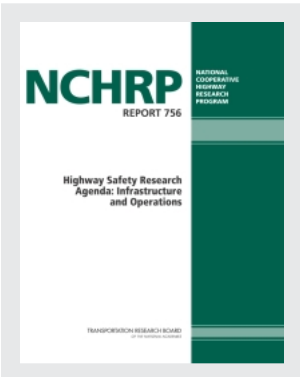


Highway Safety Research Agenda: Infrastructure and Operations

DETAILS

92 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-28352-6 | DOI 10.17226/22533

AUTHORS

Zegeer, Charles; Srinivasan, Raghavan; Carter, Daniel; Gross, Frank; Sawyer, Mike; Hauer, Ezra; Bonneson, James; and Bahar, Geni

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 756

Highway Safety Research Agenda: Infrastructure and Operations

Charles Zegeer
Raghavan Srinivasan
Daniel Carter
UNIVERSITY OF NORTH CAROLINA HIGHWAY SAFETY RESEARCH CENTER
Chapel Hill, NC

Forrest Council
Frank Gross
Mike Sawyer
VANASSE HANGEN BRUSTLIN, INC.
Vienna, VA

Ezra Hauer
Toronto, Ontario, Canada

James Bonneson
TEXAS TRANSPORTATION INSTITUTE
College Station, TX

Geni Bahar
NAVIGATS INC.
Toronto, Ontario, Canada

Subscriber Categories
Highways • Research • Safety and Human Factors

Research sponsored by the American Association of State Highway and Transportation Officials
in cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2013
www.TRB.org

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Academies was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NCHRP REPORT 756

Project 17-48
ISSN 0077-5614
ISBN 978-0-309-28352-6
Library of Congress Control Number 2013948693

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at:

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

COOPERATIVE RESEARCH PROGRAMS

AUTHOR ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 17-48. The University of North Carolina Highway Safety Research Center (HSRC) was the contractor for this study. Vanasse Hangen Brustlin, Inc. (VHB); NAVIGATS, Inc.; and Texas Transportation Institute were subcontractors; and Jim Bonneson and Ezra Hauer were project consultants. Charles Zegeer was the Principal Investigator. The other authors of the report are Raghavan Srinivasan and Daniel Carter from HSRC; Forrest Council, Frank Gross, and Mike Sawyer from VHB, Inc.; and consultants Ezra Hauer, Jim Bonneson, and Geni Bahar.

The authors wish to express sincere thanks to the individual members of the project panel who provided extremely helpful feedback for the many documents they were asked to review.

Finally, this project would not have been possible without the help and support of members of selected state Departments of Transportation (DOTs) who provided valuable input for this project.

FOREWORD

By Christopher J. Hedges
Staff Officer
Transportation Research Board

This report develops a proposed agenda of prioritized safety research needs in the area of highway infrastructure and operations. It was developed to provide options to the U.S. transportation community on how to direct research to the areas where it can provide the most benefit. The agenda is based on a prioritization methodology developed by the research team, which can be applied on a recurring basis to update the agenda over time. Both the agenda and the methodology documented in this report will provide valuable input to all those involved in the conduct and management of highway safety research at all levels of government, the private sector, and academia.

In the year 2000, an ad hoc group was formed that shared an interest in ensuring that research and technology (R&T) programs address the needs of the highway community and the public. The group was known as the National Highway R&T Partnership; it was initiated by the U.S. Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the Transportation Research Board (TRB). It comprised a dedicated group of top experts, involving hundreds of individuals and input from more than 170 organizations. The group had two main goals: to identify highway R&T needs to assist research funding agencies as they develop their research programs, and to demonstrate the value of a partnership approach to carrying out national R&T efforts.

The group was broken down into five working groups, of which one represented highway safety research needs. One of the safety working group's key recommendations was to identify the most pressing research needs in the field of highway operations and infrastructure. In 2005, FHWA and the state departments of transportation focused on this goal and through the National Cooperative Highway Research Program (NCHRP) provided funding for a TRB Policy Study. This study convened an expert committee to conduct an independent review of the processes used to establish research priorities and coordination. The result was *TRB Special Report 292: Safety Research on Highway Infrastructure and Operations: Improving Priorities, Coordination, and Quality*. This report made recommendations for a process and administrative structure needed to establish research priorities on a national level.

Implementation of these recommendations was the objective of NCHRP Project 17-48, Highway Infrastructure and Operations Safety Research Needs. A research team led by the University of North Carolina Highway Safety Research Center developed a methodology for prioritizing research needs, implemented the procedure to develop a ranked agenda of the most pressing current needs, and made recommendations for the long-term implementation of the research agenda. The team developed a ranking methodology based on a wide range of factors, including costs and potential benefits, stakeholder input, feasibility, urgency, risk, and alignment with national strategic goals and plans. The methodology is included as a spreadsheet tool on the CD-ROM accompanying this report. A wide range of background and supporting materials are also provided on the CD-ROM, including a user guide for the prioritization tool. The report itself includes a list of specific prioritized research topics divided into two categories: (1) applied research that lends itself to the development of new Crash Modification Factors (CMFs) and (2) fundamental and applied research for which CMFs are not appropriate. Appendices A-O and R, which contain additional documentation from the research effort, are not published herein. These materials are available for download from the TRB website at the following URL: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

Executive Summary

Background

While the value of road safety research is widely recognized, many organizations face the dilemma of deciding how to invest limited research dollars and resources to yield maximum safety improvements. The challenge for these organizations is threefold:

1. Organizations need to develop and/or implement a sensible process for identifying and prioritizing the best research opportunities.
2. Organizations need to ensure that the high-priority research is funded and conducted without unnecessary duplication of effort.
3. Organizations need to ensure that the research conducted produces reliable and useful results.

In response to this need, the Transportation Research Board (TRB) convened an expert committee in 2005 to provide an independent review of the processes used to establish research priorities and coordination in the area of highway infrastructure and operations safety. *TRB Special Report 292: Safety Research on Highway Infrastructure and Operations: Improving Priorities, Coordination, and Quality* presents the findings of this committee. As part of their task, the committee was asked to recommend a process for setting research priorities in the area of highway infrastructure and operations safety.

The committee gathered information about current processes from a range of organizations that fund highway safety research. Specifically, the committee included examples of the three major categories of organizations that fund research on highway infrastructure and operations safety (i.e., federal and state governments and the private sector). The following points are taken directly from *TRB Special Report 292* and provide a summary of the findings from the committee's review:

1. **Lack of uniformity –** There is a lack of uniformity among the processes that organizations use to identify and prioritize research needs and opportunities and to select projects for funding.
2. **Lack of advice from experts –** Advice from experts, including knowledgeable researchers, does not appear to be routinely taken into account in identifying priority research areas and deciding which projects to fund.
3. **Funding bias –** The committee noted a bias in favor of short-term research aimed at solving problems of immediate concern, with relatively little attention given to longer-term fundamental research aimed at developing a foundation for further knowledge.

The committee concluded that any effort to develop a National Research Agenda would need to take account of the wide range of current processes. In addition, the development of a methodology for assigning research priorities should be a quantitative analytical approach that examines clearly defined criteria, including:

1. Needs of safety program managers.
2. State of current knowledge.
3. Value or benefit of a proposed research effort for greater road safety.
4. Potential for research to solve the problem.
5. Expert judgment about possible implementation of research outputs.

The committee that prepared *TRB Special Report 292* was also tasked with examining a series of previously prepared expert working papers proposing research topics in five different areas. Based on this review, they were to provide guidance on whether or not the topic areas and specific projects should be included in a National Research Agenda. They were also tasked with commenting on strategies to improve safety research quality. However, their most important goal was to recommend ". . . an efficient and effective research priority-setting and coordination process . . ." Thus, they were to recommend how such a National Research Agenda should be established and how best to have it accepted by national entities that fund safety-infrastructure and operations research.

While the committee succeeded in their overall task to recommend a process for setting highway safety research priorities, additional work was needed to assist in the implementation of their recommendations. Specifically, the committee recommended the formation of a Scientific Advisory Committee (SAC) to:

1. Develop a transparent process for identifying and prioritizing research needs and opportunities in highway safety, with emphasis on infrastructure and operations.
2. Apply the process to recommend a National Research Agenda focused on highway infrastructure and operations safety.

NCHRP Project 17-48, "Highway Infrastructure and Operations Safety Research Needs," was initiated to implement these two recommendations.

Objectives

The purpose of this study was to develop a process for identifying and prioritizing the best research opportunities available for highway safety research related to infrastructure and operations. The second objective was to identify and priority rank candidate Research Needs Statements (RNSs) by applying the priority ranking methodology to determine the highest research priorities based on their expected safety benefits. In short, the first primary goal of this study was to move toward the recommended agenda – to establish an initial prioritized list of research needs for possible funding. The second major goal of the study was to develop a detailed plan for establishing an ongoing, sustainable, and dynamic national safety-infrastructure research agenda for the future.

Approach

To meet the first project goal, two separate analytical methodologies were developed for ranking RNSs. One method was developed for application to studies where Crash Modification Factors (CMFs) were the intended outcome of the study. This methodology involved calculating a "Value of Research" (VOR) for each CMF-related RNS under consideration. The second priority ranking method was developed and applied to "Fundamental" and "Non-CMF Applied" RNSs, that is, studies which related to conducting background research on roadway infrastructure or operations topics, but which did not involve directly developing a CMF. These priority ranking methods were then applied to an identified list of RNSs.

To address the second major goal for this study, a detailed examination was made of possible organizational structures that could be used to maintain an ongoing and dynamic process to sustain a national safety-infrastructure research agenda for the future. This involved exploring many different options related to how existing U.S. safety research funding organizations might work together to implement such an effort. The effort also involved examining the possible development of a SAC to oversee the process and how that committee might operate.

Results

A total of more than 800 potential RNSs were obtained from a variety of sources and an RNS screening process was used to develop a list of RNS "finalists" to be further analyzed by the analytical priority ranking processes described above. RNSs were screened to select a "short list" of RNSs based on the several criteria. For example, research topics (RNSs) were eliminated if they had no clear goal or research objective, if there was already a well-established study already known to have been conducted (e.g., where there was already a 4- or -5-star rating of the CMF in the CMF Clearinghouse), or if a similar study had already been funded and was in process. Studies were also screened based on the magnitude of the nationwide fatality problem that they were intending to address, and the potential number of sites for which the results of the research could be applied in the United States. A total of 50 fundamental and non-CMF applied RNSs were selected and ranked using the priority ranking methodology. A total of 37 CMF-related RNSs were selected and priority ranked using the VOR method.

Other types of research needs were identified, but were not included in the prioritization process because they were not defined as research according to the scope of the project. Those projects that would not generate new knowledge (e.g., guidebooks, syntheses, implementation tools, and scans) were not considered "research" and were not included in the prioritization. In order to prioritize these types of "non-research implementation" projects, an agency may use subjective assessment by decision-makers, or develop a priority ranking method comparable to the method developed herein for the fundamental and non-CMF applied RNSs.

The second major project goal, the identification and examination of critical issues that must be considered in the long-term implementation of the National Research Agenda, was met by developing and exploring five criteria of a "best structure" (ability to implement the developed ranking processes, ability to ensure buy-in by both funders and researchers, ability to provide an independent collection and rating of both fundamental and directly applicable research topics, ability to ensure continual agenda process improvement, and ability to ensure continual future funding). Within each of these criteria, the advantages and disadvantages of alternatives for each of three primary structural components were discussed – size and nature of the scientific advisory group, the home/host for the structure, and the update cycle for the agenda. In addition, suggestions were provided concerning how coordination, research quality, and Agenda progress monitoring might be accomplished, along with suggestions on the membership and duties for two different sized SACs.

The next logical steps in the process should involve: (1) distributing the initial agenda (i.e., the lists of ranked CMF, non-CMF applied research, and fundamental research projects) to possible funding agencies for their use in near-term research procurement and (2) making the decisions defined in the discussion of the long-term plan. As noted there, since funding for both the Agenda-setting process and for the research conducted under the agenda will, to a great extent, have to come from FHWA and AASHTO, these are the two agencies that would likely have the major voice in these decisions. As noted above, this is also appropriate since both have demonstrated strong interest in the improvement of infrastructure safety research in the United States.

CHAPTER 1

Introduction

While the value of road safety research is widely recognized, many organizations face the dilemma of deciding how to invest limited research dollars and resources to yield maximum safety improvements. The challenge for these organizations is threefold:

1. Organizations need to develop and/or implement a sensible process for identifying and prioritizing the best research opportunities.
2. Organizations need to ensure that the high-priority research is funded and conducted without unnecessary duplication of effort.
3. Organizations need to ensure that the research conducted produces reliable and useful results.

In response to this need, TRB convened an expert committee in 2005 to provide an independent review of the processes used to establish research priorities and coordination in the area of highway infrastructure and operations safety. *TRB Special Report 292: Safety Research on Highway Infrastructure and Operations: Improving Priorities, Coordination, and Quality* presents the findings of this committee. As part of their task, the committee was asked to recommend a process for setting research priorities in the area of highway infrastructure and operations safety.

The committee gathered information about current processes from a range of organizations that fund highway safety research. Specifically, the committee included examples of the three major categories of organizations that fund research on highway infrastructure and operations safety (i.e., federal and state governments and the private sector). The following points are taken directly from *TRB Special Report 292* and provide a summary of the findings from the committee's review:

1. **Lack of uniformity** – There is a lack of uniformity among the processes that organizations use to identify and prioritize research needs and opportunities and to select projects for funding.
   a. Some accept suggestions for research topics from a wide spectrum of organizations and individuals, while others limit the submission of suggestions to specific groups.
   b. Many take a "top-down" approach to identifying research opportunities consistent with an established mission or strategic plan, while others rely on a "bottom-up" approach through which the practitioners identify problems requiring research.
   c. Some make use of outside experts to help make decisions about what research to conduct, while others rely almost exclusively on in-house expertise.
2. **Lack of advice from experts** – Advice from experts, including knowledgeable researchers, is not always taken into account in identifying priority research areas and deciding which projects to fund. Specifically, expert advice could be useful for determining the current state of knowledge, the effectiveness of research to date in solving the problem, and the availability of appropriate research methods and data.
3. **Funding bias** – The committee noted a bias in favor of short-term research aimed at solving problems of immediate concern, with relatively little attention given to longer-term fundamental research aimed at developing a foundation for further knowledge.

The committee concluded that any effort to develop a National Research Agenda would need to take account of the wide range of current processes. In addition, the development of a methodology for assigning research priorities should be a quantitative analytical approach that examines clearly defined criteria, including:

1. Needs of safety program managers.
2. State of current knowledge.

3. Value or benefit of a proposed research effort for greater road safety.
4. Potential for research to solve the problem.
5. Expert judgment about possible implementation of research outputs.

The committee that prepared *TRB Special Report 292* was also tasked with examining a series of previously prepared expert working papers proposing research topics in five different areas. Based on this review, they were to provide guidance on whether or not the topic areas and specific projects should be included in a National Research Agenda. They were also tasked with commenting on strategies to improve safety research quality. However, their most important goal was to recommend ". . . an efficient and effective research priority-setting and coordination process . . . ." Thus, they were to recommend how such a National Research Agenda should be established and how best to have it accepted by national entities that fund safety-infrastructure and operations research.

While the committee succeeded in their overall task to recommend a process for setting highway safety research priorities, additional work was needed to assist in the implementation of their recommendations. Specifically, the committee recommended the formation of a SAC to:

1. Develop a transparent process for identifying and prioritizing research needs and opportunities in highway safety, with emphasis on infrastructure and operations.
2. Apply the process to recommend a National Research Agenda focused on highway infrastructure and operations safety.

NCHRP Project 17-48, *Highway Infrastructure and Operations Safety Research Needs,* was initiated to implement these two recommendations. The goals of this project are as follows:

- Develop a methodology to be used to prioritize candidate safety operations and infrastructure research needs, for use in establishing a process for setting a National Research Agenda.
- Identify candidate research needs topics and apply the prioritization process to research needs topics to create a prioritized list.
- Develop a plan for long-term implementation of the National Research Agenda.

In short, the primary goal of this report is to move toward that recommended agenda – to establish an initial prioritized list of research needs and to propose a detailed plan for establishing an ongoing, sustainable, and dynamic agenda. The formation of this plan has included examination of institutional structures that can ensure expert scientific advice in setting the agenda, methods encouraging coordination of the identified research topics among national funding leading agencies, techniques for evaluating the quality of the research conducted, ways to monitor the overall progress in advancing the National Agenda, and methods for continuously updating and refining the agenda over the long term.

This report is organized into the following chapters:

- **Chapter 2—Developing the Prioritization Methodology.** This chapter provides a summary of current approaches for prioritizing research needs and proposes new methods for setting research priorities in the area of highway infrastructure and operations safety.
- **Chapter 3—Implementing the Prioritization Procedure.** This chapter describes the process for identifying candidate research needs and the results of implementing the prioritization methods.
- **Chapter 4—Plan for Long-Term Implementation of a National Research Agenda.** This chapter discusses the plan for implementing and sustaining a National Research Agenda, including alternative institutional structures, coordination of funding, evaluating the quality of completed research, monitoring progress, and the formation and duties of a national-level SAC.
- **Chapter 5—Conclusions and Next Steps.** This chapter provided a summary of the research and recommendations for the long-term implementation of the National Research Agenda.

When discussing the types of Research Needs Statements, this report will use the following terminology to define various types of RNSs. These include:

- Applied RNSs - These pertain to directly applicable research (DAR) studies, which include CMF studies and other studies in which the study results can be directly applied to solving highway safety problems. For example, a crash prediction modeling study may have the goal of developing a prediction model related to crashes at horizontal curves, where traffic and roadway geometric features are part of the model to predict curve-related crashes. In that case, the results of such a model may be directly useful to engineers for better understanding the relative association between various roadway features and crashes. Included in this Applied RNS category are two subcategories:
  – Applied-CMF RNSs - These include research studies where the primary goal of the study is to determine the CMF for one or more specific safety-related infrastructure or operations treatments.
  – Applied Non-CMF RNSs – These include research studies that produce results which can be immediately applied but do not consist of CMFs. An example of this

is a study which produces safety performance functions or crash prediction models.

- Fundamental (i.e., basic, exploratory) RNSs - These studies involve conducting a safety analysis study that relates to the safety of infrastructure or operations features of highways, but which do not directly result in the development of a CMF or development of crash prediction models or safety performance functions. Examples include an exploratory study of roadway and roadside features associated with crashes at horizontal curves, a study to develop the relationship between traffic conflicts and crashes, and others.

It is important to note that other types of research needs were identified, but were not included in the prioritization process because they were not defined as research according to the scope of the project. Those projects that would not generate new knowledge (e.g., guidebooks, syntheses, implementation tools, and scans) were not considered "research" and were not included in the prioritization. In order to prioritize these types of "non-research implementation" projects, an agency may use subjective assessment by decision-makers, or develop a priority ranking method comparable to the method developed herein for the fundamental and non-CMF applied RNSs.

CHAPTER 2

Developing the Prioritization Methodology

Background on Prioritization Methodologies in Use for Assessing Research Needs

The process of developing a national prioritization methodology began with a review of the literature to identify existing methods used for prioritizing research and projects both nationally and internationally. Specifically, the literature review focused on prioritization methods within the transportation field while considering general prioritization issues faced in other fields. Special attention was given to existing methods for prioritizing highway safety research. The section below provides an overview of the salient and common factors involved in the prioritization processes from the literature. The sources used in the literature review are provided in the reference list at the end of this report. Additionally, more information is given in two appendices:

Appendix A. Prioritizing Projects: General Considerations – includes literature related to project prioritization in general.

Appendix B. Prioritizing Projects: Specific Examples from the Transportation Field – features reports and literature related to specific prioritization processes employed in the transportation field. Note: These appendices are not published herein, but can be accessed on the TRB website at the following URL: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727.

Overarching Issues Observed in Previous Prioritization Methods

1. Minimize the power of politics involved in the process and clearly define and justify federal roles and responsibilities.
2. Develop a formal, consistent, and visible prioritization process based on a data-driven approach.
3. Encourage collaboration among stakeholders and bottom-up initiation of projects. Must have committed champions and should encourage joint funding so resources can be leveraged for common purposes.
4. Support overall organizational goals and strategies.
5. Focus on large, multi-modal research efforts of national importance.
6. Grant certain projects "immunity" to ensure that projects late in the development process are not reprioritized without good cause (applies to future prioritization cycles).
7. Encourage communication throughout the strategic prioritization process with and among stakeholders.
8. Ensure visibility of results to all stakeholders.

Specific Processes Observed

1. Develop selection criteria and weighting scheme.
   a. Based on strategic fit.
      i. Contribution to strategic vision, mission, and goals.
      ii. What is the appropriate perspective (national, regional, or local)?
      iii. Does the project fill a gap in existing literature or build onto areas where current information is lacking?
   b. Based on stakeholder input.
      i. Was the project ranked as a high priority, relative to other topics, by experts from a range of backgrounds?
      ii. Was the project previously identified as an issue of concern by other organizations (including TRB committees and federal agencies)?
   c. Based on urgency.
      i. Is it a short-term, intermediate-term, or long-term need?
      ii. How soon can the research be expected to contribute?
   d. Based on feasibility.
      i. Is it possible with existing skills and resources?
      ii. Does it deliver value (economically or directly to the road user)?

  e. Based on potential benefits.
    i. Does the project have the potential to address safety issues for a wide range of communities, crash types, and citizens?
  f. Based on cost.
    i. What is the level of financial investment needed for research and development and for successful implementation of the results?
  g. Based on risk.
    i. Is it likely to go over budget or over time?
    ii. Is it so complex that it is likely to fail?
    iii. Are there other risk factors including environmental challenges, stakeholder opposition, or harm to reputation?
  h. Consider the impact and implementation prioritization matrix (see Figure 1 below, from Transformation Management Team, Final Report, Volume 5: Strategic Planning and Prioritization, North Carolina Department of Transportation [NCDOT]).
    i. Used to assist in ranking the projects.
2. Provide/publish project selection criteria (make available to stakeholders).
  a. Allows self-evaluation of projects before submitting for consideration.
3. Develop a form/template of information to be completed for each proposed project by the submitting agency/person (similar to RNSs).
  a. These data will be considered for project selection.
  b. Data may include purpose, benefits, cost, and technical merits, along with subjective elements such as intermodal connectivity, geographic balance, economic importance, and relevance to a particular objective.
  c. Any risks or potential risks associated with the project should also be included in the template.
4. Identify potential list of projects.
  a. Incorporate input from all stakeholders (including the public, if applicable).
  b. Where there are inputs from multiple stakeholders, each group should prioritize their own needs prior to submitting for consideration in the overall list.
  c. Use a funnel approach to receive bottom-up input.
    i. Where there are several layers within an organization, let the organization receive input from all levels within (and prioritize) prior to submitting for consideration in the overall list.
5. Identify a priority team.
  a. Define the roles and responsibilities of the priority team.
    i. Review proposal submittals.
    ii. Assign scores based on selection criteria.
  b. Consider trade-offs among projects.
    i. Can a project be partially funded to achieve partial results or does it need to be fully funded in order to achieve any meaningful results?
  c. Develop prioritized list based on the proposal scores and overall vision/mission.
    i. Top-down approach to be consistent with overall goals.
    ii. Bottom-up approach by receiving input from stakeholders.

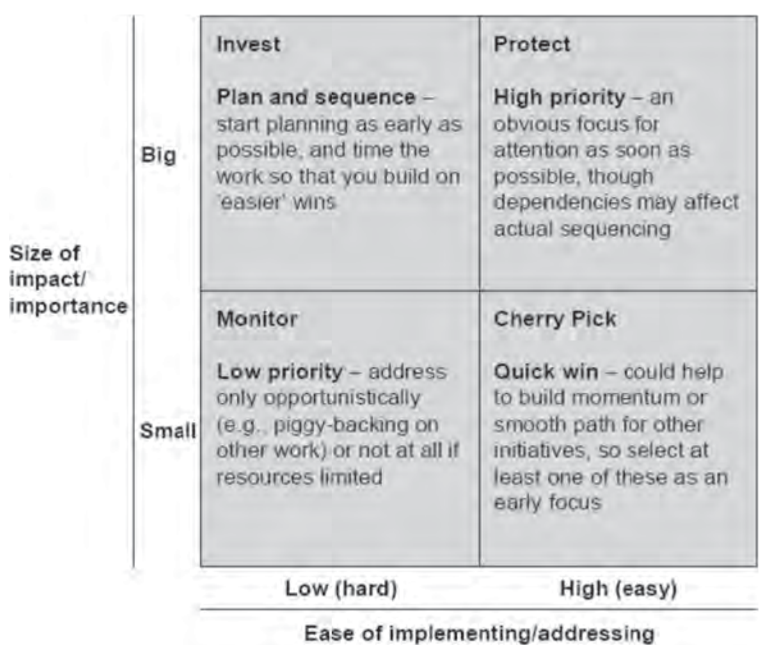


Figure 1. Impact and implementation prioritization matrix.

   d. Develop a prioritized list of unrestricted scenarios.
      i. Unrestricted with respect to financial and legal restrictions – investments that need to be made.
   e. Develop a prioritized list of restricted scenarios.
      i. Restricted with respect to financial and legal restrictions – investments that can be made.
6. Document, communicate, and market final results.
   a. Include partners, stakeholders, the public, and the media.
   b. Document to provide visibility of the prioritization process by describing the input, the scenarios evaluated, the decisions made, the anticipated effects of those decisions, and the need for additional funding and/or funding flexibility.

Perceived Weaknesses of Previous Prioritization Methods

The team noted several weaknesses in the previous prioritization methods. These previous methods were observed to be:

1. Ad-hoc.
2. Reactive.
3. Not supported by data.
4. Involving too many decision-makers.
5. Not visible to stakeholders and the general public.
6. Lacking input from stakeholders, particularly from academia and industry.
7. Selecting projects with an emphasis on local priorities and external inputs at the expense of systematically addressing long-term needs (not achieving overall goals).

Based on the limitations identified in current methods for prioritizing research, there is a need for a more consistent and rigorous prioritization process. The project team has developed a new prioritization methodology that incorporates the key elements identified in the literature review and addresses many of the shortcomings of existing methods. The methodology includes two methods – one for prioritizing research related to the development of CMFs and a second related to non-CMF research. As discussed in Chapter 1, other types of research needs were identified but were not included in the prioritization process because they were not defined as research according to the scope of the project. Those projects that would not generate new knowledge (e.g., guidebooks, syntheses, implementation tools, and scans) were not considered "research" and were not included in the prioritization. In order to prioritize these types of "non-research implementation" projects, an agency may use subjective assessment by decision-makers, or develop a priority ranking method comparable to the method developed herein for the fundamental and non-CMF applied RNSs.

A discussion of the prioritization methods for CMF research and non-CMF research is presented below.

Rating Crash Modification Factor (CMF) Research Topics

Summary of Value of Research (VOR) Method

This section provides a brief overview of the method that has been developed for prioritizing research to develop CMFs. It is referred to herein as the VOR method. More information about this method is available in Appendix C, which is not published herein. The objective of the VOR method is to provide a more objective means by which to rank candidate research projects. The underlying basis for the proposed method is that all research projects have one goal – to develop information for making a better safety-related decision (i.e., information that will reduce the chances of making an inferior decision). The decision to be made is whether or not to implement a given treatment on a specific set of roadway locations.

The standard deviation of the CMF is a measure of the uncertainty of the CMF. The smaller the standard deviation of the CMF, the lower the chance of making an inferior decision. If, by conducting a research project, it is possible to substantially reduce the standard deviation of the CMF, then one could argue that such a research project has good value because it provides a sounder basis for decision. The VOR method computes a monetary value based on the extent to which a research project can reduce the standard deviation of a CMF and thus increase the chances of making the correct decision.

Overview of VOR Concept

This subsection describes the concepts underlying the VOR method. For this discussion, the CMF is defined using the variable θ. If θ is less than 1.0, then the treatment is expected to reduce crashes, whereas if θ is greater than 1.0, the treatment is expected to increase crashes. For example, if θ is 0.8, then the treatment is expected to reduce crashes by 20 percent. The safety benefit of a treatment at a roadway segment can be expressed as follows:

$$\text{Safety Benefit} = (\text{Predicted reduction in target crashes per year}) \times (\text{\$ value of the target crash})$$

where the predicted reduction in target crashes per year equals the expected number of target crashes times (1- θ).

For the purposes of an example, say that for some roadway sections where an implementation decision must be made, the annual cost of implementing and maintaining the treatment is $9,000, the expected number of target crashes per year is 8.0, and the average cost of a target crash is $10,000. Each agency may have its own policy regarding the minimum benefit cost ratio that is necessary before a treatment can be implemented at a particular site. If the benefit cost ratio is assumed to be 2.5, then in order to justify the treatment, the reduction in crash harm due to the treatment has to be at least $2.5 \times 9{,}000$ = \$22,500. Since the average cost of a target crash is \$10,000, the proposed treatment should reduce the frequency of target crashes by 2.25 (22,500/10,000) from the current expected number of 8.0 in order to be justified. This represents a reduction of 28.125% (2.25/8.0), i.e., a θ of about 0.72. So, if θ of the treatment is greater than 0.72 (i.e., the estimated treatment effectiveness is less than 28%), then the treatment is not justified, but if it is less than 0.72, it is justified. The θ of 0.72 can be considered to be a breakeven point (denoted by θ_b).

From previous research (for example, from the CMF Clearinghouse or the Highway Safety Manual [HSM]), an estimate can be made for θ and the standard deviation of the θ for the particular treatment being considered. It is important to note that θ is not a universal constant, but a random variable with a mean and a standard deviation. It is an estimate of the true treatment effect which will never be known and which may change with different roadway characteristics. Since the topic is whether or not to implement a treatment in the future, the interest is in the θ for a future implementation. The exact θ for the future implementation is unknown, but the best assumption is that it will be a value from a distribution that can be derived from the mean and standard deviation of the value of θ based on previous research.

For the example discussed above, if the mean value of θ based on previous research is 0.6 (less than θ_b), then the decision will be to implement the treatment. However, since θ is not a universal constant, θ for a future implementation could be more than θ_b, and in that case, the decision to implement will be an incorrect decision. On the other hand, if the mean value of θ based on previous research is 0.9 (greater than θ_b), then the decision will be to not implement the treatment. Again, since θ is not a universal constant, θ for a future implementation could be less than θ_b, and the decision not to implement will be an incorrect decision. Based on the mean and standard deviation of θ (based on information from previous research) and assuming that θ is gamma distributed, one can derive the probability of making an incorrect decision and the cost of making an incorrect decision (Appendix C provides further details about the method for computing this). If the standard deviation of θ based on the previous research is very low, then the chances of making an incorrect decision will be low and the cost of making an incorrect decision will be low as well. Similarly, if the mean values of θ (based on previous research) and θ_b are very far from each other, then the likelihood of making an incorrect decision will be low and the cost of making an incorrect decision will be low as well. This phenomenon is illustrated in Figure 2.

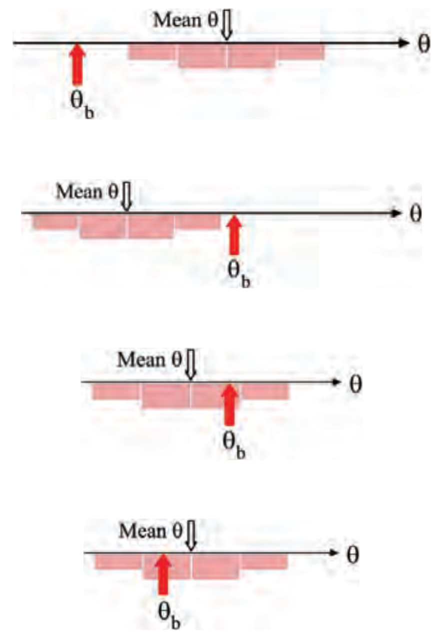


Figure 2. Relative positions of θ and θ_b and the impact on the VOR.

In Figure 2, mean θ represents the mean value of θ based on previous research, and each shaded block represents one standard error of θ. The figure illustrates four scenarios regarding relative values of mean θ and θ_b. In the top two scenarios, the mean values of θ and θ_b are relatively far apart, and θ_b is outside the 95% confidence interval of the mean value of θ (the 95% confidence interval is approximately mean $\theta \pm 2$ standard errors). Hence, in these two scenarios, the likelihood of making an incorrect decision is low, the cost of making an incorrect decision is low, and the value of conducting further research to refine the existing CMF is relatively low. On the other hand, in the bottom two scenarios, the mean values of θ and θ_b are closer to each other, and θ_b is within the 95% confidence interval of the mean value of θ. Hence, in the bottom two scenarios, the likelihood of making an incorrect decision will be higher, and the value of conducting further research to refine the existing CMF is relatively high.

If new research on a treatment substantially reduces the standard deviation of θ, then it is possible to reduce the cost of making an incorrect decision. The value of a research project is computed as the cost of making an incorrect decision based on current standard deviation of θ minus the cost of making an incorrect decision based on the revised standard deviation of θ that is expected after the research is completed.

Appendix D, which is not published herein, provides a discussion of how the current standard deviation of θ can be estimated from prior research. If no prior research is available to estimate the current mean and standard deviation of θ, then Appendix D describes how these parameters can be estimated using an expert panel or other means.

Application Steps

This subsection describes the steps followed when applying the VOR method to evaluate one CMF-based research project:

Step 1 - Identify Target Sites (Segments or Intersections) Where a Treatment Can Be Implemented

The objective of this step is to determine the types of segments or intersections at which the subject treatment can be applied. If a treatment is applicable to segments, then the number of treatable miles is determined. If a treatment is applicable to intersections, then the number of intersections is determined. The segments can be categorized by functional class (e.g., rural principal arterial) or by facility type (e.g., rural two-lane highway). The intersections can be categorized by area type, control type, number of legs, etc. If a treatment can be implemented nationwide, then it is important to be able to estimate the number of target segments or intersections nationwide.

Step 2 - Determine the Distribution of Target Crashes for These Sites

The objective of this step is to quantify the parameters of the distribution of crashes that occurred at the target sites. These parameters are then used with the gamma distribution to define the target crash distribution. If the treatment is applicable to a given state, then an existing safety performance function (SPF) derived for that state can be used to estimate the mean and variance of the target crash frequency. If the treatment is applicable to several states, then an existing SPF for each state can be used in a similar manner to estimate the mean and variance of crash frequency for each state. These parameters are then combined to determine the mean and variance of the crash frequency for all states. If the treatment is applicable to several states and an existing SPF is not available for every state, then the SPF for one state can be calibrated to the other states using ratio of the fatal crash rate of the other state to that of the base state. Further discussion about this is provided in Appendix E. This appendix is not published herein, but is available on the TRB website at: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727.

Step 3 - Determine the Mean and Standard Deviation of the CMF Based on Previous Research

The objective of this step is to quantify the mean and standard deviation of the subject treatment's effect on crash frequency based on the findings of past research. FHWA's Crash Modification Factor Clearinghouse is a good starting point for extracting this information.

Step 4 - Determine the Expected Standard Deviation of the CMF After the New Research is Completed

The objective of this step is to estimate the expected standard deviation of the subject treatment's effect on crash frequency based on the proposed research. This standard deviation must be smaller than that estimated in Step 3 if the research is to have value. This result can be achieved by using a study design that accounts for the likely sources of systematic variation that underlie the standard deviation. Appendix D provides a discussion of the methods that can be used to estimate the expected standard deviation.

Step 5 - Apply the Procedure to Estimate the Expected Value of the Research

The objective of this step is to use the information from previous steps with the VOR method to compute the expected value of the information obtained from the proposed research project. An Excel-based software tool was developed to facilitate the implementation of the VOR method. It is described in Appendix E and F. The User Manual for the VOR tool is given in Appendix G. These appendices are not published herein, but are available online at: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727.

Implementation of the VOR Method

This section summarizes the process followed to develop an implementation-ready version of the VOR method. This version of the method is intended to facilitate the cost-effective evaluation of proposed research projects. Projects suitable for local, regional, or national application can be evaluated with equal ease. It is envisioned that the implementation-ready version of the VOR method can be used by a SAC on an annual basis to update and maintain a prioritized list of proposed research projects.

As alluded to in the previous section, the VOR method requires some input data that can be challenging to acquire. It also includes some analytic components that are not amenable to manual calculation. The manner by which these issues have been addressed is described in this section.

This section consists of three subsections. The first subsection summarizes the input data needed for the VOR method and the likely sources of these data. The second subsection summarizes the procedure used to estimate the target crash distribution. The third subsection summarizes the role of expert opinion as a source of the information needed for the VOR method. Appendix E provides more detail about the development of the implementation-ready version of the VOR method.

Information Needs and Sources

This section describes the key factors that are incorporated in the VOR method. Table 1 identifies these factors and provides a brief description. The term "unit" in this table is defined herein as either an intersection or a highway segment. These two entities are typically the basis for SPF development because they are represented in this manner in the highway safety databases used for calibration. This need for consistency between the VOR method and the SPF stems from the use of the SPF regression results to define the distribution of crashes.

This section also reviews possible sources of information associated with each factor in this table. A source may be an existing database, prior research, or expert opinion. In some cases, the data obtained will require some "post processing" to convert it into the proper form for use in the VOR procedure. The calculations associated with this post processing are also described where appropriate. The role of expert opinion as a source of information is described in a subsequent section.

The source of information may vary depending on whether the treatment to be evaluated by the proposed research is applicable to an entire class of roadway in most states, or just to a specific portion of roads (e.g., curved sections, three-leg signalized intersections) in one state or region.

