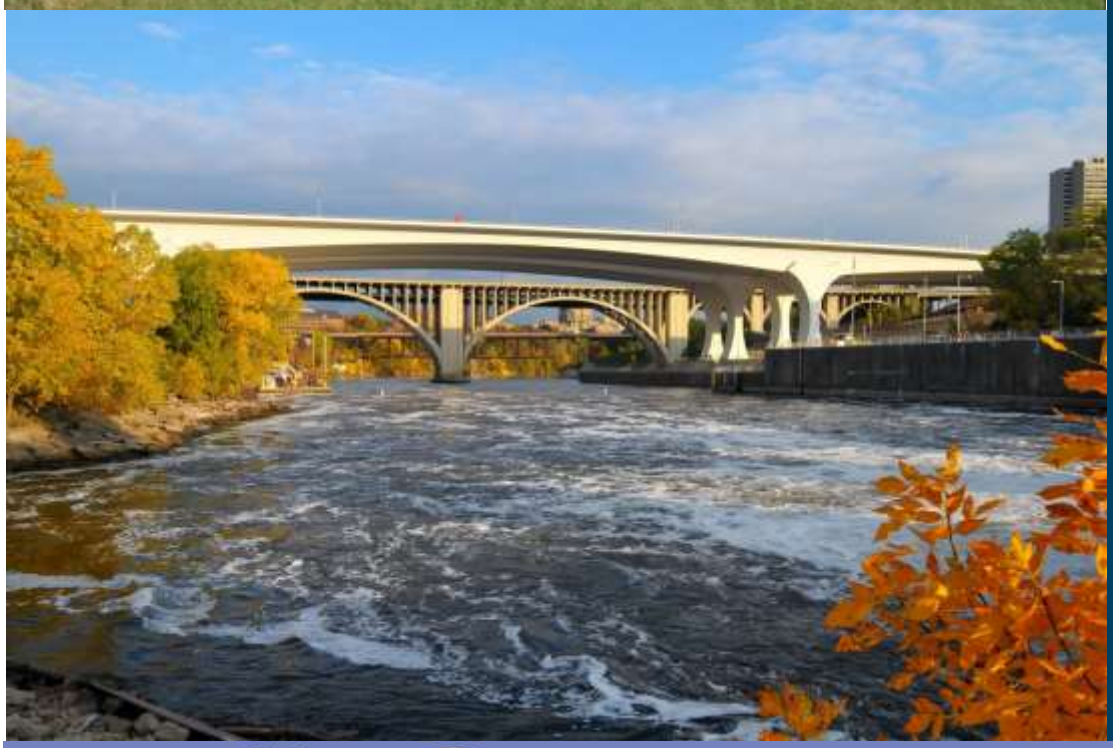
Best Practice Guide for Quantifying the Benefits of MnDOT Research

Prepared by:

Athey Creek Consultants



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Your Destination...Our Priority

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1.0 Introduction and Executive Summary

1.1 Background

The Minnesota Department of Transportation's (MnDOT's) Research Services (RS) administers approximately $10 million in research funding annually, managing an average of 190 active projects at any given time. In order to retain its funding and justify program needs, RS wishes to communicate the value and benefits of its research investments. In parallel, state departments of transportation (DOTs) around the country are exploring ways to quantify benefits, especially in light of a trend toward performance-based outcomes, as seen in the MAP-21 federal transportation legislation.

It is important to note that many research projects result in qualitative benefits that may not necessarily also result in quantifiable benefits such as cost savings, lives saved, etc. These qualitative benefits are valuable MnDOT's research program; however, the focus of this particular effort is to develop processes and practices that can be used for projects that are well-suited for benefits quantification.

MnDOT initiated this project to conduct the following tasks:

- Review and document practices in place at State DOTs from around the country
- Determine best practices that have the most potential for implementation by MnDOT
- Recommend key milestones/steps for MnDOT to quantify the benefits of its research results

The focus of this project is on program-level practices. In particular, MnDOT 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.

1.2 Approach

A request for information was sent to State DOT research managers from around the country using the AASHTO Research Advisory Committee (RAC) Listserv. Information about DOT practices for quantifying benefits of research projects (processes, procedures, examples, criteria, presentations, reports, etc.) was requested.

After initial review of submitted materials, case studies were selected for further review and summary. Case studies were selected based on practices having the most potential to be implemented by MnDOT. Interviews were conducted with research management leaders in case study agencies to collect additional information and clarify submitted information. Case studies were summarized in detail, and notable practices from non-case study states were also documented.

Upon review of submitted materials and interviews with case study agencies, best practices, trends, gaps in current practice, and challenges were identified. In addition, MnDOT's program strengths and in-place processes were reviewed and documented. Lastly, recommendations were created, outlining steps for MnDOT to consider taking as they implement a formal process to quantify research benefits.

1.3 Summary of Findings

Survey Responses

MnDOT received 17 responses to the request for information via the AASHTO RAC Listserv. 14 DOTs indicated that they quantify research benefits at some level or are developing a process to do so.

Observed Trends

A summary of observed trends resulting from review of all materials and practices is shown below.

Observed Trends from Survey Responses

Approaches	• Most programs quantify benefits only for selected projects. • It is more common to calculate actual savings after implementation.
Methods	• Most calculate cost savings; others use cost/benefit ratio. • Methods and calculations vary significantly and are customized for each project. • Complexity and accuracy of methods vary widely.
Metrics	• Most common metrics are: a) Safety Improvements, b) Materials Saved, c) Increased Efficiency
Significance of Benefits	• Research areas that tend to result in the most significant cost savings: a) Infrastructure (e.g. high-cost items such as pavements, bridges, traffic control devices, right-of-way,

Case Studies

After initial review of submitted materials, the following four (4) DOTs were identified as case studies:

- Utah DOT
- Missouri DOT
- Florida DOT
- Louisiana DOT and Development (DOTD)

Key findings from the case studies include the following:

- **Utah DOT and Missouri DOT**:
  - Operate smaller research programs, as compared to MnDOT's
  - Conduct periodic, formal evaluations of completed research (every 1-3 years)
  - Quantification efforts are streamlined, and these practices influence the mindset of those involved with the program, to be more benefits-oriented

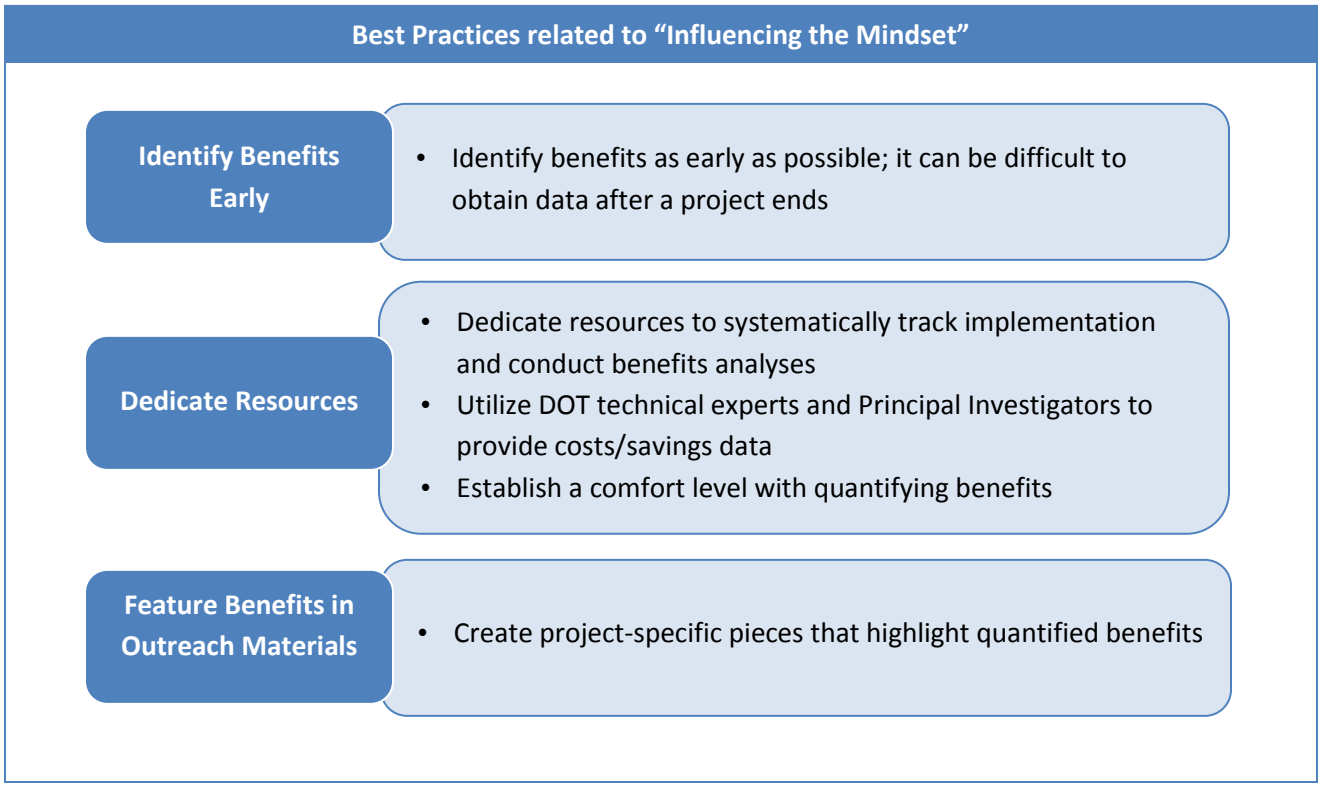
- **Florida DOT and Louisiana DOTD:**
  - Operate large research programs, comparable to MnDOT's
  - Conduct individual project tracking from initiation through implementation
  - Focus on individual projects can encourage implementation and results in structured, comprehensive reporting of benefits
- **All Case Studies**: These research programs utilize dedicated staff and/or external resources, as well as systems and processes to conduct benefits analysis.

1.4 Best Practices

Best practices are categorized into two outcome areas: 1) Influencing the mindset of those involved in DOT research; 2) Influencing individual projects. An overview of best practices is provided below; additional details are provided in Section 6.1.

Best Practices related to "Influencing the Mindset"

Facilitate and Track Implementation	• Facilitate, track, document implementation status for a time after projects end • Hold technical offices accountable for reporting
Be Selective	• Select projects based on availability of data and significance of benefits • Pay attention to projects that tend to have higher cost benefits: high-cost items (e.g. bridges, pavements), user cost savings, safety improvements, and solutions that preserve conditions to avoid construction expenses
Use Systematic Approaches	• Use databases, worksheets, templates, & reports to collect and track benefits • Conduct concentrated efforts on a regular schedule
Maintain Credibility	• Document assumptions and calculations • Be realistic and conservative to ensure that calculated benefits are defendable
Encourage Innovation	• Maintain investments in high-risk/high-reward research that may not always result in quantified benefits



1.5 Gaps in Current Practice and Challenges

Gaps in current practice and challenges related to quantifying the value of research benefits include:

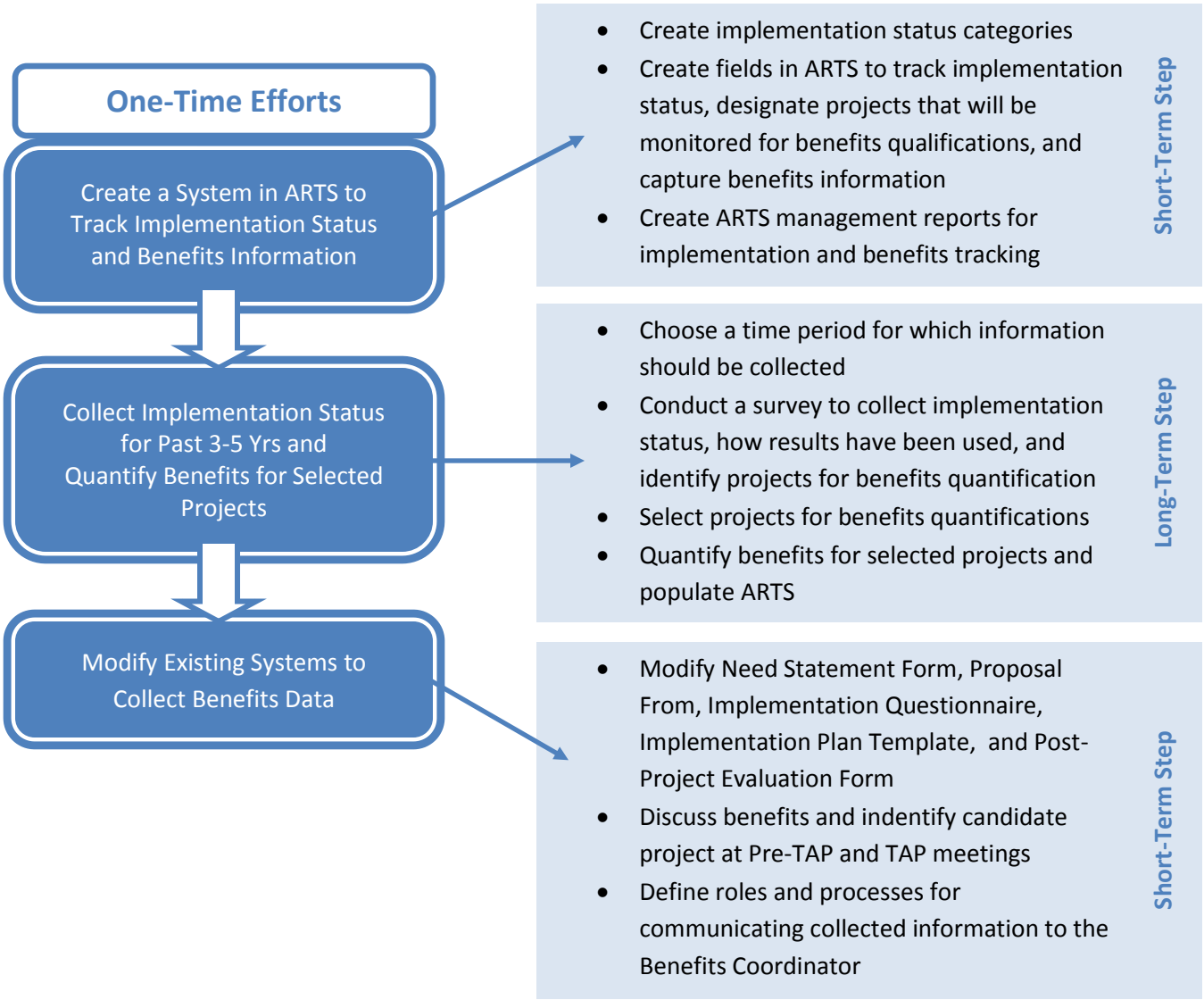
- **Lack of Consistent Methods** – Complexity and accuracy of methods vary widely, depending on the nature of the research
- **Difficult to Obtain Data** – Considerable resources may be required in order to obtain credible data (e.g. before/after conditions, accurate costs, etc.)
- **Difficult to "Look Back**"- Project champions who are vital in providing information and data may change positions. In addition, new initiatives often take priority over older projects.

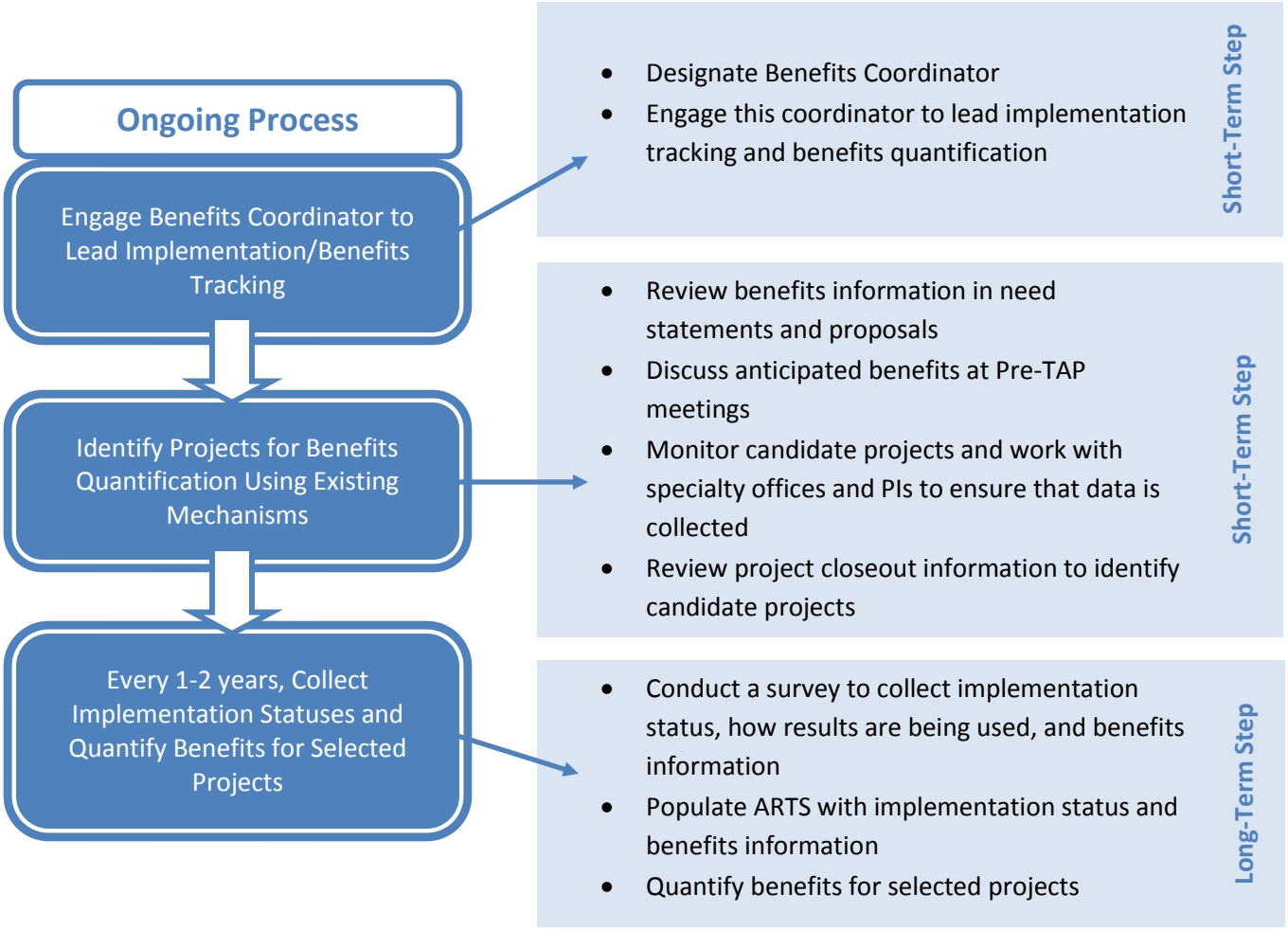
1.6 Recommendations for MnDOT's Research Program

The following provides an overview of recommendations for MnDOT to consider when initiating a structured process for quantifying research benefits.

