NCHRP PROJECT 20-44(09)
QUANTITATIVE AND QUALITATIVE METHODS FOR CAPTURING THE IMPACTS AND VALUE OF NCHRP RESEARCH

FINAL PROJECT REPORT

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Contents

Page

List of Figures ..... **vii**

List of Tables ..... **vii**

Acknowledgments ..... **viii**

Abstract ..... **ix**

Executive Summary **1**
Why Assess Impacts and Value? 2
How Are Research Implementation, Impacts, and Value Linked? 2
What Are the KEY Challenges in Measuring NCHRP Impacts and Value? 2
Finding Implementations 3
Gathering Evidence 3
Maintaining Momentum 3
What Is the Recommended RIA Approach? 4

Chapter 1. Introduction **5**
Background on NCHRP 5
Study Goal 6
Study Data Collection 6
Report Organization 7
Fundamental Concepts 7
Research Impact 7
Research Impact Assessment 8
Research Value 8
Intended Audiences 8

Chapter 2. Literature Review **10**
Introduction 10
Methodology 10
Literature Findings 11
Context and Trends in Research Impact Assessment 11
Methodological Challenges 11
Timing of Evaluations 11
Overall Assessment Approach 12
Methods/Measurement Tools 14
Data Collection Strategies 15
Key Takeaways 15

Chapter 3. Synthesis of Stakeholder Interviews **17**
Introduction 17
Methodology 17

Synthesis of Findings 17
Importance of Measuring Impacts and Value 17
Impacts 19
Methods to Consider 21
NCHRP Research Process 23
Key Takeaways 24

Chapter 4. Research Impact Assessment Framework 26
Introduction 26
Pathway to Value 26
Impact Roadmaps 27
Proof-of-Concept Applications of General Framework 29
NCHRP 12-94, LRFD Minimum Flexural Reinforcement Requirements (Report 906, 2019) 29
NCHRP 20-86, Attracting, Recruiting and Retaining Skilled Staff for Transportation System Operations and Management (TSMO) (Report 693, 2016) 30
NCHRP 08-91, Guide to Cross-Asset Resource Allocation and the Impact on Transportation System Performance (Report 806, 2016) 31
Key Takeaways 32

Chapter 5. Guidelines for Effective NCHRP Impacts Assessment 33
Step 1: Select Studies 33
Overview 33
Sampling Strategy 33
Sampling Interval 34
Step 2. Find Implementations 34
Overview 34
Strategies for Finding Implementations 35
Implementation Database 36
Evaluability Assessment 36
Step 3. Determine Relevant Impacts 37
Overview 37
Quantitative and Qualitative Measures 38
Internal Impacts 38
External Impacts 39
Step 4: Collect and Analyze Information on Impacts 40
Overview 40
Sources of Information 41
Characterizing and Reporting the Impacts 43
Step 5. Communicate Value 44
Overview 44
Approach 44

Chapter 6. Methodological challenges in assessing the impacts of NCHRP Research 46
Finding Implementations 46
Time Lag – How long to wait for impacts to become evident? 46
Attribution – what did the research implementation cause? 47

Bias – How can findings be distorted? 48
Maintaining the Momentum 49

Chapter 7. Changes to NCHRP Process to Facilitate RIA 50
Research Needs Statements 50
Requests for Proposals 51
Amplified Work Plans and Impact Roadmaps 51
Memoranda on Implementation of Research Findings and Products 52

Chapter 8. conclusions and Recommendations for Evaluating NCHRP Research 53
CONCLUSIONS 53
Evaluating NCHRP research impacts is important for program management and sustainability 53
RECOMMENDATIONS 55
Importance of assessing the Value of Research 55
Implementation Is the Path to Research Value 55
Assuring Feasibility of the Evaluation 56
Searching for Impacts 56
Mapping the Impact Process 56
Impacts in Numbers and Words 56
Benefits and Costs of Research 57
What Is Missing 57

References 58

Appendix A: Annotated Bibliographies 60
Transportation Literature 60
Non-transportation Literature 73

Appendix B: Persons Interviewed 90

Appendix C: Resource List 92
Impact Roadmaps (Logic Models) 92
Evaluability Assessment 92
Economic Analysis Methods 92
Qualitative Analysis Methods 92
Transportation Performance Measures 93

Appendix D: Impact Report Template 94

LIST OF FIGURES

Page

Figure 1. Pathway to Value. 26
Figure 2. Basic Elements of an Impact Roadmap. 28
Figure 3. Example of Impact Roadmap for New Culvert Design. 29
Figure 4. Recommended RIA Process. 33
Figure 5. Nominal Scale from NCHRP Synthesis 564. 43
Figure 6. Suggested Changes to the NCHRP Research Process to Facilitate RIA. 50

LIST OF TABLES

Page

Table 1. Common Methodological Considerations in RIA. 2
Table 2. Number of Research Projects Selected by AASHTO R&I in FY 2015 to FY 2021. 6
Table 3. Quantification of Literature Search and Review. 10
Table 4. Summary Table of Research Impact Assessment Frameworks. 13
Table 5. Evaluability Assessment Screening Questions. 37
Table 6. Potential Expected Internal Impacts of Implementations. 39
Table 7. Potential Expected External Impacts of Implementations. 40
Table 8. Suggested Modifications to the Elements of Research Needs Statements. 51
Table 9. Suggested Modifications to the Elements of Requests for Proposals. 51

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ABSTRACT

NCHRP Project 20-44(09): Quantitative and Qualitative Methods for Capturing the Impacts and Value of NCHRP Research introduces the concept of research impact assessment (RIA), presents a rationale for RIA for National Cooperative Highway Research Program (NCHRP) research, provides a recommended measurement framework, sets forth guidelines for conducting an RIA for NCHRP research, and identifies important methodological challenges. Background research including a literature review and extensive stakeholder interviews provides a foundation for the recommendations contained in this report. The recommendations include changes to the NCHRP research process that would facilitate future NCHRP RIA. A set of conclusions provides a synthesis of all significant recommendations stemming from this study.

EXECUTIVE SUMMARY

The National Cooperative Highway Research Program (NCHRP) is a national highway research program that is supported by funds from member States of the American Association of State Highway and Transportation Officials and Federal Highway Administration. NCHRP is effectively the collective research program for State departments of transportation (SDOTs), funded by State Planning and Research funds and driven by the States' needs for practical, applied research information and products. NCHRP's goal is full and effective use of the knowledge and innovations derived from NCHRP research results in the practices and policy decisions of SDOTs, metropolitan planning organizations, other transportation agencies, and the private sector.

The goal of this study was to develop quantitative and qualitative methods for measuring the impacts and value of NCHRP research. The desired product was guidance on how to assess NCHRP research impact in a scientific yet practical manner. The research team developed such a process for research impact assessment (see Chapter 5 and accompanying Guidance document) based on theory and practice in research evaluation from multiple disciplines. NCHRP chose not to test the method in the NCHRP context.

Research impact assessment is a complex and multidimensional process, particularly in the case of NCHRP, which is broad-based in term of topics covered and national implementation scope. While a narrowly quantitative, one-size fits-all approach to impact evaluation would be desirable, for NCHRP such an approach cannot recognize the nature of the research program and the broad set of values it is expected to produce.

The research team constructed a process that can assess multi-dimensional impacts of NCHRP research that is feasible, and in the process developed some useful lessons learned - recommendations in Chapter 8 - that can be applied, in whole or in part, to strengthen the Program's perspective on its impacts. Informed by stakeholder interviews conducted as a part of this work, this report also suggests ways to adapt the NCHRP research process itself (Chapter 7) to ensure that research impact assessment can be accomplished successfully.

Research impact assessment is a necessarily challenging process, but it is apparent that the NCHRP program and its stakeholders can derive substantial value from systematic and continuing assessment efforts. Experimental deployment of the recommended process would help determine the appropriate balance between resources invested in research impact evaluation and the value returned to the program and its stakeholders.

WHY ASSESS IMPACTS AND VALUE?

Increasingly, research funders and managers in all fields, including transportation, are interested in assessing the impacts that can be generated by implementation of research results. If positive, these impacts can produce longer-term value for implementing agencies and in their broader environments. Documenting this information can confirm the value of research and is critical to engendering continued financial and political support for research. While SDOTs, other transportation agencies, and private-sector organizations certainly derive value from implementation of NCHRP research results, evidence of derived value is not systematically captured and documented. This limits the ability of NCHRP to communicate powerful and rich stories of impacts and value that constitute a positive return on investment for NCHRP funding.

Regardless of industry, compiling empirical evidence of derived value from research implementation is critical for engendering continued financial and political support for research.

HOW ARE RESEARCH IMPLEMENTATION, IMPACTS, AND VALUE LINKED?

Positive impacts of NCHRP research may happen in two ways:

- Benefits within an implementing organization (i.e., internal impacts).
- Benefits beyond the implementing organization (i.e., external impacts).

Together, these two manifestations of impact provide value from the program. But positive impacts on transportation cannot occur unless research results are implemented.

WHAT ARE THE KEY CHALLENGES IN MEASURING NCHRP IMPACTS AND VALUE?

Measuring impacts and value is not straightforward and comes with a unique set of challenges. Many methodological challenges in research impact assessment (RIA) are well known to experts (Morgan-Jones et al., 2013; Guthrie et al., 2013) (see Table 1).

Table 1. Common Methodological Considerations in RIA.

Consideration	Description
Unit of assessment	What is the appropriate unit of assessment given that NCHRP is a historical portfolio of research studies?
Attribution	How do we attribute impacts to particular research projects if research is not done in isolation?
Time lags	When is the right time to assess when the time lag from research completion to implementation and the development of impacts take a long time and can vary by study?
Bias	How can we avoid bias in the selection of studies and implementations for assessment?
Marginal differences	How can we quantify impacts or distinguish high and low impacts when there is no shared understanding or assessment standards yet?
Transaction costs	How can we ensure the benefits of RIA outweigh the costs?

The challenges faced during the design and implementation of RIA by practitioners responsible for managing a portfolio of research are not well addressed in the current literature.

For NCHRP RIA, these operational challenges may include finding implementations, gathering evidence, or maintaining momentum.

Finding Implementations

NCHRP projects are intended to produce results that will be applied in practice—that is, implemented. Some implementations are readily known to NCHRP, but many go undetected for various reasons. Some research subject areas will lead obviously and directly to implementing agencies, but others may not. So, knowing about the implementation and making it a focus for impact assessment are essential. Identifying implementations of NCHRP research results is not a simple task, not because they are rare but because there is currently no systematic tracking and reporting process to record implementations. This report and associated guidance recommends the development and maintenance of a database of implementations that would provide a measure of the value of NCHRP.

Gathering Evidence

Gathering evidence of the links among research implementation, impact, and value is often problematic because it has not, in many cases, been systematically collected or may no longer be readily available. Looking forward, NCHRP will be able to reduce this challenge by encouraging implementing agencies to identify, capture, and store the evidence for use in impact assessments.

Maintaining Momentum

The benefits of systematic assessment of NCHRP are clear: growing and sustaining program support; and guiding improvements in the management, conduct, and dissemination of research. There will also be costs, in terms of personnel effort and money. Just as NCHRP is an ongoing program that continues to produce a stream of research products, evaluating its impacts needs to be an ongoing activity, not a once-and-done review. An important challenge will be to keep focused on the value to be produced by impact assessment, in terms of ensuring and enhancing the stream of NCHRP products going forward. This means devoting sufficient resources to deploy and maintain a systematic assessment effort so that it delivers the expected benefits. This also means making some recommended changes to the NCHRP research process to facilitate RIA. It will be important to integrate the outcomes of the research impact assessment into NCHRP management and decision making and, to the extent possible, into AASHTO priority setting. Researchers believe that standards and recommendations to guide research program managers and other practitioners on how to design and conduct RIA effectively would prove useful both for practical applications and for establishing a common language to facilitate mutual learning in the global community of practice.

To derive maximum return, NCHRP needs to devote sufficient resources to maintain a systematic impact assessment effort and to integrate the outcomes into decision making.

WHAT IS THE RECOMMENDED RIA APPROACH?

Given these considerations, a five-step measurement approach is recommended to effectively capture information on impacts, which can then be integrated to describe value. Briefly, the five steps are as follows:

1. **Select studies.** Every two years, a sample of NCHRP products is selected for impact assessment.
2. **Find implementations of selected studies.** Implementations are identified through several different strategies. An evaluability assessment is conducted on implementations to determine whether it is feasible and worthwhile to pursue impact assessments.
3. **Determine relevant impacts.** Each study in the sample cohort has a defined set of expected internal and external impacts that are derived from the research objectives and should be described in an impact roadmap. Core impacts and measures are suggested in this report.
4. **Collect and analyze information on impacts.** The basic methodology for collection and analysis of information on impacts follows a hybrid approach that incorporates elements from quantitative (mostly economic) and qualitative techniques. The approach minimizes primary data collection and relies on information that can be gathered from implementing agencies.
5. **Communicate value**. The multidimensional character of the contributions of NCHRP research means that absolute (or quantifiable) valuations are difficult, particularly given the lack of precision of the measurement of value. The findings regarding internal and external benefits will naturally lend themselves to the compilation of narrative stories about NCHRP program benefits. Such stories can effectively communicate the experiences and observations of people involved in implementations and what resulted from them, providing insight and understanding that go beyond quantification and giving context to implementation activities and impacts.

This recommended approach was derived from research activities for this study that included a review of the literature on RIA in transportation and non-transportation contexts, interviews with key stakeholders to understand their perspectives on NCHRP impacts and value, and proof-of-concept tests of possible measurement approaches. By following the steps and recommendations in this document, NCHRP will be able to both broaden the vision of what constitutes value and narrow the focus to impacts of specific implementations in ways that enhance its biennial reporting of impacts and value.

CHAPTER 1. INTRODUCTION

This chapter provides an overview of the National Cooperative Highway Research Program (NCHRP), presents the study's goals and research activities, summarizes the organization of this report, and identifies its intended audience and benefits.

BACKGROUND ON NCHRP

The mission of NCHRP is to manage a national program of highway research studies that address the complex problems of wide interest to State highway authorities. The program is driven by States' needs for practical research information and products. NCHRP has functioned effectively since 1962 using a cooperative research model. It provides State departments of transportation (SDOTs) the opportunity to leverage their State planning and research (SP&R) funds to address shared day-to-day problems and thereby receive greater value than the research dollars each spends. NCHRP studies are clustered into the following topics:

Since 1962, NCHRP has enables SDOTs to leverage SP&R funds to address common day-to-day problems and to receive more value in return than the research dollars spent.

- Pavements.
- Economics.
- Operations and control.
- General materials.
- Illumination and visibility.
- Snow and ice controls.
- Traffic planning.
- Planning methods and processes.
- Bituminous materials.
- Specifications, procedures, and practices.
- Law.
- Bridges.
- Equipment.
- Maintenance of way and structures.
- General design.
- Roadside development.
- Safety.
- Concrete materials.
- Finance.
- Special projects.
- Testing and instrumentation.
- Vehicle barrier systems.
- Agency administration.
- Mechanics and foundations.
- Human and natural environment.
- Pooled fund research.

Its annual research cycle starts with the identification of shared research problems by SDOTs and other stakeholders. An average of 120 problem statements are received each year. A Special Committee on Research and Innovation (R&I) of the American Association of State Highway Officials (AASHTO) reviews the problem statements and prioritizes for funding those problem statements that committee members believe will provide the greatest benefit.

Volunteer panels, representing SDOTs and other stakeholders, craft the problem statements into requests for proposals (RFPs) for each funded study and select research contractors to execute the research studies through a competitive review of proposals. Panel members then provide technical guidance to the research contractors throughout the study to ensure that the research results will be practical, implementable, and beneficial.

Typical studies have budgets of $200,000 to $750,000 and a duration of 24 to 48 months. Annual funding for fiscal year (FY) 2015 to FY 2021 averaged about $32,000,000, with 53 to 67 funded studies in progress each year (see Table 2). The research cycle is continuous, so in

addition to initiating new studies or continuing others, NCHRP is also producing research products—nearly 300 research products from FY 2015 to FY 2019.

Table 2. Number of Research Projects Selected by AASHTO R&I in FY 2015 to FY 2021.

Projects/ Funds	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Total projects	58	61	53	64	58	67	58
Total funding	$28,630,000	$30,840,000	$32,275,000	$35,317,000	$34,429,000	$33,330,000	$31,304,200

Sources: *NCHRP 2018 Annual Report* and *NCHRP 2020 Annual Report*.

STUDY GOAL

The goal of this study is to deliver guidance to NCHRP for gathering information on the impacts of its portfolio of research studies in a systematic way, with consideration of the challenges in doing so. The underpinning assumption for this study is that the mere conduct of research and dissemination of research products do not necessarily lead to value creation for users of the research products.

NCHRP has begun to accumulate information on the movement of its research into practice and associated impacts and value, through such activities as:

- The Implementation Support Program, which supports activities and products that facilitate the implementation of research results.
- Surveys of project panels to identify applications of research outputs and requests for user information when a report is downloaded.
- "Impacts on Practice" and "Paths to Practice" collections that showcase the value of NCHRP by documenting successful product implementations through case studies.
- Research Results Digests that promote early awareness of project results and their potential use in order to encourage implementation.

Still, the program lacks systematically collected evidence that its research results are being used and are associated with positive impacts and lasting value for the implementing agencies and their constituencies. Such evidence has the potential to increase commitment to implementation of NCHRP research results in the future and to encourage continued SDOT investment in NCHRP, as well as continued technical support from the Federal Highway Administration (FHWA). Evidence can also provide positive reinforcement to NCHRP study managers, who may not be aware of the impacts and value of the studies they administer.

Evidence of impacts and value derived from NCHRP research results can increase SDOT commitment to implementation and encourage continued investment.

STUDY DATA COLLECTION

The measurement approach that forms the core of this project report resulted from knowledge and insights derived via the following study activities:

- **Literature review.** A systematic search of transportation and non-transportation literature on measuring research impacts was conducted to identify and review relevant documents. These documents were then used as a platform to extract insights on relevant frameworks, methods, indicators, and data collection strategies. In total, the search identified 233 documents. Of

these, 120 documents were reviewed, and annotated reviews were produced for 60 documents.

- **Stakeholder interviews.** The team conducted 59 interviews with individuals representing four categories of stakeholders: NCHRP 20-44(9) panel members; research users, investors and beneficiaries such as SDOTs, AASHTO committees, and regional agencies; NCHRP program managers and research managers; principal investigators (PIs) of completed NCHRP projects and the panel chairs.
- **Research impact assessment (RIA) framework development and proof-of-concept tests.** The team developed several iterations of an RIA framework, which laid out a structure to evaluate research impacts. The framework was applied to four projects representing several NCHRP topic areas. The results of these simulations were used to refine the assessment framework and the overall approach.

REPORT ORGANIZATION

NCHRP is a complex research program with lots of moving parts and developing a strategy to assess its impacts and value is a challenging endeavor. This report distills information from varied sources, both within and outside transportation, to present a straightforward approach for capturing impacts and value. This report also highlights the many challenges and limitations in applying the approach to NCHRP and other research programs. This report has the following chapters:

- Executive Summary.
- Chapter 1. Introduction.
- Chapter 2. Literature Review.
- Chapter 3. Synthesis of Stakeholder Interviews.
- Chapter 4. Research Impact Assessment Framework.
- Chapter 5. Guidelines for Assessing Impacts of NCHRP Research.
- Chapter 6. Methodological Considerations in NCHRP Research Impact Assessment.
- Chapter 7. Changes to NCHRP Process to Facilitate Research Impact Assessment.
- Chapter 8. Key Recommendations for Evaluating NCHRP Research.

This report also has four appendices:

- Appendix A: Annotated Bibliographies.
- Appendix B: Persons Interviewed.
- Appendix C: Resource List.
- Appendix D: Impact Report Template.

FUNDAMENTAL CONCEPTS

Some fundamental concepts must be understood to place this research report in context.

Research Impact

Research impact is defined in this study as real change in the real world. In terms of transportation, it means safer roads, less congestion, reduced costs, better decision making, improved business processes, or more efficient operations. Research impact goes well beyond academic impact, which is the research knowledge contribution to a field of study within

academia, such as civil engineering. In the non-academic realm, research impact is all the diverse ways that research benefits individuals, organizations, jurisdictions, States, and nations. The exact impacts that might be expected depend on:

- The problem or specific topic addressed.
- Research products selected to fill the knowledge, method, or tool gap.
- The pieces of the research results that were implemented.
- Resources available to apply research results.

Research Impact Assessment

RIA is the scientific process of measuring the benefits of applying research results. As a multidisciplinary practice, RIA is in its formative stage but is not new (Adam et al., 2018). Early assessment practices focused primarily on measuring research outputs, such as publications, presentations, citations, and grants, using bibliometric and econometric techniques. More recently, assessments have tried to measure research impacts beyond such outputs. However, there is no one methodological solution for doing so. Entities conducting RIA have used a multitude of methods from social science and other disciplines to examine the research process with a view to maximizing its societal and economic impacts and other benefits.

Research Value

In contrast to research impact, which implies a results chain between research activities and impacts, "value can be thought of as a cumulative benefit, where results are achieved across a system or network" (Australian Academy of Humanities, 2015). Where impact is fixed at points in time, value is dynamic. Measuring research impact is based on study objectives, whereas measuring research value is based on program goals.

NCHRP is designed to "help state DOTs effectively plan, design, construct, operate, and maintain their surface transportation network while keeping workers and the traveling public safe, providing or improving mobility, and contributing to the economic vitality of communities and the nation" (NCHRP Annual Report, 2020). The multidimensional character of the contributions of NCHRP research in meeting these goals means that absolute (or quantifiable) valuations are difficult, particularly given the lack of precision to which the measurement of value can be made. Precision is particularly problematic with assessments of quality, which are essential for research but vary among research stakeholders. This introduces some fuzziness in assessing the value of research that makes some trained in quantitative fields uncomfortable. The lack of precision requires the use of expert judgment in making effective research value assessments, which is the approach taken in this study.

INTENDED AUDIENCES

The guidance is geared toward NCHRP program managers and staff, with the understanding that applying the process will require resources in terms of time, people, and money, but the benefits of measuring impacts and value are many, such as supporting fact-based decisions on program priorities, having detailed information to buttress research funding from SDOTs, optimizing program activities, and knowing whether the program is fulfilling its mission.

NCHRP sponsors (i.e., SDOTs, AASHTO, and FHWA) should also find this report useful in that these organizations may need to develop a process for measuring the effectiveness of their own research programs. The five-step process outlined in this report, and its underlying concepts, can be applied to other research programs. As in any technology transfer activity, the process does not need to be applied exactly as described here. The process was specifically developed to be flexible so it can be modified to suit many different contexts.

Members of the National Academies of Sciences, Engineering, and Medicine (NAS) may have an interest in the guidance since the role of NAS is to provide independent, objective advice to inform policy with evidence. The RIA process and its underlying concepts can be applied to research programs outside transportation.

Fundamental Distinction between NCHRP and SDOT Research Programs

NCHRP is a national research program. Interest in adoption of particular research results varies across States based on perceived return on investment (ROI) from implementation. Also, the time frame for implementation may vary depending on factors such as the politics in the State, technical capabilities of staff, and resources available. NCHRP is not aware of all implementations associated with a particular study and often only becomes aware of any implementation anecdotally or opportunistically.

SDOT research programs operate more like a closed system. Research investments flow to known implementations. The full benefits can therefore be known and captured. This situation enables traditional ROI calculations that measure the benefits of an investment against its cost. Examples include benefit-cost analysis, which transforms all the benefits (positive impacts) and costs (resources consumed and negative impacts) into monetary terms and produces a single figure of the ratio of benefits to costs.

This type of economic evaluation is difficult when evaluating national program benefits because not all implementations are known and, therefore, not all benefits and costs can be accounted for in the calculations. Thus, an accurate calculation of ROI cannot be quantified.

CHAPTER 2. LITERATURE REVIEW

INTRODUCTION

This chapter discusses the literature review—its methodology and the main insights. Appendix A presents annotated reviews of documents that contain information that informed this study. Because many reviews have been conducted on frameworks and methods to measure research impacts, the intention was not to conduct another appraisal of this literature. Instead, the goal was to use the existing reviews and documented experiences to understand the range of frameworks and the methods available to measure research impacts.

The literature review was used to take advantage of prior knowledge by searching transportation and non-transportation literature on measuring research impacts to identify and review relevant documents. These documents were then used as a platform to extract insights on relevant frameworks, methods, indicators, and data collection strategies.

METHODOLOGY

Researchers developed a search strategy with the Texas A&M Transportation Institute research librarian to comprehensively review literature from a spectrum of fields. It was important to look not only at transportation, but also at methods and concepts from other fields. Therefore, other sectors like medical sciences, health, education, public policy analysis, business/industry, and academia (research) were all part of the search.

Within those sectors, the team searched for methods for measuring research impacts, value of information, and valuation of research or measurement impacts. In addition, the field of program and policy evaluation was also consulted. The databases searched were the catalogues of the Texas A&M University and Northwestern University research libraries, which include broad access to millions of books, journals, articles, and reports. In addition, the team searched the Transportation Research Board (TRB) database of reports and databases from other government agencies such as FHWA.

The REFWORKS online bibliographic management program was used to consolidate and organize the search results from each of these databases and sources. REFWORKS enabled the research team to create a master list of all bibliographic references, eliminate duplicate results, and generate a complete list of references in proper format for ease of use as citations.

In total, the search identified 232 documents. After an initial screening for relevance and duplication, 117 documents were reviewed (Table 3). Of these, annotated reviews were produced for 55 documents that informed the study (Appendix A), and 62 documents were not annotated because they did not inform the study.

Table 3. Quantification of Literature Search and Review.