The "number of candidate units" is defined as the number of highway segments or intersections that *can be treated* with the subject treatment. The emphasis on "can be treated" is a reminder that all units may not be treated by the subject treatment. When the treatment can be widely applied, it should be sufficient to consider the total mileage of one or more functional classes of roadway in the states likely to use the treatment. The Highway Statistics database (http://www.fhwa.dot.gov/policy/ohpi/hss/index.cfm) provides miles by functional class and state, as needed for this type of application. When the treatment is not widely applied, then the Highway Performance Monitoring System (HPMS) database can be used to estimate the number of candidate units using its sample expansion factors. Other options are available in this case, and are discussed in Appendix E.

The "number of affected units" is computed by multiplying the number of candidate units by the proportion of those units that will likely be considered for treatment. This proportion can vary, depending on treatment cost, effectiveness, and agency policy. One possible source for obtaining the estimate of the number of affected units is the expert opinion of practicing highway safety engineers. These engineers could be organized into a transportation agency partners (TAP) group.

The "crash distribution" represents the distribution of average annual crashes per unit for the candidate units. It is developed for each proposed research project. The crashes represented in the distribution are referred to as "target" crashes. The procedure used to estimate the distribution parameters is summarized in the next subsection.

The "cost of target crash" is computed for each proposed research project. It must be representative of the range of severities included in the target crash distribution. Once the severity distribution is identified, current estimates of the crash cost for each severity level can be used to determine the target crash cost. The data for several states represented in the Highway Safety Information System (HSIS) database were used to develop representative crash severity distributions by functional class for segments and for intersections. The development of these distributions is documented in Appendix F.

The "cost of implementation" represents an annualized cost on a per-unit basis. The initial cost is annualized over the service life of the project, based on an expected service life and typical discount rate for highway investments. This project has compiled cost information for a series of countermeasures (treatments). This information should be archived by the SAC such that it can be subsequently used to evaluate other research projects whose treatments are judged to be similar to treatments previously considered.

Table 1. Factors considered in VOR calculation.

Factors	Description
Number of candidate units	Number of highway segments or intersections that can be treated with the treatment being addressed in the proposed research project.
Number of affected units	Number of segments or intersections likely to be considered for treatment.
Crash distribution	Distribution of crashes on treated units.
Cost of target crash	Average cost of the crash that is likely to be prevented by the treatment.
Cost of implementation	Average cost (per mile or intersection) to the transportation agency to implement the treatment.
Estimated treatment effectiveness	Mean effectiveness of the treatment (i.e., CMF) and its standard deviation (before new research is conducted).

The "estimated treatment effectiveness" is characterized by its mean CMF value and the standard deviation of this value. This information can be obtained from previous projects that evaluated the same (or a similar) treatment. If the proposed project is evaluating a treatment for the first time, then expert opinion may be used to estimate the necessary values. A procedure for estimating the mean and standard deviation of a CMF is described in Appendix D.

Estimating the Crash Distribution

The crash distribution used in the VOR method should be obtained from a highway safety database. Ideally, a highway safety database would be available for each of the 50 states. The crash distribution would be developed from these state databases, with consideration of the treatment characteristics. Unfortunately, this option is not currently viable because a highway safety database is not readily available for each state. This section summarizes the procedure used to estimate the distribution parameters. Additional information about the procedure is provided in Appendices E and F.

Two procedures were developed for estimating the crash distribution parameters. One procedure is applicable for evaluating research projects addressing treatments that can be widely applied. It consists of eight calculation steps. The other procedure is for projects that address treatments that are not widely applied. It consists of four calculation steps.

The procedure for widely applicable treatments is based on the use of one SPF (and its associated over-dispersion parameter) for each of the desired functional classes in one state. This SPF is calibrated to each of the other states being considered and used to estimate the mean annual crashes per unit for each state (as well as its variance). With this approach, the crash distribution parameters for all states combined are computed and one value of VOR is computed for the combined crash distribution.

The procedure for treatments that are not widely applicable is also based on the use of one SPF (and its associated over-dispersion parameter) for one state. This SPF is developed using HSIS data that are specifically screened to reflect the target site characteristic (e.g., curve road sections on rural two-lane highways). The SPF is then calibrated to each of the other states being considered and used to estimate the mean annual crashes per unit for each state (as well as its variance). The crash distribution parameters are combined in the same manner as for widely applicable treatments.

Transportation Agency Partner (TAP)

One possible source of information is the expert opinion of practicing highway safety engineers, also called as the TAP. The TAP is envisioned to be a group of engineers that provide agency perspective and information to the SAC during the research project prioritization process. Each transportation agency represented in the TAP could designate one person that could be contacted periodically (e.g., annually) by the SAC to obtain some of the information in Table 1.

The TAP members would be contacted annually to provide the information identified in Table 2. It is envisioned that the SAC will perform an initial triage on the proposed research projects at a specified time in the annual research cycle. Then, they will identify all of the information they need for the collective set of projects being considered for prioritization. One comprehensive information request will then be sent to the TAP.

Pilot Testing the VOR Method

The VOR method was pilot tested for two treatments: effectiveness of driveway access control and effectiveness of edgeline rumble strips. Further discussion about the two pilots is provided below.

Evaluation of Proposed Research on the Effectiveness of Driveway Access Control

This section is a brief summary of the pilot study entitled "Limited Driveway Access at Intersections—Sample Application of Value-of-Research Evaluation," which is given in more detail in Appendix H and which documents the conduct of a VOR analysis for a specific safety treatment. The example treatment is the removal of major-street driveway access for a corner business at an urban or suburban signalized intersection. The minor-street access to the business would be preserved or added if not existing. The objective of this treatment is to reduce the frequency of driveway-related crashes by moving driveway access maneuvers to the (lighter-volume) minor street.

The following seven questions are answered in the conduct of a VOR analysis:

1. How many units (highway segments or intersections) will be affected by the treatment of interest?
2. What is the frequency of crashes that are targeted by the treatment?
3. What is the cost of an average target crash?
4. What is the annual cost of deciding to implement the treatment on one unit?
5. What is the limiting benefit/cost ratio?
6. What are the mean and standard deviation of the CMF based on existing knowledge?
7. What is likely to be the standard deviation of the CMF after the proposed research is completed?

Table 2. Information needed from Transportation Agency Partner (TAP).

Factors	TAP Assistance
Number of candidate units	Occasional assistance needed. When a proposed countermeasure is specific to a unique application and HSIS or HPMS are not helpful, then each TAP member is asked to provide an estimate of the count of candidate units (or the proportion of total units) in the jurisdiction they represent. Aggregation of all TAP input should reflect the entire United States.
Number of affected units	Each TAP member is asked to provide an estimate of the proportion of candidate units to which a countermeasure will likely be applied in the jurisdiction they represent. Aggregation of all TAP input should reflect the entire United States.
Crash distribution	No assistance needed.
Cost of target crash	No assistance needed.
Cost of implementation	Occasional assistance needed. For those countermeasures with no cost information available, each TAP member is asked to provide an estimate of the initial cost, annual maintenance cost, and service life of each proposed countermeasure. The number of these requests will likely be reduced over time as a “library” of this information is cataloged by the SAC.
Estimated treatment effectiveness	Occasional assistance needed. For those countermeasures with no previous research, an initial attempt will be made to use effectiveness estimates for similar treatments (e.g., estimates for shoulder rumble strip effectiveness as a guide for edgeline rumble strip effectiveness). When this is not possible, each TAP member is asked to provide an estimate of the mean effect of a countermeasure and the range outside of which the expected effectiveness of a proposed countermeasure is very unlikely. The members with some familiarity with the countermeasure will likely provide a reply. It is not necessary for all TAP members to provide this information. It is important to note that the research community could also be contacted to get insight into the safety effect of a countermeasure.

With respect to Question 1, an affected unit was defined as one corner at an urban or suburban signalized intersection, where the corner has a business with a driveway on the major street and frontage to the minor street. To determine the number of affected units in the nation, the number of urban and suburban traffic signals was first estimated using information published by the Institute of Transportation Engineers (ITE). The distributions of driveway count and land use at those intersections was then estimated through a sampling of 180 intersections in Texas. This sampling involved reviewing aerial photography to count and classify driveways by the land use type that they serve. The observed trend in the Texas data was extrapolated to the rest of the nation to yield an estimated count of 482,044 affected units.

To answer Question 2, the target crash was defined as a driveway-related crash at an urban or suburban signalized intersection. Crash data from the sampled 180 Texas intersections were used to develop an SPF to estimate the number of target crashes at an intersection. Application of this SPF to an intersection with average traffic volumes (20,000 veh/d on the major street and 10,000 veh/d on the minor street) revealed that the typical urban or suburban signalized intersection experiences 0.565 injury or fatal driveway-related crashes per year.

Question 3 was answered by analyzing the severity distribution of crashes at the 180-intersection sample in Texas. The severity distribution was combined with crash cost estimates from the literature to yield an average driveway-related crash cost of $44,732.

To answer Question 4, it is necessary to determine the average construction cost of adding a driveway and the average business impact of removing driveway access. Based on cost estimates from several states, the cost of adding a driveway was estimated as $10,000. This cost would apply to affected units that lack minor-street driveway access. To determine the business impact of removing driveway access, literature sources relating to the impacts of access management were reviewed. Literature on the sales and profit trends for convenience stores was also reviewed. It was estimated that the average business would lose about $22,113 in profit annually as a result of removing major-street driveway access. When this loss is combined with the annualized cost of adding a minor-street driveway (for businesses requiring this mitigation), the annualized cost of the treatment was estimated as $22,785 per year.

To address Question 5, the limiting benefit/cost ratio was established at 2.5, a value that is often used by agencies when choosing among alternative projects.

Questions 6 and 7 were answered using the SPF that was calibrated using the sample of intersections from Texas. (This SPF was previously used to answer Question 2.) Application of the SPF revealed that if a corner business' major-street driveway is removed and replaced with a new driveway on the minor street, the expected injury and fatal crash frequency drops to 0.366 crashes per year. Similarly, if the business previously had minor-street driveway access and its major-street access is removed, the expected injury and fatal crash frequency drops to 0.244 crashes per year. These two cases yield CMFs of 0.648 and 0.431, respectively. Further statistical analysis yields standard deviations of 0.277 and 0.181 for the two CMFs.

Using the aforementioned information and the VOR calculation procedure summarized earlier and discussed further in Appendices E, F, and G, the VOR for removing major-street driveway access (and replacing it with minor-street driveway access if needed) is $18,950,000. This number represents the estimated benefit that would be realized if the following events occur:

- The suggested new research on this treatment is conducted to develop CMFs to quantify the expected crash frequency reduction,
- All 482,044 affected units are evaluated for potential treatment, and
- The units having sufficiently high crash frequencies to justify the treatment (based on the limiting benefit/cost ratio of 2.5) are treated accordingly.

It is noted that only about five percent of the affected units are likely to have sufficiently high crash frequencies to need treatment.

Evaluation of Proposed Research on the Effectiveness of Edgeline Rumble Strips

The VOR approach was used to determine the value of conducting research to develop a CMF for edgeline rumble strips. This approach involved the following steps:

- Estimate the number of target miles in the nation for this treatment.
- Determine the CMF and the standard deviation of the CMF based on previous studies of this treatment.
- Estimate the standard deviation after the new research is conducted.
- Determine the treatment cost and the limiting benefit cost ratio.
- Determine the distribution of target crashes for the target miles.
- Apply the procedure to estimate the value of conducting research on this topic.

Following is a discussion of each step.

Target Miles for Edgeline Rumble Strips (Rumble Stripes). For this example, it is assumed that the treatment is applicable to rural two-lane paved roads with either narrow paved shoulders (two feet or less in width) or unpaved shoulders (it was assumed that on roads with wider paved shoulders, shoulder rumble strips would be used instead of edgeline rumble strips). For the latter, the treatment would be located on the edgeline itself, extending into the travel lane unless the edgeline is moved slightly. The treatment could be applicable to other categories or roadways (e.g., urban two-lane roads or rural undivided multilane roads with no/narrow paved shoulders), but the two-lane rural roads would appear to be the primary target.

One possible source for estimating the number of target miles is HPMS. However, not all needed variables are included in the HPMS Universe or Sample files for all rural functional classes. Thus, assumptions are necessary. For example, as noted there, based on HSIS data from NC and MN, it appears valid to assume that all paved road mileage in the Rural Minor Collector and the Rural Local Roads categories are two-lane.

Surface/Pavement Type is a Sample File variable and data are not available for Rural Minor Collectors or Rural Local Roads. However, based on supplemental data captured by HPMS from the states, the 2008 *Highway Statistics* contains the data shown in columns 2 – 4 of Table 3. These data were then used to calculate the percent of total mileage that is paved as shown in the final column.

The HPMS data were then used to develop estimates of target miles for each functional class where data are available. Table 4 shows how that estimate was made.

The second column in Table 4 provides the estimated number of miles of two-lane paved roads with narrow or unpaved shoulders developed using the Universe and (weighted) Sample variables. Note that no estimates exist for Rural Minor Collectors or Rural Local Roads since Sample File data do not exist for those classes. What are needed are estimates of mileage for those two cells.

The third column provides the total number of paved miles in each rural functional class extracted from Table 3. The fourth column provides the percent of total paved miles which are target miles for the three classes where HPMS Sample data were available. Based on the trend shown there, the fifth column shows project team estimated percentages of the percent of paved roads expected to have narrow paved or

Table 3. Paved and unpaved miles by functional class.

Functional Class	Paved	Unpaved	Total	% Paved
1 Rural Interstate	28,846	-	28,846	100.0%
2 Rural Other Prin Arterials	94,845	-	94,845	100.0%
6 Rural Minor Arterials	134,900	-	134,900	100.0%
7 Rural Major Collectors	380,644	37,814	418,458	91.0%
8 Rural Minor Collectors	179,622	83,227	262,849	68.3%
9 Rural Local	881,206	1,157,311	2,038,517	43.2%
11 Urban Interstate	16,442	-	16,442	100.0%
12 Urban Other Freeways/Exp.	11,327	-	11,327	100.0%
14 Urban Other Princ. Arter.	64,745	-	64,745	100.0%
16 Urban Minor Arterials	106,432	510	106,942	99.5%
17 Urban Collector	113,762	1,113	114,875	99.0%
19 Urban Local	719,838	43,775	763,613	94.3%
TOTAL	**2,732,609**	**1,323,750**	**4,056,359**	**67.4%**

Source: 2008 Highway Statistics, Table HM-51 of Section 4.4.4 – Arterials and Collectors.

unpaved shoulders for road classes 8 and 9. (Note that these are simply estimates and could be changed if better information existed.) The next column then carries over the second-column mileage for the three classes where HPMS data exist and multiplies the estimated percent in column five times the total paved miles in column three for the latter two classes. These are then summed to provide the estimated target miles of 1,216,000 miles nationwide. The last column shows the percentage of total miles that are target miles in each category.

The final adjustment would be to decrease these estimates in each functional class if there were known to be substantial miles where the treatment has already been implemented. Project staff is aware of some implementation for state-system mileage in Washington, Minnesota, and Pennsylvania. However, for this example, our feeling is that the percent of miles already treated will be very small (or zero) in the final two roadway classes where the bulk of the mileage is. Thus, there were not adjustments for treated miles in this case. This, too, would be a simple change to make.

CMF for this Treatment from Previous Studies. A search of FHWA's CMF Clearinghouse did not find any CMFs for edgeline rumble strips on rural two-lane roads. However, *NCHRP Report 641: Guidance for the Design and Application of Shoulder and Centerline Rumble Strips*), provides CMFs for shoulder rumble strips on rural two lanes. The recommended CMF from that report for single vehicle run off road crashes (SVROR) was 0.85. The standard deviation of the CMF was estimated to be 0.126.

Standard Deviation of the CMF after the New Research Is Conducted. Based on procedures described in Appendix D, the standard deviation of the CMF after the new research is completed was estimated to be 0.089.

Treatment Cost and Benefit Cost Ratio. Based on information from a couple of states, the initial cost for installing edgeline rumble strips was assumed to be $2,000 per mile with an annual maintenance cost of $500 per mile. The life of

Table 4. Calculation of estimated number of target miles.

Functional Class	Miles With Narrow Paved or Unpaved Shoulders	Total Paved Miles	% of Total Paved Miles	Estimated % for Class 8 and 9	Estimated Target Miles	Total % Miles that are Target
2-Rural Principal Arterial Other	8,050	94,845	8%		8,050	8.5%
6-Rural Minor Arterial	33,891	134,900	25%		33,891	25.1%
7-Rural Major Collector	202,197	380,644	53%		202,197	48.3%
8-Rural Minor Collector		179,622		75%	134,717	51.3%
9-Rural Local		881,206		95%	837,146	41.1%
TOTAL RURAL					1,216,000	29.98%

the milled rumble strip was assumed to be 5 years. The limiting benefit cost ratio was assumed to be 2.5.

Distribution of Target Crashes. SVROR were the primary target crashes. Data from Minnesota and North Carolina were extracted from the HSIS for rural two-lane roads with unpaved shoulders or narrow paved shoulders (2 feet or less). North Carolina was chosen because this state (compared to most of the other HSIS states) includes a significant number of miles from local or minor collector roads within their HSIS files. Since a significant number of rural two-lane miles within the nation are local or minor collector, including these roadway types was important. Negative binomial regression was used to develop SPFs using Annual Average Daily Traffic (AADT) as the independent variable. The following SPF was estimated using data from North Carolina. Only rural two-lane roads with unpaved shoulder or paved shoulder less than or equal to 2 feet were included in estimating the SPF:

$$\text{SVROR Crashes per mile} = \exp\{-3.591 + 0.3662 * ln(\text{AADT})\}$$

This SPF was entered into the tool developed in this effort (see Appendices E, F, and G) to determine the VOR. When SPFs from North Carolina were used for estimating the crash distribution for the nation, the VOR was estimated to be $174,742,763. For this estimation, it was assumed that only 50% of miles identified earlier in Table 4 could be treated (the 50% number is arbitrary and could be modified if further information is available from the states or other entities such as the TAP).

Rating Fundamental and Non-CMF Applied Research Topics

The term "fundamental research" refers to various types of basic, non-CMF research. The premise of this work is that safety research has value if it makes for better decisions and if it helps to get more crash reduction per invested dollar. The monetary VOR is the amount by which its results can increase the net benefit (difference between the benefit and cost) of safety-related projects. The proposed method for estimating the monetary value of CMF research was discussed earlier, but it was not clear how to do the same for non-CMF safety research. This is primarily because fundamental research studies generally do not involve quantifying CMFs, and specific countermeasures are often not identified in the research problem statement, so it is difficult or impossible to be able to estimate countermeasure-related safety benefits for study topics where the countermeasures are unknown.

A detailed discussion of some of the initial thinking and analysis on quantifying the VOR for fundamental (non-CMF) research topics is given in Appendix I, which is available on the TRB website at: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727. Thus, the team developed another quantitative approach to rate and rank studies that deal with more fundamental (basic) research that do not directly produce CMFs. The following is a discussion of that method that was developed and applied in this study for ranking fundamental and non-CMF applied RNSs.

Research Prioritization Methodology

Background

Research needs were identified through several efforts and from several sources as discussed in Chapter 3. Not all of the identified research needs were applicable and an initial screening was conducted to eliminate projects that did not focus on infrastructure-related topics. Research needs were further divided based on the relation to decision-making.

As discussed earlier, there are two types of research considered in this report: applied research and fundamental research. (Also, as discussed earlier, other types of studies including non-research implementation studies were discussed, but not included in the prioritization, because they were considered outside the scope of this effort.) Applied research relates directly to decision-making in the roadway safety management process and includes three primary areas: (1) research to estimate CMFs, (2) research to estimate expected future crashes, and (3) research to estimate the value of target crashes. The intent of applied research is to reduce the uncertainty about any of these three factors that determine the safety benefit of a specific strategy. Research that makes applied research feasible or improves it is termed fundamental research and includes efforts such as those conducted to improve statistical methods or to better understand the underlying contributing factors of crashes.

This section focuses on a prioritization process for fundamental research needs as well as non-CMF applied research needs (i.e., research to estimate expected future crashes or the value of target crashes). These research projects cannot be compared on a common basis with CMF-related applied research as the prioritization criteria used for CMF-related applied research are not as easily nor accurately quantified for Fundamental and Non-CMF Applied Research projects. As such, the research projects cannot be compared on the same relative scale and it may be necessary to designate separate funding pools for applied and fundamental research programs. Note that in *TRB Special Report 261: The Federal Role in Highway Research and Technology,* FHWA's Research and Technology Coordinating Committee recommended that at least one-quarter of FHWA's Research and Technology budget should be invested in fundamental, long-term research. The objective of this project is not to establish this split, but instead, focus on the prioritization within each research type.

Objective

This section presents a method for prioritizing fundamental research and non-CMF applied research projects that do not rely solely on expert/practitioner experience/judgment. First, several issues are identified that are related to the prioritization of research. Next, factors are identified and defined for use in the prioritization process. A weighting scheme is then presented to combine the factors and compute a score for each potential research project. The process was pilot tested for a sample of the research needs and compared to the results of a traditional expert panel; these results are presented and discussed. Finally, the process was applied to the complete list of fundamental research and non-CMF applied research projects. A prioritized list is provided for further consideration by future funding agencies. The list is also separated by fundamental research and non-CMF applied research projects in the case that these projects are to be considered separately.

Selection Criteria

For fundamental research and non-CMF applied research, the VOR depends on several factors. The following list identifies eight quantifiable factors that should be considered when evaluating fundamental research and non-CMF applied research programs for potential funding. It is understood that other factors may influence the VOR, but these factors were identified as the most critical. Also, it was determined that these factors can be applied in a practical application of the method (i.e., factors can be quantified through existing data sources or stakeholder input). Limited stakeholder input is included in several factors (i.e., 3, 4, and 5) through the use of an expert panel or SAC. It is proposed that more general stakeholder input be included once the prioritized list of fundamental research has been developed. This is discussed at the end of the section.

For each factor, the definition and data source is provided along with the process for obtaining and applying the information. Note that each criterion is intended to be mutually exclusive to avoid double-counting considerations. Prior to quantifying the factors, it is useful to determine the target crashes and applicable area type and facility type to help provide a frame of reference for each potential project.

1. **Number of Expected Target Crashes**
   a. Definition: This factor identifies the target crash population of the proposed research and estimates the number of total crashes associated with the given population. For example, the target crash population for fundamental research related to pedestrian treatments at intersections would be pedestrian-related crashes at intersections. If the fundamental research is focused on improving statistical methods for developing CMFs, the target crash population would be all crashes because improved CMFs could be developed for any crash type.
   b. Data source: General Estimates System (GES) database is used to estimate the number of crashes for various target populations. In the event that GES is not able to provide the desired input, the HSIS may be an alternative source. HSIS provides detailed-level data for select states. Note, however, that HSIS does not provide a nationally representative sample and it would be necessary to adjust any numbers obtained from HSIS to estimate national numbers.
   c. Process: The GES crash numbers were generated using query definitions from the 2010 GES data set. The NASS GES Analytical Users Guide was used to determine all possible factors related to the crash type, area type, and facility type for each research need statement. GES data do not have a field for functional classification or area type. For all research need statements that consider different area types (i.e., rural, urban) and facility types (e.g., highways, freeways, intersections, etc.) a calibration factor was used to determine the number of crashes in 2010. The calibration factors were based on 2010 Fatal Accident Reporting System (FARS) data. For example, the pedestrian-related urban crashes calibration factor is the number of *pedestrian-related urban fatal crashes* divided by the number of *total pedestrian-related fatal crashes.* In this example, the calibration factor was then multiplied by the number of *pedestrian-related crashes* generated from the GES query.
   d. Score: VOR increases as the number of target crashes increases.
2. **Severity of Expected Target Crashes**
   a. Definition: At a national level, the current focus is on fatal and severe injury crashes. While the previous factor favors research that targets large crash populations, this factor favors research that focuses on fatal crashes. This factor identifies the target crash population of the proposed research and estimates the number of fatal crashes associated with the given population.
   b. Data source: FARS is used to estimate the number of fatal crashes for the target population. In the event that FARS is not able to provide the desired input, the HSIS database may again be an alternative source. Recall that HSIS would not provide a nationally representative sample and it would be necessary to adjust any numbers obtained from HSIS to estimate national numbers.
   c. Process: The FARS fatal crash and fatality numbers were generated by querying FARS 2010 data. The FARS Analytical Reference Guide was used to determine all possible factors related to the crash type, area type, and facility type for each research need statement. Not all the

variables for the RNSs are captured in the FARS database, so assumptions were made to narrow down the FARS variables to resemble the research need factors as close as possible.

d. Score: VOR increases as the number of fatal crashes increases.

3. **Extent of Impacts on the Science of Safety**
   a. Definition: The goal of most fundamental research is to advance the science of the particular field as opposed to providing directly applicable solutions for immediate implementation. Fundamental research may include a number of topics and some may have wider applicability than others. This factor focuses on the potential for a specific research project to advance the science of safety with respect to the number of decisions that could be improved as a result of the research. In this way, fundamental research is like the trunk of a tree and the decision to implement a specific treatment is the leaf at the end of a branch. Trees with larger trunks can support more branches and thus more leaves.
   b. Data source: An expert panel provides insight on the potential breadth of the research results (i.e., size of the tree trunk). The inclusion of non-researchers (e.g., state DOT representatives) on the expert panel would provide more comprehensive representation of the user community; however, few non-researchers have a good understanding of fundamental research needs and long-term potential. As such, this factor should include input from select "experts" within the transportation community, with significant representation from researchers.
   c. Process: Each member of the panel receives a list of potential research topics and provides feedback, including a score for each topic (i.e., rate the potential impact on a scale of 1 to 5 where 5 represents the highest level of impact). Using the tree-and-leaf example from above, the expert panel will be responsible for determining the size of the tree trunk relative to other research projects and the number of leaves each tree can support. This step requires a fair amount of judgment and insight on behalf of the experts. As such, it is critical that the potential research topics provide detailed information about the intent and applicability of the research. One method to help reviewers define the size of the trunk (i.e., extent of the impact) is to list the specific actions, processes, and decisions that would then be possible (or more effective) if the fundamental research is successful (i.e., what applied research could be conducted or would be improved as a result of the fundamental research?). For the problem statements in this study, the project team served as the expert panel and awarded points.

      Note: the expert panel should only consider the potential to impact the science of safety in this step without consideration of other factors such as project cost and probability of success as these are covered by other selection criteria.
   d. Score: Research that produces many peripheral products that support many different types of decisions would be given higher priority than research that has a limited focus.

4. **Potential to Improve Existing Information for Target Crashes**
   a. Definition: The ultimate goal of safety research is to help state and local agencies more effectively reduce the frequency and severity of crashes through new or improved tools/methods/information. The three primary areas that influence decision-making are CMFs (i.e., estimate of change in crashes given treatment); expected crashes (i.e., estimate of crashes without treatment); and crash costs. This factor focuses on the potential to improve decision-making as a result of the research.
   b. Data source: An initial estimate should be identified by the individual/agency proposing the research with written support for their estimate. A literature search could be conducted by the proposing individual/agency to identify existing research related to the target crashes. The final decision is a consideration for an expert panel such as the SAC (see Chapter 4).
   c. Process: The initial estimate will be collected during future solicitations for research needs. This project identified existing research needs that did not include a specific discussion of the potential to improve existing information for target crashes. As such, the project team based their decision on the following considerations and rated each potential project on a scale of 1 to 5 where 5 represents the highest potential for improvement.
      i. Limitations of existing knowledge – The HSM was used to identify limitations of existing knowledge, including methods for estimating the expected number of crashes, CMFs, and general safety decision-making procedures.
      ii. Quality of existing information – The HSM and CMF Clearinghouse were used to help judge the quality of existing information. The main body of the HSM presents the "best available" CMFs for specific design and operational features for each facility type, but also includes a knowledge base. The knowledge base is more inclusive, and indicates the relative quality of each CMF. The Clearinghouse provides a star rating for each CMF on a scale of 1 to 5, where 5 stars is the highest possible rating. If there are several CMFs related to a specific topic and all are of sufficient quality, the research may not

be as important as research that has the potential to improve several CMFs of relatively low quality.

d. Score: VOR increases as the quantity and quality of existing information decreases (i.e., increased potential for improvement).

5. **Probability of Success**
   a. Definition: This factor identifies the likelihood of the research to produce useful results (i.e., the result of the research will produce more value per unit cost in applied research projects). This factor is based on the likelihood of satisfactory completion of the project. A project is "successful" if it finds meaningful information with a high degree of certainty. The information could be a new method, confirmation of the adequacy of an existing method, or an indication that an existing method is, in fact, not appropriate for specific circumstances.

      Note: This factor does not include considerations of budget or time constraints as these are considered in Factor #6. It also disregards institutional obstacles, inertia, etc., for implementing the results and fundamental research is deemed successful if its results enable us to conduct applied research projects or to conduct them more effectively.
   b. Data source: An initial estimate should be identified from the individual/agency proposing the research. The final decision is a consideration for an expert panel such as the SAC (see Chapter 4).
   c. Process: The initial estimate will be collected during the solicitation for future research needs. While it may be difficult to clearly define the probability of success for an individual project, the relative probability of success could be judged by an expert panel reviewing all proposed research projects at the same time. For this project, the team based their decision on the following factors:
      i. Complexity of research – Is the research so complex that it is likely to fail?
      ii. Existing capabilities – Is it possible to conduct the research with existing skills, methods, data, and resources OR does it first require the development and implementation of sophisticated data collection equipment/techniques?
      iii. Results – Will the research produce a quantifiable improvement in the certainty of safety information?
   d. Score: The VOR increases as the probability of success increases.
6. **Cost of Research**
   a. Definition: This is the estimated cost to complete the proposed research project. One option is to divide the overall VOR for each potential project by the estimated cost of research. This option, however, may overlook relatively expensive research even though it has a high potential for improving safety. Another option is to use the cost as a factor in the overall weighting scheme. This is the option that the research team has employed.
   b. Data source: The estimated cost of research should be identified by the proposing individual/agency. The current template for identifying research needs includes a section for estimated cost.
   c. Process: This information will be collected during future solicitations for research needs. Cost estimates were not available for many of the current research needs considered in this project, so the project team estimated relative costs as discussed in the next section, *Weighting Scheme.*
   d. Score: The VOR increases as cost decreases.
7. **Potential to Identify More Effective Strategies for Target Crashes**
   a. Definition: The ultimate goal of safety research is to help state and local agencies more effectively reduce the frequency and severity of crashes through new or improved tools/methods. This factor focuses on the potential to identify new and more effective countermeasures. If relatively effective countermeasures have already been developed to address specific crashes, then additional research may not be justified in that area.
   b. Data source: The CMF Clearinghouse is used to identify existing countermeasures related to each research topic and the relative effectiveness of the related countermeasures. If a countermeasure is not included in the CMF Clearinghouse, it can be assumed that the safety effect has not yet been determined.
   c. Process: All proposed research projects are reviewed to identify target crashes and the applicable area type and facility type. The CMF Clearinghouse is then queried to identify existing countermeasures and their relative effectiveness (i.e., CMF). The CMF is an indication of the potential effectiveness of that measure. If all countermeasures related to a specific research topic are relatively ineffective (e.g., CMFs close to 1.0), then research to develop new countermeasures in this area may be more favorable than further research on countermeasures that have already proven to be very effective. The specific steps employed by the project team include the following.
      i. Query CMF Clearinghouse – search by keywords or countermeasure type and screen the list using crash, roadway, and vehicle characteristics to identify applicable countermeasures.
      ii. Eliminate CMFunctions – Crash modification functions (CMFunctions) were eliminated from the list as their value changes depending on the characteristics of the specific location to which the countermeasure will be applied.

iii. Compute Relative Effectiveness – the result from the query is a list of CMFs for the related countermeasures. The list may include CMFs greater than, less than, or equal to 1.0. To ensure that CMFs greater than and less than 1.0 do not cancel-out, the absolute effect was computed for each countermeasure. For example, a CMF of 0.7 and 1.3 both indicate a 30 percent change in crashes, but the former indicates a decrease while the later indicates an increase. For this project, any numbers greater than 1.0 were converted to the equivalent change indicated by a CMF less than 1.0. For example, a CMF of 1.3 would be converted to 0.7. In some cases, the CMF is greater than 2.0, indicating an increase of more than 100 percent. The conversion would result in a negative number and these CMFs were truncated at zero to avoid negative numbers.

iv. Compute Average – the average effectiveness is computed for the list of countermeasures associated with each research project and the average effectiveness is used to compare the potential to identify more effective strategies.

d. Score: This score pertains specifically to research focused on the identification of new countermeasures or research that would allow for the identification/analysis of new countermeasures. VOR increases as the average effectiveness of existing treatments decreases (i.e., average CMF close to 1.0). A value of 1.0 is assumed when existing strategies are not identified for a given research project.

8. **Distance Between Expected Research Results and Treatment-Related Decisions**
   a. Definition: Unlike CMF research that can produce an improved CMF that can immediately lead to a better safety decision, fundamental research develops instruments which can lead to better decision-making (i.e., better CMFs, crash costs, and methods for estimating expected crashes). Thus, fundamental research is one or more "levels" removed from actual safety decisions. Some fundamental research is one level removed (e.g., research to develop a crash surrogate to allow CMF research on pedestrian crossing treatments; research to develop better modeling techniques to allow extraction of CMFs from regression coefficients; research to develop models that will be used to estimate future target crashes). Other fundamental research is two or more levels removed (e.g., phased research, research to develop a tool which will compare different regression modeling techniques and determine which is better; research to develop a better screening tool to choose locations in need of further study). It may be the case that research that is further removed from actual safety decisions (i.e., more levels) actually has the potential to enhance and influence a great number of safety decisions than research that is fewer levels removed. However, this factor only looks at the distance between the research and treatment-related decisions. The potential impact is addressed under Factor #3 (Extent of Impacts on the Science of Safety).
   b. Data Source: An expert panel reviews all proposed research projects to extract the needed project descriptions.
   c. Process: An expert panel determines the "level" of research using the following categories.
      i. Non-CMF applied research.
      ii. Fundamental one level removed.
      iii. Fundamental two or more levels removed.
   d. Score: VOR increases as the number of levels decreases. Note that this assumes all else is equal.

Weighting Scheme

The weighting scheme discussed in this section is based on the premise that all factors identified in the previous section will contribute to the overall VOR. This is not to say that all factors should carry equal weight. For example, the levels between the research and final decision-making may not be as important as the potential impact on the target crashes and crash severity. This section attempts to identify the potential values for each factor and the relative importance of each factor in the development of an overall weighted utility index.

Values for each factor are listed below, but note that the ranges and values are highly flexible and may be revised as the method is employed and evaluated.

1. **Number of Expected Target Crashes**
   a. Score 1–5 based on related crash frequency. The number of target crashes is identified for each topic and sorted from greatest to least.
      i. 1 = topics in the lowest 10 percent.
      ii. 2 = topics between 10 to 30 percent.
      iii. 3 = topics between 30 to 70 percent.
      iv. 4 = topics between 70 to 90 percent.
      v. 5 = topics in the top 10 percent.
2. **Severity of Expected Target Crashes**
   a. Score 1–5 based on severity. The number of fatal and injury target crashes is identified for each topic and sorted from greatest to least.
      i. 1 = topics in the lowest 10 percent.
      ii. 2 = topics between 10 to 30 percent.
      iii. 3 = topics between 30 to 70 percent.
      iv. 4 = topics between 70 to 90 percent.
      v. 5 = topics in the top 10 percent.
3. **Advancement of Science of Safety**
   a. Score 1–5 based on stakeholder input and ranking.
      i. 1 = lowest impact.
      ii. 5 = highest impact.

4. **Potential to Improve Existing Information for Target Crashes**
   a. Score 1, 3, or 5 based on potential as determined by an expert panel such as the SAC.
      i. 1 = limited potential for improvement.
      ii. 3 = moderate potential for improvement.
      iii. 5 = significant potential for improvement.
5. **Probability of Success**
   a. Score 1–5 based on relative chance of success as determined by an expert panel such as the SAC.
      i. 1 = low chance of success.
      ii. 2 = medium-low chance of success.
      iii. 3 = average chance of success.
      iv. 4 = medium-high chance of success.
      v. 5 = high chance of success.
6. **Cost of Research**
   a. Score 1–5 based on overall cost of research.
      i. 1 = $5M+.
      ii. 2 = $1M to $5M.
      iii. 3 = $500,000 to $1M.
      iv. 4 = $100,000 to $500,000.
      v. 5 = <$100,000.
7. **Potential to Identify More Effective Strategies for Target Crashes**
   a. Score 1–5 based on the average effectiveness of existing countermeasures related to the research topic. This score pertains specifically to research focused on the identification of new countermeasures or research that would allow for the identification/analysis of new countermeasures.
      i. 1 = average effectiveness (i.e., CMF) of related countermeasures is less than 0.50 OR research is *not* related to the identification of new countermeasures OR research does *not* allow for the identification/analysis of new countermeasures.
      ii. 2 = average effectiveness (i.e., CMF) of related countermeasures is 0.51 to 0.74.
      iii. 3 = average effectiveness (i.e., CMF) of related countermeasures is 0.75 to 0.84.
      iv. 4 = average effectiveness (i.e., CMF) of related countermeasures is 0.85 to 0.94
      v. 5 = average effectiveness (i.e., CMF) of related countermeasures is 0.95+.
8. **Distance Between Expected Research Results and Treatment-Related Decisions**
   a. Score 1–3 based on the number of levels from treatment-related decisions.
      i. 1 = research that is three or more levels from treatment-related decisions.
      ii. 3 = research that is two levels from treatment-related decisions.
      iii. 5 = research that is one level from treatment-related decisions.