Overview of Recommendations

Recommendations are presented into two categories: 1) One-time efforts; and 2) Ongoing process. The figures below illustrate the major milestones included in the recommendations as well as suggested steps. Additional details related to the recommendations can be found in Section 7.





Identifying Projects for Benefits Quantification

These criteria and considerations will help narrow in on the most appropriate projects to evaluate and help determine where valuable efforts/resources should be allocated.

Criteria: The following criteria/questions can be used throughout the research process, to identify projects that should be considered to undergo benefits quantification:

1) Can benefits be quantified in terms of cost savings, either to MnDOT or to roadway users?
2) How significant could the savings be?
3) Do the benefits result in a high-impact result or improvement? Describe the impact.
4) Is the data needed to quantify benefits readily available (e.g. conditions before and after implementation, cost data, extent of results/change)? Is the data credible?
5) How much time and effort will be needed to access the necessary data and calculate cost savings? (Scale of 1-5: 1 = low effort, data is readily available; 5 = high effort; difficult to obtain/estimate data.)

Research Topics: Drawing from trends at other DOTs, MnDOT research topic areas that could result in more significant quantified benefits include:

- Materials and Construction
- Bridges and Structures
- Traffic and Safety
- Maintenance Operations and Security

Benefit Types: Based on findings from other DOTs, it is worthwhile to pay special attention to projects that that result in the following types of benefits:

- Material savings
- User cost savings (e.g. congestion reduction)
- Safety improvements
- Preservation of in-place conditions (e.g. avoiding the need for a costly change)
- High-cost items such as pavements, bridges, right-of-way, etc.

Implementation considerations

Historical perspectives, such as past attempts to collect implementation information, can help inform decisions about how to move forward with some or all of the recommended steps. In addition, customer-focused approaches should be utilized in order to engage internal MnDOT customers (e.g. technical staff) to actively and willingly participate in benefits quantification efforts.

1.7 Next Steps

Next steps include the following:

1) Determine level of resources (staff and funding) to dedicate toward implementing some or all recommendations
2) Conduct an implementation phase to carry out steps toward quantifying benefits
3) Consider extending efforts in the future, to assess how NCHRP research results are being used within MnDOT and quantify related benefits

2.0 Review of Responses to AASHTO RAC Listserv Request

2.1 Response Rate

In March 2013, a request for information was sent via email to the AASHTO Research Advisory Committee (RAC) Listserv. Linda Taylor, MnDOT's Director of Research Services, requested information and materials from state DOT research managers regarding current practices for quantifying benefits of research projects, including processes, procedures, examples, criteria, presentations, reports, etc.

MnDOT received 17 responses to the request for information. 14 agencies indicated that they quantify research benefits or are developing a process to do so. Four research programs were selected as case studies for further review and summary.

Transportation Agencies Responding to AASHTO RAC Listserv Request		
Quantifies Benefits or is Developing a Process		**Does not Quantify Benefits**
California DOT	*** Missouri DOT**	Maine DOT
*** Florida DOT**	Montana DOT	Mississippi DOT
Illinois DOT	New Jersey DOT	West Virginia DOT
Indiana DOT	Ohio DOT	
Iowa DOT	Texas DOT	
Kentucky Transp. Center	*** Utah DOT**	
*** Louisiana DOTD**	Wisconsin DOT	

* Denotes a Case Study Agency

2.2 Observed Trends

MnDOT's request for information did not include questions to collect specific details about DOT practices. However, a number of trends were observed after reviewing the submitted materials.

Observed Trends – DOT Practices for Quantifying Research Benefits	
Approaches	• Most research programs quantify benefits only for selected projects. • It is more common to calculate actual savings after results have been implemented. • Some programs calculate projected savings, which can encourage implementation.
Methods	• Most DOTs calculate cost savings; others determine Cost/Benefit ratio. • Methods and calculations vary significantly and are customized for each project. • Complexity and accuracy of methods vary. Some factor in time-based effects such as the time value of money. Others take a more simplified, conservative approach in order to minimize time and effort.
Metrics	• The most common metrics are: a) Safety Improvements (Lives Saved, Crashes Reduced), b) Materials Saved, c) Increased Efficiency / Reduced Labor Time.
Significance of Benefits	• Research areas that tend to result in the most significant cost savings: a) Infrastructure (e.g. high-cost items such as pavements, bridges, traffic control devices, right-of-way, preservation of in-place conditions), b) Operations, c) Safety.

3.0 Case Studies

This section provides an overview of case studies chosen for detailed review and summary.

Case studies were selected based on practices having the most potential to glean concepts that could be implemented by MnDOT. In particular, MnDOT was interested in learning about program-level practices (e.g. process steps, key milestones during research projects, input collection tools, etc.) to quantify benefits, especially from DOTs who use systematic, routine approaches for selecting projects for quantification and conducting benefits analyses.

The case studies summarize each agency's process for quantifying benefits. Aspects documented include: metrics, analysis method(s), frequency of evaluation, key process steps/milestones, evaluation tools, resources utilized, and lessons learned. Information sources for the case studies are noted in each section. For all case studies, submitted materials were reviewed, and interviews were conducted with agency staff to collect and clarify information.

3.1 Utah Department of Transportation – Case Study #1

Information Source(s):

- Materials submitted in response to AASHTO RAC Listserv request (March, 2013)
- Interview with Cameron Kergaye, UDOT Director of Research (May 6, 2013)
- Report No. UT-10.01: "Measuring the Benefits of Transportation Research in Utah" (September 2010), Douglas I. Anderson, University of Utah Dept. of Civil and Environmental Engineering. Web link to report: www.udot.utah.gov/main/uconowner.gf?n=1339002847990478

Metrics:

- Savings to UDOT operations (reduced manpower, improved assets, lower bids, etc.)
- Benefits to the public (reduced congestion, improved safety, enhanced environment, etc.)

  Note: UDOT has established user costs for congestion, safety, etc. that can be used in the calculation of benefits.

Analysis Method(s):

- Benefit-Cost Ratio (Cost savings are calculated on a project-by-project basis. Data input and calculations vary, depending on the nature of the research)
- Grading System

Frequency of Evaluation:

An evaluation of all projects is conducted every 3 years.

Key Process Steps/Milestones:

1) **Form a Technical Advisory Committee (TAC)**: A TAC, comprised of research managers and others who are likely to use the findings, is formed to provide input during the program evaluation effort.

2) **Select Projects for Evaluation**: Projects are selected for evaluation. An attempt is made to evaluate all projects, but because some research is not fully implemented immediately after the project is complete, it may be necessary to allow a period of time between project completion and the

assessment of the benefits. If a project is noted as "benefits not known at this time," the project is re-visited during the next evaluation effort.

3) **Compile a List of Projects to be Evaluated:** A list of projects to be evaluated is compiled, including project title, key champion, project manager, project cost, and deliverables received. Projects are classified into the following types: Infrastructure Related Research, Operations Related Research, or Policy Related Research. (Per Report No. UT-10.01 prepared in 2010, 41 projects were evaluated, which were completed during 2006, 2007, and 2008.)

4) **Evaluator Meets with Project Champions to Collect Benefits Data**: For each project, an evaluator meets with the key champion and others familiar with the research products. A plan is outlined for estimating benefits and total costs. A "Benefits Assessment Form" (See Appendix A-1) is used to collect and document benefits. The evaluator guides the key champion through the evaluation process by collecting input using the "Benefits Assessment Form" and calculating benefits.

5) **Calculate Project Benefits:** The evaluator calculates project benefits, using data and input from the project champion. Assumptions and calculations are conservatively estimated, in order to maintain a credible benefits value.

   In general, benefits are identified to be in one of the following categories:

   - Savings to UDOT operations (reduced manpower, improved assets, lower bids, improved level of knowledge, improved policy.)
   - Benefits to the public (reduced congestion, improved safety, enhanced environment, improved quality of life.)
   - Zero financial benefits (no savings from the deliverables)
   - Benefits are not known at this time; implementation continues; future benefits may be achieved, and are "to be determined" (TBD)

6) **Assign a Grade to Each Project**: A grade is assigned to each project, based on the following descriptions:

   A - Major impact- Enhanced operations (specification, policy, standard, method, etc.)

   B - Significant impact- Improved operations

   C - Contributed to state-of-the-practice

   D - Unclear or contradicting findings- More study needed

   E - Major tasks not completed- Objectives not met

7) **Calculate Benefit-Cost Ratios:** A benefit-cost ratio is calculated for each individual project. In addition, benefit-cost ratios are calculated for each project type and for the total three-year period.

   Benefit/Cost Ratio = Total Financial Benefit ($) / Total Project Cost ($).

   According to Report UT-10.01, at table showing "Research & Development Projects by Category (May 2000)" indicates that the highest benefit-cost ratios for projects evaluated for the period ending in 2000 were in Infrastructure (B/C = 15) and Operations (B/C = 13.) Lower benefit-cost ratios

were seen in the Administration (B/C = 6) and Policy (B/C = 5) categories, though all B/C rations were greater than 1, indicating significant net benefits.

Evaluation Tools:

- "Research Project Benefit Assessment Form" - See Appendix A-1

Resources Utilized:

- **Project Champions Provide Technical Expertise:** Input data for benefit calculations (e.g. material costs, materials saved, etc.) is provided by the project champion.
- **Services for Conducting the Evaluations are Outsourced:** The evaluation effort is outsourced to a consultant familiar with UDOT's research program. The evaluator conducts interviews with project champion, completes the "Research Project Benefit Assessment Form," and performs benefits calculations.

Lessons Learned:

- **Consider Implementation Before Projects are Funded.** UDOT aims to fund projects that will result in implemented results and benefits. Ensure a Well-defined Scope of Work. Benefits are more likely to be obtained for projects that have a well-defined, clear scope of work.
- **Be Conservative When Estimating Benefits.** Being conservative when determining assumptions and performing benefit calculations helps maintain credibility.
- **Highest Benefit-Cost Ratios are Seen with "Big-Ticket" Items.** The evaluation effort has helped UDOT identify where the highest research investment paybacks are. For the evaluation conducted in 2010, the highest benefits were achieved on studies that resulted in improvements to "big-ticket" items such as highways, bridges, traffic control devices, and right-of-way. Safety related studies also show significant benefits.
- **Challenges Occur when the Project Champion Changes.** A challenge to the process is seen when project champions changes positions before the research is implemented and the evaluation is done, as their historical knowledge is often very valuable in quantifying benefits.

Application Considerations for MnDOT Research Program:

- Conduct concentrated benefits analysis efforts every 1-2 years.
- Enlist dedicated resources (possibly external expertise) to conduct benefits analysis.
- Conduct interviews, using a structured form, with Technical Liaisons (project champions) to collect data for benefits assessment.
- A potential consideration for selecting projects for quantification could include "big ticket" (high-cost) items such as highways, bridges, traffic control devices, right-of-way, and safety.

3.2 Missouri Department of Transportation – Case Study #2

Information Source(s):

- Materials submitted in response to AASHTO RAC Listserv request (March, 2013)
- Interview with Bill Stone, Research Administrator, Construction and Materials, Missouri Department of Transportation (May 7, 2013)

Metrics:

- Organizational Savings/Benefits
- Lives Saved and Crashes Reduced (working toward quantifying benefits)

Analysis Method(s):

Calculation of Cost Savings (data input and calculations vary, depending on the nature of the research)

Frequency of Evaluation:

An evaluation of all projects is completed annually.

Key Process Steps/Milestones:

1) **Compile a List of Projects Completed during the Previous Year:** Benefits are estimated for all projects completed in the previous year. If a project has not yet been implemented, it is noted and will be re-visited the following year.

2) **Collect Savings/Benefits Information**: A "Research Planning Communications Sheet" Word document (see Appendix B-1) is used to collect information about potential savings/benefits throughout projects. A Research Planning Communications Sheet is completed both by the Principal Investigator and the MoDOT Technical Liaison; the questions are slightly different, depending on who is completing the sheet. MoDOT research program staff collect and track information reported in the "Research Planning Communications Sheet."

3) **Calculate Savings/Benefits:** Savings/benefits are calculated on a project-by-project basis. The calculations estimate savings that were actually achieved or could be achieved, if implemented. For example, a project that optimized winter snow removal operations determined cost savings based reductions in salt, diesel fuel, operator salary, and equipment costs. Another project calculated potential cost savings for diamond grinding concrete pavements, by comparing the cost of diamond grinding over an estimated extended life period vs. the cost of Ultra Thin Bonded Wearing Surface. (See Appendix B-2 for calculation examples.)

4) **Prepare a Summary Report:** A report is prepared, showing a table of all projects and benefits. For each project, either a cost savings or a cost-neutral result (e.g. informational, guidebook, not yet implemented) is documented. See Appendix B-2.

5) **Report Cost Savings to Department-Wide Performance "TRACKER"**: The total number of projects and total cost savings are reported in MoDOT's "TRACKER" performance measures. (In 2012, 10 projects were evaluated. Two projects resulted in tangible cost savings of $1.9 million; the other eight projects resulted in no cost savings. The reported metrics indicated that 10 projects were completed and $1.9 million in savings was achieved.) See Appendix B-3.

Evaluation Tools:

- Research Planning Communications Sheet (MoDOT Technical Liaison) - See Appendix B-1
- Research Planning Communication Sheet (Principal Investigator) – See Appendix B-1

Resources Utilized:

- **MoDOT Program Research Staff**: MoDOT research program staff collect input data and perform benefits calculations. The Research Communications Sheet is used to document input data.
- **Technical Experts:** Technical experts, including project champions and principal investigators, are consulted to provide input data such as material/labor/time savings, unit costs, etc.

Lessons Learned:

- **Benefits Quantification Practices have Created a Mindset Shift**: Calculating savings/benefits has changed the mindset of those involved in research, helping to continuously think about potential benefits from innovations that help MoDOT do things better, faster, cheaper.
- **Consider Potential Benefits/Savings Early in the Research Life-Cycle**: Research program staff begin thinking about potential benefits and savings when needs are determined and projects are selected. It is more difficult to obtain accurate benefits data after a project ends.
- **"Innovations" Performance Measure Acknowledges the Need to Try New Things**: A department-wide performance measure for "Innovations" offers a good way to track and reward successes for high-risk / high-reward research.
- **Projecting Future Savings Helps to Implement the Research**: However, projecting potential savings is challenging because this is done by looking at the 5-year State Transportation Improvement Program (STIP), and many projects are not yet fully designed.
- **Document Assumptions and Calculations**: Many assumptions and variables are associated with calculating benefits. Research program staff and technical experts work together to develop a plan to calculate savings. Assumptions and calculations are clearly documented. Establishing a comfort level with estimating benefits will likely take time and practice.

Application Considerations for MnDOT Research Program:

- Document potential benefits from the beginning of projects, using existing mechanisms: Need Statements, Proposals, Work plans, Pre-TAP meetings, TAP meetings, Implementation Planning Documents (online questionnaire and plan template), and Post-Project Evaluation Form. Include criteria in these documents to help identify projects for benefits quantification.
- Use questions from MoDOT's "Research Planning Communications Sheet" to collect benefits information during the research process. Questions related to benefits quantification include:
    - What type of benefits will come out of this research? How can these benefits be quantified? If the benefit is financial, what is the estimated range of savings per defined unit and for what period of time? (Please provide assumptions and reasoning.)
- Use a staffing structure that includes an evaluator to manage the process and conduct benefits calculations. Utilize PIs and technical experts for data input and calculation planning.
- Consider ways to reward high-risk/high-reward research successes that may not result in quantified benefits.

3.3 Florida Department of Transportation – Case Study #3

Information Source(s):

- Materials submitted in response to AASHTO RAC Listserv request – March, 2013
- Interview with Darryll Dockstader Manager, Research Center, Florida Department of Transportation (May 10, 2013)

Metrics:

- Safety Improvements
- Infrastructure Condition
- Congestion Reduction (travel times, gas)
- System Reliability Improved
- Freight/Economic Benefit
- Environmental Benefit
- Project Time Reduced
- Materials Saved
- Man Hours Saved
- Variation Reduced (Process, Materials)
- Liability to FDOT Reduced

Analysis Method(s):

Calculation of Cost Savings (data input and calculations vary, depending on the nature of the research)

Frequency of Evaluation:

Varies

Key Process Steps/Milestones:

1) **Create a Deployment Plan for Each Project:** A deployment plan is developed for every project, prior to contract development. An online survey, completed by the Project Manager (FDOT technical expert) is used to collect information for the deployment plan. Project Managers are asked to identify performance measures that, including quantifiable benefits and/or qualitative measures. See Appendix C-1 for survey questions.

2) **Discuss Potential for Quantifying Benefits at Kickoff Meetings**: The Performance Coordinator attends project kickoff meetings to listen for opportunities to quantify benefits. Questions to consider when identifying potential projects to quantify benefits:

    - Can benefits be quantified? Can before/after data be obtained? Is the data readily available? Is the data credible? Is it worthwhile to spend the time needed to access the data and calculate benefits?

3) **Build Tasks into Contracts to Quantify Benefits (as applicable)**: In some cases, a task will be added into research contracts, for the performing organization to quantify benefits.

