PART D— ACCIDENT MODIFICATION FACTORS

INTRODUCTION AND APPLICATIONS GUIDANCE

EXHIBITS

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PART D INTRODUCTION AND APPLICATIONS GUIDANCE

D.1. PURPOSE OF PART D

Part D presents information regarding the effects of various safety treatments (i.e. countermeasures). This information is used to estimate how effective a countermeasure or set of countermeasures will be in reducing crashes at a specific location. The effects of treatments, geometric characteristics, and operational characteristics of a location can be quantified as an accident modification factor (AMF) or described by trends (e.g. appears to cause a decrease in total crashes). The level of information (e.g. an AMF, a known trend, unknown effect) depends on the quality and quantity of research completed regarding the treatment's effect on crash frequency. The research that developed the HSM established a screening process and convened a series of expert panels to determine which safety evaluation results are considered sufficiently reliable for inclusion in the HSM (see Section D.5 for more information). *Part D* presents the information that passed the screening test and/or met expert panel approval; this information is organized in the following chapters:

Part D presents treatments (i.e. countermeasures) with known Accident Modification Factors, safety trends, or unknown effects. The AMFs can be used to estimate the change in number or severity of crashes as a result of implementing a countermeasure

- Chapter 13 - Roadway Segments
- Chapter 14 - Intersections
- Chapter 15 - Interchanges
- Chapter 16 - Special Facilities and Geometric Situations
- Chapter 17 - Road Networks

Accident modification factors presented in *Part D* can also be used in the methods and calculations shown in *Chapter 6 Select Countermeasures*, and *Chapter 7 Economic Appraisal*. These methods are used to calculate the potential crash reduction due to a treatment, convert the crash reduction to a monetary value and compare the monetary benefits of reduced crashes to the monetary cost of implementing the countermeasure(s), as well as to the cost of other associated impacts (e.g., delay, right-of-way). Some accident modification factors may also be used in the predictive method presented in *Part C.*

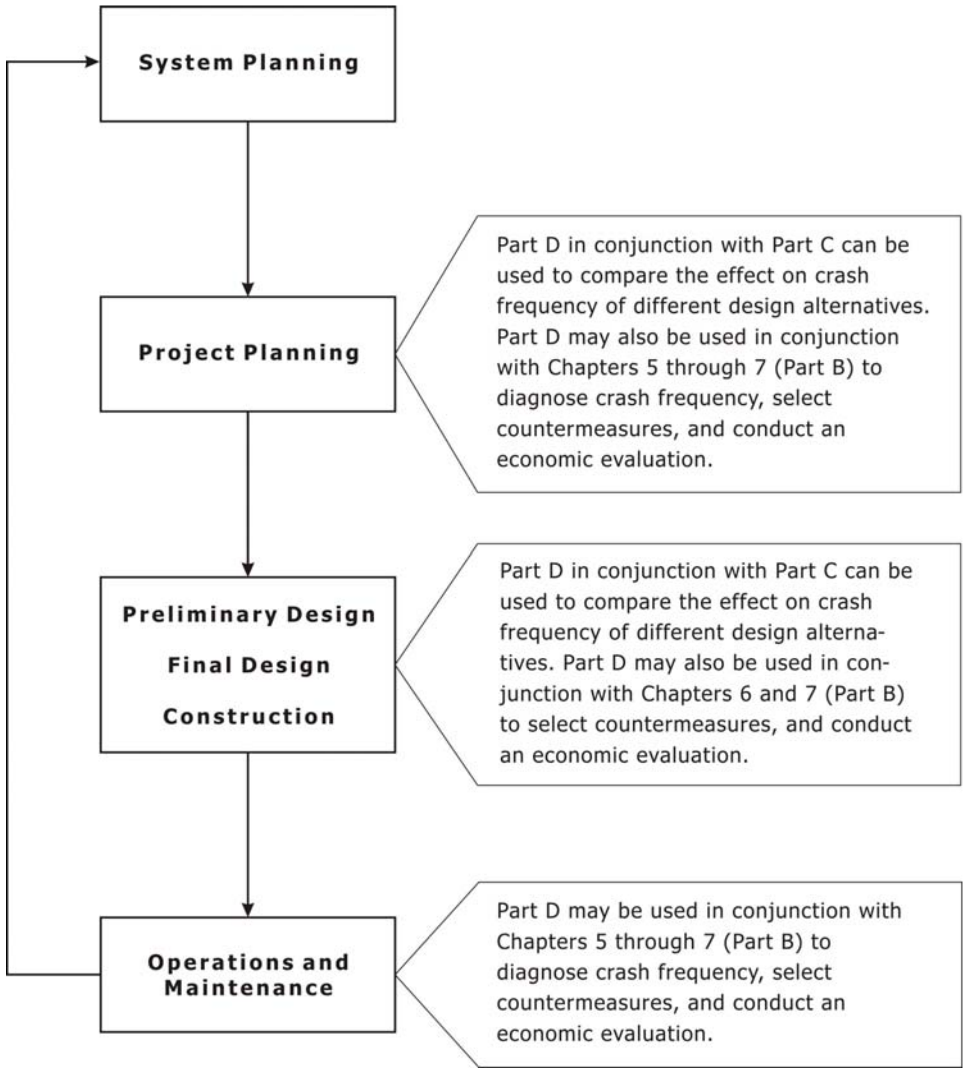
D.2. RELATIONSHIP TO THE PROJECT DEVELOPMENT PROCESS

The accident modification factors in *Part D* are used to estimate the change in crashes as a result of implementing a countermeasure(s). Applying the *Part D* material to estimate change in crashes often occurs within operations and maintenance activities. It can also occur in projects in which the existing roadway network is assessed and modifications are identified, designed and implemented with the intent of improving the performance of the facility from a capacity, safety, or multimodal perspective.

Chapter 1 provides an overview of the project development process considered in the HSM.

Exhibit D-1 illustrates the relationship between *Part D* and the project development process. As discussed in *Chapter 1*, the project development process is the framework being used in the HSM to relate safety analysis to activities within planning, design, construction, operations and maintenance.

Exhibit D-1: Part D Relation to the Project Development Process



D.3. RELATIONSHIP TO PARTS A, B, AND C OF THE HIGHWAY SAFETY MANUAL

Part A Chapter 3 provides fundamental information about Accident Modification Factors

Part A of the HSM provides introductory and fundamental knowledge needed for applying the HSM. It introduces concepts such as human factors, how to count crashes, data needs, regression-to–the-mean, countermeasures, and accident modification factors. The material in *Part A* provides valuable context regarding how to apply different parts of the HSM and how to use the HSM effectively in typical project activities or within established processes. Prior to using the information in *Part D*, an understanding of the material regarding AMFs presented in *Part A, Chapter 3 Fundamentals* is recommended, as well as an understanding of the information presented in the D.4 Guide to Applying *Part D* section below.

Part B presents the six basic components of a roadway safety management process as related to transportation engineering and planning. The material is useful for monitoring, improving and maintaining safety on an existing roadway network. Applying the methods and information presented in *Part B* creates an awareness of sites most likely to experience crash reductions with the implementation of improvements, the type of improvement most likely to yield benefits, an estimate of the benefit and cost of improvement(s), and an assessment of an improvement's effectiveness. The information presented in *Part D* should be used in conjunction with the information presented in *Chapter 6 Select Countermeasures* and *Chapter 7 Economic Appraisal*.

Part C introduces techniques for predicting crashes on two-lane rural highways, multilane rural highways, and urban and suburban arterials. This material is particularly useful for estimating expected average crash frequency of new facilities under design, and extensive re-design of existing facilities. It facilitates a proactive approach to considering safety before crashes occur. Some *Part D* AMFs are included in *Part C* and for use with specific Safety Performance Functions (SPFs). Other *Part D* AMFs are not presented in *Part C* but can be used in the methods to estimate change in crash frequency described in Section C.7.

D.4. GUIDE TO APPLYING PART D

The notations and terms cited and defined in the subsections below are used to indicate the level of knowledge regarding the effects on crash frequency of the various geometric and operational elements presented throughout *Part D*.

Section D.4 provides an explanation of the type of information associated with each treatment in Part D.

The following subsections explain useful information about:

- How the AMFs are categorized and organized in each chapter;
- The notation used to convey the reliability of each AMF;
- Terminology used in each chapter;
- Application of AMFs; and,
- Considerations when Applying AMFs.

To effectively use the accident modification factors in *Part D*, it is important to understand the notations and terminology, as well as the situation in which the countermeasure associated with the AMF is going to be applied. Understanding these items will increase the likelihood of success when implementing countermeasures.

D.4.1. Categories of Information

At the beginning of each section of *Part D*, treatments are summarized in tables according to the category of information available (i.e. accident modification factors, or evidence of trends). These tables serve as a quick reference of the information available related to a specific treatment. Exhibit D-2 summarizes how the information is categorized.

Exhibit D-2: Categories of Information in Part D

Symbol Used in Part D Summary Tables	Available Information
✓	• AMFs are available (i.e. sufficient quantitative information is available to determine a reliable AMF). • The AMFs and standard errors passed the screening test to be included in the HSM.
T	• There is some evidence of the effects on crash frequency, although insufficient quantitative information is available to determine a reliable AMF. • In some instances the quantitative information is sufficient to identify a known trend or apparent trend in crash frequency and/or user behavior; but not sufficient to apply in estimating changes in crash frequency. • Published documentation regarding the treatment was not sufficiently reliable to present an AMF in this edition of the HSM.
-	• Quantitative information about the effects on crash frequency is not available for this edition of the HSM. • Published documentation did not include quantitative information regarding the effects on crash frequency of the treatment. • A list of these treatments is presented in the appendices to each chapter.

For those treatments with AMFs, the AMFs and standard errors are provided in tables. When available each table supplies the specific treatment, road type or intersection type, setting (i.e., rural, urban, suburban), traffic volumes, accident type and severity to which the AMF can be applied.

The appendix to each chapter presents those treatments with known trends and unknown effects. For those treatments without AMFs, but which present a trend in crashes or user behavior, it is reasonable to apply them in situations where there are indications that they may be effective in reducing crash frequency. A treatment without an AMF indicates that there is an opportunity to apply and study the effects of the treatments; thereby adding to the current understanding of the treatment's effect on crashes. See *Chapter 9 Safety Effectiveness Evaluation* for more information regarding methods to assess the effectiveness of a treatment.

D.4.2. Standard Error and Notation Accompanying AMFs

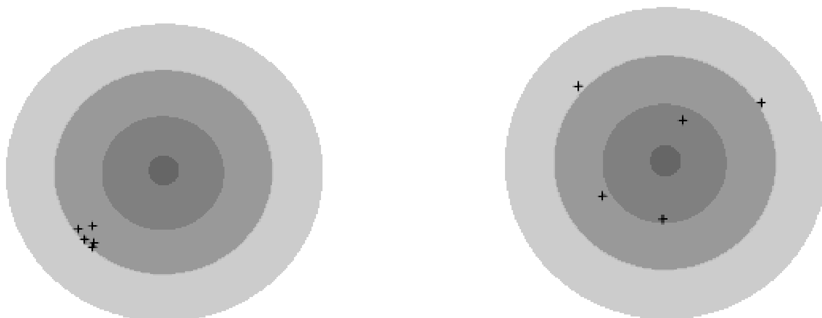
The standard deviation of the mean is the standard error. The standard error indicates the precision of an estimated AMF.

In general, the standard deviation indicates the precision of a set of repeated measurements, in other words, precision is the degree to which repeated measurements are close to each other. When calculating for example the mean of a set of measurements, then the mean itself has a standard deviation; the standard deviation of the mean is called the *standard error*. In *Part D*, the standard error indicates the precision of an estimated AMF. *Accuracy* is a measure of the proximity of an estimate to its actual or true value. The difference between the average of repeated measurements and its true value is an estimate of its bias. The true value of an AMF is seldom known but steps can be taken to minimize the bias associated with its estimate (e.g. by using an appropriate statistical approach, applying an EB adjustment for regression-to-the-mean bias). Accuracy and precision estimates are generally difficult to separate mathematically because precision is to some degree built into accuracy. Standard error in *Part D* is important because more accurate and precise AMFs lead to more cost effective decisions.

Exhibit D-3 illustrates the concepts of precision and accuracy. If the estimates (the + signs) form a tight cluster, the estimates are precise. However, if the center of that cluster is not the bull's-eye, then the estimates are precise but not accurate. If the estimates are scattered and do not form a tight cluster they are neither precise nor accurate.

Standard error reflects accuracy and precision. The lower the standard error, the more effective the treatment.

Exhibit D-3: Precision and Accuracy



Precise but not Accurate **Neither Precise nor Accurate**

Some AMFs in *Part D* have a standard error associated with them. Standard errors in *Part D* with values less than 0.1 are presented to two decimal places, standard errors greater than 0.1 have been rounded to the nearest 0.1 and are presented to one decimal place. The most reliable (i.e., valid) AMFs have a standard error of 0.1 or less, and are indicated with **bold** font. Reliability indicates that the AMF is unlikely to change substantially with new research. Less reliable AMFs have standard errors of 0.2 or 0.3 and are indicated with *italic* font. All quantitative standard errors presented with AMFs in *Part D* are less than or equal to 0.3.

To emphasize the meaning and awareness of each standard error, some AMFs in *Part D* are accompanied by a superscript. These superscripts have specific meanings:

The AMFs are summarized in Part D with additional notation about standard error. This information emphasizes the reliability of the AMF and the stability of the treatment.

- *: The asterisk indicates that the AMF value itself is within the range 0.90 to 1.10, but that the confidence interval defined by the AMF ± two times the standard error may contain the value 1.0. This is important to note since a treatment with such an AMF could potentially result in (a) a reduction in crashes (safety benefit), (b) no change, or (c) an increase in crashes (safety disbenefit). These AMFs should be used with caution.

- ^: The carat indicates that the AMF value itself is within the range 0.90 to 1.10 but that the lower or upper end of the confidence interval (defined by the AMF ± two times the standard error) may be exactly at 1.0. This is important to note since a treatment with such an AMF may result in no change in safety. These AMFs should be used with caution.

- o: The degree symbol "o" indicates that the standard error has not been quantified for the AMF; therefore, the potential error inherent in the value is not known. This usually occurs when the factor is included as an equation.

- +: The plus sign indicates that the AMF is the result of combining AMFs from multiple studies.

- ?: The question mark indicates AMFs that have the opposite effects on different crash types or crash severities. For example, a treatment may increase rear-end crashes but decrease angle crashes. Or a treatment may reduce fatal crashes but increase property damage only (PDO) crashes.

Understanding the meanings of the superscripts and the standard error of an AMF will build familiarity with the reliability and stability that can be expected from each treatment. An AMF with a relatively high standard error does not mean that it should not be used; it means that the AMF should be used with the awareness of the range of results that could be obtained. Applying these treatments is also an opportunity to study the effectiveness of the treatment after implementation and add to the current information available regarding the treatment's effectiveness (see *Chapter 9 Safety Effectiveness Evaluation* for more information).

D.4.3. Terminology

Described below are some of the key words used in *Part D* to describe the AMF values or information provided. Key words to understand are:

- Unspecified: In some cases, AMF tables include some characteristics that are "unspecified". This indicates that the research did not clearly state the road type or intersection type, setting, or traffic volumes of the study.
- Injury: In *Part D* of the HSM, injury accidents include fatal accidents unless otherwise noted.
- All Settings: In some instances, research presented aggregated results for multiple settings (e.g. urban and suburban signalized intersections); the same level of information is reflected in the HSM.
- Insufficient or No Quantitative Information Available: Indicates that the documentation reviewed for the HSM did not contain quantitative information that passed the screening test for inclusion in the HSM. It doesn't mean that such documentation does not exist.

Section D.4.4 provides an overview of the ways in which AMFs are applied to estimate crash frequency.

D.4.4. Application of AMFs to Estimate Crash Frequency

As discussed above, AMFs are used to estimate crash frequency or the change in crashes due to a treatment. There are multiple approaches to calculating an estimated number of crashes using an AMF. These include:

1. Applying the AMF to an expected number of crashes calculated using a calibrated safety performance function and Empirical Bayes to account for regression-to-the-mean bias; or
2. Applying the AMF to an expected number of crashes calculated using a calibrated safety performance function; or
3. Applying the AMF to historic crash count data.

Of the three ways to apply AMFs, listed above, the first approach produces the most reliable results. The second approach is the second most reliable and the third approach is the approach used if a safety performance function is not available to calculate the expected number of crashes. Additional details regarding safety performance functions, expected number of crashes, regression to the mean, and empirical Bayes methodology are discussed in *Chapter 3 Fundamentals.* The specific step-by-step process for calculating an estimated change in crashes using approach number 1 or number 2 listed above is presented in *Chapter 7 Economic Appraisal*.

AMFs may be presented in *Part D* chapters as numerical values, equations, graphs, or a combination of these. AMFs may be applied under any of the following scenarios:

1. Direct application of a numerical AMF value and standard error obtained from a table: The AMF is multiplied directly with the base crash frequency to estimate the crash frequency and standard error with the treatment in place.
2. Direct application of an AMF value obtained from a graph: The AMF value is obtained from a graph (which presents a range for a given treatment) and is subsequently multiplied directly with the base crash frequency to estimate the crash frequency with the treatment in place. No standard error is provided for graphical AMFs.
3. Direct application of an AMF value obtained from an equation: The AMF value is calculated from an equation (which is a function of a treatment range) and is subsequently multiplied with the base crash frequency to estimate the crash frequency with the treatment in place. No standard error is provided for AMFs calculated using equations.
4. Multiplication of multiple AMF values from a table, graph, or equation: Multiple AMFs are obtained or calculated from a table, graph, or equation and are subsequently multiplied. This procedure is followed when more than one treatment is being considered for implementation at the same time at a given location. See *Chapter 3* for guidance about the independence assumption when applying multiple AMFs.
5. Division of two AMF values from a table, graph, or equation: Two AMFs are obtained or calculated from a table, graph, or equation and are subsequently divided. This procedure is followed when one of the AMFs (denominator) represents an initial condition (not equal to the AMF base condition, and therefore not equal to an AMF value of 1.0) and the other AMF (numerator) represents the treatment condition.
6. Interpolation between two numerical AMF values from a table: An unknown AMF value is calculated as the interpolation of two known AMF values.

The graybox examples presented throughout *Part D* chapters illustrate the application of AMFs under these scenarios.

D.4.5. Considerations when Applying AMFs to Estimate Crash Frequency

Section D.4.5 presents considerations prior to the application of AMFs.

Standard errors have been provided for many AMFs in Part D. Where standard errors are available, these should be used to calculate the confidence interval of the projected change in crash frequency. Section 3.5.3 in *Chapter 3 Fundamentals* provides additional information regarding the application of standard errors.

AMFs are multiplicative when a treatment can be applied in multiple increments, or when multiple AMFs are applied simultaneously. When applying multiple AMFs, engineering judgment should be used to assess the interrelationship and/or independence of individual treatments being considered for implementation. Section 3.5.3 in *Chapter 3 Fundamentals* provides additional information regarding the application of multiplicative AMFs.

AMFs may be divided when the existing condition corresponds to an AMF value (other than the base value of 1.00) and the treatment condition corresponds to another AMF value. In this case a ratio of the AMFs may be calculated to account for the variation between the existing condition and the treatment condition. Section 3.5.3 in *Chapter 3 Fundamentals* provides additional information regarding the application of AMF ratios.

Section D.5 provides an overview of how the AMFs were developed for the HSM

D.5. DEVELOPMENT OF AMFS IN PART D

The following sections provide an overview of the Literature Review Procedure, Inclusion Process, and Expert Panel that were developed and applied while creating *Part D* of the HSM. This information provides background to the knowledge included in the HSM, and may also be useful to others in the field of transportation safety by:

- Providing a framework to review safety literature to determine the reliability of published results;
- Outlining the characteristics of safety studies that lead to more reliable results;
- Promoting higher quality evaluation of treatments to advance the knowledge of safety effects; and
- Encouraging improvements to the methods applied for the first edition by expanding and enhancing the knowledge for future editions of the HSM.

D.5.1. Literature Review Procedure

AMFs in Part D were developed through a literature review and inclusion process and through an Expert Panel review process.

The information presented in *Part D* is based on an extensive literature review of published transportation safety research mostly dated from the 1960s to June 2008.

A literature review procedure was developed to document available knowledge using a consistent approach. The procedure includes methods to calculate Accident Modification Factors (AMFs) based on published data, estimate the standard error of published or calculated AMFs, and adjust the AMFs and standard errors to account for study quality and method. The steps followed in the literature review procedure are:

1. Determine the estimate of the effect on crash frequency, user behavior, or Accident Modification Factor or Function (AMF) of a treatment based on one published study
2. Adjust the estimate to account for potential bias from regression-to-mean and/or changes in traffic volume
3. Determine the ideal standard error of the AMF
4. Apply a Method Correction Factor to ideal standard error, based on the study characteristics
5. Adjust the corrected standard error to account for bias from regression-to-mean and/or changes in traffic volume

In a limited number of cases, multiple studies provided results for the same treatment in similar conditions.

D.5.2. Inclusion Process

The AMFs from the literature review process were evaluated during the Inclusion Process, based on their standard errors, to determine whether or not they are sufficiently reliable and stable to be presented in the HSM. A standard error of 0.10 or less indicates an AMF value that is sufficiently accurate, precise, and stable. For treatments that have an AMF with a standard error of 0.1 or less, other related AMFs with standard errors of 0.2 to 0.3 may also be included to account for the effects of the same treatment on other facilities, other crash types or other severities.

Not all potentially relevant AMFs could be evaluated in the inclusion process. For example, AMFs that are expressed as functions, rather than as single values, typically do not have an explicitly defined standard error that can be considered in the inclusion process.

The basis for the inclusion process is providing sound support for selecting the most cost-effective road safety treatments. For any decision-making process, it is generally accepted that a more accurate and precise estimate is preferable to a less accurate or less precise one. The greater the accuracy of the information used to make a decision, the greater the chance that the decision is correct. A higher degree of precision is preferable to improve the chance that the decision is correct.

D.5.3. Expert Panel Review

In addition, several expert panels were formed and convened as part of the research projects that developed the predictive method presented in *Part C*. These expert panels reviewed and assessed the relevant research literature related to the effects on crash frequency of particular geometric design and traffic control features. The expert panels subsequently recommended which research results were appropriate for use as AMFs in the *Part C* predictive method. These AMFs are presented in both *Parts C* and *D*. Many, but not all, of the AMFs recommended by the expert panels meet the criteria for the literature review and inclusion processes presented in Sections D.5.1 and D.5.2. For example, AMFs that are expressed as functions, rather than as single values, often did not have explicitly defined standard errors and, therefore, did not lend themselves to formal assessment in the literature review process.

D.6. CONCLUSION

Part D presents the effects on crash frequency of various treatments, geometric design characteristics, and operational characteristics. The information in *Part D* was developed using a literature review process, an inclusion process, and a series of expert panels. These processes led to identification of AMFs, trends, or unknown effects for each treatment in *Part D*. The level of information presented in the HSM is dependent on the quality and quantity of previous research.

Part D includes all AMFs assessed with the literature review and inclusion process, including measures of their reliability and stability. These AMFs are applicable to a broad range of roadway segment and intersection facility types, not just those facility types addressed in the *Part C* predictive methods.

Some *Part D* AMFs are included in *Part C* and for use with specific SPFs. Other *Part D* AMFs are not presented in *Part C* but can be used in the methods to estimate change in crash frequency described in Section C.7 of the *Part C Introduction and Applications Guidance*.

The information presented in *Part D* is used to estimate the effect on crash frequency of various treatments. It can be used in conjunction with the methodologies in *Chapter 6 Select Countermeasures* and *Chapter 7 Economic Appraisal*. When applying the AMFs in *Part D*, understanding the standard error and the corresponding potential range of results increases opportunities to make cost-effective choices. Implementing treatments with limited quantitative information presented in the HSM presents the opportunity to study the treatment's effectiveness and add to the current base of information.

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