Figure 3 illustrates the relative importance of the factors. The level of relative importance increases on the horizontal axis from left to right. In this case, number of target crashes is identified as the most influential factor. As such, it would receive a greater weight in the overall utility index than other factors.

Based on the level of importance identified in Figure 3, the following weighting scheme is proposed to estimate the relative utility index (RUI) for fundamental research. The weighting scheme is based on four tiers of relative importance with two factors per tier. The first tier includes the number and severity of target crashes. This tier provides a top-down approach to the prioritization (i.e., problem-centric). The second tier is an attempt to balance the problem-centric input with practical needs and potential to advance the science of safety. This

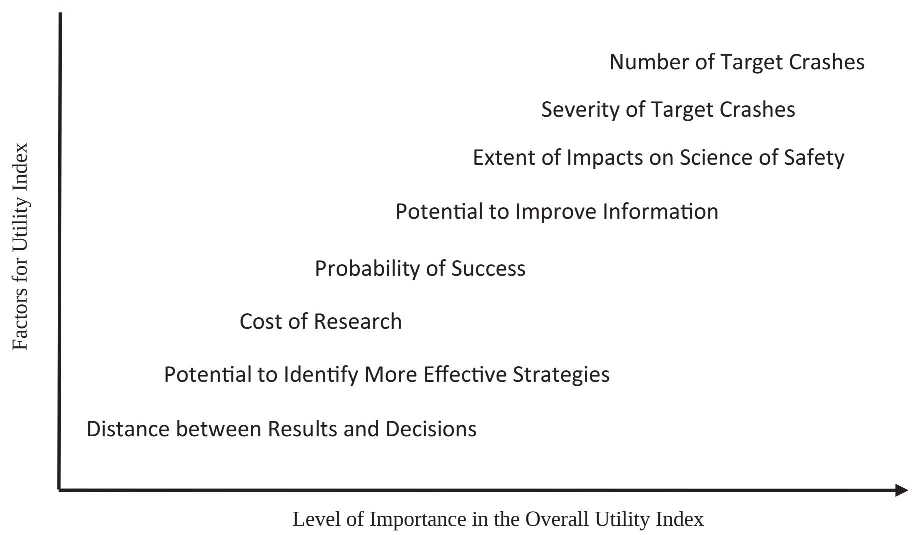


Figure 3. Relative importance of factors to be included in utility index.

is accomplished through stakeholder input (a bottom-up approach) and identification of knowledge gaps. The third tier incorporates the probability of success and cost of a proposed research topic; both are important factors, but should not drive the prioritization of fundamental research. The fourth tier includes the potential to identify more effective strategies and the distance between expected research results and treatment-related decisions. These additional factors will not influence the higher-level prioritization, but can help to refine the final list of prioritized topics when two or more topics are assigned the same score based on the previous factors.

$$RUI = 4TC + 4SC + 3SS + 3QI + 2PS + 2CR + ES + DR$$

Where:

TC = Number of Expected Target Crashes.
SC = Severity of Expected Target Crashes.
SS = Extent of Impacts on Science of Safety.
QI = Potential to Improve Quality of Information for Target Crashes.
PS = Probability of Success.
CR = Cost of Research.
ES = Potential to Identify More Effective Strategies for Target Crashes.
DR = Distance between Expected Research Results and Treatment-Related Decisions.

The RUI is based on a total possible score of 100. If each factor received the maximum possible score,

$$\begin{aligned} RUI &= 4TC + 4SC + 3SS + 3QI + 2PS + 2CR + ES + DR \\ &= 4(5) + 4(5) + 3(5) + 3(5) + 2(5) + 2(5) + 5 + 5 \\ &= 100. \end{aligned}$$

Pilot Test of Prioritization Method

The RUI and associated weights were based on a review of the literature and careful consideration of the application of other prioritization methods in the transportation field; however, there was a need to test the proposed method. A formal verification of the RUI is difficult because there is no baseline truth to which the results can be compared. Instead, the research team devised a plan to pilot test the method, using a sample of 20 fundamental research problem statements. The sample included a range of projects, varying by topic area, research costs, and anticipated timeframe. The same set of problem statements was distributed to the NCHRP panel for review and prioritization using a traditional "expert panel" ranking (i.e., preference based on personal experience and understanding of the underlying issues and research needs). Specifically, the 20 RNSs were distributed to each panel member with instructions to rank them by assigning a number between 1 and 20 to each of the research statements, where 1 is the highest priority. It should be noted that the list was randomized for each panel member to address potential order bias.

Figure 4 and Figure 5 present the results of the pilot test, comparing the VOR from the RUI with the results from the panel review. The research team received responses from six panel members; the individual and average panel rankings are presented in Figure 4, while Figure 5 shows the average and standard deviation of the panel rankings.

The following points are based on a comparison of the RUI and panel rankings as well as general observations from the application of the RUI.

- General correlation: There is a slight increasing trend in the average panel rankings when the research needs are sorted by RUI ranking. This indicates that the RUI is relatively consistent with the general responses from the panel.
- Variability: There is substantial variability in the panel rankings as shown by the individual points in Figure 4 and the standard deviation bars in Figure 5. While the RUI does include inputs from an expert panel or SAC, it also incorporates several quantitative factors that help to reduce the variability in the results.
- Limited detail: There was limited information provided by the author for several of the RNSs. This made it difficult to clearly define the eight factors for the RUI, particularly those that required input from the SAC. In the future, these RNSs would be returned to the author for additional information (convert them to projects, as per earlier paragraphs) before they can be included in the ranking process.

Summary and Conclusions on Recommended Prioritization Methods

One of the major objectives of this project was to develop prioritization methods to rank and rate research projects. For this purpose, research studies have been divided into two categories: (1) research studies that develop CMFs, and (2) research studies that do not directly deal with the development of CMFs (also referred to as fundamental research).

The prioritization method for research studies that develop CMFs is based on the VOR approach. This approach is more objective compared to other methods that are currently being used by agencies to rank research projects. It relies on data to develop the priorities rather than having priorities based on the subjective opinions of individuals and stakeholder groups. The underlying basis for the proposed approach is that all research projects have one goal – to develop information for making a better safety-related decision (i.e., information

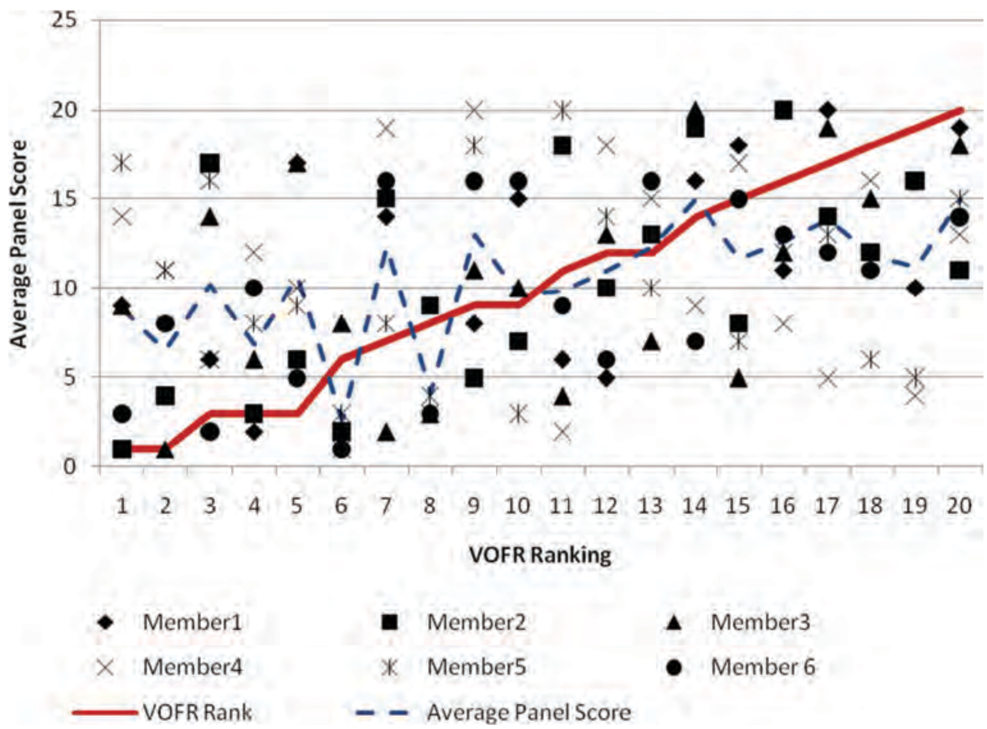


Figure 4. Value of fundamental research (VOFR) versus average panel score (Individual Points).

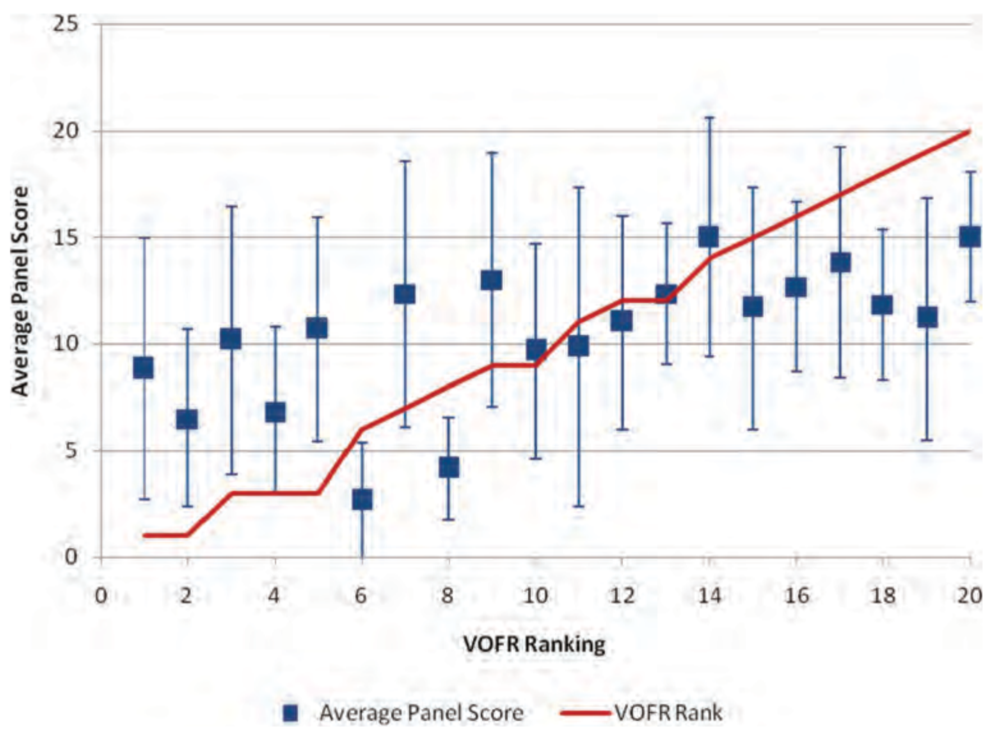


Figure 5. Value of fundamental research (VOFR) versus average panel score with standard deviations.

that will reduce the chances of making an inferior decision). Safety-related decisions involving CMFs concern whether or not to implement a given treatment on a specific set of roadway locations.

The standard deviation of the CMF is a measure of the uncertainty of the CMF. The smaller the standard deviation of the CMF, the lower the chance of making an inferior decision based on this CMF. If by conducting a research project it is possible to substantially reduce the standard deviation of the CMF, then one could argue that such a research project has good value. This approach develops a monetary value based on the extent to which a research project can reduce the standard deviation of a CMF and thus increase the chances of making the correct decision. Appendices C and D provide a detailed discussion of the theoretical underpinnings of this method. Appendices E, F, and G provide a discussion of a computerized tool that has been developed in order to implement this method. These appendices are not published herein, but can be accessed on the TRB website at: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727.

Two pilot studies were conducted to test the implementation of this method. One pilot involved the estimation of the value of conducting research to determine the CMF for closing driveways at intersections. The second pilot involved the estimation of the value of conducting research to determine the CMF for implementing edgeline rumble strips on rural two-lane roads. Based on these pilot studies it is clear that this approach can be implemented for determining the value of CMF-based research. The intent is to use about 3 to 4 hours to compile the data for each CMF-based research study and apply the tool discussed in Appendices E, F, and G to estimate the VOR. Depending on the number of CMF-based research studies that need to be considered in this project, it may be necessary to develop a prescreening tool to reduce the number of studies that can be examined using the computerized tool to a manageable number.

Regarding the prioritization of non-CMF research, two methods have been proposed. The first approach is more quantitative, but we felt that it was very difficult to implement. Hence, we developed an alternative method that is less quantitative but easier to apply in practice. The alternative method identified the following eight different factors that could be considered in rating a non-CMF research study:

- Number of expected target crashes.
- Probability of success of the research study.
- Stakeholder input.
- Cost of research study.
- Potential to Improve Quality of Existing CMFs for Target Crashes.
- Potential to Identify More Effective CMFs for Target Crashes.
- Number of Existing CMFs for Target Crashes.
- Distance between Expected Research Results and Treatment-Related Decisions.

Based on the relative importance of each factor, a weighting scheme has been developed to weigh the individual factors and compute the utility of a non-CMF study. This method was pilot tested and was found to be reliable for prioritizing non-CMF studies. It is noted that while the proposed factors and weighting scheme have undergone initial review, both can be modified as more is learned from future usage of the method. (See the *Lessons Learned* section in Chapter 3 for further discussion.)

CHAPTER 3

Implementing the Prioritization Procedure

This chapter develops and presents a prioritized list of applied and fundamental research topics. The task was conducted as a two-step effort. The initial step involved the development of a "master list" of candidate research topics. The second step involved the implementation of the recommended methods to prioritize those topics. Each step is discussed separately below.

Defining the Method for Identifying Potential Research Topics

This section defines the method to identify both applied and fundamental research topics and issues that could potentially be part of the National Agenda. The method identifies potential sources of the topics, describes the process of collecting topics from the sources, and defines the level of detail needed in the description of each potential topic.

While the primary goal of this effort was to develop a list of potential research topics, an equally important goal was to develop this list in such a way that future potential users of the National Agenda will feel some ownership of that Agenda. This required widespread input from potential users (i.e., those who will choose research topics/projects either as research funders or researchers). Specifically, potential users should be involved throughout the process and shown where their input fed into the Agenda (e.g., any potential research topic listed in the master list will include the source of the idea). The list of potential topics must also include both applied and fundamental research, and these two lists should be developed separately, because the sources of potential ideas, required level of detail, and user-reviewers may differ between these two categories.

The research team developed an initial list of potential research topics based on existing databases (e.g., TRB's RNSs) and documents (e.g., knowledge gaps identified in the HSM). Sources considered for potential research topics are listed in Appendix J. In addition, several organizations and individuals were contacted for additional ideas. Appendix K contains a list of key stakeholder-reviewers. These appendices are not published herein, but are available on the TRB website at: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727.

Identification of Research Topics to be Prioritized

The research team collected several RNSs covering a wide range of safety areas and issues. The research team utilized its extensive experience in identifying available research and research needs, based on previous work on the HSM and projects for FHWA and NCHRP. RNSs were extracted from both national and local sources, including the sources provided by the NCHRP project panel members.

The research team reviewed the following sources for potential RNSs:

- AAA Foundation for Traffic Safety's *Traffic Safety Issues of the Future: A Long Range Research Agenda*
- AASHTO research needs, as defined in their plan: *Toward Zero Deaths: a National Strategy on Highway Safety*
- AASHTO Safety Management Task Group
- HSIS Research Topics
- HSM Part D/CMF most wanted list/Knowledge gaps identified in the HSM
- HSM webinars - topics of interest for CMF development discussed during HSM webinar series
- Input from FHWA Office of Safety and Office of Safety Research and Technology
- Knowledge gaps identified in the work plan for the 2nd edition of the HSM, NCHRP 20-7(279)
- Pedestrian Safety Program Strategic Plan
- Research Problem Statements from key TRB committees (including unsolicited research needs, which were submitted in September 2011 and are presented in Appendix L)
- SHRP2 Safety Project

- Topics identified by the National Highway Research and Technology Partnership
- TRB RNSs Search Engine—search keywords "crash"/ "accident"
- Unfunded high-priority NCHRP projects found in *NCHRP Report 617*
- Other sources identified by the project team, with input from the NCHRP panel

A list of some of the major research topics that were considered from these various sources is given in Appendix M, which is available on the TRB website at: http://www.trb.org/Main/Blurbs/169240.aspx.

RNSs were reviewed and a table was created with individual parameters to identify the related HSM chapter; focus area; research topic/title; research area (in terms of CMF, other applied research, or fundamental); user audience; research applicability; project description; source; year; status; and other comments. Research topics were added based on gaps identified from the CMF Clearinghouse, AASHTO and TRB Committees, and other sources. The project team reviewed and analyzed the quality of CMFs found in the HSM and discovered that 40 treatments were lacking information on applicability (e.g., exposure, target crash, site and roadway specification) even though they may have small standard errors. These were included in the RNS table and developed as research ideas. A total of 883 RNSs were developed following the activities described above.

For each non-fundamental research topic, the title was modified to indicate the site type and roadway type, and reflect the decision faced by practitioners (e.g., what is the safety effect of providing one access point within the influence area of a signalized intersection at a major arterial road with four or more lanes for both directions of travel). These parameters are needed when using the prioritization method for RNS screening. Typically, this process generated two or more RNSs by breaking an original RNS into specific scenarios (e.g., site type, roadway type, project decision, etc.).

There was considerable variability in the level of detail provided for potential research topics, particularly among the various sources. In many cases, there was insufficient detail provided to allow for a meaningful analysis of the research need. It was determined that a template would help to (1) generate thoughts from the proposer, (2) improve consistency among proposed topics, and (3) provide the level of detail needed to prioritize research needs. As part of this project, a form was developed for use by those who propose new research issues for consideration (see Appendix N). The form is designed to capture enough information about the proposed research project to allow for prioritization without becoming so cumbersome that it discourages good research ideas. Another goal of the form was to have the proposer conduct some of the initial work such as searching for "current knowledge" before proposing a new research topic. This is the primary reason for including the treatment-related questions that must be answered by searching the HSM and the CMF Clearinghouse – the two primary sources of current knowledge of treatment effects.

Prioritizing CMF Research Topics

This section presents the results of the CMF-related applied research prioritization, including the method used to prescreen the initial list to a more manageable number of topics.

Prescreening CMF Topics

The combination of suggested research topics from all sources resulted in a list of 311 CMF research topics. Time constraints under the research project did not allow for conducting the VOR prioritization for all of these topics. Thus, the team determined that 50 topics would suffice to demonstrate the VOR method and prioritization process. Several steps were taken to narrow the list of RNSs to a smaller number. The steps are detailed below and include the following:

1. Eliminate statements not meeting scope of project.
2. Eliminate vague statements.
3. Eliminate or combine similar statements.
4. Eliminate statements related to highly rated CMFs in the CMF Clearinghouse.
5. Eliminate statements with low potential to affect fatal crashes.

Eliminate Statements Not Meeting Scope of Project

The first step of the prescreening was to eliminate RNSs that did not meet the scope of the project. This step eliminated statements that specified strategies that would not be implemented by a public agency for any reason based on past research, or professional input or knowledge on the topic (e.g., curb and gutter on freeway sections); were not related to operations or infrastructure modifications (e.g., roadside memorials); or were the topics of research already underway.

Eliminate Vague Statements

The list of RNSs was then examined to determine if each RNS had enough description and specificity to be used in the prioritization process. Statements were eliminated if they were too vague or did not have the information necessary to perform other steps in the elimination and prioritization process (e.g., specification of the countermeasure of interest).

- *Example:* "Operational and safety effects of pedestrian facilities at steep grades approaches." This statement did not describe a specific countermeasure that would be studied.
- *Example:* "Safety Effects of providing distance markers on freeways and expressways." This statement did not provide enough description of what was meant by "distance markers" so that the team could be sure they were prioritizing it correctly.

Eliminate or Combine Similar Statements

The list of RNSs was further examined to determine if any statements should be combined based on similarities in scope. Twenty-three statements were combined with other statements because they addressed the same countermeasure on different road classes or the countermeasures were similar and could be logically combined into one research project.

- *Example:* "Safety Effects of Modifying Lane Width of 4- and 6-lane Urban Arterial Streets" and "Safety Effects of Modifying Lane Width of 4- and 6-lane Suburban Arterial Streets" were combined as "Safety Effects of Modifying Lane Width of 4- and 6-lane Urban and Suburban Arterial Streets."
- *Example:* "Safety Effects of Implementing Area-wide Traffic Calming in Suburban Areas" was eliminated based on similarity to another RNS entitled "Safety Effects of Traffic Calming Measures along Suburban Arterial Corridors (speed humps, chicanes and markings to be included)."

Eliminate Statements Related to Highly Rated CMFs in the CMF Clearinghouse

The next step was to check the list against the FHWA CMF Clearinghouse to determine if the proposed CMF research was similar to an existing entry in the Clearinghouse. Each statement was given a value of "yes" (statement matched exactly with a countermeasure in the CMF Clearinghouse), "related" (statement was similar to a countermeasure in the CMF Clearinghouse but not an exact match), or "no" (statement did not match any countermeasure in the CMF Clearinghouse). The team made use of the star quality ratings provided for each CMF entry in the Clearinghouse, denoting the reliability or quality of that CMF. For statements that had an exact or related match in the Clearinghouse, the team recorded the highest star rating of any CMF associated with the countermeasure, with the intention of using the star rating as a way of prioritizing the research statements. That is, if an RNS proposed research on a countermeasure that already had a highly rated CMF in the Clearinghouse, then it would be less of a priority to conduct additional research on that topic.

Eliminate Statements with Low Potential to Affect Fatal Crashes

Finally, a query was conducted to determine how many fatal crashes would potentially be addressed by the countermeasure of interest for each RNS. To determine this number, the team performed queries of the NHTSA FARS for the year 2009. The team members performing the FARS query used parameters as indicated by the RNS title and description to make reasonable assumptions about what types of crashes would be addressed by the countermeasure.

- *Example:* "Safety benefits of providing illumination at isolated pedestrian locations on 2-lane rural roads." The FARS query parameters for this RNS were pedestrian crashes at nighttime on rural 2-lane roads. The result of this query was 485 fatal crashes.

The results of the FARS query provided an estimate of the *maximum* number of fatal crashes that could be addressed by each RNS. Those with higher numbers of fatal crashes to address were considered to be a higher priority than those with lower numbers. A threshold of 500 potential fatal crashes was used to further eliminate statements from the list. The 500-crash threshold was selected because it was a threshold which eliminated a sufficient number of RNSs to bring the list down to a more manageable number for the next stage of the process. Additionally, the 500-crash threshold was low enough to allow for the possibility of including RNSs on bicycle or pedestrian topics, which had 630 and 4,092 fatal crashes in 2009, respectively.

After these elimination steps were completed, the list contained 37 RNSs. These 37 RNSs were submitted through the prioritization process to calculate a VOR for each one.

Estimating the Value of Conducting Research to Develop CMFs

This section presents the results obtained after implementing the VOR method for estimating a dollar value associated with conducting research to develop CMFs. The overview of the VOR method was presented in Chapter 2. A more detailed description of the VOR method is available in Appendix C. Appendix D describes the method for estimating the mean and variance of CMFs: estimating the variance and consequently the standard deviation of a CMF is necessary in order to properly apply the VOR method. Appendices E, F, and G describe the Excel tool that was developed to implement the VOR method. The VOR method was applied to 37 CMF research need statements that were obtained after prescreening the 311 CMF research need statements to remove those that the research team felt were of low priority (the prescreening process is discussed in the previous section). Note: The appendices for this report are available online via the TRB website at: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727.

Inputs for Implementing the VOR Method

The following is a brief overview of the inputs that were needed in order to use the Excel tool for determining the VOR for each problem statement. Further details about the inputs for each problem statement, along with the assumptions, are provided in Appendix P.

1. The number of miles by functional class (for treatments on roadway segments) and the number of intersections (by type and functional class of the major road) that could be treated. To estimate this parameter, the project team used information from multiple sources:
   a. HPMS – this database provides an estimate of the number of miles by functional class in the United States.
   b. HSIS – this information system has data from seven states in the nation with detailed information about the roadway inventory for state maintained roads.
   c. Percentage of miles or intersections that could be treated. This was estimated based on a survey of project team members and states represented in the NCHRP panel.
2. Countermeasure implementation cost information. This included an estimate of the initial cost of the project, the annual maintenance cost, the countermeasure service life, and the discount rate (assumed to be 3.0 percent). This information was estimated for each countermeasure by conducting a search of state DOT contracts and letting lists, public agency reports on the costs of safety strategies, federal and national reports on costs of countermeasures, news reports on safety strategies implemented in cities or towns, and Internet searches targeted at specific countermeasures. The full database of countermeasure costs compiled for this effort is presented in an accompanying spreadsheet and described in Appendix R, which is available on the TRB website at: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727.
3. Target crash cost information. This was estimated based on the severity distribution of the target crash. The information from Council et al. (2005) (FHWA-HRT-05-051) was used for estimating the cost for each severity level.
4. Limiting benefit-cost ratio. The limiting benefit-cost ratio defines the minimum ratio above which a project is determined to be worthy of funding. Different states may use a different value for this parameter. For this exercise, we assumed the limiting benefit-cost ratio to be 1.0 for all projects.
5. Countermeasure information. This included estimates of the following:
   a. The CMF for Total Crashes – This was obtained from the CMF Clearinghouse, the HSM, and in some cases, review of studies that were not in the CMF Clearinghouse or the HSM. In some cases, CMFs were not available in published studies for the particular treatment under consideration. This required the project team to use their judgment in determining the appropriate CMF estimate. In some cases, the project team used the information about the CMF from a closely related treatment. (It is important to note that treatments with highly rated CMFs in the Clearinghouse had already been eliminated based as part of the prescreening procedure discussed earlier.)
   b. The Standard Deviation of the CMF before Proposed Research is Undertaken – If CMFs from multiple studies were available, then the standard deviation of the CMF before research was obtained based on the procedure described in Appendix D. The CMF worksheet in the Excel tool implements this procedure. If only one CMF was available, then the standard deviation was assumed to be 0.2*CMF. This assumption was based on the results from two recent studies presented at the 2012 Annual Meeting of the TRB that estimated the standard deviation of the CMF in addition to the standard error of the estimate of the CMF:
      i. Paper 12-1658 entitled *Safety Effectiveness of Converting Signalized Intersections to Roundabouts,* and
      ii. Paper 12-2521 entitled *Crash Modification Factors for Changing Left Turn Phasing.*
   c. The Standard Deviation of the CMF after Proposed Research is Undertaken – The procedure for estimating this parameter is described in Appendix D. Estimating this parameter requires an estimate of the standard error of the CMF for the new research. Here, we assumed that the new research will have a data collection plan and statistical methods that are at least as rigorous as those used in the previous projects such that the standard error from the new project will match that of the previous projects. If previous research did not provide standard errors for the CMFs, the project team's judgment was used in estimating the standard error. For treatments mainly aimed at reducing pedestrian crashes, the standard error of a minimum of 0.1 was used unless previous research results showed standard errors less than 0.1. In other cases, the standard error corresponding to the CMF being statistically different from 1.0 at the 0.05 significance level was used.

Estimated VORs

Table 5 shows the VOR (rounded to the nearest ten thousand dollars) for each problem statement sorted in decreasing

Table 5. VOR results for CMF research topics.

Research Topic Title/Project	VOR/Year
Safety effects of installing post-mounted delineators on rural two-lane roads - tangents and curves	$ 165,160,000
Safety effects of installing transverse rumble strips prior to a horizontal curve requiring speed reduction on a two-lane rural road	$ 151,010,000
Safety effects of providing a sidewalk at urban and suburban arterials in place of a shoulder, including park and transit areas	$ 98,090,000
Safety effects of in-lane advance curve warning marking on rural two-lane roads	$ 58,800,000
Safety effects of installing raised pedestrian crosswalks at intersections on urban and suburban arterials	$ 57,720,000
Effects of multiple parallel turn lanes on pedestrian-vehicle conflicts and safety at urban signalized intersections	$ 30,970,000
Safety effects of placing converging chevron pattern markings on rural two-lane roads - curves	$ 22,020,000
Safety prediction models for rural two-lane roads with various offsets of trees and other vegetation	$ 19,660,000
Safety effects of narrowing roadway at pedestrian crossings	$ 19,540,000
Safety effects of changing speed limits on urban and suburban arterials (both system-wide and speed zoning)	$ 17,330,000
Safety effects of LED lighting in reducing pedestrian nighttime crashes	$ 14,980,000
Safety effects of installing continuous shoulder rumble strips on rural multilane divided roads	$ 10,210,000
Safety effects of in-lane advance curve warning marking on rural multilane highway	$ 9,170,000
Safety effects of installing post-mounted delineators on rural multilane roads	$ 6,790,000
Safety effects of installing centerline rumble strips at multilane roads with median barriers	$ 4,980,000
Safety effects of installing “Botts’ dots” on rural two-lane roads	$ 4,910,000
Safety effects of placing converging chevron pattern markings on rural multilane highways - curves	$ 2,510,000
Safety effects of exclusive pedestrian signal phases at urban intersections	$ 1,480,000
Safety effects of installing continuous shoulder rumble strips on rural multilane undivided roads	$ 1,120,000
Develop a CMF for installing wide edgelines (8 in.) on rural two-lane roads versus the standard (4–6 in.)	$ 1,090,000
Safety effects of retiming signal change intervals to ITE standards (four-leg urban intersections)	$ 840,000
Safety effects of reversible flow lanes along five-lane arterial street corridors	$ 790,000
Safety effects of widening external paved shoulder of two-lane rural roads	$ 700,000
Safety prediction models for rural multilane highways with various offsets of trees and other vegetation	$ 570,000
Safety effects of removing roadside obstacles along urban arterial streets	$ 480,000
Safety effects of adding lanes by narrowing existing lanes and shoulders of four- and six-lane Urban and Suburban Arterial Streets	$ 400,000
Safety effects of installing “Botts’ dots” on rural multilane roads	$ 270,000
Safety effects of retiming signal change intervals to ITE standards (three-leg urban intersections)	$ 200,000
Safety effects of increasing the forgiving area from current standards for freeways and expressways (four and more lanes)	$ 150,000
Safety effects of widening external paved shoulder of four- and six-lane multilane highways	$ 130,000
Develop a CMF for installing wide edgelines (8 in.) on urban and suburban arterials versus the standard	$ 110,000
Safety effects of improving superelevation (to meet standards) of horizontal curve on rural multilane highways	$ 100,000
Develop a CMF for installing wide edgelines (8 in.) on freeways and expressways versus the standard (4–6 in.)	$ 50,000
Safety effects of increasing the forgiving area from current standards for rural multilane (four and more lanes) highways	$ 30,000
Develop a CMF for installing wide edgelines (8 in.) on rural multilane highways versus the standard (4–6 in.)	$ 20,000
Safety effects of changing speed limits on rural two-lane roads (both system-wide and speed zoning)	$ 0
Safety effects of changing speed limits on rural multilane roads (both system-wide and speed zoning)	$ 0

order of the VOR. In general, higher values of VOR indicate that there is more value in conducting research on that topic. Hence, the VOR can be used for prioritizing the projects. In order to determine the VOR for a group of projects, the user can add the VOR for the individual projects within that group, e.g., if an agency is interested in conducting research for developing CMFs for the "Botts' dots" treatment for rural 2 lane and multilane roads, the VOR for such a research study would be $4,910,000 (VOR for rural 2 lane roads) + $270,000 (VOR for rural multilane roads) = $5,180,000 (combined VOR for rural 2 lane and multilane roads).

Details of the inputs and results for each of the CMF-related RNSs are given in Appendix P.

Sensitivity Analysis and Concluding Thoughts

As discussed in Chapter 2 and Appendix C, there are many factors that influence the VOR of a particular research study. One such factor is the number of target crashes for a particular treatment, which is a function of the number of miles/sites that could be treated. If the number of target crashes is high, the VOR will be high as well. As discussed earlier, the number of miles/sites was estimated using data from HPMS, HSIS, and an estimate of the percentage of target miles that could be treated (based on the judgment of the project team and a couple of the states). Since this is a critical input to the implementation of the VOR method, future applications of the VOR method to rank potential CMF research projects for a particular jurisdiction should strive to estimate the number of target miles/sites for a particular treatment by making use of the jurisdiction's roadway inventory files in addition to the expertise of local engineers.

Another factor that influences the number of target crashes for a particular treatment is the distribution of crashes in the target sites. For applying the VOR method, SPFs using data from an HSIS state were estimated and calibrated to represent the United States using the procedures discussed in Appendices E and F, which are available on the TRB website at: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727. For future applications of the VOR method to a particular jurisdiction, SPFs calibrated using data from that jurisdiction may provide more accurate results.

The VOR is also dependent on the implementation cost and the annual maintenance costs of a particular treatment. In this study, we compiled data from various jurisdictions and used a number that the project team considered appropriate. For future applications of the VOR method to a particular jurisdiction, local estimates of implementation and maintenance costs should be used.

Finally, the VOR is dependent on the estimated CMF and the difference between the standard deviation of the CMF after the proposed research and the standard deviation of the CMF before the proposed research. If the difference between the two standard deviations is high, the VOR will be high as well. As discussed earlier, estimating this difference between the two standard deviations requires an estimate of the standard error of the CMF for the new research. In this study, we assumed that the new research will have a data collection plan and statistical methods that are at least as rigorous as those used in the previous projects such that the standard error from the new project will match that of the previous projects. If previous research did not provide standard errors for the CMFs, the project team's judgment was used in estimating the standard error. For treatments mainly aimed at reducing pedestrian crashes, the standard error of a minimum of 0.1 was used unless previous research results showed standard errors less than 0.1. Since the assumption of 0.1 for the standard error was somewhat arbitrary, the research team felt the need to conduct some sensitivity analysis for four research problem statements to assess the impact of using different standard errors (i.e., standard errors of 0.05 and 0.15 in addition to 0.10). Table 6 shows the results of this exercise.

The sensitivity analysis illustrates the importance of taking care in estimating the standard error. While the relative rank remains the same among these four cases for the different

Table 6. VOR per year for various values of assumed standard error.

Research Topic Title/Project	S.E. = 0.05	S.E. = 0.10	S.E. = 0.15
Safety effects of exclusive pedestrian signal phases at urban intersections	$ 360,654	$ 1,481,461	$ 3,503,610
Safety effects of providing a sidewalk at urban and suburban arterials in place of a shoulder, including park and transit areas	$ 23,931,321	$ 98,093,131	$ 230,880,661
Safety effects of narrowing roadway at pedestrian crossings	$ 4,771,049	$ 19,541,285	$ 45,945,208
Safety effects of LED lighting in reducing pedestrian nighttime crashes	$ 3,711,613	$ 14,980,095	$ 34,224,253

Note: S.E. denotes standard error.

standard errors, it is clear that the standard error has a significant impact on the absolute VOR. If the absolute VOR is erroneously inflated, then this could result in the selection and funding of projects that are not cost effective. Further work is recommended to improve the manner in which the inputs are estimated when data are not available.

Prioritizing Fundamental Research and Non-CMF Applied Research Topics

This section presents the results of the Fundamental and Non-CMF Applied Research prioritization.

Estimated Relative Utility Index (RUI)

The RUI was computed for all applicable RNSs that were categorized as fundamental or non-CMF applied research. There were a total of 21 fundamental research topics and 29 non-CMF applied research topics. Table 7 and Table 8 provide the prioritized lists of fundamental and applied non-CMF research, respectively, including the research topic, focus area, project description, and RUI. The research topics are sorted from highest to lowest priority within each table based on the RUI. The complete prioritization results are presented in Appendix Q, including the individual scores for the factors included in the RUI. Table Q.1 (in Appendix Q) provides the

Table 7. Prioritization results for fundamental research topics.