Documents	Screened	Reviewed	Annotated
Transportation	59	55	28
Non-transportation	173	62	27
Total	232	117	55

LITERATURE FINDINGS

Context and Trends in Research Impact Assessment

RIA is a relatively new endeavor, with most of the literature identified published after 2006. RIA seems to have come into focus in response to declining and unpredictable research investment, leading to increased emphasis on active promotion and implementation of research outputs as a collective responsibility of research investors, research programs/institutions, and researchers. Interest has grown in identifying and highlighting the value of research, to ensure the research enterprise and research investments are directed to maximize the value of the products. Yet there are few established and accepted framework and value definitions that are widely used to assess research outcomes and impacts. There is a lack of familiarity among research stakeholders with the evaluation processes. Therefore, it can be difficult to get support for a task that is poorly understood.

Economic benefit is not the only area that should be assessed but is the most popular, largely because it speaks powerfully to funders and policy makers and is generally easier to pursue and understand than other types of evaluation measures. Stakeholders who consider only or mainly economic benefits of research results, usually in the form of cost savings for purposes such as budget or program justification, planning, or decision making, may ignore the important benefits of research and bias future research investment decisions toward only those that are likely to produce cost savings. Based on the attributes of NCHRP research and the interests of its ultimate constituencies, this study takes a different, broader approach.

Methodological Challenges

Regardless of intended uses, there was consistency in the identified methodological challenges. Researchers noted that the most difficult but important challenges to be overcome in measuring research impact are:

- **Time lags.** When is the right time to assess, given the long periods of time that can occur between research completion, implementation, and impact?
- **Attribution.** How do we attribute impacts to specific research projects?
- **Marginal differences.** How do we distinguish high and low impact if there is no shared assessment standard?
- **Transaction costs.** How do we ensure the benefits of assessing research impact outweigh the costs of the assessment itself?
- **Unit of assessment.** How do we determine an appropriate unit of assessment if research can be multidisciplinary and multi-impactful?
- **Sample selection.** How do we select projects for evaluation in ways that reflect an honest representation of the research program's performance and avoid bias?
- **Definition and assessment of the counterfactual.** What would have happened in the absence of research implementation?

Timing of Evaluations

The literature review identified three timing categories: predictive, retrospective, and prospective.

Predictive Studies

Predictive studies project benefits into the future based on a forecast using either theoretical models or minimal preliminary results. An example is the high, medium, and low implementation scenarios for the study to predict the value of NCHRP pavement research (Appendix A, source 1). This is a valid timing category but not a foundation for this work. NCHRP needs to be able to describe what happened, not what might happen. Many things can change in the future.

Retrospective Studies

Retrospective studies look back and attempt to assess (perhaps to reconstruct) the benefits. Impacts may take a long time to unfold, in large measure because implementation can take a long time. This was the most common timing used in transportation research impact studies. The case study method has been found to be an effective approach for retrospective studies.

Prospective Studies

Prospective studies track projects over time to follow implementation and impacts. This a good and systematic way to evaluate research outcomes and impacts. These studies might be accomplished at a lower cost. A sample of projects is tagged when they are completed to be tracked at a low level of effort until they are implemented, after which a more intensive follow-up evaluation effort is deployed, perhaps on a subset of the tracked projects.

There were few prospective studies in the transportation literature but many in the non-transportation literature. Prospective studies are a more common method in medical interventions and social policy changes, where large samples and/or multiple sites can provide sufficient data.

Overall Assessment Approach

Overview

The non-transportation studies tended to follow a systematic RIA process, whereas transportation studies tended to implement a pro-forma economic analysis. There were exceptions, such as the Wyoming and Kansas SDOT methodologies (Appendix A, sources 4 and 13, respectively).

Generally, in terms of best practice, studies of research impact start with the development of a conceptual framework for the overall approach, followed by the use of an impact roadmap (or logic model) for the assessment of individual studies.

Framework

The framework describes what is important to stakeholders, how to organize impacts, what factors may affect them, and which indicators to use. The indicators (i.e., factors, metrics, and performance measures) used in evaluation frameworks should be informed by how the various stakeholders define *value*. For example, the number of publications produced by a research project may be important to a professor who served as the PI in order to escalate his or her career. However, a hospital may see more value in a project that leads to a new trial drug or clinical procedure. A policy stakeholder may look for reductions in crash, injury, and fatality rates.

Sometimes the most important indicators are multidimensional or qualitative, especially if highly valued by stakeholders, such as community perceptions of a facility design or preservation of a wetland. Some important but not quantifiable indicators noted in the transportation literature included:

- The importance of specific research projects to act as a catalyst for spurring future research in the same discipline (innovation).
- Improved cooperation between researchers and practitioners.
- Improvement of a research organization's technical reputation.
- The ability to apply research theory to real-world problems.

The literature review identified several frameworks that have been applied in other fields to assess research impacts (Table 4). However, these frameworks are not applicable to the NCHRP context because they tend to be inwardly focused rather than searching for benefits in the affected system, in this case the transportation system. Thus, the sources provide information to consider but not direct applicability.

Table 4. Summary Table of Research Impact Assessment Frameworks.

Framework	Scope	Measurement Structure
Benefit-cost analysis of research	Assesses whether benefits from implementation are in excess of the estimated costs.	Typical categories of economic benefits stemming from research: • Knowledge creation: economic value of research outputs • Technological spillovers: spinoffs and technology transfer • Human capital formation: staff development and employment effects • Social capital creation: new collaborations and partnerships
Payback	Measures outcomes and impacts in a series of categories to classify the individual paybacks from research. Used primarily in health.	Typical categories with indicators for each category: • Knowledge: journal articles, conference presentations, and reports • Benefits to future research use: better targeting of future research • Capacity building: enhanced staff development • Benefits from informing policy and product development: improved information for decisions, and enhanced development of products • Health and health-sector benefits: improved health (reduced morbidity and mortality) and qualitative improvements in service delivery • Broader economic benefits: reduced health care costs and benefits to workforce
Research excellence framework	Focuses on three elements: • Quality of research • Impacts of research • Vitality of research environment	Indicators for each element: • Quality: originality, rigor, and significance of the research outputs • Impact: case studies of reach (how widely felt), significance (how transformative), and effects or outcomes of these interactions • Vitality of research environment: sustainability of the wider research base
Framework to assess the impacts from translational health research	Produces a scorecard using multiple measures: • Identifies categories of benefit • Calculates social ROI	Typical categories of benefit and indicators: • Advance knowledge: publications • Implementation: quantify implementations • Community benefit: reduction in hospitalizations • Policy and legislation: changes in policy and new guidelines • Social ROI: cost of research, cost of using research outcomes, and benefits that can be converted to dollar value • Qualitative information on community impact

Methods/Measurement Tools

There was little variety in methods/measurement tools employed in the transportation literature. The most common method found was economic analysis, which focuses primarily on cost savings. Economic analysis was used much less in the non-transportation literature. Instead, there was heavy reliance on altmetrics, bibliometrics, case studies, surveys, and interviews.

Altmetrics

Altmetrics is the use of web-based metrics for the dissemination of scholarly material, with an emphasis on social media outlets. These metrics aggregate citations, views, downloads, discussions, and recommendations of research results across the scholarly web as well as citations in nonacademic communications such as policy documents. Altmetrics offers indicators of who and how many people or organizations are looking at the products of research. Altmetrics describes the reach of the products but not necessarily much about their use. Biases associated with altmetrics are a lack of consistency among scores provided by the different altmetric software packages and bias because results might be influenced by the intensity of the research author's/sponsor's social media presence. Also, altmetrics measures distribution, not impacts. Altmetrics does not appear in transportation literature.

Bibliometrics

Bibliometrics is the use of statistical methods to analyze books, articles, and other publications. Indicators include:

- Number of publications.
- Citation counts.
- Number of downloads.
- Journal Impact Factor.
- H-index (the maximum value of h such that the author has published h papers that have each been cited h or more times).
- Eigenfactor metrics (which weight citations by the ranking of the journal the citing paper is published in).
- Order of authors.

Again, bibliometrics measures distribution, not impact (although a likely correlation exists), and focuses on journals and ignores reports/books, which make significant contributions. Biases associated with bibliometrics include under-representation of non-English language journal.

Econometric/Economic Analysis

Econometrics is a set of statistical tools. Economics is a framework: a set of dimensions (or categories) used to measure and assess value. A commonly applied method is benefit-cost analysis (BCA), which is a method that compares the cost of a project or program to the benefits it produces. BCA is related not just to quantifying but identifying monetary measures of value. An important bias associated with BCA is that monetizing certain kinds of benefits can be problematic (e.g., management or environmental outcomes), and therefore such results are often ignored. Cost reduction or minimization targets project the outcomes of what can be fully

characterized in terms of reduced costs to the agency and users, such as crash cost reductions. Values produced outside of costs are excluded.

Case Study

A case study is an intensive systematic study of one case or implementation. Two different applications of case studies were found in the literature.

- **Type 1 case study.** Documents are written to highlight a project or program; no empirical assessment is applied. An example is a description in an SDOT monthly newsletter.
- **Type 2 case study.** Empirical analysis of research outcomes and impacts is performed. An example is an intensive, retrospective study of implementation of research outputs from one project and its outcomes and impacts—broadly tracing, describing, and accounting for the consequences of implementation. Case studies are typically multi-dimensional—quantitative, qualitative, descriptive, and delivered as a narrative.

Prospective Tracing and Tracking

A few studies took a prospective timing approach, tracing a project's research outputs and impacts as they are created, searching for reports of implementation, and systematically tracing or tracking to follow what actually happens. This would entail sampling a few projects but gathering information in depth. An exemplar is the Researchfish concept from medical evaluation (https://www.researchfish.net/), a commercial tracking and data collection process that puts researchers in the assessment loop to report back to sponsors.

Data Collection Strategies

A wide variety of data collection strategies were implemented in the studies discussed in the literature:

- Document analysis.
- Analysis of secondary databases.
- Analysis of in-house data (e.g., cost data).
- Web scraping.
- Media searches.
- Surveys.
- Interviews.
- Peer review panels.
- Stakeholder meetings and workshops.
- Tracing and tracking of research implementation.

A common practice in the literature reviewed was using a mixed-mode data collection approach. Using the findings from one method (survey) to vet another (case study) is a process known as triangulation and can enhance the accuracy and reliability of the findings. Mixed mode tends to be a resource-intensive data collection strategy.

KEY TAKEAWAYS

In reviewing an extensive collection of literature, researchers found that impact roadmaps (i.e., logic models) and conceptual frameworks are frequently used in fields other than transportation to ensure systematic and comprehensive identification and measurement of

impacts and value. By applying impact roadmaps and conceptual frameworks, this study goes beyond traditional transportation research assessments, which tend to focus solely on economic analyses, such as balancing project costs against monetary project benefits, commonly measured in terms of savings of agency and user costs. This study adopted a broader perspective to capture all or most project outcomes.

This study adapted the approaches indicated by these existing frameworks to an NCHRP context and developed a new conceptual framework.

The literature review suggested that looking only at narrow measures, such as cost savings, could lead to missing the impacts of some important projects. In the long run, this could bias (narrow) future NCHRP project selection. Project benefits and costs should be considered more broadly to reflect the full range of highway research needs and topics. Transportation and transportation research bring community, societal, and political benefits that call for both qualitative and quantitative data collection methods.

As researchers work with broader frameworks that guide the search for project benefits and costs, they may have opportunities to broaden the kinds of data collection tools used to enrich and extend the information gathered in transportation research evaluation studies. These potentially richer methods, such as qualitative interviews or expert assessments, will be applicable to the large range of NCHRP research topics. NCHRP should not focus solely on capturing measures that are easily quantifiable.

CHAPTER 3. SYNTHESIS OF STAKEHOLDER INTERVIEWS

INTRODUCTION

The research team gathered information from key stakeholders to confirm the purposes (or intended outcomes) for measuring impact and capturing value, and to identify specific and unique information needs about impacts and value among different stakeholders.

METHODOLOGY

Four categories of stakeholders were interviewed:

1. **Panel members for this project, NCHRP20-44(9).**
2. **Research investors and beneficiaries:** administrators and other SDOT staff but also several members of AASHTO R&I.
3. **NCHRP program/research managers:** senior program officers that cover the range of research topics, as well as other Cooperative Research Program staff.
4. **PIs of research projects and the associated panel chairs:** selected to represent a range of topics areas and project that have been completed early enough to allow a reasonable time for outcomes and impacts to have occurred. The projects were:
   - *NCHRP Report 813: A Guide to Agency-Wide Knowledge and Management for State Departments of Transportation* (2015).
   - *NCHRP Report 600: Human Factors Guidelines for Road Systems: Second Edition* (2012).
   - *NCHRP Report 877: Performance-Based Mix Design for Porous Friction Courses* (2017).
   - *NCHRP 12-91, Report 849: Strand Debonding for Pretensioned Girders* (2017).
   - *NCHRP Report 840: A Watershed Approach to Mitigating Stormwater Impacts* (2017)

In total, 59 persons were interviewed. This chapter synthesizes the interview finding across all stakeholder groups. Appendix B contains a list of interviewees.

Interviews were conducted primarily by telephone. A few interviews with NCHRP staff were conducted in person. The average interview length was about 30–45 minutes. Interview appointments were arranged via email. All questions were emailed to the interviewee in advance, along with a sheet of brief definitions for outputs, outcomes, impacts, value, etc., to ensure that all respondents were using a consistent nomenclature. All interviews began with an explanation of the research study purpose and the purposes of the interviews. Assurance that no statements would be attributed to specific individuals was provided. Written summaries were prepared after each interview. The interviews generated a large amount of data from multiple sources. A cloud-based Microsoft Excel workbook was used to organize the information to facilitate effective analysis and interpretation. Researchers kept interview summaries as backup material.

SYNTHESIS OF FINDINGS

Importance of Measuring Impacts and Value

All interviewees agreed that it is important to measure impacts and value, while at the same time they appreciated that doing so is difficult. SDOT staff and other NCHRP research

investors agreed that quantifying and/or qualifying the benefits of research is a much-needed but challenging undertaking.

Justify Funding

Interviewees noted that NCHRP, like other national research programs, needs a convincing argument about the value of research to respond to pressure to reduce research spending. All panel members described the importance of measuring the impacts of NCHRP research primarily as justification for public spending on research. Many noted that their leadership asks what is gained from expenditures on NCHRP and other research. This is especially true because funding is tighter than ever before, and there are more competing priorities.

NCHRP must be able to demonstrate its value to the SDOTs, whose investments support the program. NCHRP needs to show that its research meets customers' needs and provides value to them. In turn, SDOT leadership must defend research sponsorship to governors and constituents, explaining why funds go to research instead of highway construction or maintenance. The same value proposition NCHRP would give to SDOTs about the impacts and value of research is the one that the SDOTs would give to those to whom they are accountable. At least one SDOT leader noted that his agency intended to apply NCHRP's national evaluation framework to informing its own research outcomes. As Brian Ness, Idaho Transportation Department director, said during testimony to the House Committee on Science, Space, and Technology, "In an era of tight funding for state governments across the country, state DOTs rely heavily on research to help solve their most challenging problems."

Inform the Research Process

NCHRP program staff noted that the program would like to have information on impacts and value to close the NCHRP research process loop: here is what you asked for, and here is what resulted. Evaluative information could be useful to the entire NCHRP research process. NCHRP is focusing more on encouraging and funding implementation. R&I is providing money expressly to do this work, and NCHRP is trying to build a systematic program rather than rely on one-off mechanisms. According to staff, NCHRP expects this part of its business to grow. If AASHTO R&I could gauge interest in research topics based on what products were used and implemented, it might be more effective at selecting research to fund. Interest in different topics can increase or decrease over time. In one instance, a four-hour training course to support implementation was included as a deliverable on the project. This kickstarted another effort to expand the training, and a two-day National Highway Institute course has been developed and delivered. The PI and the panel chair for this project both acknowledged that interest in this topic has been increasing over the last decade and may explain the additional funding provided that allowed for the development of the training.

Feedback to NCHRP Research Managers

Finally, measuring impacts and value brings intrinsic reward to the research managers. Knowing that some improvement was made as a result of an NCHRP research study that they managed is personally gratifying. Research managers do not normally have a way of systematically gathering information on research implementation, impacts, and value. Research managers work on many (e.g., 20–30) research projects at a time. The moment research managers are through with an assignment, they move on to their next assigned project.

NCHRP Credibility

Additionally, panel members said that valuation is important in order to maintain the credibility and function of NCHRP. Valuation of the research outcomes and impacts may help to continue the good reputation of NCHRP in the future.

Likelihood of Implementation

Showing valuation may help more NCHRP adoption into AASHTO or U.S. Department of Transportation programs like Every Day Counts and other programs where the research can be implemented.

Impacts

Adoption Is the Best Indicator of Success

Adoption by SDOTs was the best indicator of project success. Even if the research produced usable and actionable information, if it was not implemented at the SDOT level, the chances of impact were very small. Moreover, States that do make changes as a result of the research findings need to communicate their experiences so that documentation of impacts exists.

Adopted Research Has an Impact

Because projects are identified and selected based on apparent need, it was generally expected by all categories of stakeholders that over time, all NCHRP research should have a positive impact. But it was acknowledged that such effects may not be readily apparent for every project. It is easier to assess outcomes and impacts for some types of projects than for others. For example, at the end of the study, if panel members recommend doing follow-on research on the topic or if they submit another, related problem statement to NCHRP, this is evidence that the research was considered useful. For example, it was mentioned that panel interest is what continues bike and pedestrian research.

The expected impacts of NCHRP research projects varied widely, from increased awareness of an issue to additions/considerations in the *Manual on Uniform Traffic Control Devices*. Not all the expected impacts were realized. Some PIs reported that attendance at trainings and/or webinars was an indication of use, as was implementation by SDOTs of the latest specification, even if not required. PIs acknowledged limited buy-in from SDOTs for complicated and complex processes that would be required for implementation. SDOT staff may not have the expertise to perform the analysis this requires.

Multiple SDOT interviewees noted that their agencies often experience the impacts of NCHRP work through the influence of research recommendations in AASHTO specifications, which often drive SDOT specifications. For example, the project NCHRP 12-102, Recommended AASHTO Guide Specification for ABC Design and Construction, supported AASHTO design and construction specifications for accelerated bridge construction, which resulted in an immediate impact on SDOTs.

In addition to specifications, SDOT interviewees described certain NCHRP products as foundational guidebooks for transportation agencies, especially in the areas of performance management and asset management (e.g., *NCHRP 4-46: A Guidebook for Performance-Based Transportation Planning*). As this foundational work nears completion, NCHRP has focused on

more specific but still practice-oriented reports and self-assessment guides such as *NCHRP 809: Environmental Performance Measures for State Departments of Transportation* and *NCHRP 902: Benchmarking and Comparative Measurement for Effective Performance Management by Transportation Agencies*. Research products that result in an easily implemented, spreadsheet-based tool are more likely to see immediate use (e.g., *NCHRP 806: Guide to Cross-Asset Resource Allocation and the Impact on Transportation System Performance*).

Pooling Resources and Customizing Results

All transportation agencies face unique issues but also share common interests and solutions. Some SDOT interviewees value NCHRP's ability to provide research that is broader than what SDOTs could accomplish on their own. Like pooled-fund studies, NCHRP allows agencies to leverage limited research funds to pursue larger research projects without duplicating efforts. At the same time, the various SDOTs face very different climates and contexts that limit the usability of *national* research, leaving more customized topics to the States themselves.

Cost Savings, Congestion, and Safety Improvements Stand Out

Several interviewees said that projects and reports in the three critical areas of cost savings, congestion, and safety improvements present the clearest measures of research impact. NCHRP research on concrete, for example, has been able to drive down the cost of construction materials for SDOTs. National research has also helped transportation agencies save on costs related to data purchases, roadway lighting (i.e., energy costs), incident response, winter maintenance, and other critical operations. Regarding congestion relief, NCHRP products have also clearly impacted outcomes for road users. SDOTs have used *NCHRP 3-107: Work Zone Capacity Methods for the Highway Capacity Manual*, for example, to determine allowable work hours on freeways, which supports more efficient roadway use. Finally, safety is another area of obvious research benefit, with products such as the NCHRP 500 series safety guides providing transportation agencies with data-driven safety countermeasures.

Value of Research Exceeds Research Itself

NCHRP research also brings intangible benefits to SDOTs. Multiple interviewees noted that TRB staff themselves are valuable as knowledgeable, neutral research gatekeepers. As an organization, TRB provides the structure needed to support large-scale research and professional development efforts for the Nation.

Hard Sciences Are Easier to Track, Measure, and Value

Panel members described a range of impacts from research products from NCHRP and others. Many described successful NCHRP products as those that addressed hard science topics such as guardrails, pavement design, or inspection methods. Most panel members were able to point to studies on specific technologies or treatments and how they produced successful, long-term impacts. Many said that such projects were easier to measure and track.

Soft Science Products Are Harder to Measure but Still Valuable

Panel members described studies for softer sciences such as workforce development, organizational structure, performance management, and other studies that were more abstract, for

which impacts were more difficult to identify and measure. However, most panel members were quick to mention that these types of research products are important, even though subsequent changes are harder to measure. Compared to a pavement research product where a measurable change might be AASHTO's adoption of a new standard, it is harder to capture the value of an organizational change recommended in NCHRP research.

Attribution to NCHRP Research Is Difficult

Many States do not have a formal mechanism to gauge the impact of the research they implement. Attribution or tracing back to implementation of NCHRP research is difficult. It is often not clear where a new idea came from. When States do publish the results of their innovative actions (research implementations) and cite NCHRP research products, a loose connection can be made that NCHRP contributed to the outcome or impact. It is just not clear how large or small the NCHRP contribution was, but States may know NCHRP was a source.

Information Gathering Is Opportunistic

When asked how or if the interviewees were aware of impacts and how or if they were measured, most indicated that as NCHRP staff, panel chairs and members, and PIs, they were only aware of impacts opportunistically—if they happened to hear about the impacts in professional circles. None of the interviewees mentioned proactively attempting to identify and measure research impacts. When queried about how impacts could be measured, respondents suggested starting with easily measured metrics such as report downloads, webinar attendance, or requests for training.

Methods to Consider

Interviewees provided a range of thoughts on research evaluation methods to consider. Some expressed the magnitude of the difficulty of trying to value outcomes and impacts when the range of research topics is so broad.

Simple Methodology

The methodology cannot be complicated and needs to sound plausible. NCHRP staff are willing to contribute, but if the measurement system depends on them entering data or information, it will break down.

Overcoming Common Challenges for Evaluation

Interviewees noted several challenges to evaluating the benefits of research programs. First, comparing benefits across different impact areas can be a challenge; some benefits accrue to a transportation agency (e.g., cost savings), while other are societal benefits (e.g., lives saved) or environmental benefits (e.g., roadway runoff captured). Similarly, different kinds of research (e.g., construction, materials, and planning) will require different assessment methods, such as interviews, measurement, and cost accounting. The time frame of benefits presents another challenge. If a bridge can be made to last dozens of years longer using new materials, these benefits might be so long-lived that they are difficult to interpret (e.g., whether to apply discount rates and what rates to select).

Monetizing Benefits

Panelist suggested a variety of ways to monetize research benefits to compute (ROI or BCA), including estimating the monetary value of lives saved, agency cost reductions, and operator cost savings. Representatives of some States, like Indiana, Utah, and Minnesota, described the ways they are trying to show ROI for research products.

At the same time, interviewees noted that it is not always desirable, nor possible, to fit the benefits of every research project within a monetary benefit-cost framework. Rather, monetary evaluation should be reserved for those project impacts where such valuation makes sense and provides a comprehensive picture of value. Where it does not, other dimensions of value should be used. While money is an important and well-understood communications tool, focusing only on money will leave significant values of research on the table. Research targeting organizational change, for example, is difficult to measure and monetize, even if it changes crucial agency practices (e.g., *NCHRP 885: Guide to Creating and Sustaining a Culture of Innovation for Departments of Transportation*). Where it is impossible to calculate monetary ROI, the research evaluation framework should include other options for identifying and reflecting tangible, if qualitative, values from research.

Tell Stories

Many program staff emphasized the importance of good stories of valued research impacts as being a key factor in communicating with the general public and public policy makers. Stories about the one individual whose life was saved or the improved infrastructure that now gets people where they need to be can be a quite convincing argument of research value but not necessarily a quantitative one.

Research Evaluation Needs a Framework

NCHRP panelists expected this study to build a framework for identifying some parameters for impacts and value of research, even if not perfectly or quantitatively for everything. Panelists described a methodology that considered different research categories, applied research versus theoretical, ways to adapt traditional methods (e.g., ROI) to these categories, and the use of qualitative approaches over quantitative when appropriate.

Research Is a Process, and So Is Impact Assessment

NCHRP staff noted that the seeds of outcomes and impacts might not all derive from the results of one research project. If NCHRP measures too narrowly, it may not find success. One project might not answer a research need, but a series of projects bringing incremental contributions on the topic might achieve the objective. Guardrail research was given as an example. Over many years of research, guardrail technology and deployment have evolved into the current, highly effective state of the practice. Also, it was noted that it takes time, resources, and training to get research results into practice. Sponsors sometimes expect shorter, largely unrealistic time frames.

Risks of Choosing Easy Measures

While most NCHRP staff felt that it would be useful to have information on the impacts and value of NCHRP research, some raised concerns about negative unintended consequence from applying the wrong metrics. For instance, one metric might be the number of downloads of

a final report. NCHRP staff were undecided about the utility of information on numbers of downloads. Some found it useful to know downloading is happening. Others thought downloads do not tell much. Some research topics may have a limited audience, so there might not be a lot of downloads of a report, but that does not mean the research was not of value.

Do Not Discount Failures or Null Results

Panel members said that it can be important to report on failed research and the reasons why something did not work. Otherwise, valuation methods might introduce a bias into the overall process and discourage risk-taking among SDOTs.

