GEORGIA DOT RESEARCH PROJECT 16-07
FINAL REPORT

TRANSPORTATION RESEARCH IMPLEMENTATION MANAGEMENT: DEVELOPMENT OF PERFORMANCE-BASED PROCESSES, METRICS, AND TOOLS

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GDOT Research Project 16-07

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TRANSPORTATION RESEARCH IMPLEMENTATION MANAGEMENT: DEVELOPMENT OF PERFORMANCE-BASED PROCESSES, METRICS AND TOOLS

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16. Abstract: The objective of this study is to develop an evidence-based research implementation database and tool to support research implementation at the Georgia Department of Transportation (GDOT). A review was conducted drawing from the (1) implementation science (IS); (2) intellectual capital and non-financial public agency performance (ICNPAP), and (portfolio capital asset management (PCAM) literature to understand enablers and obstacles for effective research implementation and develop a conceptual capital assets framework for organizational performance. The framework was used to extract best and effective practices from the transportation and non-transportation research implementation literature and inform the development of an enhanced research implementation process at GDOT as a next step to the existing process. The research implementation process was refined with feedback from GDOT officials and used as a basis for specifying and developing a database and tool to support research implementation management and drive agency performance through strategic goals.

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Development of Performance-Based Processes, Metrics, and Tools

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Executive Summary

The 2012 and 2015 national surface transportation legislation: MAP-21 (Moving Ahead for Progress in the 21st Century), and FAST (Fixing America's Surface Transportation) have formalized a performance-based paradigm for decision making. Performance-based research implementation management involves a formalized and ongoing research implementation process to transform research results into standard operating procedures, services and products within an agency to help it better achieve strategic goals. The objective of this study is to develop an evidence-based research implementation database and tool to support research implementation at the Georgia Department of Transportation (GDOT).

To accomplish this objective, the study reviewed conceptual frameworks in: (1) implementation science (IS); (2) intellectual capital and non-financial public agency performance (ICNPAP), and (3) portfolio capital asset management (PCAM) to understand enablers and obstacles for effective research implementation. The IS, ICNPAP, and PCAM literature all point to the importance of a carefully thought out research implementation system consisting of human capital (staff), internal capital (organizational structure and resources), external capital (researchers and other external stakeholders) and technological capital (appropriate tool(s) and data) to support agency initiatives and drive organizational performance. A capital assets framework for organizational performance was synthesized from this literature. The literature on transportation and non-transportation research implementation was reviewed through the lens of this framework and a set of best and effective practices extracted.

This study highlights the importance of the following practices for performance-based research implementation: (1) Adopting a performance-based definition of research implementation, linking implementation to organizational performance through agency strategic goals and objectives; (2) Developing and establishing a clear and formal research implementation process as part of agency business procedures, clearly articulating the roles of the researcher(s) and agency staff and ensuring that any implementation that is the primary responsibility of the researcher is placed under contract; (3) Allocating the resources (staff, funding) necessary to support research implementation; (4) Adopting a simple, clear and defensible approach to estimate research value; (5) Adopting an appropriate tool and data to support the research implementation process; and (6) Developing appropriate internal and external communication channels to augment research implementation.

GDOT's research implementation process was mapped and major process steps, stakeholders and associated responsibilities identified. Based on the conceptual framework and effective practices, areas for potential process enhancements were identified and recommendations developed for an enhanced research implementation process. These recommendations were presented to GDOT officials for feedback. Finally, a contextually-tailored research implementation tool was specified and developed based on the refined research implementation process; feedback obtained from GDOT officials, the existing resources within the agency, and effective practices in other state DOTs.

Agencies interested in the systematic improvement of their research implementation capabilities may consider adopting such practices tailored to their particular contexts to support performance-based research implementation.

Chapter 1. INTRODUCTION

1.1 Background

Federal, state and local transportation agencies in the United States spend hundreds of millions of dollars on research, development and technology transfer annually. For example, the Transportation Research Board (TRB), with the American Association of State Highway and Transportation Officials (AASHTO) and other professional organizations, invests over $40 million annually through the National Cooperative Highway Research Program (NCHRP) (TRB, n.d.). Also, over the five-year period from June 2004 through 2009, the implementation rate for NCHRP projects was 45% (CTC & Associates, 2014). In a performance-based context, effective research implementation can appropriately be considered an important asset for driving continuing innovation and improved performance, connecting agency needs with solutions and new capabilities; adopting these as part of agency business processes, and transforming opportunity-driven research into innovations that drive agency performance. Effective research implementation matters because it is a critical driver of agency business performance. Research conducted without serious and systematic attention paid to its effective implementation can be a tremendous missed opportunity for continued improvement of organizational performance. For every research initiative, one-time or ongoing, there is an associated implementation footprint that can be managed and improved. The questions: "To what extent is research being implemented effectively?" and "How can research be implemented even more effectively?" are critical ones for enhancing the organizational performance of state departments of transportation (DOTs) and other agencies. Performance-based research implementation management is timely in the context of the performance-based regulations associated with MAP-21 (Moving Ahead for Progress in the 21st Century) and FAST Act provisions.

1.2 Study Purpose

This study focuses on research implementation management (RIM). RIM may be defined as the management of relevant capital supporting research implementation to augment implementation and the return on research investment. RIM concerns itself with questions such as the following:

- What research has been conducted in the past?
- What outputs have been produced?
- What percent of implementable research conducted in the past has actually been implemented?
- To what extent has this research been implemented (i.e., not so well, moderately well, very well, extremely well)?
- What constitutes a satisfactory level of implementation?
- What outcomes have resulted?
- What value has been created?
- What staff roles and responsibilities, agency business processes, organizational structures and external relationships can be used to support and enhance research implementation?

For all organizations, enhanced research implementation should lead to a higher return on research investment. The purpose of this study is to develop an evidence-based research implementation management tool.

1.3 Study Approach

This research study was conducted in three primary phases. The first phase involved a literature review of conceptual frameworks in: (1) implementation science; (2) intellectual capital and public agency performance; and (3) portfolio capital asset management. This first set of literature was synthesized to produce an integrated conceptual framework for research asset management focused on implementation. The integrated framework then formed the lens through which literature on transportation and non-transportation research implementation was reviewed. A set of best practices was then extracted from the literature and used to develop strategies for enhancing GDOT's research implementation program.

The second phase of the research involved mapping GDOT's research implementation process. Major process steps, stakeholders and associated responsibilities were identified. Areas for potential process enhancements were also identified. Following this, the recommended process changes were presented to GDOT officials for feedback. The final phase of the research consisted of the tool specification and development. **Figure 1.1** provides a summary of the study approach.

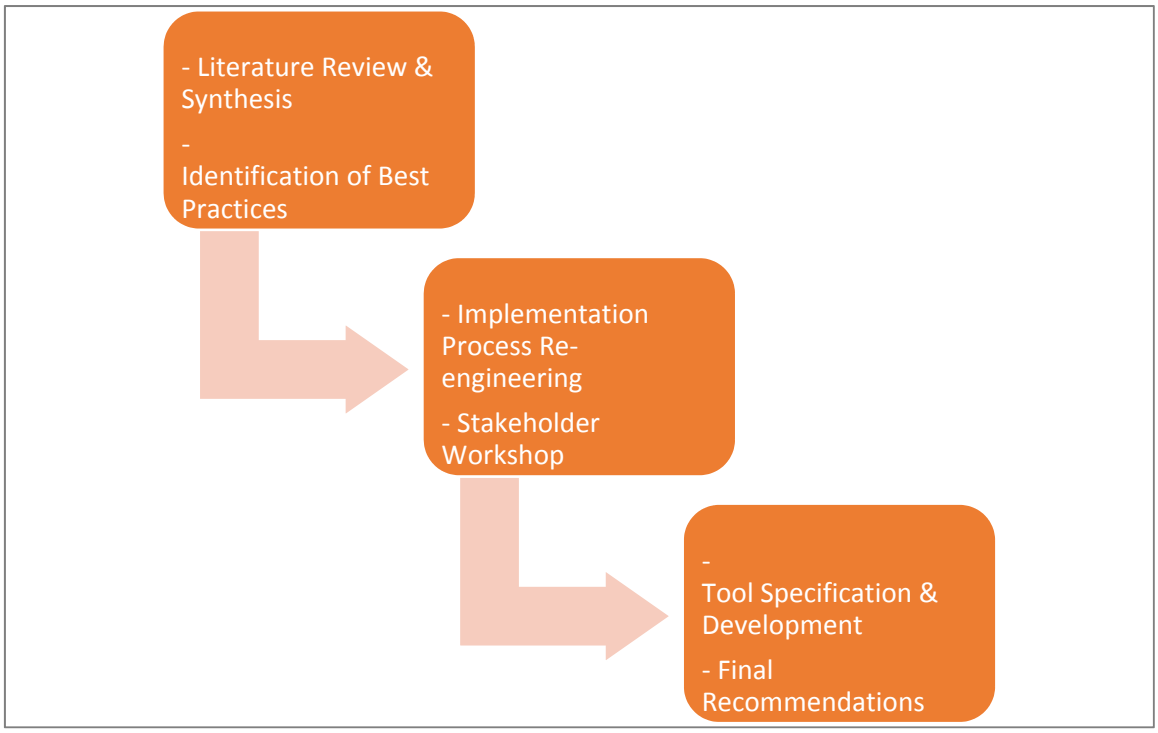


Figure 1.1 Research Study Approach

1.4 Report Outline

Chapter 2 reviews formal conceptual frameworks that lend weight to the treatment of research implementation as an asset management function. It offers an integrated performance-based framework for managing research implementation; reviews state DOT research implementation practices from the standpoint of their relative abilities to enhance organizational performance; and offers observations on research implementation effectiveness in a performance-based context. Chapter 3 discusses a set of recommendations for enhancing research implementation synthesized from the literature review. Chapter 4 introduces the RIM tool, discussing its specifications, functionality and setup. Finally, the report concludes with a summary of the research and recommended strategies for performance-based research implementation management.

Chapter 2. LITERATURE REVIEW

2.1 Introduction

This chapter first presents a review of conceptual frameworks from the Implementation Science, Intellectual Capital (IC) and agency program performance, and Capital Asset Management literature and offers an integrated framework for understanding and managing research implementation within the context of an agency and its external and internal stakeholders, strategic objectives, staff roles and responsibilities, organizational structure and processes, and technical resources in the form of appropriate management data and tools. Second, the chapter reviews the status of research implementation at state Departments of Transportation (DOTs) and other transportation agencies (such as the Transportation Research Board, U.S. Department of Transportation and the Louisiana Center for Transportation Research), characterizing the human and organizational capital, that is the staff roles; business processes and strategies for research implementation; technical capital, that is the management data and tools to support research implementation (i.e., for tracking research implementation, assessing the value and impacts of research and reporting on research program outcomes); and the challenges and opportunities for achieving success in research implementation. Thirdly, the chapter reviews the status of research implementation at non-transportation agencies with a substantial research function, e.g., the National Science Foundation, National Institutes of Health and the Department of Agriculture. Finally, the chapter identifies best practices and discusses challenges and opportunities for enhancing research implementation at state DOTs using a public agency-based capital assets framework.

2.2 Defining Implementation

In the context of state Departments of Transportation (DOTs), research implementation may be defined as the effective use of research results to enhance an agency's capacity to achieve its strategic goals. Various definitions of research implementation are listed in **Table 2.1**. Ohio DOT's definition provides a practical working definition that places an emphasis on the outputs of implementation: "the incorporation of research findings into a new or revised [agency] policy, procedure, specification, standard drawing or work method."

Table 2.1 Definitions of Implementation

Source	Field	Definition
Oxforddictionaries.com	General definition/English	"The process of putting a decision or plan into effect or execution."
Ohio DOT (CTC & Associates, 2011)	Transportation	"The incorporation of research findings into a new or revised ODOT policy, procedure, specification, standard drawing or work method."
Louisiana Transportation Research Center (LTRC, 2016)	Transportation	"The logical follow-up and application of research results to provide the basis for adopting solutions and innovations into practice."
Florida DOT (CTC & Associates, 2011)	Transportation	"The use of research results in a production mode, and may occur in a variety of ways and to varying degrees. For example, implementation may be *limited* by the nature of the application, *partial* by the scope and nature of the rollout, or *systematic* as through specifications modifications"
Texas DOT (CTC & Associates, 2011)	Transportation	"Adoption of a product for use, including technology transfer activities that promote adoption such as information dissemination, training and demonstration (which includes deployment and field testing)."
National Implementation Research Network	Multidisciplinary (health, education, social services, etc.)	"A specified set of activities designed to put into practice an activity or program."

2.3 Concepts and Frameworks for Managing Research Implementation as an Asset

2.3.1 Implementation Science

"Implementation Science is the systematic study of variables and conditions that lead to full and effective use of evidence-based programs and other effective innovations in typical human service settings" (Blasé and Fixsen, 2010). **The field seeks to understand the factors that facilitate effective implementation, the challenges encountered and the barriers that impede it thereby bridging the gap between science and service.** Implementation science is a multidisciplinary field with applications primarily in the healthcare/medical practice, education, and social services sectors.

The implementation science literature can be divided into three general categories: (1) Letting it Happen, (2) Helping it Happen, and (3) Making it Happen (Greenhalgh et al., 2004; NIRN, n.d.). The "Letting it Happen" literature focuses on diffusion of innovation. This type of implementation approach also results in the situation where the research results are published and recipients of these results are entirely accountable for putting new innovations into practice, albeit with some general guidance. In the second category of literature, recipients of research results/innovation are still accountable for implementation but some professional development or guidance is provided. Also in this area of literature, supporting materials such as toolkits or similar products may be designed. Lastly, "Making it Happen" transfers accountability to the implementation system (Davis, n.d.; Duda et al., 2014; Franks, n.d.). Here, implementation practice and science is used as a process to ensure effective implementation. This relates to the concept of "accelerating practical application of research results" found elsewhere in the literature (NCHRP Synthesis 461).

In applying principles of implementation science to the education field, researchers indicate that stakeholders planning implementation programs need a blend of strategies that cut across the following three areas: effective interventions, effective implementation methods, and enabling contexts as shown in **Figure 2.1** (Fixsen et al., 2010).

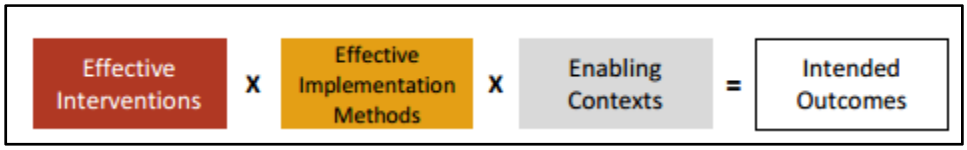


Figure 2.1 Formula for Success Framework
Source: Duda et al., (2014)

Another set of frameworks developed by the National Implementation Research Network form the five overarching frameworks known as the *Active Implementation Frameworks.* The frameworks, developed in 2005 after a synthesis of research findings from various fields, are designed to answer the what, who, when, and how questions in implementation, as shown in **Figure 2.2** (Duda et al., 2014).

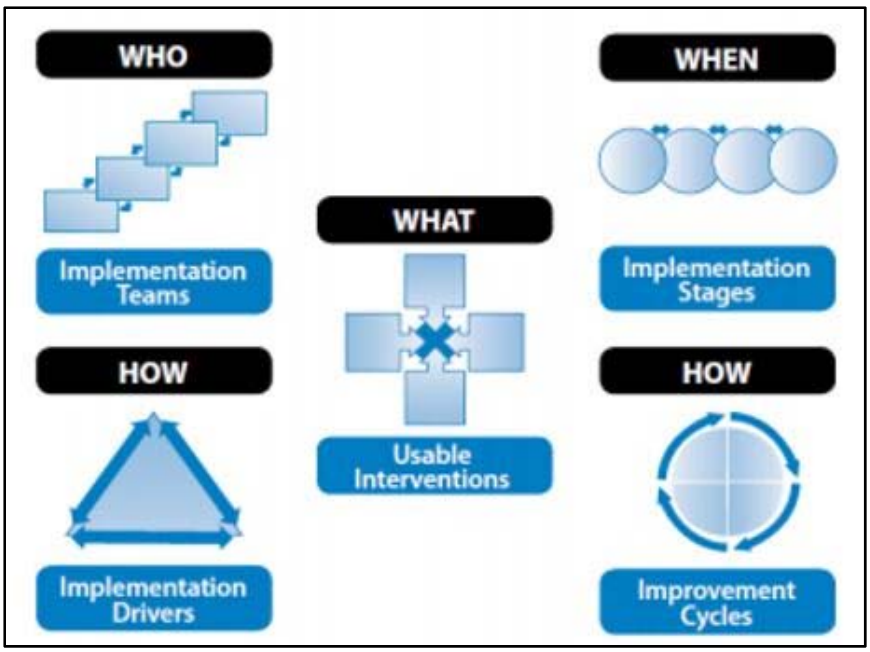


Figure 2.2 Active Implementation Frameworks
Source: Fixsen et al. (2005); NIRN, (2013)

Figure 2.3 shows a further development of the Active Implementation Frameworks linked with the Formula for Success Framework.

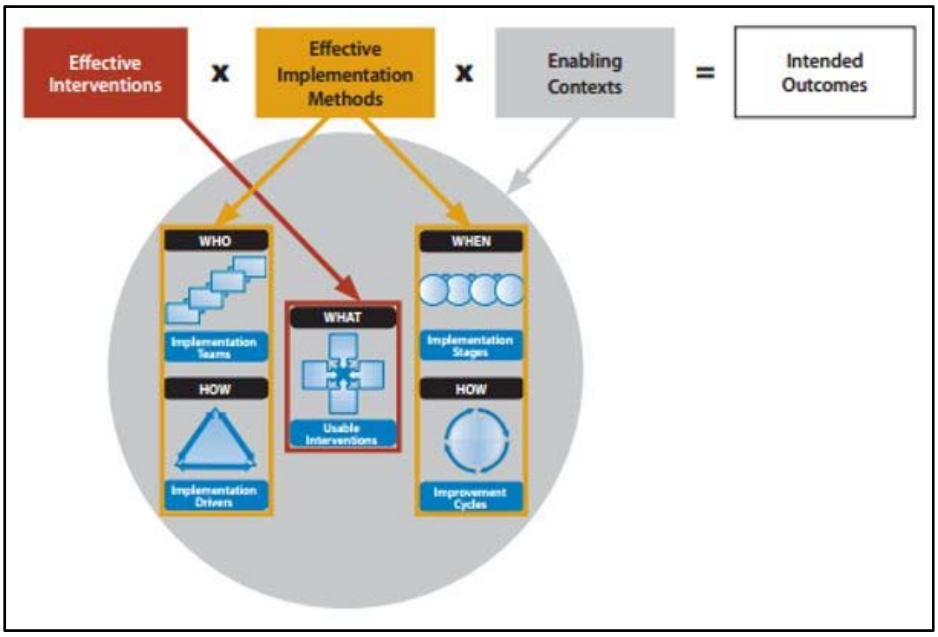


Figure 2.3 Linking the Formula for Success with the Active Implementation Frameworks

A summary description of the steps involved in these frameworks is provided in **Table 2.2**.

Table 2.2 Summary Descriptions for Active Implementation Frameworks

Stage of Framework	Description
Effective Interventions | What – Usable Intervention	• Evidence-based program or practice selected • Clear description of: o Intervention description o Essential functions o Operational definitions o Performance assessments
Effective Implementation Methods | Who – Implementation Teams	Core group with dedicated time, appropriate knowledge, appropriate skills, and enough authority to make decisions
Effective Implementation Methods | When – Implementation Stages	Developing appropriate activities and anticipating challenges to be encountered at each of four implementation stages: • Exploration • Installation • Initial Implementation • Full Implementation
Effective Implementation Methods | How – Implementation Drivers	Elements that influence program success (cover capacity and infrastructure): • Competency drivers: Supporting staff in adopting intervention • Organization drivers: Policies, systems, regulations, etc., to support new intervention • Leadership drivers: Matching different challenges with appropriate leadership strategies Elements are integrated and compensatory (NIRN, 2013)
Effective Implementation Methods | How – Improvement Cycles	• Employs three improvement cycles to initiate and manage changes (NIRN, 2016): • Plan-do-study-act (PDSA) cycle, • Usability testing • Practice-policy communication loops • Aids in systematic decision making

The Implementation Science literature provides useful concepts to apply in the development of effective research implementation processes in state DOTs. The Formula for Success Framework indicates that it takes not only **effective interventions**, but also **effective implementation methods** and **enabling contexts** to attain **intended outcomes (Figure 2.1**). This framework indicates that in developing a useful decision support tool for research implementation in state DOTs, it is important to pay attention to how to ensure the development of effective interventions, to identify effective implementation methods, and to identify what factors can help create enabling contexts to attain the intended outcomes. At a more disaggregate level, it is important to define who will be responsible for implementation (i.e., the roles of the researchers versus the agency's implementation team); how the implementation actors will facilitate implementation (i.e., what the implementation drivers will be), when implementation activities will occur (i.e., the stages of implementation for each

intervention from initial to full implementation). The "who," "how," and "when" of implementation constitute "implementation methods" (**Figure 2.2** and **Figure 2.3**). It is also important to determine when implementation activities for a particular project will be considered complete.

2.3.2 Capital Asset Management

Enhancing research implementation and the return on research investment within a public agency such as a state DOT can also be viewed through the lens of capital asset management. Research implementation is dependent on a wide range of capital factors such as the agency's internal and external stakeholders (human capital) who develop its strategic objectives; the appropriate staff roles and responsibilities influencing research implementation (directly or indirectly); the agency's internal organization and business processes (organizational capital) as well as the agency's data and tools (technical capabilities or capital) supporting research and implementation. Transportation Research Implementation Management (RIM) may be framed using concepts from intellectual capital management (Kamaruddin and Abeysekera, 2013; Durlak and DuPre, 2008), transportation asset management (AASHTO, 2011), and capital asset management (Amekudzi et al., 2015). Such a framing can help to more properly characterize the holistic system of capital factors that enables and supports research and research implementation, as well as the attributes of a planning, analytic and reporting tool that can effectively serve organizations contextually in their efforts to augment research implementation and return on investment.

2.3.2.1 Intellectual Capital and Public Agency Performance

Kamaruddin and Abeysekera (2013) discuss how managing intellectual capital becomes an important agency tool for driving public organizational performance. They investigate the management of intellectual capital in the Malaysian public sector as a tool to improve **non-financial organizational performance**. They define intellectual capital as the organizational knowledge that is not recognized in financial statements and could support non-financial organizational performance. Specifically, intellectual capital (IC) is "**the collective knowledge of an organization which is embedded in the personnel, organizational routines and network relationship[s] of an organization**" as defined by Kamaruddin and Abeysekera (2013), based on Bontis et al. (2002), Kong (2008), and Stewart (1997). The IC literature focuses on the resources and capabilities of firms to achieve non-financial organizational performance (Kong, 2007; Peppard & Rylander, 2001). IC in their study is a collection of intangibles in the public-sector organizations identified by the knowledge leveraged from the staff's know-how, the operation systems and the external affiliations built in the public-sector organizations. Skinner (2008) notes that organizations are increasingly competitive in the search for ways and means of delivering products and services with features that enhance non-financial organizational performance and IC has become a driver in this context. This organizational knowledge, when properly identified and leveraged, can be translated to increase non-financial organizational performance. Intangible research products are part of this organizational knowledge. **An important intent of this project is to identify and support the development of the agency's capital to improve the implementation of these products in ways that elevate its non-financial organizational performance**.

The study analyzed the theoretical relationship between intellectual capital and non-financial organizational performance, and secondly, investigated the empirical relationships between intellectual capital observed variables and the non-financial organizational performance observed variables. Observed variables of intellectual capital in this study were human capital, internal capital, and external capital and observed variables of non-financial organizational performance were effectiveness, efficiency, and reputation. This study proposed that intellectual capital resource-bundles lead to capabilities and competence that should enhance non-financial organizational performance. The results of the survey questionnaire were analyzed using a multivariate Structural Equation Model to ensure that the data appropriately fit the theoretical model proposed in the study, which meant selecting the survey instrument items through the Structural Equation Model analysis. Not surprisingly, **a significant and positive relationship was found between intellectual capital and performance**. Second, **human capital** (staff related) was found to have a significant and positive relationship with observed variables of non-financial organizational performance (that is, effectiveness, efficiency, and reputation) in the public sector. Thirdly, **internal capital** (organizational structure related) was found to have a significant and positive relationship with observed variables of non-financial organizational performance (that is, effectiveness, efficiency, and reputation) in the public sector. And fourth, **external capital** (resulting from an organization's interaction with external environments) was found to have a significant and positive relationship with observed variables of non-financial organizational performance (that is, effectiveness, efficiency, and reputation) in the public sector. **Figure 2.4** below was created as part of this research to capture Kamaruddin and Abeysekera's conceptualization of how intellectual capital affects non-financial public organizational performance (2013).

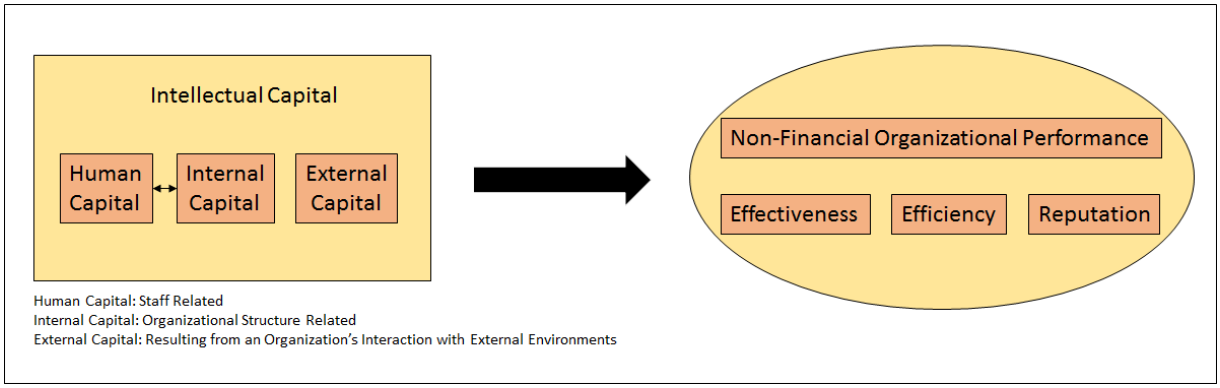


Figure 2.4 Conceptual Model: Intellectual Capital and Non-Financial Organizational Performance
(Extracted from Kamaruddin and Abeysekera, 2013)

2.3.2.2 Factors Affecting Organizational Capacity for Implementation

Durlak and DuPre (2008) report on a meta-analytic study to assess the impact of implementation on program outcomes and to identify factors affecting the implementation process, in the area of prevention and promotion targeting children and adolescents. They report that the implementation process is affected by variables related to communities, providers and innovations, and aspects of the organizational functioning and training and technical elements. They identify the following as three

factors related to organizational capacity for implementation: general organizational features, specific organizational factors and processes, and specific staffing considerations. These factors or types of capital closely align with the intellectual capital identified in Kamaruddin and Abeysekera's conceptual framework (**Figure 2.4**).

2.3.2.3 Intellectual Capital Statements

The Danish Ministry of Science, Technology and Innovation (Danish MSTI) offers an Intellectual Capital Statements Guideline (2003). The Guideline focuses on supporting the management and administration of knowledge resources to create value in future society. **The Danish MSTI notes that the ability of manage and administer knowledge resources will determine whether the substantial potential that lies within private companies and public organizations can be released.** The Guideline, first published in 2000, is used by private and public agencies to prepare intellectual capital statements. The Guideline is a cooperation between researchers, companies, industry organizations, consultants and civil servants that intends to help Danish companies become international leaders in the strategic use of knowledge to create value and enhance competitiveness.

The Guideline views an intellectual capital statement as an integrated part of company knowledge management (company is used in this document to refer to private enterprises and public institutions). It identifies the company's knowledge management strategy that includes identification of its objectives, initiatives and results in the composition, application and development of the company's knowledge resources. It also communicates the company's strategy to both internal and external stakeholders. The intellectual capital statement is therefore a management tool used to generate value in the company and a communication tool to communicate to internal and external stakeholders how a company generates value for them.

Knowledge in this document refers to information, insight and thinking. **Knowledge is managed to drive agency performance – used to improve agency internal processes and performance, making it stronger and better able to create growth and quality.** Per the Guideline, **a company's knowledge management is about four types of knowledge resources and *their interactions*: employees, customers, processes and technologies.** Employees (or internal stakeholders) include their skills, personal competencies and experience. Customers include the mix of customers, existing relationships with customers and their satisfaction. Processes relate to the knowledge content embedded in the company's stable procedures and routines. These can be the company's innovation processes, quality procedures, management and control processes and mechanisms for handling information. Technologies refer to the technological support for the prior three knowledge resources (the company's information technology (IT) systems - software and hardware) (Danish MSTI, 2003). **The Guideline prompts considerations of how employees, customers, agency processes and technologies interact to drive agency performance**.

Like any other accounting statement, the intellectual capital statement monitors initiatives and results and shows whether a company is developing its resources in the right direction. Intellectual capital statements in this case show whether a company has improved the development and management

of its knowledge resources. If a company does not manage its knowledge resources, working with intellectual capital statements can develop this resource. If knowledge resources are already being managed in one form one another, working with intellectual capital statements can help systemize knowledge management, add other relevant initiatives and through this develop a proper strategy for knowledge management (Danish MSTI, 2003).

The IC statement consists of four elements that together express the company's knowledge management: (i) a *knowledge narrative* that expresses the company's ambition to increase the value a user receives from a company's goods or services -- the use value. The knowledge narrative shows which types of knowledge resources are required to create the use value the company wants to supply. The second element is a set of *knowledge management challenges*, which highlight the knowledge resources that need to be strengthened through in-house development or through sourcing them externally. Addressing knowledge management challenges may also require the acquisition of new knowledge resources. The third element is a *set of initiatives* that can be started to do something about the management challenges. These initiatives address how to compose, develop and procure knowledge resources and how to monitor their effects and the extent of these effects. This could include investing in IT, hiring more R&D consultants or software engineers or launching training programs in company processes and procedures. The fourth element is a *set of indicators*, which make it possible to follow up on whether the initiatives have been launched and how they are performing with respect to addressing the management challenges. **Figure 2.5** shows the intellectual capital statement model.

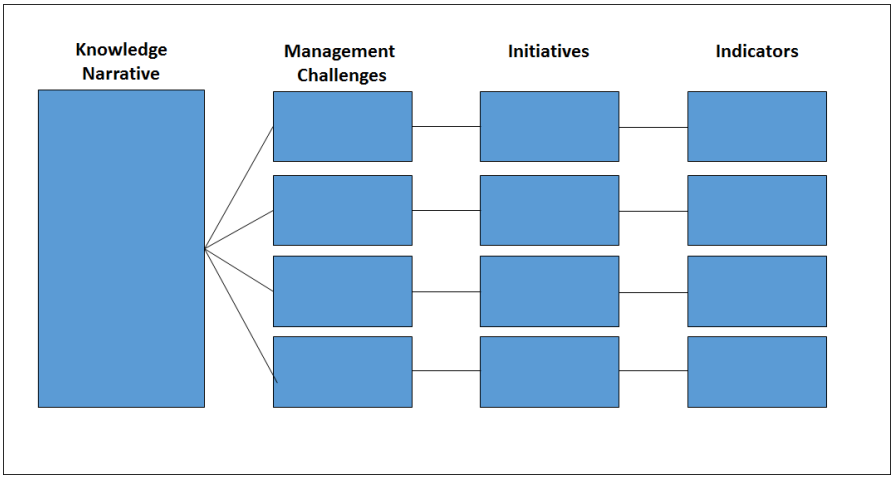


Figure 2.5 Danish MSCI Intellectual Capital Statement Model

2.3.2.4 Asset Management Maturity Scale

The American Association of State Highway and Transportation Officials' (AASHTO) Transportation Asset Management (TAM) Implementation Guide (2011) presents a maturing scale of asset management capability using a combination of human and structural capital (i.e., agency business processes) and technical capital (i.e., data and tools) to systematically improve organizational performance.

Figure *2.6* shows the Transportation Asset Management maturity framework reflecting that staff resources, organizational business processes and technical resources come together to drive organizational performance, and an organization's asset management system continues to be evolved to higher levels of maturity. **The maturity scale prompts considerations that align decision support systems with the level of maturity of the particular business processes being supported. In the case of research implementation management, it will be important to understand which employees constitute the implementation team, what roles they play, and what activities they will use a decision support tool for.**

TAM Maturity Scale Level	Generalized Description
Initial	No effective support from strategy, processes, or tools. There can be lack of motivation to improve.
Awakening	Recognition of a need, and basic data collection. There is often reliance on heroic effort of individuals.
Structured	Shared understanding, motivation, and coordination. Development of processes and tools.
Proficient	Expectations and accountability drawn from asset management strategy, processes and tools.
Best Practice	Asset management strategies, processes and tools are routinely evaluated and improved.