Research Topic	Focus Area	Project Description	RUI
Updating Databases of In-depth Crash Attributes - Expansion to F-SHRP 2	Data Management	Enhance knowledge about roadway crashes for improved understanding of crash causes. Continue maintenance and digitization of the library, including database updates and online accessibility improvements.	83
Develop/Test Procedures to Identify Locations for Cost-Effective Programs of System-Wide Improvements	Network Safety	The purpose of this project is to develop and test procedures to identify locations for cost-effective programs of system-wide/region-wide/area-wide improvements.	81
Develop a Tool for Assessing the Extent to which a New Statistical Method or Modeling Approach Succeeds in Identifying The Cause-Effect Relationship in the Data	Evaluation Methods	With highway safety data, cause-and-effect conclusions obtained through the use of existing statistical methods are unreliable. The objective of this research project is to develop a tool for assessing the extent to which a new statistical method or modeling approach succeeds in identifying the cause-effect relationship in the data.	81
Development of Driver Behavior Models for Structural Modeling	Evaluation Methods	The objective of this project is to develop realistic representations of road-user behavior for use in structural models, with consideration given to all road users, including drivers, pedestrians, and motorcyclists. The focus should be on driver behaviors that are associated with infrastructure design, traffic control, and vehicle operation (e.g., reaction time, visual acuity, speed choice, etc.).	81
Establish Criteria to Assess the Validity of Surrogate Measures and Safety Relationships. Evaluate and Validate Candidate Surrogate Measures (Continuation of Research Idea #355)	Evaluation Methods	The objective of this project is to conduct a state-of-the-art review of knowledge in the area of surrogate safety measures and synthesize the findings. The synthesis should identify and define candidate surrogate measures. It should also establish criteria to assess the validity of alternative surrogate measures. The criteria should consider the use and usefulness of each measure in road safety evaluation. Thereafter, research is needed to identify potential roles for each candidate measure (e.g., for countermeasure evaluation, or as an independent variable in a safety prediction model). This research component would consist of a series of separate research projects. Each project would evaluate and validate one candidate surrogate safety measure or one specific class of related measures (e.g., surrogates from simulation modeling, surrogates from field studies).	81
Refine Geometric Design Models and Process Including the Science of Safety	Alignment	The objective of this project is to perform a critical review of the format, structure, and basic assumptions included in the AASHTO Policies governing geometric design of highways and streets. AASHTO presents basic geometric guidance information inconsistently. A critique of all models is needed as to their adequacy and applicability across the range of location, traffic conditions and functional classification. This research effort should directly involve the AASHTO Geometric Design Task Force and Subcommittee on Design. The inclusion of the Science of Safety and the HSM are key components of this research project.	80
Develop a National Data Warehouse and Archived Data	Data Management	The purpose of this project is to develop a data warehousing and archiving system. As a result, data previously gathered and analyzed could be available for future analyses.	80
Developing Methodologies to Determine Cost–Benefit of Data Investment	Data Management	Encourage the use of information on the basis of quality data and analytical processes to make better safety decisions. Develop methodologies to determine cost-benefit of data investment.	73
Understanding the Influence of Road Features on Crashes - Expansion to F-SHRP 2	Data Management	Enhance knowledge about roadway crashes for improved understanding of crash causes. Pursue second phase of rollover study to link empirical results to simulation analysis to establish a more comprehensive understanding of the influence of road features on rollover crashes.	71

(continued on next page)

Table 7. (Continued).

Research Topic	Focus Area	Project Description	RUI
Develop Methods and Tools for Design and Evaluation of Roadway Departure Programs and Treatments. Develop Finite Element Models for Representative Vehicles to Support Simulation of Various Types of Crashes	Evaluation Methods	Develop methods and tools for design and evaluation of roadway departure programs and treatments. Develop finite element models for representative vehicles to support simulation of various types of crashes.	70
Data Collection and Analysis of Vehicle Paths and the Safety Effects of Alternative Curve Design Elements (Compound Circular Curves, Spiral Transition, and Tangent-To-Curve Transitions)	Alignment	Develop an experimental and/or field study protocol to collect data to study the nature of vehicle paths and operating speeds on transition curves, focused primarily on freeway exit ramps. Determine if, and how much, excessive lateral vehicle shifts are caused by compound circular curves, spiral transition, and tangent-to-curve transitions; compare the results with collision and speed reduction data.	69
Assessment of Compatibility of Modern Vehicles and Roadside Safety Hardware	Roadside Furniture	Assessment of compatibility of modern vehicles and roadside safety hardware. There is concern that the newer model vehicles may be incompatible with current roadside hardware that was developed using older models in crash tests, and that this problem will become worse in the future.	63
Develop an In-depth Understanding of Crashes with Utility Poles	Roadside Furniture	The objectives of this project are to (1) Identify the human, site, and traffic conditions associated with crashes involving poles and (2) Combine those characteristics with those already available related to vehicle type size, speed, and trajectory to develop better empirical/analytical methods of separating the predictable collisions, subject to cost-effective treatments from the purely random collision, that which is not reasonably predictable.	61
Investigate the Accuracy of Automated Pedestrian/Vehicle Conflict Video Data Collection in Comparison with Human Observations	Pedestrians	Research on the use of video data collection to detect, measure, and evaluate pedestrian/vehicle conflicts and the accuracy compared to human observations.	60
Motorcycle Crash Causation Study	Motorcyclists	Devising effective crash and injury countermeasures requires comprehensive researching into current causes of motorcycle crashes and defining the population at risk. The objective of this research is to conduct on-scene, in-depth research on motorcycle crashes and user population at risk, and to harmonize such research with previous studies.	59
Developing Valid Estimates of Motorcycle Exposure for Safety Analysis	Data Management	The objective of this research is to identify a reliable means for estimating motorcyclist exposure for motorcyclist safety analysis.	58
Evaluation of Existing and New Commercial Vehicle Exposure Measures to Generate Meaningful Safety Estimates for Freeways and Multilane Highways Using these Surrogate Measures	Commercial Vehicles	The objective of this research is to evaluate the validity and usefulness of existing and potential exposure measures corresponding to key crash data variables for the purpose of generating more valid and meaningful relative risk estimates. This may include surrogate exposure measures, but should include actual measures of normal driving, including those based on: 1. Highway/traffic monitoring. 2. Naturalistic driving baseline (random epoch) data. 3. Fleet-based real-time documentation of random trip "exposure points." 4. Government or carrier records (e.g., Hours-of-Service [HOS] logs). 5. Surveys. 6. Non-crash controls (e.g., non-crash trucks and drivers).	57
Empirical Testing of W-Beam Guardrail to Expected Safety Performance	Roadside Furniture	Evaluation of W-beam guardrail failures to the expected performance.	56
Development of a Safer Concrete Barrier	Roadside Furniture	The objective of this research project is to develop a new concrete barrier design that can be as economical and durable as safety shape and single slope barriers without producing the same rollover potential. The new barrier shape should essentially eliminate vehicle climb, minimize the risk of head-slap against the barrier, and be slip-formable.	54
Evaluation of the Applicability of and the Effect of Detection Technologies Related to Pedestrian Real-Time Data (Walking Speeds, Crossing Times, Etc.) and Vehicular Operations at Intersections Toward Enhancing the Safety and Operations of Signalized Intersections at Urban Collector and Arterial Roadways	Advanced Technology and ITS	The purpose of this project is to test and apply existing detection technologies to capture real-time pedestrian walking speed/location data and behavioral needs in conjunction with vehicular traffic operations to accommodate the data input in a new intersection signal system.	48
Investigate Measures to Enhance Interactions Between Pedestrians and Large Commercial Vehicles (Trucks and Buses) in Urban Areas	Pedestrians	Research identifying pedestrian safety improvements with regard to large commercial vehicles, especially in urban areas.	47

Table 8. Prioritization results for non-CMF applied research topics.

Research Topic	Focus Area	Project Description	RUI
AASHTO Design Criteria and Design Model Research including the Science of Safety (Relates to Project #69 and #536)	Alignment	Based on the findings from the previous project, a series of research studies to fill the gaps in design policy formulation would occur. The following issues (which would need confirmation) are believed to represent core needs. Task 1. AASHTO Horizontal Curve Design Model. Task 2. Roadside Design Criteria for the Urban Environment. Task 3. Cross Section Design Criteria for the Urban Environment. Task 4. Relationship of Level of Service to Substantive Safety. Task 5. Influence of Geometric Design Dimensions on Highway Maintenance. Task 6. Discretionary Decision-making, Tort Law, and Risk Management State Practices. Task 7. AASHTO Sight Distance Design Models.	83
Demonstrate Application of Surrogates and an Understanding of Safety Issues (Continuation of Research Idea # 356)	Evaluation Methods	This project would follow the previous one (356). It would consist of a series of separate research projects, each project focusing on one of the surrogate safety measures evaluated in the previous research project and identified as having the most promise. One objective will be to demonstrate the application of the surrogate safety measure (or class of related surrogate measures) for safety evaluation. A second objective will be to evaluate the ability of each safety surrogate (or class of related surrogate measures) to describe facility safety, or to quantify the safety effect of a treatment.	82
Updating the Cost of Crashes	Data Management	Develop and deploy support that facilitates an evidence-based decision-making approach to improve safety. Update Cost of Crashes Report and Guidance.	81
Evaluate and Improve Criteria for Collecting Speeding-Related Crash Data	Speed	Better define the relationship between speed and safety. Evaluate and improve criteria for collecting speeding-related crash data.	76
Develop Safety Prediction Models for Corridors with Different Access Point Density on Multilane Highways and Expressways	Access Management	Develop safety prediction models for corridors with different access point density on multilane highways and expressways.	75
Develop a Program for New Safety Prediction Models for Part C of HSM	Safety Tools	Research is needed to expand the range of intersection types addressed in predictive methods in Chapters 10, 11, and 12 in HSM Part C.	72
Safety Effects of Dynamic Speed Feedback Signs on Curves along Two-lane Rural Roads	Speed	Better define the relationship between speed and safety. Evaluate dynamic speed feedback signs on curves.	71
Development of National Service Level Criteria for the Interstate and National Highway System for Rest Area Facilities With Explicit Safety Impacts	Rest Area	The objectives of this research effort are to develop national service level criteria for safe and secure rest area facilities development and maintenance along interstate highways.	64
Safety Effects of Increasing Drivers' Response to the First Signalized Intersection When Entering Urban Areas (Following Rural Travel)	Intersection Traffic Control	Investigate methods to increase the safety of the "first signal" in the urbanized area such as real-time activated vs. static flashers.	63
Barrier System Maintenance Procedures Based on Damage and Potential Safety Impacts	Roadside Furniture	The final product expected from this research is an objective set of guidelines for determining the limits of damage to a longitudinal barrier that will not cause the barrier to have unacceptable safety performance. The guidelines will also address which safety feature components require replacement or refurbishment when repair is deemed to be necessary.	62
Best Practices in the Identification and Prioritization of High Pedestrian Crash Locations/Areas	Pedestrians	Research to generate best practices in pedestrian problem area identification (including the use of GIS, crash data, and land use data) and prioritization to assist practitioners in accurately and systematically identifying pedestrian risk areas that could be proactively treated.	62
Develop Safety Prediction Models for Corridors with Different Access Point Density on Two-Lane Rural Roads	Access Management	Develop safety prediction models for corridors with different access point density on two-lane rural roads.	61
Safety Performance of Large Trucks by Volume and Time-of-Day for Planning and Operations of Freeway and Multilane Highway Networks	Commercial Vehicles	The recommended study would review the literature and available data sources on large truck crash rates and risks by time-of-day. This would include crash distributions; crash harm distributions (derived from severity statistics); mileage exposure distributions; time-of-driving distributions (i.e., from naturalistic driving studies); and any other data metrics representing either a numerator or denominator in the overall time-of-day risk assessment. A successful study would derive time-of-day crash risk functions to inform carrier dispatching and other operational decisions. Potential approaches to how to incorporate heavy trucks into freeway and multilane highway network operations with safety explicitly quantified.	60
Development of Incident Duration and Secondary Crash Prediction Models for Freeways and Multilane Highways	Advanced Technology and ITS	Development of an incident duration and secondary crash occurrence prediction models on freeways and multilane highways for use by Transportation Management Centers, so users can make more informed travel choices.	58

(continued on next page)

Table 8. (Continued).

Research Topic	Focus Area	Project Description	RUI
Safety Predictive Models for Multi-Vehicle Collisions Based On Tunnel Characteristics and Service Areas, and Response Needs	Tunnels	Determine probabilities for multi-vehicle collisions based on tunnel characteristics and service areas, and develop predictive models for crashes in tunnels and response requirements.	58
Development of a Bicycle Safety Prediction Methodology for Road Segments and Signalized and Unsignalized Intersections	Bicyclists	The proposed research will explore exposure measures (effects of distance, time, traffic volume, number of lanes, etc.) and develop a predictive method for geometric treatments for bicyclists: 1. Along road segments (marked bicycle lanes, separated bicycle lanes, and raised bicycle lanes). 2. At signalized intersections. 3. At unsignalized intersections.	57
Development of Safety Prediction Models for Pedestrian Target Crashes at Midblock Locations with Marked Crosswalks Along Urban Multilane Roadways	Pedestrians	Development of safety prediction models for pedestrian target crashes at given design characteristics of midblock locations with marked crosswalks - urban multilane roadways.	56
Development of Safety Prediction Models for a Set of Two Three-Leg Intersections	Intersection Geometry	Development of safety prediction models for a set of two three-leg intersections on rural two-lane roads, rural multilane highways, and urban and suburban arterials.	56
Operational and Safety Effects of Marking a New Crosswalk at Midblock Locations	Pedestrians	Research to evaluate how new pedestrian facilities affect pedestrian exposure data and to determine the increased facility use by conducting before and after case studies of pedestrian facility projects.	55
Develop Safety Predictive Models for Roundabouts in Rural and Urban Conditions with Four Approaches and One- or Two-Lane Entries/Approaches	Intersection Geometry	Develop Predictive Methods for Roundabouts for Part C of the HSM.	53
Safety Impacts to Pedestrian at Different Levels of Visibility and Sightlines at an Urban Intersection	Pedestrians	A study of the safety impacts of lighting and other roadside elements such as newspaper boxes, shrubs, and other obstructions on driver-pedestrian visibility at urban intersections.	52
Best Practices and Pedestrian Safety Concerns Related to Transit Access in Urban Areas	Pedestrians	Research on (1) pedestrian safety concerns around transit (including bus stops, light and heavy rail, and streetcars), around at-grade rail crossings, and along railways and on (2) best practices related to transit access and increasing transit ridership through pedestrian facility improvement.	52
Development of National Service Level Criteria for Freeways and Multilane Highways with Four Lanes or More with Explicit Safety Impacts of Different Drainage Features	Roadside Furniture	The objectives of this research effort are to develop national service level criteria for functional drainage features (culverts, inlets, rutted pavement lanes that pond water, ditches, under drains, etc.) for freeways and multilane highways of four lanes or more.	51
Development of a Pedestrian Safety Prediction Methodology for Unsignalized Intersections	Pedestrians	The proposed research will develop a predictive method for geometric treatments for pedestrians at unsignalized intersections.	49
Systematic Data Management of Crashes on Shared Use Pathways	Shared Pathways	The purpose of this project is to develop recommendations for a national and standardized data management for shared use pathway crash and injury data: collection, analysis, and publication system.	49
Accessible Pedestrian Signals	Pedestrians	Research on APS devices, specifically the impacts and benefits for non-disability users, guidance on maintenance audits and protocol, as well as guidance on where APS devices are most beneficial and should be prioritized, or where fixed-time operation should be used.	49
Safety Impacts to Pedestrian at Different Levels of Visibility and Sightlines at a Roundabout	Pedestrians	A study of the safety impacts of lighting and other roadside elements such as newspaper boxes, shrubs, and other obstructions on driver-pedestrian visibility at roundabouts.	44
Animal-Vehicle Crash Severity Reduction Using Advanced Technologies along Freeways and Multilane Highways	Advanced Technology and ITS	This study will examine innovative ways to mitigate the damage from animal-vehicle crashes using traditional measures as well as advanced technologies. Since preventing such crashes has proven to be very difficult, this study will investigate ways to reduce the severity of the crashes.	43
Costs of Vehicle-Train Collisions At Urban And Rural Crossings	Highway-Railway	The objective of this research is to develop a cost model that takes into account direct costs from multiple perspectives that accrue as the result of a vehicle-train collision at urban and rural railroad grade crossings.	42

combined list of prioritized research, including both fundamental research and non-CMF applied research. While Table Q.1 appears to show a good distribution of the two types of research (i.e., not top-heavy with one or the other), it may be more appropriate to consider them separately. Reasons for separating the two types of research are discussed in the *Lessons Learned* section following this table. Tables Q.2 and Q.3 present the results separately for fundamental research and non-CMF applied research, respectively. Stakeholders may use the prioritized lists to help identify projects for funding. This is similar to the current method used to select NCHRP projects for funding, but the prioritized list will help to support the decision-making process.

Lessons Learned

This project is the first attempt to develop a formal method for prioritizing fundamental research and non-CMF applied research related to highway infrastructure safety. The prioritization method evolved through the course of the project. As such, there were several lessons learned and opportunities for further refinements as discussed below.

General Stakeholder Input

It would likely become too cumbersome to incorporate general stakeholder input in the prioritization process for fundamental research. It is also the goal of this project to develop a more quantitative method for prioritizing fundamental research, moving away from the traditional "voting" methods. With that said, stakeholders will play a vital role in the process, including the identifying research needs to be prioritized and helping to select the final list of topics for funding. The latter will be conducted once the list of research needs has been prioritized using the method described above.

Other Applications of Prioritization Process

The prioritization of CMF-based research is based on a highly rigorous and repeatable method. An attempt was made to develop a similar process for prioritizing fundamental research, but the method has proven to be impractical for a repeatable process. As such, the alternative method proposed in this project was developed for the prioritization of fundamental research. The team further determined that the prioritization method for CMF-based research would not be appropriate for non-CMF applied research. As such, the method proposed for fundamental research was adjusted slightly and used for the non-CMF applied research.

There are several factors and detailed data included in the prioritization of research. It would be useful to identify high-priority research (conduct initial screening to eliminate low priority topics) before collecting further details and completing the more rigorous prioritization process. This would reduce the effort in collecting detailed data for each proposed research project and limit the detailed data collection to those that pass the initial screening process. The proposed prioritization process for fundamental research includes eight factors. Several of these factors could be included in a modified weighting scheme to conduct an initial screen of CMF-based research. For example, target crashes (frequency and severity) would be a quick and easy method to screen potential research topics. However, target crashes alone could overlook important topics such as pedestrian and bicycle research. As such, the number, quality, and average effectiveness of existing CMFs could be included in the modified weighting scheme. These data are readily available from the CMF Clearinghouse. Stakeholder input would be another potential factor to include in the weighting scheme, but this would include a higher level of effort to solicit and summarize feedback.

Program Monitoring and Evaluation

For both fundamental and applied research programs, it is important to monitor and regularly (e.g., annually) evaluate the programs to ensure that they are providing the intended products. In addition, any benefits derived from fundamental research through subsequent use in applied research projects should be documented for use in future research prioritizations.

Separation of Fundamental and Non-CMF Applied Research

While the same method was applied to prioritize both the fundamental research and non-CMF applied research, it may not be appropriate to compare both types of projects side-by-side. Instead, it may be more appropriate to consider fundamental research and non-CMF applied research separately. The reason for this is that some of the factors used to determine the RUI are inherently different. For example, the factor related to the "Extent of Impacts on the Science of Safety" will likely favor fundamental research as these topics tend to have more far-reaching benefits compared to a specific non-CMF applied research project. Conversely, the probability of success is likely to favor non-CMF applied research projects as they tend to be less complex and shorter duration than fundamental topics.

CHAPTER 4

Plan for Long-Term Implementation of a National Research Agenda

Chapters 2 and 3 described the proposed methodology for providing a prioritized listing of both directly applicable research and fundamental research and documented the process followed by the research team in using the proposed methodology to develop an initial draft National Agenda. This final task documents a proposed plan for establishing a structure (1) to ensure that the development of the agenda continues on an annual basis, (2) to encourage coordination of National Agenda research funding, (3) to evaluate the quality of research conducted for the National Agenda projects, and (4) to monitor progress of the National Agenda in terms of determining if highly ranked projects are indeed funded and successfully carried out.

TRB Special Report 292 recommended some of what that committee felt was the necessary structure for this process, e.g., the establishment of an independent SAC with adequate staff and outside expert support. That report did not define all details of the necessary structure nor make a recommendation of where such an advisory body should be housed. The following narrative describes the project team's assessment of alternative structures or methods. The narrative provides an assessment of the advantages and disadvantages of different structures, without recommending a final structure. That decision will be made by the ultimate funder(s) of the National Agenda process.

Alternative Institutional Structures to Ensure Expert Advice for a Dynamic and Continuing Agenda

Goals and Basic Criteria for Best Structure

The goal of a long-term implementation plan is to establish a structure and process which will develop a National Agenda for infrastructure safety research. The National Agenda is viewed as a tool for use by all research funding agencies and independent researchers in deciding what projects they will fund and conduct. It is not to be a prescriptive document recommending who should fund the highly ranked research projects. Indeed, the research needs (projects) within the Agenda and the ranking of those projects will be independent of the goals and funding constraints of the current funders – thus the National Agenda will be composed of the best projects for the nation. The funding agencies will then follow their own goals and constraints in their choice of which projects they will fund, hopefully including highly ranked projects that may expand their scopes somewhat. The Agenda includes a mixture of applied research and fundamental research.

Before the advantages and disadvantages of different structures and management processes can be defined, there needs to be a concept of a "best structure" in mind. The "best structure" will be defined by a set of criteria. The goal is to design a structure that will ensure that (1) the above goals – best national projects and mixture of research types – are met, and (2) the National Agenda is accepted and used in research topic choice to the maximum extent possible by all the major funders and researchers. While there will be a variety of groups who will have input concerning potential research needs and who, it is hoped, will ultimately use the results of the National Agenda research (e.g., ITE, National Association of County Engineers, Association of Metropolitan Planning Organizations), the major agencies/groups who will fund and conduct the large majority of infrastructure safety research projects would include FHWA, AASHTO (NCHRP), state DOT research programs (again AASHTO) and universities. The structure needs to facilitate getting the higher priority research projects funded and done well so that they are successful. Thus the criteria for identifying the "best structure" are:

1. The structure necessary to conduct the data collection and analyses required in the methods proposed for development of a National Agenda.
2. The structure that will best ensure that the major funding agencies and the nation's researchers buy-in (look upon with favor and use) the National Agenda. (This criterion

is perhaps the most important in that "buy-in" refers to both continuing funding for the development and "selling" of the Agenda and funding of high-priority projects within the Agenda. Without this buy-in, even the best Agenda will be virtually useless.)

3. The structure that provides an *independent* collection and rating of both fundamental and directly applicable research projects regardless of goals and needs of individual funders – i.e., identifying projects that are best for the nation.
4. The structure that will best ensure a continuing (year after year) effort to improve the Agenda-setting process.
5. The structure that is more likely to be sustainable (funded) year after year, providing the necessary staff resources.

In the following text, a discussion of structural components required to meet each criteria will be presented. As will be introduced in the discussion of the first criterion, there are three basic needs common to all – a scientific advisory group, necessary staff, and a home/host for the structure. A fourth key decision concerns the update cycle for the Agenda – how often the Agenda-setting process will be implemented. The advantages and disadvantages of different forms of each of the four will be presented with respect to each criterion. Decisions on each will then determine the final structure.

Criterion 1. Structure Necessary to Use Proposed Agenda-Setting Methodology

As described earlier in this report, a proposed methodology for a ranked National Agenda of both fundamental and directly applicable research was developed by the project team and was used in establishing the initial Agenda. A summary of tasks necessary to conduct the proposed methodology is provided in Table 9. In general, each of the tasks will be conducted by either a group/committee of scientific advisors or by "staff." Two groups of external scientific advisors are proposed. From this point forward, the first group/committee of advisors who have more general duties will be referred to as a SAC (with no decision yet on whether this will be a non-structured group of advisors or a national-level committee). The second is the "TAP" who would provide specific inputs to the prioritization process. These inputs would include estimates of the percentage of specific site types—i.e., percent of signalized intersections—where a specific treatment could be applied. More detail on the TAP will be provided later in the discussion, but they are noted in Table 9.

The staff could either come from the host agency or from a contractor. (Note that "contractor" could include a safety-related University Transportation Center.) More discussion of pro's and con's of different "host" organizations and "staff" will be provided below under the discussion of alternative structures.

Table 9 provides both the necessary tasks and a preliminary assignment of each task to either "SAC," "TAP," or "staff." These preliminary decisions are based on the project team's knowledge of the details of each task. These decisions can be changed by the panel if necessary.

The cost of conducting these tasks to update the National Agenda in the future will be dependent on both the number of hours required and on staff wages. Staff hourly wages will depend on the staff home agency. While the eventual staff home or hourly wages cannot be determined at this time, an estimate of the number of hours expected to be required in each of the four major task categories shown in italics in Table 9 was developed based on the experience in this initial Agenda development effort. The first (RNS generation) and last (documentation and presentation) will require essentially the same number of hours regardless of how many RNSs are being studied. The effort required to conduct the actual ranking of both the applied and fundamental RNSs is determined by how many RNSs are being analyzed. For this total effort, we are estimating that approximately 50 total RNSs will be identified each cycle, of which 20 are Applied-CMF RNSs and 30 are either Fundamental or Applied Non-CMF RNSs.

The collection and refinement of the list of RNSs to be analyzed is estimated to require approximately 200 hours of staff time each time the National Agenda is updated. This estimate includes effort related to querying sources, requesting additional information from submitters and revising the RNSs, combining similar RNSs, specifying and adding road class-specific RNSs, etc. The sources expected to be queried include:

- AASHTO Safety Management Task Group
- HSIS Research Topics
- Input from FHWA Office of Safety and Office of Safety Research and Technology
- Knowledge gaps identified in work plans for future editions of the HSM
- Research Problem Statements from key TRB committees
- RNSs identified by the TRB Research Needs Statements Search Engine - search keywords "crash"/"accident"
- Unfunded high-priority NCHRP projects
- Other sources identified by the future project team, with input from the host agency and funders (or the NCHRP Panel if relevant)

The effort required to rank the fundamental and applied non-CMF RNSs is estimated at approximate 6 hours per RNS. This includes working with the RNS submitter to obtain input on expected research cost and proposed increases in knowledge and conducting the remainder of the tasks described

Table 9. Tasks required for developing and presenting a National Agenda (with proposed assignments).

Task	Assigned to
Develop Annual List of Potential Research Needs Statements (RNSs)	
1. Compile lists of new proposed RNSs for both applied (both CMF and non-CMF) and fundamental research from sources a. Check all sources indicated in Chapter 1	Project Director and Staff
2. Work with each individual submitter to clarify and complete the RNS, using the forms in Appendix N	Project Staff
3. Decide which RNS is Applied-CMF, Applied-Non-CMF, or Fundamental	Project Director and Staff
Ranking of Applied-Non-CMF and Fundamental RNSs	
4. Survey experts or conduct computer runs to develop needed inputs for each of the fundamental and applied Non-CMF RNSs. a. Determine the target crashes and applicable area type and facility type for each potential project b. Query GES Database to Obtain Number of Expected Target Crashes c. Query FARS Database to Obtain Severity of Expected Target Crashes d. Obtain expert input for: i. Extent of Impacts on the Science of Safety ii. Potential to Improve Existing Information for Target Crashes iii. Probability of Success e. Estimate Cost of Research f. Query the CMF Clearinghouse to Identify the “Potential to Identify More Effective Strategies for Target Crashes” (Staff) g. Determine Distance between Expected Research Results and Treatment-Related Decisions (Staff)	RNS Submitter and Project Staff Project Staff Project Staff Scientific Advisory Committee (SAC) SAC SAC RNS Submitter and Project Staff Project Staff
5. Determine scores for individual factors for each RNS	Project Staff
6. Apply RUI equation to produce priority rankings	Project Staff
Ranking of Applied-CMF RNSs	
7. Collect the needed inputs for each of the CMF RNSs and do the analyses to establish ranked priority. a. Conduct computer runs to develop needed inputs i. Number of candidate units – e.g., miles, intersections, curves ii. Crash distribution iii. Cost of target crash iv. Cost of implementation v. Estimated CMF and standard deviation before and after research b. Conduct spreadsheet runs to produce priority rankings	 Project Staff Staff and TAP Project Staff Project Staff Project Staff Project Staff Project Staff
Document Annual National Agenda and Present at an Annual Meeting	
8. Prepare annual report showing ranked list in all three areas	Project Staff
9. Host meeting of funders and present rankings a. Meeting logistics (Internal or contract Staff) b. Preside and answer questions (SAC and Staff)	Project Staff SAC and Staff

in detail in Chapter 2 and noted in Tasks 4–6 in Table 9 (e.g., conducting FARS and GES runs, extracting information on existing CMFs from the HSM and CMF Clearinghouse). It is estimated that Tasks 5 and 6—applying the RUI and finalizing the priority listing—would require approximately eight hours regardless of the number of RNSs analyzed. Thus, for the estimated 30 RNSs, this total effort would require approximately 188 hours per cycle.

The effort required to rank the applied-CMF Research Needs Statements is also estimated at approximately 6 hours per RNS. This includes those items listed in Task 7 of Table 9 and described in detail in Chapter 2. The three major efforts will be developing estimates of the number of candidate units to be affected, developing treatment implementation cost estimates and determining or estimating the CMF and its standard deviation before and after research. For the estimated 20 CMF-related RNSs, this would require approximately 120 hours per cycle.

Finally, it is estimated that documenting the Agenda in a report and distributing the report would require approximately 24 hours of staff time. An additional 40 hours of staff time would be required if the staff are involved in setting up and hosting the national meeting where the Agenda is publicly presented.

In total, for the scenario involving approximately 50 total RNSs, of which 20 are Applied-CMF RNSs and 30 are either Fundamental or Applied Non-CMF statements, the estimated staff time is approximately 570 – 600 person hours. As noted below, it is estimated that in addition to these hours, the overseeing of this effort will require significant dedicated effort on the part of a project director (e.g., 25% of full time, or approximately 500 hours per year), even if the remaining staff is contract staff.

Again, Table 9 and the effort-related discussion only concerns the tasks required to annually develop the National Agenda and present it to key potential funders. No tasks have yet been specified that would either increase buy-in, lead to an independent Agenda not directed to one specific funder, or lead to continual Agenda improvement.

Three key questions are raised by the preliminary task assignments in Table 9: What is the nature of the SAC? Where should the structure be "housed"? and How often should the Agenda be updated (i.e., annually, semi-annually, etc.)? These same three questions are also key determinants of whether the other criteria are met, and will be discussed again under each of those sections below. In each case, the discussion will be a comparison of alternatives. Combinations of the different alternatives related to the SAC, host, and update cycle provide a large number of possible structures for consideration.

Nature of the SAC. While *TRB Special Report 292* presented the opinion that the SAC should be a formal national committee including a balanced mixture of experienced safety program managers and knowledgeable researchers, there are other alternatives. Two alternative forms that will be compared in this and the following sections will be (1) a national committee and (2) a more limited group of advisors chosen by the host agency to provide the needed inputs. Whether the group would be paid or not would be the decision of the host agency. A third alternative—a "middle-ground" limited national committee—will be discussed later in the narrative.

As shown in Table 9, with respect to Criterion 1– implementing the methodology – there is only one task where the advisors are needed. In Task 6, inputs from experts are required in both the ranking of fundamental research and non-CMF directly applicable research. It is suggested that the fundamental research inputs would be from senior researchers very knowledgeable about what is known and not known in the safety field and whether or not specific proposed fundamental projects can help the safety field move forward. The inputs on non-CMF research would be provided by both researchers and senior safety administrators with knowledge of safety treatment implementation issues.

Given these limited Criterion 1 duties, either a formal committee or a more limited group could perform this one task adequately. The advantages of the smaller group would likely be lower cost and less effort required to appoint/hire and convene than if a committee were to be appointed.

Structure Home. The second key issue is where the structure that implements the National Agenda processed is to be housed – where is the best home for the structure? There appear to be three basic home options – FHWA, AASHTO, and TRB (funded by FHWA and AASHTO). A fourth alternative would be some other non-governmental agency with interest in infrastructure programs (e.g., AAA Foundation for Traffic Safety, Roadway Safety Foundation). However, looking ahead to the other criteria, in the opinion of the project team, there is no other non-governmental agency that can match TRB in terms of research reputation, availability of needed staff, or contracting expertise and experience in the infrastructure area. For that reason, the alternatives considered from this point forward are FHWA, AASHTO and TRB.

With respect to Criterion 1 – implementing the methodology – the major requirements would be the ability to reassign, hire or contract the needed staff and to direct their work. Given current economic conditions and limitations on new positions in both FHWA and AASHTO, it is likely that both would either contract out the process (including the project director duties) or reassign existing staff to meet at least the project director needs. [The project team does feel that oversight of this effort will require significant dedicated effort on the part of a project director (e.g., 25% of full time), even if the remaining staff is contract staff.] As is their normal working procedure, TRB could assign existing staff or hire new staff to oversee this effort and could contract for the needed staff. All three organizations could acquire the research and program management expertise needed for critical inputs. FHWA or TRB might be slightly more logical that AASHTO since both have worked more with researchers who can provide inputs concerning both fundamental and directly applicable research. AASHTO would have ready access to expert safety program managers.

Agenda Update Cycle. With respect to Criterion 1 – ability to implement the proposed process – it would appear that the Agenda could be updated (i.e., a new Agenda could be developed) on any chosen cycle – annually, every 2 years, every 3 years, etc. An annual cycle would appear to provide the necessary time needed to collect research needs and run the proposed process (as would all longer cycles). If funding for the project director is limited, a longer cycle (e.g., 2 years) would allow the tasks to be spread out over more time. A possible disadvantage of longer-than-annual cycles might be related to continuity of project director and staff. Cycles over 2 or 3 years might lead to project director (and staff) turnover with the inherent loss of experience and knowledge about the process, making the effort less efficient.

Criterion 2. Structure Best Ensuring National Agenda Buy-In

Establishing a "master list" of safety-infrastructure research priorities for the nation and trying to ensure *voluntary* coordination of research funding and conduct by all funders and researchers is a new way of doing business. Given this change, it appears important that the National Agenda has "stature" (i.e., is viewed as important on the national level), and that each of the major funding agencies (i.e., FHWA, AASHTO, State DOT Research Offices) and researcher groups (e.g., university researchers as represented by the University Transportation Centers [UTCs]) trusts that the agenda will include projects that meet their internal missions and needs and that they are "represented" in the Agenda development. This leads to the conclusion that the ideal structure should have the following characteristics:

- Includes a visible entity that can serve as a high-level national focal point for the National Agenda and that has one single mission – the continuing development, marketing, and improvement of the Agenda.
- Is composed of members who can provide liaison with the key funders to help ensure that the Agenda is acceptable and will be used and that each key agency has some "ownership" through representation.

Nature of the SAC. If these characteristics are indeed important, then for this criterion, an SAC that is a national-level committee would appear to have significant advantages over a smaller group of advisors. Such a committee not only could provide the necessary ranking inputs from both senior researchers and senior safety program administrators, but also could serve as the national single mission focal point. And if the membership is carefully chosen, such a SAC could provide the liaison role with all key user agencies/groups. (Recommendations on SAC membership under this model are presented at the end of this chapter under "National-Level SAC Membership.")

Structure Home. All three possible homes (i.e., FHWA, AASHTO and TRB) have extensive experience in establishing and hosting national-level advisory committees. The project team feels that having key safety positions represented by their current office-holders (e.g., Chair of the AASHTO Standing Committee on Highway Traffic Safety [SCOHTS], Director of the FHWA Office of Safety R&D) will increase buy-in. AASHTO (and probably FHWA) has established advisory committees with membership based to some extent on the position titles – ex-officio members. The TRB advisory committee model is usually based on individuals rather than offices. Conversations with NCHRP and TRB staff indicate that establishing a committee with ex-officio members within TRB is feasible if the committee does not fall under Section 15 of the Federal Advisory Committee Act (FACA). If the committee is subject to FACA Section 15, agency liaisons would be feasible, but not ex officios.

A second buy-in question related to the structure home concerns whether or not having the structure within either FHWA or AASHTO would affect buy-in by the staff and constituents of the other organization or buy-in by researchers? Both have a long history of cooperative efforts. At the same time, each has somewhat different sets of goals, stakeholders, and "bosses." Whether or not these differences would affect buy-in is probably a question best answered by the two organizations themselves. Based on the fact that both FHWA and AASHTO have a long cooperative working relationship with TRB and the fact that TRB is a "research" organization, it would appear that housing the structure within TRB would not raise any buy-in issues.

Agenda Update Cycle. With respect to buy-in, an annual cycle would keep the Agenda more "visible" to funders, researchers, and research users. Such a cycle would also parallel the current cycle of research needs generation by TRB committees, AASHTO, FHWA and others. In addition, an annual cycle of new/updated (ranked) National Agenda topics would parallel the current research-project-identification cycles of FHWA, AASHTO and the state DOT research programs. Keeping longer-cycle National Agendas as visible in "off years" would likely require additional emphasis on continual feedback to the key groups. (See more detail under the later discussion of "selling" unfunded highly ranked Agenda projects.)

Criterion 3. Structure Providing an Independent National Agenda

The issue here is which structure can best conduct the necessary collection of information about and rating of potential projects in order to produce an independent National Agenda, one not limited by the goals and constraints of individual funders. This independence is important to ensure that both categories of research are included and treated somewhat equally (i.e., directly applicable and fundamental research) and to maintain an unbiased Agenda in order to increase buy-in by all potential users. With respect to the latter, not only must the Agenda be independent, but it must also appear to be independent – face validity is important to buy-in.

Nature of the SAC. With respect to independence, there appear to be few advantages to a limited group of advisors who only provide inputs to the process. Such a group would likely be smaller and thus easier to appoint and coordinate meetings with. Whether or not they could fill the need of ensuring "equal treatment" (or appearing to ensure equal treatment) for the two types of research would depend on the membership of the group. The larger national committee SAC structure would be more likely to ensure equal treatment and the appearance of equal treatment due to the fact that it would need to come to agreement on endorsing a final Agenda, and to do so as a committee composed of proponents of both types of research.

Structure Home. One advantage of housing the structure within TRB would be what is essentially an "automatic" appearance of independence. With the exception of the NCHRP program (which is funded by the state DOTs and overseen by AASHTO) and other similar flow-through programs, TRB does not fund research and thus does not have and would not be seen as having potential biases in terms of either favoring fundamental or directly applicable research or which projects are highly rated. Even if truly independent, National Agendas produced at FHWA and AASHTO are less likely to be viewed as independent since all activities such as project information collection, development and interpretation of inputs and production of the final rankings would be conducted by an advisory group and project staff working directly for (and thus under the control of) the home agency. Thus, there is some question as to whether or not FHWA or AASHTO would be able to produce a truly independent Agenda. As noted above, each has internal goals and missions set by its stakeholders and bosses (i.e., state DOTs for AASHTO and Congress for FHWA).