NCHRP Research Process

Set a Strategic and Timely Research Agenda

Certain SDOT representatives noted that this project is an opportunity to think strategically about how NCHRP sets its research agenda (i.e., what projects are selected for research), which can seem disparate or uncoordinated. A uniform research strategy can make it easier to present the accumulated benefit of the research program while also making the case for its continuation. While appreciative of NCHRP products, interviewees agreed on several opportunities for NCHRP to improve its value. For example, there is a perception that NCHRP pursues multiple research efforts on the same topic simultaneously. NCHRP needs to demonstrate its value by conveying that its research is not duplicative, potentially through clearer descriptions and titles. In addition, multiple interviewees noted that the lengthy process associated with publishing NCHRP work is a challenge to presenting timely, relevant research.

Implementation Is Key

According to one interviewee, “Doing research without implementing [its results] is like cooking a meal without eating it.” Many interviewees agreed that the best way to measure impacts is simply to determine whether a research product is implemented. At a bare minimum, research must translate into results in the field to be valuable. Some State research programs track whether and how their research products are implemented. However, while implementation is necessary, valued impact is needed for research to be considered an accomplishment.

Revise the NCHRP Process to Include Implementation at All Steps

Several panelists suggested that while NCHRP has a strong reputation for executing research, more might be done to improve that process. Implementation and expected impacts should be part of the RFPs and referenced in proposer responses. NCHRP should carefully select panelists to secure research champions, and the panel should be on board through evaluation of the implementation.

Carefully Consider State Involvement and Outreach

Panelists advised careful consideration of methods to tap into what States are doing and implementing (without burdening States) because States currently are not measuring the breadth of how NCHRP gets used. Some mentioned that this will not happen if not tied to a State staff member’s or implementer’s job description.

As one interviewee put it, it is important to recognize that the way research results are communicated is a critical dimension of its value. Communicating and marketing research results are always key to effective implementation. Although many research users do not realize that NCHRP reports are available online, making reports freely accessible is an important starting point. Interviewees found workshops, peer exchanges, webinars, and spreadsheet tools were important avenues for implementing research output, especially where the research output is abstract or complex. While research users may not have the capacity to read dense research output, they are more likely to find the time to attend an online event or use an off-the-shelf tool. Panelists also described a need to encourage use of formal source citations in reports coming from the SDOT community so that connections to original research (e.g., NCHRP products) can be readily identified.

Contractor Dissemination Activities

Contractors are not required to communicate with the NCHRP research manager about relevant activities (e.g., conference presentations, trainings, and workshops) related to dissemination of their products. NCHRP staff would like to have a better handle on the types and number of dissemination activities that contractors accomplish. For example, any time people present on an NCHRP project, they could upload the presentation or link to it as part of their profile or to the project information page. In this way, research presentations could be tracked.

Technical Activities Division Involvement

NCHRP Technical Activities Division staff visit States every year. Could staff be better informed about recently released NCHRP products so they can help translate these products into practice changes? Could staff start a dialogue with SDOTs on outcomes, impacts, and value? Can TRB committees help assess value? Do the goals of the TRB committee that sponsored the problem include follow-up and assessment?

KEY TAKEAWAYS

NCHRP research projects are diverse, and so are their research products and audiences. While the outputs of all research efforts include a research report, some reports aim to bring broad ideas to senior leadership at SDOTs, while others focus on delivering methods, tools, guidelines, or specifications for engineers, designers, suppliers, and operators. When the research output involves standards development, it is easier to trace a clear cause-effect path generating research impacts and value than it is for studies that expand basic knowledge or understanding on a research topic. Mixed methods should be applied to capture the impacts of the different types or categories of projects.

Research can serve as a mechanism to broaden awareness of an issue, but implementation is key. Implementation by SDOTs puts research into practice. Therefore, it is a necessary condition for achieving positive internal and external impacts, even if the research produced usable and actionable information. The expectation of implementation should be included in RFPs and projects' statements of work.

Implementation and impacts should be discussed when a panel is drafting research RFPs. What is the time frame for implementation? What States will be champions? What are expected benefits? How can they be tracked? Can they be quantified? What qualitative information would be indicators of success, such as lessons learned or knowledge gained? This type of information

should be captured in a systematic format and provided to the selected research contractor at the start of a project to guide research execution and final product development.

The ROI from implementation of research results may not be the same across all States, and thus the interest in implementation may vary among States. Some research may be best implemented in certain regions of the United States (e.g., studies addressing snow removal), while others can be implemented everywhere (e.g., studies addressing resiliency or emergency response). Also, the time frame for implementation may be different among different States, depending on factors such as the politics in the State, technical capabilities of staff, and technical resources available to staff. Some benefits can be captured quickly after implementation, while others may take years to develop. Methods should allow for flexibility to capture variations in regions and time frames.

SDOT staff typically do not know NCHRP project numbers or report numbers. They may only know the applied products, such as software names. They may be using the *Green Book* but not be aware of its genesis as an NCHRP project. They may know procedures have changed but not that the change had its genesis in a specific NCHRP research report. In addition, the changes may not be from a single project but from a series of research projects on the same topic. Guardrail research was cited as an example of knowledge development from a series of research projects that built one upon another. For these reasons, surveys of SDOT staff may not be an effective stand-alone method for capturing impacts and value.

CHAPTER 4. RESEARCH IMPACT ASSESSMENT FRAMEWORK

INTRODUCTION

The research team developed several iterations of an RIA framework and shared them with the panel and NCHRP along the way. The framework laid out a structure to evaluate research impacts, which was applied to four projects representing several NCHRP topic areas to test the concept. The results of those simulations were used to refine the assessment framework and the overall approach.

The recommended RIA framework specifically accounts for—and provides guidance for—assessments of the wide variety of NCHRP projects, across all 26 research topics presented in Chapter 1. The recommended RIA should be set up and performed using the following steps:

1. Select studies.
2. Find implementations of selected studies.
3. Determine relevant impacts.
4. Collect and analyze information on impacts.
5. Communicate value.

Each of these activities is described in detail in Chapter 5 of this report. While the list provides a useful order in which to approach these topics, it may be necessary to work cyclically due to variations in timing of when internal and external impacts can be observed and measured, and the overall value of the program can be assessed.

PATHWAY TO VALUE

The recommended RIA framework builds upon the conceptual foundation of an impact pathway (Douthwaite et al., 2003) (see Figure 1). Important antecedents to the impact pathway are clear study objectives, usable research products, and effective dissemination.

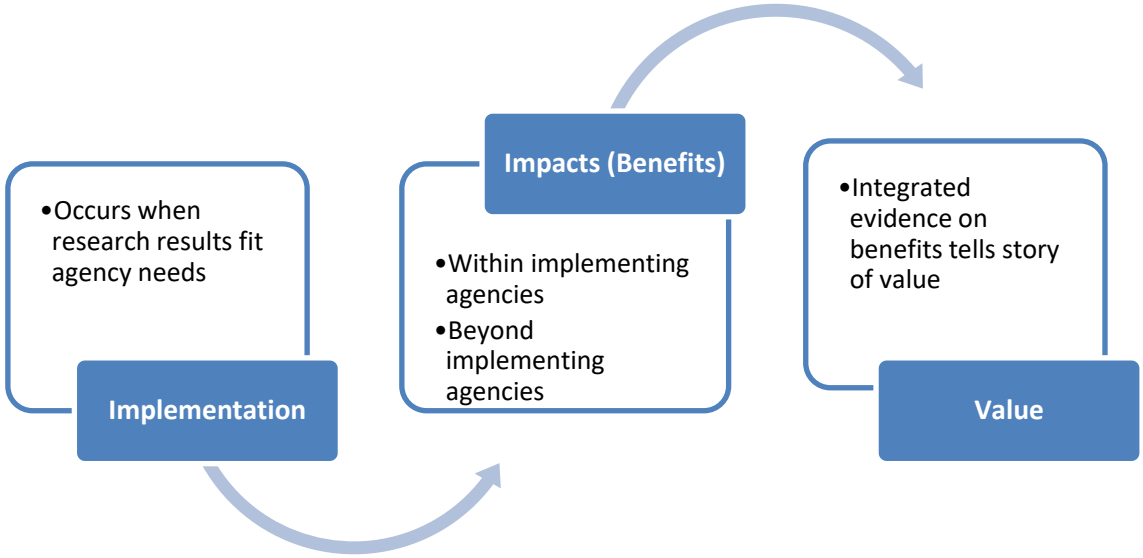

Figure 1. Pathway to Value.

Three key concepts comprising the impact pathway are described as follows:

- **Implementation.** Implementation is the act of putting something into practice and is a fundamental goal of NCHRP. Implementation depends on the fit of the research results to the needs of agencies, and documenting the locations of implementations provides important information on the perceived quality and utility of different NCHRP studies. Implementation is necessary for impacts to occur.
- **Impacts.** Impact has been defined as "provable change [benefit] of research in the 'real world.'" (Bayley, 2018). For NCHRP, impacts can happen in two ways: benefits within an implementing organization (i.e., internal benefits) and benefits beyond the implementing organization (i.e., external benefits). Internal impacts are typically changes that occur in the transportation agencies that implement research results. Examples are modifications of strategies, methods, designs, materials, organizational structures or systems, processes, procedures, or policies. External impacts are benefits in a broader context of implementing research findings, such as changes in safety, system performance, user cost savings, and equity. An example of an internal-external benefit pair is an implementation of a new guardrail design that changes the design practices of the agency (internal) that results in safety benefits, such as lives saved (external).
- **Value.** Value is defined as worth, usefulness, excellence, or importance of an impact. An estimation of value is from the perspective of the research user and results from the occurrence and capture of positive impacts of implementing NCHRP study findings across a portfolio of research studies.

While SDOT research programs differ fundamentally from NCHRP, this guidance can be generalized to serve as a fundamental resource for impact assessment at the State level.

The simplicity of thinking about this as a linear process is useful when applying a systematic approach for capturing impacts and value, but the reality is more complex. The development of impacts is an extended, iterative process due to time lags in implementation of research results and to the need to adapt research results to fit the agency and its broader context. The complexity creates challenges for attributing impacts to specific NCHRP research implementations. This is why impact roadmaps are useful tools for determining the pathway to value for research studies.

IMPACT ROADMAPS

Impact roadmaps (or logic models) are hypothesized impacts of individual NCHRP studies that guide the search for realized impacts. The impact roadmap visually depicts the link between the research study objectives and products and the expected impacts of research implementation. These are used commonly in RIA in other disciplines (e.g., the Centers for Disease Control and Prevention, Department of Health and Human Services, Innovation Network, and U.S. Department of Agriculture).

Impact roadmaps, which depict the link between research objectives and impacts, are versatile tools that help research programs understand how investments contribute to achieving intended impacts.

Developing an impact roadmap at the start of a research study helps the NCHRP research manager, panel, and contracted research team to think beyond the final deliverables of the research to customers of the research

and the necessary conditions for implementation. The roadmap should be started by the project panel with support from NCHRP staff. The roadmap is adapted by the research team as the details of the project and its products become clear. In the creation of an impact roadmap, issues such as the following should be considered:

- What are specific research objectives?
- What agencies are likely to implement the research results?
- What final deliverable formats will be most useful to likely implementers?
- If the results are implemented, what benefits are expected within implementing entities?
- How would the benefits develop—what are the requisites and the obstacles to achieving expected impacts?
- If the results are implemented, what benefits are expected in the transportation system and/or in a broader context?
- What are the requisites and the obstacles?

The answers to these questions, in turn, may bring about new perspectives among NCHRP, the panel, and the research team that will shape research execution and the development of final deliverables. Figure 2 presents the basic elements of an impact roadmap. Element 1 is the research objectives. Most NCHRP RFPs specify research objectives. Well-defined objectives establish the overall direction and focus for the research and define what the research will achieve in terms of impacts. Objectives should identify the expected results of implementation of the research findings.

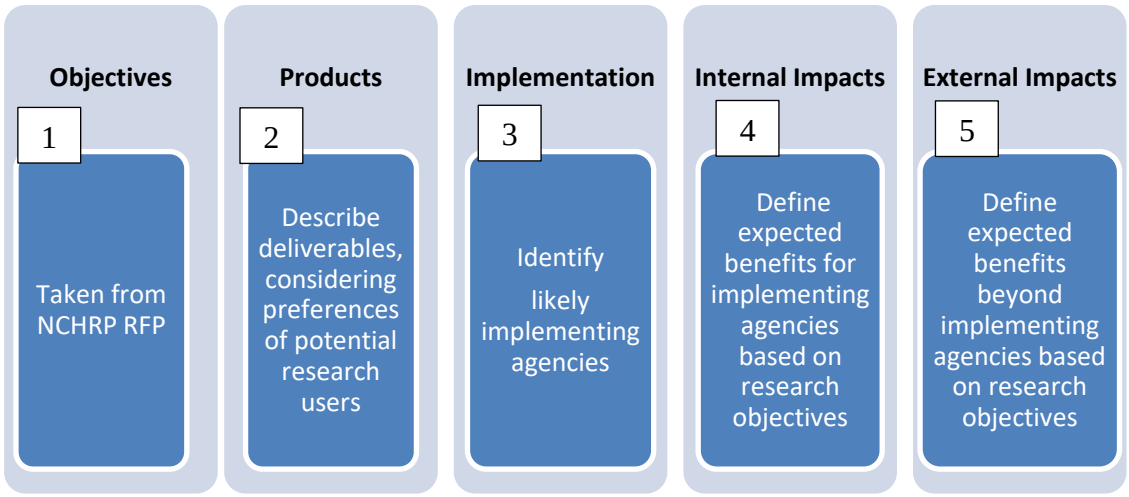

Figure 2. Basic Elements of an Impact Roadmap.

Elements 2 and 3 focus on deliverables and audiences. Audiences for NCHRP products are the likely implementing agencies. In executing the research plan, attention must be paid to identifying potential implementing agencies. Elements 4 and 5 focus on the research study's expected impacts. The RFP should provide direction in terms of desired benefits of implementing the research results, both internal and external to implementing agencies. Examples of external impacts can be improved safety, equity, cost efficiency, etc. However, attributing external impacts to the use of specific research outputs can be difficult, as discussed in Chapter 6.

Figure 3 illustrates an impact roadmap applied to a specific (hypothetical) research product, the design of a quick-install replacement culvert to restore road operations after

washouts. The objective of the research guide is product definition, which, in turn, suggests implementation opportunities. From this, the implementation steps are outlined, and expected impacts on agencies' activities are identified. Agency activities and impacts lead, in this case, to specific expectations about impacts on the transportation system, its users, and the affected community. These hypotheses about potential internal and external impacts guide the search for actual impacts in the evaluation process.

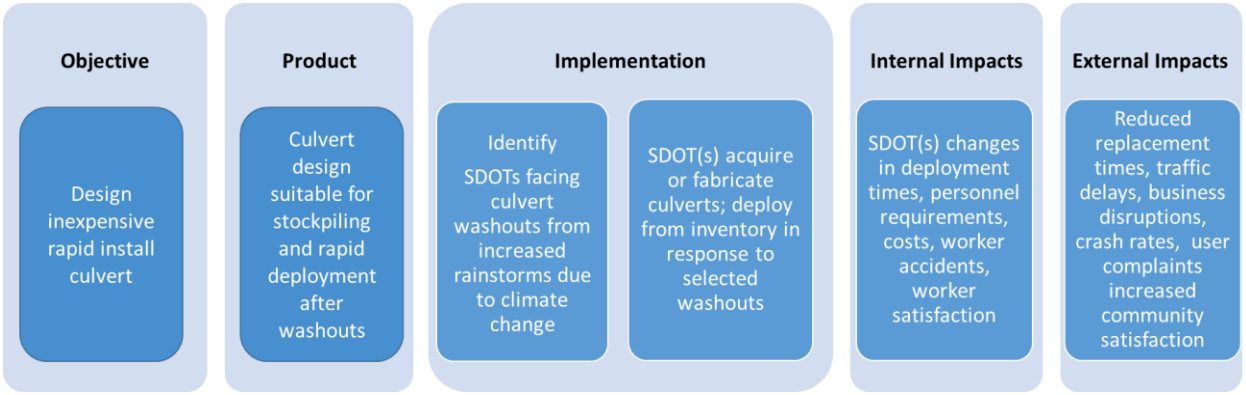

Figure 3. Example of Impact Roadmap for New Culvert Design.

PROOF-OF-CONCEPT APPLICATIONS OF GENERAL FRAMEWORK

The research team simulated the application of the general RIA framework to NCHRP projects representing a sample of NCHRP study topics. While the outcomes might be different with actual implementations, the exercise was useful for testing the feasibility and utility of a framework.

NCHRP 12-94, LRFD Minimum Flexural Reinforcement Requirements (Report 906, 2019)

Information used for the proof-of-concept test was taken from the research needs statement (RNS) and the project report. The original RFP was not available for review.

Project research objective: Develop recommended changes for AASHTO specifications based on results from this project.

Type of project: Engineering standard setting.

Likely implementers: SDOTs. The problem statement included contributors from the California Department of Transportation (Caltrans). The project panel included members from the Florida Department of Transportation, Texas Department of Transportation (TxDOT), Alaska Department of Transportation, and Caltrans.

Potential internal impacts and indicators: Adopted as design guidance and standard. Quantitative metric: Uptake percentage across SDOTs. Qualitative metric: how satisfied implementers are with the new guidance; reports of ease of application.

Potential external impacts and indicators:

- **Safety.** Better alignment of design standards with material performance as demonstrated by lab testing and field inspections. Check if any failures were ever attributed to this issue. Otherwise, the main impact of standard revision is to relax standards and make them less

conservative. Both old and new designs should be safe, but monitor them long term for any failures attributed to flexural reinforcement.

- **Economic.** Better/faster/cheaper design and construction.
  - Better: Is the standard change encouraging innovation? The report mentions that prestressed/post-tensioned concrete designs were penalized by the previous standard.
  - Faster: Less reinforcement is expected to improve constructability. Have construction schedules shortened on projects impacted by this change? It may be hard to detect because of confounding factors; get a large sample of applications if possible.
  - Cheaper: Standard change is expected to result in more efficient designs. Have costs gone down on projects impacted by this change? Also, change is hard to detect and would need a large sample of bridge projects to control for confounding factors.

Proof of concept findings: The logic model fits this project well. As an engineering standard-setting project, the potential internal impact is clear and easily measurable: did the project lead to changes in the relevant standard? External impacts are less clear and were drawn from both the project report and internal discussion. It will take longer for impacts to manifest themselves. Two impacts were identified in the RNS section on urgency, payoff potential, and implementation: "reduced project cost" and impacts to "the current design practices of structural concrete bridges with regards to minimum flexural reinforcement." No metrics were suggested for measuring these impacts.

NCHRP 20-86, Attracting, Recruiting and Retaining Skilled Staff for Transportation System Operations and Management (TSMO) (Report 693, 2016)

Information used for the proof-of-concept test was taken from the project report. The original RNS and RFP were not available for review.

Project research objective: Provide transportation agencies with strategies and resources to meet their needs for TSMO staff.

Type of project: Organization process change.

Potential internal impacts: The report includes six specific recommendations with associated action plans for each recommendation. For each recommendation, a target audience(s) is identified along with steps for implementation and the expected impacts of practice. The action plans for the recommendations also identify the implementation level (regional, State, or national), the estimated time to implement the recommendation, and the likely time frame to achieve an ROI. Changes to the workforce and the ability to meet TSMO personnel's needs are the ultimate impacts. Recommendations for cross training may improve agency efficiency and effectiveness, but it is difficult to know cause and effect. Implementation of some recommendations can lead to increased career advancement and satisfaction. A crash modification factor tool could be used to measure attainment of specific objectives using a qualitative or quantitative scale. For example, to what extent are business processes improved due to an improved, multidisciplinary workforce? Or, to what extent are the organization and workforce improved due to improved training opportunities? Does the organizational culture understand and appreciate the need for TSMO?

Potential external impacts: The underlying premise for the initial research—that the SDOT workforce needs employees that have skills that are not taught in typical engineering or technical programs—points to potential external impacts as being changes to traditional high school and college curricula. To measure external impacts, it would be necessary to find implementing SDOTs that conducted outreach to schools and universities and that measured how

curricula may have changed to address this need. Then enrollment must also be measured across many programs. Students need to take the course and apply for the jobs. So, it becomes clearer that the impact is thinner and thinner through each step. Parts of the research products can be measured, but truly tracing the chain through all the products is likely very difficult and likely not worth the cost.

Proof-of-concept findings: This project type, an organizational process change, can use the logic model to apply the RIA framework, but the difficulty is isolating the factors that may have been outcomes that led to eventual impacts. For this project, multiple steps across many organizations may each contribute to improving TSMO workforces at SDOTs. The chain of effects of this research project includes some *direct* actions like changing job descriptions, compensation packages, recruitment, etc. These are things that can be counted and measured to determine internal impacts. The research products from this project may have contributed in full or in part to these events.

In this case, the most likely mechanism for evaluating this process change (internal impact) would be a detailed case study. But it may be difficult or impossible to measure external impacts, that is, to know the extent to which changes to K-12 curricula led to increased interest in transportation careers, which fed increased enrollment in various engineering schools, which translated to a more multidisciplinary workforce that was able to meet TSMO needs. Extending this example even further, it may be possible to measure how prepared an SDOT workforce is to handle TSMO assignments as a result of this research project, but tracing that back to causal factors will be nearly impossible.

NCHRP 08-91, Guide to Cross-Asset Resource Allocation and the Impact on Transportation System Performance (Report 806, 2016)

Project research objective: Develop a guidebook that senior SDOT managers may use to analyze and communicate the likely system performance impact of investment decisions across multiple types of transportation assets (multi-objective decision analysis [MODA]). The research produced a guidebook, a spreadsheet tool, and a user's guide. The project spurred a follow-on implementation study on using MODA. The project was completed in 2018 and produced *NCHRP Report 921*. Case studies were used to illustrate key issues in implementing a cross-asset resource allocation approach, and the lessons learned were then used to improve the guidance and tools developed in *NCHRP Report 806*, the Cross-Asset Resource Allocation Spreadsheet Tool.

Type of project: Improved tool, method, or model.

Potential internal impacts: The expected impact was improved data for decisions. The tool is specific to transportation investment decisions and introduces the use of performance measures for characterizing investment impacts.

The following four case studies were conducted in the implementation study and could be used to support the evaluation:

- **Arizona Department of Transportation (ADOT):** ADOT applied the tool to improve on how ADOT should allocate its scarce highway resources in the future (2017–2018).
- **Caltrans:** Caltrans sought an improved approach for prioritizing projects in the California State Highway Operation and Protection Program. Implementation of the new approach was still in testing at the time of the case studies report.
- **Delaware Valley Regional Planning Commission (DVRPC):** DVRPC hoped to effectively and objectively prioritize a diverse set of projects, while focusing benefits toward addressing

the most critical needs and obtaining the best estimate of ROI for taxpayer dollars. MODA helped the agency stay laser focused on making progress toward goals and objectives, which has elevated DVRPC's credibility with its stakeholders.

- **Maryland Department of Transportation (MDOT) and State Highway Administration:** A new law required MDOT to develop a project-based scoring system to rank major capital transportation projects being considered for inclusion in the Consolidated Transportation Program (CTP). Major transportation projects are those transit and highway projects for which the total cost for all phases is over $5 million and that meet certain criteria based on project activities. Implementation of the tool was expected to lead to better decisions about what projects to select for funding and inclusion in the CTP.

Potential external impacts: The potential external impacts were specific to the investment goals of the implementing SDOTs. For ADOT, investment types include safety, bridge, pavement, expansion, technology, accessibility, and operations and maintenance. Applying the tool, ADOT focused the resources of the department controls on preservation, safety, and, to the extent possible, other needed modernization improvements to the existing system. For Caltrans, its portfolio of projects was composed of projects in the following categories: major damage restoration, collision reduction, regulatory mandates, mobility improvement, bridge preservation, roadway preservation, roadside preservation, and facility improvement. Using MODA, potential projects were evaluated quantitatively in terms of how well they support each of Caltrans's goals.

Proof-of-concept findings: The fact that this project had a follow-on implementation study creates a wrinkle to the application of the RIA framework. Are these two separate projects? If yes, which gets evaluated? If no, should these projects be considered as a single continuous one? It seems that the implementation study just helps with the "findability" of implementations, and so this should be considered a single continuous study. The internal impacts would be common across implementers—did MODA result in more informed investment decisions? However, the external impacts would vary across implementers, depending on their investment goals. This calls for qualitative assessments based on structured discussions with the leadership of implementing agencies.

KEY TAKEAWAYS

The overall RIA framework based on the concepts of a pathway to value and impact roadmaps worked well in simulated applications to several different NCHRP studies. What became clear in the proof-of-concept tests is that NCHRP research projects are diverse, and so are their potential internal and external impacts. This, in turn requires a portfolio of metrics to characterize impacts. While suggestions for impacts and metrics can be included in the framework, a standard set is impossible to define. Data collection was generally feasible but not necessarily simple. Confounding factors that make it difficult to detect and attribute impacts to projects are common.

CHAPTER 5. GUIDELINES FOR EFFECTIVE NCHRP IMPACTS ASSESSMENT

This chapter describes the recommended five-step RIA process (see Figure 4).

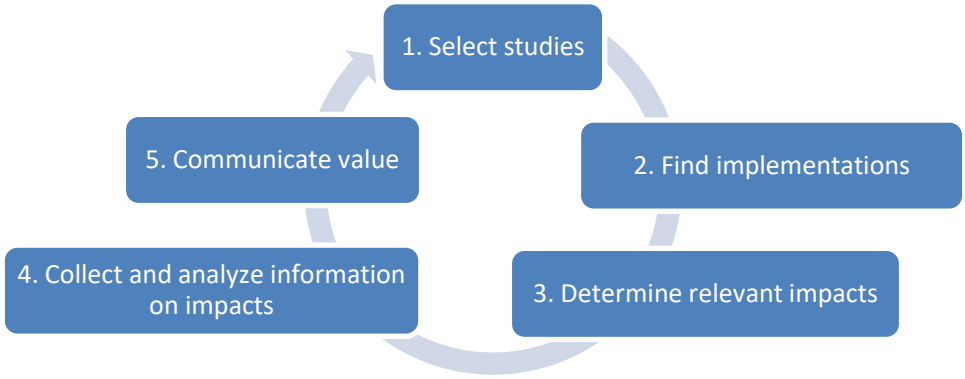

Figure 4. Recommended RIA Process.