Figure 2.6 Transportation Asset Management Maturity Framework (AASHTO, 2011)

2.3.2.5 The Sustainable Development Footprint Approach

Proposed by Amekudzi et al., (2015), the Capital Asset Management conceptual framework for sustainable development links sustainable organizational performance at a very high level (i.e., for nations, regions, cities and other scales of political organization) to various types of capital inputs (i.e., human, economic, environmental, technical, etc.). The use of these different types of capital in various settings to achieve sustainable development (i.e., performance) is measured using static and dynamic indicators. In this study, organizational performance is captured by human quality of life measured through the use of various indicators as pertinent to the objectives of the study. Static and dynamic measures are used to capture availability and rates of change of capital inputs and outputs. Ultimately, such a construct can be used to evaluate how various entities manage and use their portfolios of capital to drive sustainable performance. **Figure 2.7** illustrates the concept of capital asset management applied to sustainable development, highlighting static and dynamic measures that drive organizational performance. **This construct prompts considerations of appropriate indicators for measuring the efficiency and effectiveness of business process outputs and outcomes.**

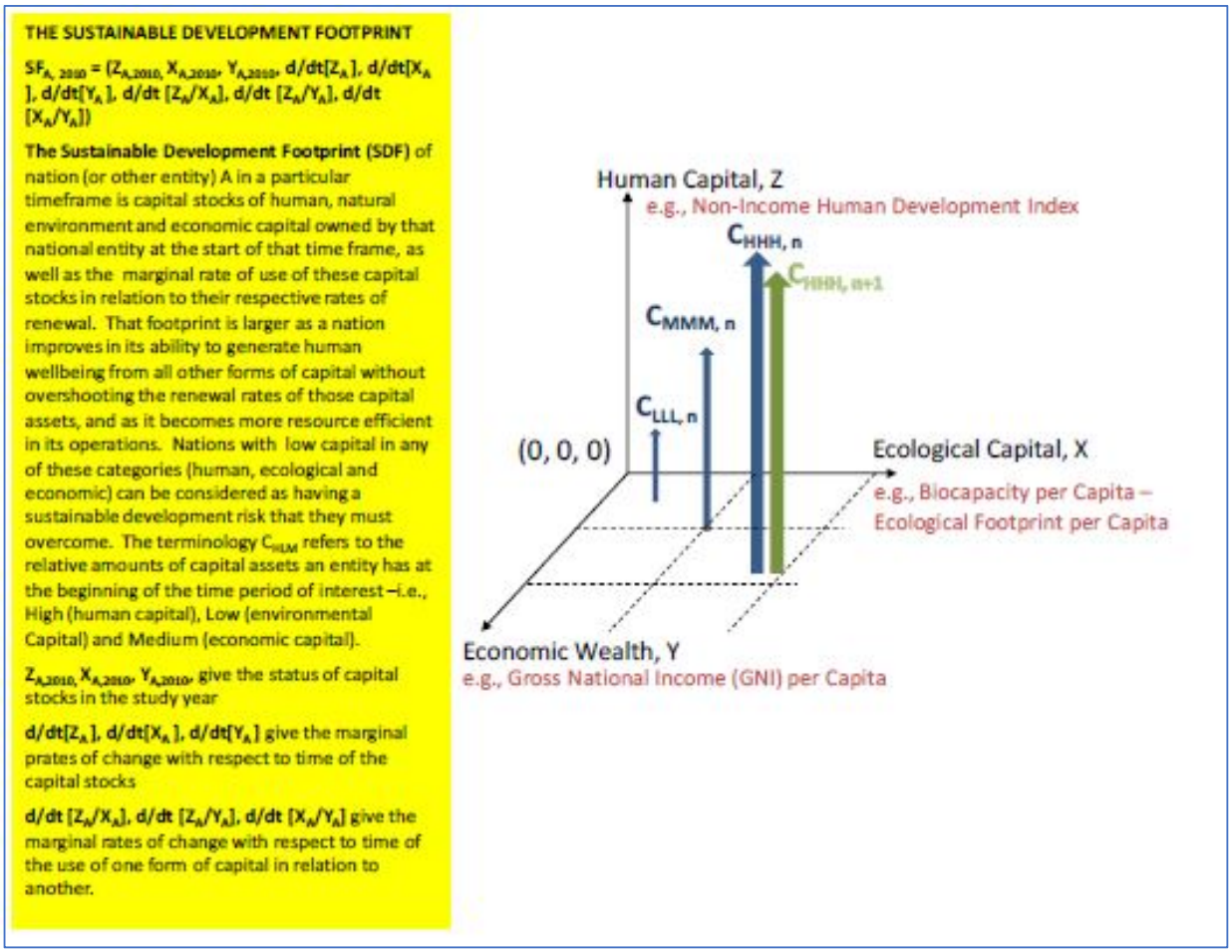


Figure 2.7 Sustainable Development Footprint
(Capital Assets Framework for Managing Sustainable Development)
(Amekudzi et al., 2015)

2.4 An Integrated Framework for Research Asset Mgmt. focusing on Implementation

The literature on Implementation Science, Intellectual Capital and Public Organizational Performance, Capital Asset Management and related areas brought to bear on the management of research as an asset highlights the importance of bringing to bear all the relevant types of agency capital to enhance the management of research as an asset, and in this particular case to enhance research implementation. Kamaruddin and Abeysekera (2013)'s study highlights that intellectual capital in the form of human (i.e., staff), internal (i.e., organizational structure) and external (i.e., non-agency stakeholders) drives non-financial organizational performance. Durlak and DuPre (2008) identify the following as three factors of organizational capacity for implementation: general organizational features, specific organizational factors and processes, and specific staffing considerations. The Danish Ministry of Science, Technology and Innovation in a multilateral initiative including public sector and private sector partners offers that knowledge capital can be managed to create value and drive organizational performance, proposing the intellectual capital (IC) statement as a tool for knowledge management -- including the process of creating a knowledge narrative, identifying

existing knowledge management challenges, developing a set of initiatives to address the challenges, and developing a set of indicators to track the progress of these initiatives relative to organizational performance. Amekudzi et al.'s work on the sustainable development footprint demonstrates how portfolio capital management concepts extended to a range of capital assets can be used to drive sustainable performance at different scales in a political context, and how this performance can be tracked using static and dynamic indicators.

This body of work in the literature lends weight to the value in considering research asset performance and in particular research implementation performance in the context of a broad range of agency capital to understand and characterize the different factors that contribute to research implementation effectiveness and improved agency performance. The working framework in **Figure 2.8** is offered as a point-of-departure conceptual framework to organize the literature and subsequent information on transportation research implementation and related areas, in order to develop a holistic understanding of the factors that drive research implementation performance. The framework is used to guide the development of a broader understanding of the holistic factors that drive research implementation performance in state Departments of Transportation (DOTs), based on the literature and subsequent data collection efforts; to better understand the major drivers of research implementation performance in state DOTs; to understand the available data; and to use these findings in creating a contextually appropriate decision-support tool for research implementation at the Georgia Department of Transportation (GDOT). **Figure 2.8** is tied to a companion integrated research implementation portfolio map (**Table 2.3**) that outlines the questions to be asked to characterize the existing research implementation infrastructure, benchmark it against existing best practices in research implementation, and determine the functionalities of an appropriate management tool to support research implementation and drive organizational performance to subsequent levels within the agency.

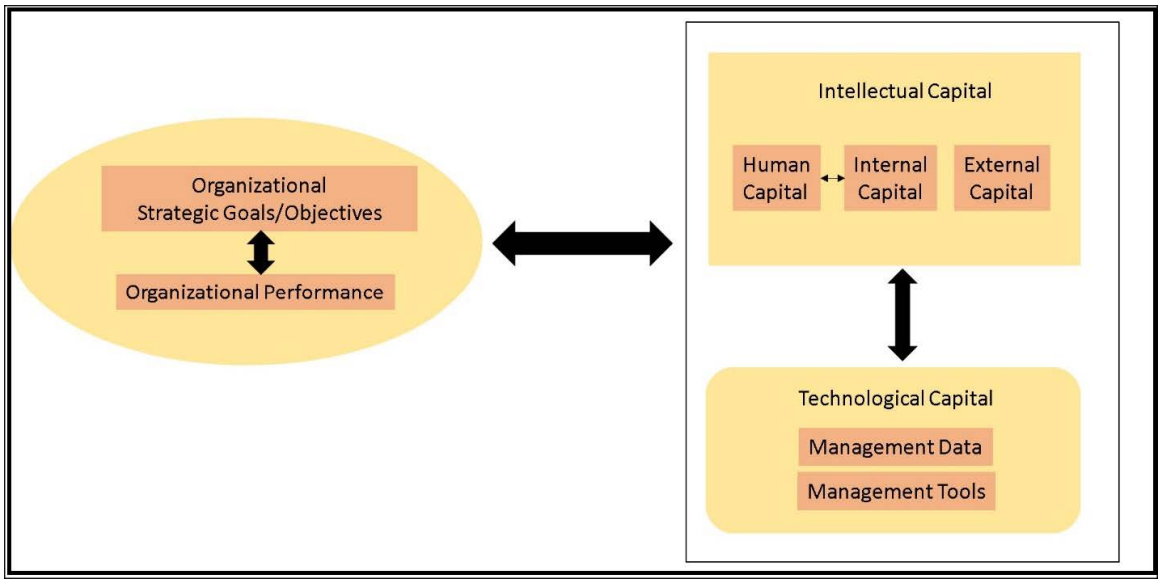


Figure 2.8 Capital Assets Framework for Organizational Performance

Table 2.3 Integrated Research Implementation Capital Map

OVERARCHING QUESTIONS • What is the agency's existing implementation process? (How are research findings incorporated into new or revised agency policies, procedures, specifications, standard drawings, or work methods?) • What factors that have been proven to facilitate effective implementation (i.e., effective implementation methods) are currently included in the agency's implementation process? • What factors that facilitate effective implementation would the agency like to adopt to move to the next level of research implementation? • What proven enabling context factors are currently included in the agency's implementation process? • What enabling context factors would the agency like to adopt? • How does the agency currently ensure that effective interventions (implementable research) is produced? • What approaches would the agency like to adopt to ensure effective interventions are produced? • [ODOT Definition of Research Implementation, Formula for Success Framework
HUMAN-INTERNAL CAPITAL • Who is responsible for implementation? (Implementation team - employees) This refers to the core group with dedicated time, appropriate knowledge and skills, and enough authority to make decisions [Active Implementation Frameworks] • What organizational structure supports effective implementation? • What are the functions/roles of these individuals/teams? (Effective Implementation Methods) [Active Implementation Frameworks, Formula for Success Framework] • What are elements that influence program success? (Implementation drivers – e.g., policies, systems, regulations to support implementation – aka enabling context) [Active Implementation Frameworks, Formula for Success Framework] • When does the implementation process begin? When does the implementation process end? (What are the stages and milestones for implementation for each project from initial to full implementation?) • How would individuals/teams involved in implementation use a decision-support tool or management tool? • What data/information is needed/available to support the uses of such a tool?
EXTERNAL CAPITAL • What roles/functions do/does the researcher/researchers play in implementation? • At what stage in the implementation process do/does the researcher's/researchers' roles fall? • What other external stakeholders can contribute to research implementation? • What roles do external stakeholders have with respect to effective research implementation?

Table 2.3 Cont'd: Integrated Research Implementation Capital Map

TECHNOLOGICAL CAPITAL • What **data** is available to support agency personnel, researchers and other key players with defined roles in research implementation? • For each research project, **how is implementation defined**, and who is responsible for defining implementation? • For each research project, when does implementation begin, and when does it end? • What **measures or indicators** can be used to **track implementation progress**? What data is available to track implementation? • What **evidences of implementation** can be used progressively through the implementation process? Who is **responsible for providing this evidence**? • What **measures of benefit and cost** can be used to estimate the return on investment on various categories of research projects? • What **routines in a planning/analytical tool** will be needed to support the intended uses of the tool?
BASELINE, GAP ANALYSIS, RECOMMENDATIONS, TOOL & DATA SPECIFICATION • What factors in all areas of capital drive implementation? (Literature Review) • Which of these factors is GDOT interested in incorporating in the existing integrated asset portfolio for research implementation? • What is the most appropriate tool design for the existing/intended integrated asset portfolio for research implementation? (AASHTO TAM Implementation Guide, TAM Maturity Model) • What data is available to support the tool? What data can be collected to support the tool? • What are the full set of functions and routines for the tool? • What other tools must the research implementation management tool interface with?

2.5 Status of Research Implementation at State DOTs

State-level transportation research is funded through a two percent aside for State Planning and Research (SP&R) activities made from each state's funding allotment of five programs: National Highway Performance Program, Surface Transportation Block Grant Program, Highway Safety Improvement Program, Congestion Mitigation and Air Quality Improvement Program, and National Highway Freight Program (FHWA, 2016a). Also, the annual SP&R funds under the FAST Act is five percent higher on average than it was under MAP-21 (FHWA, 2016b). Of this amount, a 25 percent minimum (SP&R Part 2[1]) is set aside for research purposes (including development and technology transfer) under 23 U.S. Code 505.

In general, research funded by DOTs may be classified into either applied or basic research. Applied research is research conducted specifically to solve a particular problem. Such research is typically conducted to be implemented. Policy research falls into the category of applied research although it forms a small portion of the amount of funded applied research. In addition, some agencies also consider policy research as a separate branch of research because its implementation is not in the traditional form of applied transportation research (Illinois, 2012; Deen & Harder, 1999). The second

[1] Part 1 refers to the funding portion allotted to planning.

classification is basic research. This is research conducted to promote general theory or knowledge but does not have direct or immediate application. As a result, some state DOTs also fund basic research but to a limited extent. Thus, basic and applied research form the umbrella under which three classifications of transportation research presented by Yoon et al., (2016) can be placed. These classifications are by state DOT responsibilities, civil engineering discipline or by transportation impact on communities and quality of life. **Table 2.4** presents classifications for these subcategories.

Table 2.4 Research classifications (extracted from Yoon et al., 2016)

Research Type	Category	Subcategory
State DOTs Responsibilities (Type A)	Design	Bridge/Structure
		Road Design
		Hydraulic
		Geotechnical, Pavement & Materials
	Planning	Transit/Multimodal Planning
		Freight Planning
		Land Use Planning
	Construction & Maintenance	Construction Management
		Facility Preservation & Maintenance
	Operations	Traffic and Highway Operations
		Management & Technology Administration
	Safety & Security	Transportation Safety
		Transportation Security
	Sustainability	Environment
		Economic
Civil Engineering Discipline Areas (Type B)	Structural Engineering	Bridge Design
		Design for Other Structures
	Geotechnical & Material Engineering	Soils & foundation
		Pavement & Material
		Traffic Engineering
	Transportation Engineering	Transportation Planning
		Traffic Safety & Human Factors
	Construction Engineering & Management	Project Management
		Asset Management
		Construction Safety
	Hydraulic Engineering	Water Resource Management
		Hydrology
	Environmental Engineering	Water Quality
		Air Quality
Impact Assessment Elements (Type C)	Environmental Impact	Air/Noise Quality
		Water Quality
	Design Considerations	Geotechnical
		Bridge/Structure
		Road Design
		Hydraulic
	Social Impact	Mobility
		Safety
	Economic Impact	Freight Transport
		Use of Right of Way

2.5.1 Research Implemented

Implementation of research results has been an essential component of the transportation industry and work towards enhancing implementation has been consistent. A 2012 Illinois DOT study on tracking research results implementation revealed that 50% of responding the 25 agencies implement between 60-100% of all research conducted by their respective agencies. Correspondingly, 46% of the agencies reported implementing less than 60%; however, all agencies reported conducting some implementation as shown in **Figure 2.9** (Illinois DOT, 2012).

According to the same survey, implementable results are not always new technology per se; they can be results that validate or invalidate ongoing practices. Thus, results that lead to discontinuing practices or methods are also considered to be *implemented*. Similarly, research with results that are not implementable are still considered useful because they allow the agency to redirect efforts (Illinois DOT, 2012). Despite these findings, not all research results are implemented as previously stated. While a significant number (40%) of surveyed agencies considered their research divisions as *implementation only,* implementation rates for all but one agency were less than 100% citing reasons such as budget cuts, inadequate staff, lack of appropriate implementation structure or motivation/ability of research results champions (Illinois, 2012).

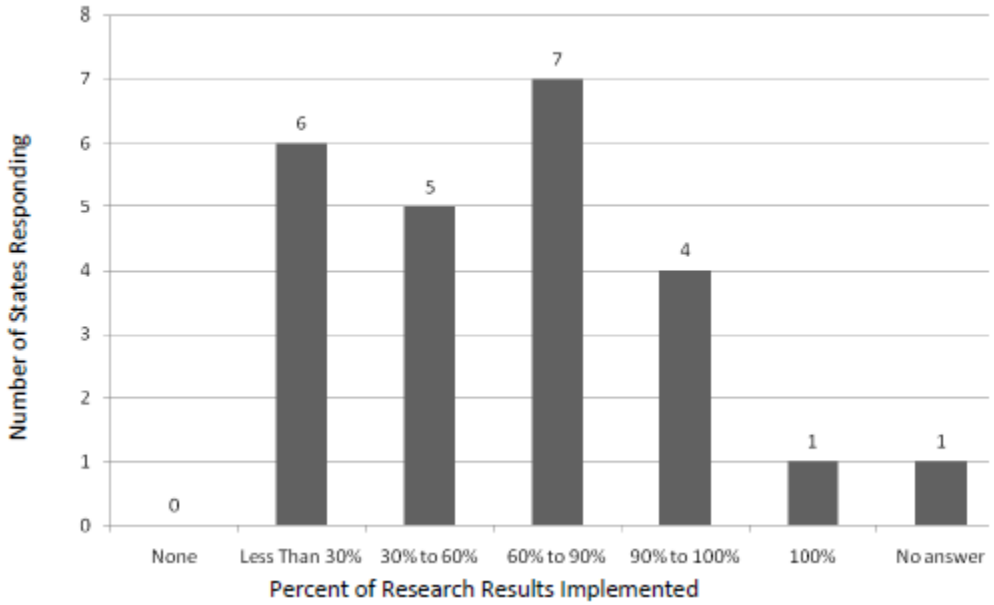


Figure 2.9 Self-reported percentage of research results implemented (Illinois DOT, 2012)

In the same study, researchers found that over 50% of research divisions did not track implementation; however, many indicated that such a system would be launched. Of those that reported using a formal tracking system for implementation, majority stated that those systems were "outdated, ineffective, or not used consistently" (Illinois DOT, 2011). **Furthermore, factors such as time limitations and inadequate staff size resurfaced as reasons why agencies either do not track implementation at all or track implementation effectively**. Despite these results, research

participants all agreed that **tracking implementation is vital** and **those that did so reported "easier upper management buy-in for their research division, increased support from project champions, and/or increased ease in reporting** to FHWA" (Illinois DOT, 2011). Bonini et al. (2011) report on principles used to build an effective research and innovation implementation system at the Pennsylvania Department of Transportation (PennDOT) using a systems approach. **The approach directly links system products with PennDOT's strategic objectives to provide the leverage to secure necessary resources to expand the system's scope and impact**. The agency responded to its need to address implementation programmatically by creating a Research and Innovation Implementation System. Key elements of the system include top management support, dedicated resources, effective communications, an implementation team with the requisite skills and credibility, champions at all levels of the agency, broad involvement of field staff, a system for measuring results, and a supportive culture of innovation.

2.5.2 Approaches & Processes (Human & Internal Capital)

This section reviews common approaches used by state DOTs that facilitate effective implementation of research results. It includes the structural processes in place in different research divisions, as well as the appropriate human capital management for effective implementation.

Implementation Champions

In some agencies, the challenge of pursuing and advocating for implementation is addressed by "implementation champions". Implementation champions can be found at various hierarchy levels in the organization but are more likely to be at the management level because of the associated authority and ability to influence change. However, it is important that selected champions remain interested as motivation and time are two of the most important factors for facilitating research results implementation (Illinois DOT, 2012). In addition to these factors, the ideal implementation champion must have a good balance between subject matter expertise and communication skills to be effective and persuasive (**Figure 2.10**).

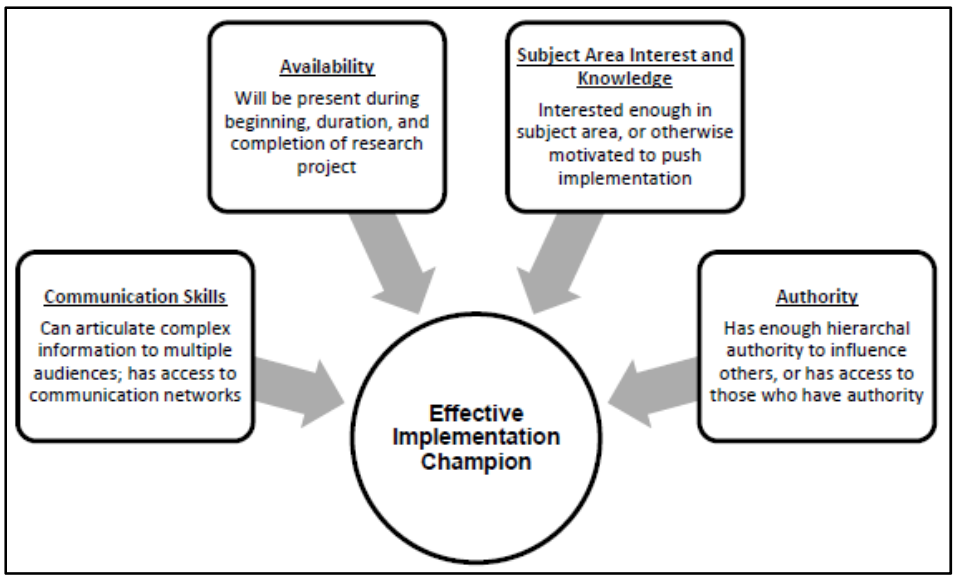


Figure 2.10 Characteristics of an effective implementation champion (Illinois, 2012)

Management Support

According to certain practitioners, research programs are usually driven by either top-level management or grassroots. **Being able to involve both upper-level management and still get buy-in from the field is important for successful implementation. Thus, many agencies have found ways of ensuring the involvement of both these groups by forming boards or committees that actively involve such agency personnel.** For example, Michigan DOT has the Research Executive Committee (REC). This committee, made up of the Chief Administrative Officer, Chief Operating Officer, bureau directors, director of the research program, and a regional representative, is actively involved in the entire lifecycle of research projects including overseeing the implementation phase. Similarly, Washington State DOT also created a Research Executive Committee that is in charge of recommending to the Research Advisory Committee (RAC), research results for implementation. The Washington State DOT RAC is made up of the assistant secretary, agency directors and regional administrators. Other examples of such agency committees include Minnesota DOT's Transportation Research Innovation Group, Pennsylvania DOT's Research and Innovation Implementation Program, South Dakota DOT's Research Review Board, and Montana DOT's Research Review Committee (CTC & Associates, 2011).

Research Implementation Staff

In the case of staffing for implementation, agencies usually use one of three approaches. The first approach that is also the least practiced, involves hiring an implementation manager/coordinator (either an in-house staff member or a consultant) whose sole responsibility is to ensure research results implementation. Michigan DOT's Implementation Coordinator (IC) is one of such positions. The IC (recommended by the Focus Area Manager) is responsible for developing an implementation plan in collaboration with the Research Advisory Panel. This individual is also supported by the program's Research Manager. The second approach is to have a position that dedicates a particular

amount of time to research implementation. Pennsylvania DOT's program uses this approach. The Implementation System Manager is typically a Research Division staff member who is appointed by the agency's Research and Innovation Implementation Program. The position requires a 50 percent time commitment for implementation activities. Last, the third approach in staffing for implementation is seen in agencies that assign implementation oversight to members of research committees/panels. This approach is the most common of the three (CTC & Associates, 2011; Bonini et al., 2011).

Considering Implementation Throughout Lifecycle of Research

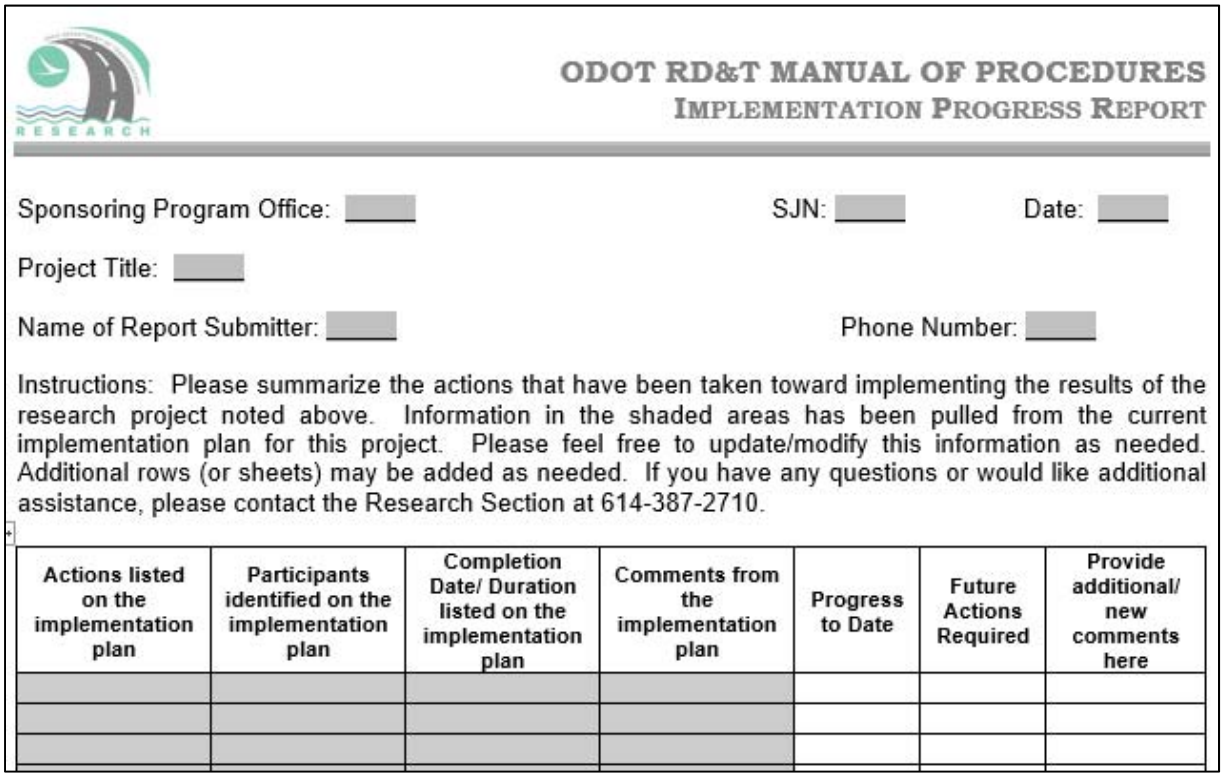
Considering research implementation throughout the lifecycle of a research project is seen as significant by many agencies. Thus, addressing implementation early in the process by exclusively calling it out in key documents such as problem statements or proposals is highly desirable. Some agencies such as the Maryland State Highway Administration use this as a factor in selecting research projects. The agency does not require an implementation plan, but does ask for a brief discussion of how results will be implemented and how implementation will be funded. Similarly, Illinois DOT created the Implementation Planning Worksheet that is used by Technical Review Panel chairs during the start of projects to identify possible implementable results and the steps necessary to see them through. The process includes identifying outcomes, implementation strategies, communication channels, etc. (CTC & Associates, 2011). Further examples of how other agencies address lifecycle implementation are shown in **Table 2.5.**

Table 2.5 Example Implementation Strategies

Agency	Example Strategy
Michigan DOT	Implementation Plan at proposal stage with: Cost/benefit analysis for implementation | Barriers to implementation and possible solutions | Methods of implementation
Arizona DOT	Description of expected implementation in Research Problem Statement Form
Washington State DOT	Research proposals contain implementation expectations | Summary n implementation included in an Executive Monthly Report on completed research projects
Texas DOT	Research Problem Statement identifies following: Office responsible for implementation | Final research outcomes and delivery format for products
Florida DOT	Deployment Plans developed prior to the start of research projects, which identifies implementation activities and stakeholders from outset May also include following components: Implementation | Performance indicators | Technology transfer | Training and marketing
Ohio DOT	Preliminary Implementation Plan required with proposal | Startup meetings include discussion of expected implementation | Research assessed for implementation during entire course of projects | Implementation progress discussed in quarterly reports

Tracking Implementation Progress

Agencies track implementation in varying degrees of detail. One such method is the use of Research Implementation Plans by Kansas DOT. The plans are prepared by the Project Manager to address implementation potential, implementation strategies, cost estimate and implementation schedule. Similarly, Ohio DOT also requires a preliminary implementation plan for every proposal that is reassessed during project review sessions. At the end of a project, the project Subject Matter Expert (SME) and sponsoring office administrator share the responsibility of tracking implementation activities upon finalizing a draft implementation plan prepared by the agency's research staff. The plan is meant to clearly articulate roles, responsibilities and timelines for activities that ensure implementation and is typically initiated at the closeout meeting although earlier initiation is encouraged. The research department then follows up by coordinating the submission of the Implementation Progress Report (shown in **Figure 2.11)** during the first scheduled follow-up with the SME (Ohio DOT, n.d.).



ODOT RD&T MANUAL OF PROCEDURES
IMPLEMENTATION PROGRESS REPORT

Sponsoring Program Office: _____ SJN: _____ Date: _____

Project Title: _____

Name of Report Submitter: _____ Phone Number: _____

Instructions: Please summarize the actions that have been taken toward implementing the results of the research project noted above. Information in the shaded areas has been pulled from the current implementation plan for this project. Please feel free to update/modify this information as needed. Additional rows (or sheets) may be added as needed. If you have any questions or would like additional assistance, please contact the Research Section at 614-387-2710.

Actions listed on the implementation plan	Participants identified on the implementation plan	Completion Date/ Duration listed on the implementation plan	Comments from the implementation plan	Progress to Date	Future Actions Required	Provide additional/ new comments here

Figure 2.11 Screenshot of Ohio DOT Implementation Progress Report (Source: Ohio DOT Research Manual)

Pennsylvania DOT created the Research and Innovation Implementation Program in 2004 to provide the infrastructure for accelerating innovation. The program requires an Implementation System Manager who works with a consultant to manage the implementation process (CTC & Associates, 2011). Further discussion of tools used by DOTs to track and monitor implementation is presented in Section 2.7 of this report.

Communication of Research Results

Effective communication of research results is an important component of implementation management as this aids research programs to better disseminate products and encourage wider adoption of research products. Communication efforts also serve as a way of showing accountability to various stakeholders including upper-level management and legislators who have the authority to fund implementation projects. Both internal and external stakeholder communications are essential and are carried out using various methods. These include web-based and print summary documents such as newsletters, briefs and posters to highlight the benefits of conducted research with using measures such as dollars saved, lives saved and increased efficiency to name a few. Other agencies also conduct webinars, seminars, conferences, workshops and other outreach activities as a means of engaging potential adopters of research results and transferring knowledge from principal investigators to transportation professionals as well as establish communication networks with other agencies with similar research interests. Of the many approaches in use by agencies, one good example of a strategic approach is that of Missouri DOT's Communication Plan. This plan is developed for every project by either the project administrator or the principal investigator to show the types of communication to send out, the audience intended for the messages, timing as well as potential controversies (CTC & Associates, 2011). PennDOT's communication plan supports implementation by engaging management, recognizing individual contributions, information and teaching, reporting on progress, and extending awareness to new audiences. The four-page implementation system newsletter includes a message from the secretary and interviews with central office and district executives, and informs all levels of the department through stories that spotlight individual and team contributors to successful innovations. Each issue has a metamessage supporting advancement of the culture of innovation. To help advance PennDOT's implementation culture, the PennDOT Bureau of Planning and Research (BPR) distributes the newsletter by email to all 12,000 plus employees of the agency. In addition, BPR has a one-sheet, 2-sided innovation implementation bulletin (IIB) which creates a steady stream of brief, informational updates on individual initiatives. Several additional modes and avenues of communication have become standard components of the implementation system including a 24/7 website on PennDOT innovations (Bonini et al., 2011).

In summary, the status of research implementation in state DOTs shows a combination of building internal and human capital to ensure that implementation is a key component of research efforts. The review also indicates that for agencies seeking to improve implementation, several types of capital must be managed strategically to make the best use of available resources and ultimately accomplish strategic goals and objectives.