Agenda Update Cycle. There do not appear to be any inherent advantages to shorter or longer cycles with respect to the real or perceived independence of the Agenda.

Criterion 4. Structure Ensuring Continual Improvement in Agenda-Setting Process

The project team feels that the research prioritization processes developed in the current project will allow a National Agenda to be developed. However, as the processes are used, there will undoubtedly be improvements that can be made. Identifying such potential improvements will require careful monitoring of the success of the process by a review body that is intimately involved in its implementation. Inputs to the review body on process problems and needed improvements are likely to be initiated by the project director and staff who conduct the processing tasks. The review body would then review these issues and suggested improvements and determine which should be made and how best to make them. Some corrections and improvements will be no or low cost, where implementation will only require careful definition of the needed change and direction to the staff to implement them. Others may require additional effort which will require funding. For example, the current process uses different methods for the two types of directly applicable research – CMF research and non-CMF research. If deemed important in the future, this could be changed. The structure of the Agenda-setting process will affect whether such continual improvement can be achieved.

Nature of the SAC. The advantage of a smaller advisor group doing the process monitoring would likely be the cost of the effort. The disadvantages would be (1) the group would have been formed for scientific and research implementation inputs rather than for process review, and (2) the group would not be a governance body who could direct that the necessary changes be done or that would have access to or control over improvement funding. The national committee level SAC would have a broader range of program improvement expertise and more influence over improvement funding. Changes made by the national committee would be more likely to be viewed as "unbiased" due to the diverse membership.

Structure Home. If the smaller advisory group is chosen, any of the three potential "homes" would work. However, as noted above, the home agency will have to take more responsibility for both reviewing staff input and defining improvements. If the home agency were located within FHWA or AASHTO as opposed to TRB, there is some question as to whether or not changes identified and funded would be viewed as agency-independent. There is also the question of whether the majority of funding for the changes would have to come from the host agency. If the larger national-level committee approach was chosen, it would appear that these potential disadvantages of hosting by FHWA or AASHTO would be lessened given that the advice is being provided by a larger, multi-agency review body.

Agenda Update Cycle. If the SAC is to be used as the body that reviews staff suggestions for process improvements, an annual cycle could help ensure more continual SAC input due to the fact that they would be meeting and discussing improvements each year. Conversely, if a major modification to the process is needed often, then a longer cycle (e.g., 2 years) would provide more time for the improvement to be made.

Criterion 5. Structure More Likely to be Sustainable over Time

The issue here is whether or not the type of advisory group and home of the structure will affect long-term funding of the National Agenda process. In the opinion of the project team, whatever the structure, it will only be sustainable over the long term if funded by both FHWA and the state DOTs (likely through AASHTO). While there may be other possible sources of funding (e.g., Congressionally mandated funding), this is viewed as unlikely to occur. Even if it did, the funding would still ultimately draw down either state DOT funds or FHWA funds. Funding from other Agenda users (e.g., universities, private research funders such as the AAA Foundation for Traffic Safety) would not be likely.

Nature of the SAC. A smaller advisory committee would be less expensive. A larger national committee SAC would be more expensive, but would also have members who are more directly tied to both FHWA and AASHTO, perhaps increasing the probability of long-term joint funding by both organizations.

Structure Home. The structure home might affect both the "ease" of structure funding and the "amount" of structure funding. With respect to the former, both FHWA and AASHTO have established means of providing funding to TRB for projects. If housed within AASHTO, FHWA can enter into agreements with AASHTO to fund joint activities. The project team is not sure if there are ways for AASHTO to transfer structure funding to FHWA if the structure were housed there. FHWA has established a "pooled fund" mechanism for research funding allowing them to use money provided by individual state DOTs. The question of whether or not this mechanism could be used for a project which would be funded by all states and would be a continuing long-term effort would have to be answered by FHWA.

With respect to structure home and "amount of funding," long-term funding could depend on the level of cost. Whether a structure housed at FHWA, AASHTO or TRB is inherently less expensive is again a difficult question to answer. If, for example, FHWA set the program up internally, it would need to fund the internal staff overseeing the effort, the internal or contractor staff doing the tasks, the SAC meeting, etc. We would assume that contractor cost would be approximately the same for both FHWA and TRB and that internal oversight staff cost would be approximately the same. (Again, this is an assumption since we have no information on differences in salary levels.) It appears that TRB would add an overhead cost to the effort. While overhead costs are always present in any organization (e.g., housing, administrative staff, etc.), it would be difficult to define the level of overhead cost if housed internally at FHWA.

Finally, just as with the issue of buy-in, there is the question of whether housing the structure in either FHWA or AASHTO would affect the likelihood and degree to which the other organization would provide long-term funding. This is again a question best answered by the two organizations themselves.

Agenda Update Cycle. A longer cycle would clearly be less expensive than an annual cycle. If long enough, a longer cycle might make it possible to update the Agenda through the normal NCHRP funding mechanism. The question here would be how often the AASHTO committees overseeing the NCHRP process would allow a repeat of the same project to be funded.

Summary

The above narrative has provided a discussion of some of the key issues that must be addressed in choosing the best institutional structure for the National Agenda. Five criteria of a "best structure" were identified, and advantages and disadvantages of different forms of the advisory committee, different homes for the structure, and different Agenda update cycles were presented. No conclusions were drawn as to which is best, leaving that decision to the ultimate funder(s) of the National Agenda process. In that discussion, two basic advisory group "sizes" were discussed—a limited advisory group and a national committee level SAC. Specific suggestions on membership for both a larger national committee level SAC and a mid-sized SAC will be presented at the end of this chapter since the choice of members is also related to the issues raised in the following sections—means to encourage coordination of National Agenda research funding, methods for evaluating the quality of research on National Agenda topics, and means of monitoring the progress of the National Agenda to determine if the higher-ranked projects are being funded and conducted.

Encouraging Coordination of National Agenda Research Funding

As has been noted numerous times in the above discussion, there will be multiple sources of possible funding for research topics ranked highly in the National Agenda. The key phrases here are "multiple sources" and "possible funding." Without some form of coordination among funders and independent researchers, the portfolio funded and conducted could be very thin (i.e., very few or no high-ranked projects funded) or could include unplanned and unneeded duplication of projects. The goal of such coordination is to ensure effective use of what will always be limited research funds by eliminating this unnecessary duplication and by ensuring that high-priority research is funded.

However, coordination here cannot be the result of "control." The committee that prepared *TRB Special Report 292* held a workshop of representatives of many of the research funding agencies (e.g., AASHTO, FHWA, AAA Foundation for Traffic Safety [AAAFTS]) and organizations representing researchers (e.g., UTCs). The clear message from that workshop was that coordination could not be "prescriptive." The committee concluded that efforts to coordinate Agenda research could only succeed if they were " . . . voluntary; easy to understand, communicate and implement; and sufficiently flexible to accommodate the different needs and approaches of the diverse funding organizations."

Given that (realistic) restriction to voluntary coordination, there is a need for (1) a national focal point for the Agenda – an organization or group that all users can look to for continual guidance and information, (2) a major annual "event" when the Agenda is presented and discussed by users, (3) a mechanism for continual tracking of Agenda project funding so that users know what has and has not been funded, and (4) other means of "selling" the un-researched higher-ranked projects to key funders and independent researchers.

National Focal Point

Discussions of alternative forms of the SAC and different homes for the National Agenda institutional structure were presented in the preceding sections. Decisions on these two issues will, in a sense, determine the national focal point. This focal point could be an office within FHWA or AASHTO or the national-level SAC. *TRB Special Report 292* recommended that this focal point be the national-level SAC. Whatever decision is made, there should be some well-advertised "contact point" for questions and inputs and to keep the Agenda "visible."

Presentation of the National Agenda

Again as recommended in *TRB Special Report 292,* the project team would suggest that the National Agenda be presented to the potential users at a national meeting held each year that a new Agenda is prepared. While this could be part of other national forums (e.g., the TRB annual meeting, AASHTO annual meeting), the attendance of the appropriate representatives of all the user groups may well require that it be a separate meeting. If the national committee level SAC is chosen, a separate meeting would also allow the members to conduct other business (e.g., discussions of changes in the procedures, possible funders for highly ranked but unfunded projects from the past year, etc.). The timing of the annual completion and presentation of the Agenda should be scheduled such that high-priority projects can be incorporated into the request-for-proposal cycles of at least AASHTO and FHWA. The date should be at least 1 to 2 months before RNSs are due to NCHRP (Subcommittee on Research Standing Committee on Research [SCOR]) and before FHWA needs them for budgeting processes.

Continual Tracking of National Agenda Project Funding

While an annual meeting will begin discussions among users concerning who might fund individual higher-ranked projects, final decisions are almost certain to be made after the meeting and independently within each funding agency/researcher group. Avoiding duplication and trying to ensure that higher-ranked projects are ultimately funded and conducted will require continual tracking of the status of high-ranked projects and the communication of this information to all funders and researchers. The project team would suggest that a National Agenda website be developed and hosted. The site would provide users with descriptions of each highly ranked RNS and would show its current status (e.g., funded, ongoing, no current action).

The project director and staff would be responsible for continually tracking funding and updating the website. Tracking funding by FHWA and AASHTO will require review of their "ongoing projects" listings and periodic (e.g., monthly) phone calls with key staff within each organization. Research and Innovative Technology Administration (RITA) maintains a Research Hub (http://ntlsearch.bts.gov/researchhub/index.do) that includes research projects from the Office of Safety Research and Development, the Office of Safety, and the Exploratory Advanced Research Program (EARP). A separate database of safety research and development projects is at http://www.fhwa.dot.gov/research/tfhrc/projects/. This can be searched for key words (e.g., safety). Both sites are updated approximately once per year, but not each time a new project is funded. Thus, there is a need for the personal contacts for more updated information.

Tracking of the funding of Agenda projects by state DOTs would be more complex, but may be possible by continual review of TRB's Research in Progress (RiP) database (http://rip.trb.org/). Agenda project funding by universities from non-state DOT sources will likely be more difficult, but again may be possible through the RiP website. In addition, the National Agenda website could be designed to allow researchers to enter information on National Agenda research they are conducting, helping in the tracking task.

Selling Unfunded National Agenda Projects

While the National Agenda website described above could be a primary mechanism for convincing funders and independent researchers to fund high-ranked projects, the diversity of organizations and groups involved in infrastructure safety research will require that additional methods be used. Indeed, it is likely that different methods may be required for the different agencies/groups. If the chosen form of the advisory group is a national-level SAC, one of their duties could be to develop such marketing methods. This would appear promising if the membership includes representatives from each user group, since each would have some idea of how best to market within their group.

FHWA. The key targets within FHWA would be the Office of Safety Research and Development, the Office of Safety, and the EARP. Strategies could include:

- Possible inclusion on the SAC of one or more of the directors of these three programs.
- National Agenda project director to hold periodic (e.g., quarterly) meetings with each director.
- Email notice to directors and their designated contacts when a change occurs on the National Agenda webpage regarding project funding.
- If requested by the directors, project director meetings with staff in these offices to discuss National Agenda contents, progress, and issues.

State DOTs/AASHTO. Marketing National Agenda projects to state DOTs and AASHTO will require efforts in two different paths—input to the NCHRP funding stream and inputs directly to State DOT Research Offices.

For NCHRP:

- Possible inclusion on the SAC of the AASHTO Highway Safety Program Manager.
- Possible inclusion on the SAC of one or more of the following – Chair of AASHTO SCOR, Chair of AASHTO SCOHTS, Chair of SCOHTS Safety Management Subcommittee, Chair of AASHTO Subcommittee on Design and Traffic Engineering.
- Present National Agenda and information on unfunded projects to SCOHTS annual meeting.
- Email notices to the Safety Program Manager and all four AASHTO Chairs and their designated contacts when a change occurs on the National Agenda webpage regarding project funding.
- Prepare and submit project statements to NCHRP—Project director will work with AASHTO and FHWA SAC members and their designees to determine which high-ranking projects have a good chance of AASHTO funding, and to determine which technical or subcommittee in AASHTO (e.g., Subcommittee on Safety Management, Technical Committee on Roadside Safety, Technical Committee on Non-Motorized Transportation, etc.) they should be submitted to. The staff would then prepare the necessary project applications and work with the appropriate SAC members from AASHTO and FHWA to have them submitted.

For State DOT Research Offices:

- Possible inclusion on the SAC of the Chair of the AASHTO SCOR's Research Advisory Committee (RAC).
- Distribution of National Agenda to State DOT Research Directors – Upon completion of National Agenda each year, the project director would work with the RAC Chair or other AASHTO representative on SAC to communicate the National Agenda and the list of unfunded highly ranked research from the prior year to each RAC member.
- Email notices to each RAC member when a change occurs on the National Agenda webpage regarding project funding.
- Present National Agenda and information on unfunded projects at the RAC annual meeting (preferable by RAC chair or other RAC member involved with SAC).

University Researchers. Some university researchers (including both faculty and graduate students) will conduct National Agenda research funded by FHWA or AASHTO. However, a large part of their research will be funded by either state DOTs or UTCs, or use little or no funding (i.e., graduate student research). The topics for this research will, to a large extent, be generated by the researchers themselves. The goal of the National Agenda marketing effort will be to have them choose to do National Agenda projects. Ideas for such marketing include:

- Possible inclusion on the SAC of the Director of the UTC program within the RITA's Office of Research, Development and Technology.
- Possible inclusion on the SAC of an officer of the Council of UTCs (CUTC), to be chosen by CUTC. The officer chosen would preferably have safety knowledge and expertise.

- Distribute annual National Agenda to all members of CUTC and alert them of webpage location and function.
- Identify and communicate with safety research units/departments in universities—Project staff would identify a list of universities, centers, departments or units who conduct safety research; identify a contact (e.g., a faculty member with an infrastructure safety research background, a center director); and distribute the National Agenda to them. CUTC members can be identified as those having a safety-related theme.
- Send email notices to each identified university safety research contact when a change occurs on the National Agenda webpage regarding project funding.
- Possible inclusion on the SAC of two representatives from TRB committees within the Safety and Systems Users Group, one representative from committees within the Design and Construction Group, and one representative from committees within the Operations Section. These representatives could be either chairs or experienced members of committees, but each would be expected to have significant experience with and knowledge of infrastructure safety research.
- Distribute annual National Agenda to chairs of pertinent TRB Committees (including information on webpage location and function) and ask them to distribute to their committee members.
- Prepare and present information on National Agenda and unfunded projects to pertinent committees at the TRB annual meeting.
- Explore possibility of incentives for conducting highly ranked research—UTC research using grant funding currently requires some percentage of matching funds from another source. Staff would work with RITA and Congressional staff to determine if the matching guidelines could be reduced for conducting research of any "Top 10" unfunded National Agenda projects.

Other Funders. The above organizations and agencies fund and conduct the majority of infrastructure safety research in the United States. There are, however, a small number of other private organizations who have funded such research in the past. Key agencies include the AAA Foundation for Traffic Safety and the Insurance Institute for Highway Safety. There may be other groups who need to be identified. The only proposed limitation here would be to agencies and organizations whose research is published openly rather than being conducted for internal use only. Project staff could identify key groups of other funders of public research, introduce the National Agenda to them, invite representatives to the annual meeting, distribute National Agenda information to them after the annual meeting and email notices to representatives when a change occurs on the National Agenda webpage regarding project funding.

Evaluating the Quality of Research Conducted for the National Agenda Projects

The overall goal of the National Agenda is to improve infrastructure safety research through better choices of projects that are funded (i.e., research project prioritization) and the use of the best research methods possible for the chosen projects. Determining whether or not "best methods" were used requires the specification of those methods for each research type. Thus, this section concerns how the quality of the research conducted under the National Agenda can be evaluated.

This discussion is divided into six sections. The first five sections and corresponding objectives include the following.

1. *Access to Publications and Ongoing Research*—Identify ways to gain access to new publications for CMF-related applied research, non-CMF-related applied research, and fundamental research.
2. *Quality of Applied Research (CMF-Related) Proposals*—Define methods for evaluating the quality of proposed CMF-related research.
3. *Quality of Fundamental and Applied Research (Non-CMF) Proposals*—Define methods for evaluating the quality of proposed Fundamental and Non-CMF Applied Research.
4. *Quality of Applied (CMF-Related) Research*—Define methods for evaluating the quality of completed CMF-related research.
5. *Quality of Fundamental and Applied (Non-CMF) Research*—Define methods for evaluating the quality of completed Fundamental and Non-CMF Applied Research.

A final section, "Inclusion of Research Quality Evaluations in the National Agenda Process," contains suggestions concerning how the different evaluations might be conducted within the proposed National Agenda process.

Access to Publications and Ongoing Research

Access to related publications and ongoing research is essential to the long-term implementation of the National Agenda. Literature searches help to determine if research has been completed on a given topic and a detailed review of the completed work helps to determine the quality of the results. Thus, this access is needed by both the submitter of the RNSs (i.e., potential National Agenda project) and by the Agenda staff. If a potential research topic has not been investigated, then it may be considered for prioritization in the National Agenda. Similarly, if research has been completed on a given topic, but the research was not of sufficient quality, then it may be considered for prioritization in the National Agenda.

On the other hand, it would not be necessary to expend resources (time and money) on a topic that has received sufficient attention. Unfortunately, this can (and does) occur when the various funding and research agencies fail to communicate and share results of completed efforts. As such, there is a need to identify ways to gain access to new publications and achieve a uniform and comprehensive process aiming to find most, if not all, research publications.

A centralized database would enhance access to publications and help to improve knowledge-sharing among the funding and research agencies. The Transport Research International Documentation (TRID), now maintained by TRB, is an example of an integrated database that combines the records from TRB's Transportation Research Information Services (TRIS) Database and the OECD's Joint Transport Research Centre's International Transport Research Documentation (ITRD) Database. TRID provides access to nearly one million research records worldwide.

Currently, each research agency typically posts completed research on their website, which may or may not be posted to TRID. If all research agencies would agree to coordinate and contribute their research publications to a central location such as TRID, the search for new publications would be simplified. The posting could include special key words (e.g., roadway, safety, and infrastructure) that would further enhance the search for research related to the National Agenda. This could be facilitated by assigning one person within each research agency to communicate completed research to TRID on an annual, semi-annual, or ongoing basis.

Another component to enhance the efficiency of a National Agenda is ongoing research. Similar to completed research, it is useful to know about ongoing research related to a given topic and the expected outcome of the study. TRB's RiP website is an example of a central repository for ongoing and recently completed research. The website allows users to search for research by various fields, browse project records by subject, look up individuals and organizations, subscribe to email notifications of new RiP records, and submit current research projects. The data-entry system allows users in state DOTs, the U.S. DOT, UTCs, and other U.S. DOT-funded universities to add, modify, and delete information on their current research projects. Non-DOT persons can submit with an online form.

Quality of Applied Research (CMF-Related) Proposals

The quality of proposals to conduct CMF-related applied research can be assessed using the *Recommended Protocols for Developing Crash Modification Factors* (Carter et al., 2012), which was developed as part of NCHRP Project 20-07, Task 314. The focus of this document is on the quality of studies producing CMFs. The primary objective of these protocols is to describe what pieces of the research study should be documented by the study authors and how various potential biases should be addressed. Specifically, there are three primary sections as discussed below.

- Knowledge section – presents basic knowledge on each of the study types that can be used to develop CMFs and other basic issues related to the development of CMFs. It features a description of potential issues that can bias the study results and recommendations as to how these biases should be addressed.
- General documentation – provides a list of the general details on the research study that can be used to determine where it is appropriate to apply the CMF.
- Biases documentation – provides a list of the potential biases for each study design.

Table 10 and Table 11 are adopted from the above protocols and identify the various sources of potential bias that should be considered and addressed during before-after and cross-sectional studies that seek to produce CMFs. In determining the quality of proposed research projects to develop CMFs, the reviewers should ensure that the study plan either adequately addresses each issue or dismisses the issue as not applicable with supporting evidence or explanation.

Quality of Fundamental and Applied Research (Non-CMF) Proposals

There are no existing protocols for the conduct of non-CMF-related applied or fundamental highway safety research. As such, it is appropriate to adhere to the general principles and guidelines of conducting research. The following are potential criteria to assess the quality of non-CMF-related applied and fundamental research proposals.

- Quality research proposals should provide a clearly identified and unambiguous statement of the research objectives and questions.
- Quality research proposals should identify the target audience and intended use of the research results.
- Quality research proposals should provide a thorough and accurate representation of previous related research conducted at national and international levels, reflecting consideration of various perspectives.
- Quality research proposals should identify *how* the research is to be conducted rather than simply stating *what* will be done.
- Quality research proposals should provide justification for the methods, procedures, and equations used. Justification should be based on current peer-reviewed research or scientific reference documents that are cited.

Table 10. Potential issues and opportunities related to before-after studies.

Potential Issue/Bias	Opportunity to Address Issue/Bias
Regression-to-the-mean	Employ a reference group and the empirical Bayes methodology.
Changes in traffic and pedestrian exposure	Use annual exposure data to develop an SPF for use in an Empirical Bayes (EB) analysis. Employ a comparison site design.
History trends	Use a suitable comparison group.
Underlying crash trends in before period	Employ reference or comparison group to determine general crash trends in before and after periods.
Changes in crash reporting	Identify any changes in crash reporting and properly account for those changes by modifying the study period or adjusting the expected crash frequencies accordingly. Employ a reference or comparison group to account for these general temporal changes.
Accounting for state-to-state differences	Select reference and comparison sites from same states as treatment sites. Employ method developed by Hauer (1997) for combining data from multiple jurisdictions in development of CMFs.
Suitability of comparison or reference groups	Employ method developed by Hauer (1997) for examining the suitability of reference/comparison groups.

Table 11. Potential issues and opportunities related to cross-sectional studies.

Potential Issue/Bias	Opportunity to Address Issue/Bias
Accounting for state-to-state differences	Include indicator variable in model to identify respective state/jurisdiction for each site.
Selection of appropriate functional form	The current state-of-the-practice is to assume a log-linear relationship between crash frequency and site characteristics. However, other forms may be more appropriate in some circumstances.
Correlation or collinearity among independent variables	Assess the extent of the issue by examining the correlation matrix of the estimated parameters.
Over-fitting of prediction models	Apply cross-validation by randomly dividing the dataset into two parts, where one part is used for estimating the model and the other part is used for validation. Use relative goodness of fit measures such as the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) that penalize models with more estimated parameters.
Low sample mean and sample size	Select a subsample with lower mean than the full sample and estimate model coefficients to check the stability of the parameter estimates and over-dispersion parameter. Plan for appropriate data collection to obtain an adequate sample size.
Bias due to incompleteness, aggregation, or averaging of data	Avoid aggregating multiple years of data in a single observation.
Temporal and spatial correlation	Employ full Bayes modeling techniques if spatial correlation is a concern. Consider generalized estimating equations, random effects models, and negative multinomial models.
Endogenous independent variables	Employ simultaneous equations techniques.
Omitted variable bias	Use matched pairs where pairs of sites are selected such that their characteristics are similar except for the treatment of interest.
Misspecification of structure or systematic variation and residuals	Employ an appropriate model form such as the negative binomial model discussed previously.
Correlation between crash types and injury severities	Employ simultaneous estimations of multiple models.

- Quality research proposals should identify potential challenges to conducting the research and identify (as necessary) opportunities to overcome these challenges. If the research team cannot identify opportunities to overcome the challenges, then the proposal should identify how those challenges will limit the results of the research.

Quality of Applied (CMF-Related) Research

FHWA's CMF Clearinghouse and AASHTO's HSM are two national sources of CMFs. Both the CMF Clearinghouse and the HSM incorporate a review process of CMFs and provide an indication of the quality of the CMF based on the quality of the study from which it was produced. The two review processes are discussed below and are options for assessing the quality of completed CMF-related applied research projects.

CMF Clearinghouse. The intent of the CMF Clearinghouse is to present all available CMFs, regardless of quality. In this manner, users of the Clearinghouse are provided with the full knowledge of the CMFs that have been published and may select which CMF is most appropriate for their situations. They are guided in their selection by the star quality rating, indicating which CMF is likely to be the most accurate and reliable, and the details about the CMF, indicating which situations are appropriate for its application.

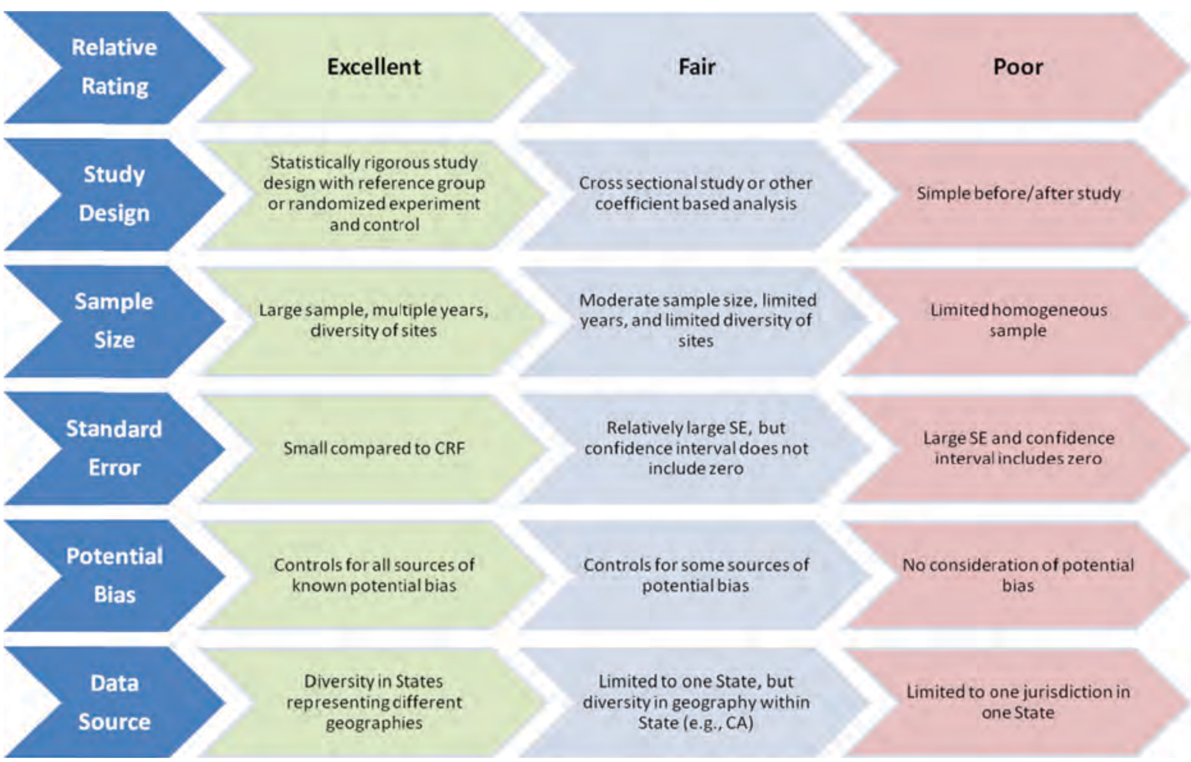
The CMF Clearinghouse review process rates the CMF according to five categories—study design, sample size, standard error, potential biases, and data source. A rating of Excellent, Fair, or Poor is first assigned to each of the five categories.

Figure 6 shows a description of the ratings for each category. A point-based system is used to provide a more quantitative translation from these categories to the star rating. Points are assigned to each of the five categories based on the level of rigor (Excellent = 2 points, Fair = 1 point, or Poor = 0 points). While the points decrease from Excellent to Poor, not all characteristics receive equal weight. Specifically, the study design and sample size categories receive twice the weight of the other characteristics. The final quality rating is based on the weighted score from Equation 1.

$$\text{Weighted Score} = 2 * SD + 2 * SS + SE + PB + DS \quad (1)$$

Where:

SD = score assigned to study design category.
SS = score assigned to sample size category.
SE = score assigned to standard error category.
PB = score assigned to potential bias category.
DS = score assigned to data source category.



Note: CRF=Crash Reduction Factor. SE=Standard Error.
Source: CMF Clearinghouse, http://www.cmfclearinghouse.org.

Figure 6. CMF Clearinghouse rating criteria.

Table 12. CMF Clearinghouse weighted score and associated star rating.

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

The star rating is assigned based on the weighted score. Table 12 shows the range of weighted scores and the associated star rating. It should be noted that information may be missing from a study report for specific characteristics such as sample size. In these cases, the rating is based on available information and the CMF will likely receive a lower rating due to the lack of information.

Highway Safety Manual (HSM). While the CMF Clearinghouse includes all available CMFs, the HSM Part D presents only the single best CMF for any particular countermeasure. There is a formal review process and strict inclusion criteria for the HSM and other indications to denote the relative level of confidence for a CMF. During the review process, an adjustment factor is applied to the CMF if it is necessary to correct for regression-to-the-mean and/or traffic volume bias. A method correction factor is also applied to the standard error of the CMF to correct for the study design and potential confounding factors.

The HSM inclusion criteria include accuracy, precision, and stability. Ultimately, the inclusion process filters CMFs so that those with standard errors of 0.1 or less (after rounding to the first decimal) are considered sufficiently accurate, precise, and stable to be included in the first edition of the HSM. However, the HSM also includes CMFs with standard errors of 0.2 to 0.3 when it is necessary to account for the effects of the same treatment on other facilities, other crash types, or other severities. The adjusted CMFs and standard errors are assigned bold and italic notations in the final list based on ranges of the adjusted standard error. Bold font denotes the most reliable CMFs, identifying those with a standard error of 0.1 or less. Less reliable CMFs have standard errors of 0.2 or 0.3 and are indicated with italic font. There are also footnotes to indicate if the CMF is not statistically different from 1.0 at the 0.05 significance level. The details of the inclusion criteria can be found in, *Methodology for the Development and Inclusion of Crash Modification Factors in the First Edition of the Highway Safety Manual* (Bahar et al., 2010).

Summary. The CMF Clearinghouse and the HSM consider similar factors to determine the quality of a CMF, including the study design, standard error of the CMF, and potential biases. The CMF Clearinghouse differs from the HSM process in that it does not attempt to adjust the standard error of the CMFs and includes additional factors (i.e., sample size and data source) in the review process. These are the primary sources of national CMFs and the related efforts will continue to identify and assess CMFs for roadway infrastructure improvements. This will ensure that CMF-related applied research will be evaluated and shared with others.

Quality of Fundamental and Applied (Non-CMF) Research

Efforts such as the CMF Clearinghouse and HSM do not exist to assess the quality of non-CMF-related applied or fundamental research. This section discusses opportunities to assess the quality of completed non-CMF-related applied and fundamental research.

There is a wide range of possible non-CMF-related applied and fundamental research topics. As such, any post-completion evaluation criteria need to be broad, yet specific enough to determine the quality of the research. The following are potential criteria to assess the quality of non-CMF applied and fundamental research.

- High-quality research contains new methods, procedures, or equations that focus on understanding or explaining *causation* rather than merely finding statistical association.
- High-quality research explores methodological linkages for new methods, procedures, or equations that are logical, transitioned, and defensible on an empirical or theoretical basis.
- High-quality research references peer-reviewed research or scientific reference documents as a basis for the derivations and theory used to develop the new method, procedure, or equation. A thorough and accurate representation of previous related research should also be provided, reflecting consideration of various perspectives.
- High-quality research documents the mathematical derivations (and theoretic basis if relevant) at a level of detail that others could replicate.
- High-quality research demonstrates the merit of the proposed new method, procedure, or equation by comparing it with currently used methods, procedures, or equations using a common database (with all relevant variables represented in it). If the new technology is intended to provide more accurate results, then the database should be derived from simulation with known underlying relationships between independent and dependent variables.

- High-quality research conducted in an objective manner with an unbiased perspective presents:
  – A clear and unambiguous statement of the research objectives and questions.
  – The target audience and intended use of the research results.
  – A thorough and accurate representation of previous related research conducted at national and international levels, reflecting consideration of various perspectives.
  – The methods, procedures, and equations used. Justification should be based on current peer-reviewed research or scientific reference documents that are cited.
  – A detailed discussion of data collection methods and summary statistics of any data that were used to conduct the research.
  – The research results and results of a validation task (where applicable). Results should include (1) a quantitative (graphical or tabular) comparison of the new procedures or equations with related procedures or equations from previous work and (2) an explanation for the observed differences. The discussion of results should recognize and discuss alternative interpretations of the research findings.
  – Recommendations for implementation of the research results. If recommendations include a new procedure or equation, then an example should be provided to clarify the intended application.
  – Potential biases and limitations of the research. This may include a discussion of opportunities for future research to build on the current results and overcome the identified limitations.

Inclusion of Research Quality Evaluations in the National Agenda Process

The above discussion suggested ways to improve access to ongoing and completed research projects and evaluation methods for both National Agenda research proposals and final research publications. The remaining questions concern how these improvements and evaluations might be incorporated into the Agenda process.

Ongoing Research. With respect to access to ongoing research, as noted both in this section and in an earlier session concerning "Continual Tracking of National Agenda Project Funding," TRB's RiP database will be a primary source of information. While input for NCHRP, state DOT research and University Transportation Center research is required by the funding agencies, research projects research conducted under other funding may or may not be. If the National Agenda funders or SAC members wish to get involved in better overall RiP reporting, one suggestion would be a more detailed examination of the source of projects not reported to or updated in RiP, and communication from the SAC or host agency to them noting why such reporting is important to the National Agenda. In a more narrow sense, for National Agenda projects, the funding agency could be encouraged to require the contractor to enter information in RiP. In addition, since funding of Agenda projects will likely be tracked, the project staff could ensure that an entry is present in RiP and, if necessary, enter information themselves.

Completed Research. Developing methods for improving inclusion of completed research entries in TRIS (and thus, TRID) would likely require detailed information on what is not being included now and exploration into the reasons why. However, since projects conducted under the National Agenda will likely be tracked until completion, a final step would be for project staff to ensure that an entry for all Agenda publications is included in TRIS. This can be done by sending information on the entry by email to tris-trb@nas.edu. There is usually a 2- to 3-month lag between publication and entry in TRIS.

National Agenda Research Proposals. The issue here is how best to incorporate the use of the proposal evaluation criteria suggested above into the National Agenda research process. For National Agenda projects funded by NCHRP, there will be an established oversight panel including one or more researchers. The panel members could be asked to use these criteria in their proposal review efforts. Since a detailed work plan is usually the first project task, the project panel could also use the criteria in that review. For complex projects where more research methodology input is needed, additional work plan review (using the criteria) could be requested of a small group of chosen researchers. Suggestions of reviewers could be made by the Chair of the pertinent TRB Committee.

FHWA would not have such external proposal review panels for their National Agenda projects, but could have these criteria used by their internal proposal review teams. In addition, once the project is awarded, FHWA could consider requesting external review of the detailed work plan by qualified researchers not involved in the project.

Reviews of National Agenda research proposals submitted to state DOTs would be difficult to initiate, primarily because the existence of the project may not be known until awarded. The same would be true of Agenda research conducted by independent researchers. Once identified by National Agenda staff (e.g., in RiP), the home agency or SAC could contact the state DOT or researcher and ask if they would desire (or agree to) a review of the work plan by a small group of external researchers. If so, the home agency or project director could then identify reviewers and coordinate the review. Again, if the review is not required during the time of normal TRB paper reviews, the pertinent TRB Committee might be an excellent source of reviewers.

National Agenda Completed Research Reports. For CMF research, the above review criteria are likely to be used without additional effort if the research is submitted to the CMF Clearinghouse or the HSM. The project funder could require that the final report and results be submitted to both these organizations.

For non-CMF and fundamental research, the use of these criteria is not likely without additional effort since they are new. For these reports, it may be necessary that a special peer-review team be established for each National Agenda final report by the home agency or SAC project staff and that they are asked to use the above criteria in their review. Project staff would coordinate the review and provide a report to the funding agency, who would then decide what action to take. Again, TRB Committee Chairs would be sources of possible reviewers.

Monitoring Progress of the National Agenda

In order for the National Agenda to be successful, the high-priority topics must be funded and researched. Given limited safety-infrastructure research funds, unintended duplication of projects must be minimized or eliminated. The word "unintended" is used here since duplication of research is not always a bad thing (e.g., evaluation of the same treatment under different conditions with knowledge of the prior study would be very useful). While monitoring could be informal in nature (e.g., asking the opinions of knowledgeable stakeholders as to the perceived level of success), truly measuring such success or progress will require the annual collection of data describing these two measurements—funding and duplication. Monitoring funding of high-priority National Agenda items will require data on which items have and have not been funded and, if so, by whom. Data on duplication can come from the same sources as data on funding.

The recommended monitoring program is that described above under "Continual Tracking of National Agenda Project Funding"—a recommended component of encouraging voluntary coordination among funders and independent researchers. As noted there, the major components of the monitoring program would be:

- A National Agenda website containing up-to-date information on the projects currently funded or being researched.
- Project director and staff would be responsible for continually tracking funding and updating the website. Tracking methods are suggested in the above narrative (e.g., review of funding agency web lists of ongoing projects, review of RITA databases and TRB's RiP, personal contact with key sources, submissions by independent researchers).

Given that coordination of National Agenda funding will be voluntary, duplication of projects will be minimized only if the funding information collected is distributed on a regular basis to the major funders/researchers. The information distribution program to help minimize duplication would not only include the up-to-date website information, but also a number of the tasks recommended earlier for "Selling Unfunded National Agenda Projects" (e.g., email notices to a number of different user groups when a change occurs on the National Agenda webpage regarding project funding).

