Preliminary Investigation (PI-0268)

Caltrans Division of Research, Innovation and System Information

Measuring the Benefits of Transportation Research: Survey of Practice

Requested by
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Executive Summary

Background

The California Department of Transportation (Caltrans) Division of Research, Innovation and System Information is interested in learning about the practices used to measure the benefits of transportation research. Of particular interest are the methodologies used by other state department of transportation (DOT) research programs to determine the return on investment (ROI) for transportation research projects at multiple points in the research cycle.

A benefits measurement process for transportation research is expected to assist Caltrans with prioritizing and selecting projects for funding; selecting projects for implementation; and providing data to support Caltrans' efforts in connection with California Senate Bill 1 (SB-1), the Road Repair and Accountability Act of 2017. (SB-1 requires Caltrans to implement efficiency measures with the goal of generating at least $100 million annually in savings to redirect toward maintaining and rehabilitating the state's highways.)

To assist Caltrans in this information-gathering effort, CTC & Associates summarized the results of an online survey of state DOT research program managers that examined the practices used to measure the benefits of transportation research. A literature search was also conducted to identify publicly available sources of best practices.

Summary of Findings

Selected Measurement Tools and Practices

Findings from the survey of practice and literature search identified several formalized tools and practices agencies are using to quantify the benefits of transportation research. Table ES1 brings together findings from both information-gathering efforts to highlight selected tools and practices that are addressed in varying levels of detail in this Preliminary Investigation.

Table ES1. Selected Tools and Practices Used to Measure Transportation Research Benefits

State/Consortium	Tool or Practice	Description
Florida	Framework	The Financial Achievability Model (FAM) is a framework to identify and quantify the benefits of Florida DOT research projects. Forms completed by project managers are among the data-gathering mechanisms used to assist in executing the model.
Indiana	Benefit–cost analysis	A consultant has conducted a benefit–cost analysis for selected projects completed in the 2016, 2017 and 2018 fiscal years. Project selection is based on the ability to quantify costs and benefits on outcomes that impact Indiana DOT operations, implementation costs and expected impact time period.
Kansas	Benefit–cost analysis	The agency has documented two approaches to assessing the benefits of transportation research: traditional benefit–cost techniques and multiobjective analysis. The latter is used in cases where project benefits cannot be expressed in strictly monetary terms. Guidelines describe a five-step process to estimate the potential economic impacts of research.

State/Consortium	Tool or Practice	Description
Minnesota	Excel template	An Excel workbook is used to execute a seven-step benefit quantification process and generate the benefit–cost ratio. The workbook performs calculations with user input values and serves as a repository for the data, assumptions and sources included in the quantification process.
New England Transportation Consortium	Excel template	A five-step process to quantify research benefits is supplemented by an Excel-based tool that performs the benefit calculation. Researchers adapted the tool from Minnesota DOT's seven-step, Excel-based benefit estimation tool.
North Carolina	Benefit–cost methodology Predictive model	Researchers presented a new cost–benefit analysis methodology that addresses the quantitative and qualitative benefits of agency research. A performance prediction model was also developed to predict the probability of success in terms of highly successful, successful and moderately successful. Researchers found that research need impacts project success four times more than the research champion and six times more than the experience of the principal investigator.
Texas	Excel template	The Value of Research (VoR) template is an Excel workbook used by Texas DOT's principal investigators to determine the value of a research project. The third of three worksheets provides data and graphics that illustrate the project's economic value in total savings, net present value, payback period (in years) and a cost–benefit ratio.
Utah	Benefit–cost analysis Grading system	Every four years, the agency completes benefit–cost studies to measure the benefits of all major research projects and initiatives completed during that time period. Agency documentation includes specific benefit–cost calculations, standard values for use in these calculations and a grading system that provides an alternate method to monitor project and program effectiveness.

Projects in process by the National Cooperative Highway Research Program (NCHRP) and soon to kick off in Arizona, Mississippi and Ohio are expected to produce new tools and practices to measure transportation research benefits. A 2018 Wyoming DOT study that developed a general benefit–cost analysis methodology indicated that a future study will develop a benefit–cost analysis tool.

Survey of Practice

An online survey examining the practices used to measure the benefits of transportation research was distributed to state DOT research program managers using the member list of the American Association of State Highway and Transportation Officials (AASHTO) Research Advisory Committee. Of the 26 state and district respondents providing complete or partial survey responses, 12 reported on practices to measure the benefits of transportation research.

Note: New Hampshire DOT provided responses that are aspirational, with the respondent addressing survey questions with what the agency would like or has plans to do. This feedback is presented with responses from the 12 agencies currently employing benefits measurement practices.

Several of the remaining respondents described their current practices and plans for or interest in measuring the benefits of research.

Survey results from the agencies reporting on benefits measurement practices are summarized below in the following topic areas:

- Measurement extent and timing.
- Data inputs and sources.
- Gathering data and completing the measurement.
- Measurement practices.
- Assessing measurement practices.
- Program documentation.
- General comments about benefits measurement.

Measurement Extent and Timing

Respondents are most likely to measure the benefits of selected completed research projects and least likely to conduct a programwide assessment (only Utah DOT reported conducting such an assessment). Seven of the 13 respondents attempt to measure the anticipated benefits of a research project at multiple points in the research cycle, though respondents are most likely to apply benefits measurement as a project is being proposed and immediately after it concludes. Three states—Arizona, Florida and Washington—measure benefits at five or more milestones in a project's life cycle.

Two respondents described periodic comprehensive analyses of research benefits:

- *Arizona*. Every five to seven years, the Research Center conducts a major investigation to identify the impact on the agency of the implementation of research recommendations and the factors influencing implementation.
- *Utah*. Currently, the agency conducts a comprehensive benefit–cost analysis every four years. The respondent indicated that a more ideal model is to move toward real-time collection (immediately after a project concludes), noting that "[t]he drawback with that is some completed research does not pay dividends until well after the close of the formal project schedule. A built-in delay fuse can help to protect against false negative values."

Responding agencies are most likely to examine or report on the benefits identified at the project or program level periodically or on an as-needed basis. Only two agencies—Arizona and Florida DOTs—are continually examining the benefits of research.

Data Inputs and Sources

<u>Data Inputs</u>

Agencies use a variety of data inputs to measure the benefits of transportation research. The data inputs most frequently cited by respondents:

- Implementation costs and material costs (10 state DOTs).
- Material quantities and project costs (nine state DOTs).

Facility life, technical panel participation costs, and time required to complete an activity were cited least frequently (by only four respondents). The Utah DOT respondent noted that his

agency does not place predefined limits on input factors that may be used to quantify value and provided the other "outcome factors" the agency considers.

Several agencies offered more details about their data-sourcing efforts. Among them is an effort by Florida DOT's Research Center to develop a repository for data management and benefits. Included in this repository are forms developed in connection with the agency's FAM framework that gather benefits data from project inception to completion. The researchers developing FAM noted that successfully implementing the framework will "require the establishment of a clear process for data collection that starts at the research kickoff presentation."

Data Sources

The survey also explored data sources that might be used by respondents, including project proposals, preliminary deliverables and the research reports that are typically a project's final deliverable.

Project Proposals and Preliminary Deliverables

Respondents reported on efforts early in the research process that allow for measuring benefits as a project unfolds:

- Kansas DOT uses the project proposal in conjunction with the project's final report to validate or verify the benefits achieved by the project.
- The Texas DOT respondent described his agency's use of its VoR Excel-based measurement tool as "progressive." The three worksheets included in this Excel workbook are completed by principal investigators in collaboration with project panels, with panel members charged with identifying relevant "benefit areas" to focus on during the research effort. Development of the final report includes an examination of the completed VoR, which is considered part of the final deliverable.
- Principal investigators submitting proposals to Vermont Agency of Transportation are expected to identify quantifiable benefits.

Final Reports

More than three quarters of respondents use the final report—the most common final deliverable for a research project—to track or document project benefits. Research programs in six states—Alaska, Indiana, Michigan, Nevada, Texas and Vermont—expect principal investigators to deliver final reports that include benefits data or calculations.

Standard Values

Only the Utah DOT respondent indicated that standard values have been established for use in benefits calculations. Calculations to codify typical Technical Advisory Committee meeting costs and standard values related to crash costs are available in the July 2016 report, *Investing in Utah Transportation Research* (see page 54 for a citation).

Other Data Sources

Respondents identified other data sources that complement the sources previously identified, including insurance and safety-related data, interviews and surveys, findings from national research and pooled fund studies, and data from state DOTs. The Utah DOT respondent noted that the agency will employ data from any reputable source that has a factual basis and can be

properly cited, while cautioning that data without information about its origination lacks legitimacy and should not be used.

Gathering Data and Completing the Measurement

Responsibility for Data Collection and Measurement

Respondents identified the individuals or groups primarily responsible for gathering the data needed to measure benefits. In almost all cases, the individual or group gathering the data is responsible for completing the benefits measurement process. Respondents are more likely to task a consultant or principal investigator with gathering and processing data than employ a collaborative effort spearheaded by agency staff.

Data Collection Challenges

Agencies encounter a range of challenges when gathering the data needed to measure research benefits. Respondents most often highlighted the timing of data collection. As the Washington State DOT respondent noted, study horizons are much shorter than the longer-term duration needed to follow up on benefits accrued. Inadequate data collection was cited by four respondents, including the Florida DOT respondent, who commented that retrospective data may not be collected on a granular level and recommended a collaborative approach to data collection.

Measurement Practices

Measuring Anticipated Benefits of Proposed Projects

Only three respondents reported on an approach designed to measure the anticipated benefits of proposed projects:

- In Alaska, the agency's research needs statement includes a section that addresses the potential benefit to the department. The scoring criteria for project selection includes points for a benefit–cost assessment that is "liberally considered" by the agency.
- The Indiana DOT respondent noted that projects resulting in a specification change sometimes take time to generate benefits. In these cases, anticipated benefits may be calculated.
- In Nevada, anticipated benefits are estimated using historical data and assumptions about the effects of new methods and processes.

Other respondents indicated that such an analysis was either premature or not yet fully implemented. The Arizona DOT respondent noted that the agency "do[es] not support the 'calculation' of anticipated benefits. Public agencies may lack the data to do this defensibly." In Texas, anticipated benefits are verified through later implementation. At that time, a standard for calculating benefits would be required for use on similar implementation projects.

Measurement Methods

Respondents are most likely to use a benefit–cost ratio when measuring the benefits of transportation research. Several agencies apply more than one measurement method. The Arizona DOT respondent reported on a custom measurement tool in development that is expected to be largely qualitative.

Specific Calculations

Four respondents described a specific calculation, series of calculations or tool that applies calculations to determine research benefits on a project-by-project or program basis:

- Florida DOT's FAM framework assesses the costs and benefits associated with research projects.
- Indiana DOT engages a consultant to prepare an annual evaluation of completed research projects. The consultant determines which projects are viable candidates for a benefit–cost analysis. The 2018 ROI analysis included an examination of agency savings and costs, road user cost savings and safety cost savings.
- Kansas DOT prepares a simple benefit–cost calculation for each project and the overall research program.
- Utah DOT's principal benefits calculation is Benefits = Number x Value x Percentage. The July 2016 report, *Investing in Utah Transportation Research*, cited on page 54, provides further details of the agency's analysis.

Further information about the calculations described by these respondents and used by other transportation agencies to assess transportation research benefits is provided in publications cited in the **Related Research and Resources** section of this Preliminary Investigation, which begins on page 35.

Assessment Categories

Some agencies assess the benefits of research using specific categories. The six respondents reporting on this type of categorization are most likely to use geotechnical, maintenance, materials and pavements, and safety classifications.

Defining Successful Research Projects

Five respondents described how their agencies define a "successful" research project. For Indiana DOT, a successful project is one that can be implemented or provides a proof of concept. The Utah DOT respondent described a grading system that the agency uses as "an alternate method to monitor project and program effectiveness." Surveys ask research project champions to assign a grade of A through E to the research project using standard definitions of each grade that range from major impact (Grade A) to major tasks not completed (Grade E).

Assessing Measurement Practices

Key Successes

Respondents offered no consensus on what constitutes success when measuring the benefits of transportation research. For some, it's the collaborative process (Kansas) or encouraging advocacy for data collection and analysis (Florida), while others focus on high-value projects that are likely to yield demonstrable benefits to the agency (Michigan, Nevada and Utah).

Key Challenges

The challenges associated with measuring the benefits of transportation research also tended to vary, with respondents most often citing the complexity of measurement and lack of resources. Other respondents cited a lack of an agencywide standard for performance metrics, limited data to quantify benefits and long-term costs, and unclear or unrealistic expectations.

Program Documentation

Resources provided by several respondents, as well as from state DOTs not responding to the survey, offer guidance for their staff members or others implementing benefits measurement practices. These publications, cited in the **Related Research and Resources** section of this Preliminary Investigation, include user guides published by Kansas, Minnesota and Utah DOTs.

General Comments About Benefits Measurement

After addressing specific survey questions, some respondents provided more general comments about measuring the benefits of transportation research. The Arizona DOT respondent offered a set of guiding principles that can inform how agencies measure the benefits of transportation research. Other respondents cited the difficulty of benefits quantification and acknowledged that their agencies are just getting started or have hopes to begin.

Agencies Without Formal Benefits Measurement Experience

All but two respondents from agencies not actively measuring the benefits of transportation research reported on some aspect of benefits measurement or an interest in doing more. State DOT members of the New England Transportation Consortium expect to make use of the benefits quantification tool recently developed for the consortium. Pending research in Mississippi and Ohio is expected to help those state DOTs quantify research benefits.

Other agencies complete small-scale assessments of implementation and project benefits for selected projects, or gather information about implementation that might inform a future benefits assessment effort. Still others are proposing to add benefits measurement as a requirement in a future university support contract, or have plans to develop processes and forms for implementation and performance measures that will inform a benefits measurement practice.

Related Research and Resources

The tables beginning on page 10 summarize the publications, research in progress and other resources highlighted in this Preliminary Investigation in these topic areas:

- National guidance.
- State DOT consortium research.
- State research and practices.

Each table provides the publication or project title, the year of publication (research in progress is noted without a year) and an excerpt from the publication's abstract or a brief description of the resource. More detail about each publication can be found in the **Detailed Findings** section of this report.

Gaps in Findings

While the survey received a robust response, there may be other state DOT research programs employing a measurement practice to assess research benefits. Reaching out to agencies not responding to the survey may yield additional findings. Engaging with the Wyoming DOT respondent may also garner useful information; the respondent indicated that her agency measures research benefits but she only provided a partial survey response.

Though some respondents provided a fairly significant level of detail in their survey responses, Caltrans could benefit from targeted follow-up inquiries that seek more details about the benefits measurement tools and practices that appear to be the most readily adaptable to the Caltrans environment.