2.6 Status of Research and Implementation at Other Transportation Agencies

2.6.1 Transportation Research Board

The Transportation Research Board (TRB) is a division of the National Academies, a private, nonprofit institution that includes the National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council. Created as the Highway Research Board in 1920, TRB promotes innovation and progress in transportation through research (TRB,

n.d.). TRB administers a number of major research programs sponsored by other organizations. Created in 1962, the oldest and largest of these programs: the National Cooperative Highway Research Program (NCHRP), is sponsored by the state transportation departments in cooperation with the Federal Highway Administration (FHWA). The Transit Cooperative Research Program (TCRP), initiated in 1992, is sponsored by the Federal Transit Administration (FTA). Both are applied research programs in which the potential users of research results have a direct role in project selection. In 2002, TRB began administering the Commercial Truck and Bus Safety Synthesis Program (CTBSSP), which is sponsored by the Federal Motor Carrier Safety Administration. The congressionally requested Airport Cooperative Research Program (ACRP), which was begun in 2006, is sponsored by the Federal Aviation Administration (FAA). Two other programs were initiated in 2006—the Hazardous Materials Cooperative Research Program (HMCRP) and the National Cooperative Freight Research Program (NCFRP), both of which were authorized in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).
For all of these programs, TRB organizes panels of experts to provide guidance on technical aspects of the research and to translate the problems into project statements with well-defined objectives. Research proposals are then solicited from private and public research organizations with capability and experience in the problem areas to be studied. The technical panels review the proposals, recommend contract awards, monitor research in progress, provide technical guidance, and determine the acceptability of the final reports. More than 3,000 experienced practitioners and research specialists currently serve on Cooperative Research Program panels. TRB also manages programs of smaller studies focused on synthesizing current practices and analyzing legal issues in the NCHRP, ACRP, and the TCRP programs. **Table 2.6** shows a funding breakdown of TRB's research programs.

Table 2.6 TRB Research Program Funding Breakdown (TRB, n.d.1)

Program	Annual Budget
NCHRP Domestic Scans	$500,000
NCHRP 8-36: Research for AASHTO Standing Committee on Planning	$600,000
NCHRP 25-25: Research for AASHTO Standing Committee on Environment	$600,000
NCHRP 20-24: Research on Administration of Highway and Transportation Agencies	$1 Million
NCHRP 20-07: Research on AASHTO Standing Committee on Highways	$1.2 Million
NCHRP 20-65: Research on AASHTO Standing Committee on Public Transportation	$450,000
Innovations Deserving Exploratory Analysis (IDEA);	$210,000
ACRP Regular Projects (Airport Cooperative Research Program)	$15 Million
ACRP Graduate Research Award Program	$100,000
TCRP Regular Projects (Transit Cooperative Research Program)	$3 Million
TCRP Synthesis Study Programs	$300,000
NCHRP Synthesis Study Programs	$600,000
ACRP Synthesis Study Programs	$200,000
TCRP J-05: Legal Aspects of Transport and Intermodal Transportation	$250,000
ACRP 11-01: Legal Aspects of Airport Development	Information under development
NCHRP 20-01: Legal Problems Arising out of Highway Programs	$100,000

2.6.1.1 National Cooperative Highway Research Program (NCHRP)

The National Cooperative Highway Research Program (NCHRP) is governed by the AASHTO Standing Committee on Research (SCOR) and the AASHTO Research Advisory Committee (RAC). With an annual budget of $40 million, the NCHRP focuses on solutions that are practical and readily usable. Successful problem statements address issues of critical concern and interest to many states (TRB, n.d.2). In addition, the review committee considers whether the problem can be handled effectively in the cooperative research environment supported by NCHRP and will have a high probability of success.

According to the NCHRP, results of conducted research are widely used across the country; however, the program lacks a systematic way of collecting information on and tracking projects after completion (SCOR, 2015). This has resulted in a new emphasis on effective implementation and the initiation of supporting research: for example, **NCHRP Report 768 – *Guide to Accelerating New***

Technology Adoption through Directed Technology Transfer (2014), and NCHRP **Project 20-44 – *Accelerating the Application of NCHRP Research Results***. According to the SCOR NCHRP 2015-2020 Implementation Plan, implementation should not only be seen as deployment of a research result but as a continuum involving a dissemination, development, deployment and practice.

Human & Internal Capital: Approaches & Processes used in Research Implementation

NCHRP Report 768 offers a ten-component roadmap to guide practitioners for research implementation: (1) Addressing societal and legal issues associated with implementation; (2) Having an effective champion; (3) Engaging decision makers; (4) Developing a Technology Transfer (T^2) Plan; (5) Identifying, informing and engaging stakeholders; (6) Identifying and securing resources; (7) Conducting demonstrations/showcases; (8) Educating, informing and providing technical assistance; (9) Evaluating progress, and (10) Reaching a deployment decision (2014)

According to another 2014 report on evaluating NCHRP product implementation, the following five key elements facilitate successful implementation of NCHRP results (Casey et al., 2014):

- **Implementation leadership:** As stated earlier, the NCHRP by itself does not own capital assets such as highways or bridges; thus, it relies on the work of implementation champions to initiate and follow through with implementation after projects have ended. These individuals or groups are usually members of state DOTs, as the main users of NCHRP research results. They are also supported by individuals committed to implementation within TRB, AASHTO and FHWA.
- **Buy-In for Implementation**: According to the researchers, it is important to get the appropriate buy-in from (1) individuals/groups in charge of implementation, (2) those affected by the research, and (3) those individuals/groups who can facilitate dissemination of findings. There is also a need to communicate effectively to stakeholders and address concerns before the end of projects.
- **Structural Support and Resources**: Researchers identified that mechanisms and resources for communicating research findings to end users are particularly beneficial. For example, task forces, committees and working groups from TRB, AASHTO and FHWA are crucial for dissemination, technical support and guidance.
- **Research Products That Address a Real Need and are Ready to Use**: Here, researchers emphasize the need for final research products to be implementation ready. This includes ensuring that guidance and supporting materials such as training manuals or demonstration software are provided in addition to final reports.
- **Targeted Dissemination:** Lastly, dissemination of results that target the right audience at the right time through effective means provides the appropriate springboard for successful implementation.

Current Implementation Strategies

The NCHRP produces a range of research results with a range of implementation strategies. These are mainly targeted at practitioners, who are the intended users of research results. Senior managers, legislators and congress are also seen as stakeholders and are therefore also targeted with “value of research” type dissemination strategies. Overall, NCHRP implementation strategies range from the

less expensive dissemination activities such as project reports and blurbs in the TRB E-Newsletter to the costlier DOT demonstrations by principal investigations (SCOR, 2015). A list of current strategies used by the NCHRP are shown in **Table 2.7**.

Table 2.7 Implementation activities/products: NCHRP projects and target audiences (SCOR, 2015)

Product	Cost	Audience		
		Practitioners	**Middle Managers**	**Senior Managers, Legislators, Congress**
Final reports	$	X		
Guidebook focused on how to implement the research findings	$	X	X	
Models, decision tools, and other software products	$$	X		
Manual and Specifications (AASHTO, FHWA, and others)	$$	X		
4-page Executive Summaries	$	X	?	
1 or 2 page flyers (hard copy or electronic) summarizing the results and how to effectively implement them	$$	X	X	
1or 2 page flyers summarizing the benefits that could accrue through implementation	$$	X	X	X
1 or 2 page flyers on the impacts of past research	$$		X	X
PPT presentations (tailored to audience)	$	X	X	X
Short (1 paragraph) blurbs	$	X	X	X
Short videos	$$$$	X	X	X
Webinars	$$	X		
Workshop, pilot, or Peer Exchange in a host DOT	$$$	X	X	
Presentations by staff or PIs at conferences and committee meetings	$	X	X	
Articles in TR News	$	X	X	X
Demonstration project involving assistance for construction or installation of technology or infrastructure. (e.g. new pavement, bridge construction method, scour abatement product, stormwater treatment method).	$$$$$	X	X	X
"Research Showcase" – Highlighting selected NCHRP products at state, regional, and national meetings and conferences. This could be done through a presentation or a "booth" arrangement similar to the SHRP 2 exhibit at the TRB annual meeting, or through presentations by Ambassadors.	$$$	X	X	X
Conference sessions	$	X	?	

NCHRP realizes that the types of research products produced vary and should therefore have different treatment. However, the NCHRP's new implementation plan emphasizes a common, flexible, systematic approach that can be applied to all types of research projects. **Table 2.8** provides a

summary of the framework for developing an implementation culture in the NCHRP. For the complete table and sample NCHRP Implementation Plan, see **Appendix A** of this report.

Table 2.8 Summary of Framework for Developing Implementation Culture in NCHRP

Framework Item	Details and Responsibilities
Problem statement submitters	**Emphasize** the following: (1) potential value and (2) likelihood of implementation-ready products. **Identify** potential barriers (institutional or political) to implementation ▪ Target audience for research ▪ Key influencers for implementation ▪ Potential implementation champions (besides problem statement submitter) **Request** sufficient funding for initial implementation
Problem Statement Reviewers	**Use** (1) value of problem statement and (2) likelihood of implementable results in rating model for statement reviews
Project Panels	▪ **Assign** Implementation Working Group and implementation leader to research project ▪ **Identify** liaison with appropriate AASHTO committee ▪ **Identify** states willing to undertake implementation project ▪ **Develop** funding request and follow through with NCHRP 20-44 funding ▪ **Explore** alternative funding programs by working with NCHRP 20-44 panel
Principal Investigators	▪ **Provide** support to project panels to develop implementation plan
Overall role of NCHRP 20-44 Panel and selection of enhanced implementation activities	▪ **Provide** DOTs with resources such as guide or synthesis on how to effectively analyze, evaluate, analyze, implement and track NCHRP research products.
NCHRP Staff Support	▪ **Create** Implementation Coordinator position ▪ **Develop** NCHRP project implementation plan guide and template

Implementation Funding

In general, the NCHRP funds some implementation (e.g., technology transfer and dissemination) out of its general administrative budget. However, with the creation of the NCHRP 20-44 project and panel, additional funding has been made available. According to SCOR (2015), a sum of $2 million was provided by SCOR (Standing Committee on Research) for FY2016 implementation activities. In addition, $1.5 million was made available in FY2016 for products that will facilitate the implementation plans of NCHRP project panels. Implementation funding requests can range from

$2,000 to $150,000. Projects over $150,000 can prepare continuation requests for the next cycle. Requests are submitted by a member of the NCHRP project panel and are then reviewed and approved by NCHRP Panel 20-44. **Table 2.9** below shows the breakdown of the aforementioned budget.

Table 2.9 NCHRP 20-44 Implementation budget breakdown source: SCOR (2015)

Product or activity	Quantity	$ Amount
Development Assistance Program		1,600,000
Research makes a difference brochure	1	10,000
Impacts on Practice (2-pages)	5	15,000
Paths to Practice	5	20,000
NCHRP Summary of Progress	1	7,000
CEO briefings	2	20,000
NCHRP Research in Brief (for individual projects)	15	50,000
"Field Folios", or Subject Compilations	10	65,000
Targeted Report distribution assistance	n/a	10,000
Tracking impacts and benefits of completed research	n/a	10,000
Webinar support (compiling topics, organizing speakers and sessions, submitting application forms)	n/a	35,000
NCHRP Ambassadors' Program	n/a	50,000
Contingency	n/a	108,000
Total		2,000,000

2.6.2 United States Department of Transportation (USDOT)

The USDOT administers its research program through the Office of the Assistant Secretary for Research and Technology (OST-R) which oversees all the research activities of the USDOT. As of 2014, this has included activities previously administered by the Research and Innovative Technology Administration (RITA). The 2013-2018 Research, Development and Technology (RD&T) Strategic Plan from RITA identifies five RD&T priority areas which are a combination of the USDOT strategic goals and congressional priorities. The five priority areas along with their associated percentage shares of research funding are as outlined[2]:

- Safety (42%)
- State of good repair (13%)
- Economic competitiveness (23%)
- Livable communities -- congestion & mobility (5%)
- Environmental sustainability (13%)

These priority areas are accompanied by both crosscutting and mode specific research priority areas and subsequently, performance measures to track outcomes. This approach ensures that each USDOT operating administration conducts and implements research to attain the agencies strategic outcomes. **Table 2.10** shows a breakdown of RD&T funding for the USDOT's operating administrations. Two examples of performance measures to track outcomes are provided in

[2] The remaining 4% of research funding used to achieve the five DOT goals goes to Organizational Excellence.

Table 2.11. According to the plan, implementation, evaluation and modification will be carried out by the RD&T Planning Team that will track the success of performance measures, modify plan priority areas and update performance measures as needed.

Table 2.10 RD&T funding for FY 2010-2014 (USDOT, 2013)

Admin.	FY 2010 Actual ($000)	FY 2011 Actual ($000)	FY 2012 Actual ($000)	FY 2013 Enacted ($000)	FY 2014 Pres. Bud ($000)	Annual App.	Multi Year Auth.	Comb.
FAA*	398,535	352,776	357,451	315,891	328,050			X
FHWA+	434,315	430,135	410,665	365,352	374,000		X	
FMCSA	9,391	6,959	6,959	8,526	9,000		X	
FRA	37,613	35,030	35,000	34,930	90,000	X		
FTA#	65,770	58.882	44,000	41,694	49,000			X
NHTSA	68,432	66,674	65,282	62,832	73,725			X
PHMSA	8.584	8,567	8,636	8,639	14,530		X	
RITA	6.036	1,433	1,407	1,333	2,618			X

*RD&T (Research, Development & Technology) administrative expenses are excluded from the table.

+Includes funding for three programs administered by FHWA (Highway Research and Development; Technology and Innovation Deployment, and Training and Education), as well as two programs administered by RITA (Intelligent Transportation Systems and University Transportation Centers.)

#Includes funding in FY 2010 – 2012 for the University Transportation Centers Program, administrated by RITA.

Table 2.11 Example Strategic outcomes and performance measurers from USDOT Strategic Plan

Priority Area	Example Strategic Outcome	Example Mode-Specific Priority Area	Example Performance Measure
Safety	Reduction in transport-related fatalities and injuries	Reduce driver distraction issues associated with vehicle and highway design, and operations	Number of technologies adopted in an operational setting to reduce fatalities and injuries
State of good repair	Improve asset management processes to maximize efficient use and maintenance of new and existing infrastructure	National system performance indicators, focusing on the National Highway System (NHS), the Strategic Highway Network, and other major arterial and intermodal connectors	Percentage of travel on NHS roads with pavement performance standards rated good (FY 2016 target was 63.8%)

Besides tracking performance measures through each of the USDOT's operating administrations to ensure implementation of research priorities, the agency has also created an initiative for furthering

technology transfer (T2). The USDOT developed a 5-year plan to focus exclusively on technology transfer acceleration and commercialization of federal research after a 2011 presidential mandate. This mandate charges federal agencies with improving results of technology transfer and commercialization of federal research as a means of supporting high-growth entrepreneurship. The USDOT's T2 plan has three main goals associated with strategies and metrics to achieve the stated goals. The goals of the T2 plan (USDOT, 2011) are:

- Increase the number of T2 partnerships with entities from academia, industry, commercial, nonprofit, government, and non-government,
- Increase the number of commercialization activities, and
- Improve the efficiency of USDOT T2 business processes.

These goals are to be accomplished through the USDOT Research, Development, and Technology (RD&T) programs through: (1) its Operating Administrations (OA), (2) federal laboratories, and (3) grants, cooperative agreements, and cooperative research and development agreements (CRADAs). As one of the USDOT's operating administrations, the Federal Highway Administration (FHWA) also seeks to accomplish these goals through its Research, Technology Transfer, and Education (RT&E) Program. The RT&E program is comprised of the following:

- Highway Research and Development program (HRD)
- Technology & Innovation Deployment Program (TIDP)
- Training and Education Program (T&E)

In particular, the TIDP was established to cater to a need within the *innovation cycle* that, according to the agency, has been traditionally underfunded, and to "accelerate the delivery and deployment of innovation and technology" (USDOT, 2011). The TIDP handles final analysis, marketing, communications, and promotional activities for research leaving the Highway Research and Development Program (HRD). Furthermore, the TIDP also collaborates with AASHTO, TRB and the States on the implementation of the Strategic Highway Research Program (SHRP 2).
In summary, the USDOT relies on its operating administrations to perform and implement research that support the strategic outcomes of the agency. The value of research is then measured by the extent to which it addresses the five focus areas using predefined performance measures.

2.6.3 Louisiana Transportation Research Center (LTRC)

The LTRC was created in 1986 by the Louisiana legislature to conduct research, provide technology assistance and transfer, engineering training and continuing education and general problem solving services to the Louisiana Department of Transportation and Development (DOTD). The Center is jointly administered by the DOTD and Louisiana State University while being funded by the DOTD through a combination of State, SP&R Part 2, Innovative Bridge Research and Deployment (federal), Surface Transportation Program (STP-Federal), as well as through grants and contracts such as the NCHRP, Federal Agency, and National Science Foundation grants (LTRC, 2016a).

Implementation potential is one of two main criteria used in selecting and ranking research problem statements, the other being importance of problem to the Louisiana transportation community. According to the center's research manual, implementable products are those that usually fall within one or more of the following categories (LTRC, 2016b):

- "Products of immediate interest to the funding agency, which provide the basis for decision-making;
- Products that identify the reasons for underlying causes or data relationships which may be used to explain, improve, or develop processes; and
- Products that enhance the ability of researchers to conduct research."

Human & Internal Capital: Approaches & Processes Used in Research Implementation

At LTRC, responsibility for implementing research results is shared by the Engineer Administrator/Project Manager and the Technology Transfer Engineer. The Technology Transfer Manager is responsible for tracking implementation status and preparing biannual status reports. Consequently, the role of Technology Transfer Engineer Administrator/Manager requires a 50% time commitment, which is included in the position description, evaluation expectations and performance measures (CTC & Associates, 2011).

Secondly, research proposals must be approved by a DOTD Office Head who then acts as the *Implementation Sponsor*. The Implementation Sponsor's role is to ensure that successful research products are implemented and any decision not to implement such research must be addressed in writing to the DOTD Secretary. A summary of roles and responsibilities for implementation is presented in **Table 2.12**.

Table 2.12 Summary of Implementation Responsibilities at LTRC

Role	Responsibility
Engineer Administrator/Manager	Shares joint responsibility with Engineer Administrator/Manager for ensuring implementation
Technology Transfer Engineer Manager	• 50% time commitment to implementation • Shares joint responsibility with Engineer Administrator/Manager for ensuring implementation • Develops biannual reports • Tracks project implementation status
Implementation Sponsor	• Upper-level DOTD employee • Must recommend proposals for approval before projects may begin • Lead decision maker regarding implementation
Project Manager	• Responsible for following through with implementation of research results together with Technology Transfer Engineer Manager

Implementation Strategies

A Research Assessment and Implementation Report (RAIR) which outlines implementation feasibility and recommendations must be completed by the Project Manager along with the Principal Investigator, Project Review Committee (PRC) and Technology Transfer Engineer (LTRC, 2016). The RAIR is first drafted in the Conduct of Research phase and reviewed at the kick-off meeting to get mutual agreements on the scope and deliverables between the researchers and the PRC. The RAIR is continually reviewed and updated at subsequent meetings as not all the information may be known at the start of the project. A sample RAIR can be found in **Appendix A**.

The LTRC also views dissemination of research results as crucial when it comes to garnering support for implementation. Such dissemination focuses on translating the value of performed research in terms of Department efficiency, lives saved, or dollars saved. The LTRC uses various modes for dissemination including the following publications:

- Project Capsule
- Interim Reports
- Final Reports
- Technical summaries (required upon completion of each study)
- Technology Transfer - Technology Today and Technology Exchange Newsletter
- Implementation Brochures – Implementation Impacts, Implementation Fact Sheets and Implementation Updates.

Other implementation strategies include the issuance of memos, formal presentations, training materials, demonstration/pilot projects, news releases, development of study proposals (for further research) and personal contact (including workshops, seminars, etc.)

Implementation Tracking & Monitoring

The Research Project Management System is used by the LTRC to track all research and implementation projects. The system comprises various modules that automate many aspects of research management including the "project solicitation process, work program development, biannual reporting, and implementation reporting" (CTC & Associates, 2011). In addition to this system, the LTRC uses the following methods to track implementation of research results:

- **Biannual Research Progress Report**: This report is prepared by the project PI and submitted through the LTRC Project Management System to keep the PRC and Project Manager abreast. It includes an *Assessment of Benefits and Recommended Implementation Strategies* section which is completed by the Technology Transfer Engineer along with the Project Manager.
- **Implementation Summary Report**: This is an annual report presented to DOTD leadership and LTRC Policy Committee which also contains information for the biannual report implementation assessment section. The LTRC Technology Transfer Engineer is responsible for updating the summaries for a five-year minimum period or until full implementation.
- **Implementation Performance Measures**: As depicted in **Table 2.13,** the LTCR uses five different labels to classify research from the project start through to give years after its due date.

Table 2.13 LTRC Implementation Measures

Classification	Implementation Status
Implementation Recommended	Status for projects recommended by PRC for deployment by DOTD.
No Implementation Expected	Research with objectives that clearly do not have any implementation outcome. Examples include basic research, syntheses, technical assistance, exploratory research, etc. Such projects are classified upon initiation.
Project/Implementation in Progress	Status for research from initiation to five years after end date.
Implementation Complete	Research results adopted and documented in Implementation Summary Report.
Not Implemented	Research with no implementable outcome or not implemented within five-year implementation window.

2.7 Technological Capital: Tools and Metrics for Assessing the Value/Impacts of Research

Implementation of transportation research projects can only be accomplished if the proper amount of time and funding can be specifically dedicated to the implementation effort. **The justification of research program needs in order to retain federal funding is accomplished by quantifying and assessing the benefits of both specific research projects and research programs as a whole** (Yoon et al., 2016). Therefore, it is essential that State DOTs are be able to accurately and effectively assess the value of their transportation research projects in order to make the case for implementation funding. Almost 70% of DOTs surveyed have tried to evaluate benefits of their research projects quantitatively and qualitatively (Ashuri et al., 2014). Obstacles to research valuation include data scarcity, difficulty in interpreting qualitative benefits, benefits remaining unknown or uncertain at the time of research results valuation, diversity of the attributes of research project, and different perspectives existing between involved groups in understanding the value of research (Yoon et al., 2016). The following review describes the current state of practice at DOTs with regard to the selection process for choosing which projects to evaluate, types of benefits evaluated and metrics used; methods of quantification, and best practices observed.

2.7.1 Project Selection Considerations

The majority of DOTs choose only to evaluate the benefits of a small selection of research projects in their program and only do so after implementation has occurred. This is due to restraints on time and funding, as well as a lack of data existing for some projects. Therefore, it is helpful for DOTs to use a standardized selection process such as exists at the Minnesota Department of Transportation (MNDOT). MNDOT uses five criteria when considering which projects should be chosen for benefits valuation. The five criteria are as follows:

- Can benefits be quantified in terms of cost savings, either to DOT or to roadway users?

- How significant could the savings be?
- Do the benefits result in a high-impact result or improvement? Describe the impact.
- 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?
- 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.) (MNDOT)

By establishing a set of standardized criteria, DOTs can more quickly and effectively choose projects for evaluation. This limits the time and resources wasted on attempting to evaluate the benefits of projects which will ultimately show little benefit or for which insufficient data exists.

2.7.2 Benefit Types and Metrics

In calculating the benefits associated with various projects, the methods and metrics employed will vary depending on the benefit types associated with that project. According to the Southeastern Transportation Consortium's (STC) Interim Report, **the most frequently used benefit categories include: Improved Mobility, Improved Safety, Improved Environment, Customer Satisfaction, Improved Infrastructure, Expedited Project Delivery, Improved Technology, and Improved Knowledge** (Yoon et al., 2016). Each of these benefit categories can fall under one or a number of the benefit classifications described below.

Four primary types of benefit classifications have been identified by the Minnesota Road Research Project (MnROAD). Direct benefits are dollar savings due to materials or enhanced performance. These benefits are easy to assign a monetary benefit and are also easily defensible. Indirect benefits are more difficult to quantify and include benefits such as new construction processes and improvements to performance. Avoidance benefits are obtained when high risk treatments are tested before implementation in order to avoid wasted time and resources. Demonstration benefits are also difficult to quantify and involve the transfer of technology through demonstration in order to instill confidence in users to try something new (Clyne et al., 2008).

Research completed by Yoon et al. classified benefit types in a different way. Three research categories were established depending on the method of project selection and prioritization of selected projects, as well as characteristics of the research such as application area, geography, and complexity. These three categories are Type A (State DOT's responsibilities), Type B (Civil Engineering Discipline Areas), and Type C (Impact Assessment Elements). Each of these types was then further classified into subcategories and assigned corresponding benefit measures. Tables containing each of the three categories along with their corresponding subcategories and associated performance measures may be found in **Appendix B** (Yoon et al., 2016).

Regardless of the initial method of benefit classification, all benefit types are further classified into quantitative and qualitative benefits. Quantitative benefits are the most commonly evaluated benefit types because of the ease of calculation and include economic benefits such as cost savings due to

reduced emissions. Qualitative benefits such as improvements to level of knowledge are less often evaluated in transportation research projects because it is difficult to assign a dollar to them (Ashuri et al., 2014). It is difficult to compare the results of various projects or summarize the total benefits of a project when it is not possible to associate a number with certain benefits. A few DOTs have attempted to circumvent this problem associated with qualitative benefits as described in the "**Methods of Quantification**" section below.

The metrics used to calculate the benefit of research are closely associated with the benefit types and encompass a large range of benefit measures. Metrics include reduction in travel time delay, dollar savings due to reduction in emissions, crash modification factors, dollar savings due to use of less materials, and sponsored university students (Yoon et al., 2016). **According to a study completed by MNDOT, the most common metrics used across state DOTs are safety improvements, materials saved, and increased efficiency** (MNDOT). It is essential that DOTs standardize the benefit types and metrics that are evaluated for their projects in order to maintain consistency throughout the process for each project.

2.7.3 Methods of Quantification

The actual methods used to calculate the benefits associated with transportation research vary greatly and depend largely on the DOT performing the calculation as well as the type of project being evaluated. The most common methods of valuation include: scaling, benefit/cost ratio estimation, dollar benefit analysis in terms of savings; benefit analysis based on before/after or experimental studies, and computer simulation (Ashuri et al., 2014).

Quantitative benefits are widely acknowledged to be the easiest type of benefits to calculate and are therefore are many times the majority or only consideration in a project's benefit valuation. Two case examples (FDOT and UDOT) are given in order to demonstrate how various DOTs measure quantitative benefits. The Florida Department of Transportation (FDOT) identifies five primary benefit categories that fall into the quantitative type. These benefit categories are: improvements to work efficiency, and reduced material costs, user costs, maintenance costs, construction costs, and operational costs. FDOT uses the cost/benefit evaluation method for all of their projects. The total savings is calculated as the savings per unit multiplied by the estimated number of units to be used over the next five years less any implementation costs. The savings and cost amounts are discounted back to the present value (Ellis et al., 2003). Although converting dollar amounts to present value is the most accurate way to calculate total cost and savings, not every DOT uses this practice (such as MNROAD). The Utah Department of Transportation (UDOT) uses a slightly different (and less standardized) approach to calculate quantitative benefits. UDOT identifies quantitative benefits as "benefits as cost savings" and identifies only two categories under the quantitative benefit type: savings to UDOT operations and benefits to the public. At UDOT every research project is assigned a research champion. This champion is responsible for providing a minimum benefit value for the project. This methodology is open more to the interpretation of the individual champion and therefore creates the opportunity for greater variability in quantification methods. The requirement

for each valuation is that the calculation be logically justifiable and if the champion provides a range of possible values, the lowest value is chosen in order to uphold a conservative approach (Anderson, 2010).

Qualitative benefits are much more difficult to evaluate and are therefore often omitted from benefit valuation completed by state DOTs. However, a few DOTs and programs (FDOT, UDOT, and MNROAD) have attempted to consider qualitative benefits alongside the more easily quantifiable quantitative benefits. FDOT identifies five primary benefit categories that fall into the qualitative type. These benefit categories are: level of knowledge, safety, quality of life, environmental, and management/policy. FDOT quantifies these benefits by scoring each qualitative benefit on a scale from 1 to 5 (along with a narrative explanation justifying the score) (Ellis et al., 2003). UDOT identifies qualitative benefits as "improved operations." There are no categories assigned to this benefit type, and each deliverable is simply given an overall letter grade ranging from A (major impact and improved operations) to E (major tasks not completed and objectives not met) (Anderson, 2010). On the other hand, although MNROAD considers qualitative benefits, they only require a written description of benefits and do not assign a "score." Although this method leaves out room for variation and ambiguity, it also makes the task of comparing benefits across projects much more difficult (Clyne et al., 2008). By assigning a score of some sort to qualitative benefit categories, projects can more easily be compared, and the value of a research program on the whole can more easily be demonstrated.

In **Figure 2.12**, FDOT's Summary of Program Research ***Benefits*** **(Ellis et al., 2003)** shows an example of how the agency is able to compare the effectiveness of research program project categories side by side using the methods they employ for both quantitative and qualitative benefits.

	Construction	Environmental	Geotechnical	ITS	Maintenance	Public Transportation
Total Research Funds ($)	$260,000	$420,000	$395,000	$650,000	$300,000	$700,000
Qualitative Benefits						
Percentage of Total Funding	3.82%	6.17%	5.80%	9.55%	4.41%	10.29%
Level of Knowledge	24	45	38	56	24	46
Safety	24	40	32	58	22	38
Quality of Life	4	48	4	41	18	20
Environmental	20	12	4	24	8	14
Management and Policy	4	12	45	21	10	10
Total Qualitative Contributions Score	80	189	135	232	86	136
Economic Benefits						
Total Economic Contribution	$9,743,750	$5,520,660	$9,001,400	$5,524,800	$6,500,400	$8,902,000

Figure 2.12 FDOT's Summary of Program Research Benefits (Ellis et al., 2003)

The nature of transportation research results in the possibility of a wide variety of project types being pursued at any one time at a DOT. The wide variety of project types means that one benefit valuation method may not be suitable for every project. A research initiative pursued by FDOT concluded that a matrix approach should be used in order to determine the most appropriate method for a given

project. **Figure 2.13** demonstrates such a matrix and shows a sample of project categories along with the recommended evaluation methods.

	Time of Evaluation		Time to Implement		Risk		Ease of Quantification		Recommended Evaluation Method				
Category	Early	Late	Short	Long	High	Low	High	Low	B/C	ROI	NPV	RO	PR
A. Develop Product or Procedure													
C. Evaluate Product of Procedure													
E. Research and Document													
F. Technology Transfer													

Figure 2.13 Matrix Approach to Project Evaluation (FDOT-Matrix)

B/C: Benefit/Cost | ROI: Return on Investment | NPV: Net Present Value | RO: Real Options | PR: Peer Review

The purpose of the matrix approach is to ultimately create a portfolio with a mixture of high-risk/high-potential payoff projects and other projects with less risk potential. In order to create the ideal portfolio, other considerations also need to be considered, such as time to implement and ease of quantification, as shown in **Figure 2**. This approach is also unique in that it recommends the use of a Real Options approach when considering projects that are characterized by elements of uncertainty. The Real Options approach shifts the mindset in the decision-making process away from a simple decision to invest or not to invest, to a perspective that allows a range of options to be considered, with the potential benefit value of each possible decision measured in regards to its "option creating value." In this mindset, research expenditures are the extent of the possible costs but are sometimes necessary in order to take advantage of opportunities in the future (Concas et al., 2002). In this sort of approach, it is essential for researchers to identify potential benefits and collect cost information early on in the research process. When benefits (or lack thereof) can be identified early, a more informed decision can be made in terms of which "option" to pursue for that project. FDOT requires early identification and documentation of potential costs and benefits as well as a specific implementation plan in the case that the option to implement is chosen (Ellis et al., 2003).

2.7.4 Data Sources and Tools

A large impediment to transportation research benefit valuation is a lack of relevant data or standardized tools to complete the task. Sufficient data is necessary to provide logical support and validation to the benefit quantification. Standardized tools and the knowledge to use them effectively

is necessary to ensure quantification efforts remain consistent across researchers in a DOT and across transportation agencies. Data scarcity has been noted as a primary roadblock to research benefit quantification in DOTs. The primary sources of data for benefit measures include the following:

- Inspections
- Surveys (to principal investigators and users)
- Engineering judgement
- Simulation
- Experiments

Data inspection efforts involve regularly reviewing data sources such as crash rate reports and traffic congestion measures. Engineering judgement is based on historical data such as material unit costs and value of time. Data can also be obtained by simulation software when historical data is not readily available (Yoon et al., 2016).