It is suggested that twice each year (i.e., 6 months after the release of each new National Agenda and each 6 months thereafter), the project director and staff would extract information concerning funding status from the website and prepare and submit a brief report to the home agency, the SAC (if a national-level committee), and other key funders. The report would request suggestions concerning what might be done to fund the unfunded projects.

If a national-level SAC is implemented, this committee could review the progress as part of their meeting held each time a new Agenda is released and suggest ways to increase high-priority project funding.

One issue not discussed in the "Continual Tracking" section above concerns whether National Agenda research conducted in nations other than the United States should be included under the "funded" category, or whether additional U.S.-based research is still needed (given differences in driving styles, roadways, etc.). It appears to the project team that, in general, there are few enough differences between the United States and Canada that tracking Canadian infrastructure safety research would be advantageous. While there are other Canadian organizations funding driver and vehicle-related safety research, the major funder of infrastructure safety research is the Transportation Association of Canada (TAC). TAC is an association of public and private agencies, organizations and companies who fund pooled fund research projects in eight different transportation areas, two of which are "road safety" and "traffic control." The TAC website includes information on projects currently being developed (http://www.tac-atc.ca/english/projects/indevelopment/roadsafety.cfm) and projects currently in progress (http://www.tac-atc.ca/english/projects/inprogress/roadsafety.cfm). Note that TAC provides input to TRB's RiP.

The decision of whether or not to monitor research in other countries and include them in the National Agenda website is a more complex decision. The issue is not only whether the results are applicable to U.S. conditions, but also whether the results from another country will be implemented by U.S. safety professionals without further research. There are also costs associated with such an expansion—staff time for identifying primary funding sources in each included country and for tracking research projects funded. The argument for inclusion of non-Canadian international research is that some will be directly applicable to the U.S. conditions and duplicating that research will be an inefficient use of the limited research funding available. This decision may be best left to the agencies funding the National Agenda effort with advice from the national-level SAC (if implemented).

Formation and Duties of a National-Level SAC

In the initial text in this chapter concerning possible National Agenda structures, a key decision is whether the SAC is to be a limited group of advisors selected by the host agency or a formal national committee including a balanced mixture of experienced safety program managers and knowledgeable researchers. Suggestions for possible members of and duties for such a national committee level SAC were then included in the discussions of coordination, research quality, and project funding monitoring. These suggestions will now be summarized in this section.

National-Level SAC Membership

If the national-level committee model for the SAC is chosen, its membership will need to be chosen carefully. As noted above, the SAC should be composed of members whose endorsement of the National Agenda means that it is trusted by each of the national funders and by independent researchers. The project team is suggesting two alternative committee memberships for consideration. (Note that in both Tables 13 and 14, while specific positions are suggested for membership, it is assumed that the committee member would either be the holder of that position or his/her designee.) The first alternative would include all possible members noted in the above discussion, under the premise that representation on the committee will increase the likelihood of "buy-in" by the group represented and will assist in promoting unfunded highly ranked projects to their membership. This would be a 20-person committee with membership being a combination of knowledgeable individuals (i.e., senior researchers and State and local safety program administrators) and holders of important positions (i.e., ex-officio positions such as the Chair of the AASHTO RAC). It is suggested that a similarly balanced subset (subcommittee) of the SAC members—those with safety program administration or safety research expertise—provide needed inputs to the Fundamental and Non-CMF Directly Applicable Research rankings. This subcommittee would need to be large enough to cover relevant major areas of expertise with some redundancy so that decisions related to a given research area would not be perceived as representing the views of one person.

The second alternative national-level SAC would include fewer members, with all having experience in infrastructure safety-related research or safety program administration.

Table 13. Suggested members of a national-level SAC.

Expert Safety Program Administrators	Research Experts
*FHWA Associate Administrator for Safety	*Director of FHWA's Office of Safety Research and Development
*AASHTO Highway Safety Program Manager	*Director of FHWA Exploratory Advanced Research Program
Chair of AASHTO SCOR	Chair of the AASHTO SCOR's RAC
*Chair of AASHTO SCOHTS Committee	One officer (preferably with a safety research background) from CUTC
*Chair of SCOHTS Safety Management Subcommittee	* Two representatives from TRB committees within the Safety and Systems Users Group
*Chair of AASHTO Subcommittee on Design and Traffic Engineering	*One representative from TRB committees within the Design and Construction Group
Director of UTC program within RITA	*One representative from TRB committees within the Operations Section
*Three senior state DOT roadway safety program administrators (i.e., safety engineers)	*Two additional senior safety researchers (preferably with fundamental research backgrounds)

*Subcommittee of SAC who would provide needed inputs to Fundamental and Non-CMF Applied Research.

Table 14. Suggested members of a mid-size national-level SAC.

Expert Safety Program Administrators	Research Experts
FHWA Associate Administrator for Safety	Director of FHWA's Office of Safety Research and Development
AASHTO Highway Safety Program Manager	Two representatives from TRB committees within the Safety and Systems Users Group
Chair of SCOHTS Safety Management Subcommittee	One representative from TRB committees within the Design and Construction Group
Chair of AASHTO Subcommittee on Design and Traffic Engineering	One representative from TRB committees within the Operations Section
Two senior state DOT roadway safety program administrators (i.e., safety engineers)	One additional senior safety researcher (preferably with a fundamental research background)

Thus, this membership would be based more on safety-related expertise and less on the need to cover the full range of organizations that might fund or conduct National Agenda research. By being smaller, this SAC would be less expensive. All members, rather than just a subcommittee, would be involved in providing needed inputs to the Fundamental and Non-CMF Applied Research rankings. Potential members of a balanced 12-person SAC are shown in Table 14.

The final choice of national-level SAC size and membership will be left to the ultimate National Agenda funder(s).

National-Level SAC Duties

Regardless of the size chosen, the following is a summary of proposed duties for a national-level SAC:

- Serve as high-level national focal point for National Agenda.
- Provide liaison with the key funders to help ensure that the Agenda is acceptable and will be used.
- Monitor success of the prioritization method and recommend changes.
- Monitor National Agenda research projects and recommend strategies to increase the number of high-priority projects that receive funding.
- Host and preside over National Agenda presentation meeting.
- (SAC Subcommittee) Provide input to Fundamental and Non-CMF Directly Applicable Research including:
  - Extent of Impacts on the Science of Safety
  - Potential to Improve Existing Information for Target Crashes
  - Probability of Success.

SAC/National Agenda Meeting

Given the above list of duties, while there may be years when additional meetings are required, it would appear that a SAC meeting each time a new Agenda is released would be sufficient. This assumes that the input to the rankings would be done by the large SAC subcommittee or the full mid-size SAC members individually (and independently) when requested by project staff well before the annual meeting. The project staff would have completed and distributed the proposed new Agenda to all SAC members prior to the meeting. The SAC would then discuss and endorse the Agenda during the first half day, host the half-day meeting in the afternoon, and then meet the next morning to discuss additional items such as the success of the prioritization method, success of National Agenda funding for the past Agenda, and other issues. The meeting agenda would be developed by the project director working with the SAC Chair.

As noted earlier, it was suggested that the project director and staff develop a "mid-year" report on funding approximately 6 months after the National Agenda is released and distribute this to the SAC and others. If funding is not at the desired level, the report is to include a request to each recipient for suggestions to increase funding. While this might require a meeting of the SAC, it appears that it could be done either through individual email contacts or a web session.

Transportation Agency Partners

As noted in earlier chapters and in Table 9 of this chapter, the development of a "VOR" for each potential CMF research project will require national-level estimates of the following:

- Number of candidate units—Number of highway segments or intersections in the U.S. that can potentially be treated with the proposed countermeasure.
- Cost of implementation—Average cost (per mile or intersection) to the transportation agency to implement the proposed countermeasure.

Estimates for the number of candidate users will be made for some treatments using only data from the HPMS database (e.g., a treatment that will potentially affect all two-lane rural roads or all signalized intersections). For other treatments, the HPMS results may have to be combined with results from HSIS or other state DOT roadway inventories (e.g., a treatment only affecting narrow paved shoulders). In other cases, there will not be suitable inventories, and information will need to be collected elsewhere.

Our suggestion would be a nationally representative group of roadway safety program experts—the TAP. The TAPs are envisioned to be a group of engineers that provide the needed information agency perspective and information to the prioritization process.

The size of the TAP and the source of (voluntary) membership are open to question. Each state DOT could have membership in the TAP (if desired), and selected city and county engineers could also be included. Alternatively, a smaller group (such as one chosen from AASHTO's Subcommittee on Safety Management) is also logical. The group needs to be large enough so that inputs would be considered "nationally representative" (e.g., by location within the United States, size of state roadway system), and small enough so that the follow-up required to obtain the requested estimates does not slow the process down significantly. At this point, the project team would suggest a TAP of approximately 15 to 20 members.

Project staff would develop specific questions for each candidate CMF research project annually (e.g., the proportion of all rural four-way stop-controlled intersections with poor sight distance) and would send these to each TAP member for an email response. Staff would then conduct the necessary follow-up effort needed to obtain estimates from what is considered a suitable sample of members.

Summary

This chapter has provided information and issues related to a proposed plan for long-term implementation of the National Research Agenda. Major topics have included possible organization and home for the operational structure, possible update cycles for the Agenda, how coordination of National Agenda research might be encouraged, how the quality of National Agenda research might be ensured, and how the progress of the Agenda might be monitored. The major decisions related to structure concern the nature of the SAC, where the structure might be housed, and the update cycle. No final recommendations were made. Instead, advantages and disadvantages of two alternative forms of the SAC, three alternative homes (i.e., FHWA, AASHTO and TRB), and annual versus longer update cycles were presented. In the other sections, the project team offered suggestions for how coordination, research quality, and monitoring might be accomplished, all subject to modification by the future Agenda host. Finally, if a national-level committee is chosen as the best structure for the SAC, suggestions for membership of two alternative committee sizes and suggestions for duties and meetings were offered.

Based on the work conducted by the project team, our conclusion is that while not all technical issues concerning research prioritization have been completely resolved, the project has demonstrated that the development of a transparent, rational research prioritization method could be accomplished. However, the long-term success of the overall goal of the effort—a continuing and dynamic National Agenda for safety-infrastructure research—is dependent on long-term funding and improvement of the Agenda-setting process and adequate funding of the high-priority research projects identified by that process. Fortunately, these factors are, to a great extent, under the control of FHWA, AASHTO, TRB, and independent researchers, and all these entities have demonstrated strong interest in the improvement of infrastructure safety research in the United States.

CHAPTER 5

Conclusions and Next Steps

The purpose of this study was to develop a process for identifying and prioritizing the best research opportunities available for highway safety research related to infrastructure and operations. Secondly, the study involved identifying and reviewing candidate RNSs and applying a screening process to select approximately 100 research topics with the highest potential importance, and then applying the developed priority ranking methodology to these RNSs to select and rank the ones which have the highest priority based on their safety benefits, or VOR. In short, the first primary goal of this study was to move toward that recommended agenda—to establish an initial prioritized list of research needs for possible funding.

The second major goal of the study involved the development of a detailed plan for establishing an ongoing, sustainable, and dynamic national safety-infrastructure research agenda for the future. Rather than propose one specific plan, the objective was to identify and examine in detail alternative solutions to the critical issues that will arise in the implementation of such a National Research Agenda. The choices between the alternative solutions will be made by the agency or agencies ultimately funding the Agenda. The issues to be explored included the institutional structure and process required to ensure expert scientific advice in the agenda-setting, methods encouraging (but not mandating) coordination of funding and conduct of the identified research topics among national funding leaders, techniques for evaluating the quality of the research conducted under the National Agenda, ways to monitor the overall progress in advancing the National Agenda and methods for continuous updating and refining the Agenda over the long term.

To meet the first project goal, two separate analytical methodologies were developed for ranking RNSs. One method was developed for application to studies where CMFs were the intended outcome of the study. This methodology involved calculating a VOR for each CMF-related RNS under consideration. The second priority ranking method was developed and applied to "Fundamental" and "Non-CMF Applied" RNSs, that is, studies that related to conducting background research on roadway infrastructure or operations topics, but did not involve directly developing a CMF.

A total of more than 800 potential RNSs were obtained from a variety of sources and an RNS screening process was used to develop a list of RNS "finalists" to be further analyzed by the analytical priority ranking processes described above. The RNS screening process was developed to select a "short list" of Research Needs Statements based on the several criteria. For example, many of the 800 RNSs were eliminated if they had no clear goal or research objective, if there was a well-established study already known to have been conducted (e.g., where there was already a 4- or 5-star rating of the CMF in the CMF Clearinghouse), or if a similar study had already been funded and was in process. Studies were also screened based on the magnitude of the nationwide fatality problem that they were intending to address, and the potential number of sites for which the results of the research could be applied in the United States. A total of 50 Fundamental and Non-CMF Applied RNSs were selected and ranked using the priority ranking methodology. A total of 37 CMF-related RNSs were selected and priority ranked using the VOR method.

The priority ranking methods developed in this study were applied to two different types of RNSs, including (1) applied research (CMF and non-CMF) topics and (2) fundamental (basic) research topics. Other types of research needs were also identified and labeled as "implementation" topics. These implementation topics include safety guidebooks, synthesis reports, implementation tools, study scans, and safety training. Such implementation topics were not included in the priority ranking process in this study, since they were not defined as "research" according to the scope of this project, that is, they were not considered to generate new knowledge on the safety effects of infrastructure or operations. However, it is also understood that implementation projects must sometimes compete for research funding with applied and fundamental research topics. In such cases, a funding agency may wish to designate a portion of their available funding to pure (i.e., applied and fundamental) research and the remaining portion of funding to implementation projects. In that case, implementation topics would not directly compete against research topics, and implementation projects can be prioritized as a separate group. A specific methodology for priority ranking of implementation projects is beyond the scope of this study, but may be based on either a subjective assessment by decision-makers, or by developing a priority ranking method comparable to the method developed herein for fundamental RNSs.

The second major project goal, the identification and examination of critical issues that must be considered in the long-term implementation of the National Research Agenda, was met by developing and exploring five criteria of a "best structure" (i.e., ability to implement the developed ranking processes, ability to ensure buy-in by both funders and researchers, ability to provide an independent collection and rating of both fundamental and directly applicable research topics, ability to ensure continual agenda process improvement, and ability to ensure continual future funding). Within each of these criteria, the advantages and disadvantages of alternatives for each of three primary structural components were discussed—size and nature of the SAC, the home/host for the structure, and the update cycle for the Agenda. In addition, suggestions were provided concerning how coordination, research quality, and Agenda progress monitoring might be accomplished, along with suggestions on the membership and duties for two different sized SACs.

Indeed, the next logical steps in the process involve (1) distributing the initial agenda (i.e., the lists of ranked CMF, non-CMF directly applicable research and fundamental research projects) to possible funding agencies for their use in near-term research procurement and (2) making the decisions defined in the discussion of the long-term plan. As noted there, since funding for both the Agenda-setting process and for the research conducted under the agenda will, to a great extent, have to come from FHWA and AASHTO, these are the two agencies that would likely have the major voice in these decisions. As noted above, this is also appropriate since both have demonstrated strong interest in the improvement of infrastructure safety research in the United States.

Bibliography

American Association of State Highway and Transportation Officials (2010). *A Manual of User Benefit Analysis for Highways.* Washington, D.C.

American Association of State Highway and Transportation Officials (2010). Highway safety manual. 1st edition. Washington, D.C.

Ades A. E., Lu G., and Claxton, K. P. (2004). Expected value of sample information calculations in medical decision modeling. *Medical Decision Making* 24 (2): 207–227.

Bahar, G. (April 2010). *Transportation Research Circular E-C142: Methodology for the Development and Inclusion of Crash Modification Factors in the First Edition of the Highway Safety Manual.* Transportation Research Board of the National Academies, Washington, D.C.

Baker, W. T. (1972). *Highway Research Record 384: An evaluation of the traffic conflicts technique.* HRB, National Research Council, Washington, D.C., pp. 1–8.

Berger, J. O. (1985). *Statistical decision theory and Bayesian analysis.* Springer Series in Statistics, 2nd Edition. Springer Science+Business Median, Inc., New York, NY.

Bojke, L., Claxton, K., Sculpher, M. J., Palmer, S., and Philips, Z. (2008). The cost-effectiveness and value of information associated with repeat screening for age related macular degeneration. *Medical Decision Making* 28: 33–43.

Brennan, A. and Kharroubi, S. A. (2007a). Efficient computation of partial expected value of sample information using Bayesian approximation. *Journal of Health Economics.* 26: 122–148.

Briggs, A., Claxton, K. P., and Sculpher, M. J. (2006). *Decision analytic modelling for the evaluation of health technologies.* Oxford University Press, Oxford, UK.

Carter, D., Srinivasan, R., Gross, F., and Council, F. (February 2012). *Recommended Protocols for Developing Crash Modification Factors.* Final Report for NCHRP Project 20-07, Task 314. Transportation Research Board, Washington, D.C.

Claxton, K. P. and Posnett, J. (1996). A*n economic approach to clinical trial design and research priority setting. Health Economics.* 5(6): 513–524.

Claxton, K. P. (1999). The irrelevance of inference: a decision-making approach to the stochastic evaluation of health care technologies. *Journal of Health Economics.* 18: 341–364.

Claxton, K. P. and Sculpher, M. J. (2006). Using value of information analysis to prioritise health research: some lessons from recent UK experience. *PharmacoEconomics.* 24 (11): 1055–1068.

Colbourn, T. E., Asseburg, C., Bojke, L., Philips, Z., Welton, N. J., Claxton, K. P., Ades, A. E., and Gilbert, R. E. (2007). Preventive strategies for group b streptococcal and other bacterial infections in early infancy: cost effectiveness and value of information analyses. *British Medical Journal.* Sep 29:335(7621):655. Epub 2007 Sep 11.

Committee on Research Priorities and Coordination in Highway Infrastructure and Operations Safety. (2008). *TRB Special Report 292: Safety Research on Highway Infrastructure and Operations: Improving Priorities, Coordination, and Quality.* Transportation Research Board of the National Academies, Washington, D.C.

Committee on the NIH Research Priority-Setting Process (1998). *Scientific Opportunities and Public Needs: Improving Priority Setting and Public Input at NIH.* Institute of Medicine of the National Academies. National Academies Press. Washington, D.C.

Council, F., Zaloshnja, E., Miller, T., and Persaud, B. (October 2005). *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries.* Report No. FHWA-HRT-05-051. Federal Highway Administration, Washington, D.C.

Eisele, W. L. and Frawley, W. E. (2000). *Assessment of Economic Impacts at Selected Raised Median Installation Locations in Texas and Development of Recommended Methodology for Economic Impacts Estimation.* Report FHWA/TX-01/3904-5. Texas Transportation Institute, College Station, TX.

Fleurence, R. L. and Torgerson, D. J. (2004). Setting priorities for research. *Health Policy* 69: 1–10.

Gluck, J., Levinson, H., and Stover, V. (1999). *NCHRP Report 420: Impacts of Access Management Techniques.* TRB, National Research Council, Washington, D.C.

Hammitt, J. K., Cave, J. A. K. (1995). *Research planning for food safety: a value of information approach.* RAND, Santa Monica, CA.

Harwood, D. W., Torbic, D. J., Richard, K. R., and Meyer, M. M. (July 2010). *Safety Analyst: Software Tools for Safety Management of Specific Highway Sites.* Report No. FHWA-HRT-10-063. Federal Highway Administration, Washington, D.C.

Hauer, E. and Gårder, P. (1986). Research into the validity of the traffic conflicts technique. *Accident Analysis and Prevention,* Vol. 18, No. 6, 471–481.

Hauer, E. and Geva, I. (1984). A decision analytic approach to the design of experiments in research on traffic safety. In: Yagar, S. (ed.), *Transport Risk Assessment.* University of Waterloo Press. Waterloo, Ontario, Canada.

Hauer, E. (1997). Observational before-after studies in road safety. Pergamon Press. Elsevier, Amsterdam, Netherlands.

Howard, R. A. (1966). *Information value theory. IEEE Transactions on Systems, Science and Cybernetics.* SSC-2 (1): 22–26.

Meltzer, D. (2001). Addressing uncertainty in medical cost–effectiveness analysis. Implications of expected utility maximization for methods to perform sensitivity analysis and the use of cost–effectiveness analysis to set priorities for medical research. *Journal of Health Economics* 20, 109–129.

Meltzer, D. O., Basu, Y., and Meltzer, H. Y. (2009). Comparative Effectiveness Research For Antipsychotic Medications: How Much Is Enough? If comparative effectiveness research is to guide policy, then it must include evaluations of changes in policy. *Health Affairs* 28, No. 5 794–808.

Miaou, S-P. (1996). *Measuring the Goodness-of-Fit of Accident Prediction Models.* FHWA-RD-96-040. Federal Highway Administration, Washington, D.C.

National Association of Convenience Stores. *Motor Fuel Sales Fact Sheet.* (January 2011). http://www.nacsonline.com/NACS/News/FactSheets/Motor%20Fuels/Pages/MotorFuelSales.aspx. Accessed March 10, 2011.

North Carolina Department of Transportation. (2009). Transformation Management Team Final Report, Volume 5: Strategic Planning and Prioritization. Accessed 11/30/12 at http://www.ncdot.gov/download/performance/volume5.pdf.

Parmigiani, G. (2002). *Modeling in medical decision making: a Bayesian approach.* Statistics in Practice Series, John Wiley & Sons Ltd., Chichester, UK.

Philips, Z., Claxton, K. P., Palmer, S. J., Sculpher, M. J. (2006). Priority setting for research in health care: an application of value of information analysis to glycoprotein iib/iiia antagonists in non-st elevation acute coronary syndrome. *International Journal of Technology Assessment in Health Care* 22(3): 379–387.

Pratt, J. W., Raiffa, H., Schlaifer, R. (1995). *Introduction to statistical decision theory.* MIT Press, Cambridge, MA.

Raiffa, H. and Schlaifer, R. (2000) *Applied statistical decision theory.* Wiley Classics Library Series, Wiley-Interscience, Hoboken, NJ.

Schlaifer, R. (1959). *Probability and statistics for business decisions: an introduction to managerial economics under uncertainty.* McGraw-Hill, New York, NY.

Texas Department of Transportation (2006). *Right-of-Way Appraisal and Review Manual.* Austin, Texas.

Texas Department of Transportation. *Statewide Construction Average Low Bid Unit Price.* ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/bidprice/as1458.txt. Accessed March 10, 2011.

Thompson, K. M. and Graham, J. D. (1996). Going beyond the single number: using probabilistic risk assessment to improve risk management. *Human and Ecological Risk Assessment* 2(4): 1008–1034.

"Traffic Signal Timing and Operations Survey." *ITE Journal.* Institute of Transportation Engineers, Washington, D.C., April 2009, p. 19.

Unit Bid History. Washington State Department of Transportation. http://www.wsdot.wa.gov/ biz/contaa/uba/bid.cfm. Accessed March 10, 2011.

U.S. Census Bureau. *Population Estimates.* Archives. http://www.census.gov/popest/archives/. Accessed March 11, 2011.

Willan, A. R. and Pinto, E. M. (2005). The value of information and optimal clinical trial design. *Stat Med.* 24:1791–806.

Winkler, R. L. (1972). *An introduction to Bayesian inference and decision.* Holt, Rinehart and Winston, New York, NY.

Yokota, F. and Thompson, K. (2004). Value of information literature analysis: a review of applications in health risk management. *Medical Decision Making* 24: 287–298.

APPENDIX P

Results for Applied-CMF Research Prioritization[1]

This appendix shows the assumptions, inputs, and results for the VOR calculations for each applied-CMF RNSs.

46.4) Safety Effects of Exclusive Pedestrian Signal Phases at Urban Intersections

Assumed treatment: Minor retiming effort
Total target miles or intersections: 93400
Miles or intersections that could be treated: 1868
Level of implementation (eligible percentage of sites that could receive this treatment): 2%
Target crash frequency: 6818

- *Proportion of crashes that are PDO*: 0.634
- *Proportion of crashes that are C injury*: 0.266
- *Proportion of crashes that are B injury*: 0.084
- *Proportion of crashes that are A injury*: 0.013
- *Proportion of crashes that are fatal*: 0.003

Cost assumptions
Initial cost: $300
Annual maintenance cost: $0
Service life (years): 20
Unit for cost: per intersection

Benefit assumptions
Estimated CMF for total crashes: 0.970
Estimated standard deviation of CMF before: 0.1940
Estimated standard deviation of CMF after: 0.1810

Other assumptions:
Assumed that this treatment would be for 3 and 4 leg signalized intersections in "other principal arterials" in urban areas. CMF of 0.97 for total crashes was estimated based on information in the FHWA tool box (http://www.walkinginfo.org/training/collateral/resources/pedToolboxofCountermeasures.pdf) and judgment of the project team. Standard error was assumed to be 0.1. Standard deviation before research was assumed to be 0.2 * CMF. Standard deviation after research was estimated using the Excel tool.

VOR (per year): $1,480,000

46.9) Effects of Multiple Parallel Turn Lanes on Pedestrian-Vehicle Conflicts and Safety at Urban Signalized Intersections

Assumed treatment: Install one turn lane
Total target miles or intersections: 93400
Miles or intersections that could be treated: 88730
Level of implementation (eligible percentage of sites that could receive this treatment): 95%
Target crash frequency: 323865

- *Proportion of crashes that are PDO*: 0.634
- *Proportion of crashes that are C injury*: 0.266
- *Proportion of crashes that are B injury*: 0.084
- *Proportion of crashes that are A injury*: 0.013
- *Proportion of crashes that are fatal*: 0.003

Cost assumptions
Initial cost: $100,000
Annual maintenance cost: $600
Service life (years): 15
Unit for cost: per intersection

Benefit assumptions
Estimated CMF for total crashes: 0.816
Estimated standard deviation of CMF before: 0.1630
Estimated standard deviation of CMF after: 0.1550

[1] Appendices A-O and R are not published herein. These appendices are available in electronic format only and can be downloaded at http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727.

Other assumptions:

Based on Survey sent out to the TAG, 5% of urban signalized turn lanes have multiple turn lanes. This implied that the remaining 95% of them do not, and could be treated. Target interesctions were 3 and 4 leg signalized intersections in "other principal arterials" in urban areas. To estimate the CMF, information from the signalized intersection guide (Ye et al., 2008), and the HSM were used along with the judgment of the project team. It was assumed that 2% of crashes are pedestrian, and 98% are non-pedestrian, and the CMF for non-pedestrian crashes was 0.81 and pedestrian crashes was 1.1. So the CMF came out to be $0.81 * 0.98 + 1.1 * 0.02 = 0.8158$. Standard deviation before research was assumed to be $0.2 * \text{CMF} = 0.163$. Standard error was estimated based on default values in the Excel sheet that assume that CMF is statistically different from 1.0 at 0.05 level.

VOR (per year): $30,970,000

95.2) Safety Effects of Installing Continuous Shoulder Rumble Strips on Rural Multilane Undivided Roads

Assumed treatment: Install rumble strips on existing surface
Total target miles or intersections: 4992
Miles or intersections that could be treated: 4492
Level of implementation (eligible percentage of sites that could receive this treatment): 90%
Target crash frequency: 5912

- *Proportion of crashes that are PDO*: 0.665
- *Proportion of crashes that are C injury*: 0.164
- *Proportion of crashes that are B injury*: 0.126
- *Proportion of crashes that are A injury*: 0.031
- *Proportion of crashes that are fatal*: 0.013

Cost assumptions
Initial cost: $650
Annual maintenance cost: $0
Service life (years): 7
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.78
Estimated standard deviation of CMF before: 0.1560
Estimated standard deviation of CMF after: 0.1430

Other assumptions:

CMF of 0.78 was estimated based on prior studies on rural 2 lane undivided and rural multilane divided (e.g., Sayed et al., 2010). Standard deviation before research was assumed to be $0.2 * \text{CMF}$. Standard error was estimated based on default values in the Excel sheet that assumes that CMF is statistically different from 1.0 at 0.05 level.

VOR (per year): $1,120,000

95.3) Safety Effects of Installing Continuous Shoulder Rumble Strips on Rural Multilane Divided Roads

Assumed treatment: Install rumble strips on existing surface
Total target miles or intersections: 27171
Miles or intersections that could be treated: 24454
Level of implementation (eligible percentage of sites that could receive this treatment): 90%
Target crash frequency: 57820

- *Proportion of crashes that are PDO*: 0.677
- *Proportion of crashes that are C injury*: 0.165
- *Proportion of crashes that are B injury*: 0.119
- *Proportion of crashes that are A injury*: 0.027
- *Proportion of crashes that are fatal*: 0.012

Cost assumptions
Initial cost: $650
Annual maintenance cost: $0
Service life (years): 7
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.78
Estimated standard deviation of CMF before: 0.1560
Estimated standard deviation of CMF after: 0.1430

Other assumptions:

CMF of 0.78 was estimated based on prior studies on rural 2 lane undivided and rural multilane divided (e.g., Sayed et al., 2010). Standard deviation before research was assumed to be $0.2 * \text{CMF}$. Standard error was estimated based on default values in the Excel sheet that assumes that CMF is statistically different from 1.0 at 0.05 level.

VOR (per year): $10,210,000

98.1) Safety Effects of Installing Bott's Dots on Rural Two-Lane Roads

Assumed treatment: Install dots at 40 per mile
Total target miles or intersections: 2911072
Miles or intersections that could be treated: 2911072

Level of implementation (eligible percentage of sites that could receive this treatment): 100%
Target crash frequency: 831935

- *Proportion of crashes that are PDO*: 0.650
- *Proportion of crashes that are C injury*: 0.160
- *Proportion of crashes that are B injury*: 0.138
- *Proportion of crashes that are A injury*: 0.037
- *Proportion of crashes that are fatal*: 0.016

Cost assumptions
Initial cost: $750
Annual maintenance cost: $0
Service life (years): 4
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 1.011
Estimated standard deviation of CMF before: 0.0490
Estimated standard deviation of CMF after: 0.0490

Other assumptions:

Used previous research on raised pavement markers (from the HSM) to estimate CMFs. To convert cmf_night to cmf_total, used the following equation: cmf_total = 1.0 × (1 − P_night) + CMF_night × P_night. To obtain s.e. of cmf_total, used the following equation: se_total = P_night × se_night. Used CMFs from Table 13-41 of HSM and used CMFunction tools in the Excel tool. Assumed that 35% of crashes occur at night. For AADT = 2500: CMF = 0.35 * 1.16 + 0.65 * 1 = 1.056 (S.E. = 0.35 * 0.03 = 0.01). For AADT = 10000: CMF = 0.35 * 0.99 + 0.65 * 1 = 0.997 (S.E. = 0.35 * 0.06 = 0.021). For AADT = 17500: CMF = 0.35 * 0.76 + 0.65 * 1 = 0.916 (S.E. = 0.35 * 0.08 = 0.028). For new research, it was assumed that it will be done on roads with AADT = 10000 with S.E. = 0.02.

VOR (per year): $4,910,000

98.2) Safety Effects of Installing Bott's Dots on Rural Multilane Roads

Assumed treatment: Install dots at 40 per mile
Total target miles or intersections: 32163
Miles or intersections that could be treated: 32163
Level of implementation (eligible percentage of sites that could receive this treatment): 100%
Target crash frequency: 70813

- *Proportion of crashes that are PDO*: 0.676
- *Proportion of crashes that are C injury*: 0.165
- *Proportion of crashes that are B injury*: 0.119
- *Proportion of crashes that are A injury*: 0.027
- *Proportion of crashes that are fatal*: 0.013

Cost assumptions
Initial cost: $750
Annual maintenance cost: $0
Service life (years): 4
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 1.011
Estimated standard deviation of CMF before: 0.0490
Estimated standard deviation of CMF after: 0.0490

Other assumptions:

Used previous research on raised pavement markers (from the HSM) to estimate CMFs. To convert cmf_night to cmf_total, used the following equation: cmf_total = 1.0 × (1 − P_night) + CMF_night × P_night. To obtain s.e. of cmf_total, used the following equation: se_total = P_night × se_night. Used CMFs from Table 13-41 of HSM and used CMFunction tools in the Excel tool. Assumed that 35% of crashes occur at night. For AADT = 2500: CMF = 0.35 * 1.16 + 0.65 * 1 = 1.056 (S.E. = 0.35 * 0.03 = 0.01). For AADT = 10000: CMF = 0.35 * 0.99 + 0.65 * 1 = 0.997 (S.E. = 0.35 * 0.06 = 0.021). For AADT = 17500: CMF = 0.35 * 0.76 + 0.65 * 1 = 0.916 (S.E. = 0.35 * 0.08 = 0.028). For new research, it was assumed that it will be done on roads with AADT = 20000 with S.E. = 0.03.

VOR (per year): $270,000

108.1) Safety Effects of Different Speed Limits on Rural Two-Lane Roads

Assumed treatment: Change speed limit to more appropriate limit by replacing speed limit signs at 2 per mile.
Total target miles or intersections: 2911071
Miles or intersections that could be treated: 2911071
Level of implementation (eligible percentage of sites that could receive this treatment): 100%
Target crash frequency: 831935

- *Proportion of crashes that are PDO*: 0.650
- *Proportion of crashes that are C injury*: 0.160
- *Proportion of crashes that are B injury*: 0.138
- *Proportion of crashes that are A injury*: 0.037
- *Proportion of crashes that are fatal*: 0.016

Cost assumptions
Initial cost: $250

Annual maintenance cost: $0
Service life (years): 10
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.901
Estimated standard deviation of CMF before: 0.0140
Estimated standard deviation of CMF after: 0.0130

Other assumptions:

Assumed that the treatment will involve reducing speed limits. CMFs from Table 3.11.2 of Elvik and Vaa (2004) (i.e., last two results from page 523) were used. According to that table, for a reduction of 14.3 kmh in speed limits, the estimated CMF for total crashes is 0.91 with a standard error of 0.005 and for a reduction of 18 kmh in speed limits, the estimated CMF for total crashes is 0.88 with a standard error of 0.015. The CMFunction tool in the Excel spreadsheet was used to estimate the standard deviation before research. For new research, it was assumed that the speed limit will be reduced by 10 mph (about 16 kmh).

VOR (per year): $ 0

108.2) Safety Effects of Different Speed Limits on Rural Multilane Roads

Assumed treatment: Change speed limit to more appropriate limit by replacing speed limit signs at 2 per mile.
Total target miles or intersections: 32163
Miles or intersections that could be treated: 32163
Level of implementation (eligible percentage of sites that could receive this treatment): 100%
Target crash frequency: 70813

- *Proportion of crashes that are PDO*: 0.676
- *Proportion of crashes that are C injury*: 0.165
- *Proportion of crashes that are B injury*: 0.119
- *Proportion of crashes that are A injury*: 0.027
- *Proportion of crashes that are fatal*: 0.013

Cost assumptions
Initial cost: $250
Annual maintenance cost: $0
Service life (years): 10
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.901
Estimated standard deviation of CMF before: 0.0140
Estimated standard deviation of CMF after: 0.0130

Other assumptions:

Assumed that the treatment will involve reducing speed limits. CMFs from Table 3.11.2 of Elvik and Vaa (2004) (i.e., last two results from page 523) were used. According to that table, for a reduction of 14.3 kmh in speed limits, the estimated CMF for total crashes is 0.91 with a standard error of 0.005 and for a reduction of 18 kmh in speed limits, the estimated CMF for total crashes is 0.88 with a standard error of 0.015. The CMFunction tool in the Excel spreadsheet was used to estimate the standard deviation before research. For new research, it was assumed that the speed limit will be reduced by 10 mph (about 16 kmh).

VOR (per year): $0

108.3) Safety Effects of Different Speed Limits on Urban and Suburban Arterials

Assumed treatment:
Total target miles or intersections: 170729
Miles or intersections that could be treated: 170729
Level of implementation (eligible percentage of sites that could receive this treatment): 100%
Target crash frequency: 1020979

- *Proportion of crashes that are PDO*: 0.685
- *Proportion of crashes that are C injury*: 0.209
- *Proportion of crashes that are B injury*: 0.086
- *Proportion of crashes that are A injury*: 0.016
- *Proportion of crashes that are fatal*: 0.004

Cost assumptions
Initial cost: $250
Annual maintenance cost: $0
Service life (years): 10
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.87
Estimated standard deviation of CMF before: 0.08100
Estimated standard deviation of CMF after: 0.07800

Other assumptions:

Assumed that the treatment will involve reducing speed limits. CMFs from Table 3.11.2 of Elvik and Vaa (2004) (i.e., the first two results from page 524) were used. According to that table, for a reduction of 20 kmh in speed limits, the estimated CMF for total crashes is 0.76 with a standard error of 0.038 and for a reduction of 10 kmh in speed limits, the estimated CMF for total crashes is 0.91 with a standard error of 0.008. The CMFunction tool in the Excel spreadsheet was used to estimate the standard deviation before research. For new research, it was assumed that the speed limit will be reduced by 10 mph (about 16 kmh).