STEP 1: SELECT STUDIES

Overview

NCHRP cannot expect to assess the impacts and value of all NCHRP studies. It will be necessary to sample from the stream of NCHRP studies. Due to resource constraints (i.e., time, money, and people), NCHRP should select studies for assessment either strategically or opportunistically:

- **Strategic selection** bases selections on the apparent significance of a study, one that has a high probability of producing both broad and substantial effects on implementing agencies and transportation systems. These should be chosen carefully, with the realistic understanding that not every study will have high strategic significance. Care must be taken to avoid bias by selecting *only* studies that seem to be especially successful.
- **Opportunistic selection** is made for studies for which the implementations are obvious or known in advance, providing an easy trail to follow. It will be advantageous, initially, to follow easy paths to build experience and sharpen RIA processes and tools.

Sampling Strategy

The most representative way to sample is by NCHRP study topics, assuring that projects from each cluster are selected over a period of several evaluation cycles. *NCHRP Impact Report 2019* grouped its reporting on NCHRP study topics into eight topic clusters. For consistency of reporting, NCHRP should use these same clusters when selecting studies for RIA. The topics are:

1. **Administration**: economics, law, finance, and agency administration.
2. **Design**: pavements, bridges, general design, roadside development, and vehicle barrier systems.
3. **Maintenance**: snow and ice control, equipment, and maintenance of way and structures.
4. **Materials and construction**: general materials, bituminous materials, specifications, procedures and practices, and concrete materials.

5. **Soils and geology:** testing and evaluation of soils, and foundations and scour.
6. **Traffic:** operations and control, illumination and visibility, traffic planning, and safety.
7. **Transportation planning:** planning methods and processes, and human and natural environment.
8. **Special projects:** all other subject matter not readily identified in the other areas.

Selected projects should have been available (widely disseminated) for at least three years to permit important impacts to develop. If the impacts are expected to be primarily external to the agency, a longer waiting period will be necessary.

A particular risk is focusing the evaluation on projects that produce easily measured impacts. NCHRP projects, which are themselves selected based on consensus priorities of SDOTs, cover a wide range of problems and products, ranging from hard quantitative to soft qualitative advice. The program evaluation should cover all these project types.

Sampling Interval

Sampling of completed NCHRP studies should be done at a consistent interval (e.g., every year, every two years, or every five years) based on NCHRP resources. Likewise, the number of studies selected for impact assessment will necessarily be based on available resources. The important point is to maintain a systematic, ongoing assessment effort so that it tracks the stream of benefits for NCHRP. A sporadic impact assessment process, occurring at irregular intervals, will not accumulate enough consistent evidence of value to be useful to NCHRP.

A pragmatic sampling strategy is to evaluate five to eight projects every two years (i.e., a sample cohort) and one or two implementations of each project in a sample cohort.

A practical process might be designed and budgeted to evaluate five to eight projects every two years (referred to as a *sample cohort* in this document).

STEP 2. FIND IMPLEMENTATIONS

Overview

Finding implementations is vital to the RIA process. Some implementations are readily known to NCHRP, but many go undetected for various reasons. Some research studies will lead obviously and directly to implementing agencies, but others may not. Therefore, it is important to seek out and document implementations in an ongoing, proactive manner.

The NCHRP RIA should include projects with different levels of implementation. Partial implementations should not be systematically excluded since they are likely to be most common. Deciding whether enough of the research product has been implemented will be a matter of judgment, but to make a project a candidate for study, there should be evidence that core ideas and principles have been adopted and new or modified practices have been in place long enough to mature. During data collection for the impact assessment, it will be important to determine just what was implemented because it is normal for this to deviate from research recommendations.

Aborted implementations should not be systematically excluded because it can be important to report on failed research implementation and the reasons why a research product was not advanced, especially why the implementation was aborted and the lessons learned from the attempt.

Strategies for Finding Implementations

Proactive Outreach to SDOTs by NCHRP

The regular visits to SDOTs by TRB senior program officers (SPOs) are an active method for teasing out applications of NCHRP research. SPOs could ask a general question about implementations or could target specific research outputs that were particularly well matched with key issues within a State.

Gathering Information Directly from Panel Members, NCHRP Research Managers, and Research Teams

Key sources of information about implementation are oversight panels. Oversight panel members are chosen because of expertise and interest in the topic, and it is not uncommon for them to be, or to know, likely first adopters of research results.

NCHRP research managers have the most direct knowledge of and contact with projects, and their hands-on engagement will be a source of information on likely implementers. In some cases, this knowledge may stem from questions coming to them from the potential implementers once results are disseminated.

Members of research teams may know of implementations of their completed research study results. Would-be implementers sometimes contact research team members for more information, and this information can be passed along to the Research Implementation Support Program. The personal investment of research team members in the project may be motivation enough for them to look for and report implementations. This motivation might be amplified by explicitly considering a team's implementation record when evaluating proposals for future contract awards.

Self-Reporting

Another way to discover implementations of NCHRP results is to give implementers an easy way to report their use of a research product to TRB. This could be done simply by putting a "report-back implementation" web address or QR code in printed documents. For digital documents, embedded hyperlinks could give a user an easy way to get to a webpage that will invite reporting of a product application. Similar report-back hyperlinks could be routinely printed/published in publications such as *TR News* and *The AASHTO Journal*. The request can be simple: Is your organization using the tools presented in NCHRP (project number)? If so, (click here/go to this website) to tell us about it.

Some commercial services provide a platform for researchers to report uses and implementations of their research results. Interfolio's Researchfish (https://researchfish.com/) is one. Some research funding agencies contract with Researchfish to collect researcher reports in multiple categories—including papers in journals and trade publications, news reports, social media, policy studies, and policy actions, among others—to build a 360-degree picture of the effects of a product, finding, or entire research portfolio.

Targeted Surveys Conducted by NCHRP

When a target group of potential implementers can be easily located, such as members of a topic-specific AASHTO committee, TRB committee, or webinar participants, it can be efficient to ask them about use of a particular NCHRP product. Survey response rates from a

known interest group tend to be higher, and the information collected can be accurate and reliable.

Integration into the NCHRP Research Process

A strategy that would not only identify potential implementers but also serve to improve the usefulness of a study's final deliverables is to gather information on likely implementers throughout the NCHRP research execution process. To do this, implementation seeking should be integrated into the entire NCHRP process by identifying likely implementing agencies by type and, where possible, by name during:

- Development of RNSs.
- Priority-setting discussions within AASHTO committees.
- Writing of RFPs.
- Preparation of the amplified work plans (AWPs) by research contractors.
- Production of interim and final deliverable products.

Implementation Database

Once implementations are determined, a record of those implementations should be systematically maintained. A new tool for doing so would be an implementation database. The database can be maintained by NCHRP's Research Implementation Support Program. The program provides funding assistance to facilitate implementation of completed and in-development NCHRP research results and products. The database of implementations would serve as an indicator of the value of completed NCHRP research. While it would not be a record of *all* implementations, it would be a documented measure of successes. The database should contain the following five data elements:

Documentation of implementations in a database will provide tangible evidence of the value of NCHRP research.

- NCHRP project title.
- Topic cluster.
- Year of dissemination of research products.
- Implementing agencies.
- Agency contact persons.

Evaluability Assessment

Every implementation is not equally suitable for assessment. *Evaluability* considers the extent to which an impact assessment for a particular implementation can be done in a reliable, credible, and cost-effective fashion. An evaluability assessment saves time and effort by screening out implementations that are likely to be overly difficult to assess because they generate impacts that cannot be accurately or reasonably captured.

The evaluability screening process should assess whether impacts are likely to be detected. The process should be a rapid, qualitative review conducted based on information available within NCHRP, along with a discussion with a knowledgeable representative of the implementing agency. In terms of level of effort, it should take no more than a few hours.

To conduct an evaluability assessment, it is necessary to obtain basic information about the implementations through some screening questions. Most importantly, it is necessary to

contact the implementing agencies to identify a key contact person who can help answer the screening questions. Table 5 shows the screening questions. Answering the questions is not about a simple *yes* or *no* but more likely involves addressing *to what extent*.

Table 5. Evaluability Assessment Screening Questions.

Screener Question	Answer	Recommended Action
1. Is there an agency representative who is knowledgeable about the implementation and willing to support the impact assessment?	If NO, then…	Drop from sample
2. Are there factors outside of the implementation setting that could prevent the implementation from generating internal or external benefits?	If YES, then…	Consider what these factors are and the extent to which they negatively impact the assessment; if extremely problematic, drop from sample
3. Has the implementation reached a sufficient level of maturity to generate expected internal benefits?	If NO, then…	Consider when timing could be right; if too long, drop from sample or set aside for future consideration
4. Has sufficient time passed so that data on external impacts for an implementation can be obtained? Do these data exist?	If NO, then…	Consider assessing internal impacts only
5. Are there other operational difficulties that would make impact assessment for this implementation particularly difficult and/or costly?	If YES, then…	Drop from sample

While it is important to assess the availability of, access to, and quality of existing information about the implementation, this should not be the sole basis for inclusion in the RIA process. The maturity of the implementation should be considered. At early stages, not much change can be expected. The concept of maturity means that enough time must pass since implementation (not the research product dissemination) began so that substantial change *could* have occurred; whether it did or not is the subject of study. For this reason, one to three years should be allowed after implementation for internal impacts to develop and before in-depth study should begin, depending again on project type and context. For example, recommended changes in design specifications or inspection methods may develop more rapidly than adjustments in organization structure or operating policies. External impacts will take longer than internal ones to develop.

STEP 3. DETERMINE RELEVANT IMPACTS

Overview

Each study in the sample cohort has a defined set of expected impacts that are derived from the research objectives and should be described in an impact roadmap (see examples in Chapter 4). Where multiple implementations of an NCHRP project are identified, each should be considered its own unit of assessment and results combined after these assessments have been completed. Relevant impact should be consistent across implementations for a given study. Not all implementations of a study's research results will have both internal and external impacts. Partial or aborted implementations for example may not have external impacts.

Quantitative and Qualitative Measures

Impacts can be measured with quantitative or qualitative metrics. Simply put, the terms *qualitative* and *quantitative* refer to the type of data generated in the research process (Garbarino and Holland, 2009). Quantitative research produces data in the form of numbers, while qualitative research tends to produce data that are stated in prose or textual forms (see Appendix C for more information)

Economic analyses tend to use quantitative measures. The two most common forms of economic analysis are BCA and cost-effectiveness analysis. The key similarity between BCA and cost-effectiveness analysis is in the collection of data on costs. BCA seeks to determine whether the benefits provided were greater than the program (or implementation) costs and requires all benefits to be expressed in monetary terms. Cost-effectiveness analysis is like BCA; while costs are still expressed in monetary terms, benefits are expressed in non-monetary terms, using a common impact metric, such as patents filed or jobs created. As a result, cost-effectiveness analysis requires comparisons among families of programs or implementations to determine which option is the most cost effective (Rogers et al., 2015). Not all quantitative measures are economic. Sample surveys produce quantifiable data that can be statistically analyzed with the main aim of measuring, aggregating, and modeling attitudes or opinions regarding impacts. Computations of accident or fatality rates are other examples of relevant quantitative measures.

Qualitative measures, in contrast, generally sacrifice numbers in order to describe and explore issues in depth. Qualitative research includes techniques such as participant observation and interviews that are often group based. Using open-ended questions, these methods are designed to capture judgments and perceptions and allow complex analyses of often non-quantifiable cause-and-effect processes (Garbarino and Holland, 2009).

Quantitative metrics are important for describing and characterizing the impacts of research implementation, such as changes in construction costs, pavement roughness, trained personnel recruited, or timely snow removal crew performance. Where metrics are available as evidence of impacts of research implementations, they should be presented along with baseline data describing the before-implementation situation so that change attributable to the implementation can be captured. Any additional information on the context of the implementation data will be valuable for understanding the degree to which the impact has taken place and can be attributed to the research implementation.

For some NCHRP projects, quantitative metrics alone may not convey the full set of impacts. For such projects, qualitative impacts can contribute importantly to understanding the value of research implementation. For this reason, qualitative impacts must be included in the characterization of impacts. For some research projects, these may be the most important outcomes.

Internal Impacts

Internal impacts are the benefits of implementing research results within an agency. A wide range of possible impacts internal to agencies can result from NCHRP research, so it is necessary to determine which of them are relevant for the studies selected. Table 6 presents a core set of possible agency benefits (i.e., the most common ones); however, these do not attempt to capture the universe of potential agency benefits. Due to the diversity of NCHRP research

topics, the universe is impossible to enumerate here. Also, for any implementation evaluated, multiple measurable internal impacts are possible.

Table 6. Potential Expected Internal Impacts of Implementations.

Internal Impact	Type of Measure	Potential Metric
Knowledge increase	Qualitative	Perceived benefit of new knowledge gained
Engineering/administration savings (planning/design costs and paperwork)	Quantitative/ qualitative	Perceived or quantified cost/time savings due to process or practice improvement; perceived quality or accuracy improvement
New design technical standard	Quantitative	Extension in life cycle or decreased life-cycle costs
Construction savings	Quantitative	Δ $ agency savings (labor, equipment, and time)
Agency operation/ maintenance savings	Quantitative	Δ $ agency savings (per worker or per week/month or per assignment, task, or project)
Better decision support	Qualitative	Perceived improvement in efficiency; effectiveness of data and analytical tools for supporting agency decisions
Worker safety	Quantitative	Δ rate of agency worker injury (per worker or per week/month), number of workers affected
Worker productivity	Quantitative	Δ agency performance (above) per worker; number of workers affected
Workforce development	Qualitative	Extent to which agency staff perceive improvements attributable to training/education
Workforce diversity	Quantitative	Δ ratio of participation by minority or disadvantaged population groups; number affected

External Impacts

External impacts are benefits that accrue to the transportation eco-system stemming from an agency implementing NCHRP research results. While the internal impact assessment tells what kind of change has occurred in an agency, an external impact assessment paints a picture of what might be the ultimate, and perhaps most important, effects of a research implementation on a broader scale—changes to the characteristics and performance of the transportation system and the effects on its users and community. Measuring external impacts, along with internal ones, enables NCHRP to communicate a comprehensive and complete story about the value of research implementations of NCHRP studies.

Table 7 presents the most common types of external impacts and associated measures. This list is not comprehensive, and applications of this guidance will need to look broadly for external impacts. The impact roadmap will be helpful here. Multiple impacts are possible for a single NCHRP study, with a wide range of possible ways in which they can occur and be measured. To make the information collection and analysis reasonable in terms of cost and time, these processes need to focus on the impacts considered to be most likely and most important.

Table 7. Potential Expected External Impacts of Implementations.

External Impact	Type of Measure	How Measured
System performance	Quantitative	Δ (change) in transport level of service, reliability, speed, delay, number served, and connectivity
System cost	Quantitative	Δ $ user savings (per capita, trip, vehicle-mile, or passenger-mile)
System revenue	Quantitative	Δ $ generated (per capita, trip, vehicle-mile, or passenger-mile)
System safety	Quantitative	Δ rate of collision, injury, or death (per vehicle-mile or passenger-mile)
System productivity	Quantitative	Δ $ outcome/$ invested (cost-effectiveness)
Environment	Quantitative	Δ emissions rate (for air or water), noise, or regional quality index
Quality of life	Quantitative/ qualitative	Δ index or rating for traveler comfort or broader quality of life; assessment by community leaders and stakeholders
Equity	Qualitative/ quantitative	Δ availability and quality of service for under-served groups (relative to well-served groups)
User satisfaction	Quantitative	Δ satisfaction rate from surveys

When attributing external impacts to NCHRP research, there should be a documented and specific connection between intervention and outcome. For example, when the NCHRP report is an evaluation of cable median barriers, an SDOT implements them while referring to the NCHRP report, and median crossover deaths go down, the attribution is clear.

But attributing external impacts to specific NCHRP research implementations is not always this clear. The impact roadmap is an important tool for establishing a plausible causal pathway but may not be sufficient. Impacts occur through a complex variety of processes, individuals, and organizations that may reference, use, adopt, or build upon the NCHRP research. In addition, it is quite possible that the original NCHRP research was itself built upon other sources of information and lessons learned from the experiences of other processes, individuals, and organizations.

There will be cases in which external impacts occur as an indirect consequence of NCHRP projects, and those indirect effects will tend to be missed when applying the roadmap (logic model) concept to identify the directly relevant impacts. For example, an NCHRP study on the use of license plate readers for transportation data collection purposes may have data collection cost savings as a desired external impact. This impact may be directly measured. But the research could also lead indirectly to an improvement in safety, depending on when and how the license plate reader technology is applied, for example, by avoiding putting field personnel at risk or disrupting traffic flows. Such safety impacts may be missed because of the indirect connection to the NCHRP study itself. For these reasons, it is seldom straightforward to attribute an impact to a single piece of research or to even isolate the contribution made by that research.

STEP 4: COLLECT AND ANALYZE INFORMATION ON IMPACTS

Overview

The basic methodology for collection and analysis of information on impacts follows a hybrid approach that incorporates elements from quantitative (mostly economic- or performance-related) and qualitative techniques. The general process is:

1. Select an implementation for a given study.

2. Formulate a checklist of information to be gathered based on the expected internal and external impacts and metrics from Table 6 and Table 7, respectively, in step 3 and guided by the logic model (impact roadmap).
3. Find an inside collaborator who knows the implementation in detail (see "Evaluability Assessment" in step 2), and recruit four or five other knowledgeable agency staff to talk with—the implementation leader, support staff, relevant technical expert, or manager.
4. In a group interview setting, obtain perceptions on expected impacts, as well as any surprising, internal, or external impacts, both positive and negative.
5. Gather documentation for impacts that have been quantified by agency staff. If important quantitative metrics are missing, ask agency staff to attempt to quantify the benefits (e.g., assign a monetary value or performance evaluation rating) through subjective assessment (see methodology for doing this in the *Subjective Assessments* section below).
6. Review gathered information and data; identify unanswered questions, conflicts, and uncertainties about impacts; and talk with individuals to clarify.
7. Formulate a draft impact report as narrative supported by quantitative metrics, using the template supplied in Appendix D.
8. Cycle the draft back to interviewees for reviews, correction, and ratification.

It is important to ensure that enough time has passed from the actual implementation of research results for agency impacts and, more importantly, broader transportation eco-system benefits to occur. The timing may differ based on the external impact category of interest. There is no set rule for identifying when the time is right; it is a matter of judgment for the evaluator and the implementing agency.

Sources of Information

The target of the data collection task is three types of information:

- Impact data from agency operations and administrative records.
- Agency performance measures.
- The views of those engaged in and experiencing the implementation.

With multiple sources of data, the evaluator can draw a more complete picture of what occurred and why. The search for information about the implementation should be guided by expected relevant impacts (as discussed in step 3). The goal is to build an understanding of the outcomes of the implementation, based as much as possible on the perspectives of those involved in the implementation. Then, narratives, including and informed by available objective data, are used to describe the impacts of the research implementation; embedding this information in a narrative will create a comprehensive story about the benefits of the research for a particular implementing agency's context.

Qualitative Interviews

Key sources of information are group interviews (not surveys) with the people who were involved in the specific sampled implementation. Group interviews are an efficient method for gathering multiple perspectives, and interactions among group members can amplify the information derived from the discussion. The project champion within the agency often has the most knowledge about the implementation's successes and failures. Interviewing four or five other persons for each implementation is recommended. Site visits for interviews are desirable, but most can take place via telephone, video conference, or webinar. Other sources are

observations and document reviews. The goal is to collect and present information from multiple sources in sufficient detail so that a critical audience will understand the research implementation story and find it credible.

Document Reviews

Documents are likely to be the primary source of quantitative data on impacts. Relevant documents are agency maintenance, construction, operations, or personnel records, depending on the expected impacts.

Quantitative Performance Measures

Many of the required impact measures can be found among the data collected and analyzed for SDOT performance management programs.[1] Using or adapting this information will reduce the need for costly, incremental data collection and analysis. It is important, as much as possible, to draw the measures of impact from the performance measures that are available from the implementing agency or its partner agencies. Any new data collection activity to populate the measures must be carefully considered and discussed with the specific implementing agencies to make the best use of the effort of the evaluation team and agency personnel.

Subjective Assessments

Even if quantitative sources of data on impact are available, subjective assessments should also be used to assess impact. *Subjective* refers to information that is based on personal opinions. It is contrasted with *objective*, which refers to information that is based on factual evidence (e.g., the performance measures in the preceding paragraph).

Agency staff should be asked to assign a numeric rating to indicate the potential significance of the research results in terms of the applicable impact factors. Nominal scales are typical in which numbers or letters serve as tags or labels only, to identify or classify an object (e.g., 1, 2, 3… or A, B, C…). These numbers or letters should be anchored or explained with verbal descriptions to promote consistency, such as with the five-point grade scale (A–F) used in most public schools.

Figure 5 is an example of a subjective scoring tool. Specific questions are drawn from the research products being evaluated and their associated objectives—the expected impacts of the research.

[1] See SDOT performance measures in an interactive map at https://www.fhwa.dot.gov/tpm/tellingperformancestory/tpmstory_map.cfm.

Example Agency Value Assessment
NCHRP Synthesis 564: Practices for Selecting Pedestrian and Bicycle Projects

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Helped select project selection approach	___	___	___	___	___
Application worked smoothly	___	___	___	___	___
Confidence in selected project was high	___	___	___	___	___
Engaging other stakeholders was valuable	___	___	___	___	___
Selected method brought agency value	___	___	___	___	___

Figure 5. Nominal Scale from NCHRP Synthesis 564.

Scoring or rating is best done using odd-number scales so there is a natural midpoint, and the ends should be labeled to represent the least and most desirable impact values. There are different approaches to the group scoring, where judgments are averaged over several raters (e.g., three to five):

- **Collaborative score.** Scores are determined by a knowledgeable group (participants or observers) in an interactive setting, such as a meeting or focus group. This builds agreement and develops shared explanatory details.
- **Independent scoring.** Scores of separate raters are aggregated. This promotes independence of views and prevents the bias that might be created by a dominant rater, such as a unit manager or advocate for the research product. Scores should be supported by brief text explanations. This helps a rater think through the choice of score and provides supporting evidence.

The Kansas Department of Transportation uses subjective assessment in its prospective RIA process. Research staff assign a numeric rating to indicate the potential significance of the research results in terms of the applicable impact factors. The applicable benefit categories are rated from 1 to 10, with 10 representing the most significant positive benefit. Their numeric ratings are:

- NA: the factor does not apply to this project.
- 0: absolutely no benefit.
- 1: an intuitive feeling that the project has some slight benefit.
- 5: no clear evidence but a strong subjective feeling that the project has a significant positive benefit.
- 10: clear evidence or a strong feeling that the project has an excellent or outstanding positive benefit.[2]

Characterizing and Reporting the Impacts

Qualitative impacts can be described in specific, credible, and consistent terms. Quantitative impacts can be documented with numbers (see Appendix C). Appendix D provides a suggested research impact report template.

[2] This approach has been adapted from the Kansas Department of Transportation.

An important source of risk in characterizing research impacts is that of ignoring or downplaying qualitative research outcomes. Among these risks are that:

- The full value of the research implementation will not be captured; evaluators will measure the measurable rather than evaluating the value of the research.
- Projects that produce high value for agency leadership and the community may be ignored or de-emphasized. Over time, this may bias the direction of the overall program away from projects that might deliver such qualitative value.

STEP 5. COMMUNICATE VALUE

Overview

Value can be thought of as a cumulative benefit, where results are achieved across a program of research. Value is based on program goals. NCHRP goals are to "help state DOTs effectively plan, design, construct, operate, and maintain their surface transportation network while keeping workers and the traveling public safe, providing or improving mobility, and contributing to the economic vitality of communities and the nation" (NCHRP Stakeholder Report, 2020). The meaning of value will be further refined based on the objectives of specific research projects. The multidimensional character of the contributions of NCHRP research in meeting these goals means that absolute (or quantifiable) valuations are difficult, particularly given the lack of precision to which the measurement of value can be made. Precision is particularly problematic with assessments of quality, which are essential for research, but may vary among research stakeholders. This introduces some fuzziness in assessing the value of research that calls for the use of expert judgment in making effective research value assessments, which is the approach taken in this study—structured questions, group assessment to collect multiple perspectives, and aggregation techniques to manage bias.

Approach

The approach for communicating value is based on the concept of a pathway to value discussed in Chapter 2. This concept is based on the fact that a results chain connects the activity from dissemination of research results, through implementation, to impacts and then value. Information on which to assess value comes from the findings related to assessment of internal and external impacts. These findings will naturally lend themselves to the compilation of narrative stories about NCHRP program benefits. Such stories can effectively communicate the experiences of experts involved in implementations and their results, providing insight and understanding that cannot be quantified, and giving context to implementation activities and impacts.

Reporting of stories is an important component of communicating research value. When presented with a story, both sides of the brain work to process the words, interpret the story, and store its meaning in memory, making the brain behave as if the events in the story have been experienced firsthand (Keene et al., 2016). The research impact template provided in Appendix D will guide preparation of the stories of NCHRP program value.

The product is a narrative discussion that tells the story of the impacts of the research, wrapped around those quantitative measures of impacts that are available. The narrative is a description of *what happened* because of the research implementation and the *value* of what happened, either explicitly measured or in the form of an integration of subjective perspectives.

The research impact reports and associated narratives should be archived in categories of research topics. This way, NCHRP can accumulate evidence of research value for clusters or streams of research. When the accumulated evidence has reached a critical mass, such as three to five assessments of individual projects, particularly where a shared pattern of impacts and values is found, a special report on research value can be produced for a particular cluster or stream of research.