Next Steps

Moving forward, Caltrans could consider:

- Reviewing the benefits quantification tools developed by respondents or described in related resources to consider how they might be adapted to meet Caltrans' needs, including:
    - Indiana DOT's benefit–cost analysis conducted for selected completed projects.
    - Kansas DOT's Excel spreadsheet used to conduct its benefit–cost analysis at the project and program levels.
    - The Excel-based benefits quantification tools developed by the New England Transportation Consortium and Minnesota DOT.
    - Texas DOT's Excel-based tool used by researchers to calculate the value of research.
    - The benefit–cost ratio calculations completed by Utah DOT in connection with its periodic comprehensive assessment of research benefits.
- Reviewing the models or frameworks developed by respondents or described in related resources to consider how they might be adapted to meet Caltrans' needs, including:
    - Florida DOT's FAM framework.
    - The benefit–cost methodology and predictive model developed for North Carolina DOT.
- Consulting with agencies and organizations conducting or preparing to conduct research in this topic area, including:
    - Arizona, Mississippi and Ohio DOTs.
    - Wyoming DOT, to determine if the agency plans to follow up its 2018 examination of a benefit–cost methodology to develop a formalized benefit–cost tool.
    - Panel members participating in NCHRP Project 20-44(09), Quantitative and Qualitative Methods for Capturing the Impacts and Value of NCHRP Research, to determine if preliminary findings will be made available before the project is expected to conclude in May 2021.

National Guidance

Publication or Project (Year)	Excerpt From Abstract or Description of Resource
NCHRP Project 20-44(09): Quantitative and Qualitative Methods for Capturing the Impacts and Value of NCHRP Research (Research in Progress)	Seeks to estimate the value of NCHRP research products, which will "likely require approaches that are sensitive to the context of the research and the perspective of the stakeholders trying to understand its benefits." Completion date: May 2021 (estimated).
NCHRP Synthesis 522: Managing State Transportation Research Programs (2019)	Provides case studies of transportation research programs in the District of Columbia, Louisiana, Minnesota, Ohio and Utah. These states were chosen to "gain a diverse range of perspectives on how agencies of different sizes, budgets, research models and geographical locations manage their research programs for program quality and value."
NCHRP Web-Only Document 127: Performance Measurement Tool Box and Reporting System for Research Programs and Projects (2008)	Describes the Research Performance Measurement (RPM) System, which includes a web site (RPM-Web) and a CD-ROM of tools (RPM-Tools). Automated benefits estimation worksheets are completed at the product level and allow users to estimate benefits using different methodologies, each with associated worksheets to assist the user through the process. Methodologies include current minus future, direct difference and percent improvement methods.

State DOT Consortium Research

Publication or Project (Year)	Consortium	Excerpt From Abstract or Description of Resource
Quick Response: Quantification of Research Results (2019)	New England Transportation Consortium	Describes a five-step process to quantify research benefits and a related Excel-based tool to perform the benefit calculation. Researchers adapted the tool from Minnesota DOT's seven-step, Excel-based benefit estimation tool.
Development of a Guidebook for Determining the Value of Research Results (2016)[1]	Southeast Transportation Consortium	Details an effort to develop a guidebook that will provide a consistent approach for measuring and documenting the value of completed research.
Development of a Guidebook for Determining the Value of Research Results (2016)	Southeast Transportation Consortium	Summarizes the pooled fund study effort described in the publication cited above.
STC Synthesis of Best Practices for Determining Value of Research Results (2014)	Southeast Transportation Consortium	Synthesizes the best practices for determining the value of research results to demonstrate the impact research has on safety, quality and cost-effectiveness. Critically reviews methods used to determine the value of transportation research.
Synthesis of Methods and Measures for Determining Value of Transportation Research (2017)	Southeast Transportation Consortium	Describes the benefit analysis method, typically the most frequently used method to determine the value of research projects. Includes a discussion of different approaches within benefit analysis.

Publication or Project (Year)	Consortium	Excerpt From Abstract or Description of Resource
Determining Value of Transportation Research: Methods, Measures and Data Sources (2014)	Southeast Transportation Consortium	Presents in poster form the key elements of the 2017 study described above, including a summary of the "identified methods to determine value of research" and the references associated with each method.

1 A consortium representative noted that work on the project was not responsive to the consortium's needs for a usable end product and the group is planning to classify the 2016 interim report as a final report.

State Research and Practices

Publication or Project (Year)	State	Excerpt From Abstract or Description of Resource
Implementation of Research at ADOT, 2012 to Present (Anticipated Research)	Arizona	Seeks to update a 2014 study by examining the quantitative and qualitative impact of research on and benefits to ADOT since 2012. Expected to include recommendations on modifications to ADOT Research Center services, processes and products. Completion date: December 2021 (estimated).
Implementation of Research at the Arizona Department of Transportation: Findings and Key Insights (2014)	Arizona	Examines 128 research studies completed by ADOT Research Center between 2002 and 2012. Identified benefits to ADOT of the research conducted and factors affecting the implementation of research and use of Research Center services.
Financial Achievability of the Florida Department of Transportation Research Projects: Putting the Financial Analysis Framework Into Action (2018)	Florida	Describes a framework developed for Florida DOT to evaluate the costs and benefits associated with research projects. Researchers identified the challenges of putting FAM into practice and developed processes that facilitate its adoption.
Financial Achievability of the Florida Department of Transportation Research Projects: Putting the Financial Analysis Framework into Action (undated)	Florida	Describes the FAM-related research cited above in a one-page brief.
Developing a Framework for Financial Achievability of Department of Transportation Research and Development Projects (2015)	Florida	Presents early efforts associated with FAM development. Researchers noted that "[s]uccessful implementation of the framework will require focused data collection with emphasis on identifying the potential net benefits of research projects."
Project Manager Forms (undated)	Florida	Provides a series of forms used by Florida DOT project managers to track project implementation and benefits from the kickoff meeting to deployment of research results.

Publication or Project (Year)	State	Excerpt From Abstract or Description of Resource
Repository for Data Management and Benefits (undated)	Florida	Shows the SharePoint data repository under development that will allow the agency to track project-related data and benefits measurement. (Provided to Caltrans separately.)
INDOT Research Program Benefit Cost Analysis—Return on Investment for Projects Completed in FY 2018 (2019)	Indiana	Presents the results of a benefit–cost analysis conducted for selected projects completed in fiscal year 2018. Project selection is based on the ability to quantify costs and benefits on outcomes that impact Indiana DOT operations, implementation costs and expected impact time period.
INDOT Research Program Benefit Cost Analysis—Return on Investment for Projects Completed in FY 2017 (2018)	Indiana	Presents results of the same type of benefit–cost analysis described in the 2019 publication cited above.
INDOT Research Program Benefit Cost Analysis—Return on Investment for Projects Completed in FY 2016 (2017)	Indiana	Presents results of the same type of benefit–cost analysis described in the 2019 publication cited above.
Quantifying the Value of Research in Indiana (2015)	Indiana	Describes use of a modified internal rate of return (MIRR) to assess the benefits of Indiana DOT's research. The MIRR spreadsheet was developed by Indiana DOT's Central Office to calculate the value of ROI in research and development. (MIRR was replaced by the benefit–cost analysis applied to projects completed in 2016, 2017 and 2018, as described in the citations listed above.)
An Economic Analysis Methodology for Project Evaluation and Programming (2013)	Indiana	Provides details of MIRR, a practice previously used by Indiana DOT's research program to calculate research benefits.
INDOT R&D Financial Valuation Model (RDVAL) (2011)	Indiana	Excel workbook used for the agency's calculation of MIRR. (Provided to Caltrans separately.)
Research, Development and Technology Transfer Procedures Manual (2017)	Kansas	Describes the process used to track the benefits of Kansas DOT's research program using the Research Implementation System. Implementation is considered at each step in a project's life cycle.
Guidelines for Estimating the Triennial Benefits of Kansas Transportation Research and New Developments (K-TRAN) Research Projects (2004)	Kansas	Discusses two approaches to assessing the benefits of transportation research: traditional benefit–cost techniques and multiobjective analysis. Provides recommended guidelines for a five-step process to estimate the potential economic impacts of research.
Research Program Council Meeting Agenda (2020)	Kansas	Includes a status report that presents a benefit–cost ratio for the overall program and implemented projects.
Status Report (undated)	Kansas	Excel workbook that Kansas DOT Research uses to track research projects and the associated benefit–cost ratio. (Provided to Caltrans separately.)

Publication or Project (Year)	State	Excerpt From Abstract or Description of Resource
Development of a Process for Quantifying the Benefits of Research (2017)	Minnesota	Describes an "easy-to-apply process for quantifying the potential benefits of research and comparing the monetary benefits of implemented research results with the cost of doing the research." An Excel workbook is used to execute the seven-step process and generate the benefit–cost ratio. (New England Transportation Consortium researchers adapted the process and workbook to develop a similar Excel-based tool.)
User Guide: Process for Quantifying the Benefits of Research (2017)	Minnesota	Explains the seven-step benefit quantification process and use of an Excel-based benefit quantification spreadsheet tool that performs calculations with user input values and serves as a repository for the data, assumptions and sources included in the quantification process.
MnDOT Research Program Strategic Plan 2017-2022 (2017)	Minnesota	Examines the agency's assessment of research program outcomes, noting that the spreadsheet-based estimation tool "standardizes the formulas and relationships across the templates, which can easily be updated when necessary, so that the entire organization has a consistent approach to benefit quantification."
Best Practice Guide for Quantifying the Benefits of MnDOT Research (2013)	Minnesota	Describes an effort to identify "process steps, key milestones during research projects and tools used to quantify benefits"; references the 2013 Southeast Transportation Consortium synthesis of best practices for determining the value of research results.
A Framework for Determining Value of MDOT Research Projects (undated) (Anticipated Research)	Mississippi	Seeks to provide guidelines for identifying a set of performance measures that will be quantified when research begins to serve as a basis for comparison when research results are implemented.
Capturing and Communicating the Value of NCDOT Research (2018)	North Carolina	Presents a new cost–benefit analysis methodology that addresses the quantitative and qualitative benefits of agency research. Researchers also developed a performance prediction model to predict the probability of success in terms of highly successful, successful and moderately successful.
Technology Transfer Support and Evaluation of ROI for Ohio's SP&R-B Program (2019) (Anticipated Research)	Ohio	Seeks to develop and execute a repeatable methodology for assessing project- and program-level ROIs for Ohio DOT and Ohio's Research Initiative for Locals (ORIL).
Research Development and Technology Transfer (RD&T^2) Manual of Procedures (2019)	Ohio	Includes Chapter 6, Implementation, which presents the agency's new approach (yet to be implemented, according to the survey respondent) for implementation assessment and calculation of ROI.
Research Implementation Summary: Rapid Orthophoto Development System (2013)	Ohio	Serves as an example of Ohio DOT's Research Implementation Summary, which is completed after a research project concludes. The form includes a section for implementation evaluation and ROI.

Publication or Project (Year)	State	Excerpt From Abstract or Description of Resource
Value of Research Template (undated)	Texas	Excel workbook used by Texas DOT's principal investigators to determine the value of a research project. Includes three worksheets used for selection of benefit areas, economic benefit variable amounts, and determining the value of research. The final worksheet provides data and graphics that illustrate the project's economic value in total savings, net present value, payback period (in years) and a cost–benefit ratio.
University Handbook (2019)	Texas	Describes the VoR template and provides guidance on how it should be used by the university researchers participating in the agency's research program.
Research and Innovation Division: Manual of Instruction (2018)	Utah	Addresses the benefit—cost studies the agency is advised to undertake every three to five years to measure the benefits of research, noting that the "analysis should include all major projects and initiatives completed during that time period."
Investing in Utah Transportation Research (2016)	Utah	Estimates the benefits of the agency's research projects over a four-year period and a benefit–cost ratio for the program. Studies completed during the period 2009 through 2012 had an estimated benefit–cost ratio of 14. The analysis included 76 deliverables produced by 66 projects.
Program to Measure Research Benefits and Track Implementation: Manual of Instruction (2016)	Utah	Accompanies the publication cited above and provides various calculations and other guidance for completing the benefit–cost assessments. (This manual is currently being revised.)
Measuring the Benefits of Transportation Research in Utah (2010)	Utah	Estimates the benefits of research projects over a three-year period and a benefit–cost ratio for the program. Provides feedback on the management processes used by research staff.
Evaluation of the WYDOT Research Center (Phase III) (2018)	Wyoming	Presents a detailed analysis on the proposals submitted to the agency from 2011 to 2017 to evaluate the effectiveness of the Research Center.
Development of Benefit Cost Analysis Tools for Evaluating Transportation Research Projects (2019)	Wyoming	Describes benefit–cost analyses that estimate the benefits for changes in the level of service of a roadway, reductions in the vehicle travel time, changes in vehicle operating costs and reductions in the number of crashes.
Evaluating Department of Transportation's Research Programs: A Methodology and Case Study (2012)	Wyoming	Presents a methodology for conducting an evaluation of a transportation research program that includes 10 performance measures used to summarize the findings of the evaluation.

Detailed Findings

Background

The California Department of Transportation (Caltrans) Division of Research, Innovation and System Information is interested in learning about the practices used to measure the benefits of transportation research. Of particular interest are the methodologies used by other state department of transportation (DOT) research programs to determine the return on investment (ROI) for transportation research projects at multiple points in the research cycle. A benefits measurement process is expected to assist Caltrans with:

- Prioritizing and selecting the projects most likely to result in quantifiable benefits to Caltrans and its stakeholders.
- Selecting projects for implementation.
- Demonstrating the impact of Caltrans' research efforts to internal and external stakeholders.
- Providing data to support Caltrans' efforts in connection with California Senate Bill 1, the Road Repair and Accountability Act of 2017, which requires Caltrans to implement efficiency measures with the goal of generating at least $100 million annually in savings to redirect toward maintaining and rehabilitating the state's highways. (Caltrans is seeking to save over $200 million per year.)

To assist Caltrans in this information-gathering effort, CTC & Associates summarized the results of an online survey of state DOT research program managers that examined the practices used to measure the benefits of transportation research. A literature search was also conducted to identify publicly available sources of best practices. Findings from these efforts are presented in this Preliminary Investigation in two areas:

- Survey of practice.
- Related research and resources.

Survey of Practice

An online survey gathered information from state DOT research program managers using the member list of the American Association of State Highway and Transportation Officials (AASHTO) Research Advisory Committee.

Survey questions are provided in Appendix A. The full text of survey responses is presented in a supplement to this report.

Summary of Survey Results

The respondents from 26 state and district DOTs providing complete or partial survey responses are identified below in two categories: those agencies with research benefits measurement experience and those without research benefits measurement experience. Twelve of these respondents reported on practices to measure the benefits of transportation research.

Agencies With Research Benefits Measurement Experience

- Alaska.
- Arizona.
- Florida.
- Indiana.
- Kansas.
- Michigan.
- Nevada.
- Texas.
- Utah.
- Vermont.
- Washington.
- Wyoming.

Agencies Without Research Benefits Measurement Experience

- Connecticut.
- District of Columbia.
- Illinois.
- Kentucky.
- Maryland.
- Mississippi.
- Missouri.
- Montana.
- New Jersey.
- North Dakota.
- Ohio.
- Rhode Island.
- Tennessee.