VOR (per year): $17,330,000

149.1) Safety Prediction Models for Rural Two-Lane Roads with Various Offsets of Trees and Other Vegetation

Assumed treatment: Remove trees alongside road to create larger offset
Total target miles or intersections: 2911071
Miles or intersections that could be treated: 2911071
Level of implementation (eligible percentage of sites that could receive this treatment): 100%
Target crash frequency: 831935

- *Proportion of crashes that are PDO*: 0.650
- *Proportion of crashes that are C injury*: 0.160
- *Proportion of crashes that are B injury*: 0.138
- *Proportion of crashes that are A injury*: 0.037
- *Proportion of crashes that are fatal*: 0.016

Cost assumptions
Initial cost: $275,000
Annual maintenance cost: $0
Service life (years): 20
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.637
Estimated standard deviation of CMF before: 0.1120
Estimated standard deviation of CMF after: 0.1070

Other assumptions:
Using the results from Elvik and Vaa (2004) for increasing distance to roadside obstacle, used the CMFunction tool to estimate the standard deviation before research. For new research, assumed that it will look at increasing distance to roadside obstacle from 1 to 5 m (S.E. of new research expected to be 0.02).

VOR (per year): $19,660,000

149.2) Safety Prediction Models for Rural Multilane Highways with Various Offsets of Trees and Other Vegetation

Assumed treatment: Remove trees alongside road to create larger offset
Total target miles or intersections: 32163
Miles or intersections that could be treated: 32163
Level of implementation (eligible percentage of sites that could receive this treatment): 100%
Target crash frequency: 70813

- *Proportion of crashes that are PDO*: 0.676
- *Proportion of crashes that are C injury*: 0.165
- *Proportion of crashes that are B injury*: 0.119
- *Proportion of crashes that are A injury*: 0.027
- *Proportion of crashes that are fatal*: 0.013

Cost assumptions
Initial cost: $275,000
Annual maintenance cost: $0
Service life (years): 20
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.637
Estimated standard deviation of CMF before: 0.1120
Estimated standard deviation of CMF after: 0.1070

Other assumptions:
Using the results from Elvik and Vaa (2004) for increasing distance to roadside obstacle for rural roads, used the CMFunction tool to estimate the standard deviation before research. For new research, assumed that it will look at increasing distance to roadside obstacle from 1 to 5 m (S.E. of new research expected to be 0.02).

VOR (per year): $570,000

155) Safety Effects of Removing Roadside Obstacles Along Urban Arterial Streets

Assumed treatment: Remove poles only (does not include estimate for relocating poles or power lines)
Total target miles or intersections: 170729
Miles or intersections that could be treated: 170729
Level of implementation (eligible percentage of sites that could receive this treatment): 100%
Target crash frequency: 1020979

- *Proportion of crashes that are PDO*: 0.685
- *Proportion of crashes that are C injury*: 0.209
- *Proportion of crashes that are B injury*: 0.086
- *Proportion of crashes that are A injury*: 0.016
- *Proportion of crashes that are fatal*: 0.004

Cost assumptions
Initial cost: $13,000

Annual maintenance cost: $0
Service life (years): 50
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.637
Estimated standard deviation of CMF before: 0.1120
Estimated standard deviation of CMF after: 0.1070

Other assumptions:
Using the results from Elvik and Vaa (2004) for increasing distance to roadside obstacle for rural roads, used the CMFunction tool to estimate the standard deviation before research. For new research, assumed that it will look at increasing distance to roadside obstacle from 1 to 5 m (S.E. of new research expected to be 0.02). Assumed that treatment is applicable for urban "other principal arterial" and "other minor arterial."

VOR (per year): $480,000

160) Safety Effects of Reversible Flow Lanes Along Five-lane Arterial Street Corridors

Assumed treatment: Install reversible lane system operating on red X / green arrow lane lighted signs
Total target miles or intersections: 64557
Miles or intersections that could be treated: 2582
Level of implementation (eligible percentage of sites that could receive this treatment): 4%
Target crash frequency: 24822

- *Proportion of crashes that are PDO*: 0.690
- *Proportion of crashes that are C injury*: 0.210
- *Proportion of crashes that are B injury*: 0.081
- *Proportion of crashes that are A injury*: 0.014
- *Proportion of crashes that are fatal*: 0.004

Cost assumptions
Initial cost: $1,500,000
Annual maintenance cost: $20,000
Service life (years): 20
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 1.04
Estimated standard deviation of CMF before: 0.2080
Estimated standard deviation of CMF after: 0.2050

Other assumptions:
Used results from Elvik and Vaa (2004) for the CMF and the standard error. Standard deviation before research was assumed to be 0.2 * CMF value. Assumed that treatment was applicable for urban "other principal arterial."

VOR (per year): $790,000

169.3) Safety Effects of Adding Lanes by Narrowing Existing Lanes and Shoulders of Four- and Six-lane Urban and Suburban Arterial Streets

Assumed treatment: Add lanes by restriping on existing pavement
Total target miles or intersections: 38980
Miles or intersections that could be treated: 38980
Level of implementation (eligible percentage of sites that could receive this treatment): 100%
Target crash frequency: 294077

- *Proportion of crashes that are PDO*: 0.688
- *Proportion of crashes that are C injury*: 0.210
- *Proportion of crashes that are B injury*: 0.083
- *Proportion of crashes that are A injury*: 0.015
- *Proportion of crashes that are fatal*: 0.004

Cost assumptions
Initial cost: $5,000
Annual maintenance cost: $0
Service life (years): 5
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 1.079
Estimated standard deviation of CMF before: 0.0300
Estimated standard deviation of CMF after: 0.0260

Other assumptions:
Used the results from Bauer et al. (2004) that were done for urban freeways to enter the values in the CMFunction tool. From the Bauer et al. results, entered CMFs for 4 to 5 lane and 5 to 6 lane conversions. Assumed that future research will be for 4 to 5 lane with S.E. of 0.03. Based on data from HSIS states, estimated the proportion of urban principal arterials (0.39) and urban minor arterials (0.13) that could be treated.

VOR (per year): $400,000

170.3) Safety Effects of Widening External Paved Shoulder of Four- and Six-lane Multilane Highways

Assumed treatment: Widen shoulder by paving an additional 2 feet on each side of the road

Total target miles or intersections: 32163
Miles or intersections that could be treated: 3859
Level of implementation (eligible percentage of sites that could receive this treatment): 12%
Target crash frequency: 8498

- *Proportion of crashes that are PDO*: 0.676
- *Proportion of crashes that are C injury*: 0.165
- *Proportion of crashes that are B injury*: 0.119
- *Proportion of crashes that are A injury*: 0.027
- *Proportion of crashes that are fatal*: 0.013

Cost assumptions
Initial cost: $60,000
Annual maintenance cost: $0
Service life (years): 7
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.7
Estimated standard deviation of CMF before: 0.1390
Estimated standard deviation of CMF after: 0.1200

Other assumptions:
Used CMFunction tool based on information in Table 13-8 (page 13-12) of the HSM. For 6 to 8 feet conversion, CMF = 1/1.04 = 0.96; for 4 to 8 feet, CMF = 1/1.09 = 0.92; for 2 to 8 feet, CMF = 1/1.13 = 0.89; for 0 to 8 feet, CMF = 1/1.18 = 0.85. Standard errors were estimated assuming that CMFs were statistically different from 1.0 at the 0.05 significance level. For new study, assumed that the conversion will be from 6 to 8 feet.

VOR (per year): $130,000

170.4) Safety Effects of Widening External Paved Shoulder of Two-lane Rural Roads

Assumed treatment: Widen shoulder by paving an additional 2 feet on each side of the road
Total target miles or intersections: 2911071
Miles or intersections that could be treated: 436660
Level of implementation (eligible percentage of sites that could receive this treatment): 15%
Target crash frequency: 124790

- *Proportion of crashes that are PDO*: 0.650
- *Proportion of crashes that are C injury*: 0.160
- *Proportion of crashes that are B injury*: 0.138
- *Proportion of crashes that are A injury*: 0.037
- *Proportion of crashes that are fatal*: 0.016

Cost assumptions
Initial cost: $60,000
Annual maintenance cost: $0
Service life (years): 7
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.938
Estimated standard deviation of CMF before: 0.0130
Estimated standard deviation of CMF after: 0.0120

Other assumptions:
Used CMFunction tool based on information in Table 11-12 (page 11-27) of the HSM and equation 11-14. Used the CMFs for >2000 feet AADT. Standard errors were estimated assuming that CMFs were statistically different from 1.0 at the 0.05 significance level. For new study, assumed that the conversion will be from 6 to 8 feet.

VOR (per year): $700,000

175.4) Safety Effects of Increasing the Forgiving Area from Current Standards for Rural Multilane (Four and More Lanes) Highways

Assumed treatment: Regrade embankment to increase forgiving area
Total target miles or intersections: 32164
Miles or intersections that could be treated: 16081
Level of implementation (eligible percentage of sites that could receive this treatment): 50%
Target crash frequency: 35407

- *Proportion of crashes that are PDO*: 0.676
- *Proportion of crashes that are C injury*: 0.165
- *Proportion of crashes that are B injury*: 0.119
- *Proportion of crashes that are A injury*: 0.027
- *Proportion of crashes that are fatal*: 0.013

Cost assumptions
Initial cost: $75,000
Annual maintenance cost: $0
Service life (years): 20
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.906
Estimated standard deviation of CMF before: 0.0120
Estimated standard deviation of CMF after: 0.0110

Other assumptions:
Used CMFunction tool based on information in Table 13-18 (page 13-20) of the HSM for rural two-lane roads. Standard errors were estimated assuming that CMFs were statistically different from 1.0 at the 0.05 level. Assumed that the before condition will be 1:2 and the after condition 1:7. Assumed that the standard error of new study will be 0.03

VOR (per year): $30,000

175.5) Safety Effects of Increasing the Forgiving Area from Current Standards for Freeways and Expressways (Four and More Lanes)

Assumed treatment: Regrade embankment to increase forgiving area
Total target miles or intersections: 58086
Miles or intersections that could be treated: 29043
Level of implementation (eligible percentage of sites that could receive this treatment): 50%
Target crash frequency: 544706

- *Proportion of crashes that are PDO*: 0.709
- *Proportion of crashes that are C injury*: 0.188
- *Proportion of crashes that are B injury*: 0.084
- *Proportion of crashes that are A injury*: 0.014
- *Proportion of crashes that are fatal*: 0.005

Cost assumptions
Initial cost: $75,000
Annual maintenance cost: $0
Service life (years): 20
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.945
Estimated standard deviation of CMF before: 0.0230
Estimated standard deviation of CMF after: 0.0230

Other assumptions:
Used CMFunction tool based on information in Table 13-18 (page 13-20) of the HSM for rural two-lane roads. Standard errors were estimated assuming that CMFs were statistically different from 1.0 at the 0.05 level. Assumed that the before condition will be 1:4 and the after condition will be 1:7. Assumed that the standard error of new study will be 0.03.

VOR (per year): $150,000

182) Safety Effects of Improving Superelevation (to Meet Standards) of Horizontal Curve on Rural Multilane Highways

Assumed treatment: Add pavement to surface to improve superelevation
Total target miles or intersections: 5766
Miles or intersections that could be treated: 1153
Level of implementation (eligible percentage of sites that could receive this treatment): 20%
Target crash frequency: 7897

- *Proportion of crashes that are PDO*: 0.705
- *Proportion of crashes that are C injury*: 0.145
- *Proportion of crashes that are B injury*: 0.080
- *Proportion of crashes that are A injury*: 0.052
- *Proportion of crashes that are fatal*: 0.018

Cost assumptions
Initial cost: $20,000
Annual maintenance cost: $0
Service life (years): 10
Unit for cost: per curve

Benefit assumptions
Estimated CMF for total crashes: 0.955
Estimated standard deviation of CMF before: 0.0230
Estimated standard deviation of CMF after: 0.0210

Other assumptions:
Based on Table 13-27 of HSM, used CMFunction tool in CMF worksheet. Standard errors were estimated assuming that CMFs were statistically different from 1.0 at the 0.05 level. For improvement of 0.015 of Superelevation variance (SV), CMF = 1/1.03 = 0.971. For improvement of 0.03 of SV, CMF = 1/1.09 = 0.917. Assumed that new research will have standard error of 0.012 (assuming that the improvement in SV will be 0.015).

VOR (per year): $100,000

189.1) Safety Effects of Installing Post-Mounted Delineators on Rural Two-Lane Roads—Tangents and Curves

Assumed treatment: Install post-mounted delineators every 100 feet
Total target miles or intersections: 2911071
Miles or intersections that could be treated: 1018875

Level of implementation (eligible percentage of sites that could receive this treatment): 35%
Target crash frequency: 291177

- *Proportion of crashes that are PDO*: 0.650
- *Proportion of crashes that are C injury*: 0.160
- *Proportion of crashes that are B injury*: 0.138
- *Proportion of crashes that are A injury*: 0.037
- *Proportion of crashes that are fatal*: 0.016

Cost assumptions
Initial cost: $4,000
Annual maintenance cost: $400
Service life (years): 10
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 1.05
Estimated standard deviation of CMF before: 0.2100
Estimated standard deviation of CMF after: 0.1980

Other assumptions:
CMFs (along with standard errors) reported in the HSM for rural two-lane roads were used. Standard deviation before research was estimated as 0.2 * CMF.

VOR (per year): $165,160,000

189.2) Safety Effects of Installing Post-Mounted Delineators on Rural Multilane Roads

Assumed treatment: Install post-mounted delineators every 100 feet
Total target miles or intersections: 32163
Miles or intersections that could be treated: 6432
Level of implementation (eligible percentage of sites that could receive this treatment): 20%
Target crash frequency: 14163

- *Proportion of crashes that are PDO*: 0.676
- *Proportion of crashes that are C injury*: 0.165
- *Proportion of crashes that are B injury*: 0.119
- *Proportion of crashes that are A injury*: 0.027
- *Proportion of crashes that are fatal*: 0.013

Cost assumptions
Initial cost: $4,000
Annual maintenance cost: $400
Service life (years): 10
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 1.05
Estimated standard deviation of CMF before: 0.2100
Estimated standard deviation of CMF after: 0.1980

Other assumptions:
CMFs (along with standard errors) reported in the HSM for rural two-lane roads were used. Standard deviation before research was estimated as 0.2 * CMF.

VOR (per year): $6,790,000

198.1 - curves) Safety Effects of Placing Converging Chevron Pattern Markings on Rural Two-Lane Roads—Curves

Assumed treatment: Install chevron pavement markings at curve
Total target miles or intersections: 143935
Miles or intersections that could be treated: 28787
Level of implementation (eligible percentage of sites that could receive this treatment): 20%
Target crash frequency: 56630

- *Proportion of crashes that are PDO*: 0.681
- *Proportion of crashes that are C injury*: 0.170
- *Proportion of crashes that are B injury*: 0.081
- *Proportion of crashes that are A injury*: 0.054
- *Proportion of crashes that are fatal*: 0.015

Cost assumptions
Initial cost: $2,300
Annual maintenance cost: $0
Service life (years): 5
Unit for cost: per curve

Benefit assumptions
Estimated CMF for total crashes: 0.68
Estimated standard deviation of CMF before: 0.1900
Estimated standard deviation of CMF after: 0.1340

Other assumptions:
Used results from Griffin and Reinhardt (1996) reported in the Clearinghouse for urban areas. Estimated standard deviation before research as 0.2 * CMF. Estimate of standard error was available in the Clearinghouse.

VOR (per year): $22,020,000

198.2 - curves) Safety Effects of Placing Converging Chevron Pattern Markings on Rural Multilane Highways—Curves

Assumed treatment: Install chevron pavement markings at curve
Total target miles or intersections: 5766
Miles or intersections that could be treated: 864
Level of implementation (eligible percentage of sites that could receive this treatment): 15%
Target crash frequency: 5923

- *Proportion of crashes that are PDO*: 0.705
- *Proportion of crashes that are C injury*: 0.145
- *Proportion of crashes that are B injury*: 0.080
- *Proportion of crashes that are A injury*: 0.052
- *Proportion of crashes that are fatal*: 0.018

Cost assumptions
Initial cost: $2,300
Annual maintenance cost: $0
Service life (years): 5
Unit for cost: per curve

Benefit assumptions
Estimated CMF for total crashes: 0.68
Estimated standard deviation of CMF before: 0.1900
Estimated standard deviation of CMF after: 0.1340

Other assumptions:
Used results from Griffin and Reinhardt (1996) reported in the Clearinghouse for urban areas. Estimated standard deviation before research as 0.2 ∗ CMF. Estimate of standard error was available in the Clearinghouse.

VOR (per year): $2,510,000

203.3) Safety Effects of Installing Transverse Rumble Strips Prior to a Horizontal Curve Requiring Speed Reduction on a Two-Lane Rural Road

Assumed treatment: Install transverse rumble strips at each side of curve
Total target miles or intersections: 143935
Miles or intersections that could be treated: 21590
Level of implementation (eligible percentage of sites that could receive this treatment): 15%
Target crash frequency: 42473

- *Proportion of crashes that are PDO*: 0.681
- *Proportion of crashes that are C injury*: 0.170
- *Proportion of crashes that are B injury*: 0.081
- *Proportion of crashes that are A injury*: 0.054
- *Proportion of crashes that are fatal*: 0.015

Cost assumptions
Initial cost: $2,000
Annual maintenance cost: $0
Service life (years): 5
Unit for cost: per curve

Benefit assumptions
Estimated CMF for total crashes: 0.94
Estimated standard deviation of CMF before: 0.2700
Estimated standard deviation of CMF after: 0.1910

Other assumptions:
Used results from Elvik and Vaa (2004) to obtain the CMF and standard error. Standard deviation before research was assumed to be equal to the standard error.

VOR (per year): $151,010,000

206) Safety Effects of Providing a Sidewalk at Urban and Suburban Arterials in Place of a Shoulder, Including Park and Transit Areas

Assumed treatment: Construct concrete sidewalk where no sidewalk or shoulder existed before
Total target miles or intersections: 170729
Miles or intersections that could be treated: 59755
Level of implementation (eligible percentage of sites that could receive this treatment): 35%
Target crash frequency: 357343

- *Proportion of crashes that are PDO*: 0.685
- *Proportion of crashes that are C injury*: 0.209
- *Proportion of crashes that are B injury*: 0.086
- *Proportion of crashes that are A injury*: 0.016
- *Proportion of crashes that are fatal*: 0.004

Cost assumptions
Initial cost: $300,000
Annual maintenance cost: $0
Service life (years): 30
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.996

Estimated standard deviation of CMF before: 0.1990
Estimated standard deviation of CMF after: 0.1860

Other assumptions:

Based on judgment of the project team, the CMF was estimated as 0.12 for pedestrians walking along roadway crashes. Based on assumptions on the percentage of such crashes, the CMF for total crashes was estimated to be 0.996. Standard deviation before research was estimated to be 0.2 ∗ CMF. The standard error was assumed to be 0.1. Assumed that the treatment would be applicable in urban principal arterial and urban other minor arterial.

VOR (per year): $98,090,000

207.1) Safety Effects of Installing Raised Pedestrian Crosswalks at Intersections on Urban and Suburban Arterials

Assumed treatment: Install raised crosswalk
Total target miles or intersections: 219164
Miles or intersections that could be treated: 21916
Level of implementation (eligible percentage of sites that could receive this treatment): 10%
Target crash frequency: 8737

- *Proportion of crashes that are PDO*: 0.558
- *Proportion of crashes that are C injury*: 0.250
- *Proportion of crashes that are B injury*: 0.138
- *Proportion of crashes that are A injury*: 0.038
- *Proportion of crashes that are fatal*: 0.016

Cost assumptions
Initial cost: $24,000
Annual maintenance cost: $0
Service life (years): 15
Unit for cost: per intersection

Benefit assumptions
Estimated CMF for total crashes: 0.64
Estimated standard deviation of CMF before: 0.5400
Estimated standard deviation of CMF after: 0.3820

Other assumptions:

Used information from Elvik and Vaa (2004) to obtain the CMF and standard error. Both the standard deviation before research and standard error were assumed to be 0.54.

VOR (per year): $57,720,000

244) Safety Effects of Narrowing Roadway at Pedestrian Crossings

Assumed treatment: Install curb extensions at existing ped crossing
Total target miles or intersections: 266591
Miles or intersections that could be treated: 53318
Level of implementation (eligible percentage of sites that could receive this treatment): 20%
Target crash frequency: 14757

- *Proportion of crashes that are PDO*: 0.564
- *Proportion of crashes that are C injury*: 0.249
- *Proportion of crashes that are B injury*: 0.148
- *Proportion of crashes that are A injury*: 0.030
- *Proportion of crashes that are fatal*: 0.009

Cost assumptions
Initial cost: $46,000
Annual maintenance cost: $0
Service life (years): 20
Unit for cost: per intersection

Benefit assumptions
Estimated CMF for total crashes: 0.989
Estimated standard deviation of CMF before: 0.1980
Estimated standard deviation of CMF after: 0.1850

Other assumptions:

Based on the judgment of the project team, this could reduce pedestrian crashes by about 25%, and have minimal impact on other crashes. The overall CMF was estimated to be 0.989. The standard error was assumed to be 0.1. The standard deviation before research was estimated as 0.2 ∗ CMF. Assumed that the treatment is applicable for urban minor arterial, collector, and local roads.

VOR (per year): $19,540,000

329.1) Safety Effects of LED Lighting in Reducing Pedestrian Nighttime Crashes

Assumed treatment: Install overhead LED lighting at crosswalks where no lighting existed
Total target miles or intersections: 467892
Miles or intersections that could be treated: 163762
Level of implementation (eligible percentage of sites that could receive this treatment): 35%
Target crash frequency: 72735

- *Proportion of crashes that are PDO*: 0.610
- *Proportion of crashes that are C injury*: 0.258
- *Proportion of crashes that are B injury*: 0.108
- *Proportion of crashes that are A injury*: 0.016
- *Proportion of crashes that are fatal*: 0.008

Cost assumptions
Initial cost: $80,000
Annual maintenance cost: $24,000
Service life (years): 20
Unit for cost: per intersection

Benefit assumptions
Estimated CMF for total crashes: 0.984
Estimated standard deviation of CMF before: 0.1970
Estimated standard deviation of CMF after: 0.1840

Other assumptions:

Assumed that treatment will only affect pedestrian crashes since LED lighting is generally intended to be installed at unsignalized pedestrian crossings to illuminate when pedestrians are present. Based on the judgment of the project team, it was assumed that the CMF for nighttime pedestrian crashes would be 0.5. Based on the assumption on the percentage of such crashes, the CMF for total crashes was estimated to be 0.984. The standard deviation was assumed to be 0.2 ∗ CMF. The standard error was assumed to be 0.1. Assumed that the treatment applies to unsignalized intersections on urban arterial and collector streets.

VOR (per year): $14,980,000

507) Safety Effects of Installing Centerline Rumble Strips at Multilane Roads with Median Barriers

Assumed treatment: Install inside shoulder rumble strips to existing surface where median barrier exists already
Total target miles or intersections: 11335
Miles or intersections that could be treated: 2833.75
Level of implementation (eligible percentage of sites that could receive this treatment): 25%
Target crash frequency: 74150

- *Proportion of crashes that are PDO*: 0.690
- *Proportion of crashes that are C injury*: 0.210
- *Proportion of crashes that are B injury*: 0.081
- *Proportion of crashes that are A injury*: 0.014
- *Proportion of crashes that are fatal*: 0.004

Cost assumptions
Initial cost: $1,000
Annual maintenance cost: $0
Service life (years): 7
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.981
Estimated standard deviation of CMF before: 0.1960
Estimated standard deviation of CMF after: 0.1930

Other assumptions:

Assumed that urban freeways are the target. Assumed that implementation level is 25%. Assumed that 13% of crashes are median-related (based on Wisconsin data from FHWA low-cost five-study design for median barrier with inside shoulder rumble strips), and the CMF for median-related crashes is 0.85 (based on judgment of the project team). Based on this assumption, the CMF for total crashes was estimated as $0.85 * 0.13 + 1 * 0.87 = 0.9805$ (assuming no effect on non-median-related crashes). Standard error was estimated based on the assumption that CMF was statistically significant at 0.05 level. Standard deviation was assumed to be 0.2 ∗ CMF.

VOR (per year): $4,980,000

510.1) Safety Effects of In-Lane Advance Curve Warning Marking on Rural Two-Lane Roads

Assumed treatment: Install one curve warning marking per lane on each side of curve
Total target miles or intersections: 143935
Miles or intersections that could be treated: 28787
Level of implementation (eligible percentage of sites that could receive this treatment): 20%
Target crash frequency: 56630

- *Proportion of crashes that are PDO*: 0.681
- *Proportion of crashes that are C injury*: 0.170
- *Proportion of crashes that are B injury*: 0.081
- *Proportion of crashes that are A injury*: 0.054
- *Proportion of crashes that are fatal*: 0.015

Cost assumptions
Initial cost: $200
Annual maintenance cost: $0
Service life (years): 5
Unit for cost: per curve

Benefit assumptions
Estimated CMF for total crashes: 0.958
Estimated standard deviation of CMF before: 0.0890
Estimated standard deviation of CMF after: 0.0630

Other assumptions:

To estimate curve mileage, used HPMS to get curves by degree category for each functional class, and then used average curve length from Ohio HSIS curve data for a specific degree category. This gave an estimated total curve mileage by functional class. Based on CMFs from Elvik and Vaa (2004) for injury and PDO crashes, we estimated the CMF for total crashes (assuming PDO crashes represent 70% of total crashes). Then this was combined with the results from Srinivasan et al. (2009) study on improving curve delineation to obtain standard deviation before research. For new research, the standard error of 0.09 was assumed to estimate the standard deviation after new research.

VOR (per year): $58,800,000

510.2) Safety Effects of In-Lane Advance Curve Warning Marking on Rural Multilane Highways

Assumed treatment: Install one curve warning marking per lane on each side of curve
Total target miles or intersections: 5766
Miles or intersections that could be treated: 1153
Level of implementation (eligible percentage of sites that could receive this treatment): 20%
Target crash frequency: 7897

- *Proportion of crashes that are PDO*: 0.705
- *Proportion of crashes that are C injury*: 0.145
- *Proportion of crashes that are B injury*: 0.080
- *Proportion of crashes that are A injury*: 0.052
- *Proportion of crashes that are fatal*: 0.018

Cost assumptions
Initial cost: $400
Annual maintenance cost: $0
Service life (years): 5
Unit for cost: per curve

Benefit assumptions
Estimated CMF for total crashes: 0.958
Estimated standard deviation of CMF before: 0.0890
Estimated standard deviation of CMF after: 0.0630

Other assumptions:

To estimate curve mileage, used HPMS to get curves by degree category for each functional class, and then used average curve length from Ohio HSIS curve data for a specific degree category. This gave an estimated total curve mileage by functional class. Based on CMFs from Elvik and Vaa (2004) for injury and PDO crashes, we estimated the CMF for total crashes (assuming PDO crashes represent 70% of total crashes). Then this was combined with the results from Srinivasan et al. (2009) study on improving curve delineation to obtain standard deviation before research. For new research, the standard error of 0.09 was assumed to estimate the standard deviation after new research.

VOR (per year): $9,170,000

574.3) Safety Effects of Retiming Signal Change Intervals to ITE Standards (Three-Leg Urban Intersections)

Assumed treatment: Major retiming effort
Total target miles or intersections: 57122
Miles or intersections that could be treated: 17136
Level of implementation (eligible percentage of sites that could receive this treatment): 30%
Target crash frequency: 20239

- *Proportion of crashes that are PDO*: 0.636
- *Proportion of crashes that are C injury*: 0.263
- *Proportion of crashes that are B injury*: 0.087
- *Proportion of crashes that are A injury*: 0.012
- *Proportion of crashes that are fatal*: 0.003

Cost assumptions
Initial cost: $10,000
Annual maintenance cost: $0
Service life (years): 10
Unit for cost: per intersection

Benefit assumptions
Estimated CMF for total crashes: 0.7
Estimated standard deviation of CMF before: 0.1390
Estimated standard deviation of CMF after: 0.1200

Other assumptions:

Used two CMFs from CMF Clearinghouse and the NCHRP 17-35 results (Srinivasan et al., 2011). Used the CMF tool to estimate standard deviation before study. Assumed that new study will have 0.09 standard error.

VOR (per year): $200,000

574.4) Safety Effects of Retiming Signal Change Intervals to ITE Standards (Four-Leg Urban Intersections)

Assumed treatment: Major retiming effort
Total target miles or intersections: 212920

Miles or intersections that could be treated: 63876
Level of implementation (eligible percentage of sites that could receive this treatment): 30%
Target crash frequency: 178990

- *Proportion of crashes that are PDO*: 0.636
- *Proportion of crashes that are C injury*: 0.263
- *Proportion of crashes that are B injury*: 0.087
- *Proportion of crashes that are A injury*: 0.012
- *Proportion of crashes that are fatal*: 0.003

Cost assumptions
Initial cost: $10,000
Annual maintenance cost: $0
Service life (years): 10
Unit for cost: per intersection

Benefit assumptions
Estimated CMF for total crashes: 0.834
Estimated standard deviation of CMF before: 0.0610
Estimated standard deviation of CMF after: 0.0510

Other assumptions:
Used two CMFs from CMF Clearinghouse and the NCHRP 17-35 results (Srinivasan et al., 2011). Used the CMF tool to estimate standard deviation before study. Assumed that new study will have 0.09 standard error.

VOR (per year): $840,000

580.1) Develop a CMF for Installing Wide Edgelines (8 In.) on Rural Two-Lane Roads Versus the Standard (4–6 In.)

Assumed treatment: Install 8-in. wide edgelines on both sides of road
Total target miles or intersections: 2911071
Miles or intersections that could be treated: 2881961
Level of implementation (eligible percentage of sites that could receive this treatment): 99%
Target crash frequency: 823615

- *Proportion of crashes that are PDO*: 0.650
- *Proportion of crashes that are C injury*: 0.160
- *Proportion of crashes that are B injury*: 0.138
- *Proportion of crashes that are A injury*: 0.037
- *Proportion of crashes that are fatal*: 0.016

Cost assumptions
Initial cost: $13,000
Annual maintenance cost: $0
Service life (years): 5
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.794
Estimated standard deviation of CMF before: 0.0470
Estimated standard deviation of CMF after: 0.0450

Other assumptions:
Used the results from the latest TTI study (Park et al., 2012). Results from three states were used. The CMF worksheet was used to determine the standard deviation before research. Assumed that new research will have standard error of 0.03.

VOR (per year): $1,090,000

580.2) Develop a CMF for Installing Wide Edgelines (8 In.) on Rural Multilane Highways Versus the Standard (4–6 In.)

Assumed treatment: Install 8-in. wide edgelines on both sides of road
Total target miles or intersections: 32163
Miles or intersections that could be treated: 31198
Level of implementation (eligible percentage of sites that could receive this treatment): 97%
Target crash frequency: 68689

- *Proportion of crashes that are PDO*: 0.676
- *Proportion of crashes that are C injury*: 0.165
- *Proportion of crashes that are B injury*: 0.119
- *Proportion of crashes that are A injury*: 0.027
- *Proportion of crashes that are fatal*: 0.013

Cost assumptions
Initial cost: $13,000
Annual maintenance cost: $0
Service life (years): 5
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.794
Estimated standard deviation of CMF before: 0.0470
Estimated standard deviation of CMF after: 0.0450

Other assumptions:
Used the results from the latest TTI study (Park et al., 2012). Results from three states were used. The CMF worksheet was used to determine the standard deviation before research. Assumed that new research will have standard error of 0.03.

VOR (per year): $20,000

580.3) Develop a CMF for Installing Wide Edgelines (8 In.) on Freeways and Expressways Versus the Standard (4–6 In.)

Assumed treatment: Install 8-in. wide edgelines on both sides of road (assumes two edgelines in each direction because of median)
Total target miles or intersections: 58086
Miles or intersections that could be treated: 54600
Level of implementation (eligible percentage of sites that could receive this treatment): 94%
Target crash frequency: 1024048

- *Proportion of crashes that are PDO*: 0.709
- *Proportion of crashes that are C injury*: 0.188
- *Proportion of crashes that are B injury*: 0.084
- *Proportion of crashes that are A injury*: 0.014
- *Proportion of crashes that are fatal*: 0.005

Cost assumptions
Initial cost: $20,000
Annual maintenance cost: $0
Service life (years): 5
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.794
Estimated standard deviation of CMF before: 0.0470
Estimated standard deviation of CMF after: 0.0450

Other assumptions:
Used the results from the latest TTI study (Park et al., 2012). Results from three states were used. The CMF worksheet was used to determine the standard deviation before research. Assumed that new research will have standard error of 0.03.

VOR (per year): $50,000

580.5) Develop a CMF for Installing Wide Edgelines (8 In.) on Urban and Suburban Arterials Versus the Standard

Assumed treatment: Install 8-in. wide edgelines on both sides of road
Total target miles or intersections: 170729
Miles or intersections that could be treated: 163899.84
Level of implementation (eligible percentage of sites that could receive this treatment): 96%
Target crash frequency: 980140

- *Proportion of crashes that are PDO*: 0.685
- *Proportion of crashes that are C injury*: 0.209
- *Proportion of crashes that are B injury*: 0.086
- *Proportion of crashes that are A injury*: 0.016
- *Proportion of crashes that are fatal*: 0.004

Cost assumptions
Initial cost: $13,000
Annual maintenance cost: $0
Service life (years): 5
Unit for cost: per mile

Benefit assumptions
Estimated CMF for total crashes: 0.794
Estimated standard deviation of CMF before: 0.0470
Estimated standard deviation of CMF after: 0.0450

Other assumptions:
Used the results from the latest TTI study (Park et al., 2012). Results from three states were used. The CMF worksheet was used to determine the standard deviation before research. Assumed that new research will have standard error of 0.03.

VOR (per year): $110,000

References

Bauer, K. M., Harwood, D. W., Hughes, W. E., and Richard, K. R. (2004). "Safety Effects of Using Narrow Lanes and Shoulder-Use Lanes to Increase the Capacity of Urban Freeways." 83rd Transportation Research Board Annual Meeting. Washington, D.C.

Elvik, R. and Vaa, T. (2004). *The Handbook of Road Safety Measures.* Elsevier. Oxford, UK.

Griffin, L. I. and Reinhardt, R. N. (1996). "A Review of Two Innovative Pavement Patterns that Have Been Developed to Reduce Traffic Speeds and Crashes." AAA Foundation for Traffic Safety. Washington, D.C.

Park, E. S., et al. "Safety effects of wider edge lines on rural, two-lane highways." *Accident Analysis & Prevention* 48 (2012): 317–325.

Sayed et al. (2010). "Impact of Rumble Strips on Collision Reduction on BC Highways: A Comprehensive Before and After Safety Study." TRB 89th Annual Meeting Compendium of Papers CD-ROM. Washington, D.C.

Srinivasan, R., Baek, J., Carter, D., Persaud, B., Lyon, C., Eccles, K., Gross, F., and Lefler, N. (2009). "Safety Evaluation of Improved Curve Delineation." Report No. FHWA-HRT-09-045, Federal Highway Administration. Washington, D.C.

Srinivasan, R., et al. (2011). *NCHRP Report 705*: *Evaluation of Safety Strategies at Signalized Intersections.* Transportation Research Board of the National Academies, Washington, D.C.

Ye, X., Pendyala, R. M., Washington, S. P., Konduri, K., and Oh, J. (2008). "A Simultaneous Equations Model of Crash Frequency By Collision Type for Rural Intersections." 87th Annual Meeting of the Transportation Research Board, TRB 2008 Annual Meeting CD-ROM. Washington, D.C.

APPENDIX Q

Results of Fundamental Research and Applied Non-CMF Prioritization[2]

Appendix Q presents the detailed results of the prioritization of fundamental and applied non-CMF research. While this information was summarized in Chapter 3, Appendix Q provides the complete details of factor scores that are used to compute the relative utility index (RUI). A total of 21 fundamental research topics and 29 applied non-CMF research topics were included in the prioritization. Table Q.1 provides the combined list of prioritized research, including both fundamental and applied non-CMF research. While Table Q.1 appears to show a good distribution of the two types of research (i.e., not top-heavy with one or the other), it may be more appropriate to consider them separately. Reasons for separating the two types of research were discussed in Chapter 3. Tables Q.2 and Q.3 present the results separately for fundamental and applied non-CMF research, respectively.

Tables Q.1 through Q.3 are sorted from highest to lowest priority based on the RUI. The RUI is composed of eight factors as follows:

$$RUI = 4TC + 4SC + 3SS + 3QI + 2PS + 2CR + ES + DR$$

TC = Number of Expected Target Crashes.
SC = Severity of Expected Target Crashes.
SS = Extent of Impacts on Science of Safety.
QI = Potential to Improve Quality of Information for Target Crashes.
PS = Probability of Success.
CR = Cost of Research.
ES = Potential to Identify More Effective Strategies for Target Crashes.
DR = Distance between Expected Research Results and Treatment-Related Decisions.

[2]Appendices A-O and R are not published herein. These appendices are available in electronic format only and can be downloaded at http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2727.

Table Q.1. Prioritization results for fundamental research and applied non-CMF prioritization.