4) **Complete Implementation Reports:** Implementation reports are completed on a regular basis throughout the life of projects (e.g. bi-annually or quarterly) to collect information about implementation potential and benefits.

5) **Discuss Benefits at Closeout Meetings**: Actual and expected benefits are discussed and collected at project closeout meetings.

6) **Monitor Implementation Status of Projects:** Implementation statuses of all projects are tracked and monitored using an implementation survey and implementation tracker:

Implementation Survey:
Each year, an Implementation Survey is sent to functional offices. (See Appendix C-3 for an example of a completed Implementation Survey.) A table is prepared, listing research projects completed by that office in the past year. Functional offices are asked to provide "Implementation Status" and "Explanation of Implementation Status," for each project, as described below:

Options for implementation status (see Appendix C-2 for definitions):

- The project can't be implemented
- The project will be implemented later
- The project is being implemented
- The project has been implemented

Questions requesting explanation of implementation status:

- Why the project can't be implemented
- What the plan is to start/complete implementation
- How the project was implemented (e.g. spec change, best practice put in place, etc.)
- Any noted success or failure in implementation

Implementation status is tracked until the project has been designated as "implemented" or "can't be implemented."

Implementation Tracker (Excel Template):
A template is used to track implementation status, implementation results, and to record quantified benefits/impacts. See Appendix C-4.

7) **Quantify Benefits for Selected Projects**: Projects are selected for benefits quantification based on the availability of benefits data and effort needed to perform the analysis /calculation. See Appendix C-5 for a number of examples of quantified benefits.

Evaluation Tools:

- Development Plan Survey – See Appendix C-1
- Implementation Survey – See Appendix C-3
- Implementation Tracker (Excel Template) – See Appendix C-4

Resources Utilized:

- **Performance Coordinator Position**: 1 FTE position is dedicated to performance coordination.
- **Costs for Benefits Analysis Integrated into Research Contracts:** Costs associated with selected projects in which the benefits calculation is conducted within the research contract.
- **Funding for Pilot Demonstration Program**: Funding used to conduct pilot demonstrations for new technologies or practices resulting from research that show high implementation potential.
- **Development of a Framework to Assess Research Projects:** FDOT initiated a project, currently being conducted at Florida State University, to develop a financial analysis framework for assessing implemented research projects.

Lessons Learned

- **Dedicate Appropriate Resources.** Dedicated resources to monitor implementation and quantify benefits (including the Performance Coordinator position) have allowed FDOT to make meaningful progress with quantifying benefits. Requests from FDOT management for performance/benefits information have further justified the need for dedicated resources. Enlist qualified expertise to conduct benefits analysis, in order for results to be credible.
- **Begin Identifying and Tracking Benefits as Early as Possible.** Start identifying potential benefits at the beginning of each project, starting with the deployment plan.
- **Hold Functional Offices Accountable for Reporting on Implementation.** The research office issues the implementation survey to functional offices at the same time they call for new research needs, indicating that the survey needs to be completed in order to be eligible for new project funding. Functional offices have Research Coordinators who report on implementation.
- **No "Magic Bullet" Exists for Quantifying Research Benefits.** A lack of straightforward, legitimate tools, resources, and methods exist for quantifying the benefits of transportation research. It is challenging and complex. Ideally, methods need to be sophisticated enough to be credible, yet easy enough to use.

Application Considerations for MnDOT Research Program:

- Track status of implementation of projects, using an implementation survey that sorts projects by functional office.
- Hold functional offices accountable for reporting on implementation and benefits.
- Quantify benefits only for selected projects, rather than quantifying all projects.
- Use FDOT's criteria/questions to help identify and select projects for quantification:
    - Can benefits be quantified? Can before/after data be obtained? Is the data readily available? Is the data credible? Is it worthwhile to spend the time needed to access the data and calculate benefits?
- Incorporate tasks into contracts, as appropriate, for benefits analysis.
- Use questions similar to those outlined in the Deployment Plan Survey (Appendix C-1) to help prompt input related to benefits. For example:
    - Can economic benefits be determined if the results of this research are successfully implemented?
    - Are there non-economic quantifiable benefits that could be assessed if the research results are successfully implemented?
    - Will successful implementation of the research result in system efficiencies?
    - Will successful implementation of the research result in resource savings?
    - Will successful implementation of the research result in environmental gains?
    - Will successful implementation of the research result in community enrichment?

3.4 Louisiana Transportation Research Center – Case Study #4

Information Source(s):

- Interview with Harold "Skip" Paul, Director, Louisiana Transportation Research Center (LTRC), and Mark Morvant, Associate Director, Research, LTRC (May 6, 2013)
- Documents and other materials provided by Skip Paul and Mark Morvant (May 2013)

Metrics:

- Cost Savings (metrics vary by project)
- Program-Level Performance Measures (See Appendix D-1)

Analysis Method(s):

Calculation of Cost Savings (data input and calculations vary, depending on the nature of the research)

Frequency of Evaluation:

Varies

Key Process Steps/Milestones:

1) **Track Implementation Status for All Projects**: Implementation potential and status is tracked for all projects, starting at the beginning of the project until 5 years after the project ends (or until the project is implemented.) Anticipated benefits are discussed as early as possible during the research cycle, when project needs are determined and projects are selected. Implementation statuses:

    - Implementation Recommended
    - Implementation in Progress
    - Implementation Completed
    - Not Implemented
    - No Implementation Expected

2) **Systematically Collect Benefits and Implementation Information**: A bi-annual report is used to collect implementation status and benefits for every project. Information is entered into a web-based reporting system that automatically populates fields in LTRC's research management database. Implementation information is entered by the LTRC Implementation Engineer, using input from the Research Manager (typically an LRTC technical expert and could also be the principal investigator conducting the research.) A "Research Assessment and Implementation Report" template (See Appendix D-2) is used to prompt input.

3) **Quantify Benefits for Selected Projects**: Benefits are quantified only for projects that demonstrate high value and benefits. Benefits data is tracked from the beginning of the project, as data needed to quantify benefits is more difficult to obtain after a project is complete. Benefits are quantified on a project-by-project basis based on the nature of the project; data and methods vary.

4) **Feature Quantified Benefits in Marketing Materials:** Information about quantified benefits is used to help market the impact of LTRC research. An example outreach piece "Louisiana Transportation Center Fact Sheet" can be found in Appendix D-3.

5) **Use Performance Measures to Manage Overall Program Performance:** LTRC also tracks a number of performance measures, to manage overall program performance. Percentage of projects implemented is a performance measure.

Evaluation Tools:

- Bi-Annual Project Progress Reports
- Research Assessment and Implementation Report – See Appendix D-2

Staff and Technical Resources Utilized:

NOTE: LTRC is jointly sponsored by the Louisiana Department of Transportation and Development and Louisiana State University. It employs over 70 professionals, including research and training staff, university faculty, and students.

- **LRTC Staff Researchers:** Benefit calculations are conducted by LTRC staff researchers, who conduct research in their respective technical areas on a regular basis. LTRC staff researcher personnel positions typically include 30-40% time for implementation.
- **LTRC Administrators and Leadership:** LTRC administrator and leadership positions include 50% or greater dedicated to implementation.

Lessons Learned:

- **Identify Projects to Quantify Benefits as Early as Possible.** This will allow for tracking and collecting data needed to quantify benefits after results are implemented.
- **A Culture of Implementation Exists at LTRC.** This is a result of heavy emphasis on tracking, monitoring, and encouraging of implementation. The establishment of related performance measures elevates implementation as a priority.
- **Dedicate Resources:** The most difficult aspect of tracking implementation and quantifying benefits is the time needed to go back to previous projects, when demands on current projects exist. It is important to emphasize that this is a priority, and dedicate resources to it.
- **Showing Quantified Benefits at a Project Level have Made Significant Impacts to Stakeholders**. Short communications materials (brochures/one-pagers) that demonstrate quantified benefits have been used to address legislative inquiries regarding the value of LTRC's research funding.

Application Considerations for MnDOT Research Program:

- Quantify benefits only for selected projects. Identify projects as early as possible.
- Use ARTS database to track implementation status and benefits information.
- Include a question related to "potential impact" in existing mechanisms for implementation planning (e.g. implementation questionnaire and implementation plan). Example question from "Research Assessment and Implementation Report" in Appendix D-2:
    - Potential Impact: Describe the potential impact of the results in terms of cost, efficiency, safety, convenience, aesthetics, etc.
    - Evaluation: Identify methods for evaluating the implementation effort. How will benefits be quantified or assessed?
- Feature quantified benefits in outreach/marketing materials (e.g. separate heading for potential fiscal impacts, as noted in the fact sheet Appendix D-3.)

3.5 Observations from Case Studies

Two of the case studies (Utah and Missouri) operate smaller research programs than MnDOT's. The other two DOTs (Florida and Louisiana) operate research programs that are quite large in size and scope. The LTC is unique in that it is jointly sponsored by the LA DOTD and Louisiana State University, employing over 70 professionals including research and training staff, university faculty, and students.

A key finding common to both the Utah and Missouri programs is that each program conducts formal evaluations of completed research. Utah conducts this evaluation once every three years and Missouri conducts it annually. Feedback from both case studies suggests that these concentrated, formal evaluations have streamlined efforts and has influenced the "mindset" of the respective research programs, elevating quantified benefits as a priority for research.

The Florida and Louisiana case studies provided details of how each state tracks individual projects from initiation through completion and implementation. The lessons learned from these states provide multiple insights into best practices for how close monitoring and working with teams conducting the research can help to encourage implementation of research results and quantifiable benefits.

All case study research programs utilize dedicated resources for benefits quantification. These programs also use systems and tools (forms, surveys, etc.) to collect and track benefits information. A central contact person and/or systems -- such as a dedicated staff position and databases or spreadsheets – are commonly used to manage the resulting information. For instance, the Louisiana DOTD Implementation Engineer collects and retrieves benefits information using a survey that feeds the research management database. The Florida DOT Performance Coordinator maintains a tracking table, sorted by specialty office. The Utah DOT enlists services of a consultant to quantify benefits and prepare a summary report that documents the effort and findings. Tools and forms are used to "narrow in" on selected projects, thereby reducing the amount of data to be managed and communicated.

Case Study Application Considerations for MnDOT Research Program

The following summarizes specific applications from case study practices, for MnDOT to consider as they move forward to quantify research benefits.

Utah DOT Case Study #1	
	• Conduct concentrated benefits analysis efforts every 1-2 years. • Enlist dedicated resources (possibly external expertise) to conduct benefits analysis. • Conduct interviews, using a structured form, with Technical Liaisons (project champions) to collect data for benefits assessment. • A potential consideration for selecting projects for quantification could include "big ticket" (high-cost) items such as highways, bridges, traffic control devices, right-of-way, and safety.

Missouri Department of Transportation Case Study #2

- Document potential benefits from the beginning of projects, using existing mechanisms: Need Statements, Proposals, Work plans, Pre-TAP meetings, TAP meetings, Implementation Planning Documents (online questionnaire and plan template), and Post-Project Evaluation Form. Include criteria in these documents to help identify projects for benefits quantification.
- Use questions from MoDOT's "Research Planning Communications Sheet" to collect benefits information during the research process. Questions related to benefits quantification include:
    - What type of benefits will come out of this research? How can these benefits be quantified? If the benefit is financial, what is the estimated range of savings per defined unit and for what period of time? (Please provide assumptions and reasoning.)
- Use a staffing structure that includes an evaluator to manage the process and conduct benefits calculations. Utilize PIs and technical experts for data input and calculation planning.
- Consider ways to reward high-risk/high-reward research successes that may not result in quantified benefits.

Florida Department of Transportation Case Study #3

- Track status of implementation of projects, using an implementation survey that sorts projects by functional office.
- Hold functional offices accountable for reporting on implementation and benefits.
- Quantify benefits only for selected projects, rather than quantifying all projects.
- Use FDOT's criteria/questions to help identify and select projects for quantification:
    - Can benefits be quantified? Can before/after data be obtained? Is the data readily available? Is the data credible? Is it worthwhile to spend the time needed to access the data and calculate benefits?
- Incorporate tasks into contracts, as appropriate, for benefits analysis.
- Use questions similar to those outlined in the Deployment Plan Survey (Appendix C-1) to help prompt input related to benefits. For example:
    - Can economic benefits be determined if the results of this research are successfully implemented?
    - Are there non-economic quantifiable benefits that could be assessed if the research results are successfully implemented?
    - Will successful implementation of the research result in system efficiencies?
    - Will successful implementation of the research result in resource savings?
    - Will successful implementation of the research result in environmental gains?
    - Will successful implementation of the research result in community enrichment?

Louisiana Transportation Research Center Case Study #4

- Quantify benefits only for selected projects. Identify projects as early as possible.
- Use ARTS database to track implementation status and benefits information.
- Include a question related to "potential impact" in existing mechanisms for implementation planning (e.g. implementation questionnaire and implementation plan). Example question from "Research Assessment and Implementation Report" in Appendix D-2:
    - Potential Impact: Describe the potential impact of the results in terms of cost, efficiency, safety, convenience, aesthetics, etc.
    - Evaluation: Identify methods for evaluating the implementation effort. How will benefits be quantified or assessed?
- Feature quantified benefits in outreach/marketing materials (e.g. separate heading for potential fiscal impacts, as noted in the fact sheet Appendix D-3.)

4.0 Noteworthy Practices

In addition to the case studies summarized earlier in the guide, materials submitted by other DOTs were reviewed, and selected practices are highlighted in this section. Information sources used for this section were provided by agency staff, in response to the AASHTO RAC Listserv request (March, 2013.)

This section does not comprehensively summarize all practices within each respective agency's research program. Rather, selected practices were chosen, with MnDOT's program in mind, to help understand current "state-of the-practice" and to provide examples that may be used for future reference.

California Department of Transportation (Caltrans)

Caltrans is currently developing a process to quantify research benefits and program performance; seven areas of measurement have been selected:

- Dollars Saved
- Lives Saved
- Crashes Avoided
- % of Projects with a Deployed Product or Service
- % Contract on Time
- % Contracts within budget
- Customer Satisfaction

Caltrans provided examples where benefits were quantified for selected innovations being explored for market potential. An example can be found in the final report "Transfer Transfer Tank Longitudinal Crack Sealer Business Development Case" (Hargadon, Olson, and Woodallcan – 2006), at: www.dot.ca.gov/research/deployment_support/business_cases-to-be-removed/ttls_final_report-2006-05-23.pdf.

Indiana Department of Transportation

The Indiana Department of Transportation (INDOT) uses two methods to quantify benefits:

- Modified Internal Rate of Return (MIRR)
- Benefit-Cost Ratio

Project costs and calculated benefits are adjusted to account for the time-value of money (See Appendix E-1 "Determining the Value of Research for Transportation in Indiana.")

When MIRR is used to calculate projected savings, a sophisticated spreadsheet tool "INDOT R&D Financial Valuation Model (RDVAL)" is utilized. Users enter costs (e.g. R & D costs, implementation costs), projected savings to INDOT (e.g. labor, construction materials, supplies, etc.), and projected savings to customers (e.g. mobility and driving efficiency, safety improvements, economic development) into the spreadsheet tool, and the MIRR is calculated.

An example of quantified benefits is shown in the "Research Pays Off" outreach piece that highlights the project "Field Investigation of Subgrade Lime Modification – SPR 3380." (See Appendix E-2.)

Iowa Department of Transportation

The Iowa Department of Transportation (Iowa DOT) provided two examples of quantified benefits. Areas of savings included reduced staff time and cost savings

Iowa DOT prepared an outreach piece "Iowa DOT Innovates – and Delivers—Using NCHRP Research," which highlighted examples of how the agency implemented NCHRP research results (see Appendix E-3.) The outreach piece noted that the Iowa DOT had instituted an implementation engineer position.

Illinois Department of Transportation

The Indiana Department of Transportation (IN DOT) developed an implementation planning worksheet to monitor implementation throughout the life of projects. The worksheet also identifies areas of potential benefits and whether benefits can be quantified. See Appendix E-4.

Benefit areas include:

- Construction Savings
- Operation and Maintenance Savings
- Increase Lifecycle
- Decrease in Lifecycle Cost
- Safety
- Decrease Engineering/Administrative Costs
- Environmental Aspects
- Technology
- User Benefits
- Other

IDOT has also developed draft verbiage for inclusion in RFPs and work plans, to shift some of the responsibility for estimating expected benefits to PI during research projects.

Wisconsin Department of Transportation

The Wisconsin Department of Transportation (WisDOT) recently conducted a review of completed projects to determine implementation status.

Implementation status options include:

- Implemented - Change in Practice
- Implemented - Validated Current Practice
- Not Implemented - Not Implementable
- Not Implemented - Additional Research/Implementation Project Funding

Kentucky Transportation Center

The Kentucky Transportation Center (KTC) at the University of Kentucky serves as the research arm of the Kentucky Transportation Cabinet, which is the state's transportation agency.

As described in an email from Chuck Knowles (March 2013), KTC uses an annual process in which PIs submit candidate projects for consideration as KTC's "high-value" research submittal to AASHTO RAC. PIs describe the value and benefits of research projects in quantifiable terms, if possible. The submittals are reviewed, and a small number of projects are selected for further development. Utilizing KTC marketing, publications, and outreach activities, the selected projects and their value/benefits are publicly shared. On a five-year cycle, the annually selected projects are compiled and documented.

The KTC conducted formal "value of research" assessments in 2001 and 2006:

- The approach used in 2001 was to identify all completed research projects from 1995-1999 and select eleven for which benefits were defined. The 2001 report can be found at: www.ktc.uky.edu/projects/value-of-research-spr-projects-from-1995-to-1999/.
- The approach used in 2006 was to identify all completed research projects from 2000-2005 and assess each project with respect to how it addressed/supported the Kentucky Transportation Cabinet's strategic goals and what type of benefits were provided. Six projects were selected to provide information on their implementation. The 2006 report can be found at: www.ktc.uky.edu/projects/value-of-research-from-2000-2005-the-kentucky-spr-program-for-highway-research/

New Jersey Department of Transportation

The New Jersey Department of Transportation (NJDOT) has produced Implementation Reports that identify and document quantitative and qualitative benefits of NJDOT research projects. The report "New Jersey Department of Transportation 2007 Research Implementation Report" (Knezek) (www.state.nj.us/transportation/refdata/research/pdf/rir2007.pdf) provides the following highlights:

1) Research benefits were defined as:
   - Enhancements
   - Cost savings and economic impact
   - Improvement of safety
   - Reduction of labor time for customers, known as champions
2) Principal investigators and customers were interviewed to collect information about benefits and follow-up activities.
3) Safety projects provided the greatest financial benefit.
4) FHWA data was referenced and used for the average cost of fatalities and injuries due to crashes.

Ohio Department of Transportation

The Ohio Department of Transportation (Ohio DOT) conducted an analysis of 19 research projects sponsored by the Office of Pavement Engineering during calendar years 2007-2012. "Research Return" was documented for the following:

- Cost Savings
- Percent Increase in Productivity, Resulting in Time Savings
- Number of Policies/Procedures Impacted
- Number of Specifications Impacted
- Number of Students Sponsored
- Number of Partnerships Fostered
- Enhanced Knowledge
- A draft outreach piece, with visual aids (graphs, charts, etc.), was created to summarize benefits.

Texas Department of Transportation

The Texas DOT (TxDOT) is currently developing a formal process to determine Benefit/Cost for their research program. A spreadsheet tool is being developed as a part of this effort.

In 2003, an analysis of research benefits was conducted by TxDOT. Results of the analysis were documented in a report titled "Benefits of TxDOT Research (January 2003)" submitted to MnDOT for review. Per this report, 21 improved technologies and methods were selected from a three-year period, 1999 through 2001. A benefit period of ten years was used for determining returns from the selected products. Benefits were quantified in terms of lives saved, accidents reduced, and operational costs saved.

The two products resulting in highest cost savings over 10 years included:

- Super 2 Geometric Design Guidance (Significant cost savings are seen when using this method in lieu of converting two-lane roadways to four lanes)
- Ground Penetrating Radar Testing of Pavements (Cost of full-depth repairs were found to be unnecessary using this technology)

5.0 Determining the Value of Research Results – Overview of Synthesis

A related project, sponsored by the Southeast Transportation Consortium (STC) and conducted by Georgia Institute of Technology, recently created a draft synthesis of best practices for determining the value of research results. The draft report "Synthesis of Best Practices for Determining Value of Research Results" (Authors: Baabak Ashuri, Mohsen Shahandashti, and Mehdi Tavakolan) was shared with MnDOT in June 2013. Applicable highlights from the draft synthesis are summarized in this section.

The focus of the synthesis is on methods, metrics, and data sources for determining the value of transportation research results. The following tasks were conducted: a literature review, surveys to state DOTs; and content analysis.

During the content analysis portion of the project, numerous benefits quantification examples were submitted by transportation agencies for review and summary. Benefits were identified to be among the following impact areas:

- Safety
- Environmental sustainability
- Improved Productivity and Work Efficiency
- Traffic and Congestion Reduction
- Reduced Construction, Operations and Maintenance Costs
- Management and Policy
- Customer Satisfaction
- System Reliability
- Expedited Project Delivery
- Engineering Design Improvement
- Increased Service Life
- Reduced User Cost
- Reduced Administrative Costs
- Materials and Pavements
- Intelligent Transportation Systems

Chapter 5 of the draft6 synthesis report contains a summary of methods, measures, and data sources for the benefits quantification examples, organized by impact area. This chapter contains hotlinks within the document to the appendix where each example is summarized. This format provides a useful mechanism for reviewing benefits quantification examples by topic/impact area.

6.0 Best Practices, Gaps, and Challenges

6.1 Best Practices

A number of best practices were observed from review of benefits quantification practices. In general, two themes of best practices emerged: 1) Influencing the mindset of those involved in DOT research, to increase program-wide focus on research benefits; and 2) Influencing individual projects (from inception through implementation), to encourage implementation and communicate success stories.

Best Practices Related to "Influencing the Mindset"	
Facilitate and Track Implementation	• Facilitate, track, and document the status of implementation for a period of time (2-5 years) after projects are completed. This will encourage implementation and unveil successes that may be discovered without a formal process in place. • Hold technical offices accountable for reporting on implementation.
Be Selective	• For larger research programs, it has proven effective to quantify benefits for selected projects. Select projects based on availability of before/after data, significance of benefits, and level of effort required to calculate benefits. • Pay attention to projects that tend to have higher cost benefits: high-cost items (e.g. bridges, pavements), user cost savings (e.g. congestion reduction), safety improvements, solutions that preserve conditions to avoid construction expenses.
Use Systematic Approaches	• Use databases, worksheets, templates, and reports to track implementation and collect benefits information. • Conduct concentrated efforts on a regular schedule (e.g. annually or every 2-3 years)
Maintain Credibility	• Document assumptions and calculations • Be realistic and conservative to ensure calculated benefits are defendable
Encourage Innovation	• Maintain a balanced program that invests in high-risk/high-reward research. Projects of this type may not always result in quantified benefits, but large gains can be seen when DOTs try new, innovative solutions.
Best Practices Related to Influencing Individual Projects, from Inception through Implementation	
Identify Benefits Early in the Project	• Identify projects that have quantifiable benefits as early as possible, to collect data needed for determining benefits. It can be difficult to obtain data after a project ends, as the "before" conditions may not have been adequately documented.
Commit Resources	• Dedicated resources such as staff time and/or funding for external expertise are needed to systematically track implementation and quantify benefits. • Utilize expertise of DOT technical experts and Principal Investigators, to obtain the appropriate costs/savings data. • Establishing a comfort level with quantifying benefits takes time and practice. As more benefits analyses are done, it will become easier to do.
Feature Benefits in Outreach Materials	• Create outreach products, such as formatted summaries that include photos and charts/graphs that highlight quantified benefits.

6.2 Gaps in Current Practice and Challenges

After reviewing practices and conducting interviews with research management leaders, it is apparent that gaps in current practice and challenges exist when quantifying research benefits. Gaps and challenges include:

1) **Lack of Consistent Methods**: Most DOTs quantify benefits on a project-by-project basis, depending on the nature of the project. The complexity and accuracy of methods vary widely. Some methods factor in time-based effects such as the time value of money. Others take a more simplified, conservative approach in order to minimize time and effort spent on quantifying benefits. Ideally, methods should be sufficiently sophisticated to be credible, yet easy to use. A "one size fits all" formula does not exist.

2) **Difficult to Obtain Data**: Data needed to accurately calculate benefits may not be readily available. In some cases, considerable resources may be required to obtain credible data.

3) **Difficult to "Look Back":** It can be difficult to commit time and resources to look back at completed research, take steps to implement results, and collect/track information to quantify benefits. This is especially difficult when project champions change positions and when new initiatives take priority over older projects.

Note that obtaining data and performing benefits analyses will likely become easier with practice. MnDOT will build up a repository of examples; in addition, key individuals (e.g. RS staff, TLs, PIs) will become more accustomed to providing cost savings data.

7.0 Quantifying the Benefits of MnDOT Research Results

7.1 Program Strengths and Current Practices

MnDOT administers approximately $10 million in research annually, managing an average of 190 active projects at any given time. The research program consists of a local, state, and federal funding and engages numerous transportation professionals through governing boards, technical advisory panels, universities and consultants who perform the research, and users of research results and products.

MnDOT's research program has a number of strengths and in-place procedures that will be useful in developing a formal approach for quantifying benefits of research results:

- **Implementation Program** – This program has dedicated funding to facilitate implementation of research results and a structured process for identifying results that are ready for transition into practice through pilot studies, field tests, training, manuals, etc.
- **Implementation Engineer –** Although implementation is not the sole responsibility of the Implementation Engineer, this position does maintain a focus on implementation as a core portion of the position responsibilities.
- **ARTS Database** – A sophisticated database is used for managing research; this resource could be utilized to track implementation statuses and benefits.
- **Systems Approach to Managing Research** – Structured processes exist for identifying needs, selecting research, and managing projects. Established mechanisms (e.g. need statements, kickoff meetings, technical advisory panels, etc.) can be utilized to identify candidate projects and collect benefits data.
- **Strong Marketing and Outreach** – Dedicated outreach efforts and products (e.g. technical summaries, Research and Innovation Update emails, web, videos, social media, etc.) provide excellent opportunities to share quantified benefits with leaders, stakeholders, and users.
- **Benefits of MnROAD Research** – The MnDOT Office of Materials routinely conducts benefits quantification for pavement research. The paper "Economic Benefits Resulting from Road Research Performed at MnROAD" (Worel, Jensen, Clyne – March, 2008) reports estimated benefits for Phase-1 road research conducted at the MnROAD facility (view the paper at www.mrr.dot.state.mn.us/research/pdf/2008MRRDOC033.pdf.) The experience and approaches used by MnROAD staff can be leveraged as an in-house resource.

The following processes and tools currently include mechanisms to collect information about anticipated or actual benefits:

- Need Statement Form
- Proposal Form
- Post Project Evaluation Form
- Implementation Questionnaire and Implementation Plans
- Interviews conducted when preparing technical summaries

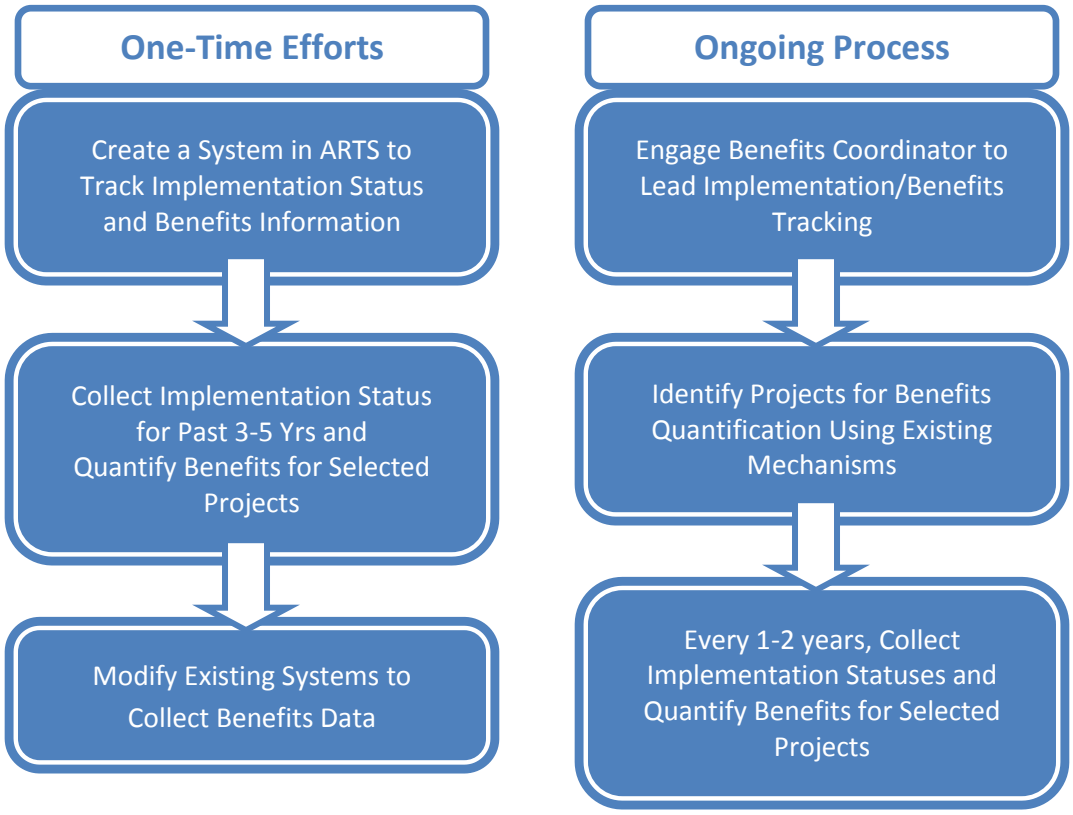
These tools and processes can be utilized and possibly expanded or modified to systematically collect qualitative benefits information and to gather data necessary to quantify benefits.

7.2 Recommendations

By leveraging its existing strengths and practices and learning from best practices of other state DOTs, MnDOT's research program can move forward in a meaningful way to quantify benefits.

Estimating and communicating benefits will require dedicated resources (e.g. staff time, potentially funding to enlist services of external resources.) As noted by DOTs that are successfully quantifying benefits, the process will become easier over time, and resources are well-spent considering how these efforts can result in success stories that demonstrate the significant value of research investments.

This section contains recommendations for MnDOT's consideration, to establish a structured process for quantifying research benefits. Recommendations are presented into two stages: 1) One-time efforts and 2) Ongoing process steps. The detailed steps include a suggested time frame (short-term or long-term) for each effort.



One-time Efforts

	Step 1: Create a System in ARTS to Track Implementation Status and Benefits Information
Short-Term Step	1.1 Create implementation status categories with associated definitions. Potential options for implementation status: • Implementation Complete • Not Yet Implemented • Not Implemented – Cannot be Implemented • Not Implemented - Additional Research 1.2 Create a field in ARTS to track implementation status. 1.3 Create a field in ARTS to designate projects that will be monitored for benefits quantification. 1.4 Create field(s) in ARTS to capture benefits information (e.g. products, quantified benefits.) 1.5 Create ARTS management reports for implementation and benefits tracking (e.g. project lists sorted by implementation status, lists showing projects designated for benefits quantification.)

	Step 2: Collect Implementation Status for Projects Completed in the Past 3-5 years and Quantify Benefits for Selected Projects
Long-Term Step	2.1 Choose a time period for which information should be collected (e.g. previous 3-5 years) 2.2 Conduct a survey to be completed by specialty offices (and possibly districts), to collect: • Implementation status • How results have been used (e.g. products, change in practice, etc.) • Identify projects for benefits quantification - Use criteria shown on page 34. 2.3 Select projects for benefits quantification. Assess MnDOT's "high-value" research projects submitted to AASTHO RAC in the past 1-3 years, as well as survey responses. 2.4 Quantify benefits for selected projects. Interview TLs and PIs to determine the quantification approach and to collect data. Conduct benefits calculations; be conservative. Document assumptions and calculations. 2.5 Populate ARTS with implementation statuses and benefits information. Also consider populating the Research Performance Management (RPM) website with benefits information, especially for "high-value" projects.

Step 3: Modify Existing Systems to Collect Benefits Data	
Short-Term Step	3.1 Need Statement Form - Retain the current question on this form: "Provide a summary of potential benefits." 3.2 Proposal Form - Modify the "expected benefits" question to include "Can anticipated benefits be quantified? If so, describe how the benefits could be quantified (e.g. cost savings, lives saved, crashes reduced, etc.)" 3.3 Pre-TAP Meeting and TAP Meetings - Set up a mechanism for discussing expected benefits and identifying candidate projects. Use the criteria/questions outlined in Process Step 2.2. 3.4 Implementation Questionnaire and Implementation Plan Template – Modify these forms to include the criteria/questions that identify projects for quantification. Add a question that asks the responder to briefly describe how the benefits could be quantified. 3.5 Post-Project Evaluation Form – Modify the form to collect qualitative benefits and identify projects for quantification. Use the criteria/questions outlined in Process Step 2.2. Separate out the portion of the form that will be used for quantifying benefits. 3.6 Define roles and processes for communicating benefits information collected via these mechanisms to the Benefits Coordinator (e.g. revise position descriptions to reflect new roles and responsibilities, hold periodic meetings with Benefits Coordinator and Project Coordinators, create ARTS reports, review proposals for benefits information, etc.) Note: Reference Section 3.5 "Case Studies Observations and Trends" of this Guide for specific ideas from case study agencies that could be applied when modifying existing mechanisms, tools, forms, etc.

Ongoing Process

Step 1: Engage Benefits Coordinator to Lead Implementation/Benefits Tracking	
Short-Term Step	1.1 Designate a Benefits Coordinator to track implementation/benefits 1.2 Engage the Benefits Coordinator to: ○ Participate in projects identified as candidates for benefits quantification (e.g. attend TAP meetings) ○ Track implementation statuses ○ Monitor the status of projects identified for benefits quantification (e.g. ensure data is being collected.)

	Step 2: Identify Projects for Benefits Quantification Using Existing Mechanisms
Short-Term Step	Note that the Benefits Coordinator could serve in a lead role for this process step. 2.1 Review benefits information in need statements and proposals. 2.2 Discuss anticipated benefits at Pre-TAP meetings : • Use established criteria to identify candidate projects. • Discuss the possibility of adding a contract task for conducting benefits analysis. (Note that often benefits can't be quantified until the project is completed and implemented. In addition, if this task is not included in the proposal, it may be necessary to set aside dedicated funding for these tasks.) • Determine mechanisms for collecting before/after data, as appropriate. 2.3 Monitor candidate projects throughout the life of the research. Work with specialty offices and PIs to ensure that before/after data is being collected as needed. 2.4 Review project closeout information to identify candidate projects. • Post-Project Evaluation Form • Technical Summary (TS) interviews 2.5 Designate candidate projects as such in ARTS or in a separate tracking system.

	Step 3: Every 1-2 years, Collect Implementation Statuses, and Quantify Benefits for Selected Projects
Long-Term Step	3.1 Run a report (or reports) in ARTS listing completed project that are "not yet implemented." Sort project lists by the specialty offices that initiated and managed the projects. 3.2 Conduct a survey to be completed by specialty offices (and possibly districts), to collect the following information for each project: • Implementation status • How results have been used (e.g. products, change in practice, etc.) • Benefits information, including whether benefits can be quantified (use established criteria/questions) 3.3 Populate ARTS with implementation status in ARTS. Track implementation status until projects have been designated as "Implementation Complete" or "Cannot be Implemented." 3.4 Select projects for benefits quantification. Use survey results, ongoing monitoring efforts through existing mechanisms, and knowledge of projects identified by RS staff as "high-impact." If ARTS is modified to designate candidate projects, a report could be run to show candidate project; otherwise a separate tracking system could be created. 3.5 Quantify benefits for selected projects: Interview TLs and PIs to determine the quantification approach and collect data. Conduct benefits calculations; be conservative. Document assumptions and calculations. 3.6 Populate ARTS with benefits information. Also consider populating the Research Performance Management (RPM) website with benefits information, especially for "high-value" projects.

Criteria and Considerations for Identifying Projects for Benefits Quantification

The following provides criteria and considerations for identifying and selecting projects for benefits quantification. These criteria and considerations will help narrow in on the most appropriate projects to evaluate and help determine where valuable efforts/resources should be allocated.

Criteria: The following criteria/questions can be used throughout the research process, to identify projects that should be considered to undergo benefits quantification:

1) Can benefits be quantified in terms of cost savings, either to MnDOT or to roadway users?
2) How significant could the savings be?
3) Do the benefits result in a high-impact result or improvement? Describe the impact.
4) Is the data needed to quantify benefits readily available (e.g. conditions before and after implementation, cost data, extent of results/change)? Is the data credible?
5) How much time and effort will be needed to access the necessary data and calculate cost savings? (Scale of 1-5: 1 = low effort, data is readily available; 5 = high effort; difficult to obtain/estimate data.)

Research Topics: It may be beneficial for MnDOT to pay special attention to projects within topic areas that have proven to result in more significant benefits. Drawing from trends of other DOTs, MnDOT research topic areas that could result in more significant quantified benefits include:

- Materials and Construction
- Bridges and Structures
- Traffic and Safety
- Maintenance Operations and Security

Note that projects conducted in these areas may not always result in significant quantified benefits, but they could be monitored more closely for cost savings potential. MnDOT's other topic areas (Planning and Policy, Environmental, and Multimodal) should also be explored for benefits quantification.

Benefit Types: Based on trends seen at other DOTs, it is worthwhile for MnDOT to pay attention to projects that that result in the following types of benefits:

- Material savings
- User cost savings (e.g. congestion reduction)
- Safety improvements
- Preservation of in-place conditions (e.g. avoiding the need for a costly change)
- High-cost items such as pavements, bridges, right-of-way, etc.

NOTE: After candidate projects are identified, several options for quantifying benefits could be used. If it is a simple calculation, internal resources (RS and technical staff) may conduct the calculation. If it is a more substantial effort, external resources (consultant or the PI) may be utilized via contracted services.

Implementation Considerations – Historical Perspective and Customer Focus

When considering next steps for implementation, it is helpful to consider historical perspectives and internal "customers" who will be engaged in benefits quantification efforts.

Historical Perspective

MnDOT Research Services has previously conducted efforts to document research benefits and impacts of research results. These efforts have changed and evolved over time. It is beneficial to capture some previous efforts and to consider historical perspectives when moving forward with implementing processes to quantify research benefits.

Two past efforts include:

- **Closeout Memos** – This process was used to collect and document information to "close out" every research project. Interviews with the Technical Liaison (TL) and Principal Investigator (PI) were conducted to collect the following information:
    - Description of the Research
    - Summary of Results
    - Summary of the Implementation Effort
    - Impacts of Implementation
    - Description of Outcomes

- **End User Products** – This concept attempted to identify the benefit of each project from the beginning (e.g. during development of the Need Statement)

These two efforts are not currently used by RS in their original formats. Closeout memos were prepared for every project and often produced information that was not used or communicated broadly. This concept evolved into a practice in which a Technical Summary (2-page project summary) is produced for each completed project. TLs and PIs are interviewed during the preparation of Technical Summaries, to document results, implementation, impacts, and outcomes – similar to information collected in Closeout Memos. The "End User Product" terminology was not necessarily intuitive and was discontinued.

"Customer Focus" Considerations

Research Services recently initiated an effort to increase its emphasis on customer-friendly services and processes. As such, it is recognized new practices resulting from benefits quantification efforts would affect MnDOT's customers, especially technical staff who would be engaged in tasks such as reporting on implementation, identifying candidate projects, and obtaining/compiling data for benefits calculations. Below are a few considerations related to anticipated level of effort and suggestions to help minimize the potential impact on MnDOT's customers.

- ***Collection of Implementation and Benefits Information for all Projects*** – This practice has the potential to be time-consuming for technical staff (e.g. Technical Liaisons and/or Office Research Coordinators) since they would be asked to report on all completed projects for a period of time after projects end. Suggestions to minimize the potential impact:

- Modify ARTS to develop a user-friendly, web-based survey interface for collecting implementation and benefits information. The survey/project information would be generated automatically by ARTS (e.g. TLs would only see their projects or specialty offices would only see their projects) and survey responses would feed directly into ARTS fields. This would also reduce RS staff time to transfer information from input forms into ARTS.
- Clearly communicate how technical staff efforts are being utilized and what the benefit is to them. (E.g. Their input is used to justify and retain research investments that provide solutions within their technical area; high-impact results will be featured in RS outreach materials, providing exposure and recognition for their efforts.)
- Note: Collecting implementation status for all projects is not necessarily required in order to quantify benefits for selected projects. However, as noted in the Utah and Florida case studies, often research results are not implemented immediately after a project ends. If projects are not re-visited for a period of time after completion, it is possible that opportunities to learn about benefits could be missed. In lieu of collecting implementation status for every project, a slight modification to this step could be to provide a list of projects completed in the past 2-3 years, asking specialty offices to review the information and report on any new implementation.

- ***Assistance with Benefits Quantification Efforts –*** Though it has not yet been tested or tried, this aspect should not have a significant impact on MnDOT technical staff, especially if the following recommendations are implemented:
  - Quantify benefits only for selected projects. This will minimize the number of technical staff involved and will limit efforts to successful, high-impact projects.
  - Limit quantification efforts to projects in which benefits can be calculated with relatively low effort (e.g. data is available and credible; calculations are relatively simple.)
  - Use RS resources (internal and/or external) to lead quantification efforts, document assumptions, and calculate benefits. This will minimize time and effort from technical staff.

7.3 Next Steps

When determining whether to move forward with some or all of the recommendations for implementing a process for quantifying research benefits, MnDOT will need to consider the level of resources they will dedicate (staff and funding), for one-time efforts and any new process steps.

Next, an implementation phase should be conducted, to carry out some or all of the recommendations. This phase includes conducting "one-time" efforts (e.g. modifying ARTS, updating forms, creating tracking mechanisms, identifying implementation statuses, quantifying benefits for selected projects) and institutionalizing ongoing efforts to identify projects as early as possible, quantify benefits, and feature these successes in marketing and outreach materials.

In the future, MnDOT may wish to extend its benefits quantification efforts to include assessing how NCHRP research results are being used within MnDOT, and whether those benefits can be quantified.

Appendix A: Utah DOT Tools and Resources

Appendix A-1: Utah DOT Research Project Benefit Assessment Form

Research Project

Benefit Assessment Form

Champion Information

Name: _____

Title:_____

Email:_____

Phone: _____

Date of Assessment:_____

Project Information

Research Project Title_____

Contract Number_____

Principal Investigator _____

Organization _____

Date Began_____Date Completed_____Duration_____months

Contract Amount $_____(including modifications)

Which functional area does this research fall under? (May select more than one)

Construction	Environmental	Geotechnical
Intelligent Trans	Maintenance	Planning
Traffic Engineering/TOC	Roadway Design	Safety
Materials	Structures	Administration
Hydraulics	Engineering Tech Services	

Objectives of the Study:

Deliverables and Primary Products:

Project Quality

Please rate the following questions as: 5-very good, 4-good, 3-fair, 2-poor, 1-very poor

1-How well did the study meet the objectives listed in the Problem Statement? ___

2-What was the quality of the Work Plan prepared and approved by the TAC? ___

3-Were the appropriate divisions, regions, and stakeholders represented on the TAC? ___

4-How well did the Principal Investigator perform and meet your expectations? _____

5-How well did the Project Manager from the Research Division coordinate with other divisions and agencies, monitor TAC activities, and administer the project contract? _____

6-How well did the Research Division support the project with funding and other resources? ___

7-What was the quality of the reports and other deliverables? _____

8-Was implementation adequately addressed and anticipated during the study? ___

9-How well were implementation strategies defined and outlined in the final report? ____

10-How would you rate the chance for successful implementation of the study recommendations and products? ____

11-Was sufficient funding allocated for the study tasks? ___

Benefits of the Project

Please provide estimates of the cost benefits associated with the project in the categories listed in the table below. Cost estimates should be conservative in nature, and based on the best information available. They should include costs to the traveling public, UDOT and our transportation stakeholders.

(Note: For each assessed grade greater than a "C", a written narrative explaining the benefits should be included.)

What grade would give this study? A, B, C, D or E (Grade each aspect of the project in the table below according to the following descriptions)

Grade	Description
A	Major impact- Revised operations (spec, policy, etc.)
B	Significant impact- Improved operations
C	Contributed to state-of-the-art
D	Unclear or contradicting findings- More study needed
E	Major tasks not completed- Objectives not met

Comments or suggestions: (Use additional sheets if needed)

Benefit Category	Grade
Asset Management This project has contributed to the management of UDOT's assets. Financial Benefit: $_____. (Could include savings related to not doing the wrong thing) Explanation:	
User Impacts This project has reduced the impacts to the traveling public. Financial Benefit: $_____. (Could include savings related to not doing the wrong thing) Explanation:	
Safety This project has improved the safety of the traveling public, UDOT and/or contractor employees. Financial Benefit: $_____. (Reduced property damage, injuries and fatalities) Explanation:	
Quality of Life This project has improved the quality of life of residents and visitors to the state, including aesthetic beauty, convenience, comfort and security. Financial Benefit: $_____. Explanation:	
Environmental This project has improved the quality of the natural environment. Financial Benefit: $_____. Explanation:	
Level of Knowledge This project has expanded the level of knowledge in this research area. Financial Benefit: $_____. (Could include savings related to not doing the wrong thing) Explanation:	
Administration and Policy This project has provided for improved administrative, management and policy decisions. Financial Benefit: $_____. Explanation:	
Grade of Project Overall	
Total Financial Benefit	$_____.

Appendix B: Missouri DOT Tools and Resources

Appendix B-1: MoDOT Research Communication Planning Sheets

Research Communication Planning Sheet (MoDOT Technical Liaison)

Project # & Title: _____

Title & Div / Dist	Name	Email Address	Implementation Decider?

Preliminary questions:
Please provide abbreviated/short answer style responses.

1) Why is this research important to MoDOT?

2) Does this research have the potential to be controversial internally or externally? If so, what are the potential controversies and with whom?

3) Which divisions/districts would be impacted by this research?

4) a) What key events or timing issues should be considered in communicating this research?
(e.g., construction season, legislative session, etc.)

b) Will the results be needed by a certain date to be relevant? If so, when and why?

Post Research Follow up:

1) Will this research be implemented? If not, why?

Research Communication Planning Sheet (Principal Investigator)

Project # & Title: _____

Contact Title	Name	Phone #	Email Address
Principal Investigator			

Preliminary questions:

Please provide abbreviated/short answer style responses.

1) Why is this research a good value to the citizens of Missouri and MoDOT?

2) a) What are the deliverables/objectives for this research?

b) If training is one of the deliverables, who will provide the training, and who will be trained?

3) a) What type of benefits will come out of this research?

b) How can we quantify these benefits?

c) If the benefit is financial, what is the estimated range of savings per <u>defined unit</u> and for what period of time? (Please include reasoning and math)

Post Research Follow up:

1) Were the deliverables/objectives met? If not, why were they not met?

2) Is the final benefit still the same as the original estimate? If not, why has it changed and what is the final estimated benefit?

Appendix B-2: Missouri DOT Research Value – Fiscal Year 2012

The Value of Missouri Transportation Research-Fiscal Year 2012

The MoDOT Research Program looks for innovations in safety, cost savings, and project delivery. Through technical exploration we discover new ways to approach problems. MoDOT's research touches the life of every driver. It saves lives, it saves money, and it saves time. This report will look at some recent research initiatives and how they've changed the way we do business or could change the way we do business. This report will also be the basis for data input into the MoDOT TRACKER measure "Value of Research – 8d". Each research contract or activity below will be evaluated on an individual basis for its impact and value for a period of one year for input into the "Value of Research" TRACKER measure. Many of these savings will be sustainable and will provide savings in subsequent years, however Tracker measure is not collecting accumulative savings.

Project/Activity Summary

Optimizing Winter/Snow Removal Operations in MoDOT St. Louis District - Includes Outcome Based Evaluation of Operations (TR1102):

The final report was received in October of 2011 so the findings were able to be implemented during the entire 2011/2012 Winter season. The biggest benefits to the findings, in the report, were in the truck routing. We were able to bring our cycle time from an average of 110 minutes to an average of 100 minutes. The final report showed that we should be able to bring that cycle time to 89 minutes but we were not able to reach that level because of the reduction of buildings and also we had a few buildings that did not implement every route recommendation. Some of the recommendations were either not practical or had political ramifications.

Cost Savings/Benefits:

St. Louis District was able to calculate the average costs per hour to operate our trucks. The summary is shown below:

$35.92	Average Salt cost/per truck/per hour
$22.80	Diesel cost/1 hour/per truck
$33.07	Year 2008/hr/with Fringe Benefit and Salary Additive
$26.36	Average equipment cost/1 hour/per truck

$118.15	Average cost per hour to operate 1 truck
$1.97	Average cost per minute to operate 1 truck

During the 2011- 2012 Winter season we had 4 events that required full deployment of our resources. During those events we averaged 2 applications of material which required 2 cycles. Using the 10 minutes saved per truck per cycle we came up with the following costs savings per storm:

10 Min. per cycle X 2 cycles X 238 trucks X $1.97 per minute = $9,377.20

Savings were approximately $9,400 per storm. So for 4 storms the total savings for the 2011-2012 season were approximately $38,000.

Last season was extraordinarily light and a typical season would see on average 8 - 12 storms that require full deployment, so St. District provided average savings that could be expected to be approximately $75,000 – $125,000. Thus, will use $125,000 for Tracker measure.

Diamond Grinding Best Practices (TR1117):

With Missouri Department of Transportation (MoDOT), Smooth Roads Initiative (SRI), a plan to bring 2200 miles of the state's major roads to good condition in less than five years, new processes had to be used to help meet this goal. One of these was an expansion of the use of Diamond Grinding. Diamond grinding had been used in the past mostly to rehabilitate small projects, but now was used on hundreds of miles of Portland Cement Concrete Pavements (PCCP) to improve their ride. There have been several locations that were diamond ground even years before SRI on I-44 and other routes in the Joplin area of the Southwest District that are now experiencing some problems. It is generally accepted that Diamond Grinding is a one-time repair for ride on concrete pavements. In the future repair methods and materials need to be established for the many miles of SRI Diamond Grinding sections of PCCP. Mike Middleton, District Maintenance Engineer, initiated the request to do research on these pavements and assisted in the inspection made in March 2011.

The objective of this study was to review Diamond Grinding sites and literature to develop guidance on when to use Diamond Grinding and how to maintain the pavement after grinding. Tasks set up in the work plan for the project included:

- A literature search on best practices (BP) of Diamond Grinding from academia and other departments of transportation.
- Research worked with Maintenance Engineer, Mike Middleton from former District 7 and John Donahue, Construction and Materials Liaison in the Pavement Section to locate and investigate various sections of Diamond Grinding (DG) to investigate and document any distresses in the PCCP.
- Research worked with District 7 to inspect these sections of pavement.
- A final report of the evaluation of the engineering and best practices of maintaining smooth, rideable diamond ground concrete pavement for many years in the future.

The literature search found the following from the Portland Cement Association:
PCA's official Research and Development Bulletin RD118 on the subject " Longevity and Performance of Diamond Ground Pavements" has some key points summarized here.

- It states that the cost is less than an asphaltic concrete overlay.
- It enhances friction and skid resistance.
- It is possible to do only one lane of a dual lane PCC pavement if that is all that's needed.
- Effects of grinding on slab thickness are inconsequential when long term strength is considered.
- Cracking is helped by smoothness of the pavement.
- Diamond grinding surfaces last at least 10 years and 10.8 million EASLs.
- Smoothness and the good skid resistance reduce the % of accidents.
- Texture lasts 8-12 years in medium freeze region.
- Undoweled pavement faulting levels off at about 2 million EASLs, wet areas are affected more; dry areas can last up to 20 million ESALs.
- Service life of 37 years, 35 million EASLs since original construction.
    - 50% reliability - 13.5 years service life or 12 million EASLs.
    - 90% reliability - 9.5 years service life or 6.5 million EASLs.
- Single grinding can add 10 years life and can be re-ground total of three times.
- Serviceability factors above don't apply to deficient pavement. (However, can get 5 years even on a deficient pavement.)

Anticipated Benefits:

Diamond Grinding of pavement using Best Practices should prolong the rideability of concrete pavement for many years. There will be a cost savings in the lengthening of the life of the pavement before a major repair job or pavement replacement. **Diamond grinding can be performed up to 3 times and can lasts 10 years before another treatment needs to be performed.**

Conclusions Recommendations:

The Southwest District's plans for the pavements that were inspected have followed the Best Practices almost to the letter. It has been found that older pavements have been diamond ground can be ground again up to three times if they do not cause any structural distress. At that time or if they are thin pavements, have ASR or D-cracking problems or an excessive amount of faulting or joint problems they need rehabilitation and probably an AC overlay. It has also been shown that diamond grinding can be used to smooth up pavement causing noise reduction , improvement of skid resistance and less distress to the pavement structure. There was some minor cracking at joints on the pavements inspected. Overall, the District's design construction, and maintenance procedures using diamond grinding have proven to be exactly what was called for to maintain these roads. A table showing the recommended Best Practices and whether diamond grinding is appropriate or not is included in the conclusion of this report as a guide in determining if a PCC pavement is a good candidate for diamond grinding.