Note: New Hampshire DOT provided responses that are aspirational, with the respondent addressing survey questions with what the agency would like or has plans to do. This feedback is presented with responses from the 12 agencies currently employing benefits measurement practices.

Survey results are presented first for those agencies reporting on benefits measurement practices in these topic areas:

- Measurement extent and timing.
- Data inputs and sources.
- Gathering data and completing the measurement.
- Measurement practices.
- Assessing measurement practices.
- Program documentation.
- General comments about benefits measurement.

Feedback from agencies not currently measuring the benefits of transportation research is presented in **Agencies Without Formal Benefits Measurement Experience** beginning on page 33.

Measurement Extent and Timing

Extent of Measurement

Respondents identified the extent to which benefits measurement is practiced in their research programs at the project and program levels. Respondents are most likely to measure the benefits of selected completed research projects and least likely to conduct a programwide assessment (only Utah DOT conducts such an assessment). Table 1 summarizes survey responses.

Table 1. Extent of Respondents' Measurement of Research Benefits

State	All Proposed Research Projects	Selected Proposed Research Projects	All Completed Research Projects	Selected Completed Research Projects	Portfolios of Completed Research Projects	Programwide Assessment
Alaska		X				
Arizona			X		X	
Florida	X	X	X	X	X	
Indiana				X		
Kansas			X			
Michigan				X		
Nevada		X		X		
New Hampshire[1]				X		
Texas[2]				X		
Utah			X			X
Vermont	X					
Washington[3]				X		
Wyoming			X			
Total	**2**	**3**	**5**	**7**	**2**	**1**

1 The agency also intends to measure the benefits of selected active research projects.

2 The agency's measurement process continues to evolve.

3 Some agency divisions have incorporated ROI into their operations from completed research projects (for example, pavement and traffic).

Timing of Measurement

Seven of the 13 respondents attempt or plan to measure the anticipated benefits of a research project at multiple points in the research cycle. Respondents are most likely to apply benefits measurement as a project is being proposed and immediately after it concludes. Three states—Arizona, Florida and Washington—measure benefits at five or more milestones in a project's life cycle. Table 2 summarizes survey responses.

Table 2. Timing of Respondents' Measurement of Research Benefits

State	As a Project is Being Proposed	While a Project is Underway	Immediately After a Project Concludes	One to Two Years After Project Completion	Two to Three Years After Project Completion	More Than Three Years After Project Completion
Alaska	X		X			
Arizona	X	X	X	X		X
Florida	X	X	X	X	X	X
Indiana			X			
Kansas			X			
Michigan			X			
Nevada	X					

State	As a Project is Being Proposed	While a Project is Underway	Immediately After a Project Concludes	One to Two Years After Project Completion	Two to Three Years After Project Completion	More Than Three Years After Project Completion
New Hampshire	X		X			
Texas		X				
Utah						X
Vermont	X	X				
Washington	X	X	X	X	X	X
Wyoming	X	X	X		X	
Total	**8**	**6**	**9**	**3**	**3**	**4**

Several respondents provided additional information about the timing of benefits measurement:

- *Arizona*. Every five to seven years, the Research Center conducts a major investigation to identify the impact on the agency of the implementation of research recommendations and the factors influencing implementation. The 2014 report, *Implementation of Research at the Arizona Department of Transportation,* cited on page 40, provides an example of this analysis.
- *New Hampshire*. Benefits may be gathered after project completion for some research topic areas.
- *Utah*. Currently, the agency conducts a comprehensive analysis every four years. The respondent indicated that a more ideal model is to move toward real-time collection (immediately after a project concludes), noting that "[t]he drawback with that is some completed research does not pay dividends until well after the close of the formal project schedule. A built-in delay fuse can help to protect against false negative values. Nonetheless, there is merit in increasing the assessment interval frequency. U[tah] DOT continues to review how to effectively shorten this review window."
- *Washington*. The agency is most likely to measure benefits as a project is being proposed, while it is underway and immediately after it concludes. In some cases, results are followed for two or more years after completion of the research.

Timing of Research Benefits Reporting

Responding agencies are most likely to examine or report on the benefits identified at the project or program level periodically or on an as-needed basis. Only two agencies—Arizona and Florida DOTs—are continually examining the benefits of research. Table 3 summarizes survey responses.

Table 3. Timing of Research Benefits Examination or Reporting

Time Period	State	Description
Monthly	Wyoming	N/A
Quarterly	Vermont	The agency's quarterly e-newsletter shares results and benefits of research projects.

Time Period	State	Description
Annually	Indiana, Kansas, New Hampshire	*New Hampshire*. Research project final reports may include listed benefits. The agency anticipates implementing annual reporting at the program level.
Continually	Arizona, Florida	*Arizona*. The agency continually observes the potential for and actual implementation from study conception to completion. The Research Center inquires about implementation every six months for up to 18 months after study completion.
Periodically or When Requested	Alaska, Michigan, Nevada, Texas, Washington	*Alaska*. When requested. *Michigan*. Once at the end of some projects. *Nevada*. Periodically throughout the year. *Texas*. Periodically, on request. *Washington*. "From time to time."

N/A Not available.

Data Inputs and Sources

Typical Data Inputs

Agencies use a variety of data inputs to measure the benefits of transportation research. The data inputs most frequently cited by respondents:

- Implementation costs and material costs (10 state DOTs).
- Material quantities and project costs (nine state DOTs).

Facility life, technical panel participation costs and time required to complete an activity were cited least frequently (by only four respondents). Tables 4A, 4B and 4C identify the types of data commonly used to measure benefits and the frequency of use among respondents.

Table 4A. Data Used to Measure Transportation Research Benefits

State	Crash Costs	Crash Data	Facility Life	Implementation Costs	Labor Hours	Labor Rates
Alaska	X	X	X	X		
Florida	X	X		X	X	X
Indiana	X			X		
Kansas	X	X		X		
Michigan	X	X	X	X	X	X
Nevada	X	X		X		
New Hampshire				X	X	X
Texas	X	X		X		
Utah	X	X	X	X	X	X
Washington		X	X	X	X	X
Total	**8**	**8**	**4**	**10**	**5**	**5**

Table 4B. Data Used to Measure Transportation Research Benefits

State	Life Cycle Estimates	Maintenance History	Material Costs	Material Quantities	Project Costs
Alaska	X	X	X	X	X
Florida	X	X	X	X	X
Indiana	X	X	X	X	
Kansas	X	X	X	X	X
Michigan	X	X	X	X	X
Nevada	X	X	X		X
New Hampshire			X	X	X
Texas		X	X	X	X
Utah	X	X	X	X	X
Washington	X		X	X	X
Total	**8**	**8**	**10**	**9**	**9**

Table 4C. Data Used to Measure Transportation Research Benefits

State	Technical Panel Participation Costs	Time Required to Complete an Activity	Traffic Volume	Travel Time	Vehicle Operating Costs
Florida	X	X	X	X	X
Indiana			X	X	
Kansas			X	X	X
Michigan	X	X	X	X	X
Nevada			X		
New Hampshire	X			X	X
Texas		X	X	X	X
Utah	X	X	X	X	X
Washington			X	X	X
Total	**4**	**4**	**8**	**8**	**7**

Several respondents offered additional details related to their agencies' use of data:

- *Arizona*. All of the data categories may apply to the agency's analyses. A major implementation study estimated to begin June 2020 will develop quantitative and qualitative methods for measuring research impacts. (See page 40 for a project description.)
- *Florida*. The Research Center is developing a repository for data management and benefits that will house forms to support the agency's Financial Achievability Model (FAM), a framework that identifies and quantifies the benefits of Florida DOT research projects. (More information about FAM appears throughout this Preliminary Investigation.) The researchers developing FAM noted that successfully implementing the framework will "require the establishment of a clear process for data collection that starts at the research kickoff presentation."

Forms developed to support FAM are used to populate an internal SharePoint site under development that will serve as a data repository for the agency's benefits measurement activities. The agency expects the repository to evolve as more projects are subjected to the FAM benefits measurement framework and the agency gains a better understanding of data needs. (Citations for resources describing FAM, the data repository and related materials begin on page 40.)

- *Texas*. Many of the various data categories are considered depending on the project.
- *Utah*. The agency does not place predefined limits on input factors that may be used to quantify value. As a result, each of the metrics identified in the survey are valid sources for input in the agency's calculation methods. The agency also considers other outcome factors:
    - Enhanced infrastructure and assets (better designs, reduced construction costs, lower maintenance requirements, reduced materials costs).
    - Savings to Utah DOT operations (reduced manpower, lower bids, lower operational costs, more efficient equipment).
    - Benefits to the public (reduced congestion, improved safety, enhanced environment).
    - Benefits in the form of institutional knowledge.
    - Zero financial benefits from the deliverables.
    - Benefits not known at this time; implementation continues; and future benefits may be achieved and are to be determined.
- *Vermont*. The agency's principal investigators are encouraged to identify items that are quantifiable and appropriate data sources.

<u>Data Sources</u>

The survey explored data sources that might be used by respondents, including project proposals, preliminary deliverables and the research reports that are typically a project's final deliverable.

Project Proposals and Preliminary Deliverables

- Arizona DOT requires research problem statements to qualitatively estimate impacts and who is responsible for implementation.
- Kansas DOT uses the project proposal in conjunction with the project's research report to validate or verify the benefits achieved by the project.
- Nevada DOT requires that proposals include an estimate of potential benefits.
- The Texas DOT respondent described his agency's use of its Value of Research (VoR) Excel-based measurement tool as "progressive." The three worksheets included in this Excel workbook are completed by principal investigators in collaboration with project panels, with panel members charged with identifying relevant "benefit areas" to focus on during the research effort. Development of the final report includes an examination of the completed VoR workbook, which is considered part of the final deliverable. (See page 52 for more information about the VoR tool.)

- Utah DOT selects research projects to fund based on two principal criteria—perceived organizational value and implementability. The agency includes an implementation plan as a standard part of the project documentation process. The respondent noted that the agency's implementation plan "is a bit oversimplified and warrants updating." (Utah DOT's Implementation Plan template is available at http://udot.utah.gov/main/uconowner.gf?n=11557711089776154.)
- Principal investigators submitting proposals to Vermont Agency of Transportation are expected to identify quantifiable benefits.

Final Reports

More than three-quarters of respondents use the final report (also referred to as a research report)—the most common final deliverable for a research project—to track or document project benefits. Research programs in six states—Alaska, Indiana, Michigan, Nevada, Texas and Vermont—expect principal investigators to deliver final reports that include benefits data or calculations. Table 5 describes how respondents are using research reports to inform benefits measurement.

Table 5. Respondents' Use of Final Reports to Measure Benefits

State	Description
Alaska	The agency's final reports include recommendations, cost–benefit calculations and the implementation steps deployed.
Arizona	The agency uses its research reports to attempt to identify the extent to which recommendations are implemented and the effect of that implementation.
Indiana	Research reports will include both qualitative and quantitative data, impact to operations and other benefits, as appropriate.
Kansas	The final report is used to evaluate if the project goals were met; benefits are based on the probable implementation.
Michigan	Research reports frequently include data that document project benefits.
Nevada	All projects require production of a final report that includes next steps for implementation and an estimate of potential benefits when implemented.
New Hampshire	Final reports are expected to identify benefits resulting from the research and a suggested measurement process.
Texas	The final report includes the VoR workbook that quantifies research benefits.
Utah	Project deliverables like final reports become critical when measuring longitudinal values, especially because many of the original project managers or project champions have moved on. The agency conducts a targeted analysis of project and program benefits in four-year intervals.
Vermont	The final report is expected to include a benefit quantification section.

Standard Values

Only the Utah DOT respondent indicated that standard values have been established for use in benefits calculations. Calculations to codify typical Technical Advisory Committee meeting costs and other values are available in the July 2016 report, *Investing in Utah Transportation Research* (see page 54 for a citation). Two examples:

- *Technical Advisory Committee (TAC) investment* (from page 13 of the July 2016 report):

  Technical Advisory Committees provided oversight, data, information, deliverable reviews and discussions in meetings. It was assumed that an average TAC had eight members, met six times and required three hours of time for each member including preparation. An hourly wage of $40 with 50% overhead was assumed.

  TAC Costs = 8 members x $60/hr x 3 hrs x 6 meetings x 66 projects = $570,000

Note: The calculation described above provides a result of $570,240; the report includes the rounded result of $570,000.

- *Average cost per crash based on severity* (from page 51 of the July 2016 report):

Fatality	$ 1,961,100
Serious Injury	$ 1,961,100
Non-Capacitating	$ 122,400
Possible Injury	$ 62,500
Property Damage Only	$ 3,200

Other Data Sources

Respondents identified other data sources that complement the sources previously identified:

- Insurance data (Florida).
- Interviews with the project manager and principal investigator (Michigan).
- Interviews/surveys/focus groups with research stakeholders (Arizona).
- National research and data (Alaska, Kansas).
- Pooled fund studies (Alaska).
- Safety or crash data (Florida, Nevada, New Hampshire).
- State DOT data (Kansas).

The Utah DOT respondent noted that the agency will employ data from any reputable source that has a factual basis and can be properly cited. The respondent cautioned that data without information about its origination lacks legitimacy and should not be used.

Gathering Data and Completing the Measurement

Responsibility for Data Collection and Measurement

Respondents identified the individuals or groups primarily responsible for gathering the data needed to measure benefits. In almost all cases, the individual or group gathering the data is responsible for completing the benefits measurement process. Respondents are more likely to task a consultant or principal investigator with gathering and processing data than employ a collaborative effort spearheaded by agency staff. Table 6 summarizes survey responses.

Table 6. Primary Responsibility for Gathering and Processing Measurement Data

Primary Responsibility	State	Description
Collaboration Among Agency Staff	Arizona, Florida, Kansas, Nevada, New Hampshire	*Arizona*. A research study's project manager is responsible for attempting to document implementation for 18 months following the conclusion of a study. Research customers are asked to provide qualitative and quantitative data for this documentation. *Florida*. The project manager, principal investigator and Research Center collaborate with assistance from subject matter experts (SMEs) to gather data. Actual measurement is a collaboration among SMEs. *Kansas*. The Research Bureau and project monitor proposing and approving the project and the final report collaborate on gathering and processing data. *Nevada*. The agency's research coordinator is responsible for conducting benefits measurement on a project-by-project basis with the assistance of project champions and principal investigators. *New Hampshire*. The project champion and Research Section are expected to collaborate on gathering and processing data.
Consultant	Arizona, Indiana, Utah	*Arizona*. A consultant conducts the agency's major implementation study under the guidance of a project manager and with significant input from research customers. *Indiana*. Third-party consultant. *Utah*. The agency uses a consultant, which helps to establish neutrality.
Principal Investigator	Alaska, Michigan, Texas, Vermont	*Alaska*. The principal investigator for each project must address benefits in the final report's recommendations. *Michigan*. The principal investigator is responsible for gathering data and making calculations in accordance with the project scope. The measurement process changes from project to project based on the scope of work. *Texas*. The researcher is responsible for gathering and processing data with input from various sources, including articles, engineers and agency staff. *Vermont*. The principal investigator is responsible for gathering and processing data.

Data Collection Challenges

Agencies encounter a range of challenges when gathering the data needed to measure research benefits. Respondents most often highlighted the timing of data collection (Alaska, Texas, Utah and Washington) and inadequate data collection (Arizona, Florida, Nevada and Utah). Table 7 summarizes survey responses.

Table 7. Data Collection Challenges

Type of Challenge	State	Description
Cost of Data Collection	Washington	Data procurement costs are relatively high.
Identifying Appropriate Data	Michigan, Texas	*Michigan.* Measured benefits are based on the extent of implementation and the extent of implementation is not always known. *Texas*. Having project teams agree to the level of data needed.
Inadequate Data Collection	Arizona, Florida, Nevada, Utah	*Arizona*. The agency does not adequately collect or maintain baseline data against which impact can be measured. The respondent noted that documentation of that baseline is now seen as a Research Center responsibility. *Florida*. Retrospective data may not be collected on a granular level; a collaborative approach to data collection is recommended. *Nevada*. When maintenance or construction methods are improved using research, the agency has had difficulty tracking benefits in terms of life cycle costs because benchmark maintenance costs before the improvement was made are unavailable. *Utah*. People are frequently more focused on the present and future than the past, and it requires time and energy to generate interest in identifying and gathering retrospective documentation.
Limited Resources	New Hampshire	Other priorities and limited resources.
Projects Difficult to Quantify	Indiana, Kansas	*Indiana*. Some projects are difficult to measure quantitatively even when data are available. *Kansas*. In some projects, it is difficult to define the monetary value of the benefits.
Timing of Data Collection	Alaska, Texas, Utah, Washington	*Alaska*. Cost–benefit is hard to quantify before actual implementation. Results tend to be theoretical and not based on data. *Texas*. Receipt of the data in a timely manner. *Utah*. Too much elapsed time. Project managers or champions have moved on. *Washington*. Study horizons are much shorter than the longer-term duration needed to follow up on benefits accrued.
General Challenges	Vermont	Data collection is addressed in project proposals, and the agency has attempted to use Technical Advisory Committees to enforce data collection requirements. The respondent noted that "it's not a great system so far."

Measurement Practices

Measuring Anticipated Benefits of Proposed Projects

Only three respondents reported on an approach designed to measure the anticipated benefits of proposed projects:

- In Alaska, the agency's research needs statement includes a section that addresses potential benefit to the department. The scoring criteria for project selection includes points for a benefit–cost assessment that is "liberally considered" by the agency.

- The Indiana DOT respondent noted that projects resulting in a specification change sometimes take time to generate benefits. In these cases, anticipated benefits may be calculated.
- In Nevada, anticipated benefits are estimated using historical data and assumptions about the effects of new methods and processes.

Other respondents noted that such an analysis was either premature or not yet fully implemented:

- *Arizona*. The respondent noted that the agency "do[es] not support the 'calculation' of anticipated benefits. Public agencies may lack the data to do this defensibly."
- *Florida*. Anticipated benefits are initially considered from a qualitative perspective, which may, depending on the project, be further developed as a quantitative measure.
- *Texas*. Anticipated benefits are verified through later implementation. At that time, a standard for calculating benefits would be required for use on similar implementation projects.
- *Utah*. Currently, the agency does not compare expected pre-project benefits and actual realized post-project benefits. Such an analysis would "be a good comparison point that requires front- and back-end process alignments."
- *Vermont*. The respondent noted that relevant literature advises agencies to identify potential benefits early in the research cycle to allow for any type of evaluation during a project or as it concludes. The agency is currently emphasizing identification of quantifiable benefits identified at the beginning of projects and implementation of project results, and is less focused on an "evaluation."

Measurement Methods

Respondents are most likely to use a benefit–cost ratio when measuring the benefits of transportation research. Several agencies apply more than one measurement method. The Arizona DOT respondent mentioned a custom measurement tool in development that is expected to be largely qualitative. Table 8 summarizes survey responses.

Table 8. Respondents' Measurement Methods

State	Before and After Analysis	Benefit Cost Ratio	Custom Measurement Tool	Life Cycle Cost Analysis	Return on Investment Calculation
Alaska[1]	X	X		X	X
Arizona			X[2]		
Florida		X			X
Indiana[3]		X		X	X
Kansas		X			
Michigan	X	X		X	X
Nevada	X	X			X
New Hampshire	X	X			
Texas	X	X			

State	Before and After Analysis	Benefit Cost Ratio	Custom Measurement Tool	Life Cycle Cost Analysis	Return on Investment Calculation
Utah		X[4]			
Washington[5]	X	X	X	X	X
Total	**6**	**10**	**2**	**4**	**6**

1 The agency also tracks the number of implemented results or recommendations the department has adopted.

2 The agency is developing a measurement tool that is expected to be largely qualitative. The respondent noted that "[q]uantitative tools may be inappropriate and misleading if reliable baseline and post-implementation data are not available."

3 The agency also tracks impacts to operations and other qualitative benefits such as efficiency.

4 Although benefit–cost ratio is a go-to for conventional research valuation practices, other methodologies are applied in different settings across the agency.

5 The methodology is project- and division-dependent using a mix of all methods.

Specific Calculations

Four respondents described a specific calculation, series of calculations or tool that applies calculations to determine research benefits on a project-by-project or program basis:

- Florida DOT's FAM framework assesses the costs and benefits associated with research projects.
- Indiana DOT engages a consultant to prepare an annual evaluation of completed research projects. The consultant determines which projects are viable candidates for a benefit–cost analysis. The 2018 ROI analysis included an examination of agency savings and costs, road user cost savings and safety cost savings.
- Kansas DOT prepares a simple benefit–cost calculation for each project and the overall research program.
- Utah DOT's principal benefits calculation is Benefits = Number x Value x Percentage. The July 2016 report, *Investing in Utah Transportation Research*, cited on page 54, provides further details of the agency's analysis.

Further information about the calculations described by these respondents and used by other transportation agencies to assess transportation research benefits is provided in publications cited in the **Related Research and Resources** section of this Preliminary Investigation, which begins on page 35.

Assessment Categories

Some agencies assess the benefits of research using specific categories. Respondents reporting on this type of categorization are most likely to organize research using geotechnical, maintenance, materials and pavements, and safety classifications. Table 9 identifies categories used by respondents when assessing research benefits.

Table 9. Categories Used to Organize and Assess Research Benefits

Category	Alaska	Florida	Kansas	Michigan	Nevada	Utah[1]
Administration and Management	X	X				

Category	Alaska	Florida	Kansas	Michigan	Nevada	Utah[1]
Construction	X	X	X	X		
Design		X	X	X		
Environmental	X	X		X	X	
Geotechnical	X	X	X	X		X
Hydraulics	X	X		X		
Innovations	X	X	X			
Intelligent Transportation Systems		X		X		
Maintenance	X	X	X	X		X
Materials and Pavements	X	X	X	X		X
Planning	X	X	X			X
Project Delivery		X		X		
Safety	X	X	X	X	X	X
Sustainability	X	X				
Traffic Operations		X	X	X	X	

1 The agency combines structures-related projects with geotechnical projects and includes aeronautics and public transit categories.

Other respondents addressed the question of categorizing research benefits differently:

- Arizona DOT might use any or all of the categories identified and others depending on the topics of completed research.
- Texas DOT categorizes research using the following benefit areas identified in its VoR template:
  - Level of knowledge.
  - Management and policy.
  - Quality of life.
  - Customer satisfaction.
  - Environmental sustainability.
  - System reliability.
  - Increased service life.
  - Improved productivity and work efficiency.
  - Expedited project delivery.
  - Reduced administrative costs.
  - Traffic and congestion reduction.
  - Reduced user cost.
  - Reduced construction, operations and maintenance cost.
  - Materials and pavements.
  - Infrastructure condition.
  - Freight movement and economic vitality.
  - Intelligent transportation systems.
  - Engineering design improvement.
- Vermont Agency of Transportation does not have enough projects to use categories.
- Washington State DOT assesses the benefits of research on an ad hoc basis as determined by project outcomes.

Defining Successful Research Projects

Five respondents described how their agencies define a "successful" research project:

- For Arizona DOT, a successful project produces useful information, or the agency implements at least one recommendation developed by the study.
- Florida DOT's implementation of FAM will help the agency "perfect benefits [measurement] upfront," though its application will vary project to project.
- For Indiana DOT, a successful project is one that can be implemented, whatever the benefits—qualitative or quantitative—or as a proof of concept.
- A successful New Hampshire DOT project is one completed on time, within budget and still of interest to the department.
- Utah DOT uses a grading standard to assess its projects. Attachment D describes a grade system that "provides an alternate method to monitor project and program effectiveness." Surveys ask research project champions to assign a grade to the research project using definitions similar to those listed in the table below:

Grade	Definition
A	Major impact: New or revised specifications, policy, methods, etc.
B	Significant impact: Improved operations, procedures or policies.
C	Contributed to state of the practice or institutional knowledge.
D	Unclear or contradicting findings: More study needed.
E	Major tasks not completed: Objectives not met.

Assessing Measurement Practices

Key Successes

Respondents offered no consensus on what constitutes success when measuring the benefits of transportation research. For some, it's the collaborative process or encouraging advocacy for data collection and analysis, while others focus on high-value projects that are likely to yield demonstrable benefits to the agency. Table 10 summarizes survey responses.

Table 10. Transportation Research Benefits Measurement Successes

Effective Practice	State	Description
Consistency	Utah	The respondent noted that "[w]e're consistent. We are in our third four-year measurement process now."
Encouraging Advocacy	Florida	A cultural change has encouraged project managers to discuss benefits and become advocates for data collection and analysis.
Encouraging Collaboration	Kansas	Measurement is a joint effort that engages the principal investigator, project monitor and Bureau of Research.

Effective Practice	State	Description
Focusing on High-Value Projects	Michigan, Nevada, Utah	*Michigan*. The agency focuses on high-value projects that are expected to provide the greatest benefit when results are documented and communicated. *Nevada*. The agency has received the AASHTO Research Advisory Committee's high-value research award twice in the past three years. Agency submissions demonstrated project benefits using concrete data on cost savings. *Utah*. The agency looks for end products that remove or replace existing workload before looking at end products that simply add new workload.
Implementation Action Plans	Indiana	The agency develops an implementation action plan at the end of the research project.
Valuing Research	Texas	Measurement practices provide agency administration with insight into the importance of research and promote its value, which encourages buy-in for further implementation of the results or product.

Key Challenges

The challenges associated with measuring the benefits of transportation research also tended to vary, with respondents most often citing the complexity of measurement and lack of resources. Table 11 summarizes survey responses.

Note: The Mississippi DOT respondent, while not among those reporting on current benefits measurement practices, addressed the challenges associated with quantifying the benefits of research. Her responses are included in the table below.

Table 11. Transportation Research Benefits Measurement Challenges

Type of Challenge	State	Description
Data	Alaska, Florida	*Alaska*. Limited data to quantify existing and long-term costs. *Florida*. Data, data, data.
Engaging With Project Results	Mississippi	There is a disconnect after projects are completed that the agency is trying to bridge, but other than informal communication efforts—which can be effective—the respondent noted that she hasn't found a way to do this systematically.
Ensuring Output Values	Utah	Research projects require significant effort to complete, and the respondent noted that "everyone likes a clean finish line. A big challenge is helping to develop a new mindset that research is not complete until an output value assignment stage has been reached. This is an area that all research communities need to improve. A good start would be to create some standardized high-level illustrations that clearly show a project is not really complete until output values are memorialized."
Lack of Agency Standards	Washington	An agencywide standard performance metric still needs to be established.

Type of Challenge	State	Description
Lack of Resources	Arizona, Nevada, New Hampshire, Washington	*Arizona*. Research customers may lack the resources to respond to requests for data and implementation updates, and may not be able to provide reliable, complete data to enable quantitative measurement. Turnover in personnel may weaken customers' commitment to research over time. *Nevada*. The respondent highlighted the challenges of a two-person team managing the research program. Staff members' responsibility for initiating, processing and managing a portfolio of research projects across the state does not permit a lot of time to measure benefits of the research conducted. *New Hampshire*. Limited staff time. *Washington*. Limited funding and staff resources.
Measurement Complexity	Kansas, Indiana, Michigan, Mississippi, New Hampshire, Texas	*Kansas*. The agency's research program has a very broad base and some projects do not lend themselves well to determining a benefit–cost ratio. *Indiana*. Some research projects are only proof-of-concept research projects for which calculating benefits proves difficult. *Michigan*. Not all project benefits are easily measured quantitatively and instead require a comprehensive narrative description of benefits. *Mississippi.* As for all DOTs, "research is not neat and tidy like a construction project." The respondent cited as a national example her work on the NCHRP 20-44(09) panel (*Quantitative and Qualitative Methods for Capturing the Impacts and Value of NCHRP Research*), which is trying to measure the impacts of NCHRP reports and studies. As the respondent noted, "[W]e know [NCHRP projects] have huge impact, but not a lot of DOT personnel know that what ends up as AASHTO policy and guidance often started out life as an NCHRP project." *New Hampshire*. Difficulty in quantifying benefits. *Texas*. Measuring is not "a plug-and-play of factors" entered into a formula.
Other Priorities	New Hampshire, Vermont	*Vermont*. While the agency's proposal template addresses benefits measurement, benefits quantification is not regularly addressed. Currently the agency is focused on implementing research results, and the respondent noted that "quantifying benefits seems like an advanced step."
Staffing Changes	Mississippi, Utah	*Mississippi*. Two to three years—and sometimes more—can elapse from the time of the study idea to the end of a contract. The research champion may leave the agency, which can negatively impact implementation as the momentum provided by an advocate for the research is lost. *Utah*. Too much elapsed time; project managers or champions have moved on.

Type of Challenge	State	Description
Unclear or Unrealistic Expectations	Utah	• Unclear implementation expectations at project onset. Some research is only intended to increase the body of existing institutional knowledge. • For digital tools in particular, not understanding technology readiness levels. Some projects conducted as a pilot effort are not intended to result in the application of technology in its final form. Expectations for a project's end product should be clearly identified in the project scope.

Program Documentation

Resources provided by several respondents, as well as from state DOTs not responding to the survey, offer guidance for their staff members or others implementing benefits measurement practices. These publications are cited in the **Related Research and Resources** section of this Preliminary Investigation, beginning on page 35. Listed below is a sampling of these publications:

- Arizona: *Implementation of Research at the Arizona Department of Transportation: Findings and Key Insights* (October 2014).
- Indiana: *INDOT Research Program Benefit Cost Analysis—Return on Investment for Projects Completed in FY 2018* (December 2019).
- Kansas: *Guidelines for Estimating the Triennial Benefits of Kansas Transportation Research and New Developments (K-TRAN) Research Projects* (July 2004).
- Minnesota: *User Guide: Process for Quantifying the Benefits of Research* (July 2017).
- New England Transportation Consortium (NETC): *Quick Response: Quantification of Research Results* (January 2019).
- North Carolina: *Capturing and Communicating the Value of NCDOT Research* (February 2018).
- Ohio: *Research Development and Technology Transfer (RD&T^2) Manual of Procedures*, (November 2019).
- Texas: *Value of Research Template* (undated).
- Utah: *Program to Measure Research Benefits and Track Implementation: Manual of Instruction* (July 2016).