Research Topic	Research Category	Focus Area	Project Description	Factors Applied to Compute Relative Utility Index								RUI
				TC	SC	SS	QI	PS	CR	ES	DR	
AASHTO Design Criteria and Design Model Research including the Science of Safety (relates to project #69 and #536)	Applied Non-CMF	Alignment	Based on the findings from the previous project, a series of research studies to fill the gaps in design policy formulation would occur. The following issues (which would need confirmation) are believed to represent core needs. Task 1. AASHTO Horizontal Curve Design Model. Task 2. Roadside Design Criteria for the Urban Environment. Task 3. Cross Section Design Criteria for the Urban Environment. Task 4. Relationship of Level of Service to Substantive Safety. Task 5. Influence of Geometric Design Dimensions on Highway Maintenance. Task 6. Discretionary Decision-making, Tort Law, and Risk Management State Practices. Task 7. AASHTO Sight Distance Design Models.	5	5	4	4	4	2	2	5	83
Updating databases of in-depth crash attributes - expansion to F-SHRP 2	Fundamental	Data Management	Enhance knowledge about roadway crashes for improved understanding of crash causes. Continue maintenance and digitization of the library, including database updates and online accessibility improvements.	5	5	4	4	4	4	2	1	83
Demonstrate Application of Surrogates and an Understanding of Safety Issues (continuation of research idea # 356)	Applied Non-CMF	Evaluation Methods	This project would follow the previous one (356). It would consist of a series of separate research projects, each project focusing on one of the surrogate safety measures evaluated in the previous research project and identified as having the most promise. One objective will be to demonstrate the application of the surrogate safety measure (or class of related surrogate measures) for safety evaluation. A second objective will be to evaluate the ability of each safety surrogate (or class of related surrogate measures) to describe facility safety, or to quantify the safety effect of a treatment.	5	5	4	3	3	4	2	5	82
Develop/test procedures to identify locations for cost-effective programs of system-wide improvements	Fundamental	Network Safety	The purpose of this project is to develop and test procedures to identify locations for cost-effective programs of system-wide/region-wide/area-wide improvements.	5	5	4	4	3	4	2	1	81
Develop a tool for assessing the extent to which a new statistical method or modeling approach succeeds in identifying the cause-effect relationship in the data	Fundamental	Evaluation Methods	With highway safety data, cause-and-effect conclusions obtained through the use of existing statistical methods are unreliable. The objective of this research project is to develop a tool for assessing the extent to which a new statistical method or modeling approach succeeds in identifying the cause-effect relationship in the data.	5	5	4	4	3	4	2	1	81

Development of Driver Behavior Models for Structural Modeling	Fundamental	Evaluation Methods	The objective of this project is to develop realistic representations of road-user behavior for use in structural models, with consideration given to all road users, including drivers, pedestrians, and motorcyclists. The focus should be on driver behaviors that are associated with infrastructure design, traffic control, and vehicle operation (e.g., reaction time, visual acuity, speed choice, etc.).	5	5	4	4	3	4	2	1	81
Establish criteria to assess the validity of surrogate measures and safety relationships. Evaluate and validate candidate surrogate measures (continuation of research idea #355)	Fundamental	Evaluation Methods	The objective of this project is to conduct a state-of-the-art review of knowledge in the area of surrogate safety measures and synthesize the findings. The synthesis should identify and define candidate surrogate measures. It should also establish criteria to assess the validity of alternative surrogate measures. The criteria should consider the use and usefulness of each measure in road safety evaluation. Thereafter, research is needed to identify potential roles for each candidate measure (e.g., for countermeasure evaluation, or as an independent variable in a safety prediction model). This research component would consist of a series of separate research projects. Each project would evaluate and validate one candidate surrogate safety measure or one specific class of related measures (e.g., surrogates from simulation modeling, surrogates from field studies).	5	5	5	3	3	3	2	3	81
Updating the Cost of Crashes	Applied Non-CMF	Data Management	Develop and deploy support that facilitates an evidence-based decision-making approach to improve safety. Update Cost of Crashes Report and Guidance.	5	5	3	3	4	4	2	5	81
Refine Geometric Design Models and Process including the Science of Safety	Fundamental	Alignment	The objective of this project is to perform a critical review of the format, structure and basic assumptions included in the AASHTO Policies governing geometric design of highways and streets. AASHTO presents basic geometric guidance information inconsistently. A critique of all models is needed as to their adequacy and applicability across the range of location, traffic conditions and functional classification. This research effort should directly involve the AASHTO Geometric Design Task Force and Subcommittee on Design. The inclusion of the Science of Safety and the HSM are key components of this research project.	5	5	4	3	3	4	2	3	80
Develop a national data warehouse and archived data	Fundamental	Data Management	The purpose of this project is to develop a data warehousing and archiving system. As a result, data previously gathered and analyzed could be available for future analyses.	5	5	4	3	3	5	2	1	80

(continued on next page)

Table Q.1. (Continued).

Research Topic	Research Category	Focus Area	Project Description	Factors Applied to Compute Relative Utility Index								RUI
				TC	SC	SS	QI	PS	CR	ES	DR	
Evaluate and Improve Criteria for Collecting Speeding-Related Crash Data	Applied Non-CMF	Speed	Better define the relationship between speed and safety. Evaluate and improve criteria for collecting speeding-related crash data.	4	4	3	4	3	5	2	5	76
Develop safety prediction models for corridors with different access point density on multilane highways and expressways	Applied Non-CMF	Access Management	Develop safety prediction models for corridors with different access point density on multilane highways and expressways.	4	4	3	3	5	4	2	5	75
Developing Methodologies to Determine Cost-Benefit of Data Investment	Fundamental	Data Management	Encourage the use of information on the basis of quality data and analytical processes to make better safety decisions. Develop methodologies to determine cost-benefit of data investment.	5	5	3	3	2	4	2	1	73
Develop a Program for New safety prediction models for Part C of HSM	Applied Non-CMF	Safety Tools	Research is needed to expand the range of intersection types addressed in predictive methods in Chapters 10, 11, and 12 in HSM Part C.	4	4	3	4	4	2	2	5	72
Understanding the Influence of Road Features on Crashes—expansion to F-SHRP 2	Fundamental	Data Management	Enhance knowledge about roadway crashes for improved understanding of crash causes. Pursue second phase of rollover study to link empirical results to simulation analysis to establish a more comprehensive understanding of the influence of road features on rollover crashes.	4	4	4	4	3	3	2	1	71
Safety Effects of Dynamic Speed Feedback Signs on Curves along 2-lane rural roads	Applied Non-CMF	Speed	Better define the relationship between speed and safety. Evaluate dynamic speed feedback signs on curves.	3	3	4	4	4	4	2	5	71
Develop methods and tools for design and evaluation of roadway departure programs and treatments. Develop finite element models for representative vehicles to support simulation of various types of crashes	Fundamental	Evaluation Methods	Develop methods and tools for design and evaluation of roadway departure programs and treatments. Develop finite element models for representative vehicles to support simulation of various types of crashes.	4	4	4	3	3	4	2	1	70
Data Collection and Analysis of Vehicle Paths and the Safety Effects of Alternative Curve Design Elements (compound circular curves, spiral transition, and tangent-to-curve transitions)	Fundamental	Alignment	Develop an experimental and/or field study protocol to collect data to study the nature of vehicle paths and operating speeds on transition curves, focused primarily on freeway exit ramps. Determine if, and how much, excessive lateral vehicle shifts are caused by compound circular curves, spiral transition, and tangent-to-curve transitions; compare the results with collision and speed reduction data.	4	4	3	3	3	4	2	3	69

Development of National Service Level Criteria for the Interstate and National Highway System for rest area facilities with explicit safety impacts	Applied Non-CMF	Rest Area	The objectives of this research effort are to develop national service level criteria for safe and secure rest area facilities development and maintenance along interstate highways.	4	4	1	1	3	5	5	5	64
Assessment of compatibility of modern vehicles and roadside safety hardware	Fundamental	Roadside Furniture	Assessment of compatibility of modern vehicles and roadside safety hardware. There is concern that the newer model vehicles may be incompatible with current roadside hardware that was developed using older models in crash tests, and that this problem will become worse in the future.	4	3	3	3	3	3	2	3	63
Safety Effects of Increasing Drivers' Response to the 1st signalized intersection when entering urban areas (following rural travel)	Applied Non-CMF	Intersection Traffic Control	Investigate methods to increase the safety of the "first signal" in the urbanized area such as real-time activated vs. static flashers.	3	1	3	4	4	5	3	5	63
Barrier System Maintenance Procedures based on Damage and Potential Safety Impacts	Applied Non-CMF	Roadside Furniture	The final product expected from this research is an objective set of guidelines for determining the limits of damage to a longitudinal barrier that will not cause the barrier to have unacceptable safety performance. The guidelines will also address which safety feature components require replacement or refurbishment when repair is deemed to be necessary.	4	3	2	3	2	4	2	5	62
Best Practices in the Identification and Prioritization of High Pedestrian Crash Locations/Areas	Applied Non-CMF	Pedestrians	Research to generate best practices in pedestrian problem area identification (including the use of GIS, crash data, and land use data) and prioritization to assist practitioners in accurately and systematically identifying pedestrian risk areas that could be pro-actively treated.	2	3	3	4	3	4	2	5	62
Develop an In-depth Understanding of Crashes with Utility Poles	Fundamental	Roadside Furniture	The objectives of this project are to (1) Identify the human, site, and traffic conditions associated with crashes involving poles and (2) Combine those characteristics with those already available related to vehicle type size, speed, and trajectory to develop better empirical/analytical methods of separating the predictable collisions, subject to cost-effective treatments from the purely random collision, that which is not reasonably predictable.	3	3	3	3	3	5	2	1	61
Develop safety prediction models for corridors with different access point density on two-lane rural roads	Applied Non-CMF	Access Management	Develop safety prediction models for corridors with different access point density on 2-lane rural roads.	1	4	3	3	4	4	2	5	61

(continued on next page)

Table Q.1. (Continued).

Research Topic	Research Category	Focus Area	Project Description	Factors Applied to Compute Relative Utility Index								RUI
				TC	SC	SS	QI	PS	CR	ES	DR	
Safety performance of large trucks by volume and time-of-day for planning and operations of freeway and multilane highway networks	Applied Non-CMF	Commercial Vehicles	The recommended study would review the literature and available data sources on large truck crash rates and risks by time-of-day. This would include crash distributions, crash harm distributions (derived from severity statistics), mileage exposure distributions, time-of-driving distributions (i.e., from naturalistic driving studies), and any other data metrics representing either a numerator or denominator in the overall time-of-day risk assessment. A successful study would derive time-of-day crash risk functions to inform carrier dispatching and other operational decisions. Potential approaches to how to incorporate heavy trucks into freeway and multilane highway network operations with safety explicitly quantified.	3	3	2	3	3	4	2	5	60
Investigate the Accuracy of Automated Pedestrian/Vehicle Conflict Video Data Collection in Comparison with Human Observations	Fundamental	Pedestrians	Research on the use of video data collection to detect, measure, and evaluate pedestrian/vehicle conflicts and the accuracy compared to human observations.	2	3	3	4	3	5	2	1	60
Motorcycle Crash Causation Study	Fundamental	Motorcyclists	Devising effective crash and injury countermeasures requires comprehensive research into current causes of motorcycle crashes and defining the population at risk. The objective of this research is to conduct on-scene, in-depth research on motorcycle crashes and user population at risk, and to harmonize such research with previous studies.	1	4	3	4	3	5	1	1	59
Development of incident duration and secondary crash prediction models for freeways and multilane highways	Applied Non-CMF	Advanced Technology and ITS	Development of incident duration and secondary crash occurrence prediction models on freeways and multilane highways for use by Transportation Management Centers, so users can make more informed travel choices.	2	2	3	3	3	4	5	5	58
Developing Valid Estimates of Motorcycle Exposure for Safety Analysis	Fundamental	Data Management	The objective of this research is to identify a reliable means for estimating motorcyclist exposure for motorcyclist safety analysis.	1	4	3	3	3	5	1	3	58
Safety predictive models for multi-vehicle collisions based on tunnel characteristics and service areas, and response needs	Applied Non-CMF	Tunnels	Determination of probabilities for multi-vehicle collisions based on tunnel characteristics and service areas, and develop predictive models for crashes in tunnels and response requirements.	3	2	2	2	3	5	5	5	58

Development of a Bicycle Safety Prediction Methodology for Road Segments and Signalized and Unsignalized Intersections	Applied Non-CMF	Bicyclists	The proposed research will explore exposure measures (effects of distance, time, traffic volume, number of lanes, etc.) and develop a predictive method for geometric treatments for bicyclists: 1. Along road segments (marked bicycle lanes, separated bicycle lanes, and raised bicycle lanes). 2. At signalized intersections. 3. At unsignalized intersections.	3	2	2	4	2	4	2	5	57
Evaluation of existing and new commercial vehicle exposure measures to generate meaningful safety estimates for freeways and multilane highways using these surrogate measures	Fundamental	Commercial Vehicles	The objective of this research is to evaluate the validity and usefulness of existing and potential exposure measures corresponding to key crash data variables for the purpose of generating more valid and meaningful relative risk estimates. This may include surrogate exposure measures, but should include actual measures of normal driving, including those based on: 1. Highway/traffic monitoring. 2. Naturalistic driving baseline (random epoch) data. 3. Fleet-based real-time documentation of random trip “exposure points.” 4. Government or carrier records (e.g., Hours-of-Service [HOS] logs). 5. Surveys. 6. Non-crash controls (e.g., non-crash trucks and drivers).	3	3	3	2	3	4	3	1	57
Development of safety prediction models for pedestrian target crashes at midblock locations with marked crosswalks along urban multilane roadways	Applied Non-CMF	Pedestrians	Development of safety prediction models for pedestrian target crashes at given design characteristics of midblock locations with marked crosswalks - urban multilane roadways.	1	2	3	4	3	5	2	5	56
Empirical testing of W-Beam Guardrail to Expected Safety Performance	Fundamental	Roadside Furniture	Evaluation of W-beam guardrail failures to the expected performance.	3	2	2	3	3	5	2	3	56
Development of safety prediction models for a set of two three-leg intersections	Applied Non-CMF	Intersection Geometry	Development of safety prediction models for a set of two three-leg intersections on rural two-lane roads, rural multilane highways, and urban and suburban arterials.	3	2	2	3	3	4	2	5	56
Operational and Safety Effects of marking a new crosswalk at midblock locations	Applied Non-CMF	Pedestrians	Research to evaluate how new pedestrian facilities affect pedestrian exposure data and to determine the increased facility use using before and after case studies of pedestrian facility projects.	2	3	2	2	3	5	2	5	55
Development of a Safer Concrete Barrier	Fundamental	Roadside Furniture	The objective of this research project is to develop a new concrete barrier design that can be as economical and durable as safety shape and single slope barriers without producing the same rollover potential. The new barrier shape should essentially eliminate vehicle climb, minimize the risk of head-slap against the barrier, and be slip-formable.	3	2	3	3	3	3	1	3	54

(continued on next page)

Table Q.1. (Continued).

Research Topic	Research Category	Focus Area	Project Description	Factors Applied to Compute Relative Utility Index								RUI
				TC	SC	SS	QI	PS	CR	ES	DR	
Develop Safety Predictive Models for Roundabouts in rural and urban conditions with four approaches and one or two-lane entries/approach	Applied Non-CMF	Intersection Geometry	Develop Predictive Methods for Roundabouts for Part C of the HSM.	2	1	3	4	4	3	1	5	53
Safety impacts to pedestrian at different levels of visibility and sightlines at an urban intersection	Applied Non-CMF	Pedestrians	A study of the safety impacts of lighting and other roadside elements such as newspaper boxes, shrubs, and other obstructions on driver-pedestrian visibility at urban intersections.	2	2	2	3	2	5	2	5	52
Best Practices and Pedestrian Safety Concerns Related to Transit Access in Urban Areas	Applied Non-CMF	Pedestrians	Research on (1) pedestrian safety concerns around transit (including bus stops, light and heavy rail, and streetcars); around at-grade rail crossings; and along railways and on (2) best practices related to transit access and increasing transit ridership through pedestrian facility improvement.	2	3	1	2	3	5	2	5	52
Development of National Service Level Criteria for Freeways and Multilane Highways with four lanes or more with explicit safety impacts of different drainage features	Applied Non-CMF	Roadside Furniture	The objectives of this research effort are to develop national service level criteria for functional drainage features (culverts, inlets, rutted pavement lanes that pond water, ditches, under drains, etc.) for freeways and multilane highways of four lanes or more.	2	2	2	2	3	5	2	5	51
Development of a Pedestrian Safety Prediction Methodology for Unsignalized Intersections	Applied Non-CMF	Pedestrians	The proposed research will develop a predictive method for geometric treatments for pedestrians at unsignalized intersections.	1	1	2	4	3	5	2	5	49
Systematic Data Management of Crashes on Shared Use Pathways	Applied Non-CMF	Shared Pathways	The purpose of this project is to develop recommendations for a national and standardized data management for shared use pathway crash and injury data: collection, analysis, and publication system.	1	1	2	3	3	5	5	5	49
Accessible Pedestrian Signals	Applied Non-CMF	Pedestrians	Research on APS devices, specifically the impacts and benefits for non-disability users, guidance on maintenance audits and protocol, as well as guidance on where APS devices are most beneficial and should be prioritized, or where fixed-time operation should be used.	2	2	2	2	2	5	2	5	49

Evaluation of the applicability of and the effect of detection technologies related to pedestrian real-time data (walking speeds, crossing times, etc.) and vehicular operations at intersections toward enhancing the safety and operations of signalized intersections at urban collector and arterial roadways	Fundamental	Advanced Technology and ITS	The purpose of this project is to test and apply existing detection technologies to capture real-time pedestrian walking speed/location data and behavioral needs in conjunction with vehicular traffic operations to accommodate the data input in a new intersection signal system.	2	2	3	2	3	4	2	1	48
Investigate Measures to Enhance Interactions Between Pedestrians and Large Commercial Vehicles (Trucks and Buses) in Urban Areas	Fundamental	Pedestrians	Research identifying pedestrian safety improvements with regard to large commercial vehicles, especially in urban areas.	1	1	2	3	3	5	5	3	47
Safety impacts to pedestrians at different levels of visibility and sightlines at a roundabout	Applied Non-CMF	Pedestrians	A study of the safety impacts of lighting and other roadside elements such as newspaper boxes, shrubs, and other obstructions on driver-pedestrian visibility at roundabouts.	1	1	2	2	2	5	5	5	44
Animal-Vehicle Crash Severity Reduction Using Advanced Technologies along Freeways and Multilane Highways	Applied Non-CMF	Advanced Technology and ITS	This study will examine innovative ways to mitigate the damage from animal-vehicle crashes using traditional measures as well as advanced technologies. Since preventing such crashes have proven to be very difficult, this study will investigate ways to reduce the severity of the crashes.	1	1	3	2	2	5	1	5	43
Costs of vehicle-train collisions at urban and rural crossings	Applied Non-CMF	Highway-Railway	The objective of this research is to develop a cost model that takes into account direct costs from multiple perspectives that accrue as the result of a vehicle-train collision at urban and rural railroad grade crossings.	1	1	2	2	3	5	1	5	42

Table Q.2. Prioritization results for fundamental research prioritization.

Research Topic	Research Category	Focus Area	Project Description	Factors Applied to Compute Relative Utility Index								RUI
				TC	SC	SS	QI	PS	CR	ES	DR	
Updating databases of in-depth crash attributes—expansion to F-SHRP 2	Fundamental	Data Management	Enhance knowledge about roadway crashes for improved understanding of crash causes. Continue maintenance and digitization of the library, including database updates and online accessibility improvements.	5	5	4	4	4	4	2	1	83
Develop/test procedures to identify locations for cost-effective programs of system-wide improvements	Fundamental	Network Safety	The purpose of this project is to develop and test procedures to identify locations for cost-effective programs of system-wide/ region-wide/area-wide improvements.	5	5	4	4	3	4	2	1	81
Develop a tool for assessing the extent to which a new statistical method or modeling approach succeeds in identifying the cause-effect relationship in the data	Fundamental	Evaluation Methods	With highway safety data, cause-and-effect conclusions obtained through the use of existing statistical methods are unreliable. The objective of this research project is to develop a tool for assessing the extent to which a new statistical method or modeling approach succeeds in identifying the cause-effect relationship in the data.	5	5	4	4	3	4	2	1	81
Development of Driver Behavior Models for Structural Modeling	Fundamental	Evaluation Methods	The objective of this project is to develop realistic representations of road-user behavior for use in structural models, with consideration given to all road users, including drivers, pedestrians, and motorcyclists. The focus should be on driver behaviors that are associated with infrastructure design, traffic control, and vehicle operation (e.g., reaction time, visual acuity, speed choice, etc.).	5	5	4	4	3	4	2	1	81
Establish criteria to assess the validity of surrogate measures and safety relationships. Evaluate and validate candidate surrogate measures (continuation of research idea #355)	Fundamental	Evaluation Methods	The objective of this project is to conduct a state-of-the-art review of knowledge in the area of surrogate safety measures and synthesize the findings. The synthesis should identify and define candidate surrogate measures. It should also establish criteria to assess the validity of alternative surrogate measures. The criteria should consider the use and usefulness of each measure in road safety evaluation. Thereafter, research is needed to identify potential roles for each candidate measure (e.g., for countermeasure evaluation, or as an independent variable in a safety prediction model). This research component would consist of a series of separate research projects. Each project would evaluate and validate one candidate surrogate safety measure or one specific class of related measures (e.g., surrogates from simulation modeling, surrogates from field studies).	5	5	5	3	3	3	2	3	81

Refine Geometric Design Models and Process including the Science of Safety	Fundamental	Alignment	The objective of this project is to perform a critical review of the format, structure, and basic assumptions included in the AASHTO Policies governing geometric design of highways and streets. AASHTO presents basic geometric guidance information inconsistently. A critique of all models is needed as to their adequacy and applicability across the range of location, traffic conditions, and functional classification. This research effort should directly involve the AASHTO Geometric Design Task Force and Subcommittee on Design. The inclusion of the Science of Safety and the HSM are key components of this research project.	5	5	4	3	3	4	2	3	80
Develop a national data warehouse and archived data	Fundamental	Data Management	The purpose of this project is to develop a data warehousing and archiving system. As a result, data previously gathered and analyzed could be available for future analyses.	5	5	4	3	3	5	2	1	80
Developing Methodologies to Determine Cost-Benefit of Data Investment	Fundamental	Data Management	Encourage the use of information on the basis of quality data and analytical processes to make better safety decisions. Develop methodologies to determine cost-benefit of data investment.	5	5	3	3	2	4	2	1	73
Understanding the Influence of Road Features on Crashes—expansion to F-SHRP 2	Fundamental	Data Management	Enhance knowledge about roadway crashes for improved understanding of crash causes. Pursue second phase of rollover study to link empirical results to simulation analysis to establish a more comprehensive understanding of the influence of road features on rollover crashes.	4	4	4	4	3	3	2	1	71
Develop methods and tools for design and evaluation of roadway departure programs and treatments. Develop finite element models for representative vehicles to support simulation of various types of crashes	Fundamental	Evaluation Methods	Develop methods and tools for design and evaluation of roadway departure programs and treatments. Develop finite element models for representative vehicles to support simulation of various types of crashes.	4	4	4	3	3	4	2	1	70
Data Collection and Analysis of Vehicle Paths and the Safety Effects of Alternative Curve Design Elements (compound circular curves, spiral transition, and tangent-to-curve transitions)	Fundamental	Alignment	Develop an experimental and/or field study protocol to collect data to study the nature of vehicle paths and operating speeds on transition curves, focused primarily on freeway exit ramps. Determine if, and how much, excessive lateral vehicle shifts are caused by compound circular curves, spiral transition, and tangent-to-curve transitions; compare the results with collision and speed reduction data.	4	4	3	3	3	4	2	3	69
Assessment of compatibility of modern vehicles and roadside safety hardware	Fundamental	Roadside Furniture	Assessment of compatibility of modern vehicles and roadside safety hardware. There is concern that the newer model vehicles may be incompatible with current roadside hardware that was developed using older models in crash tests, and that this problem will become worse in the future.	4	3	3	3	3	3	2	3	63

(continued on next page)

Table Q.2. (Continued).

Research Topic	Research Category	Focus Area	Project Description	Factors Applied to Compute Relative Utility Index								RUI
				TC	SC	SS	QI	PS	CR	ES	DR	
Develop an In-depth Understanding of Crashes with Utility Poles	Fundamental	Roadside Furniture	The objectives of this project are to (1) Identify the human, site and traffic conditions associated with crashes involving poles and (2) Combine those characteristics with those already available related to vehicle type size, speed, and trajectory to develop better empirical/analytical methods of separating the predictable collisions, subject to cost-effective treatments from the purely random collision, that which is not reasonably predictable.	3	3	3	3	3	5	2	1	61
Investigate the Accuracy of Automated Pedestrian/Vehicle Conflict Video Data Collection in Comparison with Human Observations	Fundamental	Pedestrians	Research on the use of video data collection to detect, measure, and evaluate pedestrian/vehicle conflicts and the accuracy compared to human observations.	2	3	3	4	3	5	2	1	60
Motorcycle Crash Causation Study	Fundamental	Motorcyclists	Devising effective crash and injury countermeasures requires comprehensive research into current causes of motorcycle crashes and defining the population at risk. The objective of this research is to conduct on-scene, in-depth research on motorcycle crashes and user population at risk, and to harmonize such research with previous studies.	1	4	3	4	3	5	1	1	59
Developing Valid Estimates of Motorcycle Exposure for Safety Analysis	Fundamental	Data Management	The objective of this research is to identify a reliable means for estimating motorcyclist exposure for motorcyclist safety analysis.	1	4	3	3	3	5	1	3	58
Evaluation of existing and new commercial vehicle exposure measures to generate meaningful safety estimates for freeways and multilane highways using these surrogate measures	Fundamental	Commercial Vehicles	The objective of this research is to evaluate the validity and usefulness of existing and potential exposure measures corresponding to key crash data variables for the purpose of generating more valid and meaningful relative risk estimates. This may include surrogate exposure measures, but should include actual measures of normal driving, including those based on: 1. Highway/traffic monitoring. 2. Naturalistic driving baseline (random epoch) data. 3. Fleet-based real-time documentation of random trip "exposure points." 4. Government or carrier records (e.g., Hours-of-Service [HOS] logs). 5. Surveys. 6. Non-crash controls (e.g., non-crash trucks and drivers).	3	3	3	2	3	4	3	1	57

Empirical Testing of W-Beam Guardrail to Expected Safety Performance	Fundamental	Roadside Furniture	Evaluation of W-beam guardrail failures to the expected performance.	3	2	2	3	3	5	2	3	56
Development of a Safer Concrete Barrier	Fundamental	Roadside Furniture	The objective of this research project is to develop a new concrete barrier design that can be as economical and durable as safety shape and single slope barriers without producing the same rollover potential. The new barrier shape should essentially eliminate vehicle climb, minimize the risk of head-slap against the barrier, and be slip-formable.	3	2	3	3	3	3	1	3	54
Evaluation of the applicability of and the effect of detection technologies related to pedestrian real-time data (walking speeds, crossing times, etc.) and vehicular operations at intersections toward enhancing the safety and operations of signalized intersections at urban collector and arterial roadways	Fundamental	Advanced Technology and ITS	The purpose of this project is to test and apply existing detection technologies to capture real-time pedestrian walking speed/location data and behavioral needs in conjunction with vehicular traffic operations to accommodate the data input in a new intersection signal system.	2	2	3	2	3	4	2	1	48
Investigate Measures to Enhance Interactions Between Pedestrians and Large Commercial Vehicles (Trucks and Buses) in Urban Areas	Fundamental	Pedestrians	Research identifying pedestrian safety improvements with regard to large commercial vehicles, especially in urban areas.	1	1	2	3	3	5	5	3	47

Table Q.3. Prioritization results for non-CMF applied research prioritization.

Research Topic	Research Category	Focus Area	Project Description	Factors Applied to Compute Relative Utility Index								RUI
				TC	SC	SS	QI	PS	CR	ES	DR	
AASHTO Design Criteria and Design Model Research including the Science of Safety (relates to project #69 and #536)	Applied Non-CMF	Alignment	Based on the findings from the previous project, a series of research studies to fill the gaps in design policy formulation would occur. The following issues (which would need confirmation) are believed to represent core needs. Task 1. AASHTO Horizontal Curve Design Model. Task 2. Roadside Design Criteria for the Urban Environment. Task 3. Cross Section Design Criteria for the Urban Environment. Task 4. Relationship of Level of Service to Substantive Safety. Task 5. Influence of Geometric Design Dimensions on Highway Maintenance. Task 6. Discretionary Decision-making, Tort Law, and Risk Management State Practices. Task 7. AASHTO Sight Distance Design Models.	5	5	4	4	4	2	2	5	83
Demonstrate Application of Surrogates and an Understanding of Safety Issues (continuation of research idea # 356)	Applied Non-CMF	Evaluation Methods	This project would follow the previous one (356). It would consist of a series of separate research projects, each project focusing on one of the surrogate safety measures evaluated in the previous research project and identified as having the most promise. One objective will be to demonstrate the application of the surrogate safety measure (or class of related surrogate measures) for safety evaluation. A second objective will be to evaluate the ability of each safety surrogate (or class of related surrogate measures) to describe facility safety, or to quantify the safety effect of a treatment.	5	5	4	3	3	4	2	5	82
Updating the Cost of Crashes	Applied Non-CMF	Data Management	Develop and deploy support that facilitates an evidence-based decision-making approach to improve safety. Update Cost of Crashes Report and Guidance.	5	5	3	3	4	4	2	5	81
Evaluate and Improve Criteria for Collecting Speeding-Related Crash Data	Applied Non-CMF	Speed	Better define the relationship between speed and safety. Evaluate and improve criteria for collecting speeding-related crash data.	4	4	3	4	3	5	2	5	76
Develop safety prediction models for corridors with different access point density on multilane highways and expressways	Applied Non-CMF	Access Management	Develop safety prediction models for corridors with different access point density on multilane highways and expressways.	4	4	3	3	5	4	2	5	75
Develop a Program for New safety prediction models for Part C of HSM	Applied Non-CMF	Safety Tools	Research is needed to expand the range of intersection types addressed in predictive methods in Chapters 10, 11, and 12 in HSM Part C.	4	4	3	4	4	2	2	5	72

Safety Effects of Dynamic Speed Feedback Signs on Curves along two-lane rural roads	Applied Non-CMF	Speed	Better define the relationship between speed and safety. Evaluate dynamic speed feedback signs on curves.	3	3	4	4	4	4	2	5	71
Development of National Service Level Criteria for the Interstate and National Highway System for rest area facilities with explicit safety impacts	Applied Non-CMF	Rest area	The objectives of this research effort are to develop national service level criteria for safe and secure rest area facilities development and maintenance along interstate highways.	4	4	1	1	3	5	5	5	64
Safety Effects of Increasing Drivers' Response to the First signalized intersection when entering urban areas (following rural travel)	Applied Non-CMF	Intersection Traffic Control	Investigate methods to increase the safety of the "first signal" in the urbanized area such as real-time activated vs. static flashers.	3	1	3	4	4	5	3	5	63
Barrier System Maintenance Procedures based on Damage and Potential Safety Impacts	Applied Non-CMF	Roadside Furniture	The final product expected from this research is an objective set of guidelines for determining the limits of damage to a longitudinal barrier that will not cause the barrier to have unacceptable safety performance. The guidelines will also address which safety feature components require replacement or refurbishment when repair is deemed to be necessary.	4	3	2	3	2	4	2	5	62
Best Practices in the Identification and Prioritization of High Pedestrian Crash Locations/Areas	Applied Non-CMF	Pedestrians	Research to generate best practices in pedestrian problem area identification (including the use of GIS, crash data, and land use data) and prioritization to assist practitioners in accurately and systematically identifying pedestrian risk areas that could be pro-actively treated.	2	3	3	4	3	4	2	5	62
Develop safety prediction models for corridors with different access point density on 2-lane rural roads	Applied Non-CMF	Access Management	Develop safety prediction models for corridors with different access point density on 2-lane rural roads.	1	4	3	3	4	4	2	5	61
Safety performance of large trucks by volume and time-of-day for planning and operations of freeway and multilane highway networks	Applied Non-CMF	Commercial Vehicles	The recommended study would review the literature and available data sources on large truck crash rates and risks by time-of-day. This would include crash distributions, crash harm distributions (derived from severity statistics), mileage exposure distributions, time-of-driving distributions (i.e., from naturalistic driving studies), and any other data metrics representing either a numerator or denominator in the overall time-of-day risk assessment. A successful study would derive time-of-day crash risk functions to inform carrier dispatching and other operational decisions. Potential approaches to how to incorporate heavy trucks into freeway and multilane highway network operations with safety explicitly quantified.	3	3	2	3	3	4	2	5	60

(continued on next page)

Table Q.3. (Continued).

Research Topic	Research Category	Focus Area	Project Description	Factors Applied to Compute Relative Utility Index								RUI
				TC	SC	SS	QI	PS	CR	ES	DR	
Development of incident duration and secondary crash prediction models for freeways and multilane highways	Applied Non-CMF	Advanced Technology and ITS	Development of an incident duration and secondary crash occurrence prediction models on freeways and multilane highways for use by Transportation Management Centers, so users can make more informed travel choices.	2	2	3	3	3	4	5	5	58
Safety predictive models for multi-vehicle collisions based on tunnel characteristics and service areas, and response needs	Applied Non-CMF	Tunnels	Determination of probabilities for multi-vehicle collisions based on tunnel characteristics and service areas, and develop predictive models for crashes in tunnels and response requirements.	3	2	2	2	3	5	5	5	58
Development of a Bicycle Safety Prediction Methodology for Road Segments and Signalized and Unsignalized Intersections	Applied Non-CMF	Bicyclists	The proposed research will explore exposure measures (effects of distance, time, traffic volume, number of lanes, etc.) and develop a predictive method for geometric treatments for bicyclists: 1. Along road segments (marked bicycle lanes, separated bicycle lanes, and raised bicycle lanes). 2. At signalized intersections. 3. At unsignalized intersections.	3	2	2	4	2	4	2	5	57
Development of safety prediction models for pedestrian target crashes at midblock locations with marked crosswalks along urban multilane roadways	Applied Non-CMF	Pedestrians	Development of safety prediction models for pedestrian target crashes at given design characteristics of midblock locations with marked crosswalks-urban multilane roadways.	1	2	3	4	3	5	2	5	56
Development of safety prediction models for a set of two three-leg intersections	Applied Non-CMF	Intersection Geometry	Development of safety prediction models for a set of two three-leg intersections on rural two-lane roads, rural multilane highways, and urban and suburban arterials.	3	2	2	3	3	4	2	5	56
Operational and Safety Effects of marking a new crosswalk at midblock locations	Applied Non-CMF	Pedestrians	Research to evaluate how new pedestrian facilities affect pedestrian exposure data and to determine the increase in facility use by using before and after case studies of pedestrian facility projects.	2	3	2	2	3	5	2	5	55
Develop Safety Predictive Models for Roundabouts in rural and urban conditions with four approaches and one- or two-lane entries/approach	Applied Non-CMF	Intersection Geometry	Develop Predictive Methods for Roundabouts for Part C of the HSM.	2	1	3	4	4	3	1	5	53
Safety impacts to pedestrian at different levels of visibility and sightlines at an urban intersection	Applied Non-CMF	Pedestrians	A study of the safety impacts of lighting and other roadside elements such as newspaper boxes, shrubs, and other obstructions on driver-pedestrian visibility at urban intersections.	2	2	2	3	2	5	2	5	52

Best Practices and Pedestrian Safety Concerns Related to Transit Access in Urban Areas	Applied Non-CMF	Pedestrians	Research on (1) pedestrian safety concerns around transit (including bus stops, light and heavy rail, and streetcars); around at-grade rail crossings; and along railways and on (2) best practices related to transit access and increasing transit ridership through pedestrian facility improvement.	2	3	1	2	3	5	2	5	52
Development of National Service Level Criteria for Freeways and Multilane Highways with four lanes or more with explicit safety impacts of different drainage features	Applied Non-CMF	Roadside Furniture	The objectives of this research effort are to develop national service level criteria for functional drainage features (culverts, inlets, rutted pavement lanes that pond water, ditches, under drains, etc.) for freeways and multilane highways of four lanes or more.	2	2	2	2	3	5	2	5	51
Development of a Pedestrian Safety Prediction Methodology for Unsignalized Intersections	Applied Non-CMF	Pedestrians	The proposed research will develop a predictive method for geometric treatments for pedestrians at unsignalized intersections.	1	1	2	4	3	5	2	5	49
Systematic Data Management of Crashes on Shared Use Pathways	Applied Non-CMF	Shared Pathways	The purpose of this project is to develop recommendations for a national and standardized data management for shared use pathway crash and injury data: collection, analysis, and publication system.	1	1	2	3	3	5	5	5	49
Accessible Pedestrian Signals	Applied Non-CMF	Pedestrians	Research on APS devices, specifically the impacts and benefits for non-disability users, guidance on maintenance audits and protocol, as well as guidance on where APS devices are most beneficial and should be prioritized, or where fixed-time operation should be used.	2	2	2	2	2	5	2	5	49
Safety impacts to pedestrians at different levels of visibility and sightlines at a roundabout	Applied Non-CMF	Pedestrians	A study of the safety impacts of lighting and other roadside elements such as newspaper boxes, shrubs, and other obstructions on driver-pedestrian visibility at roundabouts.	1	1	2	2	2	5	5	5	44
Animal-Vehicle Crash Severity Reduction Using Advanced Technologies along Freeways and Multilane highways	Applied Non-CMF	Advanced Technology and ITS	This study will examine innovative ways to mitigate the damage from animal-vehicle crashes using traditional measures as well as advanced technologies. Since preventing such crashes has proven to be very difficult, this study will investigate ways to reduce the severity of the crashes.	1	1	3	2	2	5	1	5	43
Costs of vehicle-train collisions at urban and rural crossings	Applied Non-CMF	Highway-Railway	The objective of this research is to develop a cost model that takes into account direct costs from multiple perspectives that accrue as the result of a vehicle-train collision at urban and rural railroad grade crossings.	1	1	2	2	3	5	1	5	42

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation