 - 71280	Divided with TWLTL	Eqn. 1- 22		3	NV
			Rear-end	29320 - 96080	Divided with median	Eqn. 1- 23		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 24		3	NV
			Sideswipe	29320 - 96080	Divided with median	Eqn. 1- 25		3	NV
		PDO	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 71280	Divided with TWLTL	Eqn. 1- 26		3	NV

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Change in unsignalized cross roads from X to Y unsignalized cross roads per mile	Urban	All	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 71280	Divided with TWLTL	Eqn. 1- 27		3	NV
			Fixed object,Run off road,Single vehicle	29320 - 96080	Divided with Median	Eqn. 1- 28		3	NV
			Head-on	4883 - 71280	Divided with TWLTL	Eqn. 1- 29		3	NV
			Rear-end	4883 - 71280	Divided with TWLTL	Eqn. 1- 30		3	NV
			Sideswipe	29320 - 96080	Divided with Median	Eqn. 1- 31		3	NV
				4883 - 71280	Divided with TWLTL	Eqn. 1- 32		3	NV
		Injury	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	4883 - 71280	Divided with TWLTL	Eqn. 1- 33		3	NV
Change in median opening density from X to Y median openings	Urban	All	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 34		3	NV
			Angle	29320 - 96080	Divided with median	Eqn. 1- 35		3	NV
			Head-on	29320 - 96080	Divided with median	Eqn. 1- 36		3	NV
		Injury	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 37		3	NV
		PDO	Angle,Fixed object,Head-on,Rear-end,Run off road,Sideswipe,Single vehicle	29320 - 96080	Divided with median	Eqn. 1- 38		3	NV
Implement home zone design in residential neighborhoods		All	All		Home zones, or shared spaces, are streets designed to be shared by vehicles and pedestrians. Home zones may include: entrance treatments, shared vehicle and pedestrian space, traffic calming, on-street parking, streetscaping, social space, and interface between buildings and roads.	0.71	0.13	3	
Install wide median (>2 m) on major road of a 4-leg signalized intersection	Urban	All	Motorcycle			1.2		3	notusa
Add markings to the major approach of unsignalized 3-leg intersection to serve as a median	All	All	All			0.7	0.1385	3	FL
Convert an open median to a mixed median on the major approach to a 3-leg unsignalized intersection	All	All	All			0.95	0.133	3	FL
Convert an open median to an undivided median on the major approach to an unsignalized 3-leg intersection	All	All	All			0.85	0.083	3	FL
Convert an open median to a closed median on the major approach to unsignalized 3-leg intersection	All	All	All			1.02	0.1106	3	FL
Convert an open median to a TWLTL		All	All			1.45	0.21	3	FL
Convert an open median to a directional median on the major approach of an unsignalized 3-leg intersection	All	All	All			0.86	0.1297	3	FL
Convert an open median to a directional median	Urban/Suburban	Incapacitating injury	All	27000 - 96000		0.76	0.0548	4	FL
		Fatal and injury	All	27000 - 96000		0.77	0.0632	4	FL
		Major injury	All	27000 - 96000		0.82	0.0632	4	FL
		Minor injury	All	27000 - 96000		0.82	0.0894	4	FL
		PDO	All	27000 - 96000		1.13	0.1703	3	FL
		All	All	27000 - 96000		0.93	0.1095	3	FL
			Left-turn	27000 - 96000		0.43	0.0447	3	FL
Convert an open median to a left-in only median	Urban/Suburban	Fatal and injury	All	45000 - 75000		0.93	0.2429	3	FL
		Minor injury	All	45000 - 75000		0.8	0.2236	3	FL
		PDO	All	45000 - 75000		1.13	0.2324	3	FL
		All	All	45000 - 75000		0.95	0.2258	3	FL
		All	Left-turn	45000 - 75000		0.55	0.1183	3	FL
Change the natural log of the upstream distance to the nearest signalized intersection from an unsignalized 3-leg intersection from X to Y	All	All	All			Eqn. 1- 39		3	FL

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Change the natural log of the downstream distance to the nearest signalized intersection for an unsignalized 3-leg intersection from X to Y	All	All	All			Eqn. 1- 40		3	FL
Change the natural log of the downstream distance to the nearest signalized intersection for an unsignalized 4-leg intersection from X to Y	All	All	All			Eqn. 1- 41		3	FL
Change the natural log of the distance between two consecutive unsignalized intersection	All	All	All			Eqn. 1- 42		3	FL
Presence of grade-separated interchange	All	Fatal	All	1094 - 213544	Compared to no access points	1.77	0.78	3	notusa
		Injury	All	1094 - 213544	Compared to no access points	1.02	1.91	3	notusa
Presence of parking entrances	Urban/Suburban	All	Vehicle/bicycle			1.01		3	notusa
Presence of median	Urban/Suburban	All	Vehicle/bicycle			0.97		3	notusa
Absence of access points	Urban	All	All			0.56	0.27	3	notusa
Change number of 3-leg intersections from X to Y	Urban	All	Angle,Cross median,Fixed object,Head-on,Left-turn,Non-intersection,Parking related,Rear-end,Rear to rear,Right-turn,Run off road,Sideswipe,Single vehicle,Truck related		Census block group area	Eqn. 1- 43		3	TX
			Angle,Cross median,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe		Census block group area	Eqn. 1- 44		3	TX
			Fixed object		Census block group area	Eqn. 1- 45		3	TX
			Parking related		Census block group area	Eqn. 1- 46		3	TX
			Vehicle/bicycle		Census block group area	Eqn. 1- 47		3	TX
			Vehicle/pedestrian		Census block group area	Eqn. 1- 48		3	TX
Change number of 4-leg intersections from X to Y	Urban	All	Angle,Cross median,Fixed object,Head-on,Left-turn,Non-intersection,Parking related,Rear-end,Rear to rear,Right-turn,Run off road,Sideswipe,Single vehicle,Truck related		Census block group area	Eqn. 1- 49		3	TX
			Angle,Cross median,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe		Census block group area	Eqn. 1- 50		3	TX
			Fixed object		Census block group area	Eqn. 1- 51		3	TX
			Parking related		Census block group area	Eqn. 1- 52		3	TX
			Vehicle/bicycle		Census block group area	Eqn. 1- 53		3	TX
			Vehicle/pedestrian		Census block group area	Eqn. 1- 54		3	TX
Install median on the minor approach of an unsignalized 3-leg intersection	All	All	All			0.82	0.0903	3	FL
Convert a 3-leg unsignalized intersection at a driveway to a regular 3-leg unsignalized intersection	All	All	All			1.41	0.1095	3	FL
Add Two-Way-Left-Turn-Lane (TWLTL) to the major approach of an unsignalized 3-leg intersection	All	All	All			0.69	0.0894	3	FL
Add Two-Way-Left-Turn-Lane (TWLTL) to the major approach of an unsignalized 4-leg intersection	All	All	All			0.66		3	FL
Convert frontage road from two-way operation to one-way operation		All	Rear-end			0.27		3	TX
		Fatal and injury	All			0.43		3	TX
		Minor injury	All			0.32		3	TX
			All			0.46		3	TX

Table B. Advanced Technology and ITS

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install red-light cameras at intersections	Urban	Fatal	Red light running crashes			0.76		4	CA,MD,AZ,IL,TX,OR,NC,OH,DC,AK,VA,CO,AL,ID,MA,NY,MI,IN
		Injury	Angle,Left-turn			0.84	0.07	4	
			Rear-end			1.24	0.14	4	
		All	All			0.6		3	IA
					3-leg intersection, Camera on major road	0.45		3	notusa
			Angle			0.75	0.03	5	
						0.67	0.08	4	
			Rear-end			1.15	0.04	5	
						1.45	0.11	4	
						1.18	0.03	5	
			Other			0.74	0.03	5	
			Motorcycle		4-leg intersection, Camera on major road	0.63		3	notusa
					4-leg intersection, Camera on minor road	0.75		3	notusa
	All	All	All			0.9		3	TX
						0.76		3	TX
						0.73		3	TX
						0.71		3	TX
						0.72		3	TX
						0.7		3	TX
						0.84		3	TX
						0.76		3	TX
			Angle			0.74		3	TX
						0.61		3	TX
						0.57		3	TX
						0.69		3	TX
						0.78		3	TX
						0.68		3	TX
			Rear-end			2.69		3	TX
						2.06		3	TX
						0.77		3	TX
		All	All			0.8		4	IA
						1.15	0.1046	3	
						0.54	0.17	4	
						1.15	0.1046	3	
			Angle			0.1	0.1276	3	
						0.54		4	notusa
			Rear-end			1.43	0.1276	4	
						1.15		4	notusa
		Fatal and injury	Rear-end			1.13	0.1352	3	
Install red-light cameras with warning signs at all camera locations		Injury	Angle			0.57	0.031	3	
		All	Rear-end			1.46	0.13	3	
Install red-light cameras with warning signs at some locations		All	Angle			0.75	0.028	3	
			Rear-end			1.15	0.031	3	
		Injury	Rear-end			1.24	0.13	3	
Media coverage of automated speed enforcement cameras		All	All			0.92	0.06	3	NC
		Fatal and injury	All			0.9	0.12	3	NC
		PDO	All			0.91	0.11	3	NC
Removal of automated speed enforcement cameras		All	All		Compared to before enforcement	0.81	0.05	4	NC
		Fatal and injury	All		Compared to before enforcement	0.83	0.11	3	NC
		PDO	Nighttime		Compared to before enforcement	0.79	0.09	4	NC
		All	All		Compared to after enforcement	0.97	0.04	3	NC
		Fatal and injury	All		Compared to after enforcement	0.98	0.07	3	NC
		PDO	All		Compared to after enforcement	0.96	0.05	3	NC

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install automated section speed enforcement system	All	Fatal and injury	All			0.83	0.01	5	
	Urban	All	All			0.12	0.09	3	AZ
						0.46	0.07	4	AZ
			Single vehicle			0.37	0.09	4	AZ
			Sideswipe			0.52	0.16	3	AZ
			Rear-end			0.74	0.18	3	AZ
		Fatal and injury	All			0.85	0.11	3	NC
		Injury	All			0.14	0.13	3	AZ
						0.52	0.14	3	AZ
			Single vehicle			0.57	0.25	3	AZ
			Sideswipe			0.36	0.25	3	AZ
			Rear-end			0.77	0.3	3	AZ
		PDO	All			0.82	0.11	3	NC
						0.1	0.1	3	AZ
						0.44	0.08	4	AZ
			Single vehicle			0.33	0.09	3	AZ
			Sideswipe			0.57	0.2	3	AZ
			Rear-end			0.69	0.2	3	AZ
	Urban/suburban	All	All			0.84	0.07	4	NC
		All	All	23000 - 42000	Average speed determned over long distance	0.69	0.04	4	notusa
			Run-off-road	23000 - 42000	Average speed determned over long distance	0.82	0.08	4	notusa
			Rear-end	23000 - 42000	Average speed determned over long distance	0.86	0.1	4	notusa
			Sideswipe	23000 - 42000	Average speed determned over long distance	0.52	0.08	4	notusa
			Daytime	23000 - 42000	Average speed determned over long distance	0.74	0.05	4	notusa
			Nighttime	23000 - 42000	Average speed determned over long distance	0.62	0.05	4	notusa
			Dry weather	23000 - 42000	Average speed determned over long distance	0.69	0.04	4	notusa
			Wet road	23000 - 42000	Average speed determned over long distance	0.69	0.12	4	notusa
				23000 - 42000	Average speed determned over long distance	0.62	0.05	4	notusa
		Incapacitating injury	All	23000 - 42000	Average speed determned over long distance	0.44	0.07	4	notusa
		Minor and PDO	All	23000 - 42000	Average speed determned over long distance	0.73	0.04	4	notusa
Install automated section speed enforcement system on tangents		All	All	23000 - 42000	Average speed determned over long distance	0.72	0.04	4	notusa
Install automated section speed enforcement system on curves		All	All	23000 - 42000	Average speed determned over long distance	0.57	0.08	4	notusa
Temporal effects of automated section speed enforcement system - 6 months		All	All	23000 - 42000	Average speed determned over long distance	0.61	0.07	3	notusa
Temporal effects of automated section speed enforcement system - 12 months		All	All	23000 - 42000	Average speed determned over long distance	0.66	0.07	4	notusa
Temporal effects of automated section speed enforcement system - 18 months		All	All	23000 - 42000	Average speed determned over long distance	0.68	0.07	4	notusa
Temporal effects of automated section speed enforcement system - 24 months		All	All	23000 - 42000	Average speed determned over long distance	0.69	0.07	4	notusa
Temporal effects of automated section speed enforcement system - 30 months		All	All	23000 - 42000	Average speed determned over long distance	0.81	0.07	4	notusa
Install automated speed camera at signalized intersection		PDO	Speed related			0.87		4	notusa
		Injury	Speed related			0.76	0.1059	4	notusa
Implement mobile speed cameras	Rural	Fatal and injury	All			1.09	0.14	4	notusa
		Incapacitating injury	All			1.2	0.29	4	notusa
		All	All		Noticeable visual presence/media coverage	0.91	0.041	3	NC
Install changeable crash ahead warning signs	Urban	Injury	All			0.56	0.17	4	
Install changeable "Queue Ahead" warning signs		Injury	Rear-end			0.84	0.1	3	
		PDO	Rear-end			1.16	0.15	3	
Convert existing barrier tollbooths to open road tolling (ORT) facility						0.76	0.024	4	NJ
Install ramp meter		All	All	53500 - 204000		0.64	0.07	3	CA

Table C. Alignment

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality	State
						Value	Std. Err	Rating	
Increase in horizontal curvature by one degree	Urban/suburban	PDO	Run-off-road			1.04	0.01	5	
		Fatal and injury	Run-off-road			1.06	0.01	5	
		All	Run-off-road			1.05	0.01	5	
	Rural	All	Truck related			1.05	0.008	3	OH
Increase in horizontal curvature by two degrees	Rural	All	Truck related			1.11	0.017	3	OH
Increase in horizontal curvature by three degrees	Rural	All	Truck related			1.16	0.027	3	OH
Increase in horizontal curvature by four degrees	Rural	All	Truck related			1.23	0.039	3	OH
Increase in horizontal curvature by five degrees	Rural	All	Truck related			1.29	0.051	3	OH
Increase in horizontal curvature from X to Y degrees	Rural	All	Truck related			Eqn. 3- 1		3	OH
		Fatal and injury	All			Eqn. 3- 2		3	TX
		All	All	6 - 98395		Eqn. 3- 3		3	notusa
Increase degree of curve on freeways from 0 to 5	All	Fatal and injury	All			1.73	0.286	3	TX
	Urban	Fatal and injury	All			1.83	0.66	3	TX
Increase degree of curve on freeways from 0 to 10	All	Fatal and injury	All			2.99	1	3	TX
	Urban	Fatal and injury	All			3.35	2.58	3	TX
Increase degree of curve on freeways from 0 to 15	All	Fatal and injury	All			5.18	2.66	3	TX
	Urban	Fatal and injury	All			6.12	7.82	3	TX
Increase degree of curve on freeways from X to Y	All	Fatal and injury	All			Eqn. 3- 5		3	TX
	Urban	Fatal and injury	All			Eqn. 3- 6		3	TX
Change the number of horizontal curves per mile from X to Y		All	All	3923 - 27149		Eqn. 3- 7		3	notusa
Change the horizontal curve radius from greater than 1500m to less than or equal to 600m	Rural	Fatal and injury	Run-off-road	1200 - 2400		2.44		3	notusa
Change the horizontal curve radius from greater than 1500m to between 600m and 1500m	Rural	Fatal and injury	Run-off-road	1200 - 2400		1.42		3	notusa
Increase in horizontal curve radius from X to Y feet (curves)	Rural	Fatal and injury	All			Eqn. 3- 23		3	TX
Horizontal curves on straight grade	Rural	Fatal and injury	All	169 - 26088		Eqn. 3- 9		3	WA
		PDO	All	169 - 26088		Eqn. 3- 10		3	WA
Tangents at non-level grade	Rural	Fatal and injury	All	169 - 26088		Eqn. 3- 11		3	WA
		PDO	All	169 - 26088		Eqn. 3- 12		3	WA
Change maximum gradient from X to Y		All	All	6 - 98395		Eqn. 3- 8		3	notusa
Change grade from positive or zero to negative	Rural	Fatal and injury	Run-off-road	1200 - 2400		1.3		3	notusa
Increase vertical grade by 1%	Rural	All	Run-off-road,Single vehicle			1.04	0.02	3	
Flatten crest vertical curve	All	Fatal and injury	All			0.49	0.19	3	OH
Horizontal curves on type 1 crest vertical curves	Rural	Fatal and injury	All	175 - 26088		Eqn. 3- 13		3	WA
		PDO	All	175 - 26088		Eqn. 3- 14		3	WA
Tangents at type 1 crest vertival curves	Rural	Fatal and injury	All	169 - 26088		1.00		3	WA
		PDO	All	169 - 26088		1.00		3	WA
Horizontal curves on type 1 sag vertical curves	Rural	Fatal and injury	All	169 - 19373		Eqn. 3- 15		3	WA
		PDO	All	169 - 19373		Eqn. 3- 16		3	WA
Tangenets at type 1 sag vertical curves	Rural	Fatal and injury	All	175 - 26088		Eqn. 3- 17		3	WA
		PDO	All	175 - 26088		Eqn. 3- 18		3	WA
Horizontal curves on type 2 crest vertical curves	Rural	Fatal and injury	All	202 - 20931		Eqn. 3- 19		3	WA
		PDO	All	202 - 20931		Eqn. 3- 20		3	WA
Tangents at type 2 crest vertival curves	Rural	Fatal and injury	All	175 - 21825		1.00		3	WA
		PDO	All	175 - 21825		1.00		3	WA
Horizontal curves on type 2 sag vertical curves	Rural	Fatal and injury	All	175 - 21825		Eqn. 3- 21		3	WA
		PDO	All	175 - 21825		Eqn. 3- 22		3	WA
Tangents at type 2 sag vertical curves	Rural	Fatal and injury	All	169 - 23334		1.00		3	WA
		PDO	All	169 - 23334		1.00		3	WA

Table D. Bicyclists

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install bicycle tracks (2-2.5 m wide)		All	All	5000 - 28000	Intersections and segments	1.1	0.064	3	notusa
					Intersections	1.18	0.036	3	notusa
				5000 - 28000	Segments	0.9	0.092	3	notusa
			Rear-end	5000 - 28000		0.93	0.087	3	notusa
			Angle			0.99	0.061	3	notusa
			Bicycle/pedestrian	5000 - 28000	Ped from right	1.13	0.099	3	notusa
				5000 - 28000	Bike with ped from right	1.8	0.301	3	notusa
			Fixed object	5000 - 28000	Parked vehicle	0.79	0.089	3	notusa
			Left-turn			1.12	0.066	3	notusa
					Left-turn vehicle	1.09	0.143	3	notusa
			Rear-end	5000 - 28000		1.01	0.066	3	notusa
			Right-turn			2.4	0.235	3	notusa
						1.7	0.347	3	notusa
			Single vehicle	5000 - 28000		0.97	0.115	3	notusa
				5000 - 28000		0.92	0.122	3	notusa
			Vehicle/bicycle	5000 - 28000		0.37	0.061	3	notusa
						2.29	0.449	3	notusa
					Left-turn vehicle with bike	1.48	0.27	3	notusa
			Vehicle/pedestrian		Left-turn vehicle with ped	1.01	0.219	3	notusa
				5000 - 28000	Vehicle with ped from right	0.9	0.043	3	notusa
				5000 - 28000	Entering or exiting bus passenger	6.19	3.145	3	notusa
		Fatal and injury	All	5000 - 28000		1.12	0.054	3	notusa
		PDO	All	5000 - 28000		1.06	0.077	3	notusa
	Urban	Incapacitating injury	All	5000 - 28000		1.1	0.061	3	notusa
		Fatal and injury	Vehicle/pedestrian	5000 - 28000		1.19	0.092	3	notusa
				5000 - 28000	Intersections	1.3	0.128	3	notusa
				5000 - 28000	Segments	1.07	0.13	3	notusa
			Vehicle/bicycle	5000 - 28000		1.1	0.077	3	notusa
				5000 - 28000	Intersection	1.24	0.105	3	notusa
				5000 - 28000	Bicycle and moped riders, Segments	0.87	0.107	3	notusa
			All	5000 - 28000		1.04	0.171	3	notusa
				5000 - 28000	Intersections	0.97	0.181	3	notusa
				5000 - 28000	Intersections	1.18	0.064	3	notusa
				5000 - 28000	Segments	0.96	0.074	3	notusa
		Minor injury	All	5000 - 28000		1.08	0.145	3	notusa
	Urban/suburban	All	Vehicle/pedestrian			1.75	0.498	3	notusa
Install bicycle lanes (1.5-2 m wide)	Urban	All	All	5000 - 28000	All	1.05	0.084	3	notusa
					Intersections	1.00	0.087	3	notusa
					Segments	1.057	0.053	3	NY
					Intersections	0.944	0.101	3	NY
			Multiple vehicle			0.44	0.128	3	NY
					Intersections	1.007	0.059	3	NY
			Vehicle/bicycle			1.509	0.583	3	NY
					Intersections	1.281	0.175	3	NY
			Vehicle/pedestrian			0.855	0.21	3	NY
					Intersections	1.065	0.175	3	NY
		Fatal and injury	All	5000 - 28000		1.14	0.171	3	notusa
				5000 - 28000	Segments	1.15	0.166	3	notusa
					Segments	0.946	0.114	3	NY
					Intersections	1.07	0.059	3	NY
		PDO	All	5000 - 28000		1.01	0.094	3	notusa
	Urban/suburban	All	Vehicle/bicycle			0.55	0.167	3	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install cycle-tracks, bicycle lanes or on-street cycling	Urban	Injury	Vehicle/bicycle		Intersections, with or without parking between the bicycle lane and traffic	0.26		3	notusa
					Segments	0.27		3	notusa
					Intersections, with parking between the bicycle lane and traffic	0.41		3	notusa
					Segments	0.41		3	notusa
Install bicycle boulevard	Urban/suburban	All	Vehicle/bicycle			0.37	0.052	3	CA
Replacement of traditional intersection with roundabout with cycle lanes	Urban	All	Vehicle/bicycle			1.93	0.334	3	notusa
Replacement of traditional intersection with roundabout with separated cycle path	Urban	All	Vehicle/bicycle			0.83	0.171	3	notusa
Replacement of traditional intersection with roundabout with a grade separated cycle path	Urban	All	Vehicle/bicycle			0.56	0.691	3	notusa
Installation of red color and high quality markings for bicycle crossings with cyclist priority at intersections	Urban/suburban	All	Vehicle/bicycle			2.53	0.788	3	notusa
Installation of raised bicycle crossing or other speed reducing measure for vehicles entering or leaving the side road	Urban/suburban	All	Vehicle/bicycle			0.49	0.114	3	notusa

Table E. Delineation

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install snowplowable, permanent raised pavement markers	Rural	All	Nighttime	0 - 20000		1.13	0.16	3	
				20001 - 60000		0.94	0.25	3	
				> 60000		0.67	0.25	3	
Install snowplowable, permanent raised pavement markers (Radius greater than 1640 ft)	Rural	All	Nighttime	0 - 5000		1.16	0.03	5	
				5001 - 15000		0.99	0.06	3	
				15001 - 20000		0.76	0.08	4	
Install snowplowable, permanent raised pavement markers (Radius less than or equal to 1640 ft)	Rural	All	Nighttime	0 - 5000		1.43	0.1	4	
				5001 - 15000		1.26	0.11	4	
				15001 - 20000		1.03	0.13	3	
Provide "Stop Ahead" pavement markings	Rural	All	All		All intersections	0.69	0.14	4	
					All-way stop controlled intersections	0.44	0.16	4	
					One-way or two-way stop controlled intersections	0.87	0.22	3	
					3-leg intersections	0.4	0.2	4	
					4-leg intersections	0.77	0.18	3	
			Angle			1.04	0.33	3	
			Rear-end			0.71	0.32	3	
		Injury	All		All intersections	0.78	0.22	3	
					AWSC	0.58	0.27	3	
					OWSC/TWSC	0.92	0.32	3	
					3-leg intersections	0.45	0.3	3	
					4-leg intersections	0.88	0.27	3	
Increase pavement marking retroreflectivity from X to Y mcd/m^2/lux	Rural	All	Cross median,Fixed object,Frontal and opposing direction sideswipe,Head-on,Nighttime,Run-off-road,Sideswipe,Single vehicle			Eqn. 5-1		3	IA
Increase pavement marking retroreflectivity of white edgelines from X to Y mcd/m^2/lux		All	Nighttime target crashes	2752 - 47572	2 lanes	Eqn. 5-2		3	NC
				2752 - 47572	3 lanes	Eqn. 5-3		3	NC
Increase pavement marking retroreflectivity of white skiplines from X to Y mcd/m^2/lux		All	Nighttime target crashes	2752 - 47572		Eqn. 5-4		3	NC
Increase pavement marking retroreflectivity of yellow centerlines from X to Y mcd/m^2/lux		All	Nighttime target crashes	2752 - 47572		Eqn. 5-5		3	NC
Increase pavement marking retroreflectivity of yellow edgelines from X to Y mcd/m^2/lux		All	Nighttime target crashes	2752 - 47572		Eqn. 5-6		3	NC
Resurface and install wider pavement markings (4 to 6 in) and both edgeline and shoulder rumble strips	Rural	Incapacitating injury	All		2 lanes, undivided	0.53	0.167	3	MO
		Fatal and injury	All		2 lanes, undivided	0.62	0.095	4	MO
Install raised pavement markers	Rural	All	All	20000 - 60000		0.81	0.07	3	LA
				> 60000		0.87	0.06	3	LA
Install raised pavement markers with restriping (center and edgelines)	Rural	All	All	20000 - 60000		0.78	0.09	3	LA
				> 60000		0.78	0.06	3	LA
Install post-mounted delineators	Rural	Injury	All			1.04	0.1	3	
		PDO	All			1.05	0.07	3	
Place centerline markings	Rural	Injury	All			0.99	0.06	3	
		PDO	All			1.01	0.05	3	
Add lane lines on multilane roadway segments	Urban	All	All			0.82	0.39	3	
Install distance markers (angle symbols) on roadway segments		Injury	All			0.44	0.26	3	
Placing edgelines and background/ directional markings on horizontal curves	Rural	Injury	Run-off-road			0.81	0.31	3	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install edgelines (curves)	Rural	All	All		Lane widths 9-11 ft, Shoulder widths < 5 ft	0.741	0.024	3	TX
					Lane widths 9 ft, Shoulder widths < 5 ft	0.671	0.063	3	TX
	Urban	All	Run-off-road			0.89	0.031	3	TX
Install edgelines (tangent)	Rural	All	All			0.939	0.027	3	TX
			Run-off-road			0.866	0.035	3	TX
Install edgelines (tangents and curves)	Rural	All	All			0.921	0.019	3	TX
			Run-off-road		Lane widths 9-11 ft, Shoulder widths < 5 ft	0.888	0.023	3	TX
					Lane widths 9 ft, Shoulder widths < 5 ft	0.868	0.065	3	TX
Place standard edgeline marking (4-6 in)	Rural	Injury	All			0.97	0.04	3	
		PDO	All			0.97	0.11	3	
Install edgelines and centerlines	Rural	Injury	All			0.76	0.11	4	
		All	All			0.87	0.14	3	
Install edgelines, centerlines, and post-mounted delineators	All	Injury	All			0.55	0.11	4	
Install wider edgelines (4 in to 5 in)	Rural	All	All			0.699	0.046	3	IL
			Daytime			0.709	0.056	3	IL
			Fixed object			0.705	0.071	3	IL
			Nighttime			0.701	0.078	3	IL
			Nighttime,Single vehicle			0.705	0.086	3	IL
			Nighttime,Wet road			0.643	0.181	3	IL
			Other			0.759	0.096	3	IL
			Single vehicle			0.63	0.053	3	IL
			Single vehicle,Wet road			0.672	0.124	3	IL
			Wet road			0.653	0.114	3	IL
		Fatal and injury	All			0.623	0.061	3	IL
			Daytime			0.64	0.077	3	IL
			Nighttime			0.658	0.106	3	IL
			Single vehicle			0.578	0.07	3	IL
			Nighttime,Single vehicle			0.637	0.115	3	IL
		PDO	All			0.761	0.063	3	IL
Install wider edgelines (4 in to 6 in)	Rural	All	All			0.825	0.028	4	KS
						0.806	0.045	3	MI
			Daytime			0.714	0.043	4	KS
			Fixed object			0.81	0.066	4	KS
			Nighttime			0.962	0.043	4	KS
						0.812	0.059	3	MI
			Nighttime,Single vehicle			0.816	0.084	4	KS
						0.82	0.061	3	MI
			Nighttime,Wet road			0.757	0.147	4	KS
						0.208	0.074	3	MI
			Single vehicle			0.73	0.048	4	KS
						0.813	0.047	3	MI
			Single vehicle,Wet road			0.341	0.073	3	MI
			Wet road			0.771	0.106	4	KS
						0.374	0.073	3	MI
		Fatal and injury	All			0.635	0.052	4	KS
			Nighttime			0.873	0.107	4	KS
			Single vehicle			0.632	0.061	4	KS
			Nighttime,Single vehicle			0.813	0.121	4	KS
			Daytime			0.585	0.066	4	KS
						0.77	0.13	3	MI
		PDO	All			0.877	0.032	4	KS
						0.804	0.047	3	MI