General Comments About Benefits Measurement

After addressing specific survey questions, some respondents offered more general comments about measuring the benefits of transportation research:

- *Arizona*. The respondent provided a set of guiding principles that can inform how agencies measure the benefits of transportation research:
    - *Realistic approach:* What information can be reliably acquired in the actual state DOT environment?
    - *Defensible methods:* What can we determine with the information we are reliably able to acquire?

    - *Introspection:* How can we refine our processes and products to positively influence implementation? How do we ensure that our research products are worth implementing? For example, the inability to respond quickly to customers' needs, or the slow process to procure consultants and conduct research, lessens the value of research products.

- *Connecticut*. The agency is embarking on an effort to measure benefits, "aware that measuring benefits of transportation research [is] difficult and using a quantitative measure is risky (it is biased toward outcomes that are implementable in the short term; and, in research there is a non-insignificant proportion of initiatives that don't produce a readily and neatly quantifiable benefit). Discipline in assessing outcomes is necessary to continually improve and scope the program properly."
- *New Hampshire*. The respondent provided survey responses that are aspirational, and noted that the agency "would need a simplistic way" of measuring benefits. While the agency would like to get started, the respondent wonders what the agency should be asking its researchers and project panel members to provide.
- *Rhode Island*. The respondent noted that there is "no easy way" to determine direct benefits using a benefit–cost ratio for most projects in terms of dollars saved or deaths and injuries reduced. Determining indirect benefits can be even more challenging.
- *Tennessee*. Research champions from within DOTs, especially at the leadership level, are needed to pave the way for measurement. Agency leaders can help make program review a priority, which the respondent noted was not the case in her agency at this time.
- *Vermont*. Based on experience to date and consideration of the Excel-based quantification tool developed in a recent NETC project, the respondent noted that "benefits quantification is really, really hard. We're just trying to get started." (See page 37 for more information about the tool developed by NETC.)

Agencies Without Formal Benefits Measurement Experience

Respondents from agencies not currently measuring the benefits of transportation research were asked if their agencies had plans to measure research project or program benefits. All but two agencies—North Dakota and Rhode Island DOTs—reported on some aspect of benefits measurement or an interest in doing more.

Research Efforts (Recent or Pending)

- *Connecticut*. The agency plans to use NETC's recently developed quantification tool to track the benefits of research projects, and expects to build on the tool and framework to capture the benefits of its research program. (See page 37 for more information about the tool developed by NETC.)
- *Mississippi*. A research project kicking off soon will develop a framework to prepare and refine research proposals and scopes of work. The research needs statement for this project (see Attachment C) directs researchers to develop "a set of performance measures as a function of type or category of research. Ideally each performance measure will be quantified at the onset of the given study to serve as a basis for comparison subsequent to the conclusion of that research and/or implementation of the recommendations from that research."

- *Ohio.* A pending research project is expected to provide assistance in determining the current ROI of the overall program and developing a repeatable methodology that can be used going forward. A start date for the project was not known at the time of publication of this report.
- *Vermont*. The respondent noted that the agency is "following several other states and their efforts to quantify research" and also cited the recent NETC project on research benefit quantification.

Limited Agency Application

- *Illinois*. Information about anticipated benefits is solicited as part of the agency's Implementation Planning Worksheet. Lack of staff precludes the agency from following up to validate those predictions.
- *Kentucky*. While some quick and small-scale assessments are conducted to highlight implementation and project benefits, this is not done for every project.
- *Mississippi*. An informal database is maintained, but the agency does not conduct an economic assessment unless a project lends itself to that type of analysis.
- *Missouri*. The agency measures project benefits for some projects and always considers conducting an analysis on a project-by-project basis. The respondent noted that "we are always seeking better ways of doing this."
- *Vermont*. The agency is trying to get researchers to identify quantifiable benefits in their proposals and asks researchers to provide updates on benefits assessment during Technical Advisory Committee updates and meetings.

Future Plans and Interest

- *District of Columbia*. The agency is proposing to add benefits measurement as a requirement in its next university support contract. The university partner will be required to develop an annual report on implementation that would ideally include project benefits.
- *Maryland*. While the program manager is interested in benefits measurement, with a small staff of 2.5 employees, it has been very challenging to make any real progress.
- *Montana*. The research programs manager is reviewing reports, forms and other publications related to research performance measures with the goal of developing processes and forms for implementation performance measures in 2020.
- *New Jersey*. The agency would like to "eventually implement some kind of [v]alue of [r]esearch assessment for each project much like TxDOT [Texas DOT] does and require it as a deliverable."
- *Ohio*. Recent changes to the agency's research program manual address the collection of information on implementation and ROI. The revised process has not yet been implemented. (See page 51 for a citation for Ohio DOT's manual and a description of this process.)
- *Tennessee*. The agency is considering a review of relevant documentation and projects to identify a method to measure program benefits. This is currently at the idea stage and has not been further developed.
- *Washington*. A performance metric is in the preliminary stages of development.

Related Research and Resources

Findings from a literature search that examined publications describing practices and methods to measure the benefits of transportation research are presented below in the following topic areas:

- National guidance.
- State DOT consortium research.
- State research and practices.

Tabular summaries of the citations presented below begin on page 10.

National Guidance

Research in Progress: NCHRP Project 20-44(09): Quantitative and Qualitative Methods for Capturing the Impacts and Value of NCHRP Research, effective date: May 1, 2019. (This effort is expected to require 24 months.)
Project description at https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4608
From the project description: Estimating the value of NCHRP research products is challenging. A research product can have multiple outcomes, which in turn can lead to multiple impacts. Significant time can pass between when the research product is developed, when it is put into practice and when the impacts of that practice are realized; this affects the timing of any evaluation activities. The nature of research products is wide-ranging; some research products are geared towards improving existing practices, while others are useful for informing policy decisions. A variety of techniques may be used to measure the impacts themselves, influenced by what measures would be most useful, how easy performance data are to collect, monitor and replicate. Finally, attributing impacts to a research product, when the research product is used as part of a portfolio of other research products, needs to be considered. Estimating the value of NCHRP research will likely require approaches that are sensitive to the context of the research and the perspective of the stakeholders trying to understand its benefits.

NCHRP Synthesis 522: Managing State Transportation Research Programs, Donald Ludlow, Vivek Sakhrani and Camille Wu, 2019.
Report available at https://www.nap.edu/download/25436
Chapter 3, Case Examples, which begins on page 55 of the report (page 64 of the PDF), provides case studies of transportation research programs in the District of Columbia, Louisiana, Minnesota, Ohio and Utah. As the authors note, these states were chosen "to gain a diverse range of perspectives on how agencies of different sizes, budgets, research models and geographical locations manage their research programs for program quality and value." Note in particular the discussion of each agency's practices on assessing program value.

NCHRP Web-Only Document 127: Performance Measurement Tool Box and Reporting System for Research Programs and Projects, Paul Krugler, Melissa Noggle Walden, Bradley Hoover, Yu-ying Diana Lin and Sandra Tucker, 2008.
https://rppm.transportation.org/communicatingvalue/Shared%20Documents/Value%20of%20Research/PM_%20Toolbox.pdf
This document describes the Research Performance Measurement (RPM) System, which includes a web site (RPM-Web) and a CD-ROM of tools (RPM-Tools). While the focus of this report and the related tools is on performance measures, there are elements of the report that will be of interest to those wishing to estimate research benefits, including:

- *Benefit estimation worksheets*. Automated worksheets included in the CD-ROM are completed at the product level and allow users to "estimate benefits using different methodologies, each with associated work sheets to assist the user through the process. The intent of these options is to provide the user as much flexibility as possible to address the wide variety of research products which exist."
- Three methodologies are described for estimating benefits:
    - *Current minus future method*. This method requires two determinations of costs, fatalities and/or numbers of crashes. While this method is almost universally applicable to benefit determination situations, it usually requires more statistical data than the other two methods described below.
    - *Direct difference method*. This method is particularly well suited for use when the research project provides estimated benefits per application of the research product, or when the expected benefits per application can be estimated after the research project is completed. This method is simpler than the current minus future method because it does not require determinations of agencywide costs, fatalities and/or numbers of crashes. Instead, agencywide annual benefits are estimated by multiplying the expected benefits from each application of the research product by the number of locations or applications where the product will be implemented.
    - *Percent improvement method*. This method is ideal when the research project determines a percentage improvement to be expected in costs, fatalities and/or numbers of crashes, or when a percentage improvement can be estimated after the research project is completed. This method requires the estimator to determine the current annual costs, fatalities and/or number of crashes associated with the situation to be improved by the research product. Then, the percentage improvement is applied to determine annual expected benefits.

Appendices that may be of particular interest:

- *Appendix I, Resource Collection Items* (page 160 of the PDF). The report describes this appendix as "a listing of sources for statistics and other information frequently needed during the process of estimating benefits to be derived from research products."
- *Appendix J, Standard Benefit Estimation Examples* (page 184 of the PDF). This set of examples supplements the Benefit Estimation Catalog provided in both RPM-Tools and RPM-Web.

State DOT Consortium Research

The citations below describe efforts made by two regional consortia to quantify the benefits of transportation research:

- *NETC*. The tool recently developed by this group is adapted from an Excel tool developed for Minnesota DOT.
- *Southeast Transportation Consortium*. The consortium has suspended an effort to develop a guidebook for determining the value of research results and is planning to classify a June 2016 interim report as a final report. A consortium representative noted that work on the project was not responsive to the consortium's needs for a usable end product.

New England Transportation Consortium

Quick Response: Quantification of Research Results, Frank Gross and Thanh Le, New England Transportation Consortium, January 2019.
https://www.newenglandtransportationconsortium.org/wp-content/uploads/NETC_Qr17-2_final.pdf
This report describes the development of a research benefit quantification tool for the six states participating in the New England Transportation Consortium (NETC). Researchers were tasked with developing a tool to "help the NETC in evaluating and financially justifying its research projects."

This project produced a five-step process to quantify research benefits and a related Excel-based tool to perform the benefit calculation. Researchers adapted the NETC tool from Minnesota DOT's seven-step, Excel-based benefit estimation tool. (See page 47 for the July 2017 Minnesota DOT publication, *Development of a Process for Quantifying the Benefits of Research*.) The tool customized for NETC was applied to two NETC projects to demonstrate the tool and inform efforts to refine it.

Chapter 3, beginning on page 9 of the report (page 15 of the PDF), includes a detailed discussion of the five-step quantification process:

- *Step 1: Determine applicable benefit categories (deconstruction phase)*. Researchers used the same set of benefit categories applied in the MnDOT tool with minor changes in category names:
    - Engineering and administrative costs.
    - Construction and installation costs.
    - Operation and maintenance costs.
    - Road user costs (time, fuel, wear and tear, user costs).
    - Environmental costs.
    - Life cycle costs.
    - Safety costs.
    - Risk management costs.
    - Other costs.

  The NETC tool can apply one category or separate subcategories or line items.
- *Step 2: Collect input data (analysis phase).* Researchers noted that "all calculations require two types of data:
    - Input value for quantifiable changes in labor hours, prices, quantities from before and after implementing the research results.
    - The anticipated level of deployment or frequency of activity."
- *Step 3: Populate the benefit estimation tool (analysis phase).* Users enter input data into color-coded Excel templates, modifying the templates as needed.
- *Step 4: Calculate the benefits and the benefit–cost ratio (rebuilding phase).* The Excel workbook automates this process with built-in formulas that link the individual categories and subcategories and perform the calculations.

- *Step 5: Evaluate the results (evaluation phase).* Key outputs of the Excel calculations include the total monetary benefit in current dollars and benefit–cost ratio. Researchers described benefit–cost results as follows:
    - Benefit–cost ratio less than 1.0 indicates the research cost is greater than the potential monetary benefits.
    - Benefit–cost ratio greater than 1.0 indicates the potential benefits outweigh the research costs.

Other elements of the report that may be of particular interest:

- Chapter 4, beginning on page 16 of the report (page 22 of the PDF), presents comprehensive information for gathering and entering inputs for the Excel workbook.
- Appendix A, The Excel Benefit Estimation Tool User's Guide, beginning on page 22 of the report (page 28 of the PDF), describes each spreadsheet within the Excel workbook that is used to calculate benefits. Also included are a description of each benefit category and information to assist users in gathering and entering the data.

Southeast Transportation Consortium

Development of a Guidebook for Determining the Value of Research Results, Interim Report, Yoojung Yoon, Fei Dai and Amin Azimian, Southeast Transportation Consortium and Louisiana Transportation Research Center, June 2016.
https://rppm.transportation.org/Lists/ConfMtgWebinarsWS/Attachments/177/STC%20Interim%20Report%20(16-1PF)_Submitted.pdf

Note: The consortium has suspended this effort to develop a guidebook for determining the value of research results and is planning to classify this publication as a final report.

From the introduction: To achieve the research objective, the specific aims of the work proposed are therefore as follows:

- Investigate all possible aspects (e.g., state DOT organizational structures, state/national transportation missions, research objectives and research attributes such as qualitative or quantitative) to develop a list of research project categories in a hierarchical structure and to prepare the criteria for determining the research types of future projects.
- Define the parameters required for determining the values of research projects in relationship tables/diagrams.
- Develop a straightforward decision matrix to guide public agencies from a starting point (research categories) to an end point (measure quantification methods) with examples.
- Develop a rating method to determine research values by integrating all of the qualitative and quantitative measures.

Related Resource:

Development of a Guidebook for Determining the Value of Research Results, Research Project Capsule, Louisiana Transportation Research Center, February 2016.
https://www.ltrc.lsu.edu/pdf/2016/capsule_16-1PF.pdf
This two-page brief summarizes Southeast Transportation Consortium's 2016 pooled fund study effort described in the June 2016 publication cited above.

STC Synthesis of Best Practices for Determining Value of Research Results, Baabak Ashuri, Mohsen Shahandashti and Mehdi Tavakolan, Southeast Transportation Consortium and Louisiana Transportation Research Center, January 2014.
https://www.ltrc.lsu.edu/pdf/2014/FR_512.pdf
From the executive summary: The overall objective of this project is to synthesize the best practices for determining the value of research results in order to demonstrate the impact that the research has on transportation system features, such as safety, quality and cost-effectiveness. This synthesis presents a critical review of methods used for determining the value of transportation research. Furthermore, it is intended to identify various measures and data sources used for determining the value of research.
….
Flexibility is the key to creating such a guidebook. A proper guidebook should facilitate communicating the value of research. Current practices and research reports collected here can be a good starting point to developing such a guidebook. Last but not least, training is a key to succeed in implementing a proper guide for determining the value of research across all transportation agencies.

Related Resources:

"Synthesis of Methods and Measures for Determining Value of Transportation Research," Mohsen Shahandashti, Baabak Ashuri and Mehdi Tavakolan, *Journal for the Advancement of Performance Information and Value*, Vol. 9, Issue 1, 2017.
https://cibw117.org/2017/07/19/synthesis-of-methods-and-measures-for-determining-value-of-transportation-research/
From the conclusion: Benefit analysis has typically been the most frequently used method to determine the value of research projects. Benefit analysis method can be further broken down to the following approaches within a specific area: before-and-after study, statistical analysis, simulation analysis, assumption-based estimation, experiments, lab experiments, revenue estimation modeling and surveys. Various measures were also identified for determining value of research in different areas of benefits. These measures were categorized for each area of benefit. The major contribution of this paper is to identify and exemplify various methods and measures that have been successfully used for determining value of transportation research in a variety of impact areas.

Determining Value of Transportation Research: Methods, Measures and Data Sources, Mohsen Shahandashti, Baabak Ashuri and Mehdi Tavakolan, Economics of the Sustainable Built Environment (ESBE) Lab, 2014.
http://nctspm.gatech.edu/sites/default/files/u60/Shahandashti%2C%20Ashuri%20and%20Tavakolan.pdf
This poster summarizes key elements of the study described above, including a summary of the "identified methods to determine value of research" that include:

- Benefit analysis:
  - Before-and-after study.
  - Statistical analysis.
  - Simulation analysis.
  - Assumption-based estimation.
  - Field experience.
  - Lab experience.
  - Revenue estimation modeling.

    - Surveys.
    - Benefit in other areas.
- Benefit (dollar) analysis.
- Benefit (dollar)/cost (dollar) analysis.
- Life cycle cost analysis.
- Analysis of dissemination of research output.

The poster also lists the references associated with each of the methods identified above.

State Research and Practices

Arizona

Anticipated Research: **Implementation of Research at ADOT, 2012 to Present**, Arizona Department of Transportation; estimated start date: June 2020; estimated completion date: December 2021.
Project description at https://trid.trb.org/view/1516638
From the project description: In 2012, the Research Center concluded a study that quantified and categorized the implementation or influence of recommendations developed by research studies over the previous 10 years. This study will update that information by examining the quantitative and qualitative impact of research on and benefits to ADOT since 2012. The study will advise the Research Center on modifications to its services, processes and products so as to positively influence the implementation of future recommendations.

Related Resource:

> **Implementation of Research at the Arizona Department of Transportation: Findings and Key Insights**, Diane Ginn and Deb Pryor, Arizona Department of Transportation, October 2014.
> https://apps.azdot.gov/files/ADOTLibrary/publications/project_reports/pdf/spr727.pdf
> *From the abstract:* The study examined 128 research studies completed by the Arizona Department of Transportation (ADOT) Research Center between 2002 and 2012, the extent to which their recommendations were implemented at the department, and the impact of the implemented research. It concluded that for 78 percent of the completed studies, one or more recommendations had been implemented. The study also identified benefits that research provided to the agency, as well as factors affecting the implementation of research and the utilization of Research Center services.

Florida

Financial Achievability of the Florida Department of Transportation Research Projects: Putting the Financial Analysis Framework Into Action, Patricia H. Born, Randy E. Dumm and Robert J. Eger III, Florida Department of Transportation, February 2018.
Report available for download at https://rosap.ntl.bts.gov/view/dot/36021
From the abstract:

> The Florida State University Center for Insurance Research conducted research and developed a financial analysis framework, the Financial Achievability Model (FAM), that will allow the Florida Department of Transportation (FDOT) Research Center to better assess research projects. In this report, the researchers illustrate the use of the FAM to evaluate the

costs and benefits associated with eight FDOT research projects. The main focus of the research is to identify the challenges of putting the FAM into practice and to develop processes that facilitate this. The primary challenge is identifying sources of information that can show the potential benefits of the research.

The report describes the following elements of the analysis:

- Information gathering.
- Selection of projects.
- Collection process for management costs.
- Application of framework.
- Discussion of initial data collection results.
- Framework enhancements for projects involving:
    - New materials.
    - New equipment.
    - Change in process.
- Length of time for analysis and appropriate discount rates.
- Evaluation (demonstrated with eight projects).

Researchers recommended the use of project worksheets that vary depending on the type of project and identification of areas in which data is necessary for the evaluation, and noted that the "framework is flexible and can be adapted for use in evaluating different types of projects, but project managers need guidance when considering the specific inputs to the model. Successful implementation of the framework within FDOT will require the establishment of a clear process for data collection that starts at the research kickoff presentation."

In Chapter 8, beginning on page 68 of the report (page 78 of the PDF), researchers describe developments in the following areas:

- Identification of potential research benefits in the proposal.
- Identifying sources of information on benefits.
- Promoting the identification of research benefits in project scopes.
- Addressing benefit data collection issues in kickoff presentations.
- Kickoff surveys.
- Discussing benefits in final reports.

Related Resources:

Financial Achievability of the Florida Department of Transportation Research Projects: Putting the Financial Analysis Framework into Action, Research Center, Florida Department of Transportation, undated.
https://rosap.ntl.bts.gov/view/dot/36021/dot_36021_DS2.pdf
This one-page brief summarizes the research project cited above. *From the publication*:

> The researchers previously developed the FAM in FDOT project BDK83-977-24. The FAM incorporates an understanding of the multiple stages of decision making and execution that are characteristic of research projects. It requires collection of cost–benefit data to better quantify the benefits that could be realized through implementation of a research project.

In this project, the FAM was applied on several FDOT projects as a pilot to evaluate its use and to understand the obstacles to more general implementation. First, the researchers met with FDOT project managers (PMs) to identify projects. The researchers reviewed and analyzed over 170 FDOT projects completed between 2013 to 2015 to understand the FDOT research process.

Eight projects were selected for application of the FAM. … The FAM was then applied to each of the study projects, leading to recommendations for facilitating implementation of the FAM. The researchers also developed a better understanding of project characteristics that are more suitable for application of the FAM.

"Developing a Framework for Financial Achievability of Department of Transportation Research and Development Projects," Patricia H. Born, Randy E. Dumm and Robert J. Eger III, *Transportation Research Record 2480*, pages 11-19, 2015. Citation at http://dx.doi.org/10.3141/2480-02
From the abstract: A financial analysis framework was developed to allow departments of transportation to assess research projects better. The framework recognizes that the research process contains multiple stages of decision making, and the framework details the information needed at each stage. The framework is described as it applies to each step in the research process: identifying potential research projects, evaluating research proposals, monitoring ongoing research projects and evaluating final research reports. The framework also considers the decision to implement the research and its potential effects on employees. The application of the framework is illustrated with several Florida Department of Transportation research projects that involve the development of a multipurpose survey vehicle for evaluation of Florida roadways. This illustration allows for an explanation of each step in the framework with actual data from research reports and other internal or external sources. Although the framework is flexible and can be adapted for use in evaluating different types of projects, some judgment will be required when the specific inputs to the model are considered. Successful implementation of the framework will require focused data collection with emphasis on identifying the potential net benefits of research projects.

Project Manager Forms, Research Center, Florida Department of Transportation, undated.
See Attachment A.
This series of forms is used by Florida DOT project managers to track project implementation and benefits throughout the life cycle of a research project. Data included in the forms is used to populate the agency's SharePoint data repository and its Research Contract Administration system, a project management database. Included are:

- Research Center Project Manager Kickoff Survey.
- Research Center Project Manager Midpoint Survey.
- Research Center Project Manager Closeout Survey.
- Research Center Deployment Plan.

Repository for Data Management and Benefits, SharePoint Screenshot, Research Center, Florida Department of Transportation, undated.
Provided to Caltrans separately.
This screenshot of a sample project shows the SharePoint data repository under development that will allow the agency to track project-related data and benefits measurement.

Indiana

INDOT Research Program Benefit Cost Analysis—Return on Investment for Projects Completed in FY 2018, Bob McCullouch, Governor's Office and Indiana Department of Transportation, December 2019.
https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=3267&context=jtrp
From page 2 of the report (page 5 of the PDF):

> All FY [fiscal year] 2018 completed projects were reviewed to determine if they were a viable candidate for BCA [benefit–cost analysis]. Selection was based on 1) can the costs and benefits be quantified on outcomes that impact INDOT [Indiana DOT] operations, 2) what are the implementation costs, and 3) what is the expected impact time period? The ROI [return on investment] analysis included the following savings components:
>
> - *Agency savings and costs*. This was based on research findings, engineering judgment/estimates from INDOT BO (business owner) and SME (subject matter experts), available data and projected use of the new product/process.
> - *Road User Costs (RUC) Savings*. RUC includes value of time (VOT) and vehicle operating costs (VOC). RUC unit values will be obtained from current INDOT standards which INDOT provided.
> - *Safety Costs (SC) Savings*. Safety costs (SC) can include a before and after evaluation or engineering judgment from BO/SMEs to calculate the reduction in crashes (e.g., property damage, fatalities, etc.). SC unit values will be obtained from current INDOT standards which INDOT provided.
>
> Accrued Benefits will be the combination of agency savings, RUC cost savings and SC savings. While Road User Cost (RUC) savings and Safety Cost (SC) savings are a primary goal of INDOT, savings accrued primarily benefit the customer (road user) and may not result in agency cost savings. In this year's analysis only SPR-3832 reported RUC and SC savings. A separate B/C [benefit–cost] ratio is calculated for Agency Savings and Safety/RUC Savings. As Safety and RUC savings are often related, these savings were combined into the same category.

INDOT Research Program Benefit Cost Analysis—Return on Investment for Projects Completed in FY 2017, Bob McCullouch, Governor's Office and Indiana Department of Transportation, December 2018.
https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=3223&context=jtrp
From page 6 of the report (page 9 of the PDF):

> Annual BCA provide an assessment of INDOT's investment in [r]esearch on an annual basis. For the last two years, 2016 and 2017, the investment indicates positive returns during the life of individual projects implemented. The majority of the projects in the last two years, 48 out of 66 total research projects benefits are not quantifiable due to the unavailability of quantifiable data, but provide documented qualitative benefits. [Thirteen] projects where benefits were quantified, produced significant agency savings and [three] projects produced significant road user cost savings. For the combined years of 2016 and 2017 the [a]gency and Road User BCA are:
>
> BCA (2016 and 2017) Agency Savings = $266,149,000/$10,388,000 = 25 to 1
>
> BCA (2016 and 2017) User Savings = $301,990,799/$10,388,000 = 29 to 1

INDOT Research Program Benefit Cost Analysis—Return on Investment for Projects Completed in FY 2016, Bob McCullouch, Governor's Office and Indiana Department of Transportation, December 2017.
https://rosap.ntl.bts.gov/view/dot/36131
From page 6 of the report (page 9 of the PDF): The aggregate benefit is significant, resulting in more than $367 million in savings over the projected service lives (in 2016$). The basis for the numbers used in the BCA came from INDOT personnel, [i]ndustry [a]ssociations and researchers. These are described in detail in the individual analyses located in the [a]ppendix.

A ROI of 59 to 1 is considered an outstanding return on the research investment. While the ROI is significant, a review of the individual project analysis shows a conservative approach was taken in any assumption made and in the calculations, and actual savings may be much higher. This analysis indicates that INDOT is receiving a significant return on its research investment which will continue to grow due to recently passed legislation (HB 1002), authorizing more funding for construction, reconstruction and preservation.

For 29 projects completed in FY 2016, quantifiable benefits could not be calculated, however other qualitative benefits resulted that brought significant value to the [d]epartment and are highlighted in the annual IMPACT report. Ten of the projects were quantified and described herein, and three of the projects were not successfully implemented due to various reasons.

"Quantifying the Value of Research in Indiana," Tommy Nantung, *AASHTO RAC Annual Meeting*, July 2015.
https://research.transportation.org/wp-content/uploads/sites/31/2017/07/2_C_vortf_indot_presentation-rac2015.pptx
This presentation describes the use of a modified internal rate of return (MIRR) to assess the benefits of Indiana DOT's research. The MIRR spreadsheet was developed by Indiana DOT's Central Office to calculate the value of ROI in research and development. Investment is calculated by the schedule and amount of free cash returned to the investor; costs to conduct research and development are all-inclusive and comprise direct expenditures as well as indirect costs.

Related Resources:

An Economic Analysis Methodology for Project Evaluation and Programming, Yi Jiang, Guangyuan Zhao and Shuo Li, Indiana Department of Transportation, August 2013.
https://rosap.ntl.bts.gov/view/dot/26781/dot_26781_DS2.pdf

Note: While the economic analysis this publication describes is not applied to transportation research, we include it to provide details of a previous practice used by Indiana DOT's research program that applied MIRR to calculate research benefits.

From the abstract: This research was conducted to provide the Indiana Department of Transportation (INDOT) with a uniform economic analysis methodology. The developed economic evaluation model applies the methodology of life-cycle benefit cost analysis to perform economic analysis for proposed highway projects. As a result of this research, an Excel based computer program, the Indiana Highway Economic Evaluation Model (IHEEM), was developed to provide a convenient tool for INDOT personnel to implement the method. The main costs and benefits contained in the model are agency costs and user benefits. Agency costs include initial costs, routine maintenance costs, rehabilitation costs, and remaining value of the facility. User benefits contain travel time savings, vehicle operating

cost savings, and crash reduction savings. In addition to the deterministic method for cost and benefit analysis, an alternative probabilistic approach was also developed and incorporated into IHEEM so that the outputs can be expressed as ranges of values with likelihoods of occurrence.

INDOT R&D Financial Valuation Model (RDVAL), Version 2.0, Indiana Department of Transportation, July 2011.
Provided to Caltrans separately.
This Excel workbook was used for the agency's calculation of MIRR. *From the workbook*:

> RDVAL is an Excel based spreadsheet used to calculate the value (return on investment) of an investment in research and development, including the cost to implement the results of such R&D [research and development] and institutionalize the findings for sustainable benefit to INDOT and its customers.

Kansas

Research, Development and Technology Transfer Procedures Manual, Kansas Department of Transportation, Revision 3, October 2017.
https://www.ksdot.org/Assets/wwwksdotorg/bureaus/BurResearch/KDOT%20RD&T%20Manual%20October%202017.pdf
Kansas DOT tracks the benefits of the K-TRAN research program using its Research Implementation System. Implementation is considered at each step in a project's life cycle:

- Principal investigator includes a draft implementation plan in the project proposal and implementation recommendations in the final report.
- Project monitor prepares an implementation plan at the time the final report is published. The implementation plan "details what findings and recommendations from the project will be implemented along with the responsible parties and the expected costs and benefits of doing so," and includes "tables for the project monitor to assess the benefits of the project by category, if implemented, and to assess the research team performance for the project. The Implementation Plan form also includes the *Research Project Implementation Progress Report*."
- Area panel leader approves the implementation plan and completes the annual research project implementation summary report.
- Research Unit prepares the annual research implementation summary report and presents it to the Research Program Council and Research Technical Committee.

Related Resources:

Guidelines for Estimating the Triennial Benefits of Kansas Transportation Research and New Developments (K-TRAN) Research Projects, Robert W. Stokes, Michael W. Babcock, Eugene R. Russell and Margaret J. Rys, Kansas Department of Transportation, July 2004.
https://pdfs.semanticscholar.org/d6fb/0d5cc7e02eb4595f3651a43e88b2aa671430.pdf?_ga=2.51137577.1442357948.1588882644-180670685.1581623323
Chapter 3, Guidelines for Estimating the Benefits of K-TRAN Research Projects, beginning on page 8 of the report (page 15 of the PDF), discusses two approaches to assessing the benefits of transportation research:

- *Traditional benefit–cost techniques*. Can be used when the economic impacts (benefits and costs) of transportation research projects can be expressed primarily in monetary terms to assess the economic effectiveness of the project.
- *Multiobjective analysis*. Applicable to those cases where project benefits cannot be expressed in strictly monetary terms. In these situations, project benefits are assigned numeric ratings that reflect how well the research results satisfied the study objectives.

A summary of recommended guidelines begins on page 10 of the report (page 17 of the PDF) and include:

- Step 1: Determine if research findings can be implemented.
- Step 2: Identify benefit impact areas affected by the research project.
- Step 3: Assign a numeric rating to the applicable benefit categories.
- Step 4: Document the results of Steps 2 and 3.
- Step 5: Estimate the potential economic impacts of the research.

The report's authors advise the principal investigator and project monitor attempting to quantity benefits to "brainstorm on the implications of a range of potential strategies concerning the implementation of the research results." Recommended questions to consider:

- Does the research propose (or imply) changes in existing policy, standards or practice?
- If the research proposes changes in existing policy, standards or practice, how soon could the research findings be implemented?
- If the research proposes changes in existing policy, standards or practice, what would be the scope of the changes in terms of agencies and geographic areas affected?
- If the research proposes changes in existing policy, standards or practice, are there specific agencies and/or project sites where the research results could be evaluated?
- Does the research provide any evidence concerning the potential magnitude of the impacts of the proposed changes?
- Does the research provide any evidence concerning the potential magnitude of the economic impacts of the proposed changes?

Research Program Council Meeting Agenda, Kansas Department of Transportation, February 2020.
See Attachment B.
This set of meeting materials for Kansas DOT Research's oversight body includes a status report that provides a periodic assessment of the benefit–cost ratio for the overall program and implemented projects.

Status Report, Kansas Department of Transportation, undated.
Provided to Caltrans separately.
This is the Excel workbook Kansas DOT Research uses to track research projects and the associated benefit–cost ratio.

Minnesota

Development of a Process for Quantifying the Benefits of Research, Howard Preston and Jacqueline Dowds Bennett, Minnesota Department of Transportation, July 2017.
http://dot.state.mn.us/research/reports/2017/201713.pdf
From the abstract:

> This project developed an easy-to-apply process for quantifying the potential benefits of research and comparing the monetary benefits of implemented research results with the cost of doing the research.
>
> Researchers applied this process to a limited number of previously completed MnDOT research projects and determined that the potential three-year cost savings (approximately $69 million) of just 11 sample projects was enough to fund the cost of the entire research program for approximately seven years.
>
> The ultimate outcome of this project is a guidance document and user tool for quantifying the benefits of research recommendations.

An Excel workbook (described in the citation below) is used to execute the seven-step process and generate the benefit–cost ratio.

Related Resource:

> **User Guide: Process for Quantifying the Benefits of Research**, Howard Preston and Jacqueline Dowds Bennett, Minnesota Department of Transportation, July 2017.
> http://dot.state.mn.us/research/reports/2017/201713A.pdf
> *From the abstract*:
>
> > The purpose of this user guide is to explain the seven-step benefit quantification process and use of Research Services' benefit quantification spreadsheet tool. The tool calculates the potential benefit of research recommendations in terms of the potential cost savings that could be realized by their implementation, and estimates a benefit–cost ratio. The tool performs the calculations with user input values and serves as a repository for the data, assumptions and sources included in the quantification process.
>
> Below is a brief description of the seven-step process:
>
> - *Step 1: Determine benefit category*. Users select all appropriate benefit categories from the following list:
> - Construction saving (materials, labor/time, equipment).
> - Decrease engineering/administrative costs (planning/design costs, paperwork).
> - Decrease life cycle costs.
> - Environmental aspects (pollution, hazardous waste reductions, recycling).
> - Increase life cycle.
> - Operation and maintenance saving (materials, labor/time, equipment).
> - Safety (reduction of crash frequency and/or severity).
> - User benefits (time/dollars).
> - Risk management (tort liability, environmental fines).

- *Step 2: Build the benefit estimation tool*. The user selects the applicable templates based on the benefit categories identified in Step 1 and assembles them into a single workbook.
- *Step 3: Collect input data*. The authors note that "[t]he necessary data to estimate potential benefits will ideally be included in the research report. If this is not the case, the user should pursue the data through other means such as meeting with the MnDOT staff and university researchers involved with the project or staff with outside sources such as local agency engineers and industry representatives."
- *Step 4: Document implementation of recommendations*. The user is directed to "include the number of potential locations for implementation, but not necessarily specific locations (with the exception of a safety benefit calculation for a designated location). Data from the existing condition before implementation should be representative of the cost/quantity/activity prior to the start of construction or be representative of the current practices."
- *Step 5: Populate the benefit estimation tool*. The user enters all the required input data into the appropriate color-coded cells.
- *Step 6: Determine benefit*. The guide notes that the "user determines the benefit during this sixth step by referring to the value presented in the Net Present Value column of the template spreadsheet. If more than one type of benefit is likely from a set of recommendations, the user can document the applicable benefit category and corresponding Net Present Value along with the total benefit on one of the benefit calculation tabs in the quantification spreadsheet."
- *Step 7: Compare benefit to cost*. The Excel workbook will automatically perform the benefit-to-cost calculation after the user has entered all necessary data and information in the Benefit–Cost Ratio Estimation section of the spreadsheet.

MnDOT Research Program Strategic Plan 2017-2022, Vivek Sakhrani, Donald Ludlow, Dave Ekern and Gary Allen, Minnesota Department of Transportation, March 2017.
http://dot.state.mn.us/research/reports/2017/201712.pdf
From the abstract:

> In response to the top transportation trends in Minnesota, and opportunities and challenges facing its transportation system, MnDOT [Minnesota DOT] has developed this five-year Research Program Strategic Plan (2017–2022) to take stock of its research portfolio, refine its research strategy to support its overall vision and mission, and communicate the value of its research to a variety of stakeholders and audiences.

Beginning on page 34 of the strategic plan (page 42 of the PDF) is an examination of MnDOT's assessment of research program outcomes. Researchers note that the spreadsheet-based estimation tool "standardizes the formulas and relationships across the templates, which can easily be updated when necessary, so that the entire organization has a consistent approach to benefit quantification."

Best Practice Guide for Quantifying the Benefits of MnDOT Research, Minnesota Department of Transportation, June 2013.
http://www.dot.state.mn.us/research/documents/Best_Pract_Guide_ResearchBenefits_Final_06_27_13.pdf
From the introduction and executive summary: The focus of this project is on program-level practices. In particular, MnDOT [Minnesota DOT] was interested in learning about process

steps, key milestones during research projects, and tools used to quantify benefits. A related project, sponsored by the Southeast Transportation Consortium (STC) and conducted by Georgia Institute of Technology, created a synthesis of best practices for determining the value of research results. The focus of the synthesis was on methods, metrics and data. The STC synthesis and this MnDOT project are highly related and complementary, focusing on two different aspects of the topic.

Mississippi

Anticipated Research: A Framework for Determining Value of MDOT Research Projects, Draft Research Needs Statement, Mississippi Department of Transportation, undated.
See Attachment C.
This research needs statement describes a project that will kick off soon. The research is expected to include the following tasks:

1. Take some past research studies and quantify benefits, either quantitative and/or qualitative.
2. For studies that were not successfully implemented, identify barriers and reasons.
3. Develop a framework for Research Division staff, subject matter experts (SMEs) who participate in research study [T]echnical [A]dvisory [C]ommittees (TACs) and PIs [principal investigators] to use when developing and refining research proposals and scopes of work (SOWs). This framework will provide guidelines for identifying a set of performance measures as a function of type or category of research. Ideally each performance measure will be quantified at the onset of the given study to serve as a basis for comparison subsequent to the conclusion of that research and/or implementation of the recommendations from that research.

North Carolina

Capturing and Communicating the Value of NCDOT Research, Thomas Nicholas II, Don Chen and John Hildreth, North Carolina Department of Transportation, February 2018.
https://connect.ncdot.gov/projects/research/RNAProjDocs/2017-21%20Final%20Report.pdf
Researchers developed a new cost–benefit analysis methodology to include both quantitative and qualitative benefits of agency research. See Chapter 3, Development of a Cost Benefit Analysis Methodology, which begins on page 10 of the report (page 21 of the PDF) for details.

Survey and interview findings informed researchers' development of "research success indicators":

- Active North Carolina DOT research champion.
- Proposal quality.
- Research need priority.
- Researcher experience with North Carolina DOT.
- Regular communication from the principal investigator.

As the report notes, "[t]hese success indicators were used as independent variables in conjunction with the categorical variables of highly successful, successful and moderately successful in an ordinal regression model to predict the probability of project success. This prediction model will assist in identifying potential high value projects."

From Chapter 6, Conclusions and Recommendations (page 41 of the report, page 52 of the PDF):

- A new Cost Benefit Analysis Methodology [CBA] was developed and presented. It is recommended that the new CBA tool be used for newly awarded projects. The benefit realized from soft costs (safety, environmental, etc.) and qualitative variables (knowledge, dissemination, student exposure, etc.) were included.
    - The evaluation of the impact factor, K, relies on a good engineering judgment by the research group as to the level each impact factor was truly engaged.
    - In defining monetary values in the calculation of soft costs, it is recommended that politically neutral references such as the Department of Labor, OSHA [Occupational Safety and Health Administration], FHWA [Federal Highway Administration], etc., be used to avoid inflation of monetary benefits.
    - End user costs and global impact costs (e.g., environmental at a global level) should be avoided when calculating soft costs. The resulting monetary benefit is at a level that is not believable and therefore is difficult to communicate.
- A performance prediction model was developed to predict the probability of success in terms of highly successful, successful and moderately successful. The presented models, at current confidence levels should be considered a framework for research prediction.
    - The quality of the proposal or research idea was found to be an indicator for success in PI [principal investigator] selection but not an indicator of project success. All proposals regardless of project outcome, were rated as high to very high in quality.
    - The current data set is biased towards highly successful projects. The levels were adjusted from [h]igh, medium and low probability to high, medium and moderate due to the data bias. The model should be amended as unsuccessful project data becomes more available.
    - The confidence level of PI [e]xperience is currently well below target level. However, it is readily apparent that PI [e]xperience is an indicator for success and the low confidence level is a function of the small data set.
    - Due to the data set size, outliers cannot be properly addressed/removed and are affecting the model accuracy. The performance prediction model should be redeveloped once more project dat[a] becomes available. Ideally, a homogenous data set for all three success levels of [10] or more will result in a more robust ordinal logistic regression model.
    - According to the current model, research need impacts project success four times more than the research champion and six times more than the experience of the principal investigator. Again, utilizing the continuous improvement process at the research needs statement level will improve the probability of project success.

Ohio

Anticipated Research: Technology Transfer Support and Evaluation of ROI for Ohio's SP&R-B Program, Ohio Department of Transportation, December 2019.
http://www.dot.state.oh.us/Divisions/Planning/SPR/Research/RFP/Documents/2020-RFPs/2020-17_TTROI_ver2.pdf
Ohio DOT is currently contracting for work to begin in connection with this request for proposal (RFP). At the time of publication, a specific start date for the research effort was not known.
From the RFP:

> In December 2019, FHWA approved ODOT's [Ohio DOT's] revised Research Manual. As part of the revision, the process for tracking implementation (chapter 6) was significantly changed. As of this posting, ODOT has **not** utilized this new process. Both ODOT and ORIL [Ohio's Research Initiative for Locals] intend to utilize the new process.
>
> The researcher is expected to provide a work plan that will address the following items:
>
> - Review the Research Retrospective (2007-2012) and provide an introductory executive summary that will allow for the publication of the report.
> - As appropriate, the researcher may opt to evaluate ODOT's new process for tracking and reporting on implementation of research results and provide recommendations for execution and potential improvements.
> - Develop a repeatable methodology for assessing a project[-] and program-level ROI for both ODOT and ORIL programs.
> - Upon approval, execute the methodology. Note, based on discussions with the Technical Advisory Committee and the methodology developed, it may be determined that the methodology will be piloted on only one program as opposed to both.

Research Development and Technology Transfer (RD&T^2) Manual of Procedures, Ohio Department of Transportation, November 2019.
http://www.dot.state.oh.us/Divisions/Planning/SPR/Research/researchmanual/Chapters/ResearchManual.pdf
Chapter 6, Implementation, which begins on page 40 of the manual (page 41 of the PDF), includes the following about Ohio DOT's approach to implementation assessment and ROI:

> During the project close-out meeting (see Chapter 5.10), the Research Section will conduct the final implementation assessment with the TAC [Technical Advisory Committee]. This assessment is developed by ODOT [Ohio DOT] staff, not the PI [principal investigator], and is separate from the project's final report.
>
> The final implementation assessment will consist of the following:
>
> - Review of the most recent implementation assessment and revise with implementation activities that have been in process.
> - Review the PI's recommendations for implementation from the final report and develop the TAC's recommendations for implementation. The TAC's recommendations may or may not coincide with the PI's recommendations but should state ODOT's intentions concerning the research results. Identify the following information for the TAC's recommendation:
> - General description of action items and approximate timeline for the completion of those items.

    - Identify whether the ROI for implementation is qualitative, quantitative or both. Identify the information needed to calculate the ROI:
        - Data—what is needed and how to access it.
        - Contact(s)—person(s) who can assist with the ROI calculation.
        - Duration—timing of when the calculation should occur and how frequently it should it be updated.
- Identify the primary point of contact for follow-up of implementation activities to report to the Research Section.
- Develop a schedule for the Research Section to follow up with the primary point of contact for implementation activities.

The final implementation assessment will be shared with the TAC and other staff as appropriate. Responsibility for implementation activities ultimately lies with the sponsoring [o]ffice [a]dministrator(s) and the TAC. The Research Section will assist these individuals by following up on the progress based on the time frame established in the final implementation assessment. The Research Section will continue to check on the progress with the appropriate individual(s) to ensure information is gathered for determining ROI and capturing realized benefits from the research findings.

Related Resource:

Research Implementation Summary: Rapid Orthophoto Development System, Office of CADD and Mapping Services, Ohio Department of Transportation, November 2013.
OHDOT_SampleImplementationSummary.pdf
This sample of Ohio DOT's Research Implementation Summary completed after a research project concludes includes a section for implementation evaluation and ROI.

Texas

Value of Research Template, Research Forms, Texas Department of Transportation, undated.
http://ftp.dot.state.tx.us/pub/txdot-info/rti/forms/value-research.xlsx
This Excel workbook used by Texas DOT to determine the value of a research project includes three worksheets:

- *Selection*. The user selects from among 19 benefit areas that are qualitative, economic or both, and impact Texas DOT, the state or both.
- *Economic benefit variable amounts*. For the economic benefit areas, the template is set up to allow the user to easily enter up to five variable amounts (more variable amounts can be added if needed).
- *Value of research*. The final worksheet provides data and graphics that illustrate the project's economic value in total savings, net present value, payback period (in years) and a cost–benefit ratio.

University Handbook, The Research and Technology Implementation Division, Texas Department of Transportation, March 2019.
https://ftp.dot.state.tx.us/pub/txdot-info/rti/university-handbook.pdf
This publication prepared for university researchers participating in Texas DOT's research program describes the VoR template. *From page 32 of the PDF*:

The Performing Agency shall complete the Value of Research Template, and include it with a write-up on the economic based calculations, a description of economic variables used within the calculations, and the qualitative values of the [p]roject [s]ponsor's selected benefit areas.

The [p]erforming [a]gency shall direct all benefit area data requests to the [r]eceiving [a]gency's PM [project manager]. A summarization of this information shall be included within the Project Summary Report (PSR) and a detailed analysis should be submitted as a separate section in the Research Report (R1).

Guidance for completing the form appears in Chapter 6. *From page 56 of the PDF*:

Value of Research (as part of R1)
The initial version of the Value of Research (VoR) should be included in the [p]roject [a]greement as the first deliverable. The VoR template shall be completed and included with the write-up on the economic based calculations, the description of economic variables used within the calculations, and the qualitative values of the [p]roject [s]ponsor's selected benefit areas within a Tech Memo.

- The VoR for TxDOT [Texas DOT] and the State of Texas shall be determined for all projects. Value turns the subjective into the objective, which can often turn uncertainty into support. It also builds stakeholder support for projects and to further research if new phases or possibilities arise. It can also uncover additional benefits. Determining value services practitioners to investigate benefits that might not have seemed obvious at project inception.

Utah

Research and Innovation Division: Manual of Instruction, Utah Department of Transportation, May 2018.
https://www.udot.utah.gov/main/uconowner.gf?n=9805417978678989
From page 69 of the manual (page 74 of the PDF):

8.2.3 Benefit–Cost Studies
Studies should be undertaken every three to five years to measure the benefits of research. The analysis should include all major projects and initiatives completed during that time period. The benefit–cost ratios of the research program should be estimated.

These studies estimate the benefits of UDOT's [Utah DOT's] major research projects and compare with the costs expended to conduct the studies. In addition, the benefits of various types of projects can be projected, including those related to infrastructure, operations, administration and policy research. Three such studies are listed in the [b]ibliography.

Some research initiatives are not fully implemented immediately after the project is completed. For this reason it is necessary to allow a period of time between the project completion and the estimation of the benefits of the deliverables. By allowing this time period end users of the research products have had sufficient time to determine if the concept will really work as reported, and a better estimation of the benefits will emerge. However, it is important to maintain contact with the project champions and end user in the interim, as detailed in the implementation plan, to ensure that project implementation knowledge is not lost due to staffing changes.

The benefits and costs of individual projects are estimated to acquire composite values for the study period. The main objective of the analysis should be:

- Estimate the benefits of major research projects and compare them with the costs to conduct the studies.
- Determine which types of projects produce the highest benefit–cost ratios and which projects are more often unsuccessful or marginal.
- Make recommendations concerning the research program and the types of projects undertaken in the future.

Investing in Utah Transportation Research, Douglas I. Anderson, Utah Department of Transportation, July 2016.
https://www.udot.utah.gov/main/uconowner.gf?n=33001711481373783
From the abstract:

This study was initiated to estimate the benefits of UDOT's research projects over a four-year period, and estimate a benefit–cost ratio for the program. Benefit information gathered in this study indicate that the studies completed during the years 2009 through 2012 by the UDOT [Utah DOT] Research Program had an estimated benefit–cost ratio of 14. This included 76 deliverables produced by 66 projects.

Projects were also assigned a grade based on the success of the project and the value of the deliverables. The four year program received a grade of 3.0 based on a 1 to 4 rating system. In addition ratings were compiled for the project managers, principal investigators, and the UTRAC Process used to select projects for funding. Recommendations were provided to aid UDOT research managers in improving the implementation of research deliverables and products.

A separate guide—*Program to Measure Research Benefits and Track Implementation: Manual of Instruction*—was prepared as part of this contract. This guide, cited below and currently being revised, describes the processes and tools for use in evaluating Utah DOT's research program on an annual basis.

Related Resource:

Program to Measure Research Benefits and Track Implementation: Manual of Instruction, Utah Department of Transportation, July 2016.
See Attachment D.
Developed in connection with the July 2016 report, *Investing in Utah Transportation Research*, this publication is undergoing revision after completing the agency's most recent benefits calculation exercise. The manual describes the data gathering process for calculating research benefits, including the review and use of interviews, forms, reports and surveys to track project progress and calculate research benefits. Sample forms and examples of the benefit calculation method are presented.

Benefit types include:

- Asset management.
- User impacts.
- Safety.
- Quality of life.
- Environmental.

Chapter VII, Benefit–Cost Calculations, beginning on page 22, provides calculations and examples of their application:

Benefit Calculations:

- Number of items increased, saved, avoided, etc.
  - Facility life in years.
  - Crash number/severity prevented.
  - Person-hours saved.
- Value of item.
  - Cost of a facility, crash costs, wages, etc.
- Percentage attributed to research project.
  - Portion of initiative enhanced by the research.

Benefit = Number x Value x Percentage

Cost of Research Estimates:

- Contract amount.
- TAC [Technical Advisory Committee] investment.
  - Number of members x TAC meetings x Ave hours x Loaded hourly rate.
- PM [project management] costs.
  - Assume 10[%] to 30% of project contract.

Cost = Contract + TAC + PM costs

(Note: For program B/C estimates include all project costs even when benefits could not be identified.)

Benefit–Cost Ratio Calculations:

Benefit/Cost = (Number x Value x Percentage)/(Contract + TAC + PM costs)

Measuring the Benefits of Transportation Research in Utah, Douglas I. Anderson, Utah Department of Transportation, September 2010.
https://www.udot.utah.gov/main/uconowner.gf?n=1339002847990478
From the abstract: This study was initiated to estimate the benefits of UDOT's [Utah DOT's] research projects over a three-year period, estimate a benefit–cost ratio for the program, and provide feedback on the management processes used by the research staff.

The data gathered in this study indicate that the studies completed during the years 2006, 2007 and 2008 by the UDOT Research Program had an estimated benefit–cost ratio of 17. This included the results from 46 deliverables produced by 41 projects.

The highest benefits were achieved by studies on big ticket items, such as highways, bridges, traffic control devices and right-of-way. Safety related studies also show significant benefits.

Wyoming

Evaluation of the WYDOT Research Center (Phase III), Promothes Saha, Nikolai A. Greer, Er Yue and Khaled Ksaibati, Wyoming Department of Transportation, March 2018.
http://www.dot.state.wy.us/files/live/sites/wydot/files/shared/Planning/Research/1806F%20RS04217%20Evaluation%20Research%20Center.pdf
From the abstract:

> This study performed a detail analysis on the proposals submitted to Wyoming Department of Transportation (WYDOT) from 2011 to 2017 to evaluate the effectiveness of the WYDOT Research Center. The analysis included the investigation of performance measures, and compared that to the Phase II [s]tudy completed in 2012. These performance measures are quantifiable, meaning they are designed to place a score or value on the accomplishments of the WYDOT Research Center, which can then be used to make managerial decisions for the Research Center. … In addition, a methodology for benefit-to-cost analysis (BCA) was developed to be included as a future performance measure.

Chapter 7, Methodology for Benefit-to-Cost Analysis (BCA), which begins on page 59 of the report (page 71 of the PDF), describes the general BCA methodology. The authors note that a future study will develop a BCA tool.
Among the sample data the authors provide are typical costs of a research project and project implementation. The current effort includes templates the agency can use to estimate a benefit–cost ratio for the following types of projects:

- Infrastructure upgrade.
- Preservation.
- Safety.
- Wildlife studies.
- Shared knowledge.
- Public affairs.

Templates available in Appendix 6 (see page 146 of the report, page 158 of the PDF) provide fill-in forms for costs and benefits input tables.

Related Resources:

> **"Development of Benefit Cost Analysis Tools for Evaluating Transportation Research Projects,"** Nikolai Greer and Khaled Ksaibati, *Transportation Research Record 2673*, pages 123-135, January 2019.
> Citation at https://journals.sagepub.com/doi/abs/10.1177/0361198118821675
> *From the abstract*: The purpose of this paper is to develop benefit cost analysis (BCA) tools to assist transportation agencies in evaluating transportation research projects. The BCA tools provide analysis methods for estimating the benefits for changes in the level of service (LOS) of a roadway, reductions in the vehicle travel time, changes in vehicle operating costs and reductions in the number of crashes. Three case studies were investigated to illustrate the usage of the BCA tools.

Evaluating Department of Transportation's Research Programs: A Methodology and Case Study, Justin Terfehr and Khaled Ksaibati, Wyoming Department of Transportation, June 2012.
https://rosap.ntl.bts.gov/view/dot/27345/dot_27345_DS1.pdf?
From the abstract: This report will present a methodology for conducting an evaluation of a research program within a transportation agency. The methodology provides [10] performance measures that are used to summarize the findings of the evaluation. These performance measures are quantifiable, meaning they are designed to place a score or value on the accomplishments of the research program, which can then be used to make managerial decisions for the research program.

Contacts

CTC contacted the individuals below to gather information for this investigation.

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Appendix A: Survey Questions

The following survey was distributed to state DOT members of the American Association of State Highway and Transportation Officials (AASHTO) Research Advisory Committee.

Measuring the Benefits of Transportation Research

Note: The response to the question below determines how a respondent is directed through the survey.

(Required) Does your agency measure the benefits of the investments made in transportation research? This measurement could be at the project or program level.

- No (Skips the respondent to **Agencies Not Measuring Research Project or Program Benefits**.)
- Yes (Skips the respondent to **Measuring Research Project or Program Benefits**.)

Note: After answering the question below, this set of respondents skips to the **Wrap-Up** section of the survey.

Agencies Not Measuring Research Project or Program Benefits

Does your agency have plans to measure research project or program benefits?

- No
- Yes (Please describe your agency's plans.)

Measuring Research Project or Program Benefits

1. From the list below, please select the elements of your agency's research program that are included in the benefits measurement process. Select all that apply.
    - All proposed research projects
    - Selected proposed research projects
    - All completed research projects
    - Selected completed research projects
    - Portfolios of completed research projects segregated by research focus areas
    - A programwide assessment
    - Other (Please describe.)
2. At what point(s) in the research cycle does your agency attempt to measure the anticipated benefits of a research project? Select all that apply.
    - As a project is being proposed
    - While a project is underway
    - Immediately after a project concludes
    - One to two years after project completion
    - Two to three years after project completion
    - More than three years after project completion
    - Other (Please describe.)

3. How often does your agency examine or report on the benefits identified at the project and/or program levels?
    - Monthly
    - Quarterly
    - Periodically throughout the year
    - Annually
    - Every two years
    - Every three years
    - Other (Please describe.)

Data

1. Please identify the data your agency uses to measure the benefits of transportation research by selecting all that apply.
    - Crash costs
    - Crash data
    - Facility life
    - Implementation costs
    - Labor hours
    - Labor rates
    - Life cycle estimates
    - Maintenance history
    - Material costs
    - Material quantities
    - Project costs
    - Technical panel participation costs
    - Time required to complete an activity
    - Traffic volume
    - Travel time
    - Vehicle operating costs
    - Other (Please describe.)
2. Does your agency use a project proposal or preliminary deliverable to inform the benefits measurement process?
    - No
    - Yes (Please describe how these documents are used.)
3. Does your agency use a project's final deliverable, typically a research report, to inform the benefits measurement process?
    - No
    - Yes (Please describe the type of information or data you pull from research reports.)
4. Please briefly describe **other sources of the data** your agency uses to measure benefits of transportation research.
5. Please describe particular challenges your agency has encountered when gathering the data needed to measure research benefits.

Methodology

1. What method(s) does your agency use to measure the benefits of research? Select all that apply.
    - Before-and-after analysis
    - Benefit–cost ratio
    - Custom measurement tool
    - Life cycle cost analysis
    - Return on investment calculation
    - Other (Please describe.)

2. Does your agency use one or more calculations or series of calculations to determine research benefits on a project-by-project or program basis?
    - No
    - Yes (Please briefly describe the calculation(s) or provide a link to a document describing them. Send any files not available online to chris.kline@ctcandassociates.com.)
3. What categories does your agency use when organizing and assessing the benefits of research at the project or program level? Select all that apply.
    - Administration and management
    - Construction
    - Design
    - Environmental
    - Geotechnical
    - Hydraulics
    - Innovations
    - Intelligent transportation systems
    - Maintenance
    - Materials and pavements
    - Planning
    - Project delivery
    - Safety
    - Sustainability
    - Traffic operations
    - Other (Please describe.)
4. Has your agency established standard values for use in calculating benefit–cost ratios or returns on investment? These standards might associate a dollar value with travel time savings or estimate a per-crash cost for fatal and injury crashes.
    - No
    - Yes (Please briefly describe these standard values or provide a link to a document describing them. Send any files not available online to chris.kline@ctcandassociates.com.)
5. If your agency attempts to measure the **anticipated benefits of proposed projects**, please describe how that measurement process differs from an evaluation of a completed project.
6. Has your agency defined what constitutes a "successful" research project under your benefits measurement program?
    - No
    - Yes (Please provide this definition and an example of how it is applied.)

Participation in the Measurement Process

1. Please identify who is responsible for gathering the data needed to measure benefits and briefly describe the process used to gather data.
2. Who is responsible for completing the benefits measurement process?
3. Has your agency developed a user guide or other training materials to assist research staff or others implementing benefits measurement practices?
    - No
    - Yes (Please provide a link to these guidance or training documents or send any files not available online to chris.kline@ctcandassociates.com.)

Assessment

1. Does your agency produce a report (internal or public-facing) that describes results of the benefits measurement process?
    - No
    - Yes (Please provide a link to the report or send any files not available online to chris.kline@ctcandassociates.com.)

2. Has your agency identified the types of projects or specific project characteristics that are most likely to produce the most significant quantifiable benefits to the agency and its stakeholders?
    - No
    - Yes (Please describe these project types or characteristics.)
3. Please describe the **key successes** of your agency's efforts to measure the benefits of transportation research.
4. Please describe the **key challenges** associated with your agency's efforts to measure the benefits of transportation research.
5. Are you available for follow-up conversations regarding your agency's benefits measurement practices?
    - No
    - Yes

Wrap-Up

Please use this space to provide any comments or additional information about your previous responses.