Pavement Condition	Diamond Grind	Don't DG
IRI > 190 in./mile		X
Lacks structural Integrity (Voids, Excessive Faulting)		X
Spalling due to ASR		X
Freeze/Thaw Damage, D-Cracking		X
Poor Load Transfer (need to fix joints)		X
Soft Aggregate (*may widen blade spacing)	X*	X
Skid Resistance	X	
Wet/Dry Accident Reduction	X	
Ride (Smoothness)	X	
Noise Reduction	X	
Slab Curling	X	
Multiple Treatments (10 year life and up to 3 times)	X	
Faulting (Remove up to 1/64")	X	
Reduces Dynamic & Impact Loads	X	
Less than AC Overlay	X	

Texture Lasts 8-10 years	**X**	
Service Life Extended 10 years **or 6.5 M EASLs**	**X**	
Cost Competitive, $1.70-$6.70 per sq. yd. **(MoDOT Avg. Bid Price 2010 = $2.33 sq.yd.**	**X**	

Cost Savings/Benefits:

During the SRI program it was found that the average improvement took IRI from 123.1 inches/mile to 79.1 inches/mile after diamond grinding for an average improvement of 44 inches/mile. Over a 10 year period (equal to the life of diamond grinding according to the research) conservatively could expect an degradation on average of 4 inches/mile for those 10 years before another treatment would be needed. The assumption is that we can extend the life of the concrete pavement for 10 years and defer the need for an overlay during that same time period. The assumption is to compare the DG cost to the cost of a Nova-Chip treatment are similar with a 10 year life cycle. Reviewing Statewide 2011 Unit Bid Costs found that 3,201,624 sq.yds were diamond ground at a cost of $2.19/sq.yd. Whereas, UltraThin Bonded Wearing Surface-Type C (Nova Chip) had 4,648,417 sq.yds. placed at a cost of $4.38/sq.yd. This leaves a difference (cost savings) of $2.19/sq.yd.

The Transportation Management System (TMS) was queried for concrete pavements from 80-100 inches/mile (equal to a 5 year period). There were 348.11 lane miles of PCR, 11.028 lane miles of PC and 812.59 lane miles of PCN. This totals 1,171.73 lane miles will round to 1,150 miles.

(1,150 lane miles x 5,280 ft/mile x 12 ft/lane mile) / 9 = 8,096,000 sq.yds. (over 10 year life)

Annual Cost savings = (8,096,000sq.yds. x $2.19/sq.yd.)/10 years = $1,773,024 for the Tracker.

Projected Annual Savings/Benefits from Fiscal Year 2012 MoDOT Research

Improved Technology	Lives Saved	Crashes Reduced	Organizational Savings/Benefits (Annual)
Optimizing Winter/Snow Removal Operations in MoDOT St. Louis District - Includes Outcome Based Evaluation of Operations (TR1102)			$125,000
Diamond Grinding Best Practices (TR1117)			$1,773,024
I-64 Before and After Analysis			Informational in nature (no cost savings) and I-64 was not developed because of Research. Will become useful if future full-closures are evaluated
Striping and Delineation Study – SRI 3 year evaluation with focus on the elements of SRI (wider strips, rumble strips, brighter signs, etc.)			Crash reduction numbers for Major Routes evaluated for
Slide Repair			Guidebook was developed to share best practices
Settling Pipes in District 7			Review of settling pipes was evaluated to determine cause of settlement – no cost savings was calculated
Vegetation Management of Center Medians			Recommendations determined by

			Maintenance to cost prohibitive
LED Luminaires Project			Traffic has not implemented LED Luminaires to date
Dynamic Message Signs			User Cost numbers were developed as part of study
Missouri River Freight Corridor Development Plan			Research was developed to inventory facilities along the Missouri River, therefore not benefits calculated to date
Total			$1,898,024 ($1.9 million)

Appendix B-3: Missouri DOT TRACKER Measure – Value of Research

Value of research-8d New!

Result Driver: Dave Ahlvers, State Construction & Materials Engineer
Measurement Driver: Bill Stone, Research Administrator

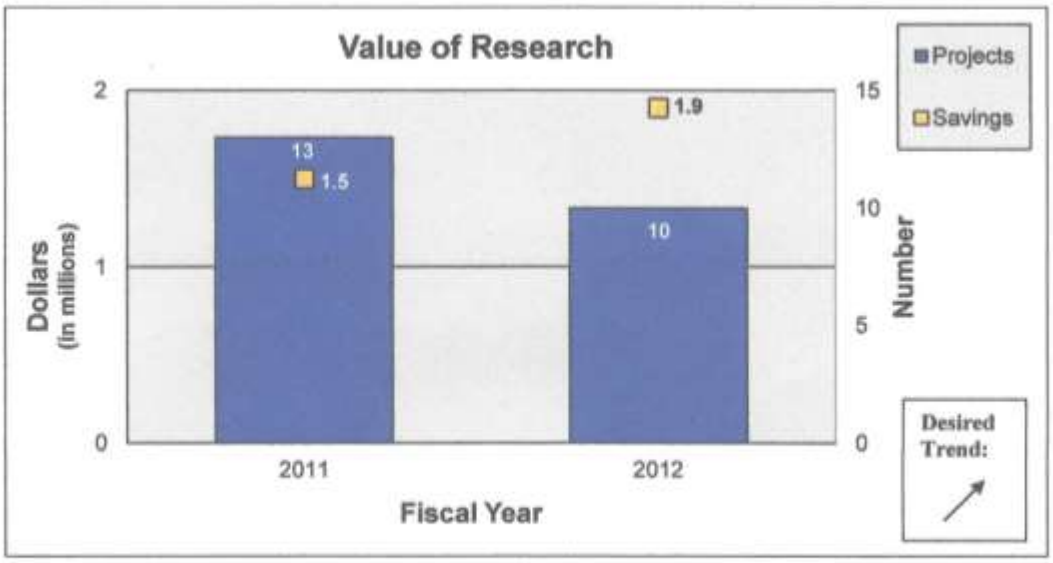
Purpose of the Measure:
This measure tracks the organizational impact of research activities from the department's research program. A strong research program supports innovative solutions where they can make the greatest impact on the department.

Measurement and Data Collection:
The data for this measure is collected each June for research activities conducted the previous fiscal year. The MoDOT research program touches many areas of the organization and the public. Research projects and activities include all research (internal and external) funded through the department's research program. The evaluation of the value of research is compiled as it relates to crashes reduced and organizational savings and benefits. For this reason, each research project will be evaluated individually for its impact and value of anticipated annual savings to MoDOT.

As an example of how the savings is compiled, MoDOT completed research in Fiscal Year 2011 on drilled shafts in the geotechnical program and put the savings at approximately $45,000 for a typical bridge. Reviewing the STIP in Fiscal Year 2013, there are 18 bridges incorporating drilled shafts. This results in $810,000 in annual savings (18 bridges times $45,000 per bridge).

Improvement Status:
For Fiscal Year 2012, there were 10 research projects completed and evaluated which resulted in $1.9 million anticipated annual savings to MoDOT. The St. Louis District implemented snow route logistics research, which resulted in a reduction on average of 10 minutes per cycle time. Using the cost of operation per truck (salt, fuel, equipment and labor) and calculating that for the fleet (238 trucks) during implementation, in a typical winter would result in savings of $125,000.

The research section continues to work closely with researchers and MoDOT staff on research projects and activities during the implementation phase and also in the evaluation of the annual savings.



Appendix C: Florida DOT Tools and Resources

Research Deployment Plan Survey

Research Project Deployment Plan Survey

All research projects shall have a deployment plan which must be submitted prior to contract finalization. The purpose of this survey is to aid project managers in preparing the initial or baseline deployment plan. The deployment plan may be updated over the course of the project, as needed. The following 24 questions will ask project managers to input project identifier information and deployment information dealing with implementation, performance measurement, technology transfer, marketing, and training.

NOTE: This survey should not take a project manager familiar with the purpose and intended outcome of the research more than 15 minutes to complete. This survey must be completed once started or entered information will be lost. Once you have selected "Done," you will be directed to a closeout page, where you will be requested to click a link to initiate an email to the Research Center advising that the deployment plan has been completed.

1. Project Manager

2. Office

3. Project Information

Title

Contract Number (leave blank if not yet assigned)

4. Project Status

5. Please identify any other offices that may be affected by the outcome of this research.

- Aviation
- Construction
- Drainage
- Environmental Management
- Geotechnical
- Maintenance
- Materials
- Motor Carrier Compliance
- Pavement Management
- Planning-Policy
- Planning-Statistics
- Planning-Systems
- Product Evaluation
- Rail
- Research
- Roadway Design
- Safety
- Seaports
- Specifications and Estimates
- Structures
- Surveying and Mapping
- Traffic Engineering and Operations
- Transit
- Turnpike

IMPLEMENTATION

This section of the survey asks project managers to identify any prerequisites to or requirements for

implementation. It should identify potential barriers to implementation and any actions that should or will need to take place before the research can be put into practice.

6. Will implementation of the research results require a change to legislation?

Yes

No

If "yes," explain.

7. Will implementation of the research results require a change to an FDOT Rule?

Yes

No

If "yes," explain.

8. Will implementation of the research results require a policy change?

Yes

No

If "yes," explain.

9. Will implementation of the research results require a change to a procedure or the development of a new procedure or test method?

Yes

No

If "yes," explain.

10. Will implementation of the research results require a change to specifications or a new specification?

Yes

No

If "yes," explain.

11. Will a demonstration or experimental project be required?

Yes

No

If "yes," explain.

12. If this project will result in the development of a product(s), please identify the type(s) of product(s) to be developed.

No product will be developed

Field device

Scientific equipment

Software

Other

Other (please specify)

13. If a product will be developed, please identify any of the following that may be required. If more than one product was identified in the previous question, be sure to identify the need(s) for each product in the comments box provided below.

No product will be developed

Approved Products List (evaluation and acceptance)

Commercialization

☐ Copyright

☐ Patent

☐ Qualified Products List (evaluation and acceptance)

Please provide an explanation for each of the choices selected (for each of the products).

PERFORMANCE MEASURES

This section of the survey requests project managers to identify performance measures that could be applied to the output and/or outcome of the research. Quantitative measures refer to quantifiable benefits that can be measured. Qualitative measures refer to non-quantifiable benefits, i.e., which are not subject to discrete analysis.

14. Can economic benefits be determined if the results of this research are successfully implemented?

○ Yes

○ No

If "yes," please explain.

15. Are there non-economic quantifiable benefits that could be assessed if the research results are successfully implemented?

○ Yes

○ No

If "yes," please explain.

16. Will successful implementation of the research result in a safety enhancement?

○ Yes

○ No

If "yes," please explain.

17. Will successful implementation of the research result in system efficiencies?

○ Yes

○ No

If "yes," please explain.

18. Will successful implementation of the research result in resource savings?

○ Yes

○ No

If "yes," please explain.

19. Will successful implementation of the research result in environmental gains?

○ Yes

○ No

If "yes," please explain.

20. Will successful implementation of the research result in community enrichment?

○ Yes

○ No

If "yes," please explain.

21. Are there any other qualitative benefits that could be measured?

Yes

No

If "yes," please explain.

TECHNOLOGY TRANSFER

The Research Center currently performs a variety of technology transfer activities. These activities are intended to inform practitioners of the research results. They include posting reports online; distributing final reports to national repositories and online transportation resources; using listservs to notify FDOT and non-FDOT recipients of report availability; and production of project cards. This section asks project managers to identify any additional technology transfer needs. If no additional technology transfer is needed please check that box.

22. Are any of the following additional technology transfer efforts needed or expected to be performed? If so, please identify who is anticipated or desired to perform the activity in the comment box below--for example, if your office has a newsletter or hosts a conference/meeting that you anticipate being used to perform technology transfer for this project. If any of the following options is selected as a need, but no provider has yet been identified, please so indicate.

- No additional technology transfer needed
- Conference
- Executive summary
- Meeting
- Newsletter
- Technical summary
- Web posting
- Workshop
- Other

Please explain the anticipated need for any of the options selected, and identify anticipated venue or provider, if known.

MARKETING

Unlike technology transfer, marketing is directed towards a larger, general audience. Current activities include general project summaries, a research showcase magazine, and development of videos. These activities are done in coordination with project managers. In this section, project managers should identify additional marketing efforts that may be warranted.

23. A small percentage of projects may warrant additional marketing efforts. With respect to news media options, candidate projects would likely either be highly visible to the public, in which case marketing may be conducted as part of the project, or have a substantial safety or cost-savings benefit.

- ☐ No marketing needed
- ☐ News media (radio, TV, newspaper)
- ☐ Printed materials
- ☐ CDs/DVDs
- ☐ Other

Please explain the anticipated need for any of the options selected, and identify desired provider, if known.

TRAINING

Training may sometimes be needed to implement the results of research, and it may be delivered by a variety of means, including processes already established within the implementing office. This section asks project managers to identify any training that might be needed for the research to be implemented.

24. Please identify any of the following that may apply, and provide a brief explanation.

- ○ No training needed
- ○ Training for FDOT and/or non-FDOT using existing processes
- ○ Training for non-FDOT to be provided by non-FDOT source(s)
- ○ Training may be needed, source unidentified

Comments

Done

Appendix C-2: Florida DOT Implementation Definitions

"Implementation" is defined as the use of the research results or outcomes by FDOT or an FDOT affiliate in Florida, with usage results that encourage future deployment, or as the enacting of FDOT specifications that will require the use of research results or outcomes for future work by FDOT or an FDOT affiliate.

"Can't be Implemented" is defined as a research project whose results and outcomes will not be used by FDOT or an FDOT affiliate in Florida. This includes projects whose results do not merit further investigation, projects that were used by FDOT but the results of that use do not encourage future deployment, projects with successful results or outcomes that will not be used by FDOT or an FDOT affiliate based on policy or any other internal decision, and projects not used for any other reason.

"Will be Implemented" is defined as a project whose results or outcomes are expected to be used by FDOT or an FDOT affiliate in Florida in the future, but this use has not begun and is not yet programmed. Status will change to "Implemented" or "Can't be Implemented" after this future use depending on results.

"Is Being Implemented" is defined as a project who's results or outcomes are currently being used by FDOT or an FDOT affiliate in Florida, but if usage results will encourage future deployment is not yet determined. If the results of use encourage future deployment the project will be classified as "Implemented". If the results of use do not encourage future deployment then the project will be classified as "Can't be Implemented".

Appendix C-3: Florida DOT Example of Completed Implementation Survey

Materials Research Projects
2010-11 Implementation Survey

Below is a table containing the Research Center projects completed by your office in fiscal year 2011/12. Please take a moment to answer two questions about each project that you managed (or, if not manager, for which you are the designated responder.) Explanations of each question are below.

If you have any questions on how to complete this table please contact Mark Greeley (Research Performance Coordinator) at Mark.Greeley@dot.state.fl.us or (850) 414-4613

Responder:
Name of person providing information for the project who can be contacted for further information.

Implementation Status Options:
Please consider the results of the project and make an assessment of the current state of implementation by choosing one of the four options below. Input the appropriate number into the table below:

1. The project can't be implemented.
2. The project will be implemented later.
3. The project is being implemented.
4. The project has been implemented.

Explanation of Implementation Status:
Please write a few words to indicate, as appropriate:

- Why the project can't be implemented
- What the plan is to start/complete implementation
- How the project was implemented (e.g. spec change, best practice put in place, etc)
- Any noted success or failure in implementation

Example of a Completed Table (selected projects only)

PM	Responder	Title	Contract	Status	Explanation of Status
(Name)	(Name)	Literature Review of Hot-In-Place Recycling	PR5620597	3	The project identified the number of hot in-place recycling projects typically performed by selected states. It also identified typical performance as well as a number of design and construction methodologies being used. This information is being used by FDOT Management as a basis for determining the viability of future hot in place recycling projects in Florida.
(Name)	(Name)	Base Course Resilient Modulus for the Mechanistic-Empirical Pavement Design Guide	BDK75 977-10	2	This project developed a procedure to obtain a single input modulus for the M-E PDG software, taking into account moisture and non-linear strain effects. This approach appeared to work for the current cracking model, but additional work is needed to assess the non-linear strain effects of the subgrade layer on rutting. Therefore, it is anticipated that this project's procedure to obtain a single modulus input will be used when all of the failure models for the M-E PDG have been finalized and the non-linear strain effects of the subgrade on the rutting model have been performed.
(Name)	(Name)	Development of Tiered Aggregate Specifications for FDOT Use	BDK75 977-29	2	The Specifications Office has provided a clean copy of Standard Specification 901. A Developmental Specification will be created with language from the finished report for uses in non-structural concrete. The SMO needs to find a project where this Specification can be piloted.

Appendix C-4: Florida DOT Implementation Tracker (Excel Template)

Project Name	Evaluation of Camera-Based Systems to Reduce				
Project Number	BDK85 977-35	**Start Date**	10/1/2011	**Information Sources**	
Project Manager	Wiley, Victor	**End Date**	12/31/2012	Wiley - FDOT	
Principal Investigator	Lin, Pei-Sung	**Funding**	$98,840	Lin - USF	
				Kourtellis - USF	

Project Description

A hybrid bus side view camera system was developed and tested. Controlled driving tests were conducted with 29 drivers, evaluating the field of view and object identification. Results and driver recommendations were then used to design a long term field deployment.

Project Findings

Drivers had 96-98% object recognition with the camera system vs. 70-78% using mirrors alone. Drivers also identified object faster (4 sec vs. 5 sec) when using the camera system. Long term field tests showed general agreement that the cameras were a benefit, but only 50% of surveyed drivers said they would like them on their bus.

Is the Project Complete?	Yes	**Is Follow-up Work Planned?**	No
Resulted in FDOT Spec Change?	Yes		
Spec #	check ltr		

What is the Implementation Status of this Project? The project has been implemented

What are the results of implementation?	**What are the Expected Impacts?**
Bobby Westbrook has worked with bus manufacturers, side view cameras are now available on bus purchase contracts.	Improved visibility for bus drivers should lower accident rates, reduce accident congestion.

Expected % Utilized check crash data 3/2014

What impacts have been recorded?			**QTY**	**$**	**Comment**
Safety Improvements	✔				better visibility, less accidents
Infrastructure Condition					
Congestion Reduction (TT, gas)	✔				less accident congestion
System Reliability Improved					
Freight/Economic Benefit					
Environmental Benefit					
Project Time Reduced					
Materials Saved					
Man Hours Saved	✔				less accidents
Variation Reduced (Process, Matl)					
Liability to FDOT Reduced					
		Sum		$0	
		Years Applicable			**Total** $0

Other Comments

Follow up to BDK85 977-08. FDOT guidance will probably state these systems should not be used at night. Potential follow up could address camera filters to reduce nighttime headlight glare. Also want to have LeeTran keep cameras for more field study.

Appendix C-5: Florida DOT Examples of Quantified Benefits

This compilation of examples of quantified research benefits were provided by Mark Greeley, FDOT (March 2013.)

Example 1: Safety

BD545-02 Pedestrian Safety Engineering and Intelligent Transportation System-Based Countermeasures Program for Reduced Pedestrian Fatalities, Injuries, Conflicts and Other Surrogate Measures: Miami-Dade Site

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_SF/FDOT_BD545_02_rpt.pdf

This project had three primary goals:

1.) The installation of pedestrian countermeasures;

2.) The scientific evaluation of the countermeasures in order to determine their efficacy;

3.) To produce a significant crash reduction along the treated high crash corridors.

Of the countermeasures that were effective in the trial, and that were left in place at the end of the trial, before and after traffic incident data was collected. Of those sites it was determined that there was a statistically significant reduction in pedestrian accidents per year in two locations (by t-test, 95% confidence). The average reduction in pedestrian accidents per year at those two locations was 16.8.

Using the calculated cost of an accident from FHWA and AAA, it can be stated that avoiding 16.8 crashes per year saves society $1,276,643/yr.

Example 2: Environmental Sustainability

BDK78 977-04 Evaluation of Pollution Levels due to Consumer Fertilizer

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_RD/FDOT_BDK78_977-04_rpt.pdf

The local water management district was going to levy fines against FDOT and many other entities for nitrogen discharge to the river. They set a target reduction for FDOT, and we were able to show that by stopping annual fertilizing we could meet 85% of their target reduction. This saves 85% of the anticipated fine (which was $1M per year, so 85% is $850,000 per year) and also saves $150,000 per year in fertilizer.

The key was determining how much nitrogen was getting out of our turf and into the water, which was the point of the project.

Example 3: Management and Policy

BDK85 977-13 Assessment Instrument for the Certified Transit Technician Program

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_PTO/FDOT_BDK85_977-13_sum.pdf

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_PTO/FDOT_BDK85_977-13_rpt.pdf

The Certified Transit tech program is a course developed by USF and FDOT to train people to work in transit maintenance. This project also developed an alternative to a traditional pre/post training knowledge test, getting feedback on how the technicians improved on their jobs after this training. The tool developed was to capture the benefits to the employee, and to the transit agencies, and it is being used to improve the program.

This class is the only one in the country where technicians get credits that they can use for community college degrees. As a result of how the class was structured and improved it was awarded an FTA grant of $188,000. I interpret the award of the grant as a financial benefit of smart management.

Example 4: Infrastructure Condition

BD550-06 Thermomechanical Durability of CFRP-Strengthened Reinforced Concrete Beams

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_STR/FDOT_BD550_06_rpt.pdf

Investigating techniques for extending the life of FDOT structures and roadways pays benefits by reducing the need to close roads to perform unplanned repairs, reducing maintenance costs, and preventing unsafe travel conditions. FDOT has funded the testing of carbon fiber-reinforced (CFR) polymer materials to increase strength or to repair damaged bridges. FDOT uses CFR wraps two-to-three times per year to repair bridges either after impacts or for strength, saving $350,000 per year vs. replacing components. Savings calculated from contract documents average $130,000 per instance.

Example 5: Quality of Life

This project was done to quantify the benefits of an FDOT program. The research was the method to do the quantification, but the program being evaluated was already in place. This might not fit with what you are looking for, but it's worth a read.

BDK84 977-15 Review and Update of Road Ranger Cost Benefit Analysis

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_TE/FDOT_BDK84_977-15_sum.pdf

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_TE/FDOT_BDK84_977-15_rpt.pdf

Road Ranger service coverage data compiled for FDOT districts where this program operates and for Florida's Turnpike Enterprise (FTE). Reviewed the Road Rangers program. Data for Rangers operations

were collected from SunGuide™, including mean spent time per incident type, mean response time without Road Ranger service, traffic profile, highway geometry, and average travel speed.

Determined delay savings, fuel savings, and total benefits. All benefits were converted to dollar equivalents. Weekend and weekday incidents were treated separately. Benefits exceeded costs in all districts, though the ratio of benefit to cost varied. Overall, the average benefit to cost was 6.78 to 1 ($134M benefit to $20M in costs for 2010).

Example 6: System Reliability

BD545-54 **Anchor Embedment Requirements for Signal/Sign Structures**

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_STR/FDOT_BD545_54.pdf

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_STR/FDOT_BD545_54_rpt.pdf

The project was mainly to design a new sign foundation to stand up to the type of torsional loading that failed signs in Hurricane Dennis. This resulted in a new design with hoops of rebar spaced at 4" instead of 12", which adds about $24 to the installation of a sign foundation.

The cost of installing a new sign is approximately $75,000. In addition, it is critical that these signs are in place for directing traffic (and to not obstruct the roadway) after a hurricane. It can be estimated that the failure of approximately one sign of this type can be avoided by using the design developed in this project (which is now in FDOT specification).

Example 7: Expedited Project Delivery

SPR-3(017) Type K Temporary Barriers

FDOT had to find a replacement for Jersey barriers (type 415) due to national phase-out. This work was crash testing to support previous pooled fund work. A new F shaped barrier had been developed that could be bolted down to concrete and deflect 6" in a crash. FDOT funded work to determine deflection when nailed to asphalt, and later a method to use barriers to protect bridge piers.

The result of this work was "the most complete temporary barrier system available to date" per a publication of the Midwest Roadside Safety Facility. The barrier could be nailed to asphalt and only deflect 1.5', allowing wider travel lanes in construction zones and wider shoulders.

A contractor estimated that employing this barrier saves $500,000 per mile by allowing work behind the barrier (avoids changing alignment of the work zone). Additional benefits that are difficult to calculate include the ability to have traffic on two lane bridges while they are under construction, and the significant savings of project overhead by using the pooled fund process (that savings is estimated to be $400,000 due to a 10% OH rate, versus 45% for direct contract with the vendor).

Example 8: Engineering Design Improvement

BDH10 M-E PDG PROGRAM IMPLEMENTATION IN FLORIDA

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_RD/FDOT_BDH10.pdf

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_RD/FDOT_BDH10_rpt.pdf

For states seeking to implement the M-E PDG, the developers of the design guide have recommended that the models be calibrated to local conditions (avoid using national defaults.) This project was that calibration for version 0.7 and 1.0.

Established and tested in-service pavement sections across Florida to develop a database for calibrating the existing M-E PDG pavement performance models. Additionally, a conceptual framework was established for developing an M-E PDG-based pavement design method that is tailored to current FDOT practice.

The benefits of this work were a 1" reduction in the average concrete thickness of Florida roads. In an average year this saves FDOT $356,000 (calculated from construction records). Additional benefit was in the analysis time saved by engineers, estimated to be $6,738 per year. The reduced concrete use also saved 570 tons of CO2 per year.

Example 9: Improved Productivity and Work Efficiency

BDK83 977-07 Applying Instructional Design Practices to RCI Training

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_PL/FDOT_BDK83_977-07_sum.pdf

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_PL/FDOT_BDK83_977-07_rpt.pdf

Developed an instructional design strategy to improve RCI training while reducing its cost. Research will provide FDOT with a plan for developing a more effective curriculum using a competency-based approach and a new method for delivery. Included in the plan will be a curriculum training and analysis, competency model, design document, and course module prototypes.

Identified competencies in the form of knowledge, skills, and abilities that the FDOT would like RCI technicians to possess. The outcomes of this research study provided a compelling case for the task-centered method of instruction that is applied within the competency-based framework.

The savings associated with this work are from reduced travel and training costs. By allowing this training online, in a format equally effective to the in-person training, 1408 man hours are saved per year ($67,584). Avoided travel costs (hotels, meeting space, gas, etc) are $37,000 per year.

Example 10: Reduced Administrative Costs

BD549-47 Development of Comprehensive Guidance on Obtaining Service Consumed Data for National Transit Database

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_PTO/FDOT_BD549-47.pdf

http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_PTO/FDOT_BD549-47_rpt.pdf

Transit agencies in Florida spend hundreds of hours per year monitoring and reporting rider miles to the Federal Transit Administration (FTA). The FDOT Public Transportation

Office (PTO), working with the National Center for Transit Research (NCTR) at the University of South Florida, addressed this labor burden by creating a more efficient statistical sampling plan for monitoring the FTA-required rider miles on all modes of transit. FTA estimates employing this new sampling plan will save a local transit agency 800 hours every year, or approximately $20,000 per year. One large early adopter interviewed captured a savings of over $90,000 per year, reducing required sampling from 4000 trips to 300. A separate (smaller) adopter realized a reduction in required sampling from 361 to 60, although they could not offer a precise financial impact.

Example 11: Reduced Construction, Operation, and Maintenance Costs

BB258 Recycling Process Water in Ready-Mixed Concrete Operations

Water management associations restricted use of potable water on concrete batches and sprinkling aggregate. Manufacturers wanted to use rinse water from mix drums (trucks come back to the yard with this, it is dumped into 1 holding pond, then when that overflows it trickles to a second pond), or trickle from aggregate piles. Results show the water was alkaline, specs changed to allow for use in sprinkling of coarse aggregate and for use in non-structural concrete from the second holding pond.

Impact is from using less potable water, and from not discharging dirty wash water. Avg 19gal/yard water for sprinkle aggregate. FDOT uses 2M yards/yr concrete, and an average water cost is $0.002/gal. Calculated savings by allowing this water re-use are $76,000 per year to the concrete producer.

Appendix D: Louisiana DOTD Tools and Resources

Research (Section 19)
Fiscal Year 12 - 13

Goal 1: Continuously improve the performance of the Office of Engineering

Objective 1.1: Meet 85 percent of target goals established for marketing of technical information and research results with publications and formal presentations current FY.

- **Input:**
  - Project capsules required (projects started)
  - Technical summaries required (final reports published)
  - Publication submittal goal (one/completed project)
  - Presentations goal (one/completed project)
  - Articles goal (one/Technology Today publication)
- **Output:**
  - Project capsules published on time (90 days)
  - Technical summaries published with final report
  - Publications submitted
  - Presentations given per project
  - Article published in Tech Today
- **Efficiency:**
  - Percent of target goals met

Goal 2: Deliver cost effective products, projects and services in a timely manner

Objective 2.1: Sixty percent of research projects final reports delivered with PRC approval by scheduled completion date each fiscal year.

- **Input:**
  - Date projects scheduled for completion
  - Date final reports receive PRC approval
  - Number of projects scheduled for completion current fiscal year
  - Projects extensions granted due to justifiable cause
- **Output:**
  - Number of final project reports approved by PRC by scheduled completion date current fiscal year
- **Efficiency:**
  - Percent final draft reports delivered to editing by scheduled completion date

Objective 2.2: Seventy percent of research projects final reports published within one year of project end date for projects completed previous fiscal year.

- **Input:**
  - Number of projects ended previous fiscal year
  - Date final reports approved for publication

- **Output:**
  - Number of final project reports published within one year of project end dates
- **Efficiency:**
  - Percent final reports published within one year of project end dates

Objective 2.3: Reduce the number of final reports published late by 10%. (greater than one year from end date)

- **Input:**
  - Number of project reports pending publication greater than one year past project end date previous fiscal year
  - Project end dates
  - Date final reports approved for posting / publication
- **Output:**
  - Time between project end date and posting / publication date for each project
  - Number of project reports pending publication greater than one year past project end date current fiscal year
  - Difference in number of late reports between fiscal years
- **Efficiency:**
  - Percent reduction in late reports from previous fiscal year compared to current fiscal year

Goal 3: Improve customer service and public confidence

Objective 3.1: Receive an average rating of 3.5 on customer satisfaction surveys for research projects published each fiscal year.

- **Input:**
  - Research published current fiscal year
  - Rating results received from completed research project surveys
- **Output:**
  - Average rating of research projects receiving ratings of 3.5 out of 5 or better

Objective 3.2: Receive an average rating of 3.5 on customer satisfaction surveys for technical assistance project results delivered to DOTD each fiscal year.

- **Input:**
  - Technical assistance requests received current fiscal year
  - Technical assistance project results delivered current fiscal year
  - Rating results received from technical assistance satisfaction surveys
- **Output:**
  - Average rating received on technical assistance surveys 3.5 out of 5 or better

Goal 5: Effectively manage the financial resources available to the Office of Engineering

Objective 5.1: Sixty five percent of projects to expend funds within +/- 20% of the estimated budget each fiscal year.

- **Input:**
  - Number projects this fiscal year
  - Estimated funds budgeted for each project
    - July planning & January biannual update
  - Actual funds expended on each project
- **Output:**
  - Actual funds expended on each project current FY
  - Number projects that expended funds within +/- 20% of estimate current FY
- **Efficiency:**
  - Percent projects that expended funds within +/- 20% of estimate

Objective 5.3: In past 5 years, seventy five percent of completed research projects provide recommendations for implementation of results endorsed by the Project Review Committee.

- **Input:**
  - Implementation status summary from completed projects
  - Number of completed research projects within last five years
- **Output:**
  - Number of project with recommendations for implementation of results that have not yet been adopted
- **Efficiency**
  - Percentage of project within last five years with recommendations for implementation of results endorsed by the Project Review Committee.

Appendix D-2: Louisiana DOTD Research Assessment and Implementation Report

Research Assessment and Implementation Report

Project Number:

Project Title:

Objectives
[What are the objectives/deliverables/products of this research?]

Implementation Recommendations
[Provide the implementation recommendations as developed by the Project Review Committee.]

Potential Impact
[Describe potential impact of the recommendations in terms of cost, efficiency, safety, convenience, aesthetics, etc. Describe required changes to existing specifications, standards, procedures, etc.]

Target Audience
[Who will benefit from this research? List whom you want to reach, their primary interest, and your objective in reaching them.]

Strategies and Tactics
[Describe practical areas of application. List the activities required for implementation, including resource needs. Consider needs for training, multimedia, and marketing.]

Timeline
[Create a schedule for each discrete strategy or tactic.]

Implementation Responsibility
[Define roles and responsibilities of all personnel involved in the implementation effort. Identify who will be the decision makers to implement results of the research.]

Evaluation
[Identify methods for evaluating the implementation effort. How will benefits be quantified or assessed?]

Principal Investigators:
PRC Committee Members:
LTRC Manager:
LTRC Implementation Engineer

Form 1902 Rev. 11/09

Appendix D-3: Louisiana DOTD Fact Sheet

FACT SHEET

LOUISIANA TRANSPORTATION RESEARCH CENTER

Evaluation of Field Projects Using Crumb Rubber Modified Asphaltic Concrete

Louisiana saves $7500 for every mile paved with crumb rubber method

September 2009

PRINCIPAL INVESTIGATORS

Louay Mohammad, Ph.D.
LMCUTF Manager/Professor, LSU
225.767.9126

Sam Cooper, MSCE, P.E.
Associate Director, Technology Transfer & Training
225.767.9165

LTRC CONTACT

Chris Abadie, P.E.
Materials Research Administrator
225.767.9109

STUDY TIMELINE

October 1992 - August 2005

TYPE OF REPORT

Final Report 393

MORE INFORMATION

www.ltrc.lsu.edu

Louisiana Transportation Research Center
4101 Gourrier Ave
Baton Rouge, LA 70808-4443

Since its creation by the legislature in 1986, LTRC has grown to national prominence through its efforts to improve transportation systems in Louisiana. The center conducts short-term and long-term research and provides technology assistance, engineering training and continuing education, technology transfer, and problem-solving services to DOTD and others in the transportation community. The center is largely supported by funding authorized by the Federal Highway Administration.

WHAT WAS THE PROBLEM?

Since the 1960s, researchers and engineers have used shredded automobile tires in hot mix asphalt (HMA) mixtures for pavements. Not until the late 1980s did the use of recycled tire crumb rubber in HMA mixtures become popular. In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) specified that all asphalt pavement projects funded by federal agencies must use certain percentages of scrap tires. Although this mandate was later suspended from the ISTEA legislation, it has greatly encouraged the research and application of crumb rubber modified (CRM) asphalt in HMA pavements.

The Louisiana Department of Transportation and Development (LADOTD) initiated a research project to evaluate different procedures of crumb rubber modified (CRM) applications in 1994 in which the long-term pavement performance of the CRM asphalt pavements was compared to that of the control sections built with conventional asphalt mixtures. Several applications of CRM hot mix asphalt were paved in five different locations throughout the state and evaluated after eight to twelve years for field performance.

WHAT SHOULD BE DONE?

Based on the findings of this research, it is recommended that certain cement binder specifications be developed and implemented to allow the use of the CRM wet process in hot mix asphalt when creating CRM pavements in Louisiana.

WHY SHOULD YOU DO IT?

The CRM wet process has been proven to be an excellent method for reducing crack propagation due to random cracking through actual pavement performance and its use should increase the life-cycle of HMA pavements. This process also indicated the ability to be self-healing in the wheel paths based on visual inspection of LA 15. Random and transverse cracks were evident between and on each side of the wheel paths, but not visible in the wheel paths themselves. This process will be able to compete with Louisiana's current practice of using paving fabrics and grids to reduce pavement reflective cracking, all while utilizing recyable materials readily available.

Overall, LTRC researchers found, compared to conventional asphalts, crumb rubber modified roads crack less, provide for a smoother drive, and require less maintenance, which improves roads' performance while cutting costs

WHAT ARE POTENTIAL FISCAL IMPACTS?

Current crumb rubber projects have proven to reduce the project material cost by $5.00 per ton of hot mix which can be up to 5 percent of the total material cost. Louisiana saves $7500 for every mile of construction using this crumb rubber method.

Louisiana Transportation Research Center sponsored jointly by the Louisiana Department of Transportation and Development and Louisiana State University

Appendix E: Other Tools and Resources

Appendix E-1: Indiana DOT Research Value Determination

JTRP/INDOT RESEARCH PROGRAM

Research Pays Off

Determining the Value of Research for Transportation in Indiana

Research on transportation is performed with the intent that successful findings, if implemented, will result in significant cost savings to the public. These cost savings will generally exist because of increases in operating and maintenance efficiencies, reductions in investment in cost, improvements in health and safety or reductions in damage to the environment. Transportation research in Indiana has always had such a goal.

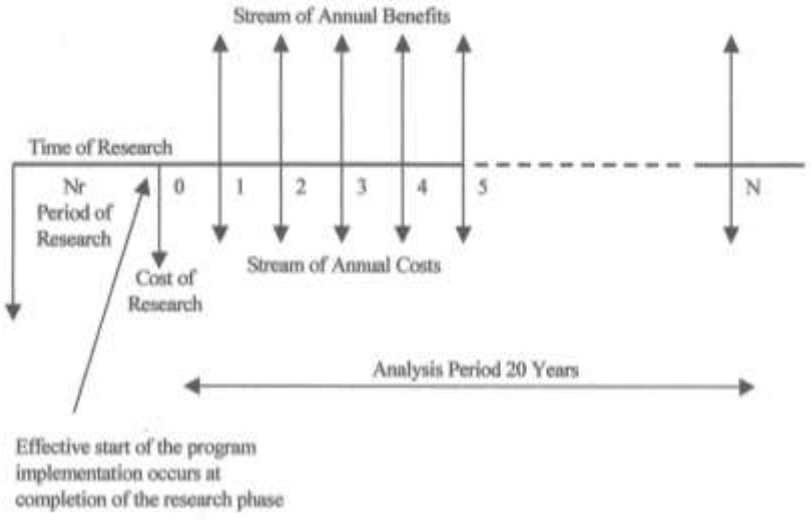
In combining benefits and costs of research, one must account for the time-value of money. This is done in the following manner:

- The cost of research is the initial cost and occurs at the beginning of the analysis.
- The cost of implementation can be expressed as a uniform annual cost.
- The benefits, which derive from the system improvements, occur annually.

Each annual cost and benefit is discounted by a discount rate, which can vary from 4% to 8%. Thus the benefits that occur 10 years from now are worth less in today's dollars. This is called Net Present Worth. When the annual benefits are the same from year to year, the discount sum or Present Value of the benefits is obtained by dividing the annual benefit by the capital recovery factor. Uniform annual costs are handled in an identical manner.

Unless specified, the discount rate of 5% over 20 years is used in the benefit analyses, which is equivalent to a discount rate of 7% for 30 years (which is the discount rate INDOT used for the Southwest Corridor Study).

Calculation of Benefits



Benefit Analysis

To convert a single present benefit (or cost) value (P) into the equivalent annual benefit (or cost) value (A) over N-year period with a discount rate i:

$$A = P\frac{i(1+i)^N}{(1+i)^N - 1}$$

Example: If the research cost of a study was $100,000 in the current dollar value, the equivalent annual cost over 20-year period (the current year is year 0) at 5% discount rate is calculated as follows:

$$A = 100{,}000\frac{0.05(1+0.05)^{20}}{(1+0.05)^{20} - 1} = 100{,}000 \times 0.080243 = \$8{,}024.3$$

To convert the annual benefit (or cost) value (A) over N years into a single present benefit (or cost) value (P) with a discount rate i:

$$P = A\frac{(1+i)^N - 1}{i(1+i)^N}$$

Example: If research resulted in an annual benefit of $100,000, the equivalent present worth of the annual benefit over a 20-year period at 5% discount rate is calculated as follows:

$$P = 100{,}000\frac{(1+0.05)^{20} - 1}{0.05(1+0.05)^{20}} = 100{,}000 \times 12.46221 = \$1{,}246{,}221$$

To convert a single future benefit (or cost) value (F) at year N into the equivalent annual benefit (or cost) value (A) over the N-year period with a discount rate i:

$$A = F\frac{i}{(1+i)^N - 1}$$

Example: If the benefit on the 20th year is estimated as $100,000, the equivalent annual benefit over the 20-year period at 5% discount rate is calculated as follows (distributing the single year benefit to uniform annual benefit over 20 years):

$$A = 100{,}000\frac{0.05}{(1+0.05)^{20} - 1} = 100{,}000 \times 0.030243 = \$3{,}024.3$$

To convert the annual benefit (or cost) value (A) over N years into a single future benefit (or cost) value (F) at year N with a discount rate i:

$$F = A\frac{(1+i)^N - 1}{i}$$

Example: If research resulted in an annual benefit of $100,000, the equivalent future benefit on the 20th year at 5% discount rate is calculated as follows (the future dollar value at year 20):

$$F = 100{,}000\frac{(1+0.05)^{20} - 1}{0.05} = 100{,}000 \times 33.06595 = \$3{,}306{,}595$$

Appendix E-2: Indiana DOT Research Pays Off: Field Investigation of Subgrade Lime Modification – SPR 3380

The Benefit/Cost Analysis was performed in 2011

Cost of Research	Benefit Cost Ratio	SHRP %
$114,195	46	271

JTRP / INDOT RESEARCH PROGRAM

Research Pays Off

Field Investigation of Subgrade Lime Modification— SPR 3380

Lime Kiln Dust (LKD) is a lime-based admixture that can be a very effective stabilizer in many soil types. LKD's blend of lime, silicates and other reactive and inert constituents work together with many soils to increase the durability and load-bearing strength of the soil.

This project was an implementation project for the SPR-3007 project - Post-Construction Evaluation of Lime-Treated Soils. The INDOT road construction project, Des. 9738220 (R-28976), was chosen for this implementation. The test site is located along SR 641, South of Terre Haute, Indiana. A 280-m long portion of the north-bound road (STA. 6+540 to STA. 6+820) was selected for the tests. The total 280-m portion was divided into two construction and test sections. The first 140-m long subgrade section was chemically treated with LKD with a target thickness of 16 inches. The remaining 140-m long section was treated with a target thickness of 14 inches. Field tests were conducted on the subgrade after seven chemical treatment days. These tests measured the stiffness of the pavement subgrade for the two thicknesses.

Research Findings and Implementation

Current INDOT design and construction procedures call for 16 inch thick treated subgrades. The 14 inch thickness, if effective, can save INDOT time and money.

Test results revealed the following:

The 14 inch thick section soil density was better and more uniform. It was found that the bottom 2" of the 16" subgrade was loose due to lack of compaction. This was verified by California Bearing Ratio (CBR) results that showed the 14 inch section had a higher value and a smaller variability. The numbers were:

14" - 30.7 CBR with deviation of 6.6
16" - 27.5 CBR with deviation of 7.4

This improvement in subgrade stiffness can reduce pavement thickness. INDOT pavement designers state that with this subgrade stiffness increase, pavement thickness can be reduced 1" for asphalt base course and 1/2" for concrete pavements.

Potential Benefits

Going from 16" to 14" for the treated subgrade will reduce subgrade treatment costs by 16/14 or 1/8.

Increased subgrade stiffness correlates to thinner pavements. According to pavement design, pavement thickness can be reduced 1 inch for asphalt and 1/2 inch for concrete pavements.

In 2009 and 2010 subgrade treatments on INDOT projects were 4,142,816 and 1,907,035 square yards, respectively.

Cost of Research $114,195	Benefit Cost Ratio	MIRR %
Known and measureable	46	271

Assumptions

- The average unit price for hot mix asphalt base is $43.50 per ton. One inch of asphalt weighs 110 lbs./square yard. A 1" reduction in thickness equates to the following cost saving.

  $43.50/2000#/ton = $.02/lb. Cost saving = $.02/lb. x 110 lb./SY = $2.39/SY
- A 1/2" reduction in concrete pavement thickness is a $2/SY savings in concrete material.
- These savings are based upon reducing pavement thickness over subgrade modification areas. Based on pavement surface data, approximately 92% of the area is asphalt and 8% concrete.
- For 2010, the subgrade treatment area was 1,907,035 square yards. The average subgrade treatment cost was $5.45 per square yard.
- Asphalt annual pavement savings 1,907,035 *.92 * $2.39 = $ 4,193,188
- Concrete annual pavement savings 1,907,035 *.08 * $2.00 = $305,125
- Subgrade annual treatment savings 1,907,035 * 1/8 * $4.70 = $1,120,383
- The cost of research is a combination of the grant amount and the Research Division overhead. Research and Finance have determined that the average annual overhead charge for a research project is $8,832. This project is the implementation of SPR 3007 so the grant costs will be the combination of both projects and the overhead charge will be for the duration of both projects. The total duration for both projects is 18 + 8 = 26 months, therefore the overhead cost is $19,136. The total grant cost is $60,000 + $35,059 = $95,059. The total cost of research is $19,136 + $95,059 = $114,195.
- This analysis is based on using 2010 quantities only. 2011 quantities and projections for future years are unknown. This project has changed subgrade modification so future savings will occur over a ten year analysis period , but they are not calculated.

Economic Analysis

Known and measureable calculations are based on 2010 quantities.

Research costs and calculated savings are capitalized over the project duration and the economic life which is 1 year.

References

- Subgrade treatment amounts obtained through the Office of Geotechnical services.
- Thickness reduction obtained from the Office of Research and Development.
- Asphalt pavement costs provided by Office of Research and Development.
- Concrete pavement costs provided by the Indiana Concrete Pavement Association.
- Asphalt/Concrete pavement area percentage breakdown provided by Jeffrey James at INDOT.

Appendix E-3: Iowa DOT NCHRP research

Iowa Department of Transportation

Research at Work at the Iowa DOT

The Iowa DOT innovates—and delivers—using NCHRP research

Guided by NCHRP research, the Iowa DOT saves time and money by using prefabricated bridge components.

The Iowa Department of Transportation is committed to getting full value out of research, whatever its source, to help improve the state's transportation system. "Successful implementation of research requires a shared attitude—an institutional mind-set that we're always working toward," says Sandra Larson, director of the Iowa DOT's Research and Technology Bureau.

Just how critical is it to the Iowa DOT to put research results into practice? "We recently instituted the position of implementation engineer—a dedicated staff member whose primary role is helping us find and use research to innovate practices and continuously deliver a better transportation system," says Larson.

While the Iowa DOT makes extensive use of state-driven research to help address local challenges, looking beyond the state's borders is equally important. The Iowa DOT seeks to implement applicable research wherever it can be found, whether from neighboring states, the Transportation Pooled Fund Program or the National Cooperative Highway Research Program (NCHRP) that the Iowa DOT voluntarily funds.

"Our state is an active participant in NCHRP," Larson says, "and we make the most of our investment by putting NCHRP research to work, especially in high-priority areas." A few examples from three of these areas—structures, safety and winter maintenance—help tell the story of how the Iowa DOT uses NCHRP results to get the job done.

"We recently instituted the position of implementation engineer—a dedicated staff member whose primary role is helping us find and use research to innovate practices and continuously deliver a better transportation system."

Bridges and Structures

To stay on the cutting edge of bridge technology, Iowa uses accelerated construction techniques and advanced designs and construction materials. Jim Nelson, final bridge design section leader of the Iowa DOT's Office of Bridges and Structures, frequently draws upon NCHRP research results to support the state's efforts. "NCHRP publications do a good job of presenting information that can be used by engineers," he says. "Over the last several years, I have saved and referred to a dozen or more of these publications."

For example, Iowa engineers used *NCHRP Report 584: Full-Depth Precast Concrete Bridge Deck Panel Systems* as a reference for the agency's federally funded prefabricated bridge projects in Boone County and Council Bluffs. "The report had good documentation on lessons learned from other projects, especially in relation to the component connections," says Nelson.

NCHRP Synthesis Report 324: Prefabricated Bridge Elements and Systems to Limit Traffic Disruption During Construction had similar value to the Iowa DOT: "*Synthesis Report 324* was an important reference for our accelerated bridge construction projects, most recently U.S. 6 over Keg Creek in Pottawattamie County," he says. Funded in part by both the Strategic Highway Research Program 2 and FHWA's Highways for LIFE program, the Keg Creek bridge is a landmark demonstration helping prove first-of-their-kind construction techniques for ultra high-performance concrete.

The Iowa DOT has incorporated findings from other NCHRP reports in its bridge projects, including *NCHRP Synthesis Report 345: Steel Bridge Erection Practices* and *NCHRP Report 503: Application of Fiber Reinforced Polymer Composites to the Highway Infrastructure*.

Traffic and Safety

The Iowa DOT is always looking for ways to improve safety, and Jeremey Vortherms, state traffic safety engineer of the Office of Traffic and Safety, keeps many NCHRP reports within easy reach. "I often turn to these when particularly challenging problems arise that our standard practices cannot address," he says. "They give us a good idea of what the best practices are nationwide and provide a rich source of ideas for us to consider." Among the reports at Vortherms' fingertips are the *NCHRP Report 500* guides—a series covering a range of user, vehicle and highway safety factors.

Other NCHRP publications help the Iowa DOT address such topics as pavement markings and intersection design. Deanna Maifield, methods engineer of the Office of Design, cites *NCHRP Report 672: Roundabouts: An Informational Guide* as an example. "Our staff frequently references *Report 672* as we develop state safety and design standards for roundabouts," she says. "We'll use this as a starting point and training tool."

To help support overall institutional commitment to safety, the Iowa DOT has used *NCHRP Report 667: Model Curriculum for Highway Safety Core Competencies* to strengthen highway designers' understanding of highway safety principles and help them improve how they integrate safety into the design process.

Winter maintenance

Having partnered in Transportation Pooled Fund snow and ice research for years, Iowa knows the value of cooperative state research for winter maintenance. The agency similarly looks to NCHRP research products to address winter maintenance challenges. Bob Younie, Iowa's state maintenance engineer, says, "There are so many NCHRP reports that have so much value to the Iowa DOT. You'll probably hear that same answer no matter who you ask."

Indeed, Leland Smithson, formerly with the Iowa DOT and now the Snow and Ice Pooled Fund Cooperative Program coordinator for the American Association of State Highway and Transportation Officials (AASHTO), can name several examples, including *NCHRP Report 577: Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts* and the Material Selection Decision Tool software developed from that

"Our staff frequently references Report 672 as we develop state safety and design standards for roundabouts."

research. "Although Iowa mainly uses salt for snow and ice control, if the Iowa DOT needs to consider other chemicals, this is the reference the agency turns to," Smithson says. "*Report 577* and the user-friendly software decision tool together help public and private agencies consider impacts to the receiving environment as they weigh their snow and ice control options."

Cooperative research works in two directions. As much as Iowa makes use of NCHRP research, it gives back to the other states. Consider how Iowa helped implement the results of NCHRP Project 6-17, "Performance Measures for Snow and Ice Control Operations." Smithson was part of the team that developed the findings into AASHTO's *Winter Roadway Maintenance Computer-Based Training* suite. "A team of technical experts and trainers worked to simplify the research results and help convey very technical information in a user-friendly way," Smithson says. It's a textbook example of how the Iowa DOT makes the most of NCHRP research to advance state of practice and improve its transportation system.

AASHTO's *Winter Roadway Maintenance Computer-Based Training* suite. (Image courtesy of AASHTO)

For more information, please contact the Iowa DOT's Research and Technology Bureau, **www.iowadot.gov/research**

Appendix E-4: Illinois DOT Implementation Worksheet

Illinois Department of Transportation

Implementation Planning Worksheet

Research Project Title:	Date: / /	IPW # /
	Project Number: R27-	
Principal Investigator:	TRP Chair:	
Project Objective:		
Research Findings to date:		
Is this research project conducive to implementation? ☐ Yes If yes, please continue below. If no, please explain here: ☐ No		

PART I: Implementation Potential .

A. How could this project's findings be Implemented? Briefly describe what changes need to take place in IDOT practice to implement this project. i.e. Write specification, update policy , etc.

B. What IDOT office/s may be affected/needed by this research implementation? Has this office been contacted? If not sure, leave section blank. Please attach another page if necessary.

Internal IDOT Office/s	Contact	Phone #	*Comments/further details:*
1.			
2.			
3.			
4.			
5.			

PART II: Implementation Strategies

A. What needs to be accomplished to facilitate implementation? Describe goals for implementation. i.e. present new specification to IDOT, pitch idea to upper management, set up training classes.

B. What are some potential challenges to implementation?

PART IV: Implementation Activities — Required for all projects.

Please list all the activities that will be required to implement the research results for this project. If the project is in progress, all completion dates are tentative. Project tasks cannot be implementation activities.

Activity	Contact or Sponsor (Champion)	Est. Due Date
1.	Name: Contact phone: Contact e-mail:	/ / or Month:, Year:
2.	Name: Contact phone: Contact e-mail:	/ / or Month:, Year:
3.	Name: Contact phone: Contact e-mail:	/ / or Month:, Year:

PART V: Benefits Assessment

In the following Table, rate the project on the basis of the extent to which the project, if implemented, would result in a benefit in each of the assessment categories. Rate from 1 to 10, with 10 being the most successful. Check whether obtaining Quantitative benefit values is possible and briefly describe how they can be quantified.

Assessment Category	Subjective Rating	Quantitative rating possible	Comments
Construction Savings (materials, Labor, equipment, time, quality)			
Operation and Maintenance Savings (materials, labor, equipment, time)			
Increase Lifecycle			
Decrease Lifecycle Costs			
Safety (Reduction of crash frequency, Reduction of crash severity)			
Decrease Engr./Admin. Costs (planning/design costs, paperwork)			
Environmental Aspects (pollution, hazardous waste reduction, recycling)			
Technology (technology transfer, new materials, new methods)			
User benefits (time, dollars)			
Impact On IDOT Policy			

Directions: Please return the completed form to the Technical Research Coordinator in the Bureau of Materials and Physical Research – DOT.BMPR.RESEARCH@illinois.gov. If you have any questions, please contact the Technical Research Coordinator via email or at 217-782-3547