CHAPTER 6. METHODOLOGICAL CHALLENGES IN ASSESSING THE IMPACTS OF NCHRP RESEARCH

Application of the recommendations in this document and guidance in the accompanying document to assess research impacts will bring value to NCHRP and transportation research in general but will bring complexities as well. In its application and interpretation, the research assessment requires thoughtful consideration. This chapter discusses these challenges and their implications for implementing program impact measurement.

FINDING IMPLEMENTATIONS

Finding implementations is the first topic addressed in this chapter because it is so vital to the RIA process. Some implementations are readily known to NCHRP, but many go undetected for various reasons. Some research subject areas will lead obviously and directly to implementing agencies, but others may not. It is important to seek out and document implementations in a proactive manner.

Finding research implementations is essential, for only through implementation does research produce value for agencies and their constituencies. While we do not expect that every implementation can be captured, a systematic effort to find implementations is essential for assuring that at least some, and perhaps a majority, of the value produced by the research is captured and assessed. As restated in Chapter 8, it is important to recognize that NCHRP is a national program that is quite different from State DOT research programs, where, in the latter, customers for research and implementations are close at hand and easily captured. The NCHRP market is broad, dispersed, and outside the bounds of program managers. Implementation must be actively sought out.

Identifying implementations of NCHRP projects is not a simple task, not because they are rare but because there is currently no systematic tracking and reporting process to record implementations. A necessary tool for doing so is an implementation database. The database can be maintained by NCHRP's Research Implementation Support Program. This database needs to be fed through outreach efforts integrated into routine NCHRP and TRB processes. Imbedded implementation reporting links and establishment of a culture of sharing implementation experiences, as described in Chapter 5, will support the maintenance of the database and reduce the reporting burden on both researchers and implementers.

TIME LAG – HOW LONG TO WAIT FOR IMPACTS TO BECOME EVIDENT?

The time lag from research completion to dissemination, implementation, and the development of impacts varies enormously across NCHRP research projects and impact types. It has been observed in health research that, on average, it takes over 6 years for research evidence to reach reviews, papers, and textbooks, and a further 9 years for this evidence to be implemented into practice. For some types of NCHRP research, similar timelines may be observed. In light of this, it is important to allow sufficient time for impacts to manifest, while not waiting so long that these impacts cannot be verified by stakeholders involved in the use of the research. For example, internal (agency) impacts that stem from a change in load and resistance factor design bridge design specifications can take place in a short period, through changes in the cost of design, materials, and construction. On the other hand, the safety benefits

of a new interchange design, e.g., a diverging diamond configuration, make take years to be revealed as traffic uses the facility, crash data are gathered, and patterns are observed. In this example the impacts are external, affecting agency customers, and their manifestation occurs because of the interaction of customers with the constructed product.

An understanding of this process (conceptualized in Figure 4) must inform the evaluator's judgment in the choice of implementations to evaluate, impacts to consider, and the timing of those evaluations. This understanding will come from the project-specific impact roadmap (logic model) and the evaluability assessment presented in step 2 in Chapter 5. The impact timing issue will be particularly important in deciding whether, and how, to pursue external impacts.

Long time lags in the development of impacts should not be a deterrent to considering external impacts of research, since these are often the primary objectives of the research product. Instead, variations in timing should inform project selection and evaluation, for example, by evaluating at least some projects well after implementation so impacts have time to develop.

ATTRIBUTION – WHAT DID THE RESEARCH IMPLEMENTATION CAUSE?

Internal and external impacts are caused not only by the targeted NCHRP research but also from external, confounding factors. For example, other agency policy changes may occur while the research results are being implemented, or some other modification to the road network may affect traffic volumes and safety outcomes after an NCHRP safety product is being introduced. Such parallel events can make attribution difficult or impossible. It will be important to be mindful of these kinds of confounders and to temper inferences about attribution when they are present.

Particularly when attributing external impacts to NCHRP research, it will be important to look for substantive and specific connection between intervention and outcome (NCHRP report results leading to full or partial implementation leading to internal or external change as reflected in research objectives and/or findings), as well as reasonable confidence that no other major factors were at work.

Differentiating between the various factors leading to the impact is a significant challenge but is not impossible. For example, evidence of causality (or progress toward achieving desired impacts) may be supported by information showing that a sequence of activities, outputs, audiences, and impacts has indeed occurred consistent with the original logic model: causality normally requires event A to precede event B if A is the cause of B. However, this can only be done for an individual project, and any such finding will also be affected by the length of time between when the research was implemented and when the consequent impact is observed. Was NCHRP research a key link in the chain between original idea and implementation? Did it shape the outcome or advance the timeline? In following this chain of effects, it will be important to ask: What else might have led to the internal or external changes? This is the research for rival hypotheses, alternative explanations for the impact. In the search for favorable impacts, it is tempting to attribute all positives to the research implementation, whereas, perhaps changes in population demographics, land use, traveler behavior, markets, or network structure may have contributed to the outcome.

These are confounding factors that will confuse attribution. Looking for alternative explanations can be important, e.g., examining network evolution, traffic trends, demographics or land use patterns. Interviewing engaged local professionals and leaders is one way to establish some understanding of the possible effects of these external factors in influencing research

impact measures. In the end, researchers may only be able to speculate about what would have happened without the research.

Thus, there are limits to what can be achieved from quantitative metrics that track results following from the logic model. To achieve further insight, the qualitative case study approach presented in this report may be more useful for identifying causality than the sole use of quantitative metrics because case studies bring a richness of perspectives by integrating experiences, processes, and perceptions with hard measures.

The case study approach also works for evaluating internal impacts because the unit of analysis is a single implementing agency, making it possible to gather data and experiences from all, or most, of the people involved in an implementation and who experience its effects. External impacts, on the other hand, are much more likely to be affected by a broader and hard-to-capture set of factors. Also, external impacts can develop and change over time, as those external factors evolve and modify the outcomes of the research implementation. The point in time at which assessment takes place will therefore influence the degree and significance of those impacts.

BIAS – HOW CAN FINDINGS BE DISTORTED?

Research impact evaluation and the proposed process present numerous opportunities for bias. The most obvious is in the selection of projects for evaluation. It will be easy to choose projects that seem to be the most successful, have the most implementations, seem easiest to evaluate, or are topical favorites at the time. This argues for a balanced sampling of projects across the NCHRP portfolio, as suggested in Chapter 5.

A very natural source of bias is selecting only projects that produce quantitative outcomes; this pattern is found in methods used for research project evaluation in SDOTs. The short-term risk of this bias is ignoring the value of qualitative, organizational research often requested by agency leaders. The long-term risk is reducing the priority on funding such projects to the determent of an important segment of the NCHRP market.

The quantitative-qualitative tension can be resolved through choice of evaluation methods, specifically, relying on case-study-based interview approaches to capture the value of projects that produce outcomes not readily quantified or monetized. As suggested in Chapter 5, with the right experience and tools, these can be applied systematically and with a high level of reliability, leading to balanced program evaluation. Again, making sure that sample projects span the set of project types within NCHRP will help manage this bias.

There are multiple opportunities to *game* the evaluation process – to intentionally bias the selection of projects for evaluation, the methods used, or –for agency respondents – the answers to data and interview queries to show their efforts in the most favorable light. This is an expected outcome—people willing to engage in the evaluation process are most likely to be proud project advocates. Addressing these biases calls for careful documentation of sample selection, data and interview sources, and interview responses. Cross checking multiple information sources is a useful approach to control gaming.

Program managers need to be self-aware of their choices of projects and transparent in documenting them. Here the burden is on NCHRP program managers to resist bias in the selection of evaluation targets and to seek out documentation of reported results and benefits and, in the process, to look for any contravening evidence. The balance needs to come from neutral investigators to be sure that the results and their interpretation represent an honest report of project benefits and values.

MAINTAINING THE MOMENTUM

The benefits of systematic evaluation of NCHRP projects are clear and important for program management, optimization, and sustainability. There will also be costs, in terms of personnel effort and money. Good management data will not be free, nor will it fall easily into computer files. Outreach and action will be required.

An important challenge will be to commit the resources to maintain focus on the value to be produced by the proposed evaluation process, in terms of ensuring and enhancing the stream of evaluation products going forward. This means devoting sufficient resources to deploy and maintain this systematic evaluation effort to deliver the required information about program effectiveness on an ongoing basis: a once-and-done, or aperiodic evaluation process cannot provide a strong basis for program management and advocacy. It will be important to integrate the process and the products of this process into NCHRP management and decision making and, to the extent possible, into AASHTO priority setting, as well. This evaluation-driven philosophy should also flow down to contractors and volunteer panels. The challenge of maintaining momentum underscores the importance of a periodic review and update of the evaluation process to confirm and enhance its own value to NCHRP and the transportation community.

CHAPTER 7. CHANGES TO NCHRP PROCESS TO FACILITATE RIA

In developing the approach recommended in this report, learning from work in other fields, perspectives of the stakeholders, and the characteristics of NCHRP projects themselves all pointed to opportunities to adapt the NCHRP process to facilitate research impact assessment. To provide a data-driven basis for evaluating the impacts of NCHRP, it is desirable to introduce some modest process adjustment to assure that, throughout the research effort, the focus is on implementation of results and anticipation of their impacts and values, and that essential data for evaluation – not currently available in the current process – is captured. If NCHRP intends to implement a comprehensive research impact assessment component to the program in the future, then it is incumbent on the organization to facilitate a research process that produces the necessary data. This chapter presents the research team's recommended changes in detail, and Figure 6 provides an overview of the changes.

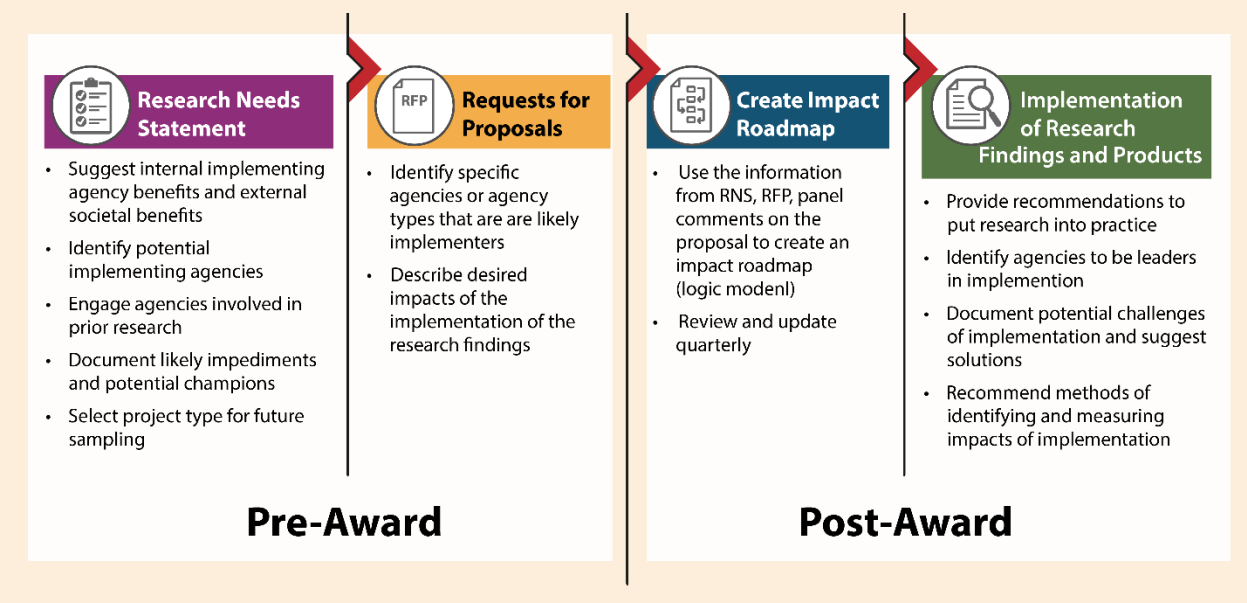

Figure 6. Suggested Changes to the NCHRP Research Process to Facilitate RIA.

RESEARCH NEEDS STATEMENTS

Most NCHRP projects begin with an RNS, which is typically developed by TRB technical committees and task forces or is generated as a product of a TRB-sponsored or co-sponsored conference or workshop. The RNS should include the key components of the logic model, specifically the desired impacts and suggested implementing agencies. The TRB website presents instructions and guidance for writing RNSs. These instructions can be modified to convey the recommendations of this study. Table 8 presents the current elements of an RNS along with the suggested modifications.

Table 8. Suggested Modifications to the Elements of Research Needs Statements.

RNS Element	Current Description	Suggested Modification
Potential benefits	Justify funding of the RNS by listing potential benefits; identify consequences of not doing research	Identify desired impacts internal to implementing organizations and potential societal benefits that are external to implementing organizations
Likely implementing agencies	None	Include potential implementing agencies; these may be agencies that are very interested in the research topic and support the RNS
Related research	Explain how research relates to other ongoing or completed research	Identify agencies that were involved in prior research and may likely be implementers of this work
Implementation	Not currently a requirement	Address potential impediments to implementation, activities, and champions needed to support the adoption of research products
Subject category	Select one to five from topics provided	Select from one of the eight project types suggested by this study (described in Chapter 5, "Sampling Strategy")

REQUESTS FOR PROPOSALS

According to the TRB website, one of the four major responsibilities of NCHRP panel members and liaisons is to translate the RNS into an RFP. In the RFP, the panel's main job is to describe the problem and the desired outcomes in enough detail that a qualified research team will clearly understand what is needed and expected. In this step, the project panel adds specifics in terms of research products and potential impacts. These elements should focus on the fact that NCHRP projects are intended to produce practical, readily implementable products that can address a specific problem. Table 9 suggests modifications to current RFP elements.

Table 9. Suggested Modifications to the Elements of Requests for Proposals.

RFP Element	Current Description	Suggested Modification
Title	Convey the study topic in a concise manner	No change
Background	Establish the importance of the topic and relate the topic to larger national or regional goals and objectives	If possible, also identify specific agencies or agency types that are concerned about the topics and are likely implementers
Objective	Describe the desired process and/or product in detail	In addition to describing the process and/or product in detail, describe the desired impacts of the implementation of the research findings

AMPLIFIED WORK PLANS AND IMPACT ROADMAPS

An AWP for NCHRP research is developed by the PI after contract award. The AWP incorporates all agreed-on changes to the proposed research plan based on NCHRP and panel comments and amplifies the approved research plan by providing as much narrative detail as necessary.

The AWP requirements should be amended to require the PI to use the information from the RNS, RFP, and panel comments on the proposal to create an impact roadmap. Not only will this facilitate evaluation of the research project, but it will also provide the PI and selected research team with the guidance needed to achieve the desired results of research and to target

implementation by specific (types of) customers. As the project proceeds, the impact roadmap should be reviewed, and the relationships among the basic elements in the impact roadmap should be updated. In addition, revisiting the impact roadmap should be a requirement for quarterly progress reporting.

MEMORANDA ON IMPLEMENTATION OF RESEARCH FINDINGS AND PRODUCTS

A final deliverable of all Cooperative Research Program projects is a stand-alone technical memorandum titled *Implementation of Research Findings and Products.* The creation of a logic model at project initiation that is updated as the project progresses will make the development of this memorandum more systematic and useful. The logic model directly informs the following required elements in the implementation of findings memo: "(a) provide recommendations on how to best put the research findings/products into practice; (b) identify possible institutions that might take leadership in applying the research findings/products; (c) identify issues affecting potential implementation of the findings/products and recommend possible actions to address these issues; and (d) recommend methods of identifying and measuring the impacts associated with implementation of the findings/products" (TRB, 2019).

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS FOR EVALUATING NCHRP RESEARCH

The process of constructing a method for assessing the multi-dimensional impacts of NCHRP research led to the development of some useful lessons learned in the form of conclusions and recommendations as described in the next sections.

CONCLUSIONS

There are four key take-aways from this study.

EVALUATING NCHRP RESEARCH IMPACTS IS IMPORTANT FOR PROGRAM MANAGEMENT AND SUSTAINABILITY

NCHRP is a national research program that is supported by funds from SDOTs through AASHTO and from FHWA. NCHRP is effectively the collective research program for SDOTs, funded by State Planning and Research funds and driven by the states' needs for practical, applied research information and products. Its goal is full and effective use of the knowledge and innovations derived from NCHRP research results in the practices and policy decisions of SDOTs, metropolitan planning organizations, other transportation agencies, and the private sector.

As such, assessing whether NCHRP is being used, by whom, and what impacts (i.e., benefits) are derived by users is necessary to assure that the program is delivering value. This conclusion is logical from a managerial perspective; it is well-supported in the research management literature, particularly in health care, where research evaluation is well-developed and routine. A caveat is that NCHRP research projects are diverse and so are their research products and audiences, and what constitutes value varies among products and audiences. A general, formulaic estimate of research value is neither feasible nor appropriate for NCHRP research. Also, the ROI from implementation of research results may not be the same across all states. Mixed methods of assessment as described in Chapter 5 must be used to capture the impacts of the different types or categories of NCHRP projects.

Stakeholders interviewed for this work underscored the importance on knowing the value produced by research investments. Valuation was thought important to maintain the credibility of and function of NCHRP. It also was viewed as necessary to provide a convincing argument about the value of research to respond to pressure to reduce research spending. This is especially true because there are more competing priorities.

EVALUATING RESEARCH – PARTICULARLY NCHRP RESEARCH – IS DIFFICULT

There are transactions costs to conduct research impact assessment. RIA involves time and money. These include the costs of planning the RIA and setting up necessary information infrastructure, finding implementations, gathering information, analyzing and reporting that information, and tracking and monitoring the results of RIA over time. These transaction costs call for resources that may well be spent on other priorities. The question for NCHRP and its stakeholders is whether the anticipated additional benefits of such costs for RIA are justifiable.

In addition to the transaction costs, there are big challenges, including finding implementations, tracing impacts, assuring attribution (controlling for confounding factors), ,

measuring, valuing and aggregating impacts across multiple dimensions (e.g., lives saved, time saved, reduced GHG emissions, improved workforce retentions).

RIA is hard but it is not infeasible – there is plenty to be learned, and important information for research management, in good research evaluation. NCHRP is particularly challenging because of the diversity of projects and products it encompasses. A new bituminous mix, an improved travel forecasting tool, better ways to communicate with communities, and innovative ways to finance highway investments are all fair game under NCHRP; all deemed important by key stakeholders; and all challenging to evaluate.

Further, the context in which NCHRP research is implemental is a national one, making it unlikely that all implementations will be identified and assessed. That means that a summative, aggregate, or all-up assessment of the relationship between benefits and costs of a particular research project can never be captured. This is quite different from a state DOT context (as noted in Chapter 1), where the research and implementation are within a closed system, i.e., the state. Ignoring or side-stepping these evaluation challenges to research evaluation will produce limited and, perhaps, biased results.

EVALUATING NCHRP IS FEASIBLE

Based on research and practice in research evaluation across many fields, feasible approaches to research evaluation have been identified and described in this study. While RIA is not common in the transportation research arena, it is practiced or attempted regularly in the health and educational settings. Chapter 2 and Appendix A provide many examples of RIA being successfully carried out. When focused on a particular situation (i.e., a case), it is feasible to identify the benefits and costs of specific implementations of NCHRP projects, in multiple, natural dimensions, and to prepare descriptive and quantitative information on value produced.

Applied to a continuing sample of NCHRP projects over time, this can produce a comprehensive value profile.

EVALUATING NCHRP CALLS FOR PROCESS CHANGE AND RESOURCE COMMITMENT

There are lessons in this study for the development and conduct of NCHRP research that will facilitate future evaluation of the program and its projects, thus amplifying its value.

Modest but consequential changes in the NCHRP research process are needed to facilitate research evaluation, as described in Chapter 7. Changes are needed to enable NCHRP program managers and researchers to focus projects on creating impacts and values, to facilitate to search for implementations, and to be able to capture impacts effectively and efficiently. It will take resources – time and money – to evaluate NCHRP research. This is not a simple back of the envelope calculation of cost versus benefit. NCHRP impact assessment needs to become an integral part of the research management process to provide information of value, not an optional add-on. Once integrated into the research program, the incremental effort for RIA should decrease and the value produced should increase.

As described in Chapter 7:

- In developing research projects (RNSs, RFPs, proposals, and project reports), the outcomes, impacts, and potential user organizations should be explicitly identified to maintain a focus on implementation and production of value;

- A systematic process for tracking research implementation needs to be in place; and
- Evaluation should become routine and regular, rather than sporadic.

RECOMMENDATIONS

IMPORTANCE OF ASSESSING THE VALUE OF RESEARCH

NCHRP would benefit from routine, systematic evaluation of its impacts on transportation agencies, the transportation system, and its users. Such an evaluation will confirm and document the value of the program and its projects and will provide useful information for guiding the management of the program itself.

Based on the research team's experience with this study, and those in many other studies and fields, it is evident that evaluations are not particularly easy and not without cost. However, they are feasible and worthwhile, especially if there is a long-term commitment to evaluation, because research impacts do not occur quickly. For many of the projects in the NCHRP portfolio, benefits accrue over long periods of time and from the synergistic effects of multiple, related research projects.

Evaluation of research should focus on uptake of products and the impacts and values created. This is a different focus than performance of the research itself—for example, whether a project has been completed and whether it is on schedule and within budget. These are relevant for operational management of a research program while projects are in progress, but the ultimate value of research will be determined by how the research results bring benefits to agencies, the transportation system, and society. These are the most important questions and also the most challenging to answer.

IMPLEMENTATION IS THE PATH TO RESEARCH VALUE

NCHRP should start to systematically track and monitor implementations. The most important step in evaluating the impacts of research is identification of implementations—value is produced when results are implemented. Identifying implementation is not simple and currently tends to be done serendipitously. It will be important to use multiple channels for identifying implementations—outreach, tracking, and networking—and, in the long run, creating a culture among transportation agencies and other entities of reporting to NCHRP managers routinely when they implement NCHRP research. Implementation of research results is itself an indicator of the perceived or expected value of the research; implementation by multiple agencies is itself a strong confirmation of the value of the research.

SAMPLING PROJECTS FOR EVALUATION

An overall understanding of program value will come from strategic sampling of evaluation targets. For example, by sampling clusters of closely related projects, it will be possible to get closer to the totality of research impacts in a specific area, such as asphalt pavement durability or pedestrian crossing safety research. Alternatively, by sampling projects from across the domain of NCHRP, an image of the value of the overall program can be assembled.

ASSURING FEASIBILITY OF THE EVALUATION

NCHRP should be judicious and strategic in identifying projects for evaluation. Not every project lends itself to the evaluation process. Evaluability assessment is an essential tool to determine if it is feasible and cost-effective to evaluate an implementation. It is a screening process that addresses whether agency access and cooperation can be secured, whether the implementation is mature enough to have produced significant impacts, and whether major obstacles would make evaluation difficult or impossible. Evaluability assessment assures that resources for evaluation will be used effectively.

SEARCHING FOR IMPACTS

NCHRP should search actively for impacts. An active search is required to find measures and indicators of research impacts and value. This is not a random process. The objectives and task statements of the research project itself should guide the development of an impact roadmap, a logic model that defines the path and processes through which impacts occur. Impacts themselves can be both internal and external to implementing agencies. Research can help agencies perform better and, in some cases, can help the transportation system itself perform better. Ignoring either of these impact categories will exclude important values from the research impact assessment.

MAPPING THE IMPACT PROCESS

NCHRP should embrace the use of impact roadmaps (logic models) for all of its funded research projects. Impact roadmaps (logic models) are qualitative, graphical models or sketches that define and explain the process by which impacts are produced and value is created. As such, they serve as practical guides in the search for those impacts. These roadmaps should be initiated during or even prior to the research process and will usually evolve during the research as the vision of products and implementation sharpens. Such logic models not only facilitate evaluation by telling us where and how to look for research impact values, they can also help mold the research by identifying barriers to successful implementation, thus amplifying the value of the products.

IMPACTS IN NUMBERS AND WORDS

NCHRP should look broadly for research impacts, avoiding the desire to find a single metric to capture impacts and value of its research. The values produced by NCHRP research come in both qualitative and quantitative dimensions. Excluding qualitative research impacts—focusing solely on easy-to-measure, quantitative impacts (e.g., saving lives or costs)—risks excluding important policy and management benefits coming from some research, particularly answers to questions coming from agency leadership and their community constituencies. Systematic description and scoring of qualitative research impacts will bring them into the evaluation process.

BENEFITS AND COSTS OF RESEARCH

Benefit-Cost analysis (BCA) is useful as a framework for evaluating NCHRP research, but strict monetary evaluation will rarely be possible because it is unlikely to be feasible to monetize all the benefits. Still, conceptually comparing benefits and costs offers a good paradigm for evaluating research projects.

Importantly, a summative evaluation of NCHRP using a BCA framework is not feasible because it would require identifying all the implementations of the program and capturing their benefits. The nature of NCHRP and its constitutive projects is that impacts will be dispersed, will develop (and continue to develop) over an extended period of time, and, most importantly, will not all be identified and included in the evaluation. One can know all the costs of conducting and disseminating the research but not all the benefits.[3]

WHAT IS MISSING

When conducting an evaluation of a research project or program, it is important to be aware of what might be left out because of obstacles to identification, measurement, or monetization of impacts. Where such exclusions are known and significant, some effort should bring them into the narrative description of a project, even if only in the form of a discussion of what might have been left out.

[3] This is importantly different from evaluating an SDOT transportation research program, where all the costs and benefits are internal to the agency and its external constituencies. This facilitates a comparison of all the costs and all the benefits of SDOT research. Under these circumstances, almost all the strategies presented here are applicable to SDOT research programs.

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APPENDIX A: ANNOTATED BIBLIOGRAPHIES

TRANSPORTATION LITERATURE

1. Nukes, William, Louw du Plessis, Mahmoud Mahdavi, Nicholas Burmas, T. J. Holland, and John Harvey. *Tools and Case Studies for Evaluating Benefits of Pavement Research*. 2011.

Topic: Economic framework
Timing: Prospective
Overview: This paper builds upon the framework presented in *Case of Australian Accelerated Loading Facility Pavement Research Program*, which quantifies the economic benefits of pavement research products.
Key takeaways: Steps in applying the tool are summarized as follows:

- Scenarios, alternatives, and benefits with and without heavy vehicle simulator (HVS) testing are identified.
- Uncertainty in assumptions and outcomes is accommodated by assigning a probability to each alternative outcome and contribution ratio (provided by survey interviews).
- Cost (life-cycle agency and user costs) of each alternative outcome is calculated.
- Expected value (cost) of each alternative outcome is calculated by multiplying its probability by its cost.
- Total expected value for each scenario (with HVS test and without HVS test) is calculated as the sum of expected costs of alternatives.
- Benefits (in terms of net present value [NPV] of cost savings) of the information from HVS testing is determined by subtracting the total expected cost without the HVS test from the total expected cost with the HVS test.
- The benefit-cost ratio (BCR) is derived by dividing the benefit by the total costs of the HVS test.
- A key contribution of this paper is the utility of sensitivity analysis in determining a range of savings instead of calculating a single BCR value.

2. Cohen, L. R., and G. J. Fielding. *New Technology Research: Costs and Benefits.* Final Report, 1993.

Topic: Economic method
Timing: Prospective
Overview: The objective of this research is to develop a method that can be used by Caltrans to evaluate proposals. The NPV method of BCA is recommended.
Key takeaways: NPV is defined as the present-day value of the benefits minus the costs for each proposal. Only proposals with a positive NPV should be funded. Those with higher NPVs should be prioritized. This report suggest that BCA is often conducted incorrectly, with the most significant errors stemming from:

- Failure to establish a proper base case against which future benefits can be compared.
- Failure to discount benefits over time.

The report also acknowledges benefit estimation is challenging because:

- Benefits are seldom captured by the research sponsor because the effects of technological change spread throughout the economy.
- The market value of research may not be apparent for many years.

The report applies these methods (NPV) on various completed projects and proposed projects to demonstrate the utility of NPV. The report also provides:

- Information on the theory behind CBA and NPV.
- A discussion of the primary shortcomings of CBA, which is the difficulty to assess the benefit of projects that are not easily quantifiable, such as those in the environmental and health sectors.
- Several helpful forms and equations that can be used for evaluations.

3. Greer, Nikolai, and Khaled Ksaibati. "Development of Benefit Cost Analysis Tools for Evaluating Transportation Research Projects." ***Transportation Research Record: Journal of the Transportation Research Board,*** **2019.**

Topic: Economic method
Timing: Prospective
Overview: This article focuses on developing an evaluation tool to be applied to completed transportation projects.
Key takeaways: The method developed blends BCA and multi-objective analysis. The method involves the following steps:

1. Identification of all cost and benefit factors of significant importance.
2. Quantification of these factors resulting in dollar figures.
3. Quantification of these factors in their own terms.
4. Determination of appropriate discount rates.

While BCA is widely practiced, multi-objective analysis is not as well known. It goes beyond BCA by the inclusion of importance weighting and socioeconomic, political, and environmental factors, and adds sensitivity analysis capabilities. This article provides the reader with the following tools:

- Written procedure for conducting the project evaluations.
- Forms for conducting the analysis.
- Software to conduct the analysis, with a user manual.

The article is also useful because it summarizes the results of a 50-State survey conducted to gain information from SDOTs about their evaluation procedures. The survey found that only 31 percent of responding agencies conduct BCA.

4. Terfehr, Justin, and Khaled Ksaibati. ***Evaluating Department of Transportation's Research Programs: A Methodology and Case Study.*** **2012.**

Topic: Evaluation process: qualitative, economic
Timing: Retrospective and prospective
Overview: This report presents a methodology for conducting an evaluation of a research program within a transportation agency (the Wyoming Department of Transportation). The methodology provides 10 performance measures that are used to summarize the findings of the evaluation. These performance measures are quantifiable and can be used to help guide decisions regarding the direction of the research program. The developed methodology was implemented for the Wyoming Department of Transportation's research program.
Key takeaways: The evaluation process has two stages, and each stage has phases.
Phase 1 is to quantify the execution of the project, identify the potential applications of the results that the SDOT can use, and assesses the overall success of the project. The SDOT

employee who sponsored the project is primarily responsible for the completion of the phase 1 performance evaluation. It has two stages:

- Stage 1 identifies and qualifies all projects proposed and funded by the research program. This information includes project category (in-house research, contract research, and pooled fund) and strategic intent (safety, shared knowledge, etc.). Information used in stage 1 comes from both documents and expert interviews.
- Stage 2 addresses the cost-benefit of the individual projects and the overall program. Performance criteria include the following:
  - The number of projects completed within budget.
  - The number of projects completed on time.
  - The number of projects implemented.
  - The level of increased knowledge.
  - The technology transfer activities.
  - The quality of final research reports.
  - The BCR.
  - The cost savings.
  - The reduction in vehicle crashes or lives saved.
  - The reduction in system delays.
  - The contribution to the overall research department mission.
  - The management and policy improvements established because of the research.

Phase 2 quantifies the actual impacts the project's results had on the operations of the SDOT, impacts to outside agencies, and a BCA. The phase 2 performance evaluation should be completed two years after the project has been completed. Evaluating the project two years after the completion date allows enough time for any implementation within the SDOT as well as quantification of the benefits associated with the implementation. The SDOT employee who sponsored the project should complete this evaluation with the help of the research program. This performance evaluation is a longer process, compared to phase 1 because a BCA and more detailed explanation are included. Because research projects have varied outcomes, not all projects have results applying to construction, maintenance, safety, and user costs. Therefore, a BCA cannot be used on such projects. The paper includes several forms that have been designed for use in the evaluation. Most are Excel based and easy to follow. The methodology includes both qualitative and quantitative elements.

5. Little, D. N., J. Memmott, F. McFarland, Z. Goff, R. Smith, C. V. Wootan, D. Zollinger, et al. *Economic Benefits of SHRP Research*. 1997.

Topic: Economic analysis

Timing: Prospective

Overview: This report assesses the economic benefits of six areas of SHRP research: asphalt, long-term pavement performance, pavement maintenance, Portland cement concrete structures, snow and ice control, and work safety. Each of these research areas had their own individual report, many of which were assessed as part of this literature review, including *Summary of SHRP Research and Economic Benefits of Snow and Ice Control*, *Summary of SHRP Research and Economic Benefits of Pavement Maintenance*, and *Summary of SHRP Research and Economic Benefits of Work Zone Safety*.

Key takeaways: The general evaluation framework is a five-step process:

- Calculate the change in motorist benefits and agency costs for implementation of research project results at one or more locations. Benefits are usually of two types:
  - Estimates of reductions in user costs associated with use of a new SHRP product.
  - Estimates of reductions in agency costs associated with use of the new SHRP product.
- Estimate the net benefit per implementation unit (e.g., mile of highway, location, ton, or bridge).
- Estimate the potential maximum number of implementation units that can be implemented and the time period over which implementation is assumed or expected to take place.
- Select an expected/assumed implementation rate and an implementation period over which the research results are expected or assumed to be implemented.
- Determine the research cost and non-specific-project implementation cost of the research effort (SHRP project/product). Non-project-specific costs are assumed to include, for example, general implementation costs at the Federal, State, and local levels of government, such as costs for implementation section personnel and costs of special training and equipment that support overall implementation of the specific SHRP product being analyzed.
- Calculate the BCR for the SHRP project or product by dividing the total benefits by the sum of research and implementation costs.

The report suggests analysis periods ranging from 20–40 years for major highway projects, and 10–25 years for minor improvement projects. The report also suggests a 3–5 percent discount rate. The report provides the user with many equations and speaks to the utility of the MicroBENCOST software program in calculating the present worth of benefits.

6. Robinson, M., L. Velardi, and C. Ulianov. "Market Impact Evaluation—The Way to Judge the Success of Completed Rail Research." ***Procedia-Social and Behavioral Sciences,*** **Vol. 48, 2012, pp. 663–671.**

Topic: Economic analysis
Timing: Retrospective
Overview: This article reviews rail research funded by the European Commission. The evaluation of projects was primarily based on the degree of implementation. Based on the results from completed projects, the European Rail Research Advisory Council has developed guidelines that can be used in the proposal stage or during the research product to increase the likelihood of implementation on completion.
Key takeaways: The focus was on "market uptake," that is, implementable research results that are adopted or commercialized by industry. The feedback from observed impacts into guidelines for ongoing and future research is noteworthy. The guidelines emphasize having a sound business case, industry partners involved in funding/supporting research projects, and clarifying ownership of research results early in the project.

7. Vasudevan, M., K. Thompson, A. Jacobi, M. Mercer, M. Brooks, S. Lawrence, D. Vickery, K. Sakai, R. Watanabe, H. Kanoshima, S. Mawatari, T. Tsukiji, E. Machek, and D. Thompson. ***Comparison of Evaluation Tools and Methods Used in the United States (U.S.) and Japan.*** **No. FHWA-JPO-16-326. Federal Highway Administration, 2016.**

Topic: Evaluation tools and methods
Timing: Retrospective

Overview: This report compares evaluation tools and methods used in the United States and Japan for cooperative systems. U.S. evaluations are generally done by independent evaluators, either by pilot demonstrations and small-scale field tests or by analysis, modeling, and simulation. Japan evaluations are generally done as field operational tests. There is a lack of long-range evaluations, controls for driver behavior, and rigorous experimental designs to isolate impacts from exogenous and confounding factors.
Key takeaways: There is a need for more rigorous and long-term field evaluations of cooperative systems.

8. Morell, Jonathan. *Evaluation of the Federal Railroad Administration's Autonomous Track Geometry Measurement System Research and Development Program.* No. DOT/FRA/ORD-16/XX. Federal Railroad Administration, Office of Research, Development, and Technology, 2016.
Topic: Economic analysis
Timing: Prospective
Overview: This report evaluates the results of Federal Railroad Administration (FRA) research on the autonomous track geometry measurement system by conducting interviews with key stakeholders. The report discusses potential short-term value (to do more track inspections with fewer resources) and long-term value (to improve track maintenance in general). The report discusses barriers to implementation, such as ambiguity in FRA rules and issues with data quality and equipment maintenance.
Key takeaways: The findings are very topic specific, but the overall process (interviews, value, and challenges) was done well and could be applied to other topics.

9. Solman, Gina Barberio, Jessica Baas, and Heather Hannon. *Federal Highway Administration Research and Technology Evaluation Final Report: Eco-Logical.* No. FHWA-HRT-17-036. Federal Highway Administration, Office of Corporate Research, Technology, and Innovation, 2018.
Topic: Mixed mode, qualitative
Timing: Retrospective
Overview: This report evaluates the results of FHWA's Eco-Logical funding program using a logic model with inputs, activities, outputs, outcomes, and impacts. The three outcomes considered were collaborative partnerships among agencies, integrated planning, and rectifying/reducing/compensating environmental impact. Performance measures included funding, effects on conservation program objectives, and improved environmental mitigation.
Key takeaways: Good baseline data and a long-time horizon are important for evaluating institutional changes.

10. Rose, Geoffrey, and David Bennett. "Benefits from Research Investment: Case of Australian Accelerated Loading Facility Pavement Research Program." *Transportation Research Record: Journal of the Transportation Research Board,* No. 1455, 1994, p. 82–90.
Topic: Economic analysis
Timing: Retrospective and prospective
Overview: This document presents results from an economic evaluation of the Accelerated Loading Facility (ALF) pavement research program. Benefits are quantified in terms of the reductions in road authority costs. Several significant but unquantifiable benefits were also identified, including:

- The importance of specific research projects to act as a catalyst for spurring future research in the same discipline (innovation).
- Improving cooperation between researchers and practitioners.
- Enhancing the reputation of a research organization's technical reputation.

Key takeaways: The evaluation framework includes three steps:

- Identify the range of costs associated with the ALF program:
  - Cost (multiplied by the probability of adopting alternatives).
  - Construction of test pavement site.
  - Staff cost associated with monitoring the test.
  - Data collection and analysis cost.
- Identify the benefit: reduction in road authority costs, calculated by taking the difference in cost with and without the ALF trial.
- Value the benefits and costs in dollar terms: Determine the values of appropriate benefit-cost criteria.

The article presents a traditional CBA that has been enhanced by incorporating a probability element. The incorporation of this element improves traditional BCA, which traditionally assigns various scenarios equal probability of occurrence. The cost information was obtained from project documentation and SDOT staff (in-house knowledge). Probabilities were vetted with SDOT staff. The resulting BCRs were reasonable and allowed an easy mechanism to compare the benefits of various scenarios, which is an asset of BCA.

11. Epps, Jon A., and Maria Ardila-Coulson. *Summary of SHRP Research and Economic Benefits of Snow and Ice Control.* No. FHWA-SA-98-015. 1997.

Topic: Economic analysis

Timing: Retrospective and prospective

Overview: This document summarizes the results of benefits-versus-costs study of the snow and ice control techniques developed through SHRP. The analysis showed a significant cost savings realize by the implementation of these techniques.

Key takeaways: This report summarizes the use of BCA for demonstrating the benefits of snow and ice control. Highway agency costs included labor, vehicle operations, and materials, with information collected from SDOT documentation. Benefits were estimated as a reduction in motor vehicle accidents, with costs for accident reduction coming from SDOT documentation. An important contribution of this research is bringing to light the potential for the speed of research implementation to increase over time. The research also highlights the importance of incorporating a discount rate into the process of benefit evaluation. A reasonable discount rate is 3–5 percent.

This document does a good job of presenting the value of research in a manner that is easily comprehensible by laypersons who may not be familiar with BCA. For example, for every $1 spent on research, a future savings of $X is realized by the traveling public. Communicating results in this manner is effective at obtaining higher levels of public support for research funding.

12. Texas Department of Transportation. *The Value of Texas Transportation Research*. 2003.

Topic: Economic analysis

Timing: Retrospective and prospective

Overview: This document demonstrates the impact that research has on transportation system safety and cost-effectiveness. Twenty-one improved technologies and methods produced by TxDOT's research program were selected from a three-year period, 1999–2001. A benefit period of 10 years was used for determining the returns from the selected research program products.
Key takeaways: The focus of the benefit analysis was on reductions in the number of fatalities occurring on the transportation system, reductions in the number of accidents, and operational cost savings for the department (reductions in taxpayer cost to provide and maintain the transportation system). The total cost savings was compared to the three-year research department budget to estimate a positive BCR, which showed net benefit from the program. This methodology proved successful in helping to demonstrate the contributions of a research program.
Another key takeaway of this report is the acknowledgement that research and research programs generate benefits that go beyond those that can be easily quantified by econometric methods like BCA. For example, TxDOT relies heavily on the cooperative university research program to develop innovative technologies and improved methods. This program benefits both TxDOT and the public universities in Texas. While TxDOT and the State's transportation system receive improved technologies and solutions to transportation challenges, university faculty members gain valuable experience applying theory to real-world situations. The research projects also provide opportunities for graduate students to expand knowledge and interest in the transportation field. This report makes a strong case for supplementing BCA with other methods (multi-objective analysis and/or qualitative analysis) to generate a more comprehensive array of benefits.

13. Stokes, R. W., M. W. Babcock, E. R. Russell, and M. J. Rys. *Guidelines for Estimating the Triennial Benefits of Kansas Transportation Research and New Developments (k-Tran) Research Projects.* 2004.
Topic: Economic analysis, multi-objective analysis
Timing: Prospective
Overview: This document provides guidelines for implementing a hybrid approach to research project assessment that incorporates elements from traditional BCA and multi-objective analysis techniques. This document does a good job at demonstrating how supplementing BCA with other methods (MOA, in this case) to more effectively assess benefit.
Key takeaways: This is one of the most prescriptive methodologies reviewed in the transportation discipline. The report includes very detailed guidelines, forms, scales, and personnel requirements for implementing this methodology. The process requires the researcher to perform an initial subjective assessment of project benefits using a checklist of potential benefit categories. The researcher is then guided through a process whereby he/she is asked to attempt to quantify (i.e., assign a monetary value to) the benefits identified in the initial subjective assessment. The process provides the researcher with guidelines for developing a range of estimates of economic benefits of research projects. If the process leads to the development of a monetary estimate of benefits, then a traditional BCA of the project can be performed. If it is determined that the project benefits cannot be expressed in purely economic terms, then the results of the subjective multi-objective assessment are assumed to represent the best assessment possible at that point in time. The guidelines for the multi-objective assessment technique include recommendations for rating project impacts and for identifying successful projects based on a project's overall rating.

The document also provides suggestions on what could be done if a case study cannot be identified to help demonstrate the benefits. In these cases, research staff are encouraged to take a what-if approach in attempting to estimate the potential economic impacts of research projects. This approach could involve assessing the economic impacts of a range of what-if scenarios concerning implementation of research findings (if X lives are saved by this project, then the estimated savings are $Y). If the PI and the project monitor can arrive at a reasonable estimate of the economic benefits of the research project, the benefits should be reported in terms of a triennial (three-year) value.

14. Anderson, Douglas I. *Measuring the Benefits of Transportation Research in Utah*. 2010.
Topic: Economic analysis
Timing: Retrospective
Overview: This study was initiated to estimate the benefits of the Utah Department of Transportation's research projects over a three-year period, estimate a BCR for the program, and provide feedback on the management processes used by the research staff.
Key takeaways: The overall methodology has eight steps:

1. Form a technical advisory committee for the study made up of research managers and others who are likely to use the findings.
2. Determine the project time frame for evaluation and the annual work programs that would be meaningful.
3. Compile a list of projects from the selected programs.
4. List each project title, key champion, project manager, project cost, and all deliverables received.
5. Meet with the key champion and others familiar with the research products, and outline a plan to obtain a good estimation of the study benefits and total costs.
6. Convert project benefits into a dollar value where possible.
7. Assign a grade to each project based on input from the champion.
8. Compile all data and calculate a BCR. This will be done for individual projects, the total three-year time period, and each project type.

This report highlights the importance of interviewing project champions to gather a deeper understanding of what is found in project documentation and help to identify project benefits that might not be easily quantified by BCA.
The financial benefits captured on the project form typically were entered and compiled as one of the following:

- Savings to Utah Department of Transportation operations (reduced manpower, improved assets, lower bids, etc.).
- Benefits to the public (reduced congestion, improved safety, enhanced environment, etc.).
- Zero financial benefits (no savings from the deliverables).
- Benefits are not known at this time; implementation continues; or future benefits may be achieved and are to be determined.

15. Gross, Frank, Thanh Le, VHB, New England Transportation Consortium, and Federal Highway Administration. *Quick Response: Quantification of Research Benefits*. 2019.
Topic: Economic analysis
Timing: Prospective

Overview: This project adapted the Minnesota Department of Transportation's Excel-based benefit estimation tool to develop an updated and enhanced tool for the New England Transportation Consortium (NETC) and its member States. The updated tool was applied to two NETC projects selected by the technical advisory committee for the purpose of both demonstration and refinement of the tool. Organizations soliciting research would be well served to include in their RFPs a requirement or at least preference for a list of applicable benefits of proposed research. This will help in quantifying the research benefits and evaluation of research programs. This requirement (or preference) would not have any significant impact on the overall cost of the research project.
Key takeaways: This research article presents a five-step evaluation process that can be implemented for BCA:

1. Select a benefit category, of which there are nine:
    - Engineering and administration cost.
    - Construction/installation cost.
    - Operation and maintenance cost.
    - Road user cost.
    - Environment cost.
    - Life-cycle cost.
    - Safety cost.
    - Risk management cost.
    - Other.
2. Collect data. All calculations require two types of data:
    - Hard costs (labor hours, materials, etc.) before and after research implementation.
    - The anticipated level of deployment or frequency of activity.
3. Input data.
4. Calculate benefit and BCR.
5. Evaluate results.

The document provides details on the specific costs that should be captured for each of the nine benefit categories and where they might be found. The document also provides case study examples for the user to reference as a guide.

16. Martin, Tim, and Lith Choummanivong. "The Benefits of Long-Term Pavement Performance (LTPP) Research to Funders." ***Transportation Research Procedia,*** **Vol. 14, 2016, pp. 2477–2486.**
Topic: Economic analysis
Timing: Retrospective
Overview: The article covers long-term pavement performance research in Australia over a time period of 20 years. Benefit measures included road agency cost, benefit to consultants and contractors, and value as a data source for other research areas (e.g., climate change).
Key takeaways: Many of these studies consider only direct benefits (i.e., to the implementing agency and users). This article also looks at broader impacts such as usefulness to industry and other research disciplines.

17. Biernbaum, Lee, Alison Bisch, Gregory Bucci, Christopher Calley, Lora Chajka-Cadin, Sharon Chan Edmiston, Gina Filosa, et al. ***FHWA Research and Technology Evaluation Program Summary Report Fiscal Year 2016.*** **No. FHWA-HRT-17-038. Federal Highway Administration, Office of Corporate Research, Technology, and Innovation Management, 2018.**
Topic: Bibliometrics
Timing: Retrospective
Overview: This report recommends metrics for evaluating research use including requests for information, citation in follow-up studies, and adoption of methods after formal training. The report also contains several case studies of completed projects. The methodology consists of review of documents and interviews with relevant stakeholders (depends on the project but potentially including researchers, industry, State and local government, and FHWA staff).
Key takeaways: Requests for information are an interesting metric but are likely much less common than accessing the report online.

18. Stufflebeam, Daniel L. ***Manual for Research, Development and Technology Program and Project Evaluations.*** **No. DOT/FRA/ORD-16/06. Federal Railroad Administration, Office of Research, Development, and Technology, 2016.**
Topic: Qualitative method
Timing: Prospective, retrospective
Overview: This document evaluates FRA research projects based on context, input, implementation, and impact. The impact portion considers reach to the targeted communities or beneficiaries, effectiveness, sustainability, and transferability. The evaluation consists of a set of qualitative questions for each group, subdivided within each evaluation area into formative (proactive evaluation) and summative (retroactive evaluation).
Key takeaways: These metrics are more tied to goals and plans established early in the proposal or kickoff stage.

19. Shackleton, Mike, and William Young. "Toward Performance Measures for Road Infrastructure Research Programs: Australian Experience." ***Transportation Research Record: Journal of the Transportation Research Board,*** **No. 2199, 2010, pp. 48–53.**
Topic: Evaluation framework performance measures
Timing: N/A
Overview: The article provides good guidance for developing evaluation framework performance measures. The article identifies the types of benefits that research users and funders see as important. This is critical in designing a process for evaluating the overall benefits of research. The means of evaluating each type of benefit are not discussed. The study was done to establish a means for measuring research performance with consideration for the set of relationships between funders, users, and researchers in Australia.
Key takeaways: The sustainability of public-good research and the institutions conducting it relies on the selling of a value proposition to those who fund research. This value proposition is largely not understood. Although single organizations both fund and use research, the views of the potential value of research are different at different organizational levels. Researchers must consider what benefits would most effectively speak to the public and in-house decision makers. Key to this effort is understanding all benefits across a wide array of internal stakeholders. In assessing research benefits, in-house decision makers will want to measure how the research has done the following:

- Enhanced their agency's ability to deliver programs of work and network efficiency more effectively with fewer resources.
- Enhanced their agency's ability to deliver on nontechnical outcomes required of them by policy makers.
- Allowed specific technical tasks to be achieved that were not achievable before.
- Helped develop expertise among researchers.

To frontline managers, success factors will focus on whether the research has achieved the following:

- Allowed specific technical tasks to be achieved that were not achievable before.
- Provided adequate information for supporting or guiding defensible policy (in the case of road safety research).
- Allowed the achievement of more of their task or reduced the cost of achieving their task.
- Enhanced their agency's ability to deliver on nontechnical outcomes required of them.

20. Du Plessis, L., and J. J. Krager. "Methods, Measures and Indicators for Evaluating Benefits of Transportation Research." ***International Journal of Pavement Engineering*****, Vol. 19, No. 2, February 2018, pp. 181–190.**

Topic: Methods

Timing: N/A

Overview: This article aims to help develop an appropriate method to determine quantitative benefits stemming from specifically accelerated pavement testing (APT)–type transportation research. In doing so, this article discusses methods, measures, and indicators for evaluating the benefits of transportation programs. The article also points out the sources driving the need for evaluating benefits and describes the challenges confronting the evaluation process. The article reviews and compares qualitative and quantitative techniques.

Key takeaways: This article does not present a specific framework. This article does a good job of identifying challenges associated with evaluating benefits of transportation research. Some of these challenges are:

- Managing the broad range of expectations by those who focus only on results analysis (ignoring evaluation processes) for such purposes as budget or program justification, planning, or decision making can lead to undue focus on econometric evaluation frameworks. Economic benefit is not the only area that should be assessed but is the most popular.
- The lack of familiarity with the evaluation process often can lead to a situation where it is a difficult concept to grasp for many.
- It is tempting to want to select projects that performed well when evaluations are conducted. Avoiding this bias in the selection of projects to be used in evaluating programs is key to an honest representation of a research program's performance.
- Data collection and summary techniques need to be well documented and clearly presented.

The article makes a strong case for evaluation methods that combine qualitative and quantitative information by pointing out that in addition to using more than one technique, some investigators have recommended using many sources of information as well as several separate investigators to evaluate benefits in a technique referred to as triangulation. The article also suggests that BCA is the ideal method to measure the impacts and benefits of APT-related research, and positive BCRs are powerful convincing tools to justify expensive research programs (e.g., APT), while bibliometrics, the number of PhDs, peer-reviewed articles, patents, etc. highlight the importance of APT in academia and political circles.

21. Bulman, E., L. Giorgi, and T. Sansom. "Assessing the Potential Impacts of Transport Research." ***Proceedings of Seminar A of the European Transport Conference 2000,*** **Homerton College, Cambridge, UK, September 11–13, 2000, Planning for Transport in Europe, Vol. P435, 2000.**
Topic: Methods
Timing: Prospective
Overview: This paper assesses the impacts of the European Union's 4th Framework Programme. Impacts were categorized into material and research capability impacts. Then a concept-of-research impact pathway was developed to measure impacts soon after the end of the project. Key steps on the pathway are production of outputs, dissemination of outputs, exploitation of outputs, and end impacts on society. Four types of output were identified: standards/criteria, guidelines/handbooks/best practice models, tools/models/methods, and assessment exercise.
Key takeaways: Realized impacts will not be known for several years after the project, but in the interim, agencies can look at the process.

22. Sabol, Scott A. ***Performance Measures for Research, Development, and Technology Programs.*** **Project 20-5 FY 1999. NCHRP Synthesis, 2001.**
Topic: BCA and peer assessment
Timing: Retrospective
Overview: This document reports that benefit-cost and anecdotal evidence of success are the most common value metrics. The document identifies peer assessment as an effective means of evaluating intangible and intractable benefits of research.
Key takeaways: Benefit-cost assessment for economic benefits and peer assessment for intangible benefits are identified as best practices.

23. Hecker, JayEtta Z. ***Highway Research: Systematic Selection and Evaluation Processes Needed for Research Program.*** **No. GAO-02-573. General Accounting Office, 2002.**
Topic: Case studies
Timing: Retrospective
Overview: This document is an assessment of FHWA research by the General Accounting Office. The author found that FHWA primarily uses a success story approach to evaluate research outcomes, where the most successful projects are widely touted and used to justify expenditures on the entire research program.
Key takeaways: The document identifies a need to rely more on systematic evaluation processes and less on anecdotes.

24. Concas, Sisinnio, Stephen L. Reich, and Ashley T. Yelds. ***Valuing the Benefits of Transportation Research: A Matrix Approach.*** **Final Report, 2002.**
Topic: Economic analysis, qualitative assessment
Timing: Prospective, retrospective
Overview: This report notes that most transportation research programs rely on anecdotes of success, and economic metrics may not be appropriate. There is no universal approach. Economic value works for some projects, but qualitative assessments are more general.
Key takeaways: NPV and discounted cash flow favor short-term, low-risk research and neglect basic research. The report recommends a matrix approach for funding agencies, that is, selecting a mix of projects with varying risk levels and benefit types.

25. Kolbenstvedt, Marika, Rune Elvik, Beate Elvebakk, Arild Hervik, and Lasse Braein. ***Effects of Swedish Traffic Safety Research 1971-2004: Main Report.*** **VINNOVA, 2007.**
Topic: Value of research
Timing: Retrospective
Overview: This study reviewed Swedish transportation research over a long time period. The method focused on effect chains, where research funding builds institutions, which produce knowledge and expertise. This knowledge and expertise lead to both academic results and the dissemination of research, which lead to effects for consumers (e.g., traffic safety and added value).
Key takeaways: This is the first study so far to discuss the value of research funding in developing institutions, not just research products (whether economic or bibliometric).

26. Roorda, M., and A. Alkema. ***Evaluation of the Value of NZTA Research Programme Reports to End Users.*** **2011.**
Topic: Quantifying end user opinion
Timing: Retrospective
Overview: This report presents the findings of an evaluation of the New Zealand Transport Agency (NZTA) research program. The key evaluation objective was to assess how valuable the findings of NZTA research reports, published from 2005 to 2009, have been for end users (individuals, organizations, and industries in the land transport sector) in New Zealand. Two secondary objectives were to:

- Identify the barriers and enablers that made the difference between successful and less successful uptake and use of findings from the research reports.
- Ascertain the extent to which current NZTA mechanisms for disseminating and promoting research findings represented the best possible use of available resources.

Key takeaways: Performance measures were developed and applied to online survey data to provide an overall assessment of respondents' use of NZTA research, the relevance of the research findings, and the ratings of NZTA's mechanisms for disseminating the research findings. This document provides an evaluative framework that is unlike others reviewed in that it is not econometric. It is based on quantifying end user opinion. The report also suggests that active promotion and implementation of findings should be a collective responsibility. Research that is unknown cannot be valued. Furthermore, research is often deemed more valuable if it is credible and innovative, and where the focus was on practical issues.

27. Palacin, Roberto, David Golightly, Vijay Ramdas, and Nastaran Dadashi. "Evaluating the Impact of Rail Research: Principles to Maximise Innovation Uptake." ***Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit,*** **Vol. 230, No. 7, September 2016, pp. 1673–1686.**
Topic: Qualitative interviews
Timing: N/A
Overview: This paper presents an analysis of railway research carried out in the United Kingdom, coupled with interview data from rail researchers. The aim of this work is to better understand the impact of research in order to identify key factors that influence successful implementation of outcomes, or present barriers to the development and adoption of rail innovation. Interviews conducted with rail research professionals suggest that research impact

should be perceived not only purely in terms of technical innovation, but also in terms of knowledge and skills developed through the process of research.
Key takeaways: A key component of the research was to categorize research projects and the scale and type of benefits. Projects were analyzed in terms of:

- Benefits (strong, medium, or weak).
- Benefits realization time period (short, medium, or long term).
- Impact area (commercial, operational, safety, environmental, social, policy, standard, and scientific).

28. Federal Highway Administration. *Assessing the Results of the Strategic Highway Research Program.* 1998.
Topic: Case studies
Timing: Retrospective and prospective
Overview: Researchers conducted 100 phone and mail surveys about use of SHRP products by highway agencies. Researchers estimated costs and benefits over a 20-year period using three different timelines for pace of implementation. The report includes savings to highway agencies (staff and materials) and motorists (safety, delay, and vehicle operation). The report predicts $126 million/year in potential savings.
Key takeaways: The project measured life-cycle cost to owners and users. Benefits depend on implementation of research results, which can be hard to estimate when a project is ongoing or recently completed.

NON-TRANSPORTATION LITERATURE

29. Smith, Joel B. E., Keith Channon, Vasiliki Kiparoglou, John F. Forbes, and Alastair M. Gray. "A Macroeconomic Assessment of the Impact of Medical Research Expenditure: A Case Study of NIHR Biomedical Research Centres." *Plos One,* Vol. 14, No. 4, April 10, 2019, pp. 1–10.
Topic: Economic analysis
Timing: Retrospective
Overview: The purpose of this this article is to assess the impact of early phase biomedical research conducted by the Oxford Biomedical Research Centre. The input output model assesses impact as a function of income and job investment.
Key takeaways: The paper found that for every 1 pound invested in the Oxford Biomedical Research Centre, it generates an additional 46 cents through income and job creation. The study also found that an investment of 98 million pounds resulted in 196 additional jobs created.
The input output model is beneficial because it does not double-count research activity and impact, which is something that other models tend to do. Since the input output model relies on economic input data, the absence of such data results in the need of costly data collection. Another potential weakness of the model is that it assumes current economic activity will take place in the future. This may not be the case.

30. Agarwal, Ashok, Damayanthi Durairajanayagam, Sindhuja Tatagari, Sandro C. Esteves, Avi Harlev, Ralf Henkel, Shubhadeep Roychoudhury, et al. "Bibliometrics: Tracking Research Impact by Selecting the Appropriate Metrics." *Asian Journal of Andrology,* Vol. 18, No. 2, March 20, 2016, pp. 296–309.
Topic: Bibliometrics

Timing: Retrospective
Overview: This article presents an overview of the various bibliometric factors, as well as an overview of the limitations of bibliometrics.
Key takeaways: The following metric were listed:

- Number of publications.
- Citation count.
- Percentiles.
- Normalized citation counts.
- Number of downloads.
- H-index.

According to Patel et al., the h-index is the most reliable bibliometrics among health care researchers in the medical science field when compared among Scopus, Web of Science, and Google Scholar.

- Journal impact factor.
- Audience factor.
- Eigenfactor metrics.
- Eigenfactor score.
- Article influence score.
- SCImago journal rank.
- Impact per publication.
- Source normalized impact per paper.
- Order of authors.
- Altmetrics.

This article identifies cautions in applying bibliometrics:

- Comparisons should be made among researchers in a similar field and at a similar stage in their career because publications and citations can vary widely between disciplines and with increasing experience. Similarly, it is important to compare research institutions of the same size.
- It is difficult to manage the issues of ghost and honorary authorship.
- Bibliometrics focuses on journal articles with less emphasis on publications in books where some excellent contributions have been made.
- New journals fare better than older journals.
- Articles that are published in English journals do better than those published in a language other than English.
- The focus is on quantity not quality.

Additionally, the article has some good tables that identify the strengths and weaknesses of the h-index and various research databases used in bibliometric assessment.

31. Dinsmore, Adam, Liz Allen, and Kevin Dolby. "Alternative Perspectives on Impact: The Potential of ALMs and Altmetrics to Inform Funders about Research Impact." ***PLoS Biology*****, Vol. 12, No. 11, November 2014, pp. 1–4.**
Topic: Altmetrics
Timing: Retrospective
Overview: This editorial-style article presents the positive and negative aspects of the use of altmetrics to assess the social impact of research. f

Key takeaways: The migration of academic literature from paper journals to web has given rise to altmetrics, which have been defined as "web-based metrics for the impact of scholarly material, with an emphasis on social media outlets as sources of data. These metrics aggregate citations, views, downloads, discussions, and recommendations of research outputs across the scholarly web as well as citations in nonacademic communications such as policy documents, patent applications, and clinical guidelines."
Positive aspects are:

- Offer research funders greater intelligence regarding the use and reuse of research, both inside and outside of academia.
- Provide evidence of the reach, uptake, and diffusion of research, which is valuable to funders looking to explore alternative routes to impact.
- Detects impact trends long before such trends might be noticeable with bibliometrics.

Negative aspects are little consistency among scores provided by altmetric software providers. For example, some may report total downloads, while others might report daily downloads. The article suggests that collaboration between research funders and altmetric software providers may be useful to ensure that the software has functionality to assess impact in a way that is meaningful for the research community.

32. Cho, Jane. "A Comparative Study of the Impact of Korean Research Articles in Four Academic Fields Using Altmetrics." ***Performance Measurement and Metrics*****, Vol. 18, No. 1, January 2017, pp. 38–51.**
Topic: Bibliometrics, altmetrics
Timing: Retrospective
Overview: The purpose of this paper is to measure and compare the impact of Korean study results in four fields that were published in international journals using altmetrics, a unique method for assessing the social impact of research.
Key takeaways: This article points out that bibliometrics has long been used to demonstrate the impact of research articles. Because non-English articles are not cited as often as English articles, the paper attempts to use altmetrics as a way of assessing the impact of Korean language research (non-English). The article also attempts to analyze the correlation between bibliometrics and altmetrics. Altmetrics is define as a "portmanteau of alternative and metrics, meaning a metrics to measure the extent to which academic papers or research data react to new media such as social media." The process essentially quantifies the frequency research is mentioned or discussed on various social media channels, with each one weighted by importance.
The article suggests that altmetrics may provide a mechanism to more quickly assess the impact of research on society because traditional bibliometrics uses downloads or citations, whereas altmetrics only relies on social media mentions. Some researchers interviewed stated that they were more likely to publish in journals that provided altmetrics.

33. Li, Zongmin, Merrill Liechty, Jiuping Xu, and Benjamin Lev. "A Fuzzy Multi-criteria Group Decision Making Method for Individual Research Output Evaluation with Maximum Consensus." ***Knowledge-Based Systems*****, Vol. 56, January 15, 2014, pp. 253–263.**
Topic: Bibliometrics
Timing: Retrospective
Overview: Individual research output (IRO) evaluation is used to assess the value of a researcher's contribution (impact). One common use is to assess the worth of a professor considered for hire. Current research relies on only bibliometrics or peer review in IRO

evaluation. This article develops new a method of combining bibliometric measures and peer review to evaluate IRO.
Key takeaways: This is an extremely technical article that develops an IRO algorithm that combines traditional single-factor bibliometric (quantitative and objective) and peer review (qualitative and subjective) methods. The article makes a strong case for the utility of combining methods to assess the impacts of individual researchers. The four components (performance measures) of the assessment are volume and impact (quantitative and objective) and quality and utility (qualitative and subjective). The article argues that this method provides an elegant way to bridge the gap between the two traditional methods and represents a process that achieves maximum agreement.

34. Wimmer, Erin N., Melissa L. Rethlefsen, Christy Jarvis, and Jean P. Shipman. "Understanding Research Impact: A Review of Existing and Emerging Tools for Nursing." ***Journal of Professional Nursing,*** **Vol. 32, No. 6, 2016, pp. 401–411.**
Topic: Bibliometrics, altmetrics
Timing: Retrospective
Overview: This article highlights both traditional and more novel tools, the impact metrics they calculate, and why the tools are particularly relevant to the field of nursing.
Key takeaways: This article highlights the scope, metrics calculated, benefits and limitations, and relevance to nursing of various traditional and innovative impact measurement tools including science citation index, Thomson Reuter's Web of Science, Scopus, Google Scholar, and altmetrics. Impact metrics are useful measures of the impact of a researcher's publications and other research dissemination. These measures should be approached with a degree of caution, though, and the benefits and limitations each tool provides should be understood. To gain the most complete and accurate picture of a researcher's impact, several tools should be consulted and the calculations from each included in a total assessment of value.

35. Bornmann, Lutz, and Werner Marx. "The Journal Impact Factor and Alternative Metrics." ***EMBO Reports*****, Vol. 17, No. 8, 2016, pp. 1094–1097.**
Topic: Bibliometrics, altmetrics
Timing: Retrospective
Overview: This article describes issues and growing concerns with journal impact factors. The article describes misuse of the journal impact factor in evaluating research because it does not necessarily reflect individual articles.
Key takeaways: This article describes some of the methodology used to create impact factors and describes some other methodologies to replace or supplement impact factors. The h-index for journals was introduced as a robust alternative indicator advantageously supplementing journal impact factors and is calculated in the same way as the h-index for individual scientists. A research group affiliated with the National Institutes of Health developed the relative citation ratio as an alternative to journal impact factors for measuring the impact of single publications. The relative citation ratio is rooted in the long-standing bibliometric tradition of using field-normalized indicators to measure citation impact instead of bare citation counts. Bibliometric indicators are generally very helpful for studying the performance of individual researchers, research groups, institutions, and countries. The data are available in large databases, and field-normalized indicators facilitate cross-field comparisons. However, bibliometric numbers are only a proxy of research quality that measure one part of quality, namely impact or resonance. Two other important parts cannot be measured by citations, namely the accuracy and importance of

research. This might be the reason why correlation studies between bibliometrics and expert opinions do not show a perfect relationship.

36. Knight, Simon R. "Social Media and Online Attention as an Early Measure of the Impact of Research in Solid Organ Transplantation." *Transplantation*, Vol. 98, No. 5, 2014, pp. 490–496.
Topic: Bibliometrics, altmetrics
Timing: Retrospective
Overview: This article analyzes associations between citation rates and statistics regarding mentions in social media, social bookmarking sites, new outlets, and expert recommendation sites.
Key takeaways: Significantly higher citation rates were associated with mention in social media, expert recommendation, social bookmarking, and for articles identified as meta-analyses, multicenter studies, randomized controlled trials, and reviews. The odds of an article being highly cited were significantly increased by a mention in social media. Qualitative analysis suggests that article topics discussed on social media are more likely to relate to the more controversial and emotive areas of transplantation. Social media and online attention act as early predictors of the impact of transplant research as measured later by citation rate.

37. Kwok, Roberta. "Research Impact: Altmetrics Make Their Mark." *Nature,* Vol. 500, No. 7463, 2013, pp. 491–493.
Topic: Altmetrics
Timing: Retrospective
Overview: This article describes how altmetrics are being used more frequently and becoming more accepted among scientific professionals.
Key takeaways: Altmetrics are available from journals that track downloads and views and from third parties. The authors caution that researchers and evaluators must interpret altmetrics data cautiously. Data sets may not be comprehensive, and the popularity of social media sites changes over time. Some services normalize data by publication year and include percentiles. Including altmetrics in decisions on grants, hiring, and tenure requires careful consideration.

38. Bornmann, Lutz. "Measuring Impact in Research Evaluations: A Thorough Discussion of Methods for, Effects of, and Problems with Impact Measurements." *Higher Education*, Vol. 73, No. 5, 2017, pp. 775–787.
Topic: Bibliometrics, altmetrics
Timing: Retrospective
Overview: The article discusses how impact is generally measured within science and beyond, which effects impact measurements have on the science system, and which problems are associated with impact measurement.
Key takeaways: This article examines the measurement of impact and investigates the reasons why the impact of science is measured in a certain way. In-depth scientometric research is required to define and assess metrics-based evaluation systems. This research should not only look at the development of reliable and valid indicators but also at the effects and problems produced by these systems. The authors detail problems with impact measurement related to inequality, errors, extreme events, anomalies, evaluated units, continuity, and randomness and unpredictability. A key question raised by the research is how far impact measurement systems

really result in science performing better. It can be challenging to separate the effects of performance from other measures (e.g., availability of funding for research).

39. Chavda, Janica, and Anika Patel. "Measuring Research Impact: Bibliometrics, Social Media, Altmetrics, and the BJGP." *British Journal of General Practice*, Vol. 66, No. 642, 2016, pp. e59–e61.
Topic: Bibliometrics, altmetrics
Timing: Retrospective
Overview: Using impact factors as a single measure of quality is outdated. There is a need to eliminate journal-based metrics. Publishers should offer a range of performance measures to assess and evaluate scholarly output.
Key takeaways: Altmetrics has the potential to add another element to measure scholarly output. Download statistics and social media use may provide a useful indicator due to their immediacy compared to citations. Altmetrics are not standardized, making the choice of indicator a challenge. When altmetrics are used in research evaluation, they must be done in an informed peer-review process, like existing metrics. Altmetric counts cannot be used at present as a measurement of societal impact because more information is needed about user groups. For example, this information could include whether the impact has been measured by citations in policy documents or guidelines, or used in health care commissioning decisions, rather than simply appearing on social media sites.

40. Cruz Rivera, Samantha, Derek G. Kyte, Olalekan Lee Aiyegbusi, Thomas J. Keeley, and Melanie J. Calvert. "Assessing the Impact of Healthcare Research: A Systematic Review of Methodological Frameworks." *PLoS Medicine*, Vol. 14, No. 8, August 9, 2017, pp. 1–24.
Topic: Review of frameworks
Timing: N/A
Overview: The purpose of this paper is to identify the existing frameworks used to measure health care research impact and to summarize common themes and metrics.
Key takeaway: Twenty-four unique methodological frameworks were identified, addressing five broad categories of impact:

- Primary research-related impact.
- Influence on policy making.
- Health and health systems impact.
- Health-related and societal impact.
- Broader economic impact.

These categories were subdivided into 16 common impact subgroups. Eighty different metrics aimed at measuring impact in these areas were identified.
The research found that the payback framework was the most dominant. Bibliometrics was the most used mechanism to assess primary short-term impact of research, which authors argue assesses dissemination, not impact. Impact on policy making was the most used to assess mid-term impact. The article stated that "the inclusion of a mixed-method approach … reflects a widespread belief expressed by the majority of authors of the included methodological frameworks in the review that individual quantitative impact metrics do not necessary capture the complexity of the relationships involved in a research project and may exclude measurement of specific aspects of the research pathway." The authors suggest that stakeholders be involved

early in the assessment process. The authors also argue that no single tool is superior to the other and that researchers should consider stakeholders input help develop a solid assessment.

41. Newson, Robyn, Lesley King, Lucie Rychetnik, Andrew Milat, and Adrian Bauman. "Looking Both Ways: A Review of Methods for Assessing Research Impacts on Policy and the Policy Utilisation of Research." ***Health Research Policy and Systems*****, Vol. 16, No. 1, June 25, 2018, pp. 54–54.**
Topic: Review of frameworks
Timing: N/A
Overview: This review focuses on methods for measuring the impacts of research on public policy specifically, where policy impacts are considered as intermediary outcomes between research outputs and longer-term impacts such as population health and socioeconomic changes. The article also documents the extent and nature of studies measuring the impacts of health research on policy, and compares forward and backward tracing approaches to assessment.
Key takeaway: This article looks at value through two different lenses: research impact and research use. RIAs predominantly use forward tracing approaches, while the converse was true for research use assessments. The payback method was the most used framework. The research found that most studies triangulated data through various data sources and/or methods, and that retrospective data collection was most common. This paper contains many tables that can provide a significant amount of detail on various models and impact factors.

42. Frank, Cyril, and Edward Nason. "Health Research: Measuring the Social, Health and Economic Benefits." ***Canadian Medical Association Journal*****, Vol. 180, No. 5, March 3, 2009, pp. 528–534.**
Metric: Review of frameworks
Timing: N/A
Overview: This methodological brief discusses current approaches to measuring returns on investment, analyze key issues and gaps that need to be bridged to improve ROIs, and present a new method that may help overcome them.
Key takeaways: This brief does a very good job at illustrating the strengths and weaknesses of some common research evaluation frameworks. The major challenges associated with demonstrating ROI for health research can be categorized as follows:

- Attribution: the inability to determine the exact contribution of health research to achieving its end goals.
- Counterfactual: the inability to determine what would happen in the absence of the research.
- Time lag: from basic discovery to effective therapy can take anywhere from 2–30 years.
- Measurement error: challenging to know what to measure and how to measure it.

The research team developed a modified payback model for research evaluation that tracks five categories of impacts:

- Advancing knowledge.
- Capacity building.
- Information decision making.
- Health benefits.
- Broad economic and social benefits.

The model can be used on individual projects and entire programs. The article did mention issues that arise from using a tailored model such as this. If a wide variety of indicators are used, not all projects will be affected by all indicators. This makes comparison across projects difficult. The indicators included in the model, even though there are many, do not represent those that may work better for other projects or programs. The selection of the proper indicators that are sensitive and specific enough to address evaluation questions, while not being too expensive or too time-consuming collect, will be a major challenge. Only the most important ROI questions can realistically be considered.

43. Bonham, Ann C., and Philip M. Alberti. "From Inputs to Impacts: Assessing and Communicating the Full Value of Biomedical Research." ***Academic Medicine: Journal of the Association of American Medical Colleges*****, Vol. 92, No. 10, October 2017, pp. 1375–1377.**

Metric: Review of frameworks
Timing: N/A
Overview: This methodological brief summarizes an initiative in which an array of research project stakeholders identified and vetted novel metrics. The initiative was in advance of a pilot test at the University of Wisconsin–Madison, which sought to assess and communicate its community-engaged science and scholarship.
Key takeaways: This article points out that traditional evaluation methods, which rely on quantifying inputs and outputs, often do a poor job of speaking to all interested stakeholders. Stakeholders now encompass a wide variety of groups. This has caused research organizations to reassess how they estimate and communicate the value of research. The Association of American Medical Colleges and RAND produced evaluation guidance, which was used by a U.S. university to help assess their research. One of the most significant contributions of this article is the generation of lists of research outcomes that were of interest to internal and external stakeholders. Research outcomes of interest to internal stakeholders are:

- Research:
  - Number of published articles.
  - Number of citations.
  - Grant application success rate.
  - Number and size of grant awards.
- Career:
  - Number of PhD graduates.
  - Five-year career outcomes for PhD students.
  - Number of publications per PhD.
  - K award to R award conversion rate.
- Prestige:
  - Number of media appearances.
  - Number of high-profile journal editorships.
  - Number and type of prizes.
  - Number of applications per open post.
- Process:
  - Start-up time for clinical trials.
  - How decisions are made to apply for grants.
  - Average time from funding to publication.

    - Number of projects completed on time and budget.
    - Proportion of funds spent on administration.
- Network:
    - Number of research projects engaging community partners.
    - Number of articles coauthored with community partners.
    - Number of grant application collaborations.

Research outcomes of interest to external stakeholders are:

- Economic:
    - Level of spending.
    - Amount of direct employment.
    - Number of patent applications/awards/citations.
- Policy:
    - Number of citations in guidelines/policy documents.
    - Number of invitations from policy makers.
    - Number of policy secondment.
- Health:
    - Narrowing of health/health care disparities.
    - Number of treatments developed in house.
    - Patient improved life expectancy.
    - Improve quality of care.
    - Improved awareness of preventative measures in community.
- Network:
    - Number of research projects engaging community partners.
    - Number of articles coauthored with community partners.
    - Number of grant application collaborations.
    - Number of staff members engaged in research.

44. Banzi, Rita, Lorenzo Moja, Vanna Pistotti, Andrea Facchini, and Alessandro Liberati. "Conceptual Frameworks and Empirical Approaches Used to Assess the Impact of Health Research: An Overview of Reviews." ***Health Research Policy and Systems,*** **Vol. 9, No. 1, 2011, p. 26.**

Metric: Review of frameworks

Timing: N/A

Overview: The purpose of this article is to identify the most common approaches to RIA, categories of impact, and their respective indicators.

Key takeaways: The paper found that the payback model was the most frequently used assessment methodology. Five broad categories of impact were identified:

- Advancing knowledge.
- Capacity building.
- informing decision making.
- Health benefits.
- Broad socioeconomic benefits.

Other key findings included the following:

- Assessments that focus on more than one category are valued more than those that focus on a single category.

- Case studies are a good starting point that provides context and can help identify other types of evaluations that might be beneficial
- The identification of appropriate factors or indicators is critical to any type of review.

Some key limitations found with the assessments include the following:

- Most are retrospective, tend to highlight what worked, and do not spend much time (if any) on what did not.
- Many assessments attribute results to research when there is no way to effectively conclude this. The lack of a control is problematic.
- Timing of research impact can be difficult to manage because years may be necessary for research to fully mature.

45. Searles, Andrew, Chris Doran, John Attia, Darryl Knight, John Wiggers, Simon Deeming, Joerg Mattes, et al. "An Approach to Measuring and Encouraging Research Translation and Research Impact." ***Health Research Policy and Systems,*** **Vol. 14, No. 1, August 8–9, 2016, pp. 60–60.**

Metric: Review of frameworks
Timing: Prospective
Overview: This report summarizes the development of framework to assess the impact from translational health research (FAIT). It is a conceptual framework designed to prospectively measure and encourage research translation and research impact.
Key takeaways: This article provides a significant amount of very useful information. Its initial contribution is a brief analysis of various evaluative tools/frameworks that have been developed. Based on modified logic model, FAIT blends three core methods: modified payback approach, social ROI, and case studies. FAIT also includes a scorecard that is used to present results and facilitate comparability.