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install wider edgelines (8 in)	Rural	Injury	All			1.05	0.08	3	
		PDO				0.99	0.15	3	
Install wider pavement markings without resurfacing	Rural	Fatal and injury	All			0.78	0.081	4	MO
Resurface and install wider pavement markings (4 to 6 in)	Rural	Incapacitating injury	All		Divided median, Principal arterial other Freeways and expressways	0.79	0.06	4	MO
					Divided median	0.66	0.097	4	MO
					Undivided	0.54	0.156	3	MO
		Fatal and injury	All		Principal arterial other freeways and expressways	0.91	0.037	4	MO
						0.75	0.055	4	MO
	Urban	Incapacitating injury	All			0.62	0.142	4	MO
		Fatal and injury	All		Principal arterial other freeways and expressways	0.96	0.019	4	MO
						0.92	0.022	4	MO
Resurface and install wider pavement markings (4 to 6 in) and edgeline rumble strips	Rural	Incapacitating injury	All		Principal arterial other freeways and expressways	0.75	0.054	4	MO
						0.76	0.065	4	MO
		Fatal and injury	All		Principal arterial other freeways and expressways	0.76	0.031	4	MO
						0.74	0.035	4	MO
	Urban	Fatal and injury	All		Principal arterial other freeways and expressways	0.9	0.027	4	MO
						0.86	0.048	4	MO
Resurface and install wider pavement markings (4 to 6 in) and shoulder rumble strips	Rural	Incapacitating injury	All		Principal arterial other freeways and expressways	0.74	0.088	4	MO
						0.51	0.183	3	MO
		Fatal and injury	All		Principal arterial other freeways and expressways	0.77	0.051	4	MO
						0.75	0.123	4	MO
	Urban	Fatal and injury	All			0.8	0.043	4	MO

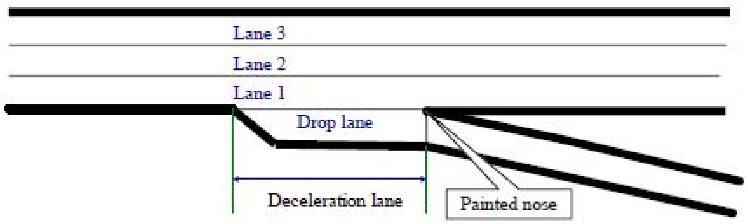
Table F. Highway Lighting

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality	State
						Value	Std. Err	Rating	
Install lighting	All	Fatal	All			0.31	0.36	3	
			Nighttime			0.51	0.0459	3	notusa
		Injury	All			0.73	0.12	4	
			Nighttime			0.54	0.0204	3	notusa
						0.5	0.01531	3	notusa
						0.69	0.0255	3	notusa
		PDO	All			0.68	0.26	3	
	Rural	Injury	All			0.8	0.12	3	
			All,Nighttime			0.46	0.0102	3	notusa
			Dry weather,Nighttime			0.44	0.01276	3	notusa
			Fixed object,Nighttime			0.46	0.02296	3	notusa
			Nighttime,Rear-end			0.49	0.02041	3	notusa
			Nighttime,Wet road			0.54	0.01786	3	notusa
	Urban	Injury	All			0.69	0.07	4	
		PDO	All			0.84	0.08	4	
		PDO	All			0.69	0.36	3	
Install lighting (highway)	All	Fatal	All	All		0.31	0.36	3	
		Injury	Nighttime			0.72	0.06	4	
		PDO	Nighttime			0.83	0.07	4	
Install lighting (intersection)	All	All	Daytime	40 - 77430		1.05	0.03	3	MN
		All	Nighttime	40 - 77430		0.881	0.054	3	MN
				40 - 77430		0.92	0.035	3	MN
	Rural	All	Angle	420 - 15200		0.67	0.12	3	GA
			Daytime	40 - 77430		1.09	0.06	3	MN
			Nighttime	40 - 77430		1.07	0.074	3	MN
			Vehicle/pedestrian	420 - 15200		0.56	0.14	3	GA
	Urban/suburban	All	Daytime	40 - 77430	Signalized intersection	1.03	0.1	3	MN
				40 - 77430	Signalized intersection	1.05	0.053	3	MN
			Nighttime	40 - 77430	Stop-controlled intersection	0.97	0.15	3	MN
				40 - 77430	Stop-controlled intersection	0.91	0.07	3	MN
		All	Nightime			0.934	0.055	3	MN
						0.953	0.023	3	MN
			Daytime			1.032	0.044	3	MN
						1.028	0.018	3	MN
		Fatal	All			0.23	0.28	3	
			Vehicle/pedestrian			0.19	0.28	3	
		Injury	All			0.5	0.21	3	
			Nighttime			0.62	0.13	4	
			Vehicle/pedestrian			0.41	0.2	4	
			Nighttime,Vehicle/pedestrian			0.58	0.18	4	
		PDO	All			0.69	0.36	3	
						0.52	0.21	3	
Install lighting (interchanges)	All	All	All			0.5	0.166	3	OH
Full to partial interchange lighting	Suburban	All	Daytime			0.984	0.029	3	OR
			Nighttime			1.035	0.047	3	OR
		Injury	Day time			0.913	0.042	4	OR
			Night time			0.886	0.06	3	OR
Full lineal to no or partial lineal lighting	Suburban	All	All			0.905	0.084	3	OR
		Injury	All			0.766	0.103	3	OR
Partial plus to partial interchange lighting	Suburban	All	Daytime			1.036	0.113	3	OR
			Nighttime			0.648	0.109	3	OR
		Injury	Nighttime			0.6	0.141	3	OR

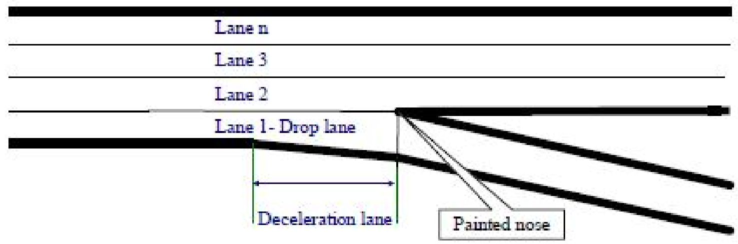
Table G. Interchange Design

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Convert at-grade intersection into grade-separated interchange		All	All		4-leg intersection	0.58	0.1	4	
					3-leg intersections	0.84	0.17	3	
					3-leg, 4-leg intersection	0.73	0.08	4	
		Injury	All		4-leg intersection	0.43	0.05	5	
					3-leg, 4-leg intersection	0.72	0.11	4	
		PDO	All			0.64	0.14	4	
Provide diamond interchange		All	All			0.93	0.09	3	
						0.62	0.23	3	
						0.98	0.17	3	
						0.91	0.16	3	
			Truck related			0.89	0.12	3	
						1.43	0.09	4	
						0.9	0.1	3	
Provide tight-urban-diamond interchange (TUDI)		All	All			1.02	0.13	3	
Design diamond, trumpet, or cloverleaf interchange with crossroad above freeway		All	All			0.96	0.1	3	
Extend acceleration lane by approx. 98 ft (30 m)		All	All			0.89	0.05	5	
Extend deceleration lane by approx. 100 ft		All	All			0.93	0.06	3	
Extend deceleration lane from 101-200 ft. to 601-700 ft.		All	All			0.064	0.014	3	FL
Extend deceleration lane from 201-300 ft. to 601-700 ft.		All	All			0.155	0.025	3	FL
Provide long ramp instead of shortramp		All	All			0.62	0.1	4	
Provide straight ramp instead of cloverleaf ramp		All	All			0.55	0.2	4	
Provide cloverleaf ramp instead of long ramp		All	All			0.77	0.2	3	
Provide short ramp instead of directional loop ramp		All	All			0.7	0.2	3	
Single-lane exit ramp without taper compared to with taper (right ramp only)		All	All			1.128	0.1136	3	FL
Single-lane entrance ramp and two-lane exit ramp with continuous auxiliary lane vs. single-lane		All	All	28500 - 282000		2.13	0.49	3	FL
		Incapacitating injury	All	28500 - 282000		2.02	0.3	3	FL
Left side off ramp						1.49	0.2628	3	FL
One lane-unbalanced freeway exit ramp vs. one lane-balanced freeway exit ramp		All	All	18800 - 291000		1.43	0.1	3	FL
Change length of deceleration lane on one-lane freeway exit ramp from X to Y miles		All	All	18800 - 291000		Eqn. 7-1		3	FL
Two lane-unbalanced freeway exit ramp vs. two lane-balanced freeway exit ramp		All	All	18800 - 291000		1.23	0.11	3	FL
Unbalanced freeway exit ramp vs. balanced freeway exit ramp		Incapacitating injury	All	18800 - 291000		0.98	0.11	3	FL
Change number of lanes on freeway exit ramp from X to Y		Incapacitating injury	All	18800 - 291000		Eqn. 7-2		3	FL
				18800 - 291000		Eqn. 7-3		3	FL
Change number of lanes on freeway exit ramp from X to Y (one-lane freeway)		All	All	18800 - 291000		Eqn. 7-4		3	FL
Change number of lanes on freeway exit ramp from X to Y (one-lane exit)		All	All	18800 - 291000		Eqn. 7-5		3	FL
Change number of lanes on freeway exit ramp from X to Y (two-lane exit)		All	All	18800 - 291000		Eqn. 7-6		3	FL
Divided vs. undivided cross road at diamond interchange ramps		All	All			0.53		3	WI
Change number of lanes on cross road at diamond interchange ramp from X to Y		All	All			Eqn. 7-7		3	WI

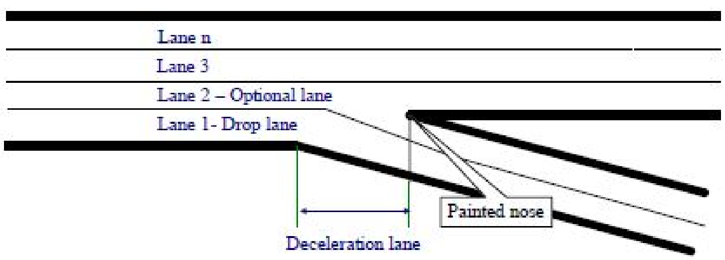
Change spacing distance between two ramp terminals at diamond interchange from X to Y feet		All	All			Eqn. 7-8		3	WI
			Angle			Eqn. 7-9		3	WI
			Rear-end			Eqn. 7-10		3	WI
Convert a Type I exit ramp to a Type II exit ramp*		All	Truck related		Type I is a full width parallel from tangent that leads to either a tangent or flat exiting curve which includes a decelerating taper. The horizontal and vertical alignment of type I exit ramps were based on the selected design speed equal or less than the intersecting roadways. Type II is when the outer lane becomes a drop lane at the exit gore forming a lane reduction. A paved and striped area beyond the theoretical gore were present at this type of exit ramps to provide a maneuver and recovery area. Type III includes two exit lanes while a large percentage of traffic volume on the freeway beyond the painted nose would leave at this particular exit. An auxiliary lane to develop the full capacity of two lane exit was developed for 1500 feet. Type IV is used where one of the through lanes, the outer lane, is reduced and another full width parallel from tangent lane developed with a taper is also forced to exit.	1.21	0.1	3	FL
Convert a Type I exit ramp to a Type III exit ramp*		All	Truck related			0.79	0.07	3	FL
Convert a Type I exit ramp to a Type IV exit ramp*		All	Truck related			1	0.15	3	FL
Convert a Type III exit ramp to a Type IV exit ramp*		All	Truck related			1.26		3	FL
Provide an auxiliary lane between an entrance ramp and exit ramp		All	All			0.8		3	WA
			Single vehicle			0.8		3	WA
			Angle,Rear-end,Sideswipe			0.76		3	WA
		Fatal and injury	All			0.77		3	WA
Modify two-lane-change to one-lane-change merge/diverge area		All	All			0.68	0.04	5	
Closely spaced single-lane entrance and exit ramp vs. single-lane entrance and exit ramps with continuous auxiliary lane		All	All	28500 - 282000		1.46	0.31	3	FL
Two lane-unbalanced freeway exit ramp vs. two lane-balanced freeway exit ramp		Incapacitating injury	All	18800 - 291000		0.97	0.21	3	FL



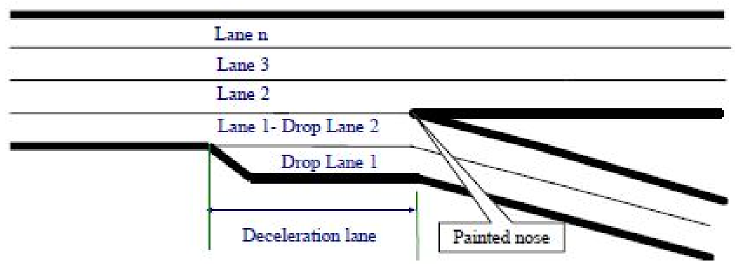
Type I Exit Ramp: Parallel from a Tangent Single-lane Exit Ramp



Type II Exit Ramp: Single-lane Exit Ramp without a Taper



Type III Exit Ramp: Two-lane Exit Ramp with an Optional Lane



Type IV Exit Ramp: Two-lane Exit Ramp without an Optional Lane

Table H. Intersection Geometry

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Convert a conventional signalized intersection to a signalized superstreet	Rural	All	All			2.11		3	NC
			Angle,Right-turn			3.66		3	NC
			Rear-end			2.93		3	NC
			Left-turn			0.44		3	NC
		Fatal and injury	All			2.09		3	NC
Provide a channelized left-turn lane on both major-road approaches	Rural	Injury	All			0.96	0.21	3	
		PDO	All			0.84	0.39	3	
						0.74	0.22	3	
Provide a channelized left-turn lane on both major- and minor-road approaches	Rural	Injury	All			0.73	0.23	3	
Provide a left-turn lane on one major-road approach		All	All			0.61	0.07	3	FL
	Rural	All	All		3-leg intersection	0.56	0.07	4	
					4-leg intersection	0.72	0.03	5	
		Fatal and injury	All		3-leg intersection	0.45	0.1	4	
					4-leg intersection	0.65	0.04	5	
	Urban	All	All	1500 - 40600	Stop-controlled, 3-leg intersection	0.67	0.15	4	
				1500 - 40600	Stop-controlled, 4-leg intersection	0.73	0.04	5	
				7200 - 55100	Signalized intersection	0.9	0.1	3	
				4600 - 40300	Signalized intersection	0.76	0.03	5	
			Motorcycle		Signalized, 4-leg intersection	1.23		3	notusa
			Motorcycle		Signalized, 3-leg intersection	1.4		3	notusa
		Fatal and injury	All	1500 - 40600		0.71	0.05	5	
						0.79		3	notusa
				7200 - 55100		0.91	0.02	5	
				4600 - 40300		0.72	0.06	4	
		PDO	All			0.8		3	notusa
Provide a left-turn lane on both major-road approaches	Rural	All	All			0.52	0.04	5	
		Fatal and injury	All			0.42	0.04	5	
	Urban	All	All	1500 - 40600		0.53	0.04	5	
				7200 - 55100		0.81	0.13	3	
				4600 - 40300		0.58	0.04	5	
		Fatal and injury	All	1500 - 40600		0.5	0.06	4	
				7200 - 55100		0.83	0.02	5	
				4600 - 40300		0.52	0.07	4	
	All	All	All			0.73		3	FL
						1.36	0.1632	3	FL
		All	All			0.98	0.13	3	FL
Install one left-turn lane on the minor approach of an unsignalized 3-leg intersection	All	All	All			0.75	0.1097	3	FL
Introduce zero or positive offset left-turn lane on crossing roadway	Urban	All	Angle			0.74	0.26	3	
						0.8	0.28	3	
Introduce raised/curb left-turn channelization	Rural	All	Rear-end,Sideswipe			0.75	0.27	3	
			All			0.87	0.28	3	
Provide a right-turn lane on one major-road approach	All	All	All		Stop-controlled, 3-leg intersection	0.83	0.1827	3	FL
					Stop-controlled, 3-leg or 4-leg intersection	0.86	0.06	4	
					Signalized intersection	0.96	0.02	3	
		Fatal and injury	All		Stop-controlled intersection	0.77	0.08	4	
					Signalized intersection	0.91	0.04	5	
		All	All		3-leg intersection	0.8	0.08	3	FL
					4-leg intersection	0.75	0.19	3	FL

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Introduce painted left-turn channelization	Rural	All	Rear-end,Sideswipe			0.61	0.19	3	
			All			0.67	0.18	3	
Provide a right-turn lane on both major-road approaches	All	All	All		Stop-controlled intersection	0.74	0.08	4	
					Signalized intersection	0.92	0.03	5	
Provide a right-turn lane on a signalized 3-leg intersection	Urban	All	Motorcycle		Major road	2.5		3	notusa
					Minor road	1.6		3	notusa
Physical channelization of both major and minor roads	Rural	Fatal and injury	All		3-leg intersection	1.16	0.09	3	
					4-leg intersection	0.73	0.06	4	
		PDO	All			0.87	0.4	3	
Painted channelization of left-turn lane on major road	Rural	Injury	All			0.78	0.25	3	
		PDO	All			0.8	0.34	3	
Painted channelization of both major and minor roads	Rural	Injury	All			0.43	0.12	4	
Addition of left- or right-turn by-pass lanes	Rural	All	All			0.95	0.21	3	
		PDO	All			0.81	0.23	3	
Presence of exclusive left turn (transit-serviced locations)	Urban	All	All			0.88	0.029	3	notusa
Presence of exclusive left or right turn on either approach (transit-serviced locations)	Urban	All	All			0.96	0.013	3	notusa
Increase the number of left-turn lanes on the major road of 2-lane intersections from X to Y	Rural	All	Sideswipe			Eqn. 8-1		3	GA
Increase the number of left-turn lanes on the minor road of 2-lane intersections from X to Y	Rural	All	Angle			Eqn. 8-2		3	GA
Change number of lanes on major road of a 4-leg signalized intersection from X to Y	Urban	All	Motorcycle			Eqn. 8-3		3	notusa
Change number of lanes on minor road of a 4-leg signalized intersection from X to Y	Urban	All	Motorcycle			Eqn. 8-4		3	notusa
Change number of lanes on minor road of a signalized 3-leg intersection	Urban	All	Motorcycle			Eqn. 8-5		3	notusa
Permit through movements from both minor approaches to an intersection instead of from only one minor approach		All	All			0.31	0.09	3	FL
Presence of exclusive right turn phase at diamond interchange ramps		All	All			0.27		3	WI
			Angle			0.13		3	WI
			Rear-end			0.37		3	WI
Change number of 3-leg intersections from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 8-6		3	NY
Change number of 5-leg intersections from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 8-7		3	NY
Convert a 4-leg unsignalized intersection at driveways to a regular 4-leg unsignalized intersection	All	All	All			1.11	0.1117	3	FL
Convert a 3-leg unsignalized intersection at a driveway to a 3-leg unsignalized intersection at a ramp junction	All	All	All			2.29	0.4604	3	FL
Convert 4-leg intersection into two 3-leg intersections	Urban	Injury	All		Minor road AADT: 0~15%	1.35	0.27	3	
					Minor road AADT: 15%~30% of total entering	0.75	0.08	4	
					Minor road AADT: > 30% of total entering	0.67	0.1	4	
		PDO	All		Minor road AADT: 0~15%	1.15	0.11	3	
					Minor road AADT: 15%~30% of total entering	1.00	0.09	3	
					Minor road AADT: > 30% of total entering	0.9	0.09	3	
Presence of 3-leg intersection vs. 4-leg intersection	Urban/suburban	All	Vehicle/bicycle			0.86		3	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Presence of right turning lane on arterial with signal coordination	Urban/suburban	All	Rear-end			0.06	0.02	3	IN
Conversion of intersection into roundabout	Rural	Injury	Vehicle/bicycle			1.01	0.44	3	
	All	Injury	Vehicle/bicycle			1.27	0.34	3	
		Injury	All			0.61	0.08	4	
		Serious injury	All			0.83	0.23	3	
		Minor injury	All			0.62	0.08	4	
Conversion of intersection into single-lane roundabout	All	All	All			0.64	0.123	4	WI
		Fatal and injury	All			0.818	0.154	3	WI
Conversion of intersection into multi-lane roundabout	All	All	All			1.062	0.153	4	WI
		Fatal and injury	All			0.367	0.128	4	WI
Conversion of no control/yield intersection into roundabout	All	All	All			1.242	0.648	3	WI
		Fatal and injury	All			0		3	WI
Conversion of unsignalized intersection into roundabout		Serious injury	All			0.8	0.3	3	
		Injury	All			0.56	0.1	4	
		Minor injury	All			0.54	0.11	4	
Conversion of stop-controlled intersection into single-lane roundabout	Rural	All	All			0.42	0.13	4	
		Injury	All			0.18	0.16	4	
	Urban	All	All			0.28	0.11	4	
						0.95	0.18	3	
		Injury	All			0.12	0.14	4	
Conversion of two-way stop-controlled intersection into roundabout	All	All	All			0.751	0.105	4	WI
						0.56	0.05	5	
		Fatal and injury	All			0.65	0.104	4	WI
		Injury	All			0.18	0.04	5	
	Rural	All	All			0.29	0.05	5	
		Injury	All			0.13	0.04	5	
	Suburban	All	All		1, 2 lanes	0.68	0.08	4	
					1 lane	0.22	0.07	4	
					2 lanes	0.81	0.11	3	
		Injury	All		1, 2 lanes	0.29	0.1	4	
					1 lane	0.22	0.12	4	
					2 lanes	0.32	0.14	4	
	Urban	All	All		1, 2 lanes	0.71	0.11	4	
					1 lane	0.61	0.12	4	
					2 lanes	0.88	0.21	3	
		Injury	All		1, 2 lanes	0.19	0.09	4	
					1 lane	0.22	0.12	4	
Conversion of all-way, stop-controlled intersection into roundabout	All	All	All		1, 2 lanes	1.03	0.18	3	
					2, 4 lanes	1.114	0.259	4	WI
		Fatal and injury	All			0.544	0.196	3	WI
Conversion of intersection into low-speed roundabout	All	All	All			1.099	0.118	4	WI
		Fatal and injury	All			0.473	0.113	4	WI
Conversion of intersection into high-speed roundabout	All	All	All			0.659	0.094	4	WI
		Fatal and injury	All			0.506	0.158	3	WI

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Conversion of high-speed rural intersection into roundabout	Rural	All	All			0.33		4	KS,MD,MN,OR,WA,WI
			Angle			0.17		3	KS,MD,MN,OR,WA,WI
			Fixed object			4.66		3	KS,MD,MN,OR,WA,WI
			Rear-end			0.85		3	KS,MD,MN,OR,WA,WI
			Sideswipe			2.79		3	KS,MD,MN,OR,WA,WI
		Injury	All			0.13		4	KS,MD,MN,OR,WA,WI
			Angle			0.09		3	KS,MD,MN,OR,WA,WI
Conversion of high-speed rural 3-leg intersection into roundabout	Rural	All	All			0.74		3	KS,OR
		Injury	All			0.28		3	KS,OR
Conversion of high-speed rural 4-leg intersection into roundabout	Rural	All	All		1, 2 lanes	0.32		4	KS,MD,MN,OR,WA,WI
					1 lane	0.26		4	KS,MD,MN,OR,WA,WI
					2 lanes	1.41		3	KS,MD,MN,OR,WA,WI
		Injury	All		1, 2 lanes	0.12		4	KS,MD,MN,OR,WA,WI
					1 lane	0.11		4	KS,MD,MN,OR,WA,WI
					2 lanes	0.4		3	KS,MD,MN,OR,WA,WI
Conversion of signalized intersection into roundabout	All	All	All			0.52	0.06	4	
						0.955	0.317	4	WI
		Fatal and injury	All			0.348	0.76	3	WI
		Injury	All			0.22	0.07	4	
	Rural	All	All			0.625		3	MS
		Injury	All			0.4		3	MS
	Suburban	All	All			0.33	0.05	4	
						0.58	0.05	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
						0.576	0.053	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Fatal and injury	All			0.259	0.066	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Injury	All			0.26	0.07	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
	Urban	All	All			0.65	0.16	3	
						0.99	0.14	3	
						1.15	0.09	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
						1.15	0.093	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Fatal and injury	All			0.445	0.1	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Injury	All			0.26	0.25	3	
						0.4	0.14	4	
						0.45	0.1	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Conversion of signalized intersection into roundabout	Urban/suburban	All	All		1, 2 lanes, 3-leg, 4-leg intersections	0.79	0.05	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 3-leg intersections	1.07	0.16	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 4-leg intersections	0.76	0.05	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					2 lanes, 3-leg, 4-leg intersections	0.81	0.06	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1 lane, 3-leg, 4-leg intersections	0.74	0.09	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 3-leg, 4-leg intersections	0.792	0.05	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					2 lanes, 3-leg, 4-leg intersections	0.809	0.061	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1 lane, 3-leg, 4-leg intersections	0.735	0.086	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 3-leg intersections	1.066	0.163	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 4-leg intersections	0.759	0.052	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Fatal and injury	All		1, 2 lanes, 3-leg, 4-leg intersections	0.342	0.058	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					2 lanes, 3-leg, 4-leg intersections	0.288	0.065	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1 lane, 3-leg, 4-leg intersections	0.451	0.115	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 3-leg intersections	0.37	0.172	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 4-leg intersections	0.338	0.061	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Injury	All		1, 2 lanes, 3-leg, 4-leg intersections	0.34	0.06	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 3-leg intersections	0.37	0.17	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1, 2 lanes, 4-leg intersections	0.34	0.06	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					2 lanes, 3-leg, 4-leg intersections	0.29	0.07	4	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
					1 lane, 3-leg, 4-leg intersections	0.45	0.12	3	CO,FL,IN,MD,MI,NY,NC, SC,VT,WA
		Minor injury	All			0.69	0.16	3	
		Serious injury	All			0.87	0.39	3	
		Injury	All			0.68	0.14	4	
Convert traffic signals to unconventional median U-turns	Urban	All	All			1.132	0.06	4	notusa

Table I. Intersection Traffic Control

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Convert minor-road stop control to all-way stop control	Rural	All	All			0.52	0.04	5	
	Urban	All	Angle			0.25	0.03	5	
			Rear-end			0.82	0.13	3	
			Vehicle/pedestrian			0.57	0.15	4	
		Injury	All			0.3	0.06	4	
Install a traffic signal	All	PDO	All			1.15		3	FL
	Rural	All	All		Stop-controlled intersection	0.56	0.03	5	
					Signalized intersection	0.85		3	FL
			Angle			0.23	0.02	5	
			Left-turn			0.4	0.06	4	
			Rear-end			1.58	0.17	4	
	Urban	All	All			0.83		3	FL
					Major road speed limit >= 40 mph	0.95	0.09	3	
			Angle		Major road speed limit >= 40 mph	0.33	0.06	4	
			Rear-end		Major road speed limit >= 40 mph	2.43	0.37	3	
		Fatal and injury	All		3-leg intersection	0.86	0.38	3	
					4-leg intersection	0.77	0.27	3	
			Angle			0.33	0.24	4	
Remove unwarranted signal (one-lane, one-way streets, excluding major arterials)	Urban	All	Angle,Left-turn,Right-turn			0.76	0.14	4	
			Rear-end			0.71	0.29	3	
			Vehicle/pedestrian			0.82	0.31	3	
		All	All			0.76	0.09	4	
Permit right-turn-on-red		All	All			1.07	0.01	5	No state(s) chosen.
			Vehicle/bicycle			1.82	0.31	3	
			Vehicle/pedestrian			1.43	0.24	4	
						1.57	0.31	3	
			Vehicle/bicycle,Vehicle/pedestrian			1.69	0.1	5	
		Injury	Right-turn			1.6	0.09	4	
		PDO	Right-turn			1.1	0.01	5	
Modify change plus clearance interval to ITE 1985 Proposed Recommended Practice		All	All			0.92	0.1	3	
			Angle			0.96	0.21	3	
			Rear-end			1.12	0.2	3	
			Vehicle/bicycle,Vehicle/pedestrian			0.63	0.16	3	
		Injury	All			0.88	0.11	3	
			Angle			1.06	0.26	3	
			Rear-end			1.08	0.21	3	
			Vehicle/bicycle,Vehicle/pedestrian			0.63	0.19	3	
Prohibit left-turns with "No Left Turn" sign	Urban/suburban	All	Left-turn			0.36	0.15	4	
			All			0.32	0.13	4	
Prohibit left-turns and U-turns with "No Left Turn" and "No U-Turn" signs	Urban/suburban	All	Left-turn,Other			0.23	0.22	4	
			All			0.28	0.22	4	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Provide flashing beacons at stop controlled intersections	All	All	All			0.95	0.04	3	
			Angle			0.87	0.06	4	
						0.72	0.25	3	
						0.88	0.07	3	
						0.42	0.2	4	
						0.87	0.06	4	
						0.86	0.12	3	
			Rear-end			0.92	0.11	3	
		Injury	All			0.9	0.06	3	
	Rural	All	Angle			0.84	0.06	4	
	Suburban	All	Angle			0.88	0.12	3	
	Urban	All	Angle			1.12	0.28	3	
Add 3-inch yellow retroreflective sheeting to signal backplates	Urban	All	All			0.85	0.005	4	notusa
Add signal (additional primary head)	Urban	All	All			0.72		3	notusa
	Urban	All	Rear-end			0.72		3	notusa
	Urban	Fatal and injury	All			0.83		3	notusa
	Urban	PDO	All			0.69		3	notusa
Convert signal from pedestal-mounted to mast arm		All	All			0.51	0.031	3	KS
						0.71	0.068	3	IA
	All	All	Angle			0.26	0.032	3	KS
			Rear-end			0.59	0.07	3	KS
		Fatal and injury	All			0.56	0.068	3	KS
		PDO	All			0.49	0.034	3	KS
Install a stop sign on minor approach of an unsignalized intersection	All	All	All			1.18	0.17	3	FL
Install a stop sign on both minor approaches of an unsignalized intersection	All	All	All			1.4	0.28	3	FL
						0.78		3	FL
Install two-way stop controlled intersections at uncontrolled intersections	Urban/suburban	All	All		Residential streets	0.489	0.066	4	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install stop sign at passive highway-rail crossing		All				**0.68**	**0.00018**	**3**	**AL,AK,AZ,AR,CA,CO,CT,DE,DC,FL,GA,HI,ID,IL,IN,IA,KS,KY,LA,ME,MD,MA,MI,MN,MS,MO,MT,NE,NV,NH,NJ,NM,NY,NC,ND,OH,OK,OR,PA,RI,SC,SD,TN,TX,UT,VT,VA,WA,WV,WI,WY**
						Eqn. 9-1		**3**	**AL,AK,AZ,AR,CA,CO,CT,DE,DC,FL,GA,HI,ID,IL,IN,IA,KS,KY,LA,ME,MD,MA,MI,MN,MS,MO,MT,NE,NV,NH,NJ,NM,NY,NC,ND,OH,OK,OR,PA,RI,SC,SD,TN,TX,UT,VT,VA,WA,WV,WI,WY**
						Eqn. 9-2		**3**	**AL,AK,AZ,AR,CA,CO,CT,DE,DC,FL,GA,HI,ID,IL,IN,IA,KS,KY,LA,ME,MD,MA,MI,MN,MS,MO,MT,NE,NV,NH,NJ,NM,NY,NC,ND,OH,OK,OR,PA,RI,SC,SD,TN,TX,UT,VT,VA,WA,WV,WI,WY**
Install stop signs at alternate intersections in residential areas	Urban	All	All			0.45		3	notusa
		Fatal and injury	All			0.28		3	notusa
Modify signal phasing (implement a leading pedestrian interval)	Urban	All	Vehicle/bicycle,Vehicle/pedestrian			**0.63**	**0.193**	**3**	**PA**
						0.554	**0.235**	**3**	**PA**
Left turn phase improvement	Urban	Fatal and injury	All			0.85		3	notusa
		PDO	All			0.96		3	notusa
Change traffic signal spacing from X to Y signals per mile	Urban	All	All			Eqn. 9-3		3	UT
			Angle			Eqn. 9-4		3	UT
Change left-turn signal phase (Permitted to protected)	Urban	All	All			0.975	0.085	3	NC
			Angle			0.021	0.021	4	NC

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Change left-turn signal phase (Permitted-protected to protected on major approach)	Urban	All	All			0.58	0.34	3	
						0.99	0.13	3	
			Angle			0.04	0.08	4	
						0.01	0.03	5	
Change left-turn signal phase (Permitted to protected-permitted or permitted protected)	Urban	All	All			1.045	0.135	3	NC
						1.031	0.022	4	notusa,NC
					Intersections only	0.958	0.036	4	notusa,NC
			Left-turn			0.862	0.05	4	notusa,NC
					Intersections only	0.787	0.072	4	notusa,NC
			Rear-end		Intersections only	1.05	0.059	4	notusa,NC
						1.075	0.036	4	notusa,NC
		Fatal and injury	All			0.962	0.035	4	notusa,NC
					Intersections only	0.914	0.055	4	notusa,NC
			Left-turn			0.84	0.02	5	
Change left-turn signal phase (Protected to protected-permitted)		All				0.96	0.44	3	
Change left-turn signal phase (Protected-permitted to protected)		All	All			1.02	0.123	3	NC
		All	Angle			0	0.006	3	NC
Change left-turn signal phase (Protected-permitted to permitted-protected)		All	All			0.87	0.42	3	
Change left-turn signal phase (to protected on one or more approaches)	Urban	All	All			0.94	0.1	3	No state(s)
			Left-turn			0.01	0.01	5	
		All	All		Intersections only	1.081	0.027	4	notusa,NC
			Left-turn		Intersections only	0.925	0.067	4	notusa,NC
			Rear-end		Intersections only	1.094	0.045	4	notusa,NC
		Fatal and injury	All		Intersections only	0.995	0.043	4	notusa,NC
Change left-turn phase from at least one permissive approach to flashing yellow arrow (FYA)	Urban	All	All		Intersections only	0.753	0.094	5	NC,OR,WA
			Left-turn		Intersections only	0.635	0.126	5	NC,OR,WA
Change left turn phase from protected-permitted to flashing yellow arrow (FYA)	Urban	All	All		Intersections only	0.922	0.104	4	NC,OR,WA
			Left-turn		Intersections only	0.806	0.146	4	NC,OR,WA
Change left-turn phase (Lag-lag to lead-lag)		All	Angle			0.33		3	TX
Change left-turn phase (Lag-lag to lead-lead)		All	Angle			0.31		3	TX
Change left-turn phase (Lead-lead to lag-lag, protected-only)		All	Angle			2.16		3	TX
Change left-turn phase (Lead-lead to lead-lag, protected-only)		All	Angle			0.69		3	TX
Change left-turn phase (Lead-lead to lead-lag, protected/permissive)		All	Angle			1.57		3	TX
Change left-turn phase (Leading protected to lagging protected exclusive)		All	All			1.15	0.42	3	
Replace 8-inch red signal heads with 12-inch		All	All			0.97	0.06	3	NC
			Angle			0.58	0.07	4	NC
Install dual red signal lenses		All	All			1.18	0.11	3	NC
			Angle			1.05	0.13	3	NC

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Convert yield signal control to signalized control (intersection crashes)	Urban	All	All		3-leg,4-leg,more than 4 leg intersection	0.64	0.07	4	notusa
					3-leg intersection	0.79	0.17	3	
					4-leg intersection	0.61	0.06	4	notusa
					More than 4 leg intersection	0.25	0.17	3	notusa
					4-leg intersection	0.45	0.1	3	notusa
					4-leg intersection	0.62	0.11	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.5		3	notusa
					3-leg intersection	0.65		3	notusa
					4-leg intersection	0.48		3	notusa
					More than 4 legs intersection	0.14		3	notusa
			Angle			0.16		3	notusa
			Left-turn,Right-turn			1.65		3	notusa
			Vehicle/bicycle			0.7		3	notusa
Convert yield signal control to signalized control (end-crossroad crashes 80-200 m away from intersection)	Urban	All	All			0.96	0.1	3	notusa
						0.92	0.08	3	notusa
						0.98	0.06	3	notusa
					Nighttime	1.06	0.08	3	notusa
Convert yield signal control to signalized control (crashes 10-100 m away from intersection)	Urban	All	Main roadway			0.82	0.07	4	notusa
			Minor roadway			0.84	0.12	3	notusa
			All			0.8	0.07	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.8	0.07	4	notusa
					3-leg intersection	0.71	0.14	4	notusa
					4-leg intersection	0.76	0.07	4	notusa
Convert yield signal control to signalized control (crashes 110-200 m away from intersection)	Urban	All	Main roadway			0.93	0.06	3	notusa
			Minor roadway			0.75	0.1	4	notusa
			All			0.84	0.06	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.87	0.05	4	notusa
					3-leg intersection	0.82	0.06	4	notusa
					4-leg intersection	0.97	0.1	3	notusa
Convert yield signal control to signalized control (crashes 210-350 m away from intersection)	Urban	All	Main roadway			0.97	0.06	3	notusa
			Minor roadway			1.12	0.14	3	notusa
			All		3-leg,4-leg,more than 4 leg intersection	1.00	0.05	3	notusa
					3-leg intersection	0.99	0.11	3	notusa
					4-leg intersection	1.00	0.07	3	notusa
						0.92	0.07	3	notusa
Convert yield signal control to signalized control (crashes 360-500 m away from intersection)	Urban	All	Main roadway			0.92	0.07	3	notusa
			Minor roadway			1.27	0.18	3	notusa
			All		3-leg,4-leg,more than 4 leg intersection	0.99	0.06	3	notusa
					3-leg intersection	1.06	0.13	3	notusa
					4-leg intersection	0.97	0.07	3	notusa
						1.11	0.11	3	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Convert yield signal control to signalized control (crashes up to 500 m away from intersection)	Urban	All	Minor roadway			0.96	0.06	3	notusa
	Urban	All	All		3-leg,4-leg,more than 4 leg intersection	0.9	0.04	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.89	0.04	4	notusa
					3-leg intersection	0.95	0.08	3	notusa
					4-leg intersection	0.88	0.03	4	notusa
						0.85	0.04	4	notusa
Convert yield signal control to signalized control (roadway crashes up to 200 m away from intersection)	Urban	All	All		3-leg,4-leg,more than 4 leg intersection	0.87		3	notusa
					3-leg intersection	0.85		3	notusa
					4-leg intersection	0.86		3	notusa
			Angle		3-leg,4-leg,more than 4 leg intersection	0.72		3	notusa
					4-leg intersection	0.68		3	notusa
			Head-on,Rear-end		3-leg,4-leg,more than 4 leg intersection	0.82		3	notusa
					4-leg intersection	0.79		3	notusa
			Left-turn,Right-turn		3-leg,4-leg,more than 4 leg intersection	0.9		3	notusa
					4-leg intersection	0.82		3	notusa
			Single vehicle		3-leg,4-leg,more than 4 leg intersection	0.97		3	notusa
					4-leg intersection	0.92		3	notusa
			Vehicle/bicycle		3-leg,4-leg,more than 4 leg intersection	0.81		3	notusa
					3-leg intersection	1.04		3	notusa
					4-leg intersection	0.7		3	notusa
			Vehicle/pedestrian		3-leg,4-leg,more than 4 leg intersection	0.68		3	notusa
					3-leg,4-leg,more than 4 leg intersection	0.62		3	notusa
					4-leg intersection	0.69		3	notusa
					4-leg intersection	0.62		3	notusa
Convert yield signal control to signalized control (intersection and roadway crashes up to 200 m away from intersection)	Urban	All	All		3-leg,4-leg,more than 4 leg intersection	0.77	0.04	4	notusa
					3-leg intersection	0.81	0.08	4	notusa
					4-leg intersection	0.74	0.04	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.79	0.04	4	notusa
					3-leg intersection	0.79	0.04	4	notusa
					4-leg intersection	0.77	0.05	4	notusa
			Angle		3-leg,4-leg,more than 4 leg intersection	0.49	0.04	4	notusa
					3-leg intersection	0.56	0.09	3	notusa
					4-leg intersection	0.46	0.05	4	notusa
			Head-on,Rear-end		3-leg,4-leg,more than 4 leg intersection	0.89	0.08	3	notusa
					3-leg intersection	1.03	0.17	3	notusa
					4-leg intersection	0.83	0.09	4	notusa
			Left-turn,Right-turn		3-leg,4-leg,more than 4 leg intersection	1.01	0.09	3	
					3-leg intersection	1.00	0.14	3	notusa
					4-leg intersection	1.01	0.11	3	notusa
			Single vehicle		3-leg,4-leg,more than 4 leg intersection	0.97	0.09	3	notusa
					3-leg intersection	1.03	0.17	3	notusa
					4-leg intersection	0.93	0.1	3	notusa
			Vehicle/bicycle		3-leg,4-leg,more than 4 leg intersection	0.8	0.08	4	notusa
					3-leg intersection	1.03	0.13	3	notusa
					4-leg intersection	0.7	0.09	4	notusa
			Vehicle/pedestrian		3-leg,4-leg,more than 4 leg intersection	0.76	0.08	4	notusa
					3-leg intersection	0.76	0.14	3	notusa
					4-leg intersection	0.77	0.1	4	notusa
					3-leg,4-leg,more than 4 leg intersection	0.7	0.08	4	notusa
					3-leg intersection	0.68	0.15	3	notusa
					4-leg intersection	0.72	0.1	3	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Convert from yield signal control to signalized control (intersection crashes with 1 signal 200-500 m away)	Urban	All	All			0.59	0.14	3	notusa
Convert yield signal control to signalized control (intersection crashes with 1-2 signals under 200 m away)	Urban	All	All			0.52	0.11	3	notusa
Convert yield signal control to signalized control (intersection crashes with 2 signals 200-500 m away)	Urban	All	All			0.66	0.12	3	notusa
Change difference between actual and ITE-recommended yellow change interval from X to Y seconds at diamond interchange ramps		All	All			Eqn. 9-5		3	WI
			Angle			Eqn. 9-6		3	WI
			Rear-end			Eqn. 9-7		3	WI
Change difference between actual and ITE-recommended red clearance interval from X to Y seconds at diamond interchange ramps		All	All			Eqn. 9-8		3	WI
			Angle			Eqn. 9-9		3	WI
			Rear-end			Eqn. 9-10		3	WI
Change number of traffic signal cycles per hour on arterial with signal coordination from X to Y	Urban/suburban	All	Rear-end			Eqn. 9-11		3	IN
Change number of all-way stop intersections from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 9-12		3	NY
Change number of signalized intersections from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 9-13		3	NY
Convert minor-road stop control to all-way stop control	All	All	All			0.319	0.022	4	NC
			Angle			0.855	0.112	3	NC
			Angle,Head-on,Left-turn,Right-turn			0.247	0.02	4	NC
		Fatal and injury	All			0.23	0.025	4	NC
Convert two-way (without flashing beacons) to all-way stop control (without flashing beacons)	All	All	All			0.393	0.033	4	NC
			Angle	680 - 15100		0.943	0.152	3	NC
			Angle,Head-on,Left-turn,Right-turn			0.299	0.03	4	NC
		Fatal and injury	All			0.276	0.037	4	NC
Convert two-way (without flashing beacons) to all-way stop control (with flashing beacons)	All	All	All			0.183	0.035	4	NC
			Angle	1340 - 9900		0.601	0.201	3	NC
			Angle,Head-on,Left-turn,Right-turn			0.143	0.033	4	NC
		Fatal and injury	All			0.134	0.04	3	NC
Convert two-way (with flashing beacons) to all-way stop control (with flashing beacons)	All	All	All			0.198	0.039	4	NC
			Angle,Head-on,Left-turn,Right-turn			0.156	0.037	4	NC
		Fatal and injury	All			0.135	0.048	3	NC
Improve signal visibility	Urban	All	All			0.93		4	notusa
			Daytime			0.94		4	notusa
			Nighttime			0.93		4	notusa
		Fatal and injury	All			0.97		4	notusa
						0.71		3	notusa
		PDO	All			0.91		4	notusa
						0.79		3	notusa
Improve signal visibility, including signal lens size upgrade, installation of new back-plates, addition of reflective tapes to existing back-plates, and installation of additional signal heads	Urban	Fatal and injury	Daytime		4-leg intersections, 3 or 4 lanes per approach, 50 km/hr posted speed	1.004	0.039	4	notusa
			Nighttime			0.902	0.056	4	notusa
		PDO	Daytime			0.901	0.029	4	notusa
			Nighttime			0.867	0.052	4	notusa
Replace standard stop sign with flashing LED stop sign		All	Angle			0.59	0.25	3	MN

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install dynamic signal warning flashers	All	All	All			0.814	0.062	4	NV,VA
			Angle			0.745	0.086	4	NV,VA
			Rear-end			0.792	0.079	4	NV,VA
			Truck related			0.956	0.177	3	NV,VA
		Fatal and injury	All			0.82	0.083	4	NV,VA
Increase yellow change interval	Urban	All	All			1.14	0.177	3	CA,MD
			Angle			1.076	0.297	3	CA,MD
			Rear-end			0.934	0.237	3	CA,MD
		Fatal and injury	All			1.07	0.216	3	CA,MD
Increase all red clearance interval	Urban	All	All		Between 1-2 second increase	0.798	0.074	4	CA,MD
			Angle		Between 1-2 second increase	0.966	0.164	3	CA,MD
			Rear-end		Between 1-2 second increase	0.804	0.135	3	CA,MD
		Fatal and injury	All		Between 1-2 second increase	0.863	0.114	3	CA,MD
Increase yellow interval and add all red interval	Urban	All	All		Yellow between 0.5-1.6 second increase, Red between 1-2 second increase	0.99	0.146	3	CA,MD
			Angle			0.961	0.217	3	CA,MD
			Rear-end			1.12	0.288	3	CA,MD
		Fatal and injury	All			1.02	0.156	3	CA,MD
Increase total change interval (remains less than ITE recommended practice)	Urban	All	All			0.728	0.077	3	CA,MD
			Angle			0.84	0.195	3	CA,MD
			Rear-end			0.848	0.142	3	CA,MD
		Fatal and injury	All			0.662	0.099	3	CA,MD
Increase total change interval (greater than ITE recommended practice)	Urban	All	All			0.922	0.089	3	CA,MD
			Angle			1.068	0.156	3	CA,MD
			Rear-end			0.643	0.13	4	CA,MD
		Fatal and injury	All			0.937	0.114	3	CA,MD
Installation of an actuated advance warning dilemma zone protection system at high-speed signalized intersections		All	All			0.918	0.058	4	NE
			Angle			0.564	0.056	4	NE
			Rear-end			0.988	0.115	4	NE
			Truck related			0.995	0.133	4	NE
		Injury	All			0.887	0.105	4	NE
Replace Nighttime Flash with Steady Operation	All	All	All			0.52	0.06	4	NC
			Angle,Head-on,Left-turn,Sideswipe			0.43	0.07	4	NC
		Fatal and injury	All			0.47	0.08	4	NC
	Urban	All	Angle,Nighttime			0.66	0.32	3	
			Nighttime			0.65	0.26	3	
		All	All			0.73	0.08	3	NC
			Frontal and opposing direction sideswipe,Head-on			0.52	0.07	3	NC
		Fatal and injury	All			0.77	0.12	3	NC

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Replace Incandescent Traffic Signal Bulbs with Light Emitting Diodes (LEDs)	Urban	All	All		4-leg intersection	1.47	0.042	3	TN
					3-leg intersection	1.042	0.051	3	NC
					4-leg intersection	0.982	0.026	3	NC
			Angle,Head-on,Left-turn		3-leg intersection	1.016	0.094	3	NC
					3-leg intersection	1.078	0.194	3	NC
					4-leg intersection	1.091	0.049	3	NC
					4-leg intersection	0.959	0.075	3	NC
			Nighttime		3-leg intersection	1.109	0.106	3	NC
					4-leg intersection	0.926	0.044	4	NC
			Rear-end		3-leg intersection	1.105	0.084	3	NC
					3-leg intersection	1.177	0.182	3	NC
					4-leg intersection	0.827	0.036	4	NC
					4-leg intersection	0.828	0.069	4	NC
		Fatal and injury	All		3-leg intersection	1.17	0.094	3	NC
					4-leg intersection	1.047	0.045	3	NC
			Nighttime		3-leg intersection	1.122	0.179	3	NC
					4-leg intersection	1.035	0.081	3	NC
Install pedestrian countdown timer		All	Vehicle/pedestrian			0.3		4	MI
Change left-turn phasing from protected to flashing yellow arrow	Urban	All	All		Intersections only	1.338	0.097	5	NC,OR,WA
			Left-turn		Intersections only	2.242	0.276	5	NC,OR,WA
Modify change plus clearance interval to ITE 1985 Proposed Recommended Practice		All	Multiple vehicle			0.95	0.07	3	
		Injury	Multiple vehicle			0.91	0.07	3	

Table J. On-Street Parking

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Prohibit on-street parking	Urban	All	All			0.58	0.08	4	
		Fatal and injury	All	30000 - 40000		0.78	0.05	5	
		Injury	All		Minor arterial	0.8	0.05	5	
					Principal arterial, Other	0.65	0.14	4	
		PDO	All		Minor arterial	0.73	0.02	5	
					Principal arterial, Other	0.52	0.1	4	
				30000 - 40000	Principal arterial, Other	0.72	0.02	5	
Convert free to regulated parking	Urban	Injury	All			0.94	0.08	3	
		PDO	All			1.19	0.05	5	
		All	All			0.89	0.06	3	
			Parking related			0.21	0.09	4	
Convert angle parking to parallel parking	Urban	All	All			0.65	0.07	4	
						0.72	0.11	4	
			Parking related			0.37	0.07	4	
						0.43	0.18	4	
		Fatal and injury	All			0.59	0.27	3	
Mark parking stalls	Urban	All	All			1.51	0.2	4	
Change unrestricted parking hours from X to Y hours	Urban	All	All		All land uses	Eqn. 10-1		3	notusa
					Residential land uses	Eqn. 10-2		3	notusa
					Residential and mixed land uses	Eqn. 10-3		3	notusa
					All land uses, during rush hours	Eqn. 10-4		3	notusa
Change unrestricted left turn hours from X to Y hours	Urban	All	All		All land uses	Eqn. 10-5		3	notusa
					Residential land uses	Eqn. 10-6		3	notusa
					Residential and mixed land uses	Eqn. 10-7		3	notusa
					All lane uses, during rush hours	Eqn. 10-8		3	notusa
					Residential land uses, during rush hours	Eqn. 10-9		3	notusa
					Residential and mixed land uses, during rush hours	Eqn. 10-10		3	notusa

Table K. Pedestrians

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Raised median with marked crosswalk (uncontrolled)	Urban/suburban	All	Vehicle/pedestrian	**> 15000**		**0.54**	**0.48**	**3**	**AZ,CA,FL,KS,LA,MD,MA,MO,NC,OH,OR,PA,TX,UT,WA,WI**
Implement to Safe Routes to School Program		All	Vehicle/bicycle,Vehicle/pedestrian			0.724	0.0651	3	CA
		Minor injury				0.839	0.0541	3	CA
Install crosswalk on one minor approach	All	All	All			0.35		3	FL
Install high-visibility yellow, continental type crosswalks at schools	Urban	All	Vehicle/pedestrian	567 - 43199		0.63	0.12	3	CA
Installation of a High intensity Activated crossWalK (HAWK) pedestrian-activated beacon at an intersection	Urban/suburban	All	All			0.712	0.065	4	AZ
			Vehicle/pedestrian			0.309	0.156	3	AZ
		Incapacitating injury	All			0.849	0.118	3	AZ
Change number of subway stations from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 11-1		3	NY
Change number of bus stations from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 11-2		3	NY
Change number of bus stops in 50m buffer from X to Y	Urban/suburban	All	Vehicle/bicycle			Eqn. 11-3		3	notusa
Convert Pelican crossing* or farside pedestrian signal to Puffin crossing**		Fatal and injury	All		Mid-block crossing or signalized intersection	0.81		3	notusa
					Signalized intersection	0.74		3	notusa
					Mid-block crossing	0.83		3	notusa
					Mid-block crossing or signalized intersection	0.84		3	notusa
			Vehicle/pedestrian		Mid-block crossing or signalized intersection	0.76		3	notusa
					Mid-block crossing	0.78		3	notusa

Pelican crossing*

These are signal-controlled crossings where flashing amber follows the red 'Stop' light. You must stop when the red light shows. When the amber light is flashing, you must give way to any pedestrians on the crossing. If the amber light is flashing and there are no pedestrians on the crossing, you may proceed with caution.

Puffin crossing**

These are similar to pelican crossings, but there is no flashing amber phase

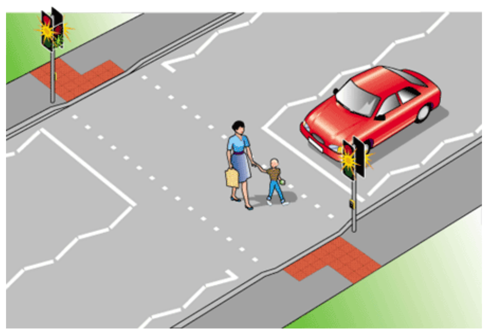


Table L. Railroad Grade Crossings

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Implementing signs and crossbucks at previously unprotected crossings			All			0.75	0.18	3	
Install flashing lights and sound signals		All	All			0.5	0.05	5	
Upgrade signs to flashing lights		All	All		Minor arterials	0.22	0.05	4	
					Multiple tracks	0.31	0.14	4	
					Local roads with single track crossing	0.21	0.04	5	
					Single track crossing at other road types (not local roads)	0.26	0.23	4	
					All	0.23	0.03	5	
Installing gates at crossings with signs		All	All		Minor arterial	0.06	0.02	5	
					Local roads	0.13	0.03	5	
					Local roads	0.09	0.02	5	
					All roads	0.07	0.01	5	
Install automatic gates at crossings that previously had passive traffic control		All	All			0.33	0.09	4	
Install automatic gates at crossings that previously had flashing lights and sound signals		All	All			0.55	0.09	4	

Table M. Roadside Features

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Flatten sideslope from 1V:3H to 1V:4H	Rural	All	Run-off-road			0.82	0.16	3	
		Injury	All			0.58	0.04	5	
		PDO	All			0.71	0.04	5	
Flatten sideslope from 1V:4H to 1V:6H	Rural	All	Run-off-road			0.76	0.21	3	
		Injury	All			0.78	0.04	5	
		PDO	All			0.76	0.02	5	
New guardrail along embankment		All	Run-off-road			0.93	0.31	3	
		Fatal	Run-off-road			0.56	0.1	4	
		Injury	Run-off-road			0.53	0.05	5	
Change barrier along embankment to less rigid type		Fatal	Run-off-road			0.59	0.31	3	
		Injury	Run-off-road			0.68	0.1	4	
Install median barrier	All	All	All			0.14	0.029	3	OH
		Fatal and injury	All			0.12	0.052	3	OH
	Rural	All	All	20000 - 60000		1.24	0.03	5	
		Fatal	All	20000 - 60000		0.57	0.1	4	
		Injury	All	20000 - 60000		0.7	0.06	4	
Install steel median barrier	Rural	Injury	All	20000 - 60000		0.65	0.08	4	
Install cable median barrier	Rural	Injury	All	20000 - 60000		0.71	0.11	4	
		All	Cross median,Frontal and opposing direction sideswipe,Head-on			0.09	0.1	4	IN
			Fixed object,Run-off-road,Single vehicle			1.83	0.76	4	IN
			Rear-end,Sideswipe			0.86	0.36	5	IN
	All	All	Cross median			0.38	0.104	3	UT
		Incapacitating injury	All			0.56	0.104	3	UT
		All	All	10000 - 180000		1.91	0.0622	3	WA
			Cross median	10000 - 180000		0.35	0.037	3	WA
			Other	10000 - 180000		0.47	0.033	3	WA
Install cable median barrier (low tension)	Rural	All	Fixed object,Run-off-road,Single vehicle		Depressed 30-50 ft median without barrier.	0.75	0.58	4	IN
					Depressed 50+ ft median without barrier.	1.87	0.81	3	IN
			Rear-end,Sideswipe		Depressed 30-50 ft median without barrier.	0.74	0.53	4	IN
					Depressed 50+ ft median without barrier.	0.78	0.39	3	IN
Install cable median barrier (high tension)	Rural	All	Cross median,Frontal and opposing direction sideswipe,Head-on			0.04	0.06	3	IN
			Fixed object,Run-off-road,Single vehicle			1.72	0.58	4	IN
			Rear-end,Sideswipe			1.08	0.63	4	IN
		All	Other	37429 - 74191		1.378	0.108	3	FL
		PDO	Other	37429 - 74191		1.881	0.218	3	FL
Install cable median barrier (on curve)	Rural	All	Cross median,Frontal and opposing direction sideswipe,Head-on			0.06	0.1	4	IN
Install cable median barrier (on tangent)	Rural	All	Cross median,Frontal and opposing direction sideswipe,Head-on			0		3	IN
Install concrete guardrail in median	Rural	All	Cross median,Frontal and opposing direction sideswipe,Head-on	10000 - 43000		0		4	CO,IL,IN,MO,NY,OH,OR,WA
			Sideswipe	10000 - 43000		0.8	0.37	4	CO,IL,IN,MO,NY,OH,OR,WA
			Single vehicle	10000 - 43000		2.2	1.13	4	CO,IL,IN,MO,NY,OH,OR,WA
		Injury	All			1.15	0.36	3	
Install beam guardrails on median of divided highway		Fatal	All			0.13	0.41	3	
		PDO	All			1.4	0.34	3	
		All	Cross median			0.22	0.19	4	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install crash cushions at fixed roadside features		Fatal	Fixed object			0.31	0.28	3	
		Injury	Fixed object			0.31	0.1	4	
		PDO	Fixed object			0.54	0.3	3	
Increase triangle sight distance		Fatal	All			**0.44**		**3**	**30+ states**
		PDO	All			0.89	0.15	3	
		Injury	All			0.53	0.29	3	
						0.63		**3**	**30+ states**
Remove or relocate fixed objects outside of clear zone	All	All	All			0.62	0.103	3	OH
		Fatal and injury	All			0.62	0.134	3	OH
Construct gateway monument (on state-owned road)	All	All	All	3300 - 34000		0.98	0.24	3	CA
				3300 - 34000		0.68	0.15	3	CA
Presence of grass land use	Urban	All	All			1.95	0.7	3	IA
Change proportion of commercial land use to total land use from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 13-1		3	NY
Change proportion of industrial land use to total land use from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 13-2		3	NY
Change proportion of open land use to total land use from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 13-3		3	NY
Change total park area (in 1000 acres) from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 13-4		3	NY
Change clear zone from greater than or equal to 8m to less than or equal to 2m	Rural	Fatal and injury	Run-off-road	1200 - 2400		2.19		3	notusa
Change clear zone from greater than or equal to 8m to between 2m and 4m	Rural	Fatal and injury	Run-off-road	1200 - 2400		1.6		3	notusa
Change clear zone from greater than or equal to 8m to between 4m and 8m	Rural	Fatal and injury	Run-off-road	1200 - 2400		1.27		3	notusa
Increase lateral clearance from 10 to 40 feet	Rural	Fatal and injury	Run-off-road,Single vehicle	3500 - 3500	On tangent sections	0.68		3	TX
				3500 - 3500	On horizontal curve sections	0.49		3	TX
Change the lateral offset of utility poles	Rural		Fixed object	377 - 16089		Eqn. 13-5		3	notusa
Change the longitudinal density of utility poles	Rural		Fixed object	377 - 16089		Eqn. 13-6		3	notusa
Increase distance to roadside features from 3.3 ft to 16.7 ft	Rural	All	All			0.78	0.02	5	
Increase distance to roadside features from 16.7 ft to 30 ft	Rural	All	All			0.56	0.01	5	

Table N. Roadway Features

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Increase lane width	Urban	All	All			0.72		3	NJ
Convert lane width (11 ft to 9 ft)	Rural	All	All			1.21	0.12	3	
Convert lane width (11 ft to 10 ft)	Rural	All	All			1.09	0.08	3	
Convert lane width (11 ft to 12 ft)	Rural	All	All			0.95	0.32	3	
Convert lane width (12 ft to 10 ft)	Rural	All	All	186 - 15106		1.05		3	ID
				186 - 400		1.04		3	ID
			Multiple vehicle	186 - 15106		1.04		3	ID
				186 - 400		1.04		3	ID
			Single vehicle	186 - 15106		1.07		3	ID
				186 - 400		1.06		3	ID
Convert lane width (12 ft to 11 ft)	Rural	All	All	186 - 15106		1.02		3	ID
				186 - 400		1.01		3	ID
			Multiple vehicle	186 - 15106		1.03		3	ID
				186 - 400		1.02		3	ID
			Single vehicle	186 - 15106		1.02		3	ID
				186 - 400		1.02		3	ID
Convert lane width (12 ft to 10 ft, with a total shoulder of X ft)	Urban/suburban	Fatal and injury	All	1183 - 47067		Eqn. 14-1		3	IL
Convert lane width (12 ft to 11 ft, with a total shoulder of X ft)	Urban/suburban	Fatal and injury	All	1183 - 47067		Eqn. 14-2		3	IL
Convert lane width (12 ft to 13 ft, with a total shoulder of X ft)	Urban/suburban	Fatal and injury	All	1183 - 47067		Eqn. 14-3		3	IL
Four to five lane conversion	Urban	All	All	79000 - 128000	One direction	1.11	0.05	4	
					Undivided	0.45	0.051	3	LA
		Fatal and injury	All	79000 - 128000		1.11	0.08	3	
		Injury and PDO	All	79000 - 128000		1.1	0.07	3	
	Suburban	All	All			0.43	0.062	3	LA
Five to six lane conversion	Urban	All	All	77000 - 126000		1.03	0.08	3	
		Fatal and injury	All	77000 - 126000		1.07	0.13	3	
		Injury and PDO	All	77000 - 126000		1.04	0.11	3	
Short-term effects of all measures to control snow, slush or ice	All		All	All		0.5	0.2	4	
				All		0.71	0.24	3	
				All		0.96	0.19	3	
Raise standard by one class for winter maintenance	All	Injury	All			0.89	0.02	5	
		PDO	All			0.73	0.02	5	
Effects of use of salt (chemical de-icing) during the whole winter season (baseline = no salt)	All	Injury	All	All		0.85	0.09	3	
				All		1.12	0.14	3	
		PDO	All	All		0.92	0.08	3	
				All		1	0.12	3	
Effects of snow fences and higher state of preparedness for the whole winter season	All	All	All	All		0.89	0.26	3	
						0.92	0.07	3	
Road diet (Convert 4-lane undivided road to 2-lanes plus turning lane)	Urban	All	All		Minor arterial	0.71	0.02	5	
				3510 - 17020		0.95	0.091	3	MI

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Road diet (Convert 4-lane undivided road to 2-lanes plus turning lane)		All	All	3510 - 17020	Target crashes	0.59	0.061	3	MI
				3510 - 17020	High crash areas	0.91		3	MI
				3510 - 17020	Residential areas	0.77		3	MI
				3510 - 17020	Mixed use areas	1.06		3	MI
				3510 - 17020	Commercial areas	1.05		3	MI
				3510 - 17020	Low driveway density	1.07		3	MI
				3510 - 17020	High driveway density	0.81		3	MI
				3510 - 17020	8 or fewer intersections	0.95		3	MI
				3510 - 17020	9 or more intersections	0.93		3	MI
	Suburban	All	All			0.47	0.01	4	
Narrow cross section (4 to 3 lanes with two way left-turn lane)	Urban	All	All			0.63	0.00632	3	MN
			Left-turn			0.76	0.01643	3	MN
			Angle		Right-angle	0.63	0.00949	3	MN
			Rear-end			0.69	0.01517	3	MN
		Fatal and injury	All			1	0.01581	3	MN
		PDO	All			0.54	0.00775	3	MN
Implement truck lane restrictions on multilane freeways (trucks prohibited from left-most lanes)		All	All	17049 - 74079		1.16	0.02	4	VA
				< 10000 vpdpl		0.87	0.041	4	VA
				> 10000 vpdpl		1.28	0.02	4	VA
			Truck related	17049 - 74079		1.15	0.041	4	VA
				< 10000 vpdpl		0.50	0.046	4	VA
				> 10000 vpdpl		1.34	0.051	4	VA
		Fatal and injury	All	17049 - 74079		1.10	0.031	4	VA
				4041 - 24361	4-lane segments, trucks traveling less than 15 mph below the speed limit prohibited on left-most lanes	0.68	0.177	3	VA
				< 10000 vpdpl		0.68	0.046	4	VA
				> 10000 vpdpl		1.23	0.036	4	VA
			Truck related	17049 - 74079		0.99	0.051	4	VA
				< 10000 vpdpl		0.6	0.082	4	VA
				> 10000 vpdpl		1.14	0.066	4	VA
Convert 12-ft lanes and 6-ft shoulders to 10-ft lanes and 3-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.13**	**0.044**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 10-ft lanes and 4-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.2**	**0.051**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 11-ft lanes and 2-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.12**	**0.047**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 11-ft lanes and 3-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.19**	**0.042**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 11-ft lanes and 4-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.14**	**0.035**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 11-ft lanes and 6-ft shoulders	Rural	All	Run-off-road	**> 1000**		**0.84**	**0.046**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 11-ft lanes and 7-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1**	**0.135**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 12-ft lanes and 2-ft shoulders	Rural	All	Run-off-road	**> 1000**		**1.16**	**0.082**	**3**	**PA**
Convert 12-ft lanes and 6-ft shoulders to 12-ft lanes and 5-ft shoulders	All	All	Run-off-road	**> 1000**		**0.87**	**0.07**	**3**	**PA**
Commercial vs. residential land use	Urban	All	All	1390 - 51200		3.42	1.321	3	UT
			Angle	1390 - 51200		1.77	0.308	3	UT
Refinish concrete pavement with inverted turf of stiff-bristled broom (wet weather crashes)		All	All			0.635	0.048	3	MN

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Refinish pavement with microsurfacing treatment (thickness from 8-10 mm)		All	All	3000/lane - 6999/lane		0.63	0.087	3	notusa
				7000/ane -		0.74	0.056	3	notusa
			Intersection	3000/lane - 6999/lane		0.62		3	notusa
				7000/lane -		0.67		3	notusa
			Rear-end	3000/lane - 6999/lane		0.5		3	notusa
				7000/lane -		0.59		3	notusa
			Wet road	3000/lane - 6999/lane		0.46		3	notusa
				7000/lane -		0.54		3	notusa
		Incapacitating injury	All	3000/lane - 6999/lane		0.57		3	notusa
				7000/lane -		0.74		3	notusa
Improve pavement friction (increase skid resistance)	All	All	All		Not intersection related	0.76	0.03	5	
				3475 - 65850		0.799	0.028	4	NY
					3-leg, Signalized intersection	0.667	0.05	4	NY
					3-leg, Stop-controlled intersection	0.819	0.048	4	NY
					3-leg intersection, Yield sign	0.59	0.114	3	NY
					4-leg, Signalized intersection	0.797	0.052	4	NY
					4-leg, Stop-controlled intersection	1.271	0.143	4	NY
					4-leg intersection, Yield sign	0.589	0.216	3	NY
				1814 - 185570	Not intersection related	0.764	0.023	4	NY
			Angle			1.045	0.078	4	NY
					3-leg, Signalized intersection	0.787	0.125	3	NY
					3-leg, Stop-controlled intersection	0.828	0.218	3	NY
					4-leg, Signalized intersection	0.898	0.117	3	NY
					4-leg, Stop-controlled intersection	1.687	0.323	4	NY
			Angle,Wet road			0.799	0.123	3	NY
					3-leg, Signalized intersection	0.47	0.161	3	NY
					3-leg, Stop-controlled intersection	0.828	0.218	3	NY
					4-leg, Signalized intersection	1.105	0.294	3	NY
					4-leg, Stop-controlled intersection	0.829	0.351	3	NY
			Rear-end		Not intersection related	0.83	0.05	5	
					Not intersection related	0.58	0.07	4	
						0.582	0.034	4	NY
					3-leg, Signalized intersection	0.554	0.065	4	NY
					3-leg, Stop-controlled intersection	0.586	0.057	4	NY
					3-leg intersection, Yield sign	0.304	0.086	3	NY
					4-leg, Signalized intersection	0.585	0.068	4	NY
					4-leg, Stop-controlled intersection	0.943	0.188	3	NY
					4-leg intersection, Yield sign	0.504	0.248	3	NY
				1814 - 185570	Not intersection related	0.828	0.043	4	NY
			Rear-end,Wet road			0.322	0.041	4	NY
				1814 - 185570	Not intersection related	0.575	0.055	4	NY
					3-leg, Signalized intersection	0.261	0.066	4	NY
					3-leg, Stop-controlled intersection	0.335	0.075	4	NY
					3-leg intersection, Yield sign	0.221	0.161	3	NY
					4-leg, Signalized intersection	0.361	0.084	4	NY
					4-leg, Stop-controlled intersection	0.482	0.215	4	NY
			Single vehicle	All	Not intersection related	0.7	0.05	5	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Improve pavement friction (increase skid resistance)	All	All	Wet road	All	Not intersection related	0.43	0.03	5	
					Not intersection related	0.426	0.03	4	NY
					3-leg, Signalized intersection	0.372	0.053	4	NY
					3-leg, Stop-controlled intersection	0.355	0.046	4	NY
					3-leg intersection, Yield sign	0.217	0.103	4	NY
					4-leg, Signalized intersection	0.546	0.07	4	NY
					4-leg, Stop-controlled intersection	0.597	0.137	4	NY
					4-leg intersection, Yield sign	0.361	0.371	3	NY
				1814 - 185570	Not intersection related	0.434	0.024	4	NY
	Rural	All	All		2 lanes, undivided	0.964	0.073	3	NY
						0.684	0.032	4	NY
			Rear-end		2 lanes, undivided	1.047	0.149	3	NY
						0.776	0.068	4	NY
			Rear-end,Wet road		2 lanes, undivided	0.971	0.256	3	NY
						0.474	0.079	3	NY
			Wet road		2 lanes, undivided	0.852	0.126	3	NY
						0.346	0.028	4	NY
	Urban	All	All		2 lanes, undivided	0.599	0.082	4	NY
						0.862	0.038	4	NY
			Rear-end		2 lanes, undivided	0.612	0.142	4	NY
						0.866	0.059	4	NY
			Rear-end,Wet road		2 lanes, undivided	0.344	0.145	3	NY
						0.64	0.084	3	NY
			Wet road		2 lanes, undivided	0.26	0.066	4	NY
						0.538	0.045	4	NY
Install TWLTL on two lane road	All	All	All	8500 - 22500		0.775	0.058	4	AR
						0.686	0.057	4	CA
						0.874	0.073	3	IL
						0.843	0.048	4	NC
						0.797	0.03	5	AR,CA,IL,NC
			Rear-end			0.506	0.073	4	CA
						0.58	0.076	3	IL
						0.783	0.077	4	NC
						0.613	0.04	5	AR,CA,IL,NC
		Fatal and injury	All	8500 - 22500		0.629	0.11	4	AR
						0.725	0.087	4	CA
						0.469	0.119	3	IL
						1.019	0.147	4	NC
						0.739	0.068	5	AR,CA,IL,NC
	Rural	All	All			0.64	0.04	5	
				8500 - 22500		0.488	0.071	4	AR
						0.492	0.057	4	CA
						0.833	0.105	3	IL
						0.727	0.055	4	NC
			Rear-end			0.53	0.05	5	
		Injury	All			0.65	0.08	4	
	Urban	All	All	8500 - 22500		0.962	0.083	3	AR
						1.028	0.134	3	CA
						0.906	0.1	3	IL
						1.05	0.088	4	NC
		All	Rear-end	8500 - 22500		0.501	0.073	4	AR

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install centerline rumble strips	Rural	All	All	5000 - 22000		0.86	0.05	4	
				1336 - 13240		0.89	0.058	4	MN
				574 - 17591		**0.98**	**0.033**	**4**	**PA**
				3167 - 20784		1.02	0.081	4	WA
				574 - 20784		**0.96**	**0.026**	**4**	**MN,PA,WA**
				574 - 20784		**0.91**	**0.02**	**5**	**CA,CO,DE,MD,MN,OR,PA,WA**
			Cross median	200 - 8000		0.328	0.151	4	KS
			Cross median,Frontal and opposing direction sideswipe,Head-on,Run-off-road			0.71		4	notusa
			Head-on,Sideswipe	5000 - 22000		0.79	0.14	4	
				1336 - 13240		0.51	0.073	4	MN
				574 - 17591		**0.74**	**0.179**	**4**	**PA**
				3167 - 20784		0.65	0.292	3	WA
				574 - 20784		**0.63**	**0.053**	**5**	**MN,PA,WA**
				574 - 20784		**0.7**	**0.045**	**5**	**CA,CO,DE,MD,MN,OR,PA,WA**
			Other	200 - 8000		0.708	0.098	4	KS
			Run-off-road	200 - 8000		0.808	0.141	4	KS
		Fatal and injury	All	1336 - 13240		0.78	0.066	4	MN
				574 - 17591		**0.94**	**0.042**	**4**	**PA**
				3167 - 20784		1.04	0.146	4	WA
				574 - 20784		**0.91**	**0.035**	**5**	**MN,PA,WA**
				574 - 20784		**0.88**	**0.028**	**5**	**CA,CO,DE,MD,MN,OR,PA,WA**
				200 - 8000		0.66	0.141	4	KS
			Head-on,Sideswipe	1336 - 13240		0.55	0.067	4	MN
				574 - 17591		**0.56**	**0.308**	**4**	**PA**
				3167 - 20784		0.65	0.292	3	WA
				574 - 20784		**0.55**	**0.064**	**5**	**MN,PA,WA**
		Injury	All	5000 - 22000		0.85	0.08	3	
			Head-on,Sideswipe	5000 - 22000		0.75	0.18	3	
	Urban	All	All	**2338 - 22076**		**1.02**	**0.08**	**4**	**PA**
			Head-on,Sideswipe	**2338 - 22076**		**0.6**	**0.17**	**4**	**PA**
		Fatal and injury	All	**2338 - 22076**		**0.91**	**0.095**	**4**	**PA**
			Head-on,Sideswipe	**2338 - 22076**		**0.36**	**0.269**	**3**	**PA**
Install centerline rumble strips on horizontal curves	Rural	All	All	1336 - 13240		0.83	0.096	4	MN
				574 - 17591		**1.16**	**0.092**	**4**	**PA**
				3167 - 20784		1.03	0.16	4	WA
				574 - 20784		**1.04**	**0.065**	**4**	**MN,PA,WA**
			Head-on,Sideswipe	1336 - 13240		0.48	0.136	3	MN
				574 - 17591		**0.53**	**0.139**	**4**	**PA**
				3167 - 20784		1.46	1.029	3	WA
				574 - 20784		**0.53**	**0.099**	**5**	**MN,PA,WA**
		Fatal and injury	All	1336 - 13240		0.63	0.116	4	MN
				574 - 17591		**1.1**	**0.114**	**4**	**PA**
				3167 - 20784		0.79	0.129	3	WA
				574 - 20784		**0.94**	**0.081**	**4**	**MN,PA,WA**

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install centerline rumble strips on tangent sections	Rural	All	All	1336 - 13240		0.9	0.055	4	MN
				574 - 17591		**0.9**	**0.084**	**4**	**PA**
				3167 - 20784		1.02	0.093	4	WA
				574 - 20784		**0.92**	**0.043**	**4**	**MN,PA,WA**
			Head-on,Sideswipe	1336 - 13240		0.51	0.079	4	MN
				574 - 17591		**0.57**	**0.184**	**3**	**PA**
				3167 - 20784		0.33	0.19	3	WA
				574 - 20784		**0.51**	**0.069**	**5**	**MN,PA,WA**
		Fatal and injury	All	1336 - 13240		0.82	0.078	4	MN
				574 - 17591		**0.78**	**0.1**	**4**	**PA**
				3167 - 20784		1.1	0.173	4	WA
				574 - 20784		**0.85**	**0.059**	**5**	**MN,PA,WA**
Install rectangular shaped centerline rumble strips	Rural	All	Other	200 - 8000		0.772	0.112	4	KS
			Cross median	200 - 8000		0.396	0.195	4	KS
			Run-off-road	200 - 8000		0.849	0.155	4	KS
		Fatal and injury	All	200 - 8000		0.689	0.155	4	KS
Install football shaped centerline rumble strips	Rural	All	Other	200 - 8000		0.331	0.156	3	KS
			Cross median	200 - 8000		0.097	0.143	3	KS
			Run-off-road	200 - 8000		0.45	0.279	3	KS
		Fatal and injury	All	200 - 8000		0.398	0.288	3	KS
Install edgeline rumble strips	Rural	Fatal and injury	Run-off-road	**6777 - 37112**		**0.71**	**0.139**	**3**	**MO,PA**
				11539 - 37112		0.75	0.1569	3	MO
				4956 - 31692		**0.75**	**0.1311**	**3**	**MN,MO,PA**
				4959 - 31692		0.7	0.1304	3	MN
				4956 - 20763		0.58	0.1446	3	MO
				8267 - 18753		**1.31**	**0.1079**	**3**	**PA**
				180 - 12776		**0.67**	**0.1222**	**4**	**MN,MO,PA**
				180 - 10386		1.08	0.2138	3	MN
				180 - 12776		**0.61**	**0.1556**	**4**	**MN,MO,PA**
				180 - 10386		0.57	0.2066	3	MN
		Fatal and injury	Run-off-road	**180 - 92757**		**0.86**	**0.0855**	**3**	**MN,MO,PA**
Install edgeline rumble strips on roadways with a shoulder width less than 5 feet	Rural	Fatal and injury	Run-off-road	**4956 - 31692**		**0.96**	**0.1554**	**3**	**MN,MO,PA**
				4956 - 20763		1.1	0.0508	3	MO
				180 - 12776		**0.53**	**0.2339**	**3**	**MN,MO,PA**
				180 - 10386		1.27	0.7837	3	MN
Install edgeline rumble strips on roadways with a shoulder width of 5 feet or greater	Rural	Fatal and injury	Run-off-road	11539 - 37112		0.75	0.1569	3	MO
				4956 - 31692		**0.34**	**0.1855**	**4**	**MN,MO,PA**
				4959 - 31692		0.7	0.1304	3	MN
				4956 - 20763		0.46	0.1283	3	MO
				8267 - 18753		**0.52**	**0.1161**	**3**	**PA**
				180 - 12776		**0.57**	**0.1452**	**4**	**MN,MO,PA**
				180 - 10386		1.11	0.5314	3	MN
Install centerline and shoulder rumble strips	Rural	All	Head-on,Run-off-road,Sideswipe			0.34	0.044	3	WA
			Head-on,Sideswipe			0.29	0.046	3	WA
			Run-off-road			0.384	0.064	3	WA
		Incapacitating injury	All			0.82		4	notusa
		All	Cross median,Frontal and opposing direction sideswipe,Head-on,Run-off-road			0.79		4	notusa
Resurface pavement		All	All			1.01	0.02	4	FL
			Rear-end			0.99	0.03	4	FL
		Incapacitating injury	All			0.95	0.05	4	FL
Resurface pavement with groove pavement (GP)	All	All	Wet road			0.5	0.19	3	CA
Resurface pavement with open-graded asphalt concrete (OGAC)	All	All	Wet road			0.59	0.16	3	CA

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Change bridge width (bridge minus roadway width) from X to Y		All	All			Eqn. 14-4		3	IA
Changing pavement macrotexture from X to Y	Rural	All	All	2090 - 11500		Eqn. 14-5		3	NC
Change roadway surface from gravel or dirt to asphalt	Rural	All	All	35 - 1468		Eqn. 14-6		3	WY
Convert High-Occupancy-Vehicle (HOV) lanes to High-Occupancy-Toll (HOT) lanes	Urban	All	All			0.95	0.04	3	MN
		Minor injury	All			1.06		3	MN
						0.96		3	MN
		PDO	All			0.89		3	MN
Presence of two-lane roadway vs. greater than two-lane roadway	Urban	All	All			0.43	0.18	3	IA
Install transverse rumble strips on stop controlled approaches	All	Incapacitating injury	All		4-leg intersection	0.745	0.121	4	IA,MN
	Rural	All	All		Minor arterial	1.223	0.142	4	IA,MN
					4-leg intersection	1.066	0.104	4	IA,MN
					4-leg intersection	1.066	0.104	4	IA,MN
					3-leg intersection	0.798	0.32	3	IA
					4-leg intersection	0.819	0.232	3	IA
					3-leg,4-leg intersection	0.818	0.191	3	IA
					3-leg intersection	0.671	0.278	3	MN
					4-leg intersection	1.357	0.447	3	MN
					3-leg,4-leg intersection	1.182	0.316	3	MN
		Incapacitating injury	All		3-leg intersection	0.903	0.211	3	IA,MN
					3-leg,4-leg intersection	0.785	0.107	4	IA,MN
		Fatal and injury	All		3-leg intersection	1.192	0.207	3	IA,MN
					4-leg intersection	0.913	0.124	4	IA,MN
					3-leg,4-leg intersection	0.987	0.109	4	IA,MN
		PDO	All		3-leg intersection	1.284	0.185	3	IA,MN
					3-leg,4-leg intersection	1.191	0.102	4	IA,MN
		PDO	All		4-leg intersection	1.138	0.121	4	IA,MN
Change proportion of 1-lane roadways to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-7		3	NY
Change proportion of 4-lane roadways to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-8		3	NY
Change proportion of 5-lane roadways to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-9		3	NY
Change proportion of primary roadway (without access restriction) to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-10		3	NY
Change proportion or primary roadway (with limited access) to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-11		3	NY
Change proportion of length of roads with widths less than 30 feet to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-12		3	NY
Change proportion of local rural road to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-13		3	NY
Change proportion of other throughfare roadway to total roadway length from X to Y	Urban	Incapacitating injury	Vehicle/pedestrian			Eqn. 14-14		3	NY
Increase surface width from X to Y feet		All	Truck related		Travel lanes only	Eqn. 14-15		3	FL
Change travel lane plus sealed shoulder width from greater than or equal to 3.5m to less than 3.5m	Rural	Fatal and injury	Run-off-road	1200 - 2400		1.21		3	notusa
Install periodic passing lanes on rural two-lane highways	Rural	Fatal and injury	All	1655 - 7031		0.58	0.09	4	TX
		Fatal and injury	Non-intersection	1655 - 7031		0.65	0.11	4	TX

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Convert 12-ft inside and outside lanes to 12-ft inside lane and X-ft outside lane	Urban	All	All	25100 - 52500		Eqn. 14-16		3	FL
		Fatal and injury	All	25100 - 52500		Eqn. 14-17		3	FL
		PDO	All	25100 - 52500		Eqn. 14-18		3	FL
Convert 12-ft inside and outside lanes to Y-ft inside lane and X-ft outside lane	Urban	All	All	7480 - 43929		Eqn. 14-19		3	FL
		Fatal and injury	All	7480 - 43929		Eqn. 14-20		3	FL
		PDO	All	7480 - 43929		Eqn. 14-21		3	FL
Installation of passing relief lane	Rural	All	All		Relief lanes 1 to 2.9 miles long	0.67	0.149	3	MI
			Daytime		Relief lanes 1 to 2.9 miles long	0.6	0.132	3	MI
			Dry weather		Relief lanes 1 to 2.9 miles long	0.53	0.119	3	MI
			Head-on,Rear-end,Run-off-road,Sideswipe		Relief lanes 1 to 2.9 miles long	0.53	0.114	3	MI
			Summer		Relief lanes 1 to 2.9 miles long	0.54	0.151	3	MI
			Non-summer		Relief lanes 1 to 2.9 miles long	0.72	0.164	3	MI
		Injury	All		Relief lanes 1 to 2.9 miles long	0.71	0.155	3	MI
Removing mainline barrier toll plazas on highways		All	All			0.528	0.016	4	NJ
		Fatal and injury	All			0.597	0.038	4	NJ
		PDO	All			0.51	0.017	4	NJ
Convert major road of a signalized T intersection from two-way to one-way	Urban	All	Motorcycle			0.4		3	notusa
Install transverse rumble strips at pedestrian crosswalks on rural low-volume roads	Rural	All	All			0.76	0.33	3	

Table O. Shoulder Treatments

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality	State
						Value	Std. Err	Rating	
Install shoulder rumble strips	Rural	All	All	6777 - 37112		1.07	0.0391	4	MO,PA
				11539 - 37112		1.08	0.0413	4	MO
				6777 - 24752		1	0.118	4	PA
				4959 - 20763		1.18	0.078	5	MN,MO,PA
				4959 - 7459		1.1	0.1468	4	MN
				5326 - 20763		1.22	0.0946	4	MO
				9653 - 18753		0.87	0.3564	3	PA
				782 - 10386		1.06	0.057	4	MN,MO,PA
				782 - 10386		1.14	0.0801	4	MN
				861 - 6205		1.4	0.18	4	MO
				948 - 9067		0.76	0.0861	4	PA
				6777 - 37112		1.01	0.0696	3	MO,PA
				11539 - 37112		1.08	0.0717	3	MO
				6777 - 34406		1.08	0.1166	3	PA
				4956 - 31692		1.2	0.0954	4	MN,MO,PA
				4959 - 31692		1.16	0.0918	3	MN
				4956 - 20763		1.28	0.1423	3	MO
				8267 - 18753		0.81	0.2015	3	PA
				180 - 12776		0.86	0.0969	3	MN,MO,PA
				180 - 10386		0.96	0.0684	3	MN
				861 - 12776		0.83	1.1599	3	MO
				910 - 10177		0.76	0.1485	3	PA
				6777 - 37112		1.07	0.0781	3	MO,PA
				11539 - 37112		1.11	0.0763	3	MO
				6777 - 24752		1.06	0.161	3	PA
				4956 - 31692		1.28	0.1092	4	MN,MO,PA
				4959 - 31692		1.17	0.1367	3	MN
				4956 - 20763		1.28	0.1431	3	MO
				8267 - 18753		0.74	0.2449	3	PA
				180 - 12776		0.94	0.1306	3	MN,MO,PA
				180 - 10386		1.18	0.1028	3	MN
				861 - 12776		0.85	1.2939	3	MO
				910 - 10177		0.76	0.1485	3	PA
			Run-off-road			0.87	0.08	4	MN
						0.66		3	CT
					< 65 mph	0.84		3	CT
					No shoulder rumble strips between on and off ramps on freeways.	0.66		3	CT
					65 mph	0.62		3	CT
					6 or more lanes	0.64		3	CT
					4 lanes	0.68		3	CT
					Undivided	0.74		4	notusa
					All	0.78		4	notusa
				6777 - 37112		0.9	0.0521	4	MO,PA
				11539 - 37112		0.92	0.0571	4	MO
				6777 - 24752		0.82	0.1227	4	PA
				4959 - 20763		1.4	0.124	5	MN,MO,PA
				4959 - 7459		1.38	0.2662	3	MN
				5326 - 20763		1.45	0.1479	4	MO
				9653 - 17018		0.75	0.3744	3	PA
				782 - 10386		0.84	0.0807	5	MN,MO,PA
				782 - 10386		1.11	0.1707	4	MN

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install shoulder rumble strips	Rural	All	Run-off-road	861 - 6205		1.17	0.2176	3	MO
				948 - 9067		**0.56**	**0.0913**	**4**	**PA**
				6777 - 37112		**0.9**	**0.0666**	**3**	**MO,PA**
				11539 - 37112		0.93	0.0686	3	MO
				6777 - 34406		**0.98**	**0.1332**	**3**	**PA**
				4956 - 31692		**1.41**	**0.1694**	**4**	**MN,MO,PA**
				4959 - 31692		1.39	0.1653	3	MN
				4956 - 20763		1.7	0.2791	3	MO
				8267 - 18753		**0.77**	**0.1319**	**3**	**PA**
				180 - 12776		**0.71**	**0.1196**	**4**	**MN,MO,PA**
				180 - 10386		1.19	0.1587	3	MN
				861 - 12776		0.91	1.0362	3	MO
				910 - 10177		**0.55**	**0.1278**	**3**	**PA**
				6777 - 37112		**0.9**	**0.073**	**3**	**MO,PA**
				11539 - 37112		0.94	0.0727	3	MO
				6777 - 24752		**0.87**	**0.1643**	**3**	**PA**
				4956 - 31692		**1.66**	**0.2319**	**4**	**MN,MO,PA**
				4959 - 31692		1.34	0.1314	3	MN
				4956 - 20763		1.67	0.276	3	MO
				8267 - 18753		**0.77**	**0.1378**	**3**	**PA**
				180 - 12776		**0.74**	**0.1696**	**3**	**MN,MO,PA**
				180 - 10386		1.12	0.2051	3	MN
				861 - 12776		0.94	1.0872	3	MO
				910 - 10177		**0.55**	**0.1278**	**3**	**PA**
						0.822	0.066	4	notusa
			Run-off-road, Nighttime	**6777 - 37112**		**0.73**	**0.0684**	**5**	**MO,PA**
				11539 - 37112		0.74	0.0764	4	MO
				6777 - 24752		**0.67**	**0.1516**	**4**	**PA**
				782 - 10386		**0.89**	**0.1254**	**4**	**MN,MO,PA**
				782 - 10386		1.27	0.2671	3	MN
				861 - 6205		1.2	0.446	3	MO
				948 - 9067		**0.62**	**0.1371**	**4**	**PA**
				6777 - 37112		**0.77**	**0.0867**	**4**	**MO,PA**
				11539 - 37112		0.82	0.1069	3	MO
				6777 - 24752		**0.72**	**0.1518**	**3**	**PA**
				180 - 12776		**0.76**	**0.163**	**3**	**MN,MO,PA**
				180 - 10386		1.11	0.2732	3	MN
				861 - 12776		1.55	2.1783	3	MO
				910 - 10177		**0.6**	**0.1719**	**3**	**PA**
				6777 - 37112		**0.78**	**0.0747**	**4**	**MO,PA**
				11539 - 37112		0.79	0.0872	3	MO
				6777 - 34406		**0.7**	**0.1434**	**3**	**PA**
				180 - 12776		**0.7**	**0.1158**	**4**	**MN,MO,PA**
				180 - 10386		1.11	0.1985	3	MN
				861 - 12776		1.41	1.948	3	MO
				910 - 10177		**0.6**	**0.1719**	**3**	**PA**

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install shoulder rumble strips	Rural	All	Run-off-road,Truck related	6777 - 37112		0.58	0.0801	5	MO,PA
				11539 - 37112		0.58	0.0838	4	MO
				6777 - 24752		0.59	0.2697	3	PA
				782 - 10386		1.83	0.5841	3	MN,MO,PA
				782 - 10386		2.82	1.2629	3	MN
				861 - 6205		2.39	1.4201	3	MO
				948 - 9067		0.81	0.5752	3	PA
				6777 - 37112		0.58	0.1224	4	MO,PA
				11539 - 37112		0.59	0.0954	3	MO
				6777 - 37112		0.54	0.1015	4	MO,PA
				11539 - 37112		0.59	0.0878	3	MO
			Run-off-road,Wet road	6777 - 37112		0.82	0.073	5	MO,PA
				11539 - 37112		0.77	0.0775	4	MO
				6777 - 24752		1.04	0.2002	3	PA
				782 - 10386		1.18	0.1538	4	MN,MO,PA
				782 - 10386		1.5	0.3023	3	MN
				861 - 6205		1.98	0.4914	3	MO
				948 - 9067		0.7	0.1642	3	PA
				6777 - 37112		0.89	0.1105	3	MO,PA
				11539 - 37112		0.86	0.1069	3	MO
				6777 - 24752		1.03	0.2908	3	PA
				180 - 12776		1.05	0.2378	3	MN,MO,PA
				180 - 10386		1.38	0.3518	3	MN
				861 - 12776		2.35	2.3699	3	MO
				910 - 10177		0.72	0.2082	3	PA
				6777 - 37112		0.94	0.1031	3	MO,PA
				11539 - 37112		0.85	0.1026	3	MO
				6777 - 34406		1.4	0.2554	3	PA
				180 - 12776		1.05	0.1523	3	MN,MO,PA
				180 - 10386		1.75	0.3079	3	MN
				861 - 12776		2.18	2.0885	3	MO
				910 - 10177		0.72	0.2082	3	PA

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality	State
						Value	Std. Err	Rating	
Install shoulder rumble strips	Rural	Fatal and injury	All	**6777 - 37112**		**0.93**	**0.059**	**4**	**MO,PA**
				11539 - 37112		0.94	0.0641	4	MO
				6777 - 24752		**0.87**	**0.1462**	**4**	**PA**
				4959 - 20763		**0.9**	**0.1022**	**4**	**MN,MO,PA**
				4959 - 7459		0.78	0.1963	3	MN
				5326 - 20763		0.95	0.1231	4	MO
				9653 - 17018		**0.6**	**0.4252**	**3**	**PA**
				782 - 10386		**0.92**	**0.0804**	**4**	**MN,MO,PA**
				782 - 10386		1.05	0.1266	4	MN
				861 - 6205		0.81	0.2182	3	MO
				948 - 9067		**0.82**	**0.1159**	**4**	**PA**
				6777 - 37112		**0.92**	**0.0671**	**3**	**MO,PA**
				11539 - 37112		0.97	0.0837	3	MO
				6777 - 34406		**0.88**	**0.111**	**3**	**PA**
				4956 - 31692		**1.01**	**0.1082**	**3**	**MN,MO,PA**
				4959 - 31692		1.07	0.1008	3	MN
				4956 - 20763		1.05	0.2217	3	MO
				8267 - 18753		**0.58**	**0.1638**	**3**	**PA**
				180 - 12776		**0.72**	**0.0862**	**4**	**MN,MO,PA**
				180 - 10386		0.87	0.0839	3	MN
				861 - 12776		0.6	0.6339	3	MO
				910 - 10177		**0.84**	**0.189**	**3**	**PA**
				6777 - 37112		**0.96**	**0.0842**	**3**	**MO,PA**
				11539 - 37112		0.99	0.0954	3	MO
				6777 - 24752		**0.91**	**0.1413**	**3**	**PA**
				4956 - 31692		**1.05**	**0.1788**	**3**	**MN,MO,PA**
				4959 - 31692		0.82	0.1508	3	MN
				4956 - 20763		1.02	0.2181	3	MO
				8267 - 18753		**0.56**	**0.1704**	**3**	**PA**
				180 - 12776		**0.86**	**0.1156**	**3**	**MN,MO,PA**
				180 - 10386		1.07	0.161	3	MN
				861 - 12776		0.65	0.698	3	MO
				910 - 10177		**0.84**	**0.189**	**3**	**PA**

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install shoulder rumble strips	Rural	Fatal and injury	Run-off-road			0.82	0.12	3	MN
				6777 - 37112		0.83	0.073	5	MO,PA
				11539 - 37112		0.84	0.0822	4	MO
				6777 - 24752		0.77	0.1571	3	PA
				4959 - 20763		0.97	0.1351	4	MN,MO,PA
				4959 - 7459		0.9	0.2863	3	MN
				5326 - 20763		1	0.1584	4	MO
				9653 - 17018		0.8	0.5695	3	PA
				782 - 10386		0.64	0.0971	5	MN,MO,PA
				782 - 10386		0.68	0.1761	3	MN
				861 - 6205		0.55	0.2316	3	MO
				948 - 9067		0.63	0.1335	4	PA
				6777 - 37112		0.86	0.0732	3	MO,PA
				11539 - 37112		0.88	0.0857	3	MO
				6777 - 34406		0.87	0.1413	3	PA
				4956 - 31692		1.05	0.1444	3	MN,MO,PA
				4959 - 31692		1.12	0.1548	3	MN
				4956 - 20763		1.19	0.2574	3	MO
				180 - 12776		0.63	0.1031	4	MN,MO,PA
				180 - 10386		1.04	0.1839	3	MN
				861 - 12776		0.41	1.55	3	MO
				910 - 10177		0.63	0.1579	3	PA
				6777 - 37112		0.82	0.0829	3	MO,PA
				11539 - 37112		0.86	0.0959	3	MO
				6777 - 24752		0.78	0.1574	3	PA
				4956 - 31692		1.15	0.2375	3	MN,MO,PA
				4959 - 31692		0.85	0.1645	3	MN
				4956 - 20763		1.12	0.2385	3	MO
				180 - 12776		0.6	0.1265	4	MN,MO,PA
				180 - 10386		0.77	0.2005	3	MN
				861 - 12776		0.43	1.8224	3	MO
				910 - 10177		0.63	0.1579	3	PA
				6777 - 37112		0.91	0.0824	3	MO,PA
				11539 - 37112		0.97	0.0811	3	MO
				4956 - 31692		1.1	0.1643	3	MN,MO,PA
				4959 - 31692		1.23	0.1755	3	MN
				4956 - 20763		1.28	0.301	3	MO
				8267 - 18753		0.52	0.1957	3	PA
				180 - 12776		0.53	0.1378	4	MN,MO,PA
				180 - 10386		0.92	0.2406	3	MN
				180 - 12776		0.58	0.2026	3	MN,MO,PA
				180 - 10386		1.11	0.3931	3	MN
	Urban	All	All	11254 - 59391		0.99	0.0572	4	PA
				11254 - 92757		0.96	0.0546	3	PA
				11254 - 92757		0.95	0.0569	3	PA
			Run-off-road	11254 - 59391		0.94	0.0732	4	PA
				11254 - 92757		0.96	0.0755	3	PA
				11254 - 92757		0.9	0.0964	3	PA
		Fatal and injury	All	11254 - 59391		0.84	0.0725	4	PA
				11254 - 92757		0.91	0.0719	3	PA
				11254 - 92757		0.8	0.0778	3	PA
			Run-off-road	11254 - 59391		0.93	0.0993	4	PA
				11254 - 92757		1.02	0.0977	3	PA
				11254 - 92757		0.9	0.1158	3	PA
				11254 - 92757		1.02	0.0977	3	PA

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install shoulder rumble strips	Urban	All	Run-off-road			0.82		3	notusa
		Fatal and injury	Run-off-road	180 - 92757		1	0.0556	3	MN,MO,PA
Install continuous milled-in shoulder rumble strips	All	All	Run-off-road,Single vehicle			0.82	0.12	3	
						0.21	0.07	4	
		Injury	Run-off-road,Single vehicle			0.87	0.21	3	
	Rural	All	All	2000 - 50000		0.84	0.13	3	
			Run-off-road,Single vehicle	2000 - 50000		0.9	0.25	3	
						0.79	0.18	3	
		Injury	All	2000 - 50000		0.83	0.19	3	
			Run-off-road,Single vehicle	2000 - 50000		0.78	0.33	3	
						0.93	0.28	3	
Install shoulder rumble strips on illuminated highways	Rural	All	Run-off-road			0.59		3	CT
Install shoulder rumble strips on unilluminated highways	Rural	All	Run-off-road			0.79		3	CT
Install shoulder rumble strips on roadways with a shoulder width equal to 5 feet	Urban	Fatal and injury	Run-off-road	11254 - 92757		0.68	0.1431	3	PA
	Rural	Fatal and injury	Run-off-road	11539 - 37112		0.97	0.0811	3	MO
				4956 - 31692		0.52	0.2658	3	MN,MO,PA
				4959 - 31692		1.23	0.1755	3	MN
				4956 - 20763		1.41	0.2362	3	MO
				8267 - 18753		0.22	0.0742	3	PA
				180 - 12776		0.46	0.1255	4	MN,MO,PA
				180 - 10386		0.92	0.4679	3	MN
Install shoulder rumble strips on roadways with a shoulder width less than 5 feet	Urban	Fatal and injury	Run-off-road	11254 - 92757		0.66	0.1163	3	PA
	Rural	Fatal and injury	Run-off-road	180 - 12776		0.35	0.7671	3	MN,MO,PA
				180 - 10386		1.21	0.8686	3	MN
Install shoulder rumble strips with an offset of 0-8 inches relative to the edgeline	Rural	Fatal and injury	Run-off-road	6777 - 37112		0.71	0.1393	3	MO,PA
				11539 - 37112		0.75	0.1584	3	MO
				4956 - 31692		0.74	0.1293	3	MN,MO,PA
				4959 - 31692		0.71	0.1291	3	MN
				4956 - 20763		0.58	0.1446	3	MO
				180 - 12776		0.67	0.123	4	MN,MO,PA
				180 - 10386		1.1	0.2196	3	MN
Install shoulder rumble strips with an offset of 9-20 inches relative to the edgeline	Urban	Fatal and injury	Run-off-road	11254 - 92757		1.02	0.0977	3	PA
	Rural	Fatal and injury	Run-off-road	6777 - 37112		0.9	0.1324	3	MO,PA
				11539 - 37112		0.49	0.0276	3	MO
				4956 - 31692		1.06	0.1431	3	MN,MO,PA
				4959 - 31692		1.3	0.1827	3	MN
				180 - 12776		0.62	0.149	4	MN,MO,PA
				180 - 10386		0.79	0.2406	3	MN
Install shoulder rumble strips with an offset of 21+ inches relative to the edgeline	Rural	Fatal and injury	Run-off-road	6777 - 37112		0.93	0.0776	3	MO,PA
				11539 - 37112		1.02	0.0839	3	MO
				4956 - 31692		1.16	0.3059	3	MN,MO,PA
				4959 - 31692		0.74	0.1352	3	MN
				4956 - 20763		1.28	0.301	3	MO
				180 - 12776		0.43	0.276	3	MN,MO,PA
				180 - 10386		1.58	0.6656	3	MN
Reduce shoulder width (6 ft to 0 ft)	Rural	All	All	95 - 25844		1.12	0.031	3	PA
Reduce shoulder width (6 ft to 1 ft)	Rural	All	All	95 - 25844		1.17	0.062	3	PA
Reduce shoulder width (6 ft to 2 ft)	Rural	All	All	95 - 25844		1.11	0.024	3	PA
Reduce shoulder width (6 ft to 4 ft)	Rural	All	All	95 - 25844		1.06	0.019	3	PA
Reduce shoulder width (6 ft to 5 ft)	Rural	All	All	95 - 25844		1.02	0.024	3	PA

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Decrease inside shoulder width from 10ft to 4ft	Urban	Fatal and injury	All	5700 - 309000		0.446	0.035	3	FL
Reduce paved shoulder from 3 ft to 0 ft	Rural	All	All	186 - 15106		1.16		3	ID
				186 - 400		1.13		3	ID
			Multiple vehicle	186 - 15106		1.15		3	ID
				186 - 400		1.11		3	ID
			Single vehicle	186 - 15106		1.17		3	ID
				186 - 400		1.14		3	ID
		All	All			1.22		4	CA,KY,MN
		All	Single vehicle			1.17		4	CA,KY,MN
Reduce paved shoulder from 3 ft to 1 ft	Rural	All	All	186 - 15106		1.13		3	ID
				186 - 400		1.11		3	ID
			Multiple vehicle	186 - 15106		1.18		3	ID
				186 - 400		1.13		3	ID
			Single vehicle	186 - 15106		1.07		3	ID
				186 - 400		1.09		3	ID
Reduce paved shoulder from 3 ft to 2 ft	Rural	All	All	186 - 15106		1.03		3	ID
				186 - 400		1.03		3	ID
			Multiple vehicle	186 - 15106		1.03		3	ID
				186 - 400		1.02		3	ID
			Single vehicle	186 - 15106		1.02		3	ID
				186 - 400		1.03		3	ID
Reduce inside paved shoulder width from 4ft to 2ft	Urban	All	All		Outside paved shoulder width = 10ft	0.668	0.1	3	FL
					Outside paved shoulder width = 8ft	0.749	0.1	3	FL
		Fatal and injury	All			0.728	0.1	3	FL
Reduce outside paved shoulder width from 10ft to 4ft	Urban	All	All		Inside paved shoulder width = 4 ft	0.417	0.1	3	FL
Reduce outside paved shoulder width from 10ft to 8ft	Urban	All	All		Inside paved shoulder width = 4ft	0.819	0.1	3	FL
				5700 - 309000		1.081	0.131	3	FL
			Rear-end	5700 - 309000		1.111	0.17	3	FL
		Fatal and injury	All	5700 - 309000		1.172	0.131	3	FL
Install curb and gutter	Suburban	All	All	8333 - 57138		0.89		3	NC
Install gravel right shoulder	Urban	All	All			4.21	1.2	3	IA
		Fatal and injury	All			0.517	0.11	3	IA
Widen shoulder width from 0 to 10 feet	Rural	Fatal and injury	Run-off-road,Single vehicle	3500 - 3500	On tangent sections	0.29		3	TX
				3500 - 3500	On horizontal curve sections	0.13		3	TX
Widen shoulder width from 6 to 7 ft	Rural	All	All	**95 - 25844**		**1.01**	**0.044**	**3**	**PA**
Widen shoulder width from 6 to 8 ft	Rural	All	All	**95 - 25844**		**0.96**	**0.022**	**3**	**PA**
Widen shoulder width from 6 to 9 ft	Rural	All	All	**95 - 25844**		**0.79**	**0.058**	**3**	**PA**
Widen shoulder width from 6 to >9 ft	Rural	All	All	**95 - 25844**		**0.82**	**0.027**	**3**	**PA**
Widen shoulder width from 10 to 11 ft	Urban	Fatal and injury	All	5700 - 309000		0.98	0.178	3	FL
Widen shoulder width from 10 to 12 ft	Urban	Fatal and injury	All	5700 - 309000		0.669	0.092	3	FL
Widen shoulder width to 5 feet or greater	Urban	Fatal and injury	Run-off-road	**11254 - 92757**	**Divided with median**	**0.64**	**0.1258**	**3**	**PA**
	Rural	Fatal and injury	Run-off-road	**4956 - 31692**	**Divided with median**	**0.47**	**0.2388**	**3**	**MN,MO,PA**
				4956 - 20763	Divided with median	1.1	0.1964	3	MO
				8267 - 18753	**Divided with median**	**0.38**	**0.125**	**3**	**PA**
				180 - 12776	**Undivided**	**0.73**	**0.1485**	**3**	**MN,MO,PA**
				180 - 10386	Undivided	1.07	0.5314	3	MN
Widen shoulder width (left shoulder by 1 foot)		Fatal and injury	All			0.925	0.04	3	IA
Widen paved shoulder width (from X to Y ft)	Rural	All	Angle		Intersection of 2-lane roads	Eqn. 15-1		3	GA
			Sideswipe		Intersection of 2-lane roads	Eqn. 15-2		3	GA
			Vehicle/pedestrian		Intersection of 2-lane roads	Eqn. 15-3		3	GA
		All	Truck related		Intersection of 2-lane roads	Eqn. 15-4		3	FL

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality	State
						Value	Std. Err	Rating	
Widen paved shoulder width (from 3 to 4 ft)	Rural	All	All	All		0.97	0.07	3	
				186 - 15106		0.97		3	ID
				186 - 400		0.98		3	ID
			Multiple vehicle	186 - 15106		0.97		3	ID
				186 - 400		0.97		3	ID
			Single vehicle	186 - 15106		0.95		3	ID
				186 - 400		0.94		3	ID
		All	All			0.94		4	CA,KY,MN
		All	Single vehicle			0.95		4	CA,KY,MN
Widen paved shoulder width (from 3 to 5 ft)	Rural	All	All	All		0.95	0.13	3	
				186 - 15106		0.95		3	ID
				186 - 400		0.94		3	ID
			Multiple vehicle	186 - 15106		0.95		3	ID
				186 - 400		0.93		3	ID
			Single vehicle	186 - 15106		0.93		3	ID
				186 - 400		0.94		3	ID
		All	All			0.87		4	CA,KY,MN
			Single vehicle			0.9		4	CA,KY,MN
Widen paved shoulder width (from 3 to 6 ft)	Rural	All	All	All		0.93	0.2	3	
				186 - 15106		0.93		3	ID
				186 - 400		0.93		3	ID
			Multiple vehicle	186 - 15106		0.94		3	ID
				186 - 400		0.94		3	ID
			Single vehicle	186 - 15106		0.91		3	ID
				186 - 400		0.9		3	ID
		All	All			0.82		4	CA,KY,MN
			Single vehicle			0.85		4	CA,KY,MN
Widen paved shoulder width (from 3 to 7 ft)	Rural	All	All	All		0.9	0.26	3	
				186 - 15106		0.91		3	ID
				186 - 400		0.9		3	ID
			Multiple vehicle	186 - 15106		0.89		3	ID
				186 - 400		0.88		3	ID
			Single vehicle	186 - 15106		0.92		3	ID
				186 - 400		0.92		3	ID
		All	All			0.76		4	CA,KY,MN
			Single vehicle			0.81		4	CA,KY,MN
Widen paved shoulder width (from 3 to 8 ft)	Rural	All	All	All		0.88	0.32	3	
				186 - 15106		0.87		3	ID
				186 - 400		0.88		3	ID
			Multiple vehicle	186 - 15106		0.83		3	ID
				186 - 400		0.84		3	ID
			Single vehicle	186 - 15106		0.9		3	ID
				186 - 400		0.91		3	ID
		All	All			0.71		4	CA,KY,MN
			Single vehicle			0.77		4	CA,KY,MN
Widen inside paved shoulder width from 4ft to 5ft	Urban	All	All		Outside paved shoulder width = 10 ft	0.573	0.1	3	FL
Widen inside paved shoulder width from 4ft to 6ft	Urban	Fatal and injury	All			0.472	0.1	3	FL
		All	All		Outside paved shoulder width = 10 ft	0.561	0.1	3	FL
					Outside paved shoulder width = 8 ft	0.757	0.1	3	FL
Widen inside paved shoulder width from 4ft to 8ft	Urban	Fatal and injury	All			0.78	0.1	3	FL
		All	All		Outside paved shoulder width = 10 ft	1.224	0.1	3	FL
					Outside paved shoulder width = 8 ft	0.639	0.1	3	FL
Widen inside paved shoulder width from 4ft to 10ft	Urban	Fatal and injury	All			0.665	0.1	3	FL
		All	All		Outside paved shoulder width = 10 ft	0.977	0.1	3	FL
					Outside paved shoulder width = 8 ft	0.776	0.1	3	FL

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Widen inside paved shoulder width from 4ft to 11ft	Urban	Fatal and injury	All			1.173	0.1	3	FL
		All	All		Outside paved shoulder width = 10 ft	1.294	0.1	3	FL
Widen inside paved shoulder width from 4ft to 12ft	Urban	Fatal and injury	All			0.992	0.1	3	FL
		All	All		Outside paved shoulder width = 10 ft	0.946	0.1	3	FL
					Outside paved shoulder width = 8 ft	1.043	0.1	3	FL
Widen outside paved shoulder width from 10ft to 11ft (inside paved shoulder width = 4ft)	Urban	All	All		Inside paved shoulder width = 4 ft	1.169	0.1	3	FL
Widen outside paved shoulder width from 10ft to 12ft (inside paved shoulder width = 4ft)	Urban	All	All		Inside paved shoulder width = 4 ft	0.793	0.1	3	FL
				5700 - 309000		0.774	0.095	3	FL
			Rear-end	5700 - 309000		0.816	0.117	3	FL
		Fatal and injury	All	5700 - 309000		0.9	0.106	3	FL
Change left shoulder width from X to Y (feet)		All	All			Eqn. 15-5		3	FL
Change right shoulder width from X to Y	All	All	All			Eqn. 15-6		3	FL
Upgrade narrow unpaved shoulder (< 5 ft) to wide unpaved shoulder (> 5 ft)	Rural	All	All	65 - 4950		0.71	0.048	3	KS
				65 - 4950		0.58	0.054	3	KS
			Head-on,Run-off-road,Sideswipe	65 - 4950		0.21	0.038	3	KS
				65 - 4950		0.23	0.048	3	KS
		Fatal and injury	All	65 - 4950		0.35	0.051	3	KS
				65 - 4950		0.28	0.048	3	KS
Upgrade unpaved or non-existent shoulders to composite shoulders	Rural	All	All	380 - 2340		1.114	0.129	4	KS
				380 - 2340	Less than or equal to 5 ft (prior condition)	0.861	0.145	4	KS
				380 - 2340	Greater than 5 ft (prior condition)	1.42	0.224	4	KS
			Head-on,Run-off-road,Sideswipe	380 - 2340		0.674	0.163	3	KS
				380 - 2340	Less than or equal to 5 ft (prior condition)	0.389	0.13	3	KS
		Fatal and injury	All	380 - 2340		0.944	0.183	3	KS
		Fatal and injury	All	380 - 2340	Greater than 5 ft (prior condition)	0.692	0.17	3	KS
Convert a 2 ft. turf shoulder to a 3 ft. turf shoulder	Rural	All	Winter			0.96	0.048	3	KS
			Non-winter			0.95	0.054	3	KS
			All			0.96	0.038	3	KS
			Shoulder (winter)			0.74	0.094	3	KS
			Shoulder (Non-winter)			0.91	0.12	3	KS
			Shoulder (All)			0.82	0.077	3	KS
		Fatal and injury	Winter			0.94	0.094	3	KS
			Non-winter			0.98	0.102	3	KS
			All			0.96	0.074	3	KS
Convert a 2 ft. turf shoulder to a 4 ft. turf shoulder	Rural	All	Winter			1	0.051	3	KS
			Non-winter			0.93	0.054	3	KS
			All			0.97	0.041	3	KS
			Shoulder (winter)			0.76	0.099	3	KS
			Shoulder (Non-winter)			0.79	0.112	3	KS
			Shoulder (All)			0.77	0.079	3	KS
		Fatal and injury	Winter			0.67	0.079	3	KS
			Non-winter			0.79	0.092	3	KS
			All			0.72	0.064	3	KS
Convert a 2 ft. turf shoulder to a 6 ft. turf shoulder	Rural	All	Winter			0.95	0.066	3	KS
			Non-winter			0.81	0.066	3	KS
			All			0.89	0.051	3	KS
			Shoulder (winter)			0.59	0.115	3	KS
			Shoulder (Non-winter)			0.59	0.13	3	KS
			Shoulder (All)			0.59	0.087	3	KS
		Fatal and injury	Winter			0.58	0.102	3	KS
			Non-winter			0.71	0.117	3	KS
			All			0.64	0.082	3	KS

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Convert a 2 ft. turf shoulder to a 6 ft. composite shoulder (first 3 ft. bituminous with remainder turf)	Rural	All	Winter			0.8	0.064	3	KS
			Non-winter			0.88	0.099	3	KS
			All			0.83	0.051	3	KS
			Shoulder (winter)			0.69	0.133	3	KS
			Shoulder (Non-winter)			0.44	0.112	3	KS
			Shoulder (All)			0.58	0.089	3	KS
		Fatal and injury	Winter			0.58	0.105	3	KS
			Non-winter			0.58	0.107	3	KS
			All			0.58	0.077	3	KS
Convert a 2 ft. turf shoulder to an 8 ft. composite shoulder (first 3 ft. bituminous with remainder turf)	Rural	All	Winter			1	0.061	3	KS
			Non-winter			0.85	0.059	3	KS
			All			0.93	0.048	3	KS
			Shoulder (winter)			0.5	0.082	3	KS
			Shoulder (Non-winter)			0.56	0.097	3	KS
			Shoulder (All)			0.52	0.064	3	KS
		Fatal and injury	Winter			0.65	0.087	3	KS
			Non-winter			0.56	0.079	3	KS
			All			0.61	0.066	3	KS
Convert a 2 ft. turf shoulder to a 10 ft. composite shoulder (first 3 ft. bituminous with remainder turf)	Rural	All	Winter			1.01	0.043	3	KS
			Non-winter			0.88	0.041	3	KS
			All			0.95	0.033	3	KS
			Shoulder (winter)			0.41	0.048	3	KS
			Shoulder (Non-winter)			0.43	0.054	3	KS
			Shoulder (All)			0.42	0.041	3	KS
		Fatal and injury	Winter			0.48	0.048	3	KS
			Non-winter			0.59	0.056	3	KS
			All			0.53	0.043	3	KS
Convert a 2 ft. turf shoulder to a 10 ft. composite shoulder (first 3 ft. bituminous with remainder aggregate)	Rural	All	Winter			1.06	0.051	3	KS
			Non-winter			0.85	0.043	3	KS
			All			0.96	0.038	3	KS
			Shoulder (winter)			0.5	0.059	3	KS
			Shoulder (Non-winter)			0.45	0.059	3	KS
			Shoulder (All)			0.47	0.046	3	KS
		Fatal and injury	Winter			0.66	0.064	3	KS
			Non-winter			0.61	0.061	3	KS
			All			0.63	0.051	3	KS
Convert a 2 ft. turf shoulder to a 10 ft. paved shoulder (bituminous base)	Rural	All	Winter			0.84	0.038	3	KS
			Non-winter			0.74	0.036	3	KS
			All			0.79	0.033	3	KS
			Shoulder (winter)			0.4	0.048	3	KS
			Shoulder (Non-winter)			0.4	0.048	3	KS
			Shoulder (All)			0.4	0.041	3	KS
		Fatal and injury	Winter			0.46	0.046	3	KS
			Non-winter			0.42	0.041	3	KS
			All			0.44	0.038	3	KS
Convert a 2 ft. turf shoulder to a 10 ft. paved shoulder (Portland cement concrete)	Rural	All	Winter			0.83	0.056	3	KS
			Non-winter			0.67	0.054	3	KS
			All			0.76	0.046	3	KS
			Shoulder (winter)			0.52	0.084	3	KS
			Shoulder (Non-winter)			0.55	0.094	3	KS
			Shoulder (All)			0.52	0.071	3	KS
		Fatal and injury	Winter			0.6	0.084	3	KS
			Non-winter			0.48	0.074	3	KS
			All			0.53	0.064	3	KS

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Implement shoulder widening in conjunction with shoulder rumble strip installation on freeways		All	All			0.81	0.2	3	
			Run-off-road			0.87	0.24	3	
Paved right shoulder vs. other right shoulder type on freeway ramp		All	All	18800 - 291000		0.81	0.04	3	FL
		Incapacitating injury	All	18800 - 291000		0.9	0.04	3	FL
Pave a 3 to 4 ft sod shoulder	Rural	All	All			0.81	0.09	4	
		Injury	All			0.86	0.18	3	
		PDO	All			0.78	0.12	4	
Installation of safety edge treatment	Rural	All	All	397 - 18697		0.923	0.096	4	GA
				310 - 15000		0.886	0.085	4	GA
				310 - 18697		0.932	0.065	4	GA
				1170 - 14662		0.845	0.144	4	IN
				376 - 13615		1.269	0.24	3	IN
				376 - 14662		1.002	0.126	4	IN
				397 - 18697		0.905	0.08	4	GA,IN
				310 - 15000		0.935	0.079	4	GA,IN
				310 - 18697		0.943	0.057	4	GA,IN
			Other	397 - 18697		0.897	0.094	3	GA
				310 - 15000		0.909	0.087	4	GA
				310 - 18697		0.934	0.065	4	GA
				1170 - 14662		0.912	0.159	3	IN
				376 - 13615		1.796	0.34	3	IN
				376 - 14662		1.197	0.154	3	IN
				397 - 18697		0.874	0.078	3	GA,IN
				310 - 15000		0.955	0.082	4	GA,IN
				310 - 18697		0.944	0.057	4	GA,IN
			Run-off-road	397 - 18697		0.863	0.09	4	GA
				310 - 15000		0.909	0.087	4	GA
				310 - 18697		0.921	0.064	4	GA
				1170 - 14662		0.918	0.158	3	IN
				376 - 13615		1.469	0.278	3	IN
				376 - 14662		1.135	0.144	3	IN
				397 - 18697		0.858	0.076	4	GA,IN
				310 - 15000		0.952	0.081	4	GA,IN
				310 - 18697		0.937	0.057	4	GA,IN
		Fatal and injury	All	397 - 18697		0.89	0.138	4	GA
				310 - 15000		1.156	0.177	4	GA
				310 - 18697		1.06	0.115	4	GA
				1170 - 14662		0.55	0.215	3	IN
				376 - 13615		0.565	0.261	3	IN
				376 - 14662		0.591	0.172	3	IN
				397 - 18697		0.835	0.119	4	GA,IN
				310 - 15000		1.064	0.151	4	GA,IN
				310 - 18697		0.983	0.098	4	GA,IN
			Other	397 - 18697		0.849	0.134	3	GA
				310 - 15000		1.184	0.182	3	GA
				310 - 18697		1.052	0.114	4	GA
				1170 - 14662		0.575	0.229	3	IN
				376 - 13615		0.615	0.287	3	IN
				376 - 14662		0.63	0.186	3	IN
				397 - 18697		0.784	0.115	4	GA,IN
				130 - 15000		1.052	0.152	3	GA,IN
				310 - 18697		0.953	0.097	4	GA,IN

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Installation of safety edge treatment	Rural	Fatal and injury	Run-off-road	397 - 18697		0.808	0.127	3	GA
				310 - 15000		1.181	0.181	3	GA
				310 - 18697		1.036	0.112	4	GA
				1170 - 14662		0.537	0.206	3	IN
				376 - 13615		1.125	0.511	3	IN
				376 - 14662		0.836	0.24	3	IN
				397 - 18697		0.769	0.111	4	GA,IN
				310 - 15000		1.2	0.171	3	GA,IN
				310 - 18697		1.026	0.102	4	GA,IN
		PDO	All	397 - 18697		0.974	0.152	4	GA
				310 - 15000		0.757	0.101	4	GA
				310 - 18697		0.868	0.086	4	GA
				1170 - 14662		0.934	0.184	4	IN
				376 - 13615		1.509	0.335	3	IN
				376 - 14662		1.129	0.165	4	IN
				397 - 18697		0.962	0.116	4	GA,IN
				310 - 15000		0.872	0.099	4	GA,IN
				310 - 18697		0.929	0.076	4	GA,IN
			Other	397 - 18697		0.975	0.152	3	GA
				310 - 15000		0.794	0.105	3	GA
				310 - 18697		0.892	0.088	3	GA
				1170 - 14662		1.026	0.203	3	IN
				376 - 13615		2.317	0.503	3	IN
				376 - 14662		1.41	0.206	3	IN
				397 - 18697		0.947	0.115	3	GA,IN
				310 - 15000		0.921	0.104	3	GA,IN
				310 - 18697		0.956	0.078	4	GA,IN
			Run-off-road	397 - 18697		0.948	0.145	3	GA
				310 - 15000		0.798	0.105	3	GA
				310 - 18697		0.885	0.087	4	GA
				1170 - 14662		1.035	0.213	3	IN
				376 - 13615		1.312	0.304	3	IN
				376 - 14662		1.129	0.174	3	IN
				397 - 18697		0.926	0.112	4	GA,IN
				310 - 15000		0.84	0.096	4	GA,IN
				310 - 18697		0.898	0.074	4	GA,IN

Table P. Signs

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality	State
						Value	Std. Err	Rating	
Install a combination of chevron signs, curve warning signs, and/or sequential flashing beacons	All	All	All	7400 - 13975		0.606	0.07	4	notusa
				7400 - 13975		0.607	0.08	3	notusa
				7400 - 13975		0.672	0.1	3	notusa
				7400 - 13975	Radius ≤ 300 m	0.478	0.08	3	notusa
				7400 - 13975		0.575	0.11	3	notusa
				7400 - 13975		0.42	0.1	3	notusa
				7400 - 13975	Radius > 300 m	0.746	0.11	3	notusa
				7400 - 13975		0.976	0.18	3	notusa
				7400 - 13975	Deflection Angle ≤ 60 gon	0.757	0.12	3	notusa
				7400 - 13975		0.638	0.12	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.49	0.08	3	notusa
				7400 - 13975		0.577	0.1	3	notusa
				7400 - 13975		0.469	0.1	3	notusa
				7400 - 13975		0.524	0.09	3	notusa
				7400 - 13975		0.477	0.11	3	notusa
			Angle	7400 - 13975		0.635	0.11	3	notusa
			Angle, Fixed object,Frontal and opposing direction sideswipe,Head-on,Rear-end,Rear to rear,Sideswipe,Single vehicle	7400 - 13975		0.72	0.22	3	notusa
				7400 - 13975		0.533	0.19	3	notusa
			Angle, Fixed object,Head-on,Rear-end,Rear to rear,Sideswipe,Single vehicle	7400 - 13975		0.715	0.17	3	notusa
				7400 - 13975		0.616	0.2	3	notusa
			Daytime	7400 - 13975		0.627	0.11	3	notusa
			Nighttime	7400 - 13975		0.592	0.12	3	notusa
				7400 - 13975	Radius ≤ 300 m	0.21	0.09	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.265	0.09	3	notusa
				7400 - 13975		0.231	0.09	3	notusa
			Run-off-road	7400 - 13975		0.585	0.07	4	notusa
				7400 - 13975	Radius ≤ 300 m	0.445	0.08	3	notusa
				7400 - 13975	Radius > 300 m	0.728	0.11	3	notusa
				7400 - 13975	Deflection Angle ≤ 60 gon	0.764	0.13	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.72	0.22	3	notusa
				7400 - 13975		0.518	0.1	3	notusa
			Wet road	7400 - 13975	All Treatment Sites Except Site 3, Which Showed Abnormal Proportion of Wet Road Crashes in the After Period	0.529	0.09	3	notusa
				7400 - 13975	Radius ≤ 300 m	0.535	0.12	3	notusa
				7400 - 13975	Radius > 300 m	0.511	0.12	3	notusa
				7400 - 13975	Deflection Angle ≤ 60 gon	0.545	0.13	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.506	0.12	3	notusa
				7400 - 13975		0.564	0.13	3	notusa
		Fatal and injury	All	7400 - 13975	All Treatment Sites Except Site 3, Which Showed Abnormal Proportion of Wet Road Crashes in the After Period	0.809	0.14	3	notusa
				7400 - 13975	Radius ≤ 300 m	0.608	0.14	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.568	0.13	3	notusa
				7400 - 13975		0.618	0.14	3	notusa
		PDO	All	7400 - 13975		0.438	0.11	3	notusa
				7400 - 13975		0.51	0.07	3	notusa
				7400 - 13975	Radius ≤ 300 m	0.381	0.09	3	notusa
				7400 - 13975	Radius > 300 m	0.612	0.11	3	notusa
				7400 - 13975	Deflection Angle ≤ 60 gon	0.582	0.11	3	notusa
				7400 - 13975	Deflection Angle > 60 gon	0.43	0.09	3	notusa

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install signs to conform to MUTCD	Urban	Injury	All			0.85	0.1	3	
		PDO	All			0.93	0.06	3	
Install combination horizontal alignment/ advisory speed signs		Injury	All			0.87	0.09	3	
		PDO	All			0.71	0.23	3	
Install chevron signs on horizontal curves	All	All	Wet road	7400 - 9746		0.406	0.22	3	notusa
	Rural	All	Head-on,Nighttime,Non-intersection,Run-off-road,Sideswipe	261 - 14790		0.78	0.101	4	WA
			Head-on,Non-intersection,Run-off-road,Sideswipe	261 - 14790		0.94	0.088	4	WA
			Nighttime,Non-intersection	261 - 14790		0.75	0.095	4	WA
			Non-intersection	261 - 14790		0.96	0.089	4	WA
		Fatal and injury	Non-intersection	261 - 14790		0.84	0.104	4	WA
		All	All	7400 - 9746		0.63	0.22	3	notusa
Install chevron signs and curve warning signs		All	All	10434 - 13975		0.592	0.1	3	notusa
				10434 - 13975		0.694	0.16	3	notusa
			Daytime	10434 - 13975		0.556	0.12	3	notusa
			Nighttime	10434 - 13975		0.66	0.19	3	notusa
			Run-off-road	10434 - 13975		0.564	0.1	3	notusa
			Wet road	10434 - 13975		0.489	0.12	3	notusa
		PDO	All	10434 - 13975		0.464	0.1	3	notusa
Install drowsy driving signs		All	Drowsy driving crashes			0.371	0.199	3	UT
Install new fluorescent curve signs or upgrade existing curve signs to fluorescent sheeting	Rural	All	Head-on,Nighttime,Non-intersection,Run-off-road,Sideswipe	895 - 20479		0.66	0.115	4	CT
			Head-on,Non-intersection,Run-off-road,Sideswipe	895 - 20479		0.82	0.084	4	CT
			Nighttime,Non-intersection	895 - 20479		0.65	0.105	3	CT
			Non-intersection	895 - 20479		0.82	0.077	4	CT
		Fatal and injury	Non-intersection	895 - 20479		0.75	0.127	4	CT
Advance street name signs	All	All	All			0.984	0.018	4	AZ,MA,WI
						1.01	0.049	3	AZ,MA,WI
			Rear-end			1.01	0.028	4	AZ,MA,WI
			Sideswipe			0.897	0.054	4	AZ,MA,WI
		Fatal and injury	All			0.99	0.031	4	AZ,MA,WI
Install a "Vehicles Entering When Flashing" (VEWF) system (advance post mounted signs on major and loops on minor)	All	All	All			0.68	0.076	4	NC
			Angle,Head-on,Left-turn,Right-turn			0.68	0.088	4	NC
		Fatal and injury	All			0.73	0.102	4	NC
Install a "Vehicles Entering When Flashing" (VEWF) system (combination of overhead and advance post	All	All	All			0.75	0.115	3	NC
			Angle,Head-on,Left-turn,Right-turn			0.8	0.144	3	NC
Install a "Vehicles Entering When Flashing" (VEWF) system (overhead signs at intersection on major and loops on minor)	All	All	All			1.06	0.098	3	NC
			Angle,Head-on,Left-turn,Right-turn			1.07	0.112	3	NC
		Incapacitating injury	All			0.61	0.236	3	NC
		Fatal and injury	All			0.92	0.108	3	NC
Install a "Vehicles Entering When Flashing" (VEWF) system (overhead signs at intersection on minor and loops on major)	All	All	All			0.95	0.084	3	NC
			Angle,Head-on,Left-turn,Right-turn			1	0.096	3	NC
		Fatal and injury	All			0.93	0.106	3	NC

Table Q. Speed Management

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Area-wide or corridor-specific traffic calming	Urban	All	All			0.68	0.08	4	
		Injury	All			0.67	0.09	4	
						0.67	0.09	4	
				0 - 30000		0.89	0.05	5	
						0.82	0.12	3	
				5000 - 30000		0.94	0.06	3	
		PDO	All			0.75	0.19	3	
				0 - 30000		0.95	0.2	3	
						0.94	0.1	3	
				5000 - 30000		0.97	0.2	3	
Install transverse rumble strips as traffic calming device	Urban/suburban	All	All			0.66	0.11	4	
		Injury	All			0.64	0.12	4	
Install speed humps	Urban/suburban	Injury	All			0.6	0.16	4	
						0.5	0.13	4	
Adjacent to roads with speed humps	Urban/suburban	Injury	All			0.95	0.06	3	
5% reduction in mean speed	All	Fatal	All	All		0.83	0.05	5	
		Injury	All	All		0.93	0.03	5	
		PDO	All	All		0.95	0.04	3	
10% reduction in mean speed	All	Fatal	All	All		0.68	0.09	4	
		Injury	All	All		0.85	0.05	5	
		PDO	All	All		0.9	0.08	3	
15% reduction in mean speed	All	Fatal	All	All		0.56	0.14	4	
		Injury	All	All		0.78	0.08	4	
		PDO	All	All		0.85	0.12	3	
5% increase in mean speed	All	Fatal	All	All		1.19	0.04	5	
		Injury	All	All		1.08	0.03	5	
		PDO	All	All		1.05	0.04	3	
Transverse bar pavement marking at roundabout approaches		Minor injury	Speed			0.48	0.24	4	
		Serious injury	Speed			0.26	0.28	3	
		Injury	Speed			0.43	0.19	4	
			Speed			0.53	0.3	3	
						0.34	0.18	4	
						0.55	0.33	3	
			Speed,Wet road			0.32	0.23	4	
Change 85th percentile speed from X to Y	Rural	All	All	35 - 1468		Eqn. 17-1		3	WY
Change freeway speed limit from X to Y mph		Incapacitating injury	All	18800 - 291000		Eqn. 17-2		3	FL
Lower posted speed	All	All	All			1.01		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
			Fatal and Injury			1.02		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Lower posted speed by 5 mph	All	All	All			1.17		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Lower posted speed by 10 mph	All	All	All			0.96		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Lower posted speed by 15-20 mph	All	All	All			0.94		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Lower posted speed from 100 km/h to 80 km.hr		All	All	3100 - 50300		0.8553	0.0792	4	notusa
			Speed	3100 - 50300		0.9123	0.161	4	notusa
		Incapacitating injury	All	3100 - 50300		1.0358	0.1717	4	notusa
		Minor injury	All	3100 - 50300		0.7915	0.086	4	notusa

Lower posted speed from 80 km/h to 60 km/h	Rural	Fatal	Non-intersection	146 - 4512		0.82		3	notusa
		Fatal	All			0.76		3	notusa
		Fatal	Fixed object	146 - 4512		0.69		3	notusa
Lower posted speed from 80 km/h to 60 km/h at intersections	Rural	Fatal	All			0.56		3	notusa
			Angle			0.53		3	notusa
Lower posted speed from 90 km/h to 70 km/h	Urban	Incapacitating injury	All			0.91	0.079	3	notusa
						0.94	0.13	3	notusa
			Non-intersection			0.64	0.11	3	notusa
		Minor injury	All			0.95	0.038	3	notusa
						1.11	0.054	3	notusa
			Non-intersection			0.89	0.056	3	notusa
Raise posted speed	All	All	All			0.9		4	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
			Fatal and Injury			0.97		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Raise posted speed by 5 mph	All	All	All			0.92		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Raise posted speed by 10 or 15 mph	All	All	All			0.85		3	AZ,CA,CO,CT,DE,ID,IL,IN,ME,MD,MA,MI,MS,NE,NJ,NM,OH,OK,TN,TX,VA,WV
Raise posted speed limit from X to Y mph	Urban/suburban	All	Rear-end			Eqn. 17-3		3	IN
		All	Truck related			Eqn. 17-4		3	FL
Raise posted speed limit of major road of a 4-leg signalized intersection from less than 50 km/h to greater than or equal to 50 km/h	Urban	All	Motorcycle			2.19		3	notusa
Raise posted speed limit of minor road of a signalized 3-leg intersection from less than 50 km/h to greater than or equal to 50 km/h	Urban	All	Motorcycle			3.57		3	notusa
Installation of fixed speed cameras	Urban	All	All			0.7	0.0459	3	notusa
Change mean speed (km/hr)	Rural	Fatal and injury	All	0 - 1000		Eqn. 17-5		3	notusa
Implement speed limit of 50 mph or greater	Urban	All	All			2.27	0.7	3	IA
Install variable speed limit signs	Urban	All	All			0.92		4	MO
Install 10 mph differential speed limit on rural Interstate Highways	Rural	All	All,Truck related			0.914	0.051	3	ID

Table R. Transit

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install transit signal priority (TSP) technology (at transit-serviced locations)	Urban	All	All			1.32	0.049	3	notusa
						1.28	0.062	3	notusa
Install transit signal priority (TSP) technology (transit-related crashes)	Urban	All	All			1.52	0.201	3	notusa
						1.26	0.146	3	notusa
Presence of far-side transit stop location (transit-related crashes)	Urban	All	All			0.55	0.066	3	notusa
Presence of near-side transit stop location (transit-related crashes)	Urban	All	All			1.85	0.205	3	notusa
						1.38	0.146	3	notusa
Presence of transit service	Urban	All	All			1.32	0.05	3	notusa
						1.31	0.049	3	notusa
Use of bus as public transit type rather than streetcar	Urban	All	All			1.73	0.09	3	notusa
						1.67	0.087	3	notusa
						1.23	0.046	3	notusa
						1.24	0.046	3	notusa
Use of bus as public transit type rather than streetcar (transit-related crashes)	Urban	All	All			0.55	0.093	3	notusa
Use of bus as public transit type rather than streetcar (transit-serviced locations)	Urban	All	All			0.87	0.034	3	notusa

Table S. Work Zones

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Active work with temporary lane closure (compared to no work zone)		All	All	0 - 50000		1.77	0.12	4	
				50000 - 100000		1.26	0.19	3	
				> 100000		1.65	0.18	4	
				All		1.66	0.09	4	
			Nighttime	0 - 50000		1.53	0.18	4	
				50000 - 100000		1.57	0.12	4	
				> 100000		1.65	0.09	4	
				All		1.61	0.07	4	
		Injury	All	0 - 50000		1.6	0.18	4	
				50000 - 100000		1.12	0.29	3	
				> 100000		1.26	0.27	3	
				All		1.46	0.13	4	
			Nighttime	0 - 50000		1.32	0.27	3	
				50000 - 100000		1.34	0.18	3	
				> 100000		1.49	0.14	4	
				All		1.42	0.1	4	
		PDO	All	0 - 50000		1.9	0.15	4	
				50000 - 100000		1.34	0.26	3	
				> 100000		1.87	0.24	4	
				All		1.81	0.12	4	
			Nighttime	0 - 50000		1.63	0.23	4	
				50000 - 100000		1.71	0.16	4	
				> 100000		1.8	0.12	4	
				All		1.75	0.09	4	
Active work with no lane closure (compared to no work zone)		All	All	0 - 50000		1.39	0.15	4	
				50000 - 100000		1.32	0.05	4	
				> 100000		1.3	0.04	5	
				All		1.31	0.03	5	
			Nighttime	50000 - 100000		1.29	0.25	3	
				> 100000		1.8	0.26	3	
				All		1.58	0.18	4	
		Injury	All	0 - 50000		1.45	0.26	3	
				50000 - 100000		1.19	0.07	4	
				> 100000		1.13	0.07	3	
				All		1.17	0.05	4	
			Nighttime	50000 - 100000		1.34	0.41	3	
				> 100000		1.4	0.38	3	
				All		1.41	0.27	3	
		PDO	All	0 - 50000		1.37	0.18	3	
				50000 - 100000		1.41	0.07	4	
				> 100000		1.39	0.05	4	
				All		1.4	0.04	5	
			Nighttime	50000 - 100000		1.23	0.3	3	
				> 100000		2.04	0.35	3	
				All		1.67	0.23	4	

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
No active with no lane closure (compared to no work zone)		All	All	0 - 50000		1.21	0.05	5	
				50000 - 100000		1.04	0.03	3	
				> 100000		1.16	0.02	5	
				All		1.13	0.02	5	
			Nighttime	0 - 50000		1.09	0.06	3	
				50000 - 100000		1.24	0.06	4	
				> 100000		1.3	0.05	4	
				All		1.24	0.03	5	
		Injury	All	0 - 50000		1.11	0.07	3	
				50000 - 100000		0.94	0.05	3	
				> 100000		1.05	0.04	3	
				All		1.02	0.03	3	
			Nighttime	0 - 50000		1.05	0.1	3	
				50000 - 100000		1.14	0.09	3	
				> 100000		1.11	0.08	3	
				All		1.11	0.05	4	
		PDO	All	0 - 50000		1.27	0.06	4	
				50000 - 100000		1.1	0.04	5	
				> 100000		1.23	0.03	5	
				All		1.2	0.02	5	
			Nighttime	0 - 50000		1.13	0.08	3	
				50000 - 100000		1.31	0.08	4	
				> 100000		1.46	0.07	4	
				All		1.33	0.05	5	
TLTWO (two way traffic operations - crossover closures) in work zones		All	All			1	0.35	3	
Implement mobile automated speed enforcement system (highly enforced sites)		All	All			0.863	0.026	3	NC
Increasing the outside shoulder width inside the work zone by one foot	Urban	All	All			0.948	0.01	3	IN
Increasing the inside shoulder width inside the work zone by one foot	Urban	All	All			0.97	0.01	3	IN

Table T. CMF Equations

Access Management

Equation Number	Equation	X	Y
1 - 1	e^(0.0232(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 2	e^(0.0152(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 3	e^(0.0087(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 4	e^(0.0084(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 5	e^(0.0096(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 6	e^(0.0090(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 7	e^(0.0046(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 8	e^(0.0030(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 9	e^(0.0077(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 10	e^(0.0029(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 11	e^(0.0071(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 12	e^(0.0094(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 13	e^(0.0059(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 14	e^(0.0026(Y-X))	Driveway density (Before)	Driveway density (After)
1 - 15	e^(0.0492(Y-X))	Freeway on-ramp density (Before)	Freeway on-ramp density (After)
1 - 16	e^(0.0456(Y-X))	Freeway on-ramp density (Before)	Freeway on-ramp density (After)
1 - 17	e^(0.0321(Y-X))	Freeway on-ramp density (Before)	Freeway on-ramp density (After)
1 - 18	e^(0.0393(Y-X))	Freeway on-ramp density (Before)	Freeway on-ramp density (After)
1 - 19	e^(0.0224(Y-X))	Freeway on-ramp density (Before)	Freeway on-ramp density (After)
1 - 20	e^(-0.1276(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 21	e^(-0.1144(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 22	e^(0.0977(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 23	e^(-0.1222(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 24	e^(-0.2493(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 25	e^(-0.1684(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 26	e^(-0.1201(Y-X))	Signal spacing /1000 ft (Before)	Signal spacing /1000 ft (After)
1 - 27	e^(0.0126(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 28	e^(0.0269(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 29	e^(0.0333(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 30	e^(0.0230(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 31	e^(0.0170(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 32	e^(0.0254(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 33	e^(0.0207(Y-X))	Number of unsignalized cross road per mile (Before)	Number of unsignalized cross road per mile (After)
1 - 34	e^(0.0481(Y-X))	Median opening density (Before)	Median opening density (After)
1 - 35	e^(0.0985(Y-X))	Median opening density (Before)	Median opening density (After)
1 - 36	e^(0.1129(Y-X))	Median opening density (Before)	Median opening density (After)
1 - 37	e^(0.0513(Y-X))	Median opening density (Before)	Median opening density (After)
1 - 38	e^(0.0456(Y-X))	Median opening density (Before)	Median opening density (After)
1 - 39	e^(-0.0803(Y-X))	The natural log of the upstream distance to the nearest signalized intersection from an unsignalized 3-leg intersection (Before)	The natural log of the upstream distance to the nearest signalized intersection from an unsignalized 3-leg intersection (After)
1 - 40	e^(-0.0345(Y-X))	The natural log of the downstream distance to the nearest signalized intersection from an unsignalized 3-leg intersection (Before)	The natural log of the downstream distance to the nearest signalized intersection from an unsignalized 3-leg intersection (After)

Equation Number	Equation	X	Y
1 - 41	e^(-0.4815(Y-X))	The natural log of the downstream distance to the nearest signalized intersection from an unsignalized 4-leg intersection (Before)	The natural log of the downstream distance to the nearest signalized intersection from an unsignalized 4-leg intersection (After)
1 - 42	e^(-0.0033(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 43	e^(0.0000(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 44	e^(0.0000(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 45	e^(-0.001(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 46	e^(0.0000(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 47	e^(0.002(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 48	e^(-0.004(Y-X))	Number of 3-leg intersections (Before)	number of 3-leg intersections (After)
1 - 49	e^(0.013(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)
1 - 50	e^(0.006(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)
1 - 51	e^(0.009(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)
1 - 52	e^(0.004(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)
1 - 53	e^(0.013(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)
1 - 54	e^(0.009(Y-X))	Number of 4-leg intersections (Before)	number of 4-leg intersections (After)

Alignment

Equation Number	Equation	X	Y
3 - 1	e^(0.05084(Y-X))	Horizontal curvature (Before)	Horizontal curvature (After)
3 - 2	e^(0.0831(Y-X))	Horizontal curvature (Before)	Horizontal curvature (After)
3 - 3	e^(0.169(log(Y-X)))	Horizontal curvature (Before)	Horizontal curvature (After)
3 - 4	e^(0.0889(Y-X))	Horizontal curvature (Before)	Horizontal curvature (After)
3 - 5	e^(0.1096(Y-X))	Degree of curve on freeways (Before)	Degree of curve on freeways (After)
3 - 6	e^(0.1208(Y-X))	Degree of curve on freeways (Before)	Degree of curve on freeways (After)
3 - 7	e^(0.0432(Y^2)-0.5870(Y))/e^(0.0432(X^2)-0.5870(X))	Number of horizontal curves per mile (Before)	Number of horizontal curves per mile (After)
3 - 8	e^(0.066(Y-X))	Maximum gradient (Before)	Maximum gradient (After)

Equation Number	Equation			
3 - 9	e^[0.044G+0.19ln(2*5730/R)+4.52(1/R)(1/Lc)]	G = Absolute value of percent grade (0 percent for level tangents; ≥ 1 percent otherwise)	Lc = Horizontal curve length (mi) (not applicable for tangents)	R= Curve radius (ft) (missing for tangents)
3 - 10	e^[0.040G+0.13ln(2*(5730/R)+3.80(1/R)(1/Lc)]	G = Absolute value of percent grade (0 percent for level tangents; ≥ 1 percent otherwise)	Lc = Horizontal curve length (mi) (not applicable for tangents)	R= Curve radius (ft) (missing for tangents)
3 - 11	e^[0.044G]	G = Absolute value of percent grade (0 percent for level tangents; ≥ 1 percent otherwise)		
3 - 12	e^[0.040G]	G = Absolute value of percent grade (0 percent for level tangents; ≥ 1 percent otherwise)		
3 - 13	e^(0.0088(5730/R)Lvc/K)	K = Lvc/A; not applicable for level tangents A=|G1 - G2| (%) G1= initial grade (%), G2= final grade (%)	Lvc = Vertical curve length (ft)	R= Curve radius (ft) (missing for tangents)
3 - 14	e^(0.0046(5730/R)Lvc/K)	K = Lvc/A; not applicable for level tangents A=|G1 - G2| (%) G1= initial grade (%), G2= final grade (%)	Lvc = Vertical curve length (ft)	R= Curve radius (ft) (missing for tangents)
3 - 15	e^[10.51*1/K+0.011*(5730/R)*Lvc/K]	K = Lvc/A; not applicable for level tangents A=|G1 - G2| (%) G1= initial grade (%), G2= final grade (%)	Lvc = Vertical curve length (ft)	R= Curve radius (ft) (missing for tangents)
3 - 16	e^[8.62*1/K+0.010*(5730/R)*Lvc/K]	K = Lvc/A; not applicable for level tangents A=|G1 - G2| (%) G1= initial grade (%), G2= final grade (%)	Lvc = Vertical curve length (ft)	R= Curve radius (ft) (missing for tangents)

Equation Number	Equation			
3 - 17	e^[10.51*1/K]	K = Lvc/A; not applicable for level tangents		
3 - 18	e^[8.62*1/K]	K = Lvc/A; not applicable for level tangents A=|G1 - G2| (%) G1= initial grade (%), G2= final grade (%)		
3 - 19	e^[0.20*ln(2*5730/R)]	R= Curve radius (ft) (missing for tangents)		
3 - 20	e^[0.10*ln(2*5730/R)]	R= Curve radius (ft) (missing for tangents)		
3 - 21	e^[0.188*ln(2*5730/R)]	R= Curve radius (ft) (missing for tangents)		
3 - 22	e^[0.022*ln(2*5730/R)*A]	R= Curve radius (ft) (missing for tangents)	A=|G1 - G2| (%), G1= initial grade (%), G2= final grade (%)	
3 - 23	e^(0.1837*(V^2)/y) / e^(0.1837*(V^2)/X)	X and Y= Horizontal curve radius (ft)	V= Speed limit minimum of 55mph	

Delineation

Equation Number	Equation	X	Y
5 - 1	e^(-0.0021(Y-X))	Pavement marking retroreflectivity (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity (mcd/m^2/lux) (After)
5 - 2	e^(-0.004(Y-X))	Pavement marking retroreflectivity of white edgelines (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity of white edgelines (mcd/m^2/lux) (After)
5 - 3	e^(-0.001(Y-X))	Pavement marking retroreflectivity of white edgelines (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity of white edgelines (mcd/m^2/lux) (After)
5 - 4	e^(-0.002(Y-X))	Pavement marking retroreflectivity of white skiplines (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity of white skiplines (mcd/m^2/lux) (After)
5 - 5	e^(-0.007(Y-X))	Pavement marking retroreflectivity of yellow centerlines (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity of yellow centerlines (mcd/m^2/lux) (After)
5 - 6	e^(0.007(Y-X))	Pavement marking retroreflectivity of yellow edgelines (mcd/m^2/lux) (Before)	Pavement marking retroreflectivity of yellow edgelines (mcd/m^2/lux) (After)

Interchange design

Equation Number	Equation	X	Y
7 - 1	e^(2.198(Y-X))	Length of deceleration lane (miles) (Before)	Length of deceleration lane (miles) (After)
7 - 2	e^(-0.547(Y-X))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 3	e^(-0.330(Y-X))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 4	e^(-0.345(Y-X))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 5	e^(-1.183(Y-X))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 6	e^(-0.387(Y-X))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 7	100*(1-e^(0.551(Y-X)))	Number of lanes on freeway exit ramp (Before)	Number of lanes on freeway exit ramp (After)
7 - 8	100*(1-e^(0.014308(Y-X)))	Spacing distance between two ramp terminals at diamond interchange (Before)	Spacing distance between two ramp terminals at diamond interchange (After)
7 - 9	100*(1-e^(0.01985(Y-X)))	Spacing distance between two ramp terminals at diamond interchange (Before)	Spacing distance between two ramp terminals at diamond interchange (After)
7 - 10	100*(1-e^(0.009803(Y-X)))	Spacing distance between two ramp terminals at diamond interchange (Before)	Spacing distance between two ramp terminals at diamond interchange (After)

Intersection geometry

Equation Number	Equation	X	Y
8 - 1	e^(0.7785(Y-X))	Number of left-turn lanes (Before)	Number of left-turn lanes (After)
8 - 2	e^(0.3495(Y-X))	Number of left-turn lanes (Before)	Number of left-turn lanes (After)
8 - 3	e^(0.125(Y-X))	Number of lanes (Before)	Number of lanes (After)
8 - 4	e^(0.171(Y-X))	Number of lanes (Before)	Number of lanes (After)
8 - 5	e^(0.548(Y-X))	Number of lanes (Before)	Number of lanes (After)
8 - 6	100*(1-e^(-0.003(Y-X)))	Number of 3-leg intersections (Before)	Number of 3-leg intersections (After)
8 - 7	100*(1-e^(-0.033(Y-X)))	Number of 5-leg intersections (Before)	Number of 5-leg intersections (After)

Intersection traffic control

Equation Number	Equation		
9 - 1	e^(-5.5172+0.6322*AADT+0.1103*Trains+0.0891*MaxSpeed)	Trains = number of trains per day	Maxspeed= maximum timetable speed (mph)
9 - 2	e^(-4.6330+0.1346*Trains)	Trains = number of trains per day	

Equation Number	Equation	X	Y
9 - 3	e^(0.919(Y-X))	Traffic signal spacing (signals/mile) (Before)	Traffic signal spacing (signals/mile) (After)
9 - 4	e^(0.453(Y-X))	Traffic signal spacing (signals/mile) (Before)	Traffic signal spacing (signals/mile) (After)
9 - 5	100*(1-e^(-1.8419(Y-X)))	Yellow change interval (seconds) (Before)	Yellow change interval (seconds) (After)
9 - 6	100*(1-e^(-3.504(Y-X)))	Yellow change interval (seconds) (Before)	Yellow change interval (seconds) (After)
9 - 7	100*(1-e^(-2.3424(Y-X)))	Yellow change interval (seconds) (Before)	Yellow change interval (seconds) (After)
9 - 8	100*(1-e^(-0.988(Y-X)))	Red clearance interval from X to Y seconds (Before)	Red clearance interval from X to Y seconds (After)
9 - 9	100*(1-e^(-1.8502(Y-X)))	Red clearance interval from X to Y seconds (Before)	Red clearance interval from X to Y seconds (After)
9 - 10	100*(1-e^(-0.8944(Y-X)))	Red clearance interval from X to Y seconds (Before)	Red clearance interval from X to Y seconds (After)
9 - 11	100*(1-e^(-0.0444(Y-X)))	Number of traffic signal cycles per hour (Before)	Number of traffic signal cycles per hour (After)
9 - 12	100*(1-e^(0.007(Y-X)))	Number of all-way stop intersections (Before)	Number of all-way stop intersections (After)
9 - 13	100*(1-e^(0.077(Y-X)))	Number of signalized intersections (Before)	Number of signalized intersections (After)

On Street Parking

Equation Number	Equation	X	Y
10 - 1	e^(0.00053(Y-X))	Unrestricted parking hours (Before)	Unrestricted parking hours (After)
10 - 2	e^(0.0018(Y-X))	Unrestricted parking hours (Before)	Unrestricted parking hours (After)
10 - 3	e^(0.0006(Y-X))	Unrestricted parking hours (Before)	Unrestricted parking hours (After)
10 - 4	e^(0.002(Y-X))	Unrestricted parking hours (Before)	Unrestricted parking hours (After)
10 - 5	e^(0.00052(Y-X))	Unrestricted left turn hours (Before)	Unrestricted left turn hours (After)
10 - 6	e^(0.0015(Y-X))	Unrestricted left turn hours (Before)	Unrestricted left turn hours (After)
10 - 7	e^(0.0006(Y-X))	Unrestricted left turn hours (Before)	Unrestricted left turn hours (After)
10 - 8	e^(0.0026(Y-X))	Unrestricted left turn hours during rush hours (Before)	Unrestricted left turn hours during rush hours (After)
10 - 9	e^(0.0047(Y-X))	Unrestricted left turn hours during rush hours (Before)	Unrestricted left turn hours during rush hours (After)
10 - 10	e^(0.0026(Y-X))	Unrestricted left turn hours during rush hours (Before)	Unrestricted left turn hours during rush hours (After)

Pedestrians

Equation Number	Equation	X	Y
11 - 1	100*(1-e^(0.114(Y-X)))	Number of subway stations (Before)	Number of subway stations (After)
11 - 2	100*(1-e^(0.012(Y-X)))	Number of bus stations (Before)	Number of bus stations (After)
11 - 3	100*(1-e^(0.133(Y-X)))	Number of bus stops in 50m buffer (Before)	Number of bus stops in 50m buffer (After)

Roadside

Equation Number	Equation	X	Y
13 - 1	100*(1-e^(0.169(Y-X)))	Commercial land use/total land use (%) (Before)	Commercial land use/total land use (%) (After)
13 - 2	100*(1-e^(2.153(Y-X)))	Industrial land use/total land use (%) (Before)	Industrial land use/total land use (%) (After)
13 - 3	100*(1-e^(0.511(Y-X)))	Open land use/total land use (%) (Before)	Open land use/total land use (%) (After)
13 - 4	100*(1-e^(1.389(Y-X)))	Total park area (in 1000 acres) (Before)	Total park area (in 1000 acres) (After)

Equation Number	Equation		
13 - 5	e^(-0.0905(Oa-Ob))	Oa = after offset	Ob = before offset
13 - 6	(Da/Db)^(0.1162)	Da = after density	Db = before density

Roadway

Equation Number	Equation	
14 - 1	3.705*e^(-0.0616*totshld)	totshld = Total width of the outside shoulder (paved and unpaved shoulder, in feet)
14 - 2	1.142*e^(-0.0335*totshld)	totshld = Total width of the outside shoulder (paved and unpaved shoulder, in feet)
14 - 3	1.238*e^(-0.0586*totshld)	totshld = Total width of the outside shoulder (paved and unpaved shoulder, in feet)

Equation Number	Equation	X	Y
14 - 4	e^(-0.116(Y-X))	Bridge width (bridge minus roadway width) (Before)	Bridge width (bridge minus roadway width) (After)
14 - 5	e^(59.9(X-Y))	Pavement macrotexture (inches) (Before)	Pavement macrotexture (inches) (After)
14 - 6	e^(0.1123-0.0003*ADT)		
14 - 7	100*(1-e^(0.214(Y-X)))	Proportion of 1-lane roadways to total roadway length (Before)	Proportion of 1-lane roadways to total roadway length (After)
14 - 8	100*(1-e^(1.243(Y-X)))	Proportion of 4-lane roadways to total roadway length (Before)	Proportion of 4-lane roadways to total roadway length (After)
14 - 9	100*(1-e^(2.896(Y-X)))	Proportion of 5-lane roadways to total roadway length (Before)	Proportion of 5-lane roadways to total roadway length (After)
14 - 10	100*(1-e^(0.530(Y-X)))	Proportion of primary roadway (without access restriction) to total roadway length (Before)	Proportion of primary roadway (without access restriction) to total roadway length (After)
14 - 11	100*(1-e^(-1.050(Y-X)))	Proportion or primary roadway (with limited access) to total roadway length (Before)	Proportion or primary roadway (with limited access) to total roadway length (After)
14 - 12	100*(1-e^(-0.418(Y-X)))	Proportion of length of roads with widths less than 30 feet to total roadway length (Before)	Proportion of length of roads with widths less than 30 feet to total roadway length (After)
14 - 13	100*(1-e^(-0.207(Y-X)))	Proportion of local rural road to total roadway length (Before)	Proportion of local rural road to total roadway length (After)
14 - 14	100*(1-e^(-0.704(Y-X)))	Proportion of other throughfare roadway to total roadway length (Before)	Proportion of other throughfare roadway to total roadway length (After)
14 - 15	e^(-0.0161(Y-X))	Surface width (Before)	Surface width (After)

Equation Number	Equation		
14 - 16	e^(-0.36(X-12))	X = Outside lane width (ft)	
14 - 17	e^(-0.31(X-12))	X = Outside lane width (ft)	
14 - 18	e^(-0.37(X-12))	X = Outside lane width (ft)	
14 - 19	[e^(-0.59(X-12))]*[e^(-0.63(Y-12))]	X = Outside lane width (ft)	Y = Inside lane width (ft)
14 - 20	[e^(-0.50(X-12))]*[e^(-0.75(Y-12))]	X = Outside lane width (ft)	Y = Inside lane width (ft)
14 - 21	e^(-0.41(X-12))	X = Outside lane width (ft)	
14 - 22	1.427*e^(-0.0593*totshld)	totshld = Total width of the outside shoulder (paved and unpaved shoulder, in feet)	
14 - 23	1.085*e^(-0.0082*medwd)	median width (feet) given the roadway is divided (div=1)	

Shoulder treatments

Equation Number	Equation	X	Y
15 - 1	e^(0.0969(Y-X))	Paved shoulder width (ft) (Before)	Paved shoulder width (ft) (After)
15 - 2	e^(0.1820(Y-X))	Paved shoulder width (ft) (Before)	Paved shoulder width (ft) (After)
15 - 3	e^(0.1069(Y-X))	Paved shoulder width (ft) (Before)	Paved shoulder width (ft) (After)
15 - 4	e^(-0.0372(Y-X))	Paved shoulder width (ft) (Before)	Paved shoulder width (ft) (After)
15 - 5	e^(-0.0912(Y-X))	Left shoulder width (ft) (Before)	Left shoulder width (ft) (After)
15 - 6	e^(-0.0017(Y-X))	Right shoulder width (ft) (Before)	Right shoulder width (ft) (After)

Speed management

Equation Number	Equation	X	Y
17 - 1	e^(0.0111(Y-X))	85th percentile speed (Before)	85th percentile speed (After)
17 - 2	e^(-0.017(Y-X))	Freeway speed limit (mph) (Before)	Freeway speed limit (mph) (After)
17 - 3	100*(1-e^(0.158(Y-X)))	Posted speed limit (mph) (Before)	Posted speed limit (mph) (After)
17 - 4	e^(-0.0136(Y-X))	Posted speed limit (mph) (Before)	Posted speed limit (mph) (After)
17 - 5	e^(0.24556(Y-X))	Mean speed (km/hr) (Before)	Mean speed (km/hr) (After)

Lower-quality CMFs

Access Management

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Closure or complete relocation of all driveways from functional area of intersection	Rural	All	All			1.17	3.25	1	
		Injury	All			1.41	4.48	1	
	Urban	All	All			0.93	2.31	1	
		Injury	All			1.67	5.05	1	
Create directional median openings to allow left-turns and U-turns		All	All	14319 - 28154		0.49		2	MI
Convert an open median to a left-in only median	Urban/Suburban	Incapacitating injury	All			1.31	0.4669	2	FL
		Serious injury	All			1.41	0.3286	2	FL
Landscape medians at intersections		All	All	4900 - 49500		1.68	0.71	2	FL
		Fatal and injury	All	4900 - 49500	For medians without trees compared to medians with trees compliant with Florida's design standards.	3.26	2.22	2	FL
				4900 - 49500	When the tree setback from median nose is increased from 100ft to 200ft.	0.82	0.09	2	FL

Advanced Technology and ITS

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Provide active close-following warning signs			Rear-end			0.94	0.72	1	
Provide limited sight distance (LSD) warning signs	Rural	All	All			1.07	0.67	1	
Changeable curve speed warning signs	Rural	All	All			1.13	1.19	1	
			Speed related			1.31	1.87	1	
			Truck related			0.29	0.96	1	
		Injury	All			1.47	2.35	1	
		PDO	All			0.98	1.38	1	
Presence of speed restriction devices (bike crashes)		All	Vehicle/bicycle			0.28	0.22	2	notusa
Install dynamic advance intersection warning system	Rural	All		5500 - 6900		0.27	0.2	2	NC
				7700 - 10100		0.15	0.19	2	NC
			All	5500 - 6900		0.46	0.19	2	NC
				7700 - 10100		0.3	0.11	2	NC
			Angle	5500 - 6900		0.55	0.26	1	NC
				5500 - 6900	Far-side right angle crash	0.33	0.19	2	NC
				5500 - 6900	Near-side right angle crash	3.19	3.66	1	NC
				7700 - 10100		0.33	0.12	2	NC
				7700 - 10100	Far-side right angle crash	0.32	0.12	2	NC
				7700 - 10100	Near-side right angle crash	0.76	1.16	1	NC
		Fatal	All	5500 - 6900		0		1	NC
			All	7700 - 10100		0.38	0.51	1	NC
		Injury	All	5500 - 6900		0.89	0.43	1	NC
			All	7700 - 10100		0.3	0.14	2	NC
		PDO	All	5500 - 6900		0.1	0.12	2	NC
			All	7700 - 10100		0.29	0.17	2	NC
Install icy curve warning system	Rural	All	All			0.82	0.08	2	CA

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Alignment

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Flatten horizontal curve		All	All			0.33	0.32	2	MN
Change in average horizontal curve radius from X to Y (in miles)	Rural	Fatal and injury	All		Major Collector	Eq. LQ 3-1		2	IN
					Minor Arterial	Eq. LQ 3-2		2	IN
					Principal Arterial Other	Eq. LQ 3-3		2	IN
		Injury	All		Major Collector	Eq. LQ 3-4		2	IN
					Minor Arterial	Eq. LQ 3-5		2	IN
					Principal Arterial Other	Eq. LQ 3-6		2	IN
		PDO	All		Major Collector	Eq. LQ 3-7		2	IN
					Minor Arterial	Eq. LQ 3-8		2	IN
					Principal Arterial Other	Eq. LQ 3-9		2	IN

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Bicyclists

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Raised bicycle crossings		Injury	Vehicle/bicycle			1.09	0.53	1	
Change sidewalk width from X to Y meters (bike crashes)		All	Vehicle/bicycle			0		2	notusa
Presence of crosswalk at signalized intersection (bike crashes)		All	Vehicle/bicycle			8.76	13.7	2	notusa
Installation of bicycle lanes at signalized intersections	Urban/Suburban	All	Vehicle/bicycle			1.37		2	notusa
						0.8		2	notusa
					Crossing crashes at 90 degrees from each other	0.63		2	notusa
					Cyclist through, left turning vehicle in oncoming direction	1.33		2	notusa
					Rear end & sideswipe, same direction	1.01		2	notusa
					Cyclist through, right turning vehicle in same direction	2.03		2	notusa
					Cyclist through, right turning vehicle in same direction	0.42		2	notusa
					Other	1.02		2	notusa
Installation of bicycle lanes at signalized intersections with shared through/right turn lanes	Urban/Suburban	All	Vehicle/bicycle			1.4		2	notusa
						0.6		2	notusa
Installation of bicycle lanes at signalized intersections with exclusive right turn lanes	Urban/Suburban	All	Vehicle/bicycle			1.36		2	notusa
						0.97		2	notusa
Installation of colored bicycle lanes at signalized intersections	Urban/Suburban	All	Vehicle/bicycle			0.61		2	notusa
Installation of a cycle track 0-2m from the side of the main road with cyclist priority at intersections	Urban/Suburban	All	Vehicle/bicycle			1.03	0.384	2	notusa
Installation of a cycle track over 5m from the side of the main road with cyclist priority at intersections	Urban/Suburban	All	Vehicle/bicycle			0.93	0.31	2	notusa
Installation of red color for bicycle crossings with cyclist priority at intersections	Urban/Suburban	All	Vehicle/bicycle			1.47	0.412	2	notusa
Installation of high quality markings for bicycle crossings with cyclist priority at intersections	Urban/Suburban	All	Vehicle/bicycle			1.74	0.618	2	notusa
Introduction of restricted visibility from vehicles on a minor road to approaching bicyclists at intersections with cyclist priority	Urban/Suburban	All	Vehicle/bicycle			1.37	0.33	2	notusa
Installation of left-turn lane or left-turn section on the main road where cyclists have priority at the intersection	Urban/Suburban	All	Vehicle/bicycle			1.12	0.207	2	notusa
Installation of a speed hump or other speed reducing measure for through motorized vehicles on the main road	Urban/Suburban	All	Vehicle/bicycle			1.28	0.345	2	notusa
Installation of raised island and left-turn lane	Urban/Suburban	All	Vehicle/bicycle			1.48	0.393	2	notusa
Installation of raised island with a separate space for cyclists	Urban/Suburban	All	Vehicle/bicycle			1.43	0.473	2	notusa
Installation of vehicle travel lanes	Urban/Suburban	All	Vehicle/bicycle			1.67	0.635	2	notusa
Installation of additional travel lanes, a raised island and left-turn lane	Urban/Suburban	All	All			0.96	0.582	2	notusa
Installation of additional travel lanes and a raised island	Urban/Suburban	All	Vehicle/bicycle			1.1	0.456	2	notusa
Moving a separate bicycle crossing to a 4-leg intersection	Urban/Suburban	All	Vehicle/bicycle			1.28	0.518	2	notusa
Moving a separate bicycle crossing to a 3-leg intersection	Urban/Suburban	All	Vehicle/bicycle			0.83	0.331	2	notusa

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Delineation

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install transverse rumble strips, raised pavement markers, and transverse markings	Rural	All	All			1.1	1.26	1	
			Wet road			0.91	1.16	1	
			Nighttime			0.83	1.88	1	
Install transverse rumble strips and raised pavement markers	Rural	All	All			0.47	0.5	2	
			Wet road			0.51	0.55	1	
			Nighttime			0.36	1.37	1	

Highway Lighting

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Partial plus to partial interchange lighting	Suburban	Injury	All			0.862	0.149	2	OR

Interchange Design

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Reverse X-ramp exit and entry ramps	Urban	All	All			0.65	0.106	2	TX
		Incapacitating injury	All			0.33	0.382	1	TX
		Minor injury	All			0.49	0.103	2	TX
		PDO	All			1.13	0.317	1	TX
Convert diamond interchange to Diverging Diamond Interchange (DDI) or Double Crossover Diamond (DCD)	Urban	All				0.81		2	MO
			All			0.54		2	MO
			Left-turn			0		1	MO
			Rear-end			0.71		2	MO
		Minor injury	All			0.28		2	MO
		PDO	All			0.63		2	MO

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Intersection Geometry

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install J-turn intersection		All	All	16900 - 20000		0.39	0.135	2	NC
				16900 - 20000	At Downstream U-turn locations	1.67	1.063	1	NC
				45000 - 47600		0.5	0.188	2	NC
				45000 - 47600	At Downstream U-turn locations	0.91	0.381	2	NC
			Angle	16900 - 20000	Broadside right-angle	0		2	NC
				16900 - 20000	Far-side right-angle	0		2	NC
				16900 - 20000	Near-side right-angle	0		2	NC
				16900 - 20000	U-turn (At main intersection)	1.27	1.199	1	NC
				45000 - 47600	Broadside right-angle	0.08	0.084	1	NC
				45000 - 47600	Far-side right-angle	0		2	NC
				45000 - 47600	Near-side right-angle	0.32	0.372	1	NC
			Left-turn	16900 - 20000	Opposing through	1.41	1.063	1	NC
				45000 - 47600	Opposing through	0.57	0.422	1	NC
			Rear-end	16900 - 20000		0.63	0.509	1	NC
			Sideswipe	16900 - 20000		0.85	0.883	1	NC
				45000 - 47600		0.95	0.959	1	NC
			Single vehicle	16900 - 20000		0.85	1.249	1	NC
				45000 - 47600		1.42	1.309	1	NC
		Fatal	All	16900 - 20000		0.85	1.249	1	NC
				45000 - 47600		0		2	NC
		Injury	All	16900 - 20000		0.2	0.118	1	NC
				45000 - 47600		0.81	0.458	1	NC
		PDO	All	16900 - 20000		0.63	0.294	2	NC
				45000 - 47600		0.36	0.195	1	NC
	Rural	All	All	10670 - 11240		0.08	0.041	1	MD
			Angle	10670 - 11240	Broadside right-angle	0		2	MD
				10670 - 11240	Far-side right-angle	0		2	MD
				10670 - 11240	Near-side right-angle	0		2	MD
			Rear-end	10670 - 11240		0.62	0.898	1	MD
			Sideswipe,Head-on	10670 - 11240		0		2	MD
			Single vehicle	10670 - 11240		0.47	0.365	1	MD
		Fatal	All	10670 - 11240		0		2	MD
		Injury	All	10670 - 11240		0		2	MD
		PDO	All	10670 - 11240		0.25	0.151	1	MD
	Suburban	All	All	28600 - 29200		0.3	0.174	1	NC
				28600 - 29200	At Downstream U-turn locations	0.36	0.148	2	NC
			Angle	28600 - 29200	Broadside right-angle	0		2	NC
				28600 - 29200	Far-side right-angle	0		2	NC
				28600 - 29200	Near-side right-angle	0		2	NC
			Left-turn	28600 - 29200	Opposing through	1.96	2.408	1	NC
			Sideswipe	28600 - 29200		0		2	NC
			Single vehicle	28600 - 29200		0.98	1.392	1	NC
		Fatal	All	28600 - 29200		0		2	NC
		Injury	All	28600 - 29200		0.49	0.427	1	NC
		PDO	All	28600 - 29200		0.28	0.226	1	NC
Install turbo roundabout		All	All			0.239	0.296	2	notusa

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Intersection Geometry (cont)

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Install single lane roundabout		All	All			0.213	0.421	2	notusa
						0.319	0.585	2	notusa
Increase the number of right-turn lanes on the major road from X to Y	Rural	All	Rear-end	420 - 15200		0		2	GA
			Sideswipe	420 - 15200		0		2	GA
Install median acceleration lane	Rural	All	All			0.77	0.19	1	MO
			Angle		Broadside right-angle	0.75	0.22	1	MO
					Near-side right-angle	0.8	0.25	1	MO
			Rear-end			0.21	0.22	1	MO
		Injury	All			0.55	0.22	1	MO
Install offset right-turn lane	Rural	All	All	7350 - 8000		0.94	0.48	1	IA
				10000 - 11300		1.02	0.42	1	IA
			Angle	5250 - 5410		0.47	0.42	1	IA
				5755 - 6525		1.37	2	1	IA
				6550 - 7225		1.41	0.91	1	IA
				7350 - 8000	Broadside right-angle	0.31	0.26	2	IA
				7350 - 8000	Near-side right-angle	0.47	0.42	1	IA
				7350 - 8000	Far-side right-angle	0		1	IA
				10000 - 11300	Broadside right-angle	0.96	0.43	1	IA
				10000 - 11300	Near-side right-angle	1.39	0.83	1	IA
				10000 - 11300	Far-side right-angle	0.6	0.43	1	IA
			Left-turn	7350 - 8000		0		1	IA
				10000 - 11300		0		1	IA
			Rear-end	7350 - 8000		0		1	IA
		Fatal	All	10000 - 11300		2.78	3.48	1	IA
		Injury	All	7350 - 8000		1.41	0.92	1	IA
				10000 - 11300		0.7	0.4	1	IA
		PDO	All	7350 - 8000		0.47	0.42	1	IA
				10000 - 11300		1.39	1.01	1	IA
Convert a conventional signalized intersection to a signalized superstreet	Rural	All		21000 - 45000		1.59		2	NC
			Sideswipe	21000 - 45000		1.48		2	NC
Convert a conventional unsignalized intersection to an unsignalized superstreet	Rural	All	Rear-end	5900 - 33500		0.99	0.24	2	NC
			Sideswipe	5900 - 33500		0.87	0.3	2	NC
Change roundabout circulating sight distance from X to Y		All	All	434 - 7300		Eq. LQ 8-1		2	
			Rear-end	434 - 7300		Eq. LQ 8-2		2	
Change roundabout intersection sight distance from X to Y		All	Run-off-road	434 - 7300		Eq. LQ 8-3		2	
Convert high-speed rural intersection to roundabout	Rural	Injury	Rear-end			0.54		2	KS,MD,MN,OR,WA,WI
Presence of an elevated road above intersection	Urban	All	All	7700 - 140300		1.58	0.32	2	

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Intersection Traffic Control

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Convert stop control to yield control	Urban/Suburban	All	All			2.27	1.26	1	
Add additional signal and upgrade to 12-inch lenses	Urban	All	All		Older driver crashes (ages 65+)	0.69	0.066	2	MI
					Younger driver crashes (age 25-64)	0.83	0.034	2	MI
Install double stop signs	Urban	All	Angle			0.45	0.52	1	NC
Install flashing beacons as advance warning	All	All	Angle			0.38	0.129	2	MD
			Rear-end			0.64	0.138	2	MD
Add centerline and STOP bar, replace 24-inch with 30-inch stop signs	Urban	All	Angle			0.33	0.11	1	NC
Change left turn phasing consistency from 27.3% to 9.1%		All	All			0.976		2	TX
			Angle			0.935		2	TX
Change left turn phasing consistency from 31.6% to 27.3%		All	All			0.922		2	TX
			Angle			0.989		2	TX
Change left turn phasing consistency from 61.9% to 31.6%		All	All			0.691		2	TN
			Angle			0.642		2	TX
Modify nighttime flash operation period		All	All			0.88	0.12	2	NC
			Sideswipe,Head-on			1	0.17	2	NC
		Fatal and injury	All			0.84	0.17	2	NC
Convert from yield signal control to signalized control (intersection crashes)		All	Head-on,Rear-end			1.01		2	notusa
			Single vehicle			0		2	notusa
	Urban	All	All	12000 - 18000		0.71	0.19	2	notusa
				18000 - 40000		0.76	0.18	2	notusa
			Angle		3-leg intersections	0.25		2	notusa
					4-leg intersections	0.14		2	notusa
					5-leg intersections	0		2	notusa
			Head-on,Rear-end		All intersections	1.37		2	notusa
					3-leg intersections	1.9		2	notusa
			Left-turn,Right-turn		All intersections	1.34		2	notusa
					3-leg intersections	0.98		2	notusa
					5-leg intersections	1.48		2	notusa
			Single vehicle		All intersections	1.34		2	notusa
					3-leg intersections	0.83		2	notusa
					4-leg intersections	2.06		2	notusa
			Vehicle/bicycle		3-leg intersections	0.86		2	notusa
					4-leg intersections	0.59		2	notusa
					5-leg intersections	3.21		2	notusa
			Vehicle/pedestrian		All intersections	0.84		2	notusa
					3-leg intersections	0.71		2	notusa
					4-leg intersections	0.94		2	notusa
					5-leg intersections	0		2	notusa
					All intersections	0.74		2	notusa
					3-leg intersections	0.46		2	notusa
					4-leg intersections	0.91		2	notusa
					5-leg intersections	0		2	notusa
Installation of channelizing separator islands on side road approaches with supplemental STOP signs	Rural	All	All			0.32		2	VA
			Angle			0.26		2	VA
			Rear-end			0		2	VA
		Fatal and injury	All			0.26		2	VA
Provide split phases	Urban	All	Angle,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe			0.44		2	NY
			Vehicle/pedestrian			0.61		2	NY
Install flashing yellow arrow		All	Vehicle/pedestrian			1		2	MI

On-street Parking

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Prohibit parking on one side of road	Urban	Injury	All			1.49	0.78	1	
Convert parallel parking to angle parking	Urban	All	All			2.11	2.56	1	
		All	Parking related			1.18	0.73	1	

Pedestrians

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install raised pedestrian crosswalks	Urban/Suburban	Injury	All			0.64	0.54	1	
						0.7	0.67	1	
			Vehicle/pedestrian			0.55	0.94	1	
Raised median with unmarked crosswalk (uncontrolled)	Urban/Suburban	All	Vehicle/pedestrian			0.61	2.02	2	AZ,CA,FL,KS,LA,MD,MA,MO,NC,OH,OR,PA,TX,UT,WA,WI
Widen sidewalks at intersections		Injury	All			1.12	1.26	1	
Raised intersections		Injury	All			1.05	0.71	1	
		PDO	All			1.13	1.4	1	
Increase cycle length for pedestrian crossing	Urban	All	Angle,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe			0.55		2	NY
			Vehicle/pedestrian			0.5		2	NY
Implement Barnes Dance	Urban	All	Angle,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe			1.1		2	NY
			Vehicle/pedestrian			0.49		2	NY
Install high-visibility crosswalk	Urban	All	Angle,Head-on,Left-turn,Rear-end,Rear to rear,Right-turn,Sideswipe			0.81		2	NY
			Vehicle/pedestrian			0.6		2	NY
Increase enforcement		All	Vehicle/pedestrian			0.77		2	
Prohibit right-turn-on-red		All	All			0.97		2	
Install pedestrian overpass/underpass		All	Vehicle/pedestrian			0.14		2	
		Incapacitating injury	Vehicle/pedestrian			0.1		2	
Install refuge islands		All	Vehicle/pedestrian			0.44		2	
Install sidewalk (to avoid walking along roadway)		All	Vehicle/pedestrian			0.12		2	

Roadside Features

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install wire guardrails between lanes of opposing traffic		All	All			1.34	0.74	1	
		Fatal	All			0	2.54	1	
		Injury	All			0.74	0.84	1	

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Roadway Features

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Flatten sideslope from 1V:3H to 1V:4H	Rural	All	Run-off-road			0.82	0.16	3	
		Injury	All			0.58	0.04	5	
		PDO	All			0.71	0.04	5	
Flatten sideslope from 1V:4H to 1V:6H	Rural	All	Run-off-road			0.76	0.21	3	
		Injury	All			0.78	0.04	5	
		PDO	All			0.76	0.02	5	
Convert continuous access HOV lanes to limited-access (HOV and left lane crashes)		All	All			1.54	1.061	2	CA
		Incapacitating injury	All			1.2	1.957	2	CA
Refinish pavement with microsurfacing treatment		All	All			0.86	0.194	2	notusa
Refinish pavement with resurfacing treatment		All	All	0 - 2999/lane		0.86	0.757	2	notusa
				3000 - 6999/lane	All	0.74	0.083	2	notusa
				3000 - 6999/lane	Intersection	0.64		2	notusa
				> 7000/lane		1.06	0.126	2	notusa
			Rear-end			0.67		2	notusa
			Wet road			0.49		2	notusa
Resurface pavement with rubberized open-graded asphalt concrete (R-OGAC)	All	All	Wet road			1.07	0.49	2	CA
Expand truck lane restrictions on 2-lane directional interstate segments (screened)		All	Truck related			0.98	0.12755	2	VA
Install Cargill SafeLane anti-icing pavement overlay system on bridges		All	All			0.61	0.16	2	MN
		Fatal and injury	All			0.27	0.21	1	MN
		PDO	All			0.71	0.21	1	MN
Installation of lane narrowing through rumble strips and painted median at rural stop-controlled approaches	Rural	All	All			0.69		2	FL,KY,MO,PA
			Angle			0.58		2	FL,KY,MO,PA
			Rear-end			1.54		2	FL,KY,MO,PA
		Fatal and injury	All			0.8		2	FL,KY,MO,PA
Change in pavement condition from X to Y	Rural	Fatal and injury	All			Eq. LQ 14-1		2	IN
		Injury	All			Eq. LQ 14-2		2	IN
		PDO	All			Eq. LQ 14-3		2	IN
Convert from two-way to one-way traffic	Urban	All	All			0.53	0.17	2	notusa

Shoulder Treatments

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Barrier curb on the road edge	Suburban	All	All			1.09	1.26	1	
						3.57	26.48	1	
						0.64	1.64	1	
Pave narrow shoulder through curve		All	All			2.04	0.76	1	MN

Signs

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF Value	CMF Std. Err	Star Quality Rating	State
Advance static curve warning signs		Injury	All			0.7	0.71	1	
		PDO	All			0.92	0.76	1	
Install improved advance freeway guidance signage	Rural	All	All	17100 - 43000		1.07	0.18	2	MN
			Angle	17100 - 43000		0.69	0.19	1	MN

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Speed Management

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Install transverse rumble strips as traffic calming device	Urban/Suburban	PDO	All			0.73	0.41	2	
Lower posted speed from 80 km/h to 60 km/h	Rural	Fatal	Head-on			0.79		2	notusa
			Parking related			0.44		2	notusa
			Truck related			0.86		2	notusa

Transit

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Installation of new streetcar platforms at unprotected stops	Urban	All	All			0.88		1	notusa
			Vehicle/pedestrian			0.38		1	notusa
			Vehicle/pedestrian		Tram/Pedestrian crashes	1.77		1	notusa

Work Zones

Countermeasures	Area Type	Crash Severity	Crash Type	AADT	Note	CMF		Star Quality Rating	State
						Value	Std. Err		
Single lane closure		All	All			1.56	0.7	1	
Implement left-hand merge and downstream lane shift (Iowa weave)	Rural	All	All			0.54		1	AR
		Fatal and injury	All			2.24		2	AR

Note: The CMFs presented on this page are low quality CMFs with star-ratings of 2 or lower. We do NOT recommend that these CMFs be used in PA.

Alignment

Equation Number	Equation	X	Y
LQ 3 - 1	e^(0.0262(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 2	e^(0.0580(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 3	e^(0.0364(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 4	e^(0.0268(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 5	e^(0.0635(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 6	e^(0.0354(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 7	e^(0.0163(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 8	e^(0.0722(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)
LQ 3 - 9	e^(0.0553(Y-X))	Average horizontal radius in miles (mi) (Before)	Average horizontal radius in miles (mi) (After)

Intersection geometry

Equation Number	Equation	X	Y
LQ 8 - 1	Y/X	Circulating sight distance (ft) (Before)	Circulating sight distance (ft) (After)
LQ 8 - 2	Y/X	Circulating sight distance (ft) (Before)	Circulating sight distance (ft) (After)
LQ 8 - 3	Y/X	Intersection sight distance (ft) (Before)	Intersection sight distance (ft) (After)

Roadway

Equation Number	Equation	X	Y
LQ 14 - 1	e^(-0.1962(Y-X))	Pavement Condition (PSI) (Before)	Pavement Condition (PSI) (After)
LQ 14 - 2	e^(-0.1969(Y-X))	Pavement Condition (PSI) (Before)	Pavement Condition (PSI) (After)
LQ 14 - 3	e^(-0.0624(Y-X))	Pavement Condition (PSI) (Before)	Pavement Condition (PSI) (After)

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