- Payback: Surveys and interviews are conducted to assess value of research, and this information is supported with bibliometric analysis and verification studies. Payback is useful because the results are intuitive, but it is very resource intensive.
- Econometric: BCA/social ROI is the most common type of econometric analysis. BCA/social ROI is useful because it provides a value for each project that can be compared to show ROI. However, BCA/social ROI forces the user to make gross oversimplifications, such as the time between research discovery and utilization.
- Case study: This method is beneficial because it provides a narrative that proves useful when someone is trying to understand the complex research cycle. However, case studies are subjective and so can be biased, and are resource intensive.

The article also highlights the utility of a logic model as being a formative step in developing a framework. The article highlights that the biggest drawback of FAIT is that it is untested as of 2016. The article also states that FAIT is characterized by the following, which are common to all frameworks:

- Difficulty in assigning causality. Did the research cause the impact?
- Difficulty in assessing the extent of attribution. Did the research cause all or part of the impact?
- Difficulty in assessing the timing. The impact of the research may take more than a decade to materialize.

46. Sarli, Cathy C., Ellen K. Dubinsky, and Kristi L. Holmes. *Beyond Citation Analysis: A Model for Assessment of Research Impact.* Vol. 98, Medical Library Association, 2010.
Metric: Review of frameworks
Timing: Retrospective
Overview: The purpose of this paper is to present a research impact model developed by the Washington University School of Medicine Becker Medical Library (the Becker Medical Library Model for Assessment of Research).
Key takeaways: The Becker model uses several indicators across four core areas to determine research impact:

- Research output:
  - Biological materials.
  - Conference materials.
  - Database, software, and algorithms.
  - License agreements.
  - Measurement instruments.
  - Media releases.
  - Medical devices.
  - Outreach visits.
  - Patents.
  - Pharmaceutical preparations.
  - Publications.
  - Research data.
  - Website of research study.
  - Knowledge transfer.
  - Biological materials.
  - Cited references.
  - Classical articles.
  - Consensus development conferences.
  - Curriculum guidelines.
  - License agreements.
  - Mass media.
  - Material transfer agreements.
  - Medical devices.
  - Meta-analyses.
  - Pharmaceutical preparations.
- Publication use statistics:
  - Ranking factors.
  - Requests for reprints.
  - New and ancillary research studies.
  - Reviews.
  - Subject headings or thesauri.
  - Systematic reviews.
  - Websites of research study.
- Clinical implementation:
  - Biological materials.
  - Clinical or practical guidelines.

    - Coding.
    - Continuing education materials.
    - Measurement instruments.
    - Medical devices.
    - Pharmaceutical preparations.
    - Private and public health care plans.
    - Quality measure guidelines.
- Community benefit:
    - Economic outcomes.
    - Health care outcomes.
    - Quality of life.

The authors describe difficulty in quantifying all research impacts, difficulty in finding data to support the model, and difficulty in finding a direct link between research and knowledge transfer, clinical implementation, or community benefit. Another challenge is timing or knowing when the model should be implemented for a research project. At the time the article was published, the model was being tested. The Becker School of Medicine created a website that provides guidance on model use: https://becker.wustl.edu/impact-assessment/model.

47. Kalucy, Elizabeth C., Eleanor Jackson-Bowers, Ellen McIntyre, and Richard Reed. "The Feasibility of Determining the Impact of Primary Health Care Research Projects Using the Payback Framework." ***Health Research Policy and Systems,*** **Vol. 7, No. 1, 2009, p. 11.**

Topic: Framework, mixed mode (interviews, bibliometrics)
Timing: Retrospective
Overview: This article explores the feasibility of using the Buxton and Hanney payback framework to determine the impact of a stratified random sample of competitively funded, primary health care research projects.
Key takeaways: The project conducted telephone interviews based on the payback framework with leaders of the research teams and nominated users of their research, used bibliometric methods for assessing impact through publication outputs, and obtained documentary evidence of impact where possible. The purpose was to determine the effectiveness of the data collection methods and the applicability of the payback framework, and any other issues that arose around the assessment of impact of primary health care research. The interviews provided better information about impact than bibliometric analysis or documentary analysis. The payback framework and logic model were a sound basis for assessing impact. Those interviewed provided substantial information relevant to the impact categories but less about the impact their research had on the wider health sector, population health, or economic benefits.

48. Ovseiko, Pavel V., Alis Oancea, and Alastair M. Buchan. "Assessing Research Impact in Academic Clinical Medicine: A Study Using Research Excellence Framework Pilot Impact Indicators." ***BMC Health Services Research,*** **Vol. 12, No. 1, January 2012, pp. 478–500.**

Metric: Review of indicators
Timing: N/A
Overview: The purpose of this article is to assess the impact indicators proposed in a 2010 Research Excellence Framework. The assessment is based on information found in the literature and a survey of clinical medicine faculty members. Twenty impact indicators from seven

categories are reviewed according to their strengths and limitations. The study concludes that most indicators have merit, but "there are significant challenges in operationalizing and measuring these indicators reliably, as well as in comparing evidence of research impact across different cases in a standardized manner."
Key takeaways: The 20 factors are:

- Staff movement between academia and industry.
- Employment of post-doctoral researchers in industry.
- Research contracts and income from industry.
- Collaborative research with industry measured through co-authored outputs.
- Income from intellectual property.
- Success measures for spin-out companies.
- Patents granted/licenses awarded and brought to market.
- Research income from overseas business.
- Changes to legislation/regulations/government policy.
- Participation on public policy advisory committees.
- Influence on public policy debate.
- Research income from the NHS and medical research charities.
- Measures of improved health services.
- Changes to clinical or health care training, practice, or guidelines.
- Development of new or improved drugs, treatments, or other medical interventions; numbers of advanced-phase clinical trials.
- Changes to public behavior.
- Measures of improved health outcomes.
- Increased levels of public engagement with science and research.
- Measures of improved social equity, inclusion, or cohesion.
- Application of new security technologies or practices.

The article identified the following challenges to assessing the importance of research, using the 20 proposed factors:

- Standardizing how the factors are used so that comparisons can be made across research organizations.
- Choosing between qualitative and quantitative assessment methods. The former is good for purposes of comparison, but the latter may be better suited to capture the highly complex nature of the research cycle.
- Standardizing data collection guidelines that will allow research organizations to effectively implement the 20 indicators.
- Preventing chosen indicators from degrading in efficacy (losing their robustness) once they become targets and benchmarks for performance metrics (Goodhart's law).

49. Thonon, Frederique, Rym Boulkedid, Tristan Delory, Sophie Rousseau, Mahasti Saghatchian, Wim van Harten, Claire O'Neill, and Corinne Alberti. "Measuring the Outcome of Biomedical Research: A Systematic Literature Review." *PLoS On*e, Vol. 10, No. 4, 2015, p. e0122239.
Topic: Review of indicators
Timing: Retrospective

Overview: The objective of this review was to identify all the indicators that could be used to measure the output and outcome of medical research carried out in institutions and enlist their methodology, use, and positive and negative points.
Key takeaways: Searches were conducted of three databases including articles presenting, discussing, or evaluating indicators measuring the scientific production of an institution. The definition, calculation, rationale, and positive or negative points were extracted for each indicator. A total of 57 indicators were identified, 9 of research activity, 24 of scientific production and impact, 5 of collaboration, 7 of industrial production, 4 of dissemination, and 8 of health service impact. The most widely discussed and described was the h-index. Most indicators are bibliometric indicators of scientific production and impact.

50. Gomes, Daniela, and Charitini Stavropoulou. "The Impact Generated by Publicly and Charity-Funded Research in the United Kingdom: A Systematic Literature Review." ***Health Research Policy and Systems,*** **Vol. 17, No. 1, 2019, p. 22.**
Topic: Empirical evidence of impact
Timing: Retrospective
Overview: The objective of this article was to identify, synthesize, and critically assess the empirical evidence of the impact generated by publicly and charity-funded health research in the United Kingdom.
Key takeaways: The authors conducted a systematic literature review of the empirical evidence published in peer-reviewed journals between 2006 and 2017. Studies meeting the inclusion criteria were selected, and their findings were analyzed using the payback framework and categorized into five main dimensions:

- Knowledge.
- Benefits to future research and research use.
- Benefits to informing policy and product development.
- Health and health-sector benefits.
- Broader economic benefits.

The studies were assessed for risk of selection, reporting, and funding bias. Thirteen studies met the criteria, 10 of which assessed impact at multiple domains including the five key themes of the payback framework. The authors concluded that empirical evidence on the impact of publicly and charity-funded research is still limited and subject to funding and selection bias. More work is needed to establish the causal effects of funded research on academic outcomes, policy, practice, and the broader economy.

51. Bloch, Carter, Mads P. Sørensen, Ebbe K. Graversen, Jesper W. Schneider, Evanthia Kalpazidou Schmidt, Kaare Aagaard, and Niels Mejlgaard. "Developing a Methodology to Assess the Impact of Research Grant Funding: A Mixed Methods Approach." ***Evaluation and Program Planning*****, Vol. 43, 2014, pp. 105–117.**
Topic: Impacts of research funding
Timing: Retrospective
Overview: This article discusses the development of a mixed-methods approach to analyze research funding. The main objective of the study was to gain a comprehensive view of the impacts of research project grants.

Key takeaways: The mixed method approach uses both quantitative (bibliometric, career progression, and survey) and qualitative (case study) methods, with primary reliance on quantitative methods. Qualitative supplements quantitative findings.
Some areas in which the method can be improved include:

- The bibliometric analysis only focused on the primary author. It may be beneficial to include all authors, but the time and effort to do so need be considered.
- There is some measurement error in the citation databases. This is difficult to overcome.
- A large share of research grants involve collaboration across organizations. This is difficult to capture with this impact assessment approach.
- The qualitative interviews that were part of the case study would have benefited from a narrower focus.
- Although all stages of this research were conducted in unison, there is advantage to taking a sequential approach with the research, to allow one phase to inform the next.

52. Cohen, Gillian, Jacqueline Schroeder, Robyn Newson, Lesley King, Lucie Rychetnik, Andrew J. Milat, Adrian E. Bauman, Sally Redman, and Simon Chapman. "Does Health Intervention Research Have Real World Policy and Practice Impacts: Testing a New Impact Assessment Tool." ***Health Research Policy and Systems,*** **Vol. 13, January 1, 2015, p. 3.**

Topic: Impact assessment process (surveys, interviews)
Timing: Retrospective
Overview: This paper presents modified impact assessment process that builds on best practice to five years (2003–2007) of intervention research funded by Australia's National Health and Medical Research Council to determine if these studies had post-research real-world policy and practice impacts
Key takeaways: The assessment uses a mixed method sequential methodology. PIs of eligible intervention studies were subject to two surveys and an interview. Data from the surveys and interviews were triangulated with related project documentation to develop comprehensive case studies. These case studies were then summarized, and the reported impacts were scored by an expert panel using criteria for four impact dimensions: corroboration, attribution, reach, and importance.
This study found that expert panel members tended to score projects more highly than expected across most impact dimensions (compared to benchmark examples provided). This suggests the importance of providing guidance to scorers prior to the evaluation. Because societal importance of research is difficult to assess, it is important to have a diverse makeup of expert panel members.

53. Donovan, Claire, Linda Butler, Alison J. Butt, Teresa H. Jones, and Stephen R. Hanney. "Evaluation of the Impact of National Breast Cancer Foundation-Funded Research." ***The Medical Journal of Australia,*** **Vol. 200, No. 4, March 3, 2014, pp. 214–218.**

Topic: Impact of research investment
Timing: Retrospective
Overview: To evaluate the impact of the National Breast Cancer Foundation's research investment, a three-pronged research program evaluation was conducted. The evaluation used a survey of chief investigators involved in research funded by the National Breast Cancer

Foundation during 1995–2012, a bibliometric analysis of National Breast Cancer Foundation–funded publications in 2006–2010, and case studies.
Key takeaways: The methodology was based on the payback method and focused on the following impact factors:

- Scientific peer-reviewed publications as the central means of sharing knowledge with the research community.
- Dissemination of knowledge produced to academic and non-academic audiences.
- Interaction with the potential end users and beneficiaries of research, which increases the scientific and broader impacts of research.
- Research training and career advancement.
- Capacity building and critical mass to undertake effective research.
- Translation of research into clinical practice, evident in changes to health service policy and decision making, and best practices in diagnosis and treatment.
- Development of drugs, prognostic tools, or diagnostic technologies.
- Actual health gain, which is often hard to show but may be evidenced in changes in the behavior or practice of health care staff, consumers, or the public.

Some additional key takeaways include the following:

- The evaluation was completed within a short time frame of the completion dates of many of the research projects. Because research benefits take time to fully mature, it is likely that had more time elapsed, the evaluation may have shown increased benefit for some projects.
- Using the findings from one method (survey) to vet another (case study) is a process known as triangulation and can prove beneficial, thus demonstrating the utility of mixed-mode approaches.

54. Gordon, L. G., and N. Bartley. "Views from Senior Australian Cancer Researchers on Evaluating the Impact of Their Research: Results from a Brief Survey." ***Health Research Policy and Systems,*** **Vol. 14, No. 1, 2015, p. 2.**
Topic: RIA
Timing: N/A
Overview: The aim of this paper was to understand the role and opinions of cancer researchers in the growing area of impact evaluation activity, to inform the logistics of a sustainable program of impact evaluation.
Key takeaways: A brief anonymous online survey was administered to 95 current and past grant recipients funded through the external grants program at Cancer Council New South Wales. The statements covered the conceptual, attitudinal, and practical aspects of impact evaluation. The survey targeted researchers from the full spectrum of cancer control research classifications. Responses were polarized for questions relating to engaging with research end users, perceived time pressure to collate data, and pressure to produce research outputs. Some researchers emphasized that quality was an important goal over quantity and warned that collecting impact data created incentives and disincentives for researchers. There was mixed support and acceptance among senior cancer researchers in Australia on their perceived role and engagement with research impact activities. Sole reliance on researchers for collating and reporting impact data may be problematic. Requesting information from researchers could be minimized and confined to final reports and possible verification of externally led evaluations.

55. Adam, Paula, Pavel V. Ovseiko, Jonathan Grant, Kathryn E. A. Graham, Omar F. Boukhris, Anne-Maree Dowd, Gert V. Balling, et al. "ISRIA Statement: Ten-Point Guidelines for an Effective Process of Research Impact Assessment." ***Health Research Policy and Systems,*** **Vol. 16, No. 1, February 8, 2018, p. 8.**

Topic: RIA

Timing: N/A

Overview: This article outlines International School for Research Impact Assessment guidelines for a rigorous and effective process of RIA applicable to all research disciplines and oriented toward practice.

Key takeaways: Even though this article does not propose a specific framework, it makes numerous contributions to the field of RIA. Of utmost importance is a theoretical model for effective evaluation (the 10 guidelines).

The article reiterates the biggest challenges to RIA as time lags, attribution and contribution, marginal differences (what defines high impact and low impact), transaction cost (ensuring the benefits of RIA outweigh the cost) and unit of assessment (the proper unit of assessment).

To analyze context:

- Reflect continuously on your purpose.
- Identify stakeholders and their needs.
- Use of a power-versus-interest grid (Mendelow matrix) is helpful in prioritizing stakeholders.
- Engage with key stakeholders early.
- Choose a conceptual framework critically.
- Use mixed methods and multiple data sources.
- "RIA is best approached using a combination of mixed methods and a variety of data sources. Triangulating methods and data sources can enhance the robustness and trustworthiness of the assessment."
- Select indicators and metrics responsibly.
- "It is recommended that a balanced set (menu) of indicators and metrics are used to answer the stakeholder assessment questions that focus on their impacts of interest."
- Anticipate and address ethical issues and conflicts of interest.
- Communicate results through multiple channels.
- Share learning with the RIA community.

APPENDIX B: PERSONS INTERVIEWED

1. Ahmad Abu-Hawash, Iowa Department of Transportation
2. Komi Ajise, Director of Planning, Southern California Association of Governments
3. Sreenivas Alampalli, PhD, PE, Director, Structures Evaluation Services, New York State Department of Transportation
4. Carlos Braceras, Director, Utah Department of Transportation
5. Nick Burmas (in place of Troy Tusup), California Department of Transportation, Division of Research
6. Mark Bush, Senior Program Officer, Transportation Research Board
7. John Campbell, Battelle (PI), *NCHRP Report 600: Human Factors Guidelines for Road Systems: Second Edition* (2012)
8. Christina Casgar, Goods Movement Policy Manager, Retired, San Diego Association of Governments
9. Gwen Chisholm-Smith, Manager, Transit Cooperative Research Program, Transportation Research Board
10. Camille Crichton-Sumners, Senior Program Officer, Transportation Research Board
11. Ray Derr, Senior Program Officer, Transportation Research Board
12. Darryl Dockstader, Florida Department of Transportation
13. David Ekern, DSEkern Consult (Panel Chair), *NCHRP Report 813: A Guide to Agency-Wide Knowledge and Management for State Departments of Transportation* (2015)
14. Mike Fitch, Virginia Department of Transportation
15. Michael Fontaine, Virginia Department of Transportation
16. Larry Goldstein, Senior Program Officer, Transportation Research Board
17. Jo Allen Gause, Senior Program Officer, Transportation Research Board
18. Ed Harrigan, Senior Program Officer, Transportation Research Board
19. Frances Harrison, Spy Pond Partners (PI), *NCHRP Report 813: A Guide to Agency-Wide Knowledge and Management for State Departments of Transportation* (2015)
20. Tom Hicks, Retired (Panel Chair), *NCHRP Report 600: Human Factors Guidelines for Road Systems: Second Edition* (2012)
21. Chris Hedges, Director, Cooperative Research Program, Transportation Research Board
22. Patricia Hendren, I-95 Corridor Coalition
23. David L. Huft, South Dakota Department of Transportation
24. Cynthia Jones, Ohio Department of Transportation
25. Dr. Cameron T. Kergaye, PE, Utah Department of Transportation
26. Bijan Khaleghi, Washington Department of Transportation (Panel Chair), *NCHRP Synthesis 500: Control of Concrete Cracking on Bridges* (2017)
27. Timothy A. Klein, Office of the Assistant Secretary for Research and Technology
28. David Kosnik, PhD, PE, CTL Consultants
29. Peter Lagasse, Ayers Associates (PI), *NCHRP Report 761: Reference Guide for Applying Risk and Reliability-Based Approaches for Bridge Scour Prediction* (2013)
30. Andy Lemer, Senior Program Officer, Transportation Research Board
31. Kendra K. Levine, University of California, Berkeley
32. Mylinh Lidder, Nevada Department of Transportation (Panel Chair), *NCHRP Report 877: Performance-Based Mix Design for Porous Friction Courses* (2017)
33. Julie Lorenz, Kansas Department of Transportation

34. Susan Martinovich, Former Director, Nevada Department of Transportation
35. Charlene R. McArthur, CPA, Idaho Transportation Department
36. George McAuley, Pennsylvania Department of Transportation
37. Catherine C. McGhee, PE, Virginia Department of Transportation
38. Sid Mohan, Implementation Program Manager, Transportation Research Board
39. Mike Mollenhauer, Virginia Tech Transportation Institute
40. Dr. Hafiz M. Munir, PE, Minnesota Department of Transportation
41. Dr. Tommy E. Nantung, Indiana Department of Transportation
42. Brian Ness, Idaho Transportation Department
43. Steve Ng, Retired (PC), *NCHRP Report 761: Reference Guide for Applying Risk and Reliability-Based Approaches for Bridge Scour Prediction* (2013)
44. Dr. Hilary Nixon, San José State University
45. Emily Parkany, Vermont Agency of Transportation
46. Stephan Parker, Senior Program Officer, Transportation Research Board
47. Dale Peabody, Maine Department of Transportation
48. Kevin J. Pete, Texas Department of Transportation
49. Bill Rogers, Senior Program Officer, Transportation Research Board
50. Ann Scholz, New Hampshire Department of Transportation
51. Dianne Schwager, Senior Program Officer, Transportation Research Board
52. Scott Sigman, FLMHarvest and Transportation and Trade Export for the Illinois Soybean Council
53. Cynthia J. Smith, PE, Mississippi Department of Transportation
54. Lori Sundstrom, Deputy Director, Cooperative Research Program, Manager, National Cooperative Highway Research Program, Transportation Research Board
55. Brian G. Thompson, PE, Pennsylvania Department of Transportation
56. Jim Tymon, American Association of State Highway and Transportation Officials
57. Don Watson, Auburn University, National Center for Asphalt Technology (PI), *NCHRP Report 877: Performance-Based Mix Design for Porous Friction Courses* (2017)
58. Neil Weinstein, Low Impact Development Center (PI), *NCHRP Report 840: A Watershed Approach to Mitigating Stormwater Impacts* (2017)
59. Dr. Richard Y. Woo, PE, Maryland State Highway Administration

APPENDIX C: RESOURCE LIST

This appendix includes a listing of publications and guides on topics introduced in this guidance document.

IMPACT ROADMAPS (LOGIC MODELS)

Centers for Disease Control and Prevention. "Logic Models: CDC Approach to Evaluation." 2018. https://www.cdc.gov/eval/logicmodels/index.htm.

Department of Health and Human Services. *Basic Logic Model Template.* https://www.acf.hhs.gov/media/4499.

Innovation Network. *Logic Model Workbook.* https://www.innonet.org/media/logic_model_workbook_0.pdf\.

Kellogg Foundation. *Logic Model Development Guide.* https://www.wkkf.org/resource-directory/resources/2004/01/logic-model-development-guide.

U.S. Department of Agriculture. "Logic Model Planning Process." 2015. https://nifa.usda.gov/resource/logic-model-planning-process.

EVALUABILITY ASSESSMENT

Centers for Disease Control and Prevention. "Evaluability Assessments." https://www.cdc.gov/eval/tools/evaluability_assessments/index.html.

Methods Lab. *Evaluability Assessment for Impact Evaluation*. https://cdn.odi.org/media/documents/9802.pdf.

Vaessen, Jos. "Evaluability and Why It Is Important for Evaluators and Non-evaluators." World Bank Group, June 13, 2017. https://ieg.worldbankgroup.org/blog/evaluability.

ECONOMIC ANALYSIS METHODS

Australian Government, Office of the Chief Economist. *Choosing Appropriate Designs and Methods for Impact Evaluation.* 2015. https://www.industry.gov.au/sites/default/files/May%202018/document/pdf/choosing_appropriate_designs_and_methods_for_impact_evaluation_2015.pdf?acsf_files_redirect.

Federal Emergency Management Agency. *BCA Reference Guide.* 2009. https://www.fema.gov/sites/default/files/2020-04/fema_bca_reference-guide.pdf.

Minnesota Department of Transportation, Office of Investment. *Benefit-Cost Analysis for Transportation Projects*. 2005. http://www.dot.state.mn.us/planning/program/pdf/BCA-Guidance-08-15-05v2.pdf#:~:text=The%20objective%20of%20a%20benefit-cost%20analysis%20is%20to,design%2C%20construction%2C%20and%20the%20long-term%20increased%20operating%20costs.

So, I., and Staskevicius, A. *Measuring the "Impact" of Impact Investing.* 2015. https://www.hbs.edu/socialenterprise/Documents/MeasuringImpact.pdf.

QUALITATIVE ANALYSIS METHODS

Merriam, S. B. *Qualitative Research: A Guide to Design and Implementatio*n. Jossey-Bass, 2009. https://www.oreilly.com/library/view/qualitative-research-a/9781119003618/.

Sage Publications. *Qualitative Research: Defining and Designing*. https://www.sagepub.com/sites/default/files/upm-binaries/48453_ch_1.pdf.

Myrick, J. "What Is Good Qualitative Research?" *Journal of Health Psychology,* Vol. 11, No. 5, pp. 799–808 2006. https://journals.sagepub.com/doi/pdf/10.1177/1359105306066643.

TRANSPORTATION PERFORMANCE MEASURES

Federal Highway Administration. "Transportation Performance Management." https://www.fhwa.dot.gov/tpm/.

APPENDIX D: IMPACT REPORT TEMPLATE

Project Information
NCHRP Project Number and Title:
Project Objectives (from RFP):
Dissemination Date:

The Implementation
Implementing Agency:
Implementation Start Date:
Motivation for the Agency to Implement the Research (e.g., the Problem(s) to Be Addressed):
Description of What Research Results Were Actually Implemented:

Summary of Internal and External Impacts
Narrative description of the internal impacts on the agency and the benefits they brought. Describe who, what was affected and how, magnitude and scope of changes, and key factors driving or limiting changes.
If external impacts were addressed, provide narrative description of them, including who, what was affected and how, magnitude and scope of changes, and factors driving or limiting changes.

Supporting Evidence
Briefly outline the evidence that supports the findings on internal and external impacts: quantitative measures illustrating changes, descriptive reports, and results of interviews with key participants, including quotes of key personnel interviewed (cite title or function, not names). Present relevant contextual information about the implementation, such as factors that affected the impacts (state of the agency and depth of the problem), positively or negatively. Provide evidence that supports attributing internal and external changes to the research results, such as describing the processes linking research results to internal and external change, following the research roadmap, providing event timelines, and including citations from reports and quotes from key players.

Subjective Assessment

A. Substantial Benefits (e.g., Significantly Revised Operations, Policies, Processes, etc.).
B. Major Benefits (e.g., Improved Operations, Policies, Processes, etc.).
C. Minor Improvements (e.g., Savings, Productivity, Knowledge, etc.).
D. Unclear or Contradictory Impacts.
E. Expected Impacts Not Realized.

Provide a supporting rationale for the grade, in terms of the value of the research to the agency and its constituencies, in comparison to implementation costs and effort. End the report with a single-sentence description of that value.