Benefit valuation tools can be useful on both the agency specific and nationwide scale. Agency specific tools can ensure that benefit valuation efforts remain consistent between individual researchers and research champions. Nationwide tools can help warrant that benefit valuations across various agencies are done in a systematic manner so as to ensure that comparisons of research efforts cross agencies are done in a consistent manner. Other benefits of these tools include the early identification of project benefits, assistance with economic aspects of benefit valuation (such as time value of money), and standardizing performance measures.

An example of an agency specific tool that is used in benefit valuation is the Implementation Planning Worksheet created by the Illinois Department of Transportation (IDOT). Researchers at IDOT are required to complete this worksheet for every research project they pursue. It is a standardized template that incorporates aspects of both benefits assessment and implementation strategies. The benefits assessment portion of the worksheet is a broad preliminary estimate of what the possible benefits of the project could be. The worksheet lists 10 assessment categories (such as construction savings or increased lifestyle) and asks for a subjective value rating (from 1 to 10) and a short narrative describing if and how a quantitative rating would be possible ("Implementation Planning," 2014).

An example of a nationwide benefit valuation tool is the Performance Measurement Toolbox and Reporting System for Research Programs and Projects (RPM Toolbox) that was created by the Federal Highway Administration. The tool was created through the National Cooperative Highway Research Program to help transportation agencies use standard performance measures with the ultimate goal of measuring transportation research program and project performance. The tool provides a way for these agencies to develop an all-encompassing customized research performance measurement system. It incorporates 30 performance measures with the ability to manually include performance measures unique to the agency. The performance measures are sorted into five classifications: outcome measurements, output measurements, resource allocation measurements, efficiency measurements, and stakeholder measurements. **Table 2.14** lists the standard performance measures included in the RPM toolbox along with a definition of each measure.

The tools included in the RPM Toolbox include PM 101 (tutorial on performance measurement principles); PM Selection Wizard (assists agencies in choosing which performance measures to use); Resource Collection (lists of sources for statistics and other information needed for accurate benefit estimation); Benefit Estimation Worksheets (worksheets available to assist in benefit calculations using 3 methodologies: Current minus future method, Direct difference method, and Percent improvement method), and Automated Present Value Calculation (helps agencies more accurately account for time value of money in their benefit estimations) (Krugler et al., 2006). Screenshots of the tool may be found below. **Figure 2.14** shows the PM Selection Wizard results and PM Selection Worksheet. **Figure 2.15** shows an example using one of the benefit estimation worksheets.

The ultimate success of this tool relies on the availability and training of dedicated research staff at any given agency, and this has been shown to be a large problem in the actual use of this tool across agencies. A survey completed in 2014 by the AASHTO Research Advisory Committee administered to state DOTs gathered information regarding the relative degree of use of the RPM Toolbox and the various pros and cons associated with it. Of the 50 state surveyed, 25 states responded and provided input on the topic. Of these 25 states, 43% responded that they do not use the RPM toolbox and only 14% found the tool extremely useful. The primary benefit cited for the tool was that it is useful in identifying the different types of research performance measures and provided structure for measuring performance. However, there were numerous cons to the tool that were cited in the survey, including the following:

- "Adapting to RPM Web would require a lot of work"
- "Have mixed feelings about the usefulness"
- "Did not find the tools very beneficial, because the benefits need to be customized for individual states …"
- "Information may be duplicated elsewhere…would need to build the measures into projects prior to start…input not required/hasn't been a priority" (Stone, 2014)

From this survey it can be seen that the success of any tool is dependent on two things: actual/perceived usefulness of the tool and overcoming the initial inertia of adoption. Many agencies see the adoption of this tool as a daunting task, and if programs are only doing the minimal to track research progress currently, there is little chance that the tool will be utilized unless it is made a mandatory requirement for the program. Also, if the actual or even more importantly the perceived usefulness of the tool is in question, states will not be incentivized to put in the extra effort to adopt to the tool.

Table 2.14 Standard Research Performance Measures used in the RPM Toolbox

Measure Name	Definiton
Outcome Measurements	
Dollars Saved	Estimated present value dollar savings in the cost of contract work, cost of agency-purchased materials, and cost of employee labor made possible by research products
Lives Saved	Projected number of lives to be saved based on the number of fatalities associated with the problem prior to the product implementation and the estimated or determined effectiveness of the research products
Crashes Avoided	Estimated reduction in number of crashes based on the number of crashes associated with the problem prior to the research product's implementation and the estimated or determined effectiveness of the product
Output Measurements	
Technical Products	Number of types of research products improving design processes, specifications, or technical standards or practices
Management Products	Number of types of research products improving the agency's management procedures, policies, and non-technical training
Knowledge Products	Number of types of research products improving basic knowledge or understanding in the subject area without creating a specific technical or management product
Environmental Products	Number of types of research products improving or protecting the natural environemnt
Congestion Mitigating Products	Number of types of research products reducing or eliminating traffic congestion and other transportation system delays
Traveler Comfort Products	Number of types of research products improving the physical or psychological comfort of the traveler or enhancing the aesthetic quality of the system or improving system security (safety products not included unless traveler comfort or well-being is improved in non-crash situations)
Quality of Life Products	Number of types of research products improving quality of life, which is defined as the total of those product types meeting the criteria for Environmental Products, Congestion Mitigating Products, or Traveler Comfort Products
Safety Products	other innovation or enhancement for the transportation system which improves safety for anyone on or near the trasnportation system
Cost-Saving Products	Number of types of research products reducing the cost of contract work, cost of agency-purchased materials, and cost of employee labor
Research Reports	Number of published research reports and other technical publications emanating from completed research projects during the evaluation year
Graduate Students	Total number of graduate students financially supported or otherwise involved in transportation research
Resource Allocation Measurements	
Dollar-Saving Projects	Number of research projects pursuing lowered cost to provide the transportation system
Safety Projects	Number of research projects pursuing safety enhancements
Quality of Life Projects	Number of research projects pursuing improved quality of life
Total Contractors	Number of unique entities with research projects that were active for any length of time during the evaluation period
Minority Contractors	Percentage of total research program contract budget that is awarded to minority universities, as defined by the US Department of Education and applicable federal regulations
In-House Percentage	Percentage of the total funding for research projects being performed by agency personnel
Efficiency Measurements	
Benefit-Cost Ratio	Total present value dollar savings associated with the project(s) compared to either the total present value cost of the project(s) plus implementation effort(s) or to the total present value cost of the fiscal year research program plus related implementation efforts. The system report generator selects the cost basis and enters cost data
% Administrative Costs	Dollar value of program overhead expenses divided by the total program cost
% Requests Funded	Number of projects funded divided by number of projects requested
% Projects Implemented	Number of projects with at least one product implemented (completely or partially implemented) divided by total number of projects completed during the evaluation period
% Projects On Time	Number of projects completed on/before the scheduled completion date divided by total number of projects to have been completed during the evaluation period
% Projects Within Budget	Number of projects completed within budget divided by total number of projects completed during the evaluation period
% Projects with Reports	Number of projects completed during the evaluation period (FY one year prior) for which all research reports have been submitted within one year of project completion divided by the total number of projects completed during the evaluation period
Stakeholder Measurements	
Customer Satisfaction	Number of customers reporting satisfied or very satisfied on survey divided by total number of customers surveyed
Agency Participation	etc.
Project Needs Statements	Number of project needs statements submitted by internal customers

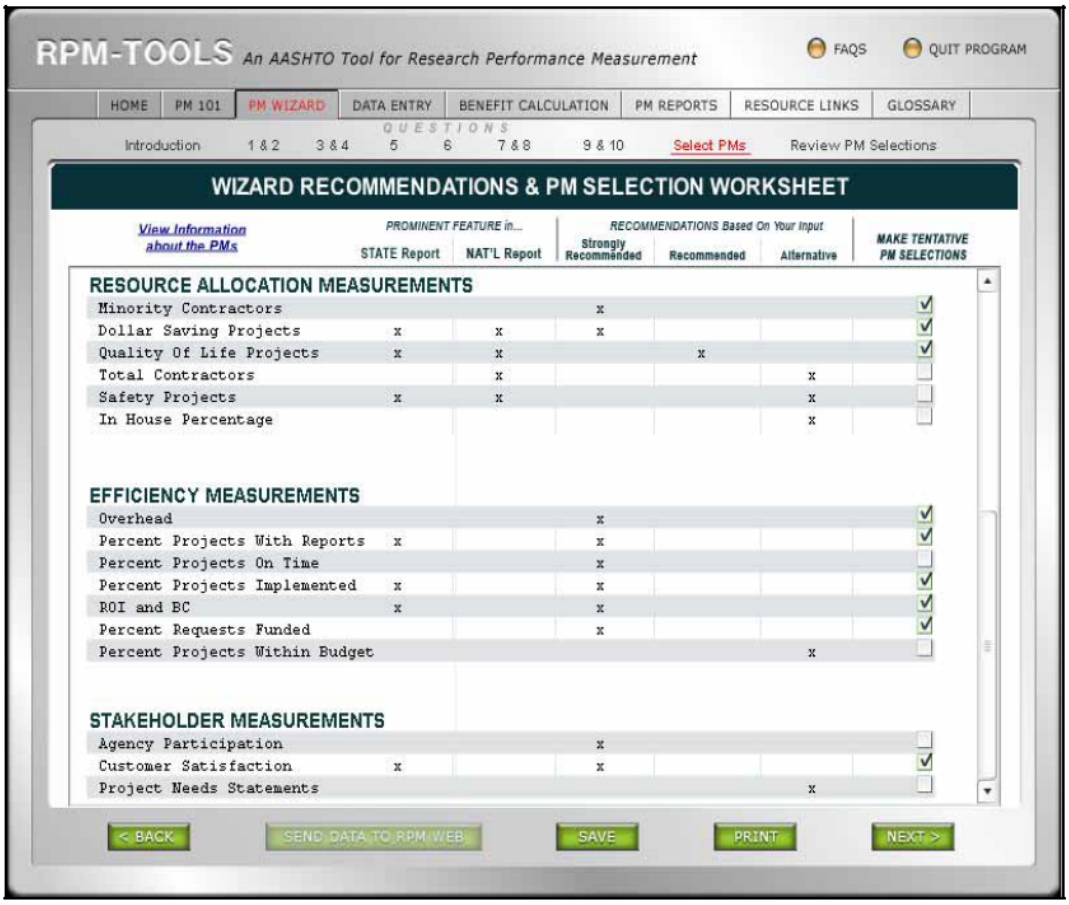


Figure 2.14 RPM Toolbox Screenshot – PM Wizard and Selection Worksheet (Krugler et al., 2006)

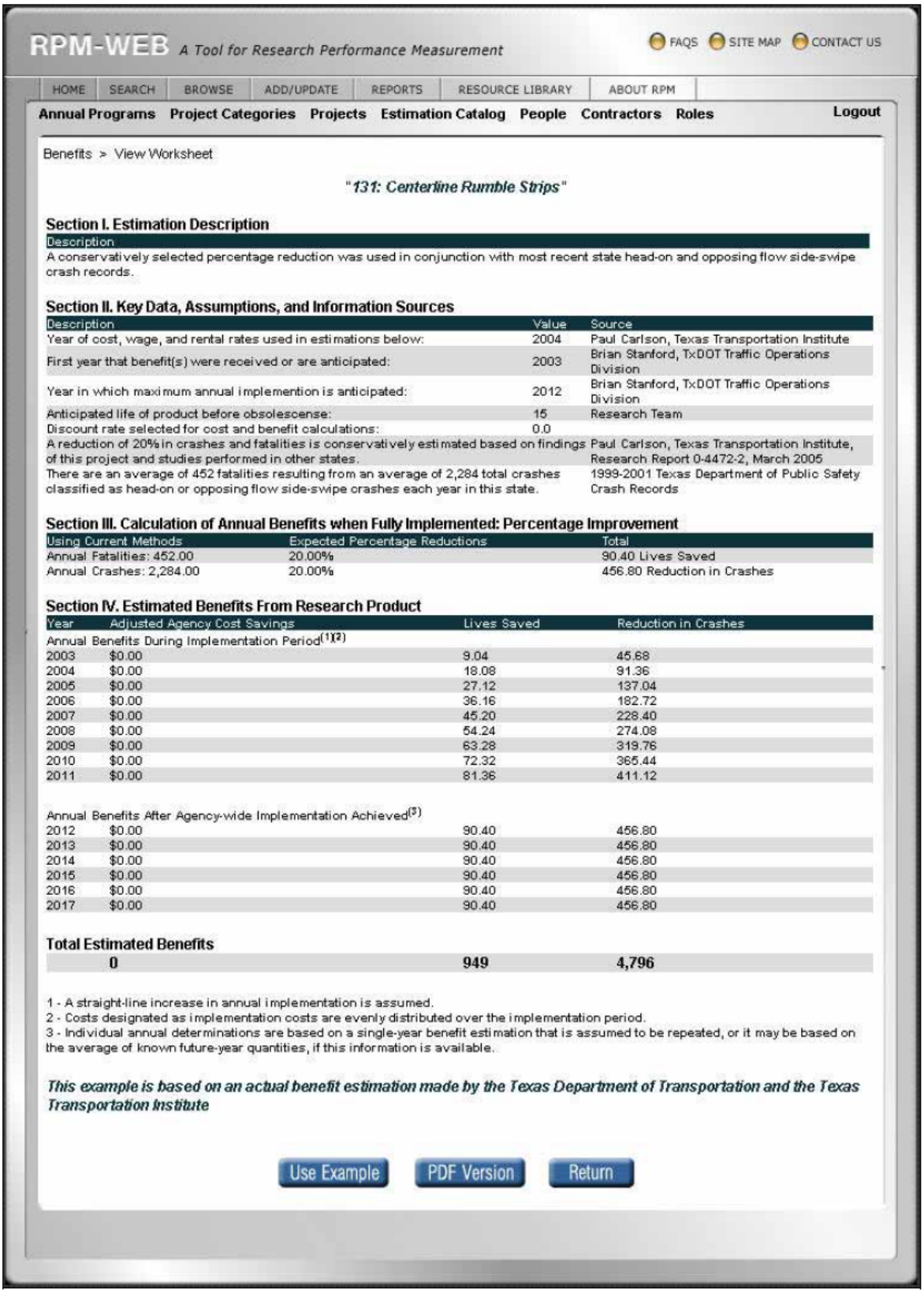


Figure 2.15 RPM Toolbox screenshot – Benefit Estimation Worksheet (Krugler et al., 2006)

2.7.5 Effective Practices

Through a thorough investigation of current practices at DOTs and transportation programs throughout the country, a number of effective practices in research valuation became apparent. These practices encompass both organization level (as found in the United States Department of Transportation) and more specific practices found in state DOTs.

The United States Department of Transportation (USDOT) provides a good example for how a transportation agency can align its research initiatives with its strategic goals and incorporate these goals through the entire research process to benefit valuation. USDOT strategic goals are combined with Congressional priorities in order to determine priority areas to be addressed by their research program. Priority areas for the 2013-2018 period include safety, state of good repair, economic competitiveness, livable communities (congestion and mobility), and environmental sustainability. Performance measures were then identified for each priority area and the quantification of benefits were solely related to the associated performance measures. The value of research at USDOT is only assessed to the extent by which it addresses the associated focus area (*"Research, Development," 2013*). PennDOT's research implementation and innovation system emphasizes the importance of taking a system's view with consideration given to the strategic, technological and human resource underpinnings of implementation, and in particular linking the research implementation process and priorities with agency strategic goals. The agency's implementation process emphasizes the provision of financial and technological resources, development of a research implementation and innovation team, broad engagement of field staff, identification of champions at all levels, multiple levels of communication and results measurement for building implementation culture and success (Bonini et al., 2011).

A number of more specific effective practices at the program and project levels were also identified. In a research initiative completed by Georgia Institute of Technology, it was noted **that valuation methodology should be concise and not too complex**. Also, flexibility in valuation methods and measures was noted to be important across differing project types and classification areas (Ashuri et al., 2014). In a research initiative completed by MNDOT, six additional best practices were found. First, **it is important for benefits to be identified as early as possible. This is important because data becomes hard to obtain after a project ends.** Also, if a Real Options Approach is used, it is important for benefits to be identified early in order to make an informed decision regarding which option to pursue (as mentioned earlier in the "Methods of Quantification" section). Second, **it is important for resources be dedicated by the DOT to track implementation and conduct benefits analysis**. Third, **it is usually not possible to quantify the benefits for every single research project, so programs should be selective and only choose projects that have data available and projects that tend to have higher cost benefits** (high-cost items, user cost savings, safety improvements, etc.). Fourth, **benefit evaluation should be completed using systematic approaches**. Databases, worksheets, templates, and reports should be used to maintain consistency. A very limited number of state DOTs (12% of DOTs surveyed) use standardized evaluation guidelines to measure research value (*Yoon et al., 2016*).

Fifth, **in order to maintain credibility, programs should document assumptions and be conservative in their estimates**. Finally, **research programs should encourage innovation and invest in high-risk/high-reward research that may not always result in quantifiable benefits** (MNDOT*, n.d.*).

2.8 Accelerating Research Implementation – Lessons Learned from Non-Transportation Agencies

Public organizations outside of the transportation context, including US and international sources, public and private institutions, and academic organizations (for example: U.S. Department of Agriculture, U.S. Department of Defense, National Institutes of Health, Food and Drug Administration, U.S. Citizen and Immigration Service) have in general done better at research implementation than those operating inside of the transportation domain (*Harder, 2014*). **The difference in research implementation success is not a result of differing strategies or tools, but a difference in overall strategic framework, structure and approach, and culture towards innovation.** A key approach to identifying opportunities for moving research implementation forward within the transportation context is to observe what is being done by these public-sector agencies that operate outside of the transportation context, private institutions, and university organizations.

Observations of these agencies reveal that the greatest opportunities for research implementation exists in a refocusing of strategic priorities; the allocation of staff and financial resources around research implementation, and strategic changes which are often the most difficult to achieve.

2.8.1 Approaches & Processes Used in Research Implementation

Observations of agencies operating outside of the transportation context indicate that the greatest shortcoming of the transportation agency is the lack of a systematic approach and infrastructure needed for sustainable research implementation. A sustainable, systematic approach to research implementation includes experienced talent, the availability of operating resources within an organizational setting, and a prioritization of research implementation at the highest levels of leadership. The current approach used by State DOTs, in comparison to that used by other agencies engaged in research implementation, is ad-hoc. The first steps needed to achieve a systematic approach towards research implementation will involve the hiring of experienced implementation professionals, and the building of capacity within organizations (*Harder, 2014*). Overall an integrated strategy "of developing a systematic approach to implementation that includes a sustainable infrastructure of experienced talent and sufficient resources operating in an organizational setting that places a priority on implementation," will be the approach that can make a significant impact (*Harder, 2014*).

Based on a review of agencies operating outside of the transportation context, areas that present themselves for improvement in the transportation agencies that can be informed by work done at non-transportation agencies include the time to implementation, methods and procedures, types and availability of resources, innovation climate and culture, the organizational leadership, and more. The practices is shown in **Table 2.15** have been used by several non-transportation agencies for implementing research results. None of these components of a systematic research approach is considered a magic bullet. It is a combination of approaches to support carefully selected strategic priorities that lead to research implementation success.

Table 2.15 Incentives used to foster motivation for change

Strategy/ Practice	Finding	Non-Transportation Agency Using Practice
Infrastructure maturity	Industries or domains have been studying the use and results of implementation efforts for longer are further advanced in providing systematic approaches to the business of implementation.	Medical research has been looking at implementation research for more than 20 years, making an effort to get evidence-based results into patient care practices DoD has developed a highly structured process for technology transition that includes detailed instructions and considerations.
Implementation Resources	In all contexts, if implementation of research results was to be done, there were resources committed (funding, expertise, equipment, materials, and the time).	Implementation success of the USDA agricultural extension work was based on the availability of adequate funding The National Science Foundation (NSF) initiated a program of investment to accelerate innovation research (AIR 2011) to include specific support for proofs of concept and technology translation plans ($9 million was awarded to 22 academic research institutions).
Culture or climate that fosters innovation	The climate that can impede or facilitate implementation (empowered staff, supportive management, a fail-fast/win-strong environment, and risk tolerance).	A senior product development professional describes a culture as innovation using the acronym CREATIVE: **C**ustomer-focused, **R**isk-tolerant, **E**ntrepreneurial, **A**ligned with strategy, **T**echnology and scientific excellence, **I**nnovative, **V**irtual organizations (or creative collaboration), **E**xecution (or) **E**xcellence in project management.
Boundary Spanning Innovations	Interventions that span the gap between researchers and users. "A boundary spanner facilitates information exchange that alerts an organization to new developments."	For example, the USDA uses Partnership Intermediary Agreements (PIAs) to offer expertise and other resources that reduce barriers to implementation and speed the use of results.
Incentives	As a tool, incentives seek to motivate behavior changes to achieve outcomes more aligned with organizational goals; incentives are often financial rewards, but not always.	No examples provided
Effectiveness measures	These are metrics that oversee and assess the success of technology transfer strategies and methods.	In health and defense there is a desire to determine which methods are most successful; there is an understanding that the cumulative application of multiple methods has bigger results, but there is little knowledge of which practice is best.

Table 2.15 Continued: Incentives used to foster motivation for change

Well written documentation	Research implementation success requires the promotion of innovations to potential users.	The USDA, DOD and others have compiled well-written documentation to communicate what it will take to transmit innovative practices to market.
Best Practice	The use of universally endorsed practices for a given context; these are practices expected to produce timely and cost effective results.	The medical field has done extensive work identifying the practices that lead to most favorable outcomes. Work needs to be done for the relevant context to ensure a body of work that can that can be considered "best practice."

2.8.2 Replication and Transferability of Practices

As discussed, best practices from public and private agencies outside of the transportation practice present opportunities for accelerating research implementation within the transportation community. However, these practices cannot simply be transferred from one organization to another. Public sector transportation agencies should prepare themselves for the adoption and use of such practices. **Key steps that should be taken to prepare for the acceleration of research results include adopting a systems perspective; dedicating appropriate talent and expertise; allocating financial resources, and preparing for the organizational restructuring and change needed to achieve research implementation** (Harder, 2014). For transportation agencies attempting to accelerate research implementation, adopting a systems perspective means moving from an ad-hoc process of implementation to a systematic process of implementation. Organizational restructuring may require creating teams, or recruiting staff for the job of implementation (Harder, 2014). In the face of limited resources or resistance to change, steps can be taken to adopt a systems perspective, and make a case to secure the necessary expertise and resources. As the value of accelerated research results becomes evident, this can support further organizational restructuring and organizational change.

2.9 Challenges and Opportunities for Successful Research Implementation

Implementation of research results will not automatically occur with the publication of a research report. Successful research results implementation requires a well-defined, properly structured strategic process. Without a targeted research implementation process, research results including reports and products are likely to "die on the shelf" (NCHRP Synthesis 461). As depicted in **Figure 2.16**, there are many obstacles and barriers to research implementation. Barriers can be internal to the DOT or external i.e., beyond the influence of the research team or practitioner (NCHRP Synthesis 461). **Identifying and understanding barriers to implementation at the beginning of a research project can greatly increase the chances of implementation.** It is anticipated that providing current and future research teams with knowledge about potential barriers and obstacles may greatly influence opportunities for research implementation success.

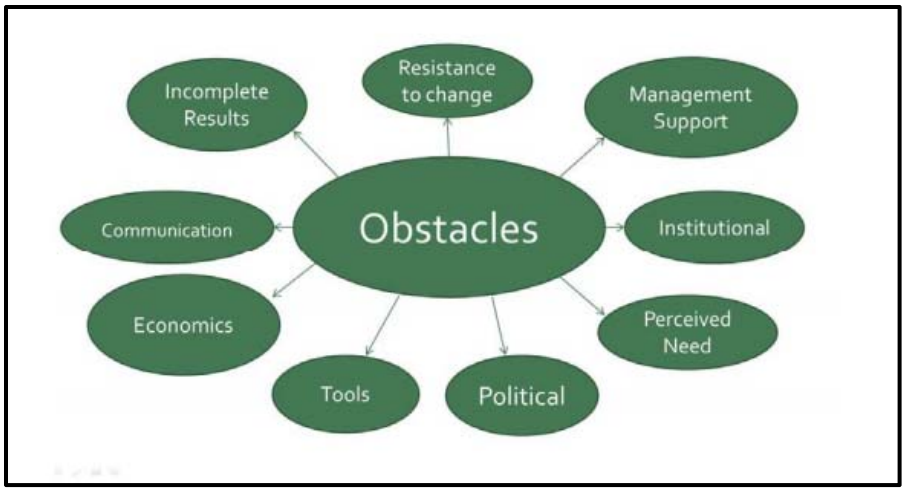


Figure 2.16: Obstacles to Implementation
Source: NCHRP Synthesis 461

Much effort has been placed on identifying the barriers to research implementation and on identifying solutions for reducing the impacts of these barriers. There are challenges that are unique to the context of research implementation in DOTs and other transportation agencies; barriers to research implementation that are present in non-transportation agencies yet are relevant to the transportation context, and barriers that impact research implementation in general no matter the context. This section of the report highlights several of the challenges reported by individuals responsible for research implementation in practice both inside and outside of the transportation practice. Also included in this section are opportunities including solutions that have been used in practice to reduce the impact of these challenges, and possible strategies and approaches that can be used to accelerate research implementation. Opportunities and challenges to research implementation reported from three areas of practice are reported here -- barriers, challenges, and opportunities for research implementation in general, in DOTs and other transportation agencies, and in non-transportation agencies.

2.9.1 Barriers to Effective Research Implementation

Barriers to effective implementation include limited understanding, organizational inertia, inflexible standards, preoccupation with first costs, mistrust of change, a desire to perpetuate jobs, decentralized multijurisdictional nature of transportation decision making, lack of economic setting or other rewards, and a risk-averse public management culture. Additional barriers to research implementation success include a failure to include users and/or stakeholders in a real way throughout the research and development process; a failure to implement or identify pilot projects within a stakeholder context, and a failure to integrate relevant processes into implementation activities (Bikson et al., 1996).

Those responsible for the implementation of research results often struggle to identify the practices that are most closely associated with successful research implementation, or to identify measures for

assessing this success. **Measures of research implementation success include timeliness, effectiveness (in terms of goal and objective alignment), and scope (proportion of possible users who adopt the new change, tool, or process).** One approach to effective measurement of research implementation may include the use of measures that capture the success or failure at overcoming specific barriers to implementation. Factors that positively or negatively influence the transfer, application, and use of research results can be can be arranged into three distinct classes (Bikson et al., 1996):

- **Characteristics of the research results:** e.g., their adaptability to various user settings or their ease of commercialization
- **Characteristics of the implementing organization:** e.g., its size, resources, and culture and its institutional context e.g., political and regulatory constraints, and
- **Characteristics of the implementation process:** i.e., the activities that are put into practice and the research outputs e.g., how the research is communicated, whether researchers and users interact, and whether users receive output-specific training.

Shown in **Table 2.16**, research implementation barriers have been identified for each of these three distinct factor classes.

Table 2.16: Research barriers by implementation factor class (Bikson et al., 2996)

Class of Factors/Characteristics	**Key Barriers to Research Implementation**
Characteristics of the research results (e.g., their adaptability to various user settings or their ease of commercialization)	- Unsettled patents - Research output doesn't fit work procedures - Research output not sufficiently tested - Mismatch between research and user needs
Characteristics of the implementing organization (pertaining to the internal organization context) (e.g., its size, resources, and culture) and its institutional context (e.g., political and regulatory constraints)	- No local precedents - Inadequate travel budget - Political involvement of managers - Skill obsolescence - Inadequate resources - Discomfort with change - Organizational inertia - Inflexible contract specs - Legal ability - Risk aversion
Characteristics of the implementing organization (pertaining to the external organization context) (e.g., its size, resources, and culture) and its institutional context (e.g., political and regulatory constraints)	- High tech government support bias - Private-public tensions - No local precedent - Dispersed funding authority - Researcher-user culture gaps - Contractor investment risk - Unclear national objectives
Characteristics of the implementation process (i.e., the activities that put into practice the research outputs; e.g., how the research is communicated; whether researchers and users interact, and whether users receive output-specific training)	- Costliness - Researchers not market-oriented - Unknown information source - One-way dissemination - Poor quality/relevance filters - User success unpublicized

2.9.2 Suggested Improvements for Successful Research Implementation

Successful research implementation has three constants – consistent communication, smooth governance, and the commitment of financial resources throughout the duration of the process (Meyer and Meyer, 2014). Meyer and Meyer (2014) offer a variety of suggestions for moving research implementation forward in a successful manner, while at the same time highlighting some of the failures in research implementation that create challenges for implementation success. **Table 2.17**

identifies known challenges to research implementation and suggested improvements to the research implementation process.

Table 2.17: Challenges to Research Implementation and Suggested Improvements

Improvements for Successful Research Implementation	**Research Implementation Challenges Address**
Structure the research	- Poorly defined objectives and misunderstood context - No implementation plan outlined - Failure to conduct a real-world test, pilot study, or demonstration project - No incentives provided to researchers
Deepen researcher stakeholder relations	- Failure to leverage stakeholder tacit knowledge - Failure to provide opportunities for researchers to be co-producers of implementation rather than seeds for innovation
Disseminate research outcomes	- Stakeholders uninformed about research (singular channels used to communicate) - Value of research not sold and no interest in outcomes - Failure to share success stories or build culture
Mitigate systemic impediments	- Policy barriers: mandates conflicts and long-term instability - Ad-hoc process; poor alignment of research and agency goals
Manage the double edge swords	- Poor balance and management of standards in research development - Unresolved issues around intellectual property rights - public research and private ownership
Track research and implementation long-term	- Poor access to the right data; failure to collect the right data - Focus only on the project ROI rather than the process ROI

Active encouragement of implementation from senior management is important for accelerating research implementation. **Strategies for institutionalizing implementation through the creation of an implementation plan and creating a line item in the budget for implementation are highly recommended.** The pooling of staff and financial resources, and the sharing of costs and risks associated with implementation can improve benefits from implementation, and provides the opportunity to strengthen relationships within agencies and between departments (Bikson et al., 1996). **Choosing the right staff is a key strategy for research implementation success.** In an era of shrinking budgets, research implementation goals and the need for technical expertise provides the opportunity to promote and reward staff development. A focus on research implementation also

provides a chance to promote and reward high-quality groundwork already underway in surface transportation thereby promoting future pursuits in research implementation (Bikson et al., 1996).

2.9.3 Suggested Improvements to the Research Implementation Process

The U.S. Transportation innovation research development and implementation process is characterized by four stages: research and development, prototype/proof of concept, demonstration pilot, and commercialization. This process has also been characterized by two valleys of death - the Technological Valley of Death and the Commercialization Valley of Death (Jenkins and Mansur, 2011) (see **Figure 2.17**). The technological valley of death results from a failure to move research from the initial phase of research and development to the second phase of prototype/proof of concept. The commercialization valley of death results from a failure to move research from the demonstration phase to the commercialization phase or broader deployment at scale. The commercialization valley is represented by the point at which government funds vanish from the implementation process and alternative often private funding has to be solicited to move the implementation process forward. Addressing these key breakdowns in the innovation process should also be a point of focus for those seeking to improved research implementation success.

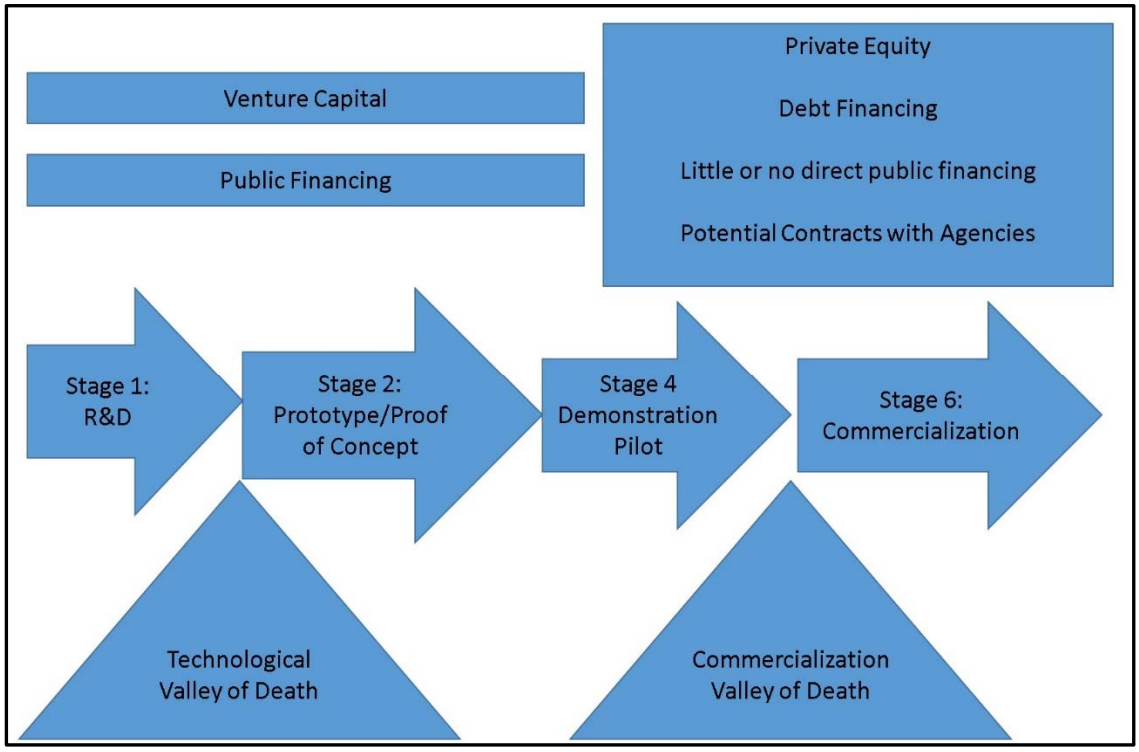


Figure 2.17: Transportation innovation process and valley of death
Source: Jenkins and Mansur, 2011

2.9.4 Technology Transfer Challenges, Opportunities, and Needs for DOTs and Other Transportation Agencies

Technology transfer enables innovation to realize its benefits (Harder and Benke, 2005). **Harder and Benke (2005) define technology transfer as any activity that leads to the adoption of or implementation of research results, the deployment of products or processes to the user, or the improvement of existing technologies that are then disseminated to the user. Technology transfer is also thought of as including the complex process of change, which includes cultural and technical undertakings** (Harder and Benke, 2005). In the 1960s, AASHTO identified technology transfer as including those activities between the completion of research and adoption of research results in practice. From the perspective of AASHTO research implementation/implementation of research results and technology transfer are therefore synonymous and often used interchangeably (Harder and Benke, 2005).

2.9.4.1 Factors Critical for Technology Transfer

Research implementation and technology transfer of transportation innovation in the United States is spearheaded through one of two organizational approaches either by State DOTs, originating from a centralized research unit or from individual operating units, or by Local Technical Assistance Program (LTAP) Centers. LTAP is a Federal Highway Administration (FHWA) program composed of a network of Centers that provides local road departments and related transportation agencies with the training, information, and new and existing technology updates needed to ensure workforce development, manage infrastructure, improve work zone safety, roadway safety, and worker safety (FHWA-LTAP, 2016).

In general, factors critical for successful technology transfer include placing the technology within the user environment; having a champion in place to push for technology transfer; and placing an emphasis on marketing and communication. Many of the elements that lead to success when present can also result in failure when absent (Harder and Benke, 2005). State DOTs responsible for research implementation and technology transfer identify the following as the top three needs for technology transfer success:

- More time to perform technology transfer;
- Additional funding, and
- Technology transfer training.

LTAP centers identify the following as the greatest needs for ensuring research implementation and technology transfer success (Harder and Benke, 2005):

- Additional funding;
- Greater management support;
- Greater access to technical expertise, and
- Greater access to staff resources.

Table 2.18 shows challenges experienced by State DOTs (research and operating units) and LTAP centers involved in technology transfer**.**

Table 2.18: Technology Transfer Challenges Experienced by State DOTs and LTAP Centers

Challenges Experienced by State DOTs and LTAP Centers	Challenges Experienced by State DOTs	Challenges Experienced by LTAP Centers
• Change and risk aversion issues • Time constraints • Mismatch of staffing and workload • Inadequate communication and coordination • Marketing and information availability • Measuring performance and outcomes • Funding and costs	• Structural and organizational issues • Commitment of the agency and of influential individuals • Weak outcomes of research - perceived and actual • Poorly defined implementation process	• Lack of instructors and technical experts • Materials and courses

According to the findings of NCHRP Synthesis 461, key barriers to research implementation faced by DOTs and proposed solutions to these barriers include the following:

- **Barriers**: Time barriers; ambiguity of research results prediction; internal communication within hierarchy; aversion to innovation, and
- **Solutions**: Setting aside special implementation funds; and using private sector consultants for implementation tracking and certain implementation activities.

An additional barrier to research implementation success is inadequate research implementation tracking. **At DOTs there are various approaches taken to research implementation tracking, somewhat dependent on the organizational approach taken to research implementation.** In some instances, tracking is done by the research division staff. This approach represents a centralized effort to store, track, and disseminate research results. In other instances, research tracking is done by other division(s) within the DOT (Harder and Benke, 2005). As shown in **Figure 18**, there are pros and cons to each approach and each DOT must determine which approach is most appropriate for their individual case.

	Research Division Staff	All/Assorted Division Staff
Pros	• Allows staff from other divisions to focus on their own responsibilities • Research division staff member will be most familiar with database tracking system • Can create external communications based off research results implementation	• Generally, most familiar with research project and subject matter • Provides opportunity to see first-hand how much the research they are involved with sees or does not see implementation • Motivates to make sure a research finding is implemented
Cons	• Research division staff member may not be as familiar with technical aspects of research results • May not have access to essential communication networks that other division staff have	• Very difficult to enforce unless already part of job description • May not understand purpose of implementation tracking

Figure 2.18: Pros and Cons for Implementation Tracking Designation
Source: Harder and Benke (2005)

Finally, assuming a proactive approach towards research implementation by including an implementation task in the research plan may also help to ensure implementation success. Development of a research implementation plan for research results can be negotiated into the research contract (NCHRP Synthesis 461). Funds set aside for implementation tracking can be viewed as seed money for implementation activities. This seed money can be used to purchase new equipment, train staff, and draft and disseminate guidance on implementation. Consultants can be used to produce videos and other communication materials that are then used to disseminate research results; consultants can assist with policy guidance, and develop training courses to keep DOT officials engaged in the research implementation process and program.

Chapter 3. IMPLEMENTATION PROCESS MAPPING AND REFINEMENT

3.1 Introduction

This chapter presents recommended strategies for enhancing GDOT's research implementation process based on the existing processes and resources available within the agency; the effective practices identified in the literature review, and drawing from the conceptual Framework (shown in Figure 3.1) developed in Chapter 2. The literature on successful research implementation clarifies that the difference in research implementation success is not a result of differing strategies or tools, but a difference in overall strategic approach, structure and approach, and culture toward innovation (Harder, 2014). Additionally, the greatest opportunities for accelerating research implementation exist in the following:

- Adopting a *systematic* approach to research implementation;
- *Hiring* experienced implementation professionals, and
- Building *capacity* for implementation within organizations (CTC & Associates, 2011; Harder, 2014)

All these elements are collectively placed within the integrated capital assets framework for organizational performance shown in **Figure 3.1**, which ties research implementation with agency strategic goals and objectives, and supports intentional activity to accelerate implementation of research to augment agency performance. The recommended strategies presented in this chapter therefore address (1) intellectual capital made up of human, internal and external capital, and (2) technological capital, made up of management data and tools. The subsequent sections present these recommended strategies in addition to a process map outlining the re-engineered research implementation process.

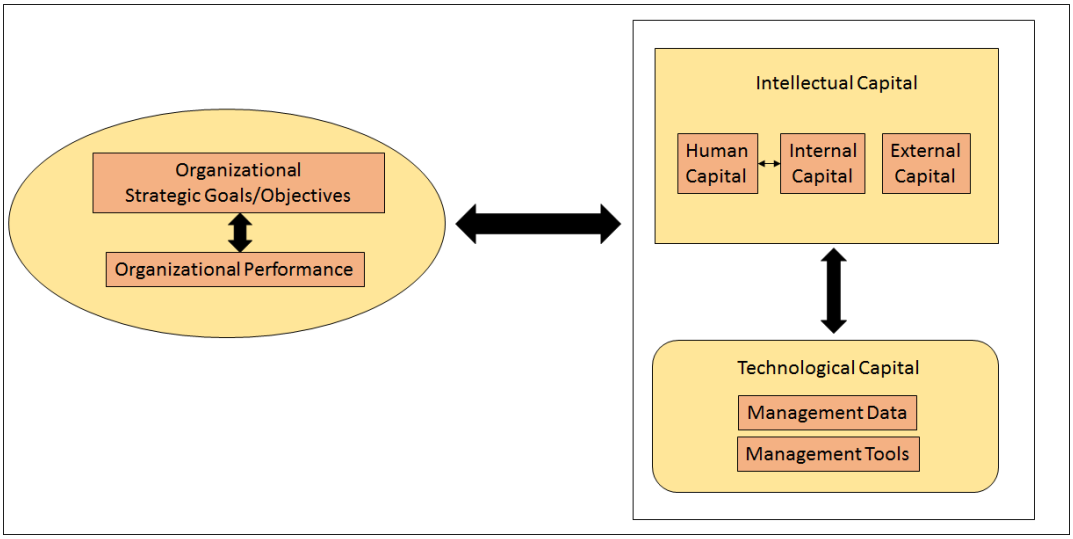


Figure 3.1 Capital Assets Framework for Organizational Performance

3.2 Recommended Strategies for Enhancing Research Implementation

In the section below, we use the capital assets framework for organizational performance to structure a discussion highlighting several strong elements of a performance-based approach to research implementation and management with respect to an agency's strategic goals and its human, internal, external and technological capital. These elements are recommended for enhancing the agency's research implementation and management process. The discussion draws from existing state DOT practices as well as the literature on Implementation Science, Intellectual Capital and Non-Financial Public Organization Performance, and Capital Asset Management.

3.2.1 Adopt a Performance-Based Definition of Research Implementation

A clear definition of research implementation is an essential element and the proposed point of departure for any structured and systematic effort to manage research implementation to drive agency performance. Implementation is generally defined as "the process of putting a decision or plan into effect or execution" (Oxford Dictionaries, n.d.). For performance-based research implementation, a strong definition will clearly articulate research implementation outputs that are part of the standard business procedures of the agency (see ODOT's definition in Chapter 2), and have a clear linkage to organizational performance (for example, through the agency's strategic goals and objectives). Thus, a modified form of Ohio DOT's definition is proposed as a generic performance-based definition of research implementation: **"*The incorporation of research findings into a new or revised policy, procedure, specification, standard drawing, work method, and the transformation of these into common practice to drive organizational performance driven by agency strategic goals and objectives*"**.

3.2.2 Develop a Clear Description of the Agency's Research Implementation Process

An agency's structure and approach towards implementation and its culture toward innovation are key factors for successful implementation (Harder, 2014). Adopting a systematic process for research implementation, rather than an ad-hoc approach contributes towards developing effective implementation methods as described by Duda et al., (2014) in the Formula for Success Framework. **Adopting a research implementation process as part of formal agency procedures is important for effective and performance-based research implementation**. This entails articulating the roles of the researcher(s) and agency staff in the implementation process, and specifying and tracking research implementation deliverables, as discussed in more detail below.

3.2.2.1 Clearly articulate the roles and responsibilities of the researcher and agency staff in the implementation process

For an agency to engage in performance-based research implementation, it is important that the research implementation process is clear and understood by all stakeholders (both internal and external) involved in the process. An effective way of doing this in practice is to specify

implementation deliverables and a timeline for implementation, and clearly articulate the roles of the researcher(s) and agency staff in the implementation process. To ensure that implementation proceeds effectively, it is important that the researcher's responsibility for implementation is clearly articulated in some formal agency document. For the portions of the implementation where the researcher does not assume primary responsibility, the agency must identify which staff member(s) will assume primary responsibility for the implementation.

Three types of research implementation projects may be identified based on the associated research project timelines. As shown in **Table 3.1**, implementation generally occurs either within the research project timeline, after the research project is completed, or during both phases.

Table 3.1 Three Types of Research Implementation Timelines

Project Type	Implementation Activity During Research Project	Implementation Activity After Research Project
I	Yes	No
II	Yes	Yes
III	No	Yes

The appropriate timeline for implementation will depend on the type of research being conducted. By using an implementation plan and specifying implementation deliverables, timelines associated with deliverables can be clearly defined in the implementation process. Implementation deliverables and timelines must be jointly agreed upon by the researcher(s) and project sponsors and clearly communicated.

3.2.2.2 Place research implementation that is the primary responsibility of external stakeholders under contract

For any research project, it is important that the portions of the research implementation that are the primary responsibility of the researcher are placed under contract. Implementation must be placed under contract if researchers are to be involved. This may be done in the following three ways:

- The research project duration must be selected to include all implementation activities the project sponsor would like the researcher(s) to complete.
- For projects where implementation can only take place after the research is completed, a specific agency employee (e.g., Technical Implementation Manager) must be assigned the responsibility for post-research-project implementation.
- In cases where the researcher(s) needs to be involved in research implementation after the contract for the research project has ended, a research implementation contract must be developed to cover project implementation.

Just as the researcher has contractual obligations to deliver research results for the research project; if research implementation is part of the agency's formal business procedures, then the researcher must also have contractual obligations for any expected research implementation deliverables from the researcher. Without contractual obligations, there will be no formal basis for ensuring performance on the part of the researcher and the project sponsor may have to rely on the goodwill of the researcher to conduct research implementation activities after the formal research project contract has ended.

3.2.2.3 Specify and track implementation deliverables that are tied to agency strategic objectives

An effective implementation process must be specified using implementation plans and progress reports that clearly articulate research implementation objectives, implementation deliverables, timelines, and performance measures for tracking implementation progress and impact. From a performance-based standpoint, the research implementation objectives must support one or more agency strategic goals and objectives. Sample implementation plans and progress reports may be found in **Appendix C** and **Appendix D**, respectively.

In practice, implementation plans are typically one to two pages long and are usually developed as part of the initial research pre-proposal or needs statement. **Addressing implementation early in the research contracting process by expressly calling it out in formal agency documents such as the research needs statements is a good practice for performance-based research implementation because it formalizes research implementation as part of agency procedures**. **Implementation progress reports may also be used to monitor implementation progress**. Submission of progress reports may vary depending on the timeline and individuals responsible for implementation. A review of agency implementation practices shows that agencies are at various levels with respect to requiring clear articulation of implementation objectives and deliverables (**Table 3.2**).

Table 3.2 Progression of Practices: Research Implementation Objectives and Deliverables

Agency	Description of Practice
Maryland State Highway Administration	Does not require implementation plans, but does ask for brief discussions of how results will be implemented and how they will be funded (CTC & Associates, 2011).
Illinois DOT	Technical Review Panel chairs use an Implementation Planning Worksheet during the start of projects to identify possible implementable results and the steps necessary to see them through (CTC & Associates, 2011).
Michigan DOT	Implementation Plan is submitted at the proposal stage and contains an analysis of costs and benefits of implementation, identification of possible impediments to implementation and associated solutions, and implementation methods (CTC & Associates, 2011).
Ohio DOT	Requires preliminary implementation plan for every proposal, which is reviewed at different stages over the course of the research (CTC & Associates, 2011).
Kansas DOT	Requires implementation plan at the final report stage. Includes information on strategies, timeline and costs for implementation (SCOR, 2015).
LTCR	Uses a Research Assessment and Implementation Report that requires potential implementation impact (safety, cost, efficiency, etc.); target audience, implementation strategies (activities), timelines associated with strategy, and assessment or quantification methods for implementation benefits (LTRC, 2011).
National Cooperative Highway Research Program	The NCHRP Implementation Plan Template is a two-page document that requires that the following and additional information be stated *(18)*: • implementation leaders and contact information • benefits of research products (e.g., increased safety, reduced timed, improved quality of life, etc.) • target audience for research products • key implementation influencers • constraints to implementation and possible solutions • methods for tracking and measuring implementation impacts • implementation activities

3.2.3 Allocate Necessary Resources for Research Implementation

3.2.3.1 Staff

Human capital management is an essential factor for effective research implementation. **Defining functional roles for individuals or teams involved in research implementation is one way to build internal capital for successful research implementation** (NIRN, 2013). **It is important to identify**

personnel with the appropriate knowledge and skills, as well as appropriate authority to make decisions affecting implementation as seen in the Active Implementation Frameworks (NIRN, 2013). The literature reviewed identifies three main types of human capital associated with research implementation: implementation champions, implementation staff and oversight committees. **Table 3.3** provides a summary of the staff types and associated roles (further details in Chapter 2).

Table 3.3 Summary of Human Capital Types and Roles

Human Capital Type	Role
Implementation champion	• Pursues and advocates for research implementation • Individuals at management levels have ability to influence change
Implementation staff	• May have a position with dedicated time for research implementation, e.g., 50 percent time commitment at both PennDOT and LTRC • May be appointed from research committee/panel • May have position solely dedicated to research implementation (rare)
Oversight Committee	• Comprises both upper level management and field employees • Promotes research involvement at multiple levels

3.2.3.2 Funding

Adequate funding also contributes to appropriate internal capital for successful research implementation. This resource provides an enabling context for implementation to be carried out. Indeed, an implementation peer exchange hosted in 2011 by Michigan DOT recommended agencies to intentionally plan for implementation funding using one of the following three strategies (CTC & Associates, 2011):

(i) Create a dedicated source;
(ii) Incorporate funding into the research work plan;
(iii) Build in flexibility into overall program budget.

Increasingly, agencies involved in research are allocating financial resources to support research implementation. For example, NCHRP Project 20-44, "Accelerating the Application of Research Results", received $2 million in approved FY 2016 funding for implementation activities (SCOR 2015). Similarly, Minnesota DOT set $1.15 million aside in 2011 to fund implementation of completed research (CTC & Associates, 2011). Still, many agencies fund research implementation on a case-by-case basis. Washington State DOT's approach to this method is, however, more structured in that the

agency's Research Advisory Committees first review recommendations from the Technical Monitors and subsequently recommend funding for implementation (CTC & Associates, 2011).

3.2.4 Adopt a Simple, Clear and Defensible Approach to Estimate Research Value

While it is important to estimate the value of research, it is generally difficult to do so credibly. The ability to value research and implementation outcomes provides the data that agencies can use to assess program effectiveness and efficiency. Developing such technological capital also aids agencies in justifying research funding (Yoon et al., 2016). According to a 2014 study on determining the value of research results, almost 70% of DOTs surveyed at the time had tried to evaluate the quantitative and qualitative benefits of their research projects (Ashuri et al., 2014). Obstacles to research valuation include data scarcity, difficulty in interpreting qualitative benefits; benefits remaining unknown or uncertain at the time of research results valuation; diversity of the attributes of research project, and different perspectives existing between involved groups in understanding the value of research (Yoon et al., 2016). **Because of the difficulties involved in estimating the return on research investments, agencies may either select a small sample of projects to evaluate, use simplified quantitative methods with assumptions, or use qualitative measures to capture project impacts**. It would be more beneficial for an agency to assess the value of high-impact or higher-impact projects for which quantitative data is available or can be accessed or developed cost-effectively. There would be little benefit in agencies spending more resources (time and money) than a project is worth in assessing its value; thus lower-impact projects with little quantitative data do not surface as priorities for research value estimation.

For this study, it is recommended that GDOT require implementation plans to indicate potential implementation outcomes. Implementation outcomes may be specified using either time saved/money saved as quantitative measures, or other types of measures appropriate to the project. This may consist of either quantitative or qualitative measures, specified by the project PI and Technical Implementation Manager in the implementation plan. The use of other measures also requires that *data sources* and potential metrics for valuation be specified. In addition, it is recommended that the Research Implementation Manager generates an Implementation Rating for each implementation project completed based on the extent to which the implementation plan deliverables are complete. A simplified rating scale is of: (1) above expectation, (2) below expectation, and (3) met expectation, is recommended.

3.2.5 Develop/Adopt Appropriate Tool(s) and Data to Support Research Implementation Management

Data and tools form an integral part of the research implementation management process, and contribute to an agency's technological capital. A well-tailored tool to support an agency's adopted research implementation process can be an asset. A generic tool without any adopted implementation process is likely to be ineffective. Once standardized methods for evaluating projects have been determined, data sources for collecting selected performance measures (to be

used for valuation of the research project) and supporting tools for managing information on research implementation can be identified. In some cases, implementation management tools can also be designed to conduct benefit valuations. This allows for some consistency in an agency's valuation efforts and also supports an agency's structures and processes for research implementation (internal capital). The RIM tool developed as part of this research is discussed in Chapter 4.

3.2.6 Develop Appropriate Communication Channels

According to the findings of NCHRP Synthesis 461 (2014), one of the key barriers to research implementation faced by DOTs is with internal communication within agency hierarchy. Consistent communication is also identified by Meyer and Meyer (2014) as one of three constraints to successful implementation (the other two being smooth governance and inadequate funding). Effective communication includes managing communications between main implementation actors, those affected by the research and those who can facilitate dissemination (CTC & Associates, 2011). When done effectively, communication can generate buy-in from stakeholders and encourage wider adoption of research products.

Communication efforts also serve as a way of showing accountability to various stakeholders including upper-level management and legislators who have the authority to fund implementation projects. Both internal and external stakeholder communications are essential and are carried out using various methods. These include web-based and print summary documents such as newsletters, briefs and posters to highlight the benefits of conducted research using measures such as dollars saved, lives saved and increased efficiency, to name a few. Other agencies also conduct webinars, seminars, conferences, workshops and other outreach activities as a means of engaging potential adopters of research results and transferring knowledge from principal investigators to transportation professionals. Some agencies establish communication networks with other agencies with similar research interests. These communication materials may be developed in-house or by consultants. Missouri DOT's Communication Plan is one good example demonstrating the use of a strategic approach to communication. Such a plan is developed for every project by either the project administrator or the principal investigator to show the types of communication to send out, the audience intended for the messages, timing, as well as potential controversies (CTC & Associates, 2011).

Managing communication channels also means that communication mechanisms and resources to be used for implementation projects should be clearly identified early in the research process. Some agencies require such information to be identified in the implementation plan (e.g., Illinois DOT's Implementation Planning Worksheet). Managing communication strengthens an agency's internal capital and ultimately contributes to successful implementation.

3.3 Refined Research Implementation Process

In addition to the recommended strategies, the project researchers mapped out the key stakeholders involved in GDOT's research implementation process, along with their associated roles. The researchers then identified points along the process map where process changes (based on recommendations from section 3.2) could enhance research implementation. **Figure 3.2** outlines the main recommended process changes.

At the pre-award stage, it is recommended that Principal Investigators (PIs) include a set of Project Implementation Objectives and Deliverables (PIODs) in the form of an Implementation Plan, as part of the Research Needs Statement (RNS). This can be done in collaboration with the Project Sponsor (PS), in this pre-proposal stage. The RNS containing the PIODs should then be reviewed by a team comprising the Project Sponsor, Technical Implementation Manager (TIM), Research Project Manager (RPM), and Research Implementation Manager (RIM). A sample Implementation Plan is shown in **Figure 3.3**.

At the award-stage the PIs must submit refined PIODs, to be finalized at the project kickoff meeting. Due dates for implementation deliverables as well as evidence of implementation are also to be finalized at the project kickoff meeting. As the project progresses, it is recommended that PIs report on PIODs as they come due using the quarterly project report. A sample progress report with an implementation section is shown in **Figure 3.4**.

Subsequently, the refined implementation data, i.e., the PIODs are to be inputted into the tool. During the post-award stage of the research project, the research implementation tool is used to assist stakeholders in managing the research implementation process. This includes assessing research return on investment and developing brief implementation program reports.

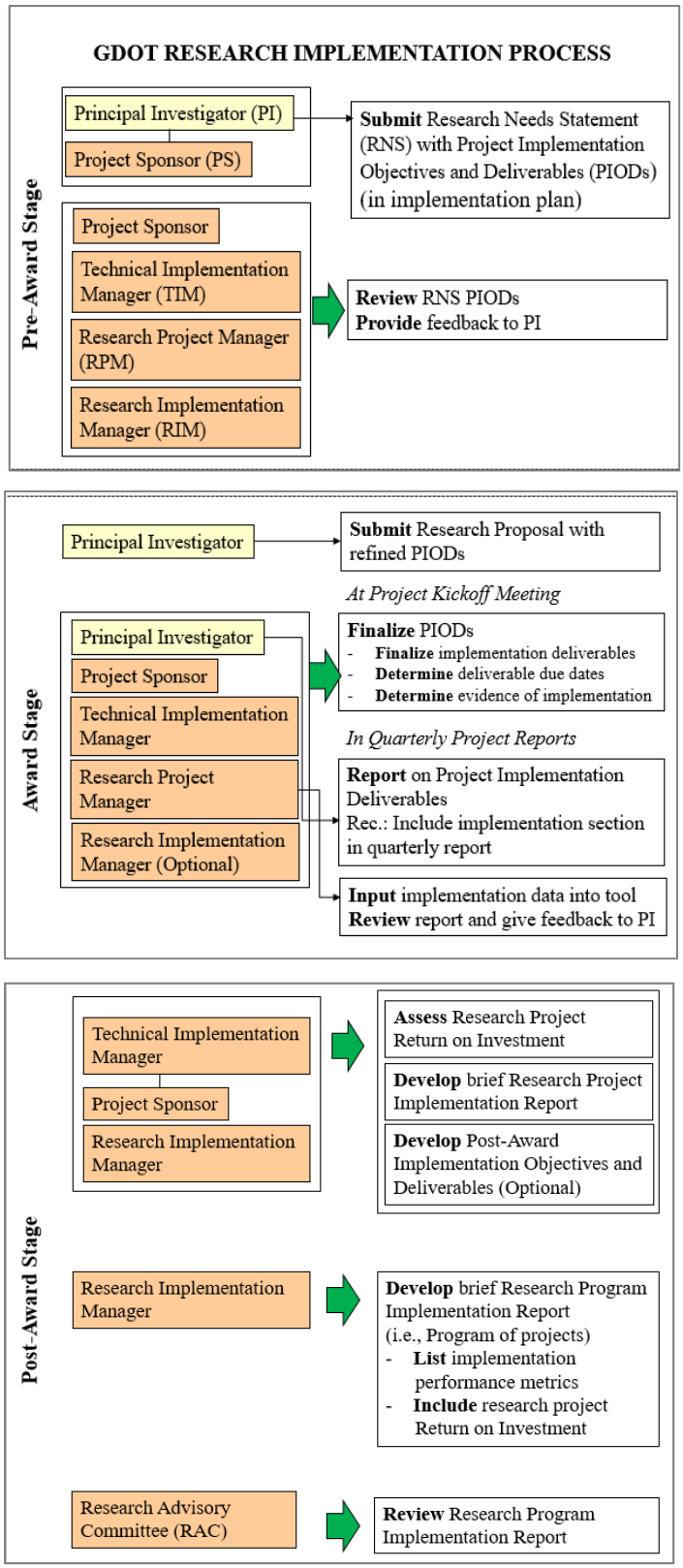


Figure 3.2 Recommended Research Implementation Process Map

RESEARCH IMPLEMENTATION PLAN

DRAFT: May 17, 2017

Research Project Title: Developing A GDOT Pavement Marking Handbook Using Field Test Deck Evaluation and Long-Term Performance

1. Strategic Area (Check all that apply):

☐ Asset Management ☒ Mobility ☐ Safety ☐ Workforce/Policy

2. Implementation Type:

☒ Developmental ☐ Response ☐ Feasibility

3. Implementation Objectives

I. Demonstrate use of Pavement Marking Handbook for material selection, inspection, testing and quality acceptance

Implementation Deliverable	Evidence	Due
1.1 Workshop with key GDOT staff on use and application of pavement marking handbook	Workshop conducted	

II. Develop tutorial on use of Pavement Marking Handbook

Implementation Deliverable	Evidence	Due
2.1 Web-based interactive tutorial on handbook for material selection and personnel training	Tool live on Web	

III. Provide handbook reference material and resources for staff use

Implementation Deliverable	Evidence	Due
3.1 User Guide for online interactive tutorial	Completion and delivery of User Guide	

4. Data Requirements

Time savings: ☒ **Yes** ☐ **No**

Money savings: ☒ **Yes** ☐ **No**

5. **Data Source(s):**

Figure 3.3 Sample Implementation Plan

I. **Time savings** - GDOT Staff feedback. Estimate of time previously spent on markings selection versus time spent after implementation of handbook.

II. **Money savings** – Maintenance staff feedback. Budget change for pavement markings management

Other Measure(s) of Performance	Data Source(s)	Metric(s)/Indicator(s)
N/A		

6. Implementation relative to project duration:

☐ Within research project timeline

☐ After research project ends

☒ Both within research timeline and after research ends

Figure 3.3: Sample Implementation Plan Continued

Additional sample implementation plans and progress reports are provided in Appendices C and D respectively. The samples were developed using past GDOT research projects as the source material, and are only meant to demonstrate implementation plan development.

IMPLEMENTATION PROGRESS REPORT DEPARTMENT OF TRANSPORTATION STATE OF GEORGIA			Report No. 1	Date:10/15/16
			Report Period From: 7/28/16	To: 9/30/16
Project No. RP 16-07	Project Title: Research Project Implementation Management: Dev. of an Evidence-Based Database and Tool			
Research Agency (s): GDOT	Project Director: XXX			
Starting Date: July 28, 2016	Completion Date: Oct 28, 2017	Total Months: 15	Time Expended Months = 2	Percent = 13.3%
Funding Source (s): GDOT	Funds Authorized: $XXX		Funds Expended Report Period XXX	Total XXX

Research Objectives:
This research will conduct a comprehensive review of best knowledge and practices for implementing research and develop an evidence-based database and tool to support research project and program implementation management at GDOT.

Implementation Objectives:
Objective 1: Present tutorial to research implementation (RI) stakeholders to demonstrate application of tool to support Research Implementation Manager (RIM), Research Project Manager (RPM) and Technical Implementation Manager (TIM) functions.
Objective 2: Present tutorial to RIM to demonstrate the evaluation of benefits and costs of research program.
Objective 3: Present tutorial to RIM to demonstrate the development of annual research program report.
Objective 4: Present to RI stakeholders (GDOT) on organizational process improvements to enhance research implementation effectiveness.
Objective 5: Present research implementation support tool and process to RI stakeholders (external) at 2018 annual Transportation Research Board Meeting to obtain peer-review and benchmark with best practices.

Implementation Deliverables:
Objective #1 Deliverable: Tutorial on functional support of tool (Gamma version)
Objective #2 Deliverable: Tutorial on estimating benefits and costs of research program
Objective #3 Deliverable: Tutorial on developing annual research program report
Objective #4 Deliverable: Presentation on organizational process improvements to enhance research implementation effectiveness
Objective #5 Deliverable: Presentation on GDOT research implementation tool and process at TRB 2018

Implementation Progress This Reporting Period:
0 of 5 deliverables complete

Implementation Work Planned for Next Report Period:
None to report.

Anticipated Problems/Course of Action:
None to report.

XXX (PI)

Figure 3.4 Sample Implementation Progress Report

Chapter 4. RIM TOOL SPECIFICATION

4.1 Introduction

The research team developed the Research Implementation Management (RIM) Tool to assist GDOT in its research implementation management. The tool's specifications, final design and functionality were developed in close collaboration with GDOT's Research Implementation Manager. The tool was based on the recommended process enhancements outlined in Chapter 3, for example, to support submission of project implementation objectives and deliverables (PIODs). The subsequent sections in this chapter provide further details on the tool's design, functionality and setup.

4.2 Tool Description

The RIM tool comprises a set of multi-user Access files with a split database set in the Access 2010 environment. Figure 4.1 shows a screenshot of the overview page showing dummy data. The overview page lists the following:

- Unique RP Number (unique to GDOT research projects)
- Project title
- Implementation deliverables pending and overdue
- Implementation time
- Sponsoring office
- RTAG (aligns with GDOT strategic areas)

In populating the tool, implementation objectives, deliverables, due dates and the associated GDOT strategic area of potential impact are required. Figures 4.2A-D show some screenshots of the form used in entering project data. A detailed description of the tool's specification is provided in **Table 4.1.**

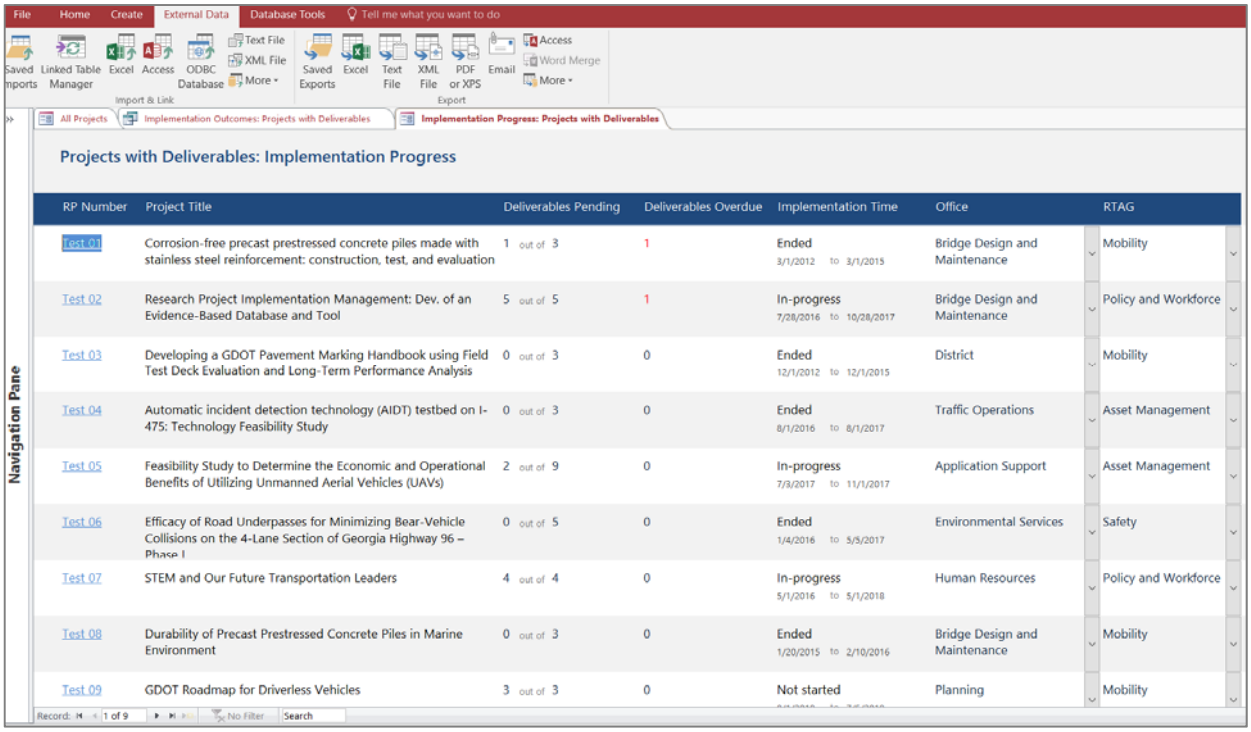


Figure 4.1 Screenshot of overview page

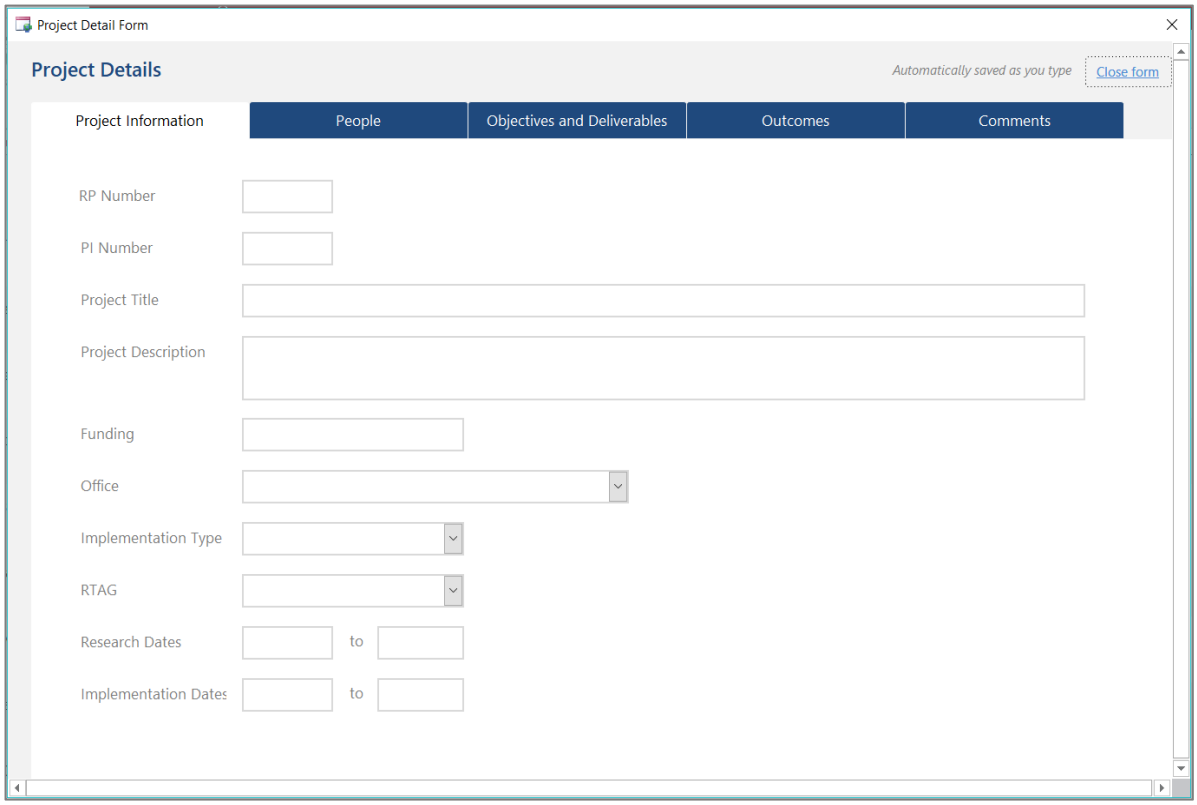


Figure 4.2A Data Input Form

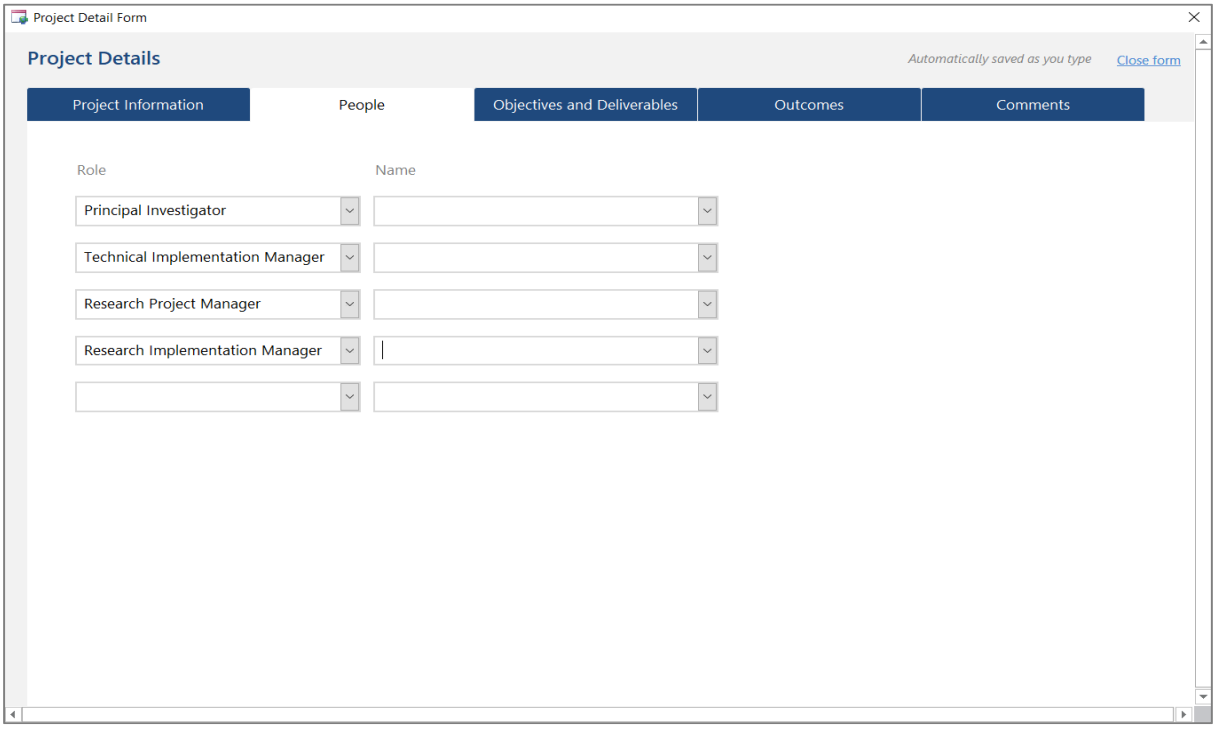


Figure 4.3B Data Input Form

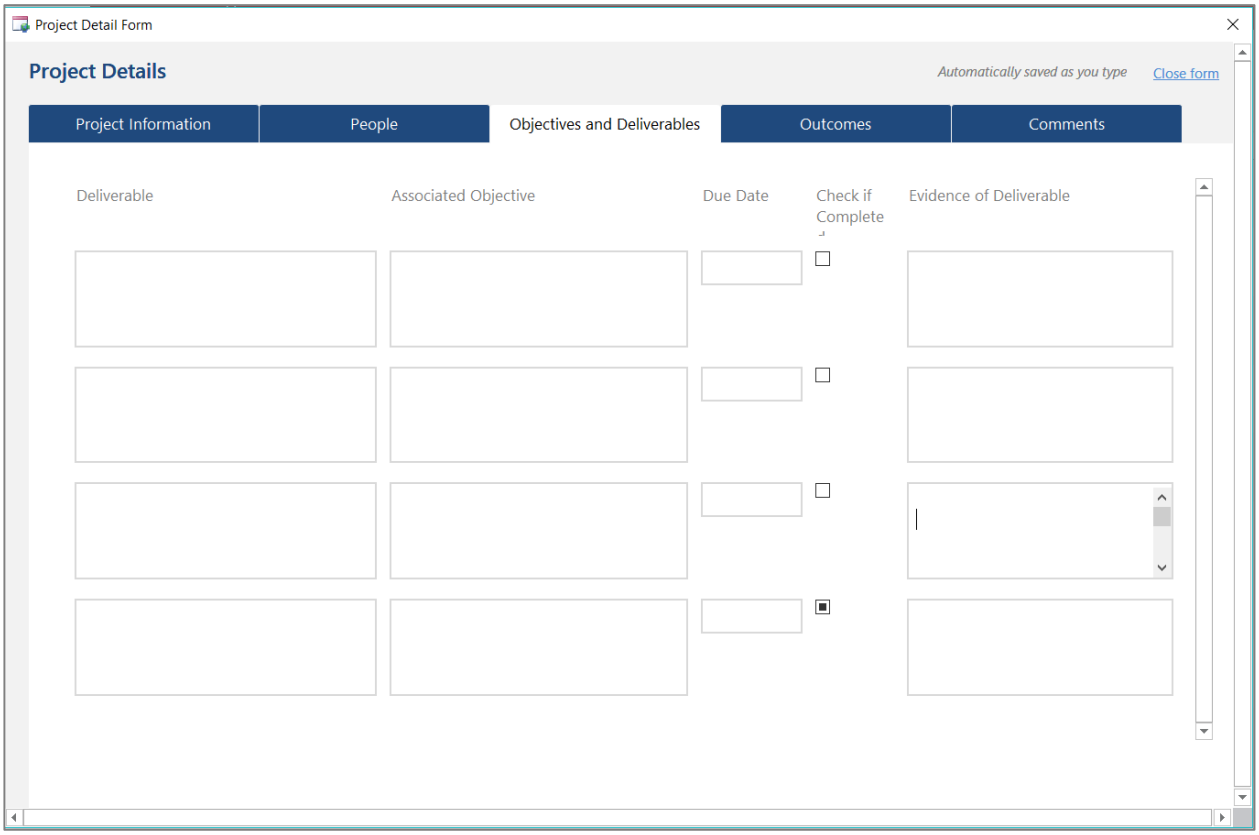


Figure 4.4C Data Input Form

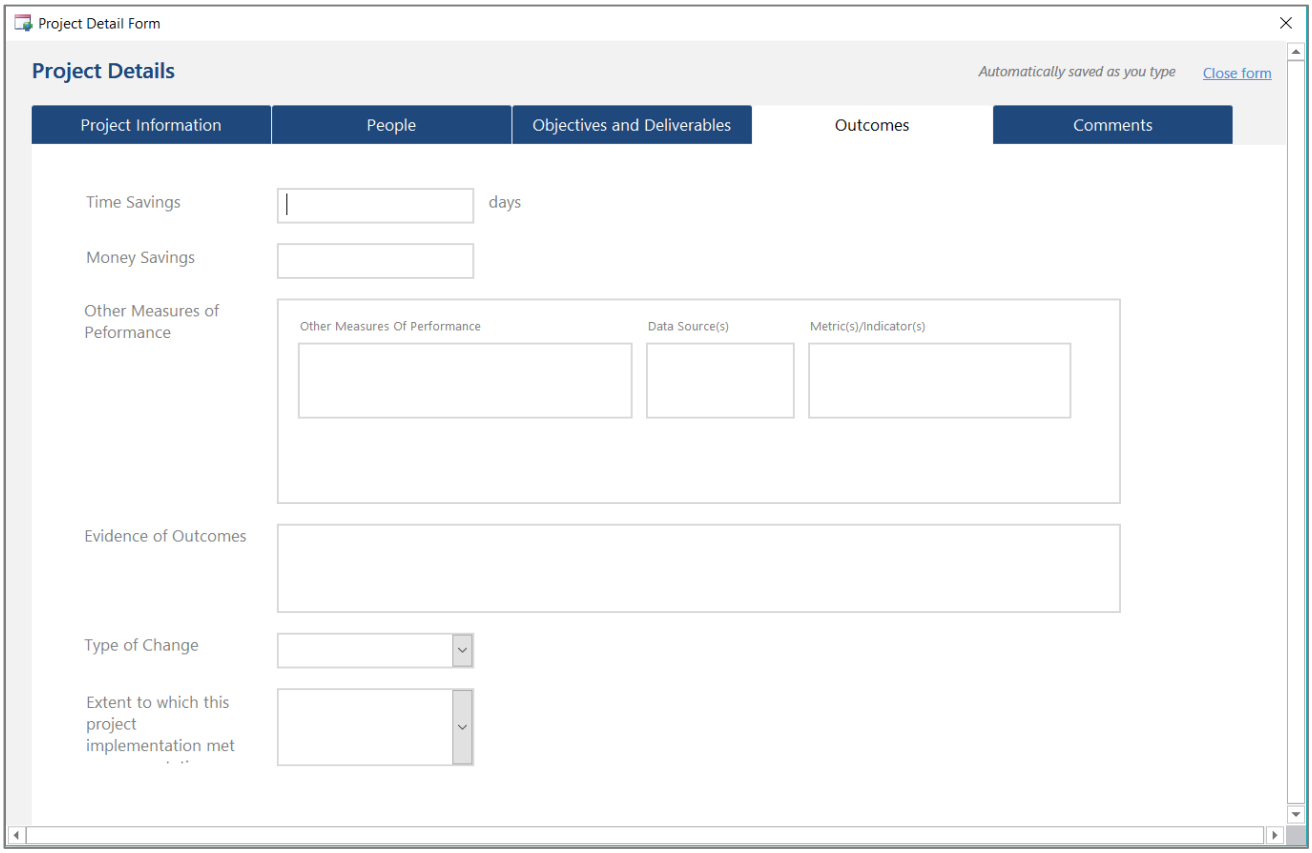


Figure 4.5D Data Input Form

Table 4.1 Detailed Description of RIM Tool Items

Section of Tool	Description	References
Project Information & People		
Basic Information	• RP Number • PI Number • Project Title • Project Description • Funding • Research dates • Implementation dates	• Existing GDOT project identifiers
Office Office requesting the research or office to be impacted by research implementation	• Application Support • Bidding Administration • Bridge Design and Maintenance • Budget Services • Construction • Design Policy and Support • District See GDOT (2016) for complete list of offices	• Georgia Department of Transportation. (2016). Organizational Chart. http://www.dot.ga.gov/AboutGeorgia/Documents/OrgChart.pdf
Implementation Type Categories used for GDOT implementation projects	• Developmental • Response • Feasibility	• Jared, D. (2013). Research & Development Manual. *Georgia Department of Transportation – Research & Development Branch.* • Yoon, Y., Dai, F., and A. Azimian (2016). Development of a Guidebook for Determining the Value of Research Results. Interim Report. Southeast Transportation Consortium.
RTAG (Strategic area) GDOT strategic goal area with which research project aligns	• Mobility • Asset Management • Safety • Policy & Workforce	• Annual Implementation Report (2016). *Georgia Department of Transportation, Office of Research.* • Performance-based research implementation management
People GDOT employees involved in implementation project and corresponding employee ID	• Principal Investigator (PI) • Technical Implementation Manager • Research Implementation Manager • Research Project Manager	• Existing GDOT project identifiers

Table 4.1 Continued: Detailed Description of RIM Tool Items

Objectives, Deliverables, Outcomes & Comments		
Implementation Objectives	• Objectives of research implementation related to expected implementation outcomes	
Deliverables/Activities & Evidence Deliverables for meeting stated objectives along with link to evidence of fulfilling objective	• Manual, Training, • Peer Exchange, • Design Method, • Performance Measures, Laboratory Tests, • Experimental Feature, Specification • Guidebook, • New Product Evaluation, • Workshop, • Webinar • Pilot/Demonstration Project, • State-of-the-practice summary, • Executive summary, • Training material, • 1-2 Flyer, Short video, • PPT Presentation, Conference/Committee Meeting Presentation, Other	Smith-Colin, J., Fischer, J., Akofio-Sowah, M. and Amekudzi-Kennedy, A. (2014). Evidence-based decision making for transportation asset management – Enhancing the practice with quality evidence and systematic documentation. Transportation Research Record: Journal of the Transportation Research Board 2014 2460:, 146-153 SCOR (Standing Committee on Research). (2015). NCHRP Implementation Facilitation Plan 2015-2020. Anderson, D., Kergaye, C., and K. Nichol (2016). Benefit/Cost of Utah's Transportation Research Program. The 96th Transportation Research Board Annual Meeting, submitted to TRB Technology Transfer Committee (ABG30). Washington DC.
Implementation Outcomes Quantitative benefits realized with hyperlink to evidence of completion Also, other measures of performance (either qualitative benefits entered by user)	**Quantitative Benefits** • Time savings (days) • Money savings ($) **Other Measures of Performance** • Measure (qualitative/quantitative) • Data source(s) • Metric(s)/indicator(s)	Yoon, Y., Dai, F., and A. Azimian (2016). Development of a Guidebook for Determining the Value of Research Results. Interim Report. *Southeast Transportation Consortium*. Ellis, R. D., J. Degner, W. O'Brien, and G. Peasley (2003). "Review, Analyze, and Develop Benefit Cost/Return on Investment Equations, Guidelines, and Variables." *Florida Department of Transportation*.

Table 4.1 Continued: Detailed Description of RIM Tool Items

	Examples of other measures of performance: <u>Quantitative</u> • Improved mobility • Improved technology • Expedited project delivery • Improved infrastructure • Improved safety <u>Qualitative</u> • Improved environment • Improved quality of life • Improved customer satisfaction • Improved knowledge	
Type of Change Final stated change at GDOT because of implementation outcomes	• Policy • Procedure • Specification • Standard drawing • Work method change	Existing GDOT labels
Implementation Rating Extent to which implementation project met expectations based on implementation deliverables	• Below expectation • Met expectation • Above expectation	Anderson, D., Kergaye, C., and K. Nichol (2016). Benefit/Cost of Utah's Transportation Research Program. The 96th Transportation Research Board Annual Meeting, submitted to TRB Technology Transfer Committee (ABG30). Washington DC. *Grades used in paper: A, B, C, D, E*
Implementation Duration Implementation timeline relative to research project duration	• Within research project timeline • After research project ends • Both within research timeline and after research ends	Amekudzi-Kennedy, et al., (2017). Performance-Based Research Implementation Management. 97th Transportation Research Board Annual Meeting, submitted to TRB Technology Transfer Committee (ABG30). Washington DC.
Comments	• Date • Person • Comments	Research team

4.3 Tool Functionality

The RIM tool serves as a database management tool for research implementation. In addition, the data collected enables a list of queries to be ran to support the development of reports by the Research Implementation Manager (RIM). The list of queries is provided below.

- Overall benefits and costs of the research program (all research projects after implementation has ended)
- Benefits and costs of all projects by strategic goal area
- Benefits and costs by research implementation type area (i.e., developmental, response & feasibility)
- Percentages of projects that did not meet, met or exceeded expectations
- Percentages of projects that did not meet, met or exceeded expectations, by strategic goal area
- Percentages of projects that resulted in some business process/element change, that is, policy, procedure, specification, standard drawing, work method change.
- Percentages of projects that resulted in some business process/element change, that is, policy, procedure, specification, standard drawing, work method change – by strategic goal area.
- Percentages of projects that resulted in some business process/element change, i.e., policy, procedure, specification, standard drawing, work method change – by office.
- Offices with overdue implementation deliverables, and their PIs, TIMs and PMs
- Projects with implementation deliverables completed and projects with implementation deliverables pending
- Projects completed and number of projects with implementation activity, year-by-year
- Projects completed and number of projects with implementation activity, cumulative

By using these queries, the RIM can efficiently manage implementation and assess the return on investment in terms of quantitative (time saved & dollars saved) and qualitative benefits (entered by user).

4.4 Tool Setup

The information provided in this section is also available in the RIM Tool Manual found in Appendix E.

The RIM tool comprises a set of multi-user Access files with a split database set in the Access 2010 environment. These files are to be hosted on a shared network folder. The Access tool has three files:

- RPIM_Common_Tables
- RPIM_User
- RPIM_Admin

The RPIM_Common_Tables is the central hub for all data and the tables. The RPIM_User file contains the forms, queries, and reports that are linked to the tables in RPIM_Common_Tables. The RPIM_Admin file has all the back-end functionality and code visible and is meant for editing the features in the tool.

4.4.1 Setting up a new user

To set up a new user, proceed with the following steps.

I. The RPIM_User file is different for each user. To set up a new user, create a copy of the file RPIM_User, and rename it to the user's name, for example, "RPIM_BinhBui". All user files should always be in the same folder with the RPIM_Common_Tables file as shown in **Figure 4.6.**

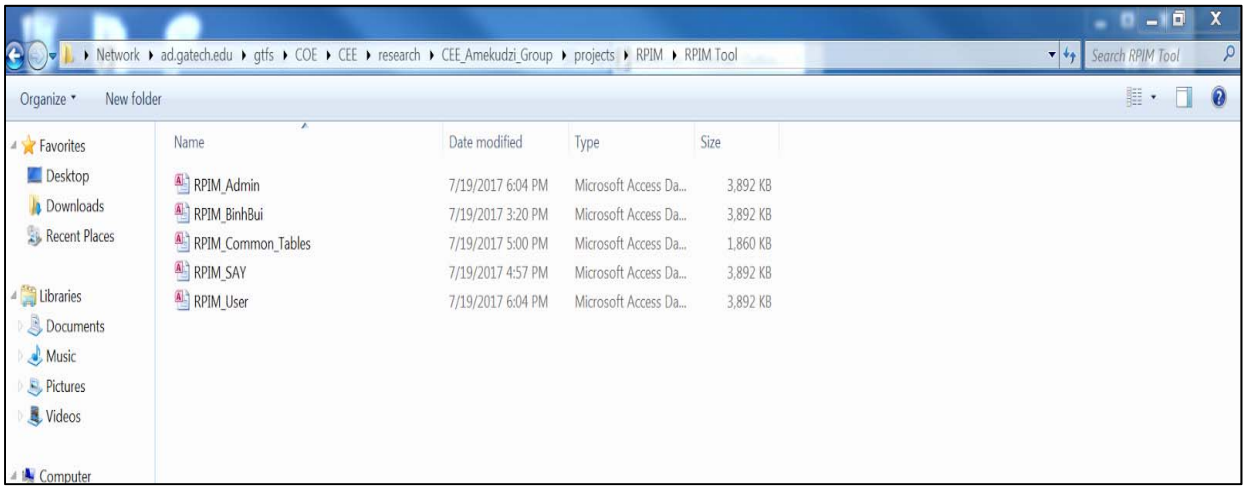


Figure 4.6 File locations

II. Always click on 'Enable Content' as shown in **Figure 4.7.**

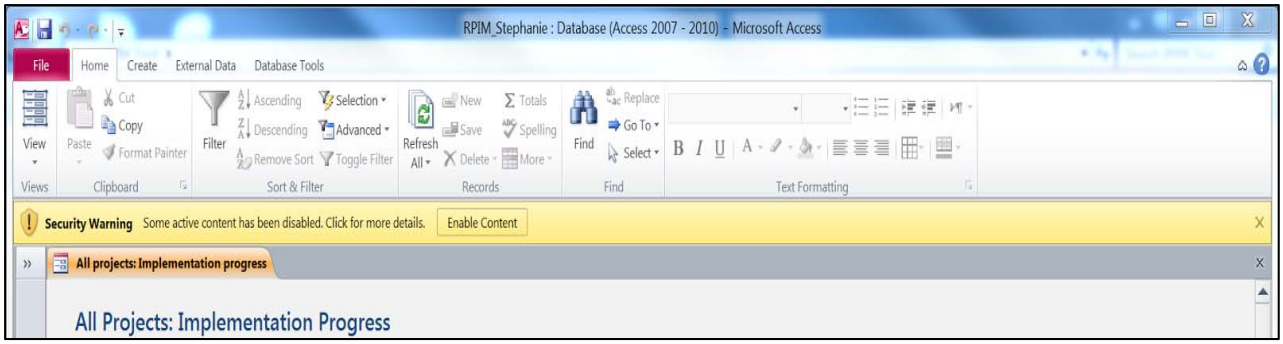


Figure 4.7 'Enable content'

III. Make sure the user file is linked to the correct tables using the following steps:

a. Open External Data -> Linked Table Manager (second option from the left in **Figure 4.8**).

b. Select all tables and check 'Always prompt for new location'. Click 'OK' (**Figure 4.9**).

c. Select the RPIM_Common_Tables file in the same folder as the current file (**Figure 4.10**).

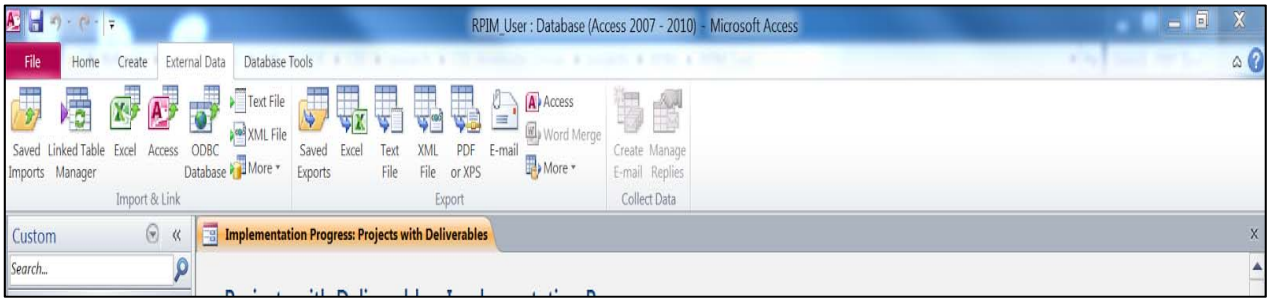


Figure 4.8 Linked Table Manager

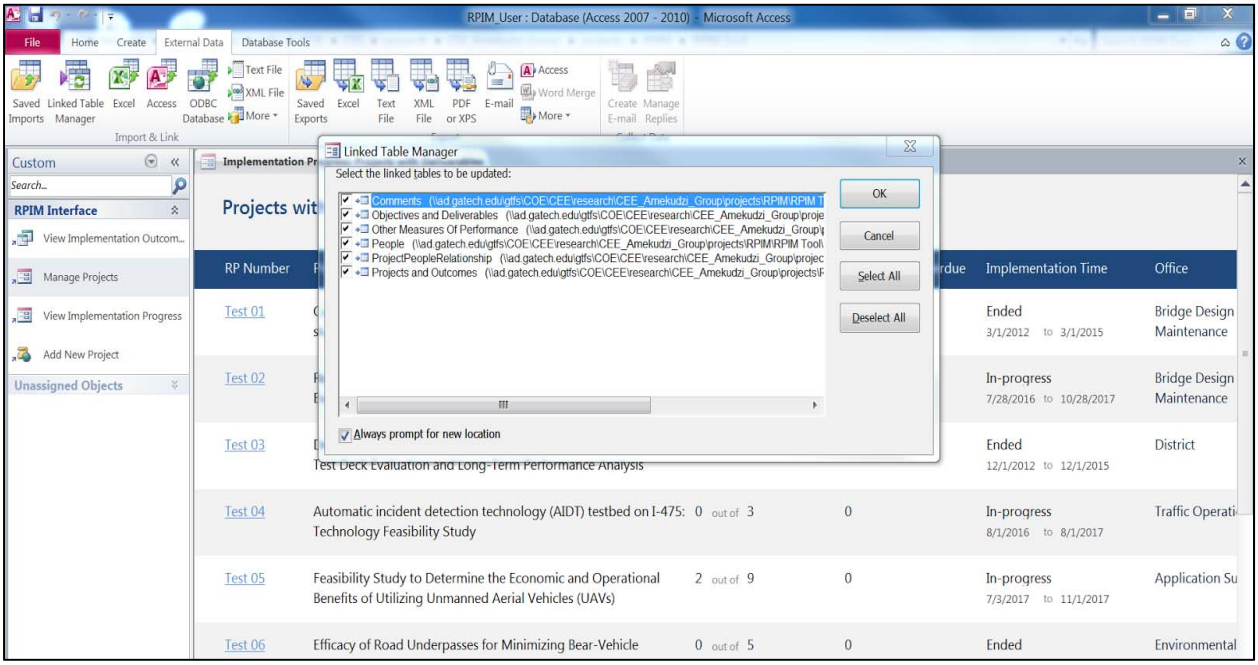


Figure 4.9 Linked Table Manager – Table selection

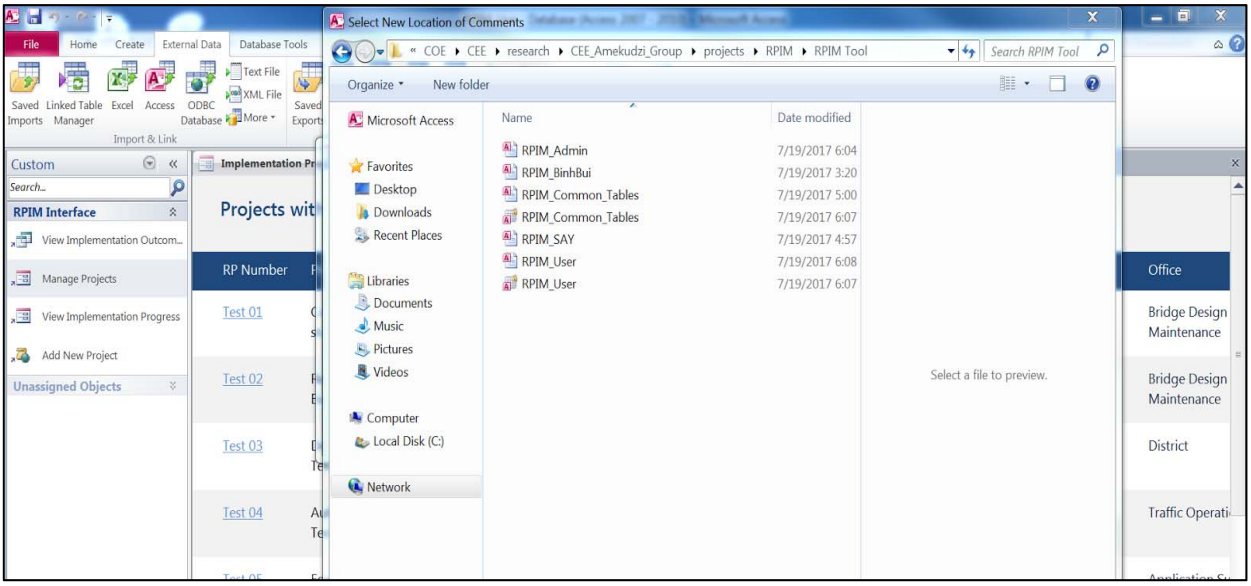


Figure 4.10 Select RPIM_Common_Tables File

4.4.2 Adding a new project

I. To add a new project, do either of the following:

   a. Double-click on “Add new project” in the left menu, or

   b. Double-click on “Manage Projects”, and then click on “Add New Project” button on the top-right (**Figure 4.11**).

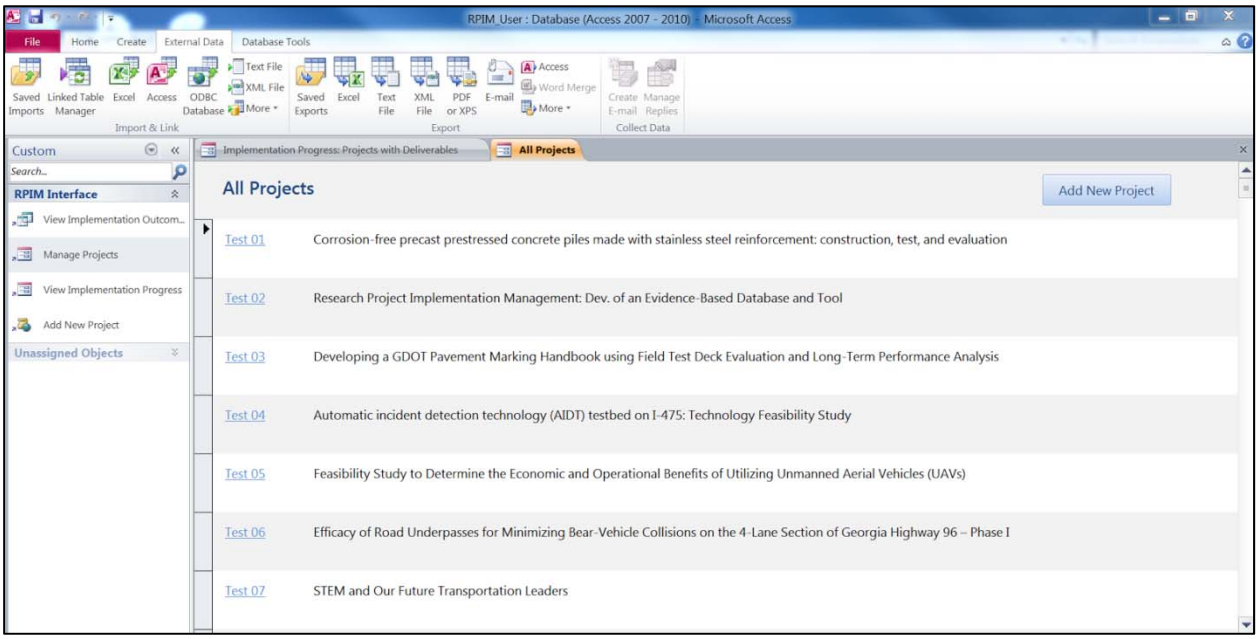


Figure 4.11 Add new project

II. Enter all required information (F**igure 4.12**; refer to RIM Tool Specifications (Table 4.1) if needed). This form saves as you type. Once you close the form, click on the “Refresh all” button in the Home section of the top-menu.

Note: If you do not add any deliverables, the project will only show in ‘Manage Projects’ file.

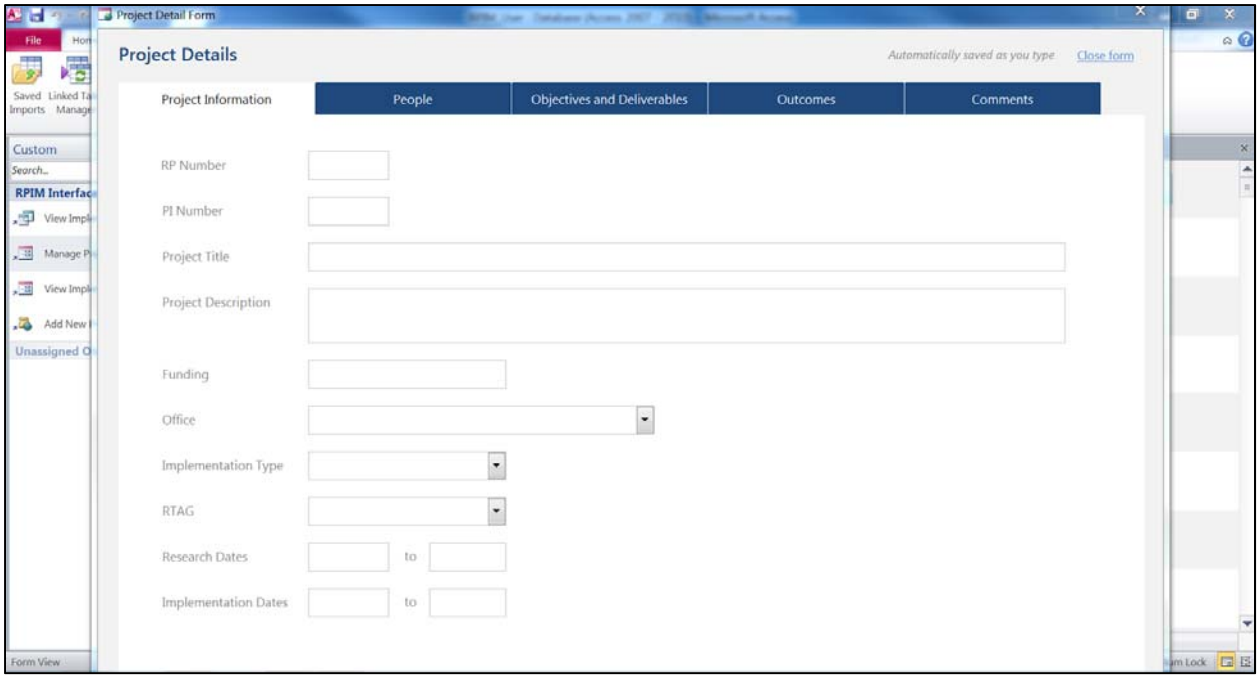


Figure 4.12 Project details form

4.4.3 Editing a project

I. To edit a project, double-click on any of the following three files in the left pane (**Figure 4.13**):

- View Implementation Outcomes
- View Implementation Progress
- Manage Projects

II. Then click on the RP number of the project you wish to edit (**Figure 4.14**).

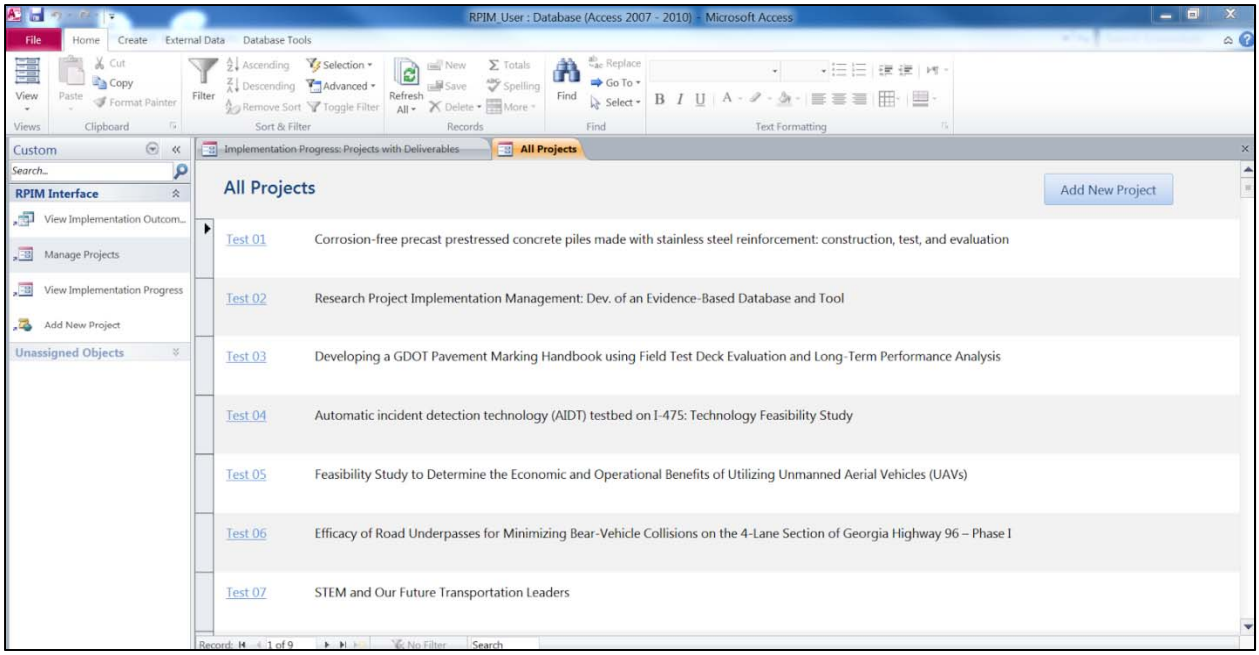


Figure 4.13 Screenshot showing left pane

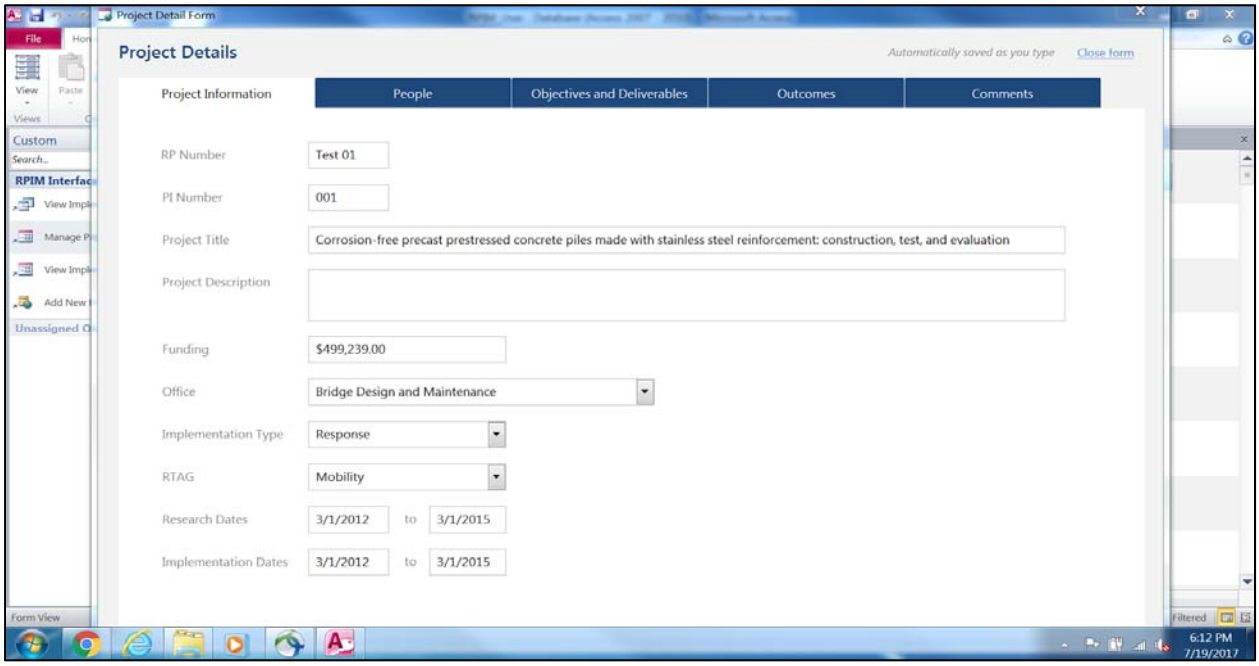


Figure 4.14 RP Number Test 01 selected for editing

4.4.4 Deleting a project

I. Double-click the “Manage Projects” file (**Figure 4.15**)

II. Click on the left grey bar which is the record selector and then press “Delete” or “Backspace” on your keyboard.

Note: You might have a problem in deleting if other people have their files open. You will all have to close files to be able to delete a project.

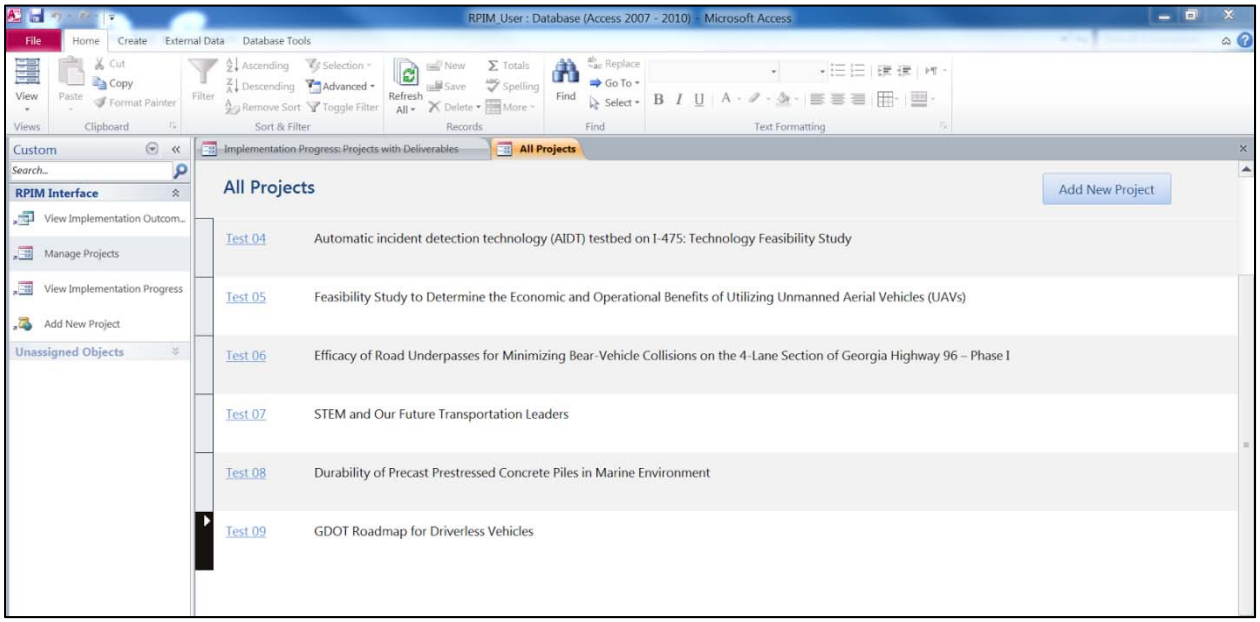


Figure 4.15 Deleting a project record (a)

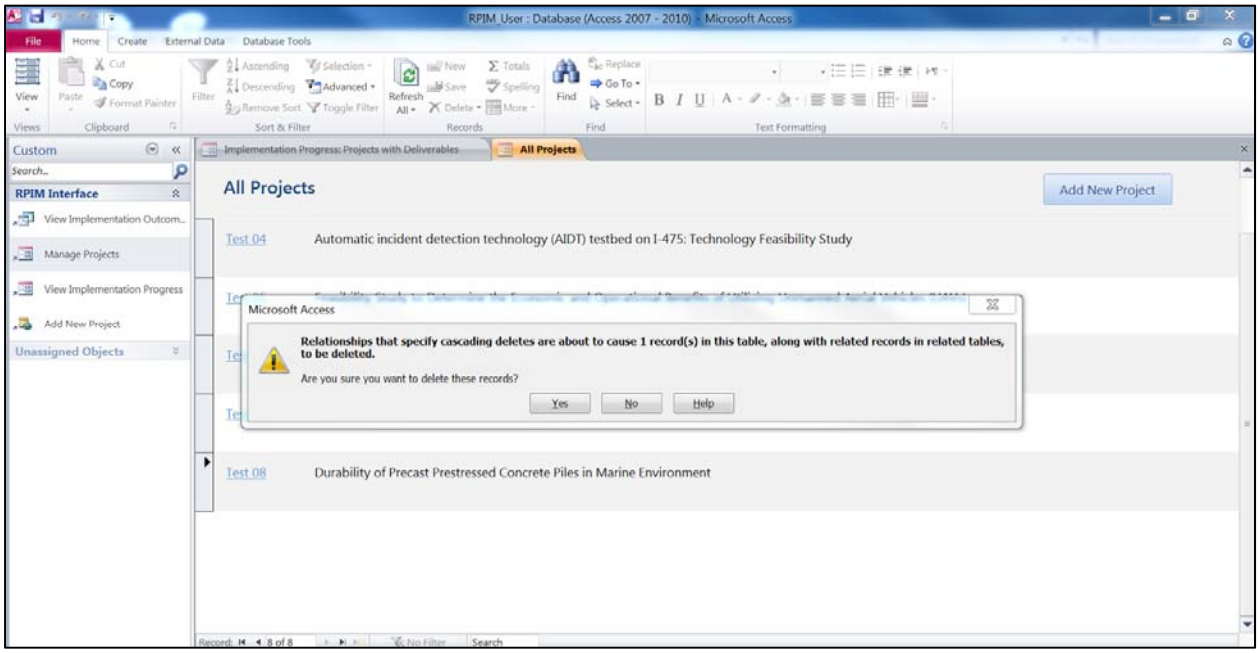


Figure 4.15 Deleting a project record (b)

4.4.5 Search and Filter

I. To search in the document:

- In the Home section of the top-menu, click on Find (**Figure 4.16**). Select the options appropriate to what you are looking for.

II. To filter based on a column:

- Click on any field of the column you want to filter. Then, in the Home section of the top-menu, click on Filter. Select the options appropriate to what you are looking for. You can also use other features that are listed next to the Filter button.

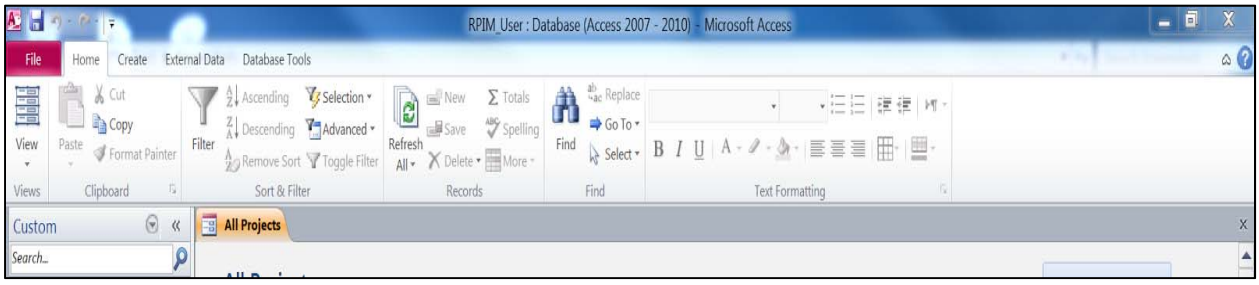


Figure 4.16 Filtering a column

4.4.6 Relational Database Table Relationships

Below is diagram showing the tables along with the table name, the fields and the relationships between different tables. The 1 to ∞ layout indicates a one-to-many relationship (**Figure 4.17**). For example, a one-to-many relationship between Projects and Outcomes and Comments means there is more than one comment for one project. The connecting field in this case is RPNumber to ProjectRPNumber.

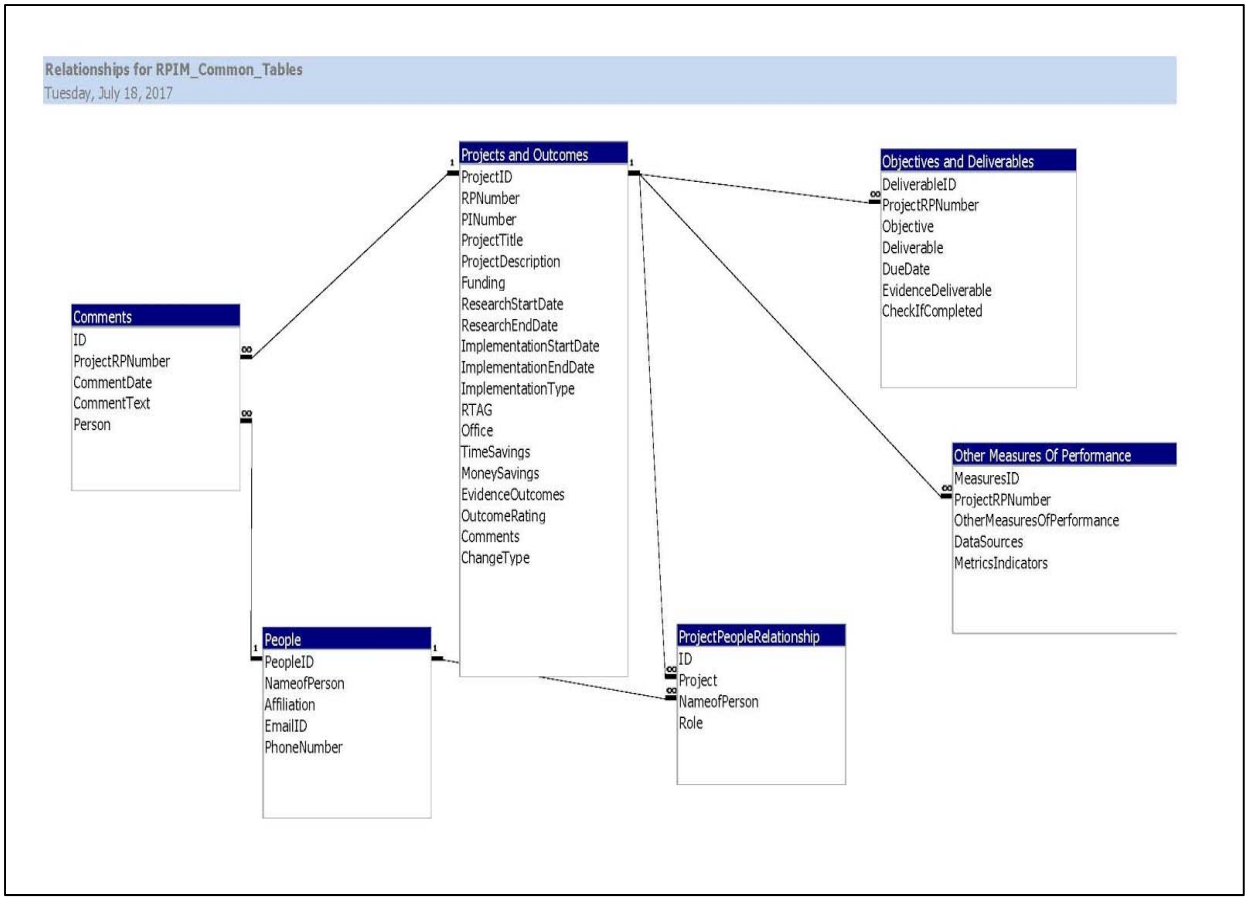


Figure 4.17 Database table relationships

Chapter 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The objective of this study is to develop an evidence-based research implementation database and tool to support research implementation at the Georgia Department of Transportation. To accomplish this objective, the research study was conducted in three phases. The first phase involved a literature review of conceptual frameworks in: (1) implementation science; (2) intellectual capital and public agency performance; and (3) portfolio capital asset management, to understand enablers and obstacles for effective research implementation management. This first set of literature was synthesized to produce a capital assets framework for agency performance. The integrated framework then formed the lens through which literature on transportation and non-transportation research implementation was reviewed. A set of effective practices was then extracted from the literature. The second phase of the research involved mapping GDOT's research implementation process. Major process steps, stakeholders and associated responsibilities were identified. Based on the capital assets framework and best/effective research implementation practices found in the literature, areas for potential process enhancements were also identified and recommendations developed for an enhanced research implementation process in GDOT. Following this, the recommended process enhancements were presented to GDOT officials for feedback. The final phase of the research consisted of the tool specification and development. A contextually-tailored research implementation tool was specified and developed based on the refined research implementation process; feedback obtained from GDOT officials, the existing resources within the agency, and best and effective practices in other state DOTs.

5.2 Recommendations

Performance-based research implementation management involves a formalized research implementation process to transform research results into standard operating procedures, services and products within an agency to help it better achieve its strategic goals. The Implementation Science, Intellectual Capital and Non-Financial Public Agency Performance, and Capital Asset management literature all point to the importance of a carefully thought out system consisting of human capital (staff), internal capital (organizational structure and resources), external capital (researchers and other external stakeholders) and technological capital (appropriate tool(s) and data) to support agency initiatives and drive organizational performance.

This study highlights the importance of the following practices for performance-based research implementation:

I. Adopting a performance-based definition of research implementation, linking implementation to organizational performance through agency strategic goals and objectives;

II. Developing and establishing a clear and formal research implementation process as part of agency business procedures, clearly articulating the roles of the researcher(s) and agency staff, and ensuring that any implementation that is the primary responsibility of the researcher is placed under contract;
III. Allocating the resources (staff, funding) necessary to support research implementation;
IV. Adopting a simple, clear and defensible approach to estimate research value;
V. Adopting an appropriate tool and data to support research implementation management; and
VI. Developing appropriate internal and external communication channels to augment research implementation.

Agencies interested in the systematic improvement of their research implementation capabilities may consider adopting such practices tailored to their particular contexts to support performance-based research implementation.

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APPENDIX A

NCHRP PROJECT IMPLEMENTATION DOCUMENTS

Table A.1 NCHRP Project Implementation Checklist

Stage	Activity
Problem statement solicitation	The NCHRP solicitation memo will stress the need for applied research producing implementable results, and provide a definition for determining successful implementation for the results. Submitters will include a basic implementation plan and identify potential champions to facilitate implementation. Submitters will be encouraged to request adequate funding for both the research and initial implementation activities.
Problem statement review	Reviewers should focus on two key criteria: the potential value of the research and the likelihood of achieving implementable results. Reviewers should also make a recommendation whether additional funding should be provided for implementation activities.
Panel formation	NCHRP staff should identify the possible target audiences for the research and determine whether representatives of each are needed on the panel. Clearly communicate the roles of panel members, the chair, and the AASHTO monitor in serving as champions for implementation.
RFP Development	Panels will be encouraged to include products to facilitate implementation that can fit within the project budget without compromising the quality and extent of the actual research. A preliminary implementation plan will be drafted during the first panel meeting.
Project Selection	NCHRP staff and others should communicate the selection of new projects to the appropriate practitioner communities, as well as partner organizations such as ITE, NACE, ASCE, and AMPO.
Project initiation	New projects should be announced to a general audience and to specific target communities.
During the research	Interim reports – if technically acceptable – should be made available to the practitioner community. Update the implementation plan after key deliverables. Identify implementation products and activities that were not included in the original scope of work. Prepare and submit requests for funding assistance to the NCHRP 20-44 panel, or develop a request for continuation funding for the next NCHRP cycle. NCHRP staff, panel members, and researchers present status reports at appropriate venues. Initiate dialog with FHWA for possible inclusion in EDC, AID or other deployment programs. Schedule a meeting of the project Implementation Working Group to initiate and identify future implementation and tracking activities.

Table A.1 Continued: NCHRP Project Implementation Checklist

Revised draft report	Issue preprints of selective reports after a review of sensitivity and technical acceptability. If appropriate, instruct the PI to complete a TRB webinar application form. Identify and prioritize research results for staff-led activities such as webinars and other communication activities.
Research completed	Implementation Working Group continues to track and report on implementation results and successes.
Ongoing	Identify various communications products to distribute and promote the value of research projects and program to practitioners and senior management. Reach out to other local, state, regional, and national organizations and meetings and explore opportunities to communicate the results of NCHRP research – individual projects, bundled by topic, or programmatic.

NCHRP Implementation Plan Template

NCHRP Implementation Plan Template

Project number and title:_____

Total budget and anticipated contract completion date: _____

Implementation leader(s) name and contact information:_____
_____
_____
_____

Research objectives and expected results: _____
_____
_____
_____
_____
_____

Benefits of the research products (such as increased safety, reductions in time or cost, or improvements to efficiency, mobility, quality of life, aesthetics, or the environment):_____
_____
_____
_____
_____
_____
_____
_____

The target audience(s) for the research products:_____
_____
_____
_____
_____

Key decision-makers who can approve or influence implementation: _____
_____
_____
_____

NCHRP Implementation Plan Template Continued

Barriers or constraints to implementation:

Plans to overcome these barriers and constraints:

Methods of tracking and measuring the impacts of implementation:

Planned activities to facilitate implementation and current status:

Names and email addresses of individuals committed to supporting implementation within their agencies as lead states:

Note: Letters of commitment for implementation champions are encouraged and preferred.

LTRC 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

APPENDIX B

RESEARCH CATEGORIES AND CORRESPONDING MEASURES

(Source: Yoon et al., 2016)

Table 4.4. Type "A" Research Categories and Corresponding Measures

Research Category	Research Subcategories	Benefit Categories	Measures
Design	Geotechnical, Pavement and Materials	Improved Infrastructure	Dollar savings due to use of durable materials
			Benefit cost ratio
		Increased Knowledge	Number of sponsored students
		Improved Environment	Reduction in emission
	Bridge/Structures	Improved Infrastructure	Dollar savings due to use of durable materials
			Average health index (0–100 scale)
			Percent structurally deficient (SD)
			Number of steel bridges with section loss in a member
		Expedited Project Delivery	Reduced installation time
	Road Design	Improved Safety	Reduction in number of crashes
			CMF
		New Technology/Innovation	Dollar savings due to reduction in labor and time
	Hydraulics	Improved Environment	The amount of water leaving or discharging from the system
		Improved Infrastructure	Benefit cost ratio
Planning	Public Transport (Transit)	Improved Mobility	Average travel time (by mode or cross modes) for a given OD pair or trip type
			Percent of urban population with convenient access to public transit
			Access time to passenger or intermodal facilities
			Trip cost by mode for origin-destination pairs
		Improved Infrastructure	Intermodal terminal capacity (transit)
			Distance (or time)between failures for transit vehicles
			Percent asset quantity out of service due to deteriorated condition
			Age of fleet by vehicle type or remaining useful life for vehicles
	Freight Transport	Improved Mobility	Travel time from freight intermodal facilities to highway facilities
			Percent on-time shipments (by commodity or mode)
			Average delivery time (by commodity or mode)
	Land Use Planning	Improved Environment	Changes in open space, gardens, parks, farmlands and wildlife habitat (#acres)

Table 4.4. Type "A" Research Categories and Corresponding Measures (Cont'd)

Research Category	Research Subcategories	Benefit Categories	Measures
Construction Engineering and Maintenance	Construction Management	Expedited Project Delivery/New Technology	Percent of contracts (or contract value) completed on-time
			Percent of contracts (or contract value) completed on-budget
	Maintenance and Facility Preservation	Improved Infrastructure	Dollar savings due to use of durable materials
			Percent length/count/area in good/fair/poor condition
Operation	Traffic	Improved Mobility	Level of service (LOS)—measure of congestion from A–F based on volume-to capacity ratio (facility-specific measure)
			Number of intersections congested (e.g., with LOS E or F) during peak hours
			Travel time under congested conditions
			Lane-mile duration index (number of congested lane-miles times the duration of congestion
			Average speed for given roadway segment or origin-destination pair
			Dollar savings due to use of less resources and materials
			Reduction in delay
		Improved Safety	Benefit cost ratios
		Customer Satisfaction	Dollar savings by offering free services to customers
	Administration	Project Delivery	Percent of contracts/projects completed on-time
			Percent of contracts/projects completed on-budget
			Number of contractor partnerships
		Workforce Development	Rating the effectiveness of the workforce training program
Safety and Security	Transport Safety	Improved Safety	Reduction in number of crashes
			Number of lives saved
			Dollar savings due to reduction in crashes
	Transport Security	Improved Safety	Number (or rate per capita or number of travelers) of crimes at rest areas, bus stops, highways, and so forth by type or severity
			Value of losses from theft per capita, person-trip, shipment value

Table 4.4. Type "A" Research Categories and Corresponding Measures (Cont'd)

Research Category	Research Subcategories	Benefit Categories	Measures
Construction Engineering and Maintenance	Construction Management	Expedited Project Delivery/New Technology	Percent of contracts (or contract value) completed on-time
			Percent of contracts (or contract value) completed on-budget
	Maintenance and Facility Preservation	Improved Infrastructure	Dollar savings due to use of durable materials
			Percent length/count/area in good/fair/poor condition
Operation	Traffic	Improved Mobility	Level of service (LOS)—measure of congestion from A–F based on volume-to capacity ratio (facility-specific measure)
			Number of intersections congested (e.g., with LOS E or F) during peak hours
			Travel time under congested conditions
			Lane-mile duration index (number of congested lane-miles times the duration of congestion
			Average speed for given roadway segment or origin-destination pair
			Dollar savings due to use of less resources and materials
			Reduction in delay
		Improved Safety	Benefit cost ratios
		Customer Satisfaction	Dollar savings by offering free services to customers
	Administration	Project Delivery	Percent of contracts/projects completed on-time
			Percent of contracts/projects completed on-budget
			Number of contractor partnerships
		Workforce Development	Rating the effectiveness of the workforce training program
Safety and Security	Transport Safety	Improved Safety	Reduction in number of crashes
			Number of lives saved
			Dollar savings due to reduction in crashes
	Transport Security	Improved Safety	Number (or rate per capita or number of travelers) of crimes at rest areas, bus stops, highways, and so forth by type or severity
			Value of losses from theft per capita, person-trip, shipment value

Table 4.5. Type "B" Research Categories and Corresponding Measures

Research Category	Research Subcategories	Benefit Categories	Measures
Structural Engineering	Bridge Design	Improved Infrastructure	Dollar savings to use of durable materials
			Average health index (0–100 scale)
			Percent structurally deficient (SD)
			Number of steel bridges with section loss in a member
		Expedited Project Delivery	Reduced installation time
Geotechnical and Material Engineering	Soils and Foundation	Improved Infrastructure	Benefit cost ratio
	Pavements and Materials	Increased Knowledge	Number of sponsored students
		Improved Infrastructure	Dollar savings due to use of durable materials
			Benefit cost ratio
		Improved Environment	Reduction in emission
Transportation Engineering (Cont'd)	Traffic Engineering	Improved Mobility	Level of service (LOS)—measure of congestion from A–F based on volume-to capacity ratio (facility-specific measure)
			Number of intersections congested (e.g., with LOS E or F) during peak hours
			Travel time under congested conditions
			Lane-mile duration index (number of congested lane-miles times the duration of congestion
			Average speed for given roadway segment or origin-destination pair
			Dollar savings
			Reduction in delay
		Improved Safety	Benefit cost ratio
		Improved Customer Satisfaction	Dollar savings by offering free services to customers
	Transport Planning (Cont'd)	Improved Mobility	Percent of urban population with convenient access to public transit
			Access time to passenger or intermodal facilities
			Trip cost by mode for origin-destination pairs
			Travel time from freight intermodal facilities to highway facilities
			Percent on-time shipments (by commodity or mode)
			Average delivery time (by commodity or mode)
			Dollar losses due to freight delays

Table 4.5. Type "B" Research Categories and Corresponding Measures (Cont'd)

Research Category	Research Subcategories	Benefit Categories	Measures
Transportation Engineering	Transport Planning	Improved Infrastructure	Intermodal terminal capacity (transit)
			Distance (or time) between failures for transit vehicles
			Asset quantity (%) out of service due to deteriorated condition
			Age of fleet by vehicle type or remaining useful life for vehicles
		Improved Environment	Reduced open space (e.g., gardens, parks, farmlands, etc.)
	Road Design	Improved Safety	Reduction in number of crashes
			CMF
		New Technology/Innovation	Dollar savings due to reduction in labor and time
	Transport Safety	Improved Safety	Reduction in number of crashes
			Number of lives saved
			Dollar savings
	Transport Security	Improved Safety	Number (or rate per capita or number of travelers) of crimes at rest areas, bus stops, highways, and so forth by type or severity
			Value of losses from theft per capita, person-trip, shipment value
Construction Engineering and Management	Project Management	Expedited Project Delivery/New Technology	Percent of contracts (or contract value) completed on-time
			Percent of contracts (or contract value) completed on-budget
	Asset Management	Improved Infrastructure	Dollar savings due to use of durable materials
			Percent length/count/area in good/fair/poor condition
	Construction Safety	Improved Safety	Reduction in # incidents in construction sites
Hydraulics Engineering	Hydrology	Improved Environment	The amount of water leaving or discharging from the system
	Water Resource Management	Improved Infrastructure	Benefit cost ratio
Environmental Engineering	Air/Noise Quality	Improved Environment	Rating the project impact (0-3 scale)
			Benefit/cost ratio
			Reduction in emission
			Dollar savings
			# of days that pollution standard index is in the unhealthful range
			Percent of vehicles using alternative fuels
			Average fuel consumption
			# of residences or percent of population exposed to highway noise exceeding established standards (or greater than X decibels)
			Number of noise receptor sites above threshold
	Water Quality	Improved Environment	Acres of wetlands replaced or protected for every acre affected by highway projects
			Level of fish habitat reduction as a result of new construction

Table 4.6. Type "C" Research Categories and Corresponding Measures

Research Category	Research Subcategories	Benefit Categories	Measures
Environment	Air/Noise Quality	Improved Environment	Rating the project impact (0-3 scale)
			Benefit/cost ratio
			Reduction in emission
			Dollar savings due to reduction in emissions
			# of days that pollution standard index is in the unhealthful range
			Percent of vehicles using alternative fuels
			Average fuel consumption
			# of residences or percent of population exposed to highway noise exceeding established standards (or greater than X decibels)
			Number of noise receptor sites above threshold
	Water Quality	Improved Environment	Acres of wetlands replaced or protected for every acre affected by highway projects
			Changes in open space, gardens, parks, farmlands and wildlife habitat (#acres)
			Level of fish habitat reduction as a result of new construction
Design	Geotechnical, Pavement and Materials	Improved Infrastructure	Dollar savings due to use of durable materials
			Benefit cost ratio
		Increased Knowledge	Number of sponsored students
		Improved Environment	Reduction in emission
	Bridge/Structures	Improved Infrastructure	Dollar savings due to use of durable materials
			Average health index (0–100 scale)
			Percent structurally deficient (SD)
			Number of steel bridges with section loss in a member
		Expedited Project Delivery	Reduced installation time
	Road Design	Improved Safety	Reduction in number of crashes
			CMF
		New Technology/Innovation	Dollar savings due to reduction in labor and time
	Hydraulics	Improved Environment	The amount of water leaving or discharging from the system
		Improved Infrastructure	Benefit cost ratio

Table 4.6. Type "C" Research Categories and Corresponding Measures (Cont'd)

Research Category	Research Subcategories	Benefit Categories	Measures
Social	Mobility	Improved Mobility and Accessibility	Level of service (LOS)—measure of congestion from A–F based on volume-to capacity ratio (facility-specific measure)
			# of intersections congested during peak hours
			Travel time under congested conditions
			Lane-mile duration index (number of congested lane-miles times the duration of congestion
			Average speed for given roadway segment or origin-destination pair
	Mobility (Cont'd)		Dollar savings due to use of less resources and materials
			Reduction in delay
			% of urban population with convenient access to public transit
			Access time to passenger or intermodal facilities
			Trip cost by mode for origin-destination pairs
			Travel time from freight intermodal facilities to highway facilities
			Percent on-time shipments (by commodity or mode)
			Average delivery time (by commodity or mode)
		Improved Safety	Benefit cost ratio
		Improved Customer Satisfaction	Dollar savings by offering free services to customers
		Improved Infrastructure	Intermodal terminal capacity (transit)
			Distance (or time)between failures for transit vehicles
			Percent asset quantity out of service due to deteriorated condition
			Age of fleet by vehicle type or remaining useful life for vehicles
		Improved Environment	Reduced open space (gardens, parks, farmlands, etc.)
	Transport Safety	Improved Safety	Reduction in number of crashes
			Number of lives saved
			Dollar savings
	Transport Security	Improved Safety	Number (or rate per capita or number of travelers) of crimes at rest areas, bus stops, highways, and so forth by type or severity
			Value of losses from theft per capita, person-trip, shipment value
Economics	Right Of Way	Improved Mobility And Accessibility	Change in property value
	Freight Transport		Dollar losses due to freight delays

APPENDIX C

SAMPLE IMPLEMENTATION PLANS

SAMPLE RESEARCH IMPLEMENTATION PLAN

May 31, 2017

Research Project Title: STEM and Our Future Transportation Leaders

1. Strategic Area (Check all that apply):

☐ **Asset Management** ☐ **Mobility** ☐ **Safety** ☒ **Workforce/Policy**

2. Implementation Type:

☒ **Developmental** ☐ **Response** ☐ **Feasibility**

3. Implementation Objectives

I. Determine adequate mix of possible STEM involvement alternatives for GDOT based on varying impact levels

Implementation Deliverable	Evidence	Due
• Determine optimum level of engagement for GDOT in STEM program • Determine optimum level of investment required from GDOT for STEM program	Summary table showing list of alternatives with associated costs (time & money)	

II. Provide framework for most feasible program alternative to be implemented by GDOT

Implementation Deliverable	Evidence	Due
• Determine program curriculum and potential partners/schools • Conduct small-scale pilot of recommended program with actual K-12 students to identify program strengths and weaknesses • Incorporate results of pilot into program refinement • Determine expected level of investment required from GDOT • Determine expected GDOT involvement, i.e., man/volunteer hours required	• Teaching material for curriculum (lesson plan, material for activity) • summary of pilot program • Submission of refined program ready for deployment	

III. Identify indicators of performance for recommended program alternatives.

Implementation Deliverable	Evidence	Due
• Determine measures of success for GDOT implementation • Identify data to be collected to track performance of programs	• List of key performance indicators for each identified alternative submitted • list of data types and sources submitted	

4. Data Requirements

Time savings: ☐ **Yes** ☒ **No**
Money savings: ☐ **Yes** ☒ **No**

5. Data Source(s):

_____

Other Measure(s) of Performance	Data Source(s)	Metric(s)/Indicator(s)
Program impact on GDOT staff	GDOT staff e.g., internal survey	% involvement before implementation versus % involvement after implementation
Program impact on students	GDOT staff; Before and after student surveys	Number of K-12 students involved in GDOT STEM programs; Student interest in STEM/transportation field
Program effectiveness	GDOT staff	Dollars expended on program versus students in program

6. Implementation relative to project duration:

☐ Within research project timeline
☒ After research project ends
☐ Both within research timeline and after research ends

SAMPLE RESEARCH IMPLEMENTATION PLAN

May 29, 2017

Research Project Title: Efficacy of Road Underpasses for Minimizing Bear-Vehicle Collisions on the 4-Lane Section of Georgia Highway 96 – Phase I

1. **Strategic Area (Check all that apply):**

☐ **Asset Management** ☐ **Mobility** ☒ **Safety** ☐ **Workforce/Policy**

2. **Implementation Type:**

☐ **Developmental** ☒ **Response** ☐ **Feasibility**

3. **Implementation Objectives**

II. Review effectiveness of locations selected for underpass citing using bear movements and bear-vehicle collision data.

Implementation Deliverable	**Evidence**	**Due**
Evaluation of the seven underpass locations based on data collected on bear movements	Finalized list of underpass locations identified	

III. Implement proposed strategies to improve underpass use by black bear population along SR 96.

Implementation Deliverable	**Evidence**	**Due**
Detailed list of strategies	Summary of enhancements implemented	

IV. Use identified factors that affect black bear movements to inform road design and underpass siting for future road construction projects in locations known to have high rates of bear-vehicle collisions.

Implementation Deliverable	**Evidence**	**Due**
Develop proposed changes to guidelines for construction in areas that impact local fauna (specifically black bears)	Revision or changes to construction necessary guidelines	

V. Determine dollars saved from implementing research project recommendations.

Implementation Deliverable	**Evidence**	**Due**
• Determine man-hours required for clearing bear-vehicle collisions	Summary table showing potential savings	

• Estimate potential construction savings from implementing recommendations • Estimate potential savings from collisions avoided, in terms of costs to driver, agency and bear population		

4. **Data Requirements**

Time savings: ☒ **Yes** ☐ **No**
Money savings: ☒ **Yes** ☐ **No**

5. **Data Source(s):** Construction savings, bear-vehicle collisions avoided, man-hours saved from clearing from highway after bear-vehicle collisions

Other Measure(s) of Performance	Data Source(s)	Metric(s)/Indicator(s)

6. Implementation relative to project duration:

☐ Within research project timeline
☐ After research project ends
☒ Both within research timeline and after research ends

SAMPLE RESEARCH IMPLEMENTATION PLAN

May 29, 2017

Research Project Title: Feasibility Study to Determine the Economic and Operational Benefits of Utilizing Unmanned Aerial Vehicles (UAVs)

1. Strategic Area (Check all that apply):

☒ **Asset Management** ☐ **Mobility** ☐ **Safety** ☐ **Workforce/Policy**

2. Implementation Type:

☐ **Developmental** ☐ **Response** ☒ **Feasibility**

3. Implementation Objectives

I. Identify GDOT Division or Office that will serve as a good candidate for a piloting UAV implementation based on operational requirements versus UAV design and manufacturing costs

Implementation Deliverable	Evidence	Due
1.1 Conduct further in-depth interviews with division/office staff to specify needs for UAV 1.2 Define UAV's technical requirements for selected division/office 1.3 Conduct detailed cost benefit analysis to determine implications of UVA adoption for pilot division/office	1.1 Summary results of conducted interviews 1.2 Summary of main technical requirements for UAV 1.3 CBA resulted submitted	

II. Outline a strategy for deploying training material in selected pilot Division/Office

Implementation Deliverable	Evidence	Due
2.1 Determine which staff members in the Division/Office that would need to be trained 2.2 Determine what kind of material needs to go into training material and potential duration of training 2.3 Determine delivery format for training	2.1 List of staff members or staff positions that require training 2.2 Summary stating main goals of training and potential duration of training 2.3 Recommendations for most effective delivery format	

III. Determine legal and social implications for implementing UAVs for selected division/office.

Implementation Deliverable	Evidence	Due

3.1 Recommendations for addressing possible issues that may arise	Submission of recommendations	

IV. Measure performance enhancements in agency practices due to implementation of UAV.

Implementation Deliverable	Evidence	Due
4.1 Compare estimated costs savings in CBA to actual savings due to performance enhancements from implementation	Actual savings from implementation after mutually agreed on period	

V. Establish communication channel with FAA on providing data for policy efforts for creating safe and efficient integration of UAV's into the nation's airspace

Implementation Deliverable	Evidence	Due
5.1 Brief report stating main implementation goals, successes and lessons learned with deploying pilot UAVs	Completion of FAA brief.	

4. Data Requirements

Time savings: ☒ **Yes** ☐ **No**
Money savings: ☒ **Yes** ☐ **No**

5. Data Source(s):

- Cost to design, construct, operate and maintain UAVs - manufacturer
- Costs for training users at the division - PI
- Possible cost of recruiting UAV expert to work for GDOT – PI/consultant
- Cost and time savings due to performance enhancements – GDOT staff (before and after pilot implementation)

Other Measure(s) of Performance	Data Source(s)	Metric(s)/Indicator(s)

6. Implementation relative to project duration:

☐ Within research project timeline
☐ After research project ends
☒ Both within research timeline and after research ends

SAMPLE RESEARCH IMPLEMENTATION PLAN

May 17, 2017

Research Project Title: Developing A GDOT Pavement Marking Handbook Using Field Test Deck Evaluation and Long-Term Performance

1. Strategic Area (Check all that apply):

☐ Asset Management ☒ Mobility ☐ Safety ☐ Workforce/Policy

2. Implementation Type:

☒ Developmental ☐ Response ☐ Feasibility

3. Implementation Objectives

I. Demonstrate use of Pavement Marking Handbook for material selection, inspection, testing and quality acceptance

Implementation Deliverable	Evidence	Due
1.1 Workshop with key GDOT staff on use and application of pavement marking handbook	Workshop conducted	

II. Develop tutorial on use of Pavement Marking Handbook

Implementation Deliverable	Evidence	Due
2.1 Web-based interactive tutorial on handbook for material selection and personnel training	Tool live on Web	

III. Provide handbook reference material and resources for staff use

Implementation Deliverable	Evidence	Due
3.1 User Guide for online interactive tutorial	Completion and delivery of User Guide	

4. Data Requirements

Time savings: ☒ **Yes** ☐ **No**

Money savings: ☒ **Yes** ☐ **No**

5. Data Source(s):

I. **Time savings -** GDOT Staff feedback. Estimate of time previously spent on markings selection versus time spent after implementation of handbook.

II. **Money savings** – Maintenance staff feedback. Budget change for pavement markings management

Other Measure(s) of Performance	Data Source(s)	Metric(s)/Indicator(s)
N/A		

6. Implementation relative to project duration:

☐ Within research project timeline
☐ After research project ends
☒ Both within research timeline and after research ends

SAMPLE RESEARCH IMPLEMENTATION PLAN

May 19, 2017

Research Project Title: Transportation Research Implementation Management

1. Strategic Area (Check all that apply):

☒ **Asset Management** ☐ **Mobility** ☐ **Safety** ☒ **Workforce/Policy**

2. Implementation Type:

☒ **Developmental** ☐ **Response** ☐ **Feasibility**

3. Implementation Objectives

I. Present tutorial to research implementation (RI) stakeholders to demonstrate application of tool to support Research Implementation Manager (RIM), Research Project Manager (RPM) and Technical Implementation Manager (TIM) functions.

Implementation Deliverable	**Evidence**	**Due**
1.1 Tutorial on how tool supports RIM, RPM and TIM functions	Delivery of Tutorial	After Beta version of tool has been created

II. Present tutorial to demonstrate the evaluation of the benefits and costs of the research program to RIM.

Implementation Deliverable	**Evidence**	**Due**
2.1 Tutorial on how tool can be used to evaluate the benefits and costs of research program	Delivery of Tutorial	After Beta version of tool has been created

III. Present tutorial to demonstrate the development of annual research program report to RIM**.**

Implementation Deliverable	**Evidence**	**Due**
3.1 Tutorial on how tool can be used to develop annual research program report	Delivery of Tutorial	After Beta version of tool has been created

IV. Present to RI stakeholders (GDOT) on organizational process improvements to enhance research implementation effectiveness.

Implementation Deliverable	**Evidence**	**Due**
4.1 Presentation on organizational process best practices that enhance research implementation effectiveness	Delivery of Presentation	Before Gamma version of tool is released.

V. Present research implementation support tool and process to RI stakeholders (external) at 2018 annual Transportation Research Board Meeting to obtain peer-review and benchmark with best practices.

Implementation Deliverable	Evidence	Due
5.1 Presentation on research implementation support tool and process to external stakeholders	Delivery of Presentation	Before final report is delivered to sponsor.

4. Data Requirements

Time savings: ☐ **Yes** ☒ **No**
Money savings: ☐ **Yes** ☒ **No**

5. Data Source(s):

_____

Other Measure(s) of Performance	Data Source(s)	Metric(s)/Indicator(s)
Use of tool for RIM functions	Feedback	Actual % of functions / anticipated % of functions
Effectiveness of tool for RIM functions	Feedback	Likert scale (scale of 1 to 5)
Use of tool for RPM functions	Feedback	Actual % of functions / anticipated % of functions
Effectiveness of tool for RPM functions	Feedback	Likert scale (scale of 1 to 5)
Use of tool for TIM functions	Feedback	Actual % of functions / anticipated % of functions
Effectiveness of tool for TIM functions	Feedback	Likert scale (scale of 1 to 5)

6. Implementation relative to project duration:

☐ Within research project timeline
☐ After research project ends
☒ Both within research timeline and after research ends

RESEARCH IMPLEMENTATION PLAN

May 16, 2017

Research Project Title: Durability of Precast Pre-Stressed Concrete Piles in Marine Environment

1. Strategic Area (Check all that apply):

☐ **Asset Management** ☒ **Mobility** ☐ **Safety** ☐ **Workforce/Policy**

2. Implementation Type:

☒ **Developmental** ☒ **Response** ☐ **Feasibility**

3. Implementation Objectives

I. Draft specifications for steel reinforcement to be used in constructing concrete piles in marine environments

Implementation Deliverable	Evidence	Due
1.1 Provide new stainless steel alloys for use in constructing bridge piles in marine environments	Update of reinforcement specifications in design manuals	

II. Draft improved concrete mix design that prolongs lifespan of bridge piles in marine environments

Implementation Deliverable	Evidence	Due
2.1 Provide new concrete mix specifications for use in bridge piles in marine environments	Update of concrete mix specifications in agency guidelines	

III. Apply new material and design specifications to 4 bridges in Georgia

Implementation Deliverable	Evidence	Due
3.1 Rehabilitate bridges using new material and design specifications	New construction using improved methods	

4. Data Requirements

Time savings: ☐ **Yes** ☒ **No**

Money savings: ☒ **Yes** ☐ **No**

5. Data Source(s): Test piles. Money saved from reduction in maintenance costs.

Other Measure(s) of Performance	Data Source(s)	Metric(s)/Indicator(s)

For concrete mix: Chloride ingress, Carbonation and Sulfate attack	Test piles	Extent of chloride ingress, carbonation and sulphate attack
For stainless steel alloy: Corrosion resistance of reinforcement	Test piles	Likert-Type Scale: Unsatisfactory, Satisfactory, Good, Very Good

6. Implementation relative to project duration:

☐ Within research project timeline

☒ After research project ends

☐ Both within research timeline and after research ends

SAMPLE RESEARCH IMPLEMENTATION PLAN

May 19, 2017

Research Project Title: GDOT ROADMAP FOR DRIVERLESS VEHICLES

1. Strategic Area (Check all that apply):

☐ **Asset Management** ☒ **Mobility** ☐ **Safety** ☒ **Workforce/Policy**

2. Implementation Type:

☒ **Developmental** ☐ **Response** ☒ **Feasibility**

3. Implementation Objectives

I. Develop a synthesis of current research and thinking on driverless vehicles including reasonable scenarios for future conditions

Implementation Deliverable	Evidence	Due
• Optimum level/number of scenarios to reasonably reflect the range of uncertainties in future conditions • Potential impacts and needs of driverless vehicles are likely to interact with the GDOT mission over the coming years	1.1 Technical Memorandum: Future Vehicle Automation Scenarios 1.2 Synthesis of Research and Thinking on Driverless Vehicles; and a baseline for development of an effective roadmap for future actions	

II. Develop a "driverless vehicle roadmap" (DVR) for future actions that should be undertaken by GDOT

Implementation Deliverable	Evidence	Due
• Preliminary Roadmap for Driverless Vehicles • Final GDOT Driverless Vehicle Roadmap (DVR)	2.1 Technical Memorandum detailing GDOT's design standards/ policies needed to be updated with respect to the DVR; effective means to incorporate driverless vehicles into the project planning Process 2.2 Technical Memorandum indicating proposed implementation schedule; suggested changes to GDOT administrative structure necessary to improve implementation	

III. Identify indicators of performance for the GDOT's DVR implementation

Implementation Deliverable	Evidence	Due
• Measures of success for GDOT implementation of DVR • Data to be collected to track performance of DVR implementation	Technical Memorandum detailing: 3.1 List of key performance indicators 3.2 List of data types and sources submitted	

4. Data Requirements

Time savings: ☐ **Yes** ☐ **No**

Money savings: ☐ **Yes** ☐ **No**

5. Data Source(s):

_____

Other Measure(s) of Performance	Data Source(s)	Metric(s)/Indicator(s)
DVR's impact on GDOT Structure		
DVR's impact on GDOT staff		
DVR's effectiveness		

6. Implementation relative to project duration:

☐ Within research project timeline

☒ After research project ends

☐ Both within research timeline and after research ends

SAMPLE RESEARCH IMPLEMENTATION PLAN

June 6, 2017

Research Project Title: Automatic Incident Detection Technology (AIDT) Testbed on I-475: Technology Feasibility Study

1. Strategic Area (Check all that apply):

☐ Asset Management ☐ Workforce/Policy

☒ Safety ☐ Mobility

2. Implementation Type:

☐ Developmental ☐ Response ☒ Feasibility

3. Implementation Objectives

I. Recommend most appropriate conditions for deployment of AIDT on highway system.

Implementation Deliverable	Evidence	Due
List of recommended conditions for deployment of AIDT*, e.g., traffic flow (congested/free flow), lighting (night and day), weather conditions, rural versus urban, ramp versus mainline, etc. (*That is, conditions under which more benefit is expected to be gained from the deployment of the system that current approaches provide).	• Deliver tutorial on appropriate conditions for deploying AIDT to appropriate agency personnel. • Update of agency procedures with appropriate conditions for deployment of AIDT (in comparison with current approaches for incident detection).	

II. Demonstrate the use of cost-benefit spreadsheets to update information every 3-5 years.

Implementation Deliverable	Evidence	Due
Demonstration of the use of cost-benefit spreadsheets to update feasibility analysis as improved AIDT technologies come to market.	• Tutorial or Workshop	

III. Provide deployment considerations for the recommended AIDT.

Implementation Deliverable	Evidence	Due

List of considerations for deploying the recommended AIDT in order to obtain full benefits.	• Deliver tutorial on appropriate considerations for deploying AIDT to appropriate agency personnel. • Update of agency procedures with appropriate considerations for deploying AIDT.	

4. Data Requirements

Time savings: ☒ **Yes** ☐ **No**

Money savings: ☒ **Yes** ☐ **No**

5. Data Source(s): GDOT TMC data, AIDT data, Video data

I. Reduction in incidence detection time (AIDT/video data compared with current approaches)

II. Reduction in associated congestion costs - GDOT TMC

III. Reduction in fatalities due to reduced incident detection times (Models)

Other Measure(s) of Performance	Data Source(s)	Metric(s)/Indicator(s)
N/A		

6. Implementation relative to project duration:

☐ Within research project timeline

☐ After research project ends

☒ Both within research timeline and after research ends

APPENDIX D

SAMPLE IMPLEMENTATION PROGRESS REPORTS

IMPLEMENTATION PROGRESS REPORT DEPARTMENT OF TRANSPORTATION STATE OF GEORGIA	Report No. 1	Date: 3/1/12
	Report Period From: 3/1/12	To: 3 /31/12

Project No. RP11-34	Project Title: Corrosion-free precast prestressed concrete piles made with stainless steel reinforcement: construction, test and evaluation

Research Agency (s): GDOT	Project Director: XXX

Starting Date: March 2012	Completion Date: March 2015	Total Months: 36	Time Expended Months = 1 Percent = 2.8%

Funding Source (s): GDOT	Funds Authorized: $499,239	Funds Expended Report Period: XX,XXX Total: XX,XXX

Research Objectives:

1. Determine extent of corrosion damage in Georgia's structural concrete bridge piling and successful methods to improve bridge pile durability.
2. Document past research and DOT investigations on reinforcement corrosion and mitigation of structural concrete in marine environments.
3. Perform preliminary experimental investigation on corrosion of reinforcement in concrete piles.
4. Identify any further research that needs to be undertaken to determine improved methods to increase pile durability in Georgia's marine environment.

Implementation Objectives:

Objective 1: Draft material specifications for steel reinforcement for constructing concrete piles in marine environments
Objective 2: Draft design specification for bridge piles
Objective 3: Apply new material and design specifications to 4 bridges in Georgia

Implementation Deliverables:

Objective #1 Deliverable: Material specifications
Objective #2 Deliverable: Design specifications
Objective #3 Deliverable: Rehabilitated bridges using new material and design specifications

Implementation Progress This Reporting Period (Attach Evidence):

1 of 3 deliverables complete

Implementation Work Planned for Next Report Period:

Finalize design specifications for bridge piles

Anticipated Problems/Course of Action:

None to report.

XXX (PI)

IMPLEMENTATION PROGRESS REPORT DEPARTMENT OF TRANSPORTATION STATE OF GEORGIA				Report No. GA-15-1231	Date: 12/01/2014
				Report Period From: 10/01/2014	To:12/30/2014
Project No. RP 12-31	Project Title: Developing a GDOT Pavement Marking Handbook using Field Test Deck Evaluation and Long-Term Performance Analysis				
Research Agency (s): GDOT	Project Director: XXX				
Starting Date: December 2012	Completion Date: December 2015	Total Months: 36	Time Expended Months = 24	Percent =66.7%	
Funding Source (s): GDOT	Funds Authorized: $ 253,526	Funds Expended Report Period XX,XXX	Total XX,XXX		

Research Objectives:
The objective of the research is to develop pavement marking handbook

Implementation Objectives:
Objective 1: Demonstrate use of Pavement Marking Handbook for material selection, inspection, testing and quality acceptance
Objective 2: Develop tutorial on use of Pavement Marking Handbook
Objective 4: Provide handbook reference material and resources for staff use

Implementation Deliverables:
Objective #1 Deliverable: Workshop with key GDOT staff on use and application of handbook: 100% complete
Objective #2 Deliverable: Web-based interactive tutorial on new Pavement Markings Handbook for material selection and personnel training: 50% complete
Objective #3 Deliverable: User Guide for Pavement Marking Interactive Tutorial: 0% complete

Implementation Data Collection:

Benefits Data Collection: None to report.
Costs Data Collection: None to report.

Implementation Progress This Reporting Period (Attach Evidence):
Workshop completed with GDOT research and maintenance staff. Workshop summary and presentation material attached as evidence.

Implementation Work Planned for Next Report Period:
Completion of

Anticipated Problems/Course of Action:

None to report.

XXX (PI)

QUARTERLY PROGRESS REPORT DEPARTMENT OF TRANSPORTATION STATE OF GEORGIA	Report No. 1	Date:10/15/16
	Report Period From: 7/28/16	To: 9/30/16

Project No. RP 16-07	Project Title: Research Project Implementation Management: Dev. of an Evidence-Based Database and Tool

Research Agency (s): GDOT	Project Director: XXX

Starting Date: July 28, 2016	Completion Date: Oct 28, 2017	Total Months: 15	Time Expended Months = 2 Percent = 13.3%

Funding Source (s):	Funds Authorized:	Funds Expended Report Period	Total
GDOT	$117,868	XX,XXX	XX,XXX

Research Objectives:
This research will conduct a comprehensive review of best knowledge and practices for implementing research and develop an evidence-based database and tool to support research project and program implementation management at GDOT.

Implementation Objectives (IO):
IO 1: Present tutorial to research implementation (RI) stakeholders to demonstrate application of tool to support Research Implementation Manager (RIM), Research Project Manager (RPM) and Technical Implementation Manager (TIM) functions.
IO 2: Present tutorial to RIM to demonstrate the evaluation of benefits and costs of research program.
IO 3: Present tutorial to RIM to demonstrate the development of annual research program report.
IO 4: Present to RI stakeholders (GDOT) on organizational process improvements to enhance research implementation effectiveness.
IO 5: Present research implementation support tool and process to RI stakeholders (external) at 2018 annual Transportation Research Board Meeting to obtain peer-review and benchmark with best practices.

Implementation Deliverables:
Objective #1 Deliverable: Tutorial on functional support of tool (Gamma version)
Objective #2 Deliverable: Tutorial on estimating benefits and costs of research program
Objective #3 Deliverable: Tutorial on developing annual research program report
Objective #4 Deliverable: Presentation on organizational process improvements to enhance research implementation effectiveness
Objective #5 Deliverable: Presentation on GDOT research implementation tool and process at TRB 2018

Implementation Progress This Reporting Period (Attach Evidence):
0 of 5 deliverables complete

Implementation Work Planned for Next Report Period:
None to report.

Anticipated Problems/Course of Action:

None to report.

XXX (PI)

APPENDIX E

RIM Tool Manual

2017

Transportation Research Implementation Management Tool

Manual

Prepared for:

Georgia Department of Transportation

By:

Georgia Institute of Technology

PI: Adjo Amekudzi-Kennedy, Ph.D.

Co-PI: Russell Clark, Ph.D.

Graduate Researchers: Stephanie Amoaning-Yankson, Akansha Gupta, Tara Rabinek, Janille Smith-Colin

August 28, 2017

Contents

List of Figures

1. Introduction

The RIM tool comprises a set of multi-user Access files with a split database set in the Access 2010 environment. These files are to be hosted on a shared network folder. The Access tool has three files:

- RPIM_Common_Tables
- RPIM_User
- RPIM_Admin

The RPIM_Common_Tables is the central hub for all data and the tables. The RPIM_User file contains the forms, queries, and reports that are linked to the tables in RPIM_Common_Tables. The RPIM_Admin file has all the back-end functionality and code visible and is meant for editing the features in the tool.

2. Setting up a new user

To set up a new user, proceed with the following steps.

IV. The RPIM_User file is different for each user. To set up a new user, create a copy of the file RPIM_User, and rename it to the user's name, for example, "RPIM_BinhBui". All user files should always be in the same folder with the RPIM_Common_Tables file (**Figure 1**).

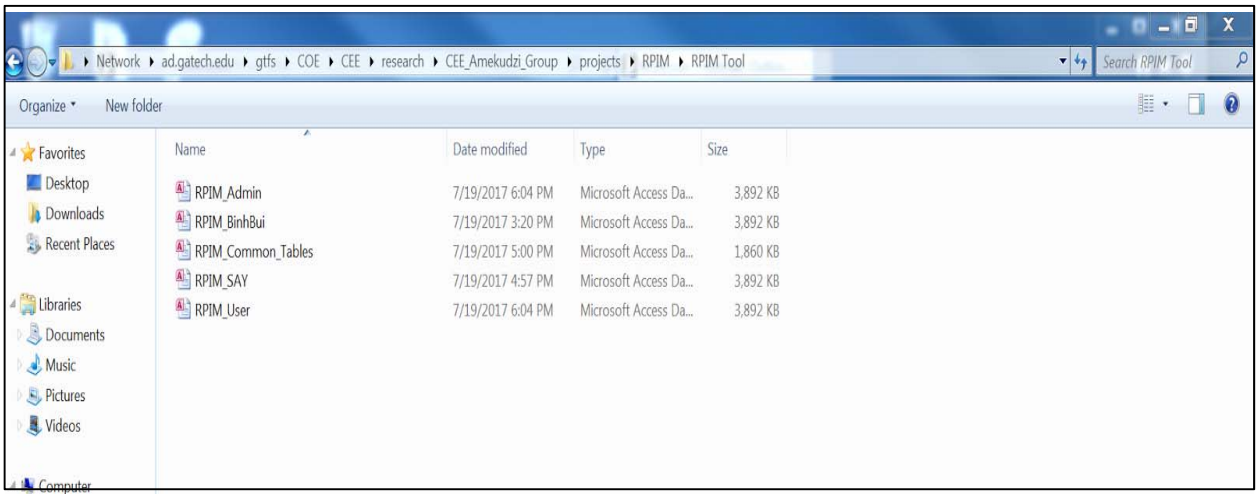

Figure 1 File locations

V. Always click on 'Enable Content' as shown in **Figure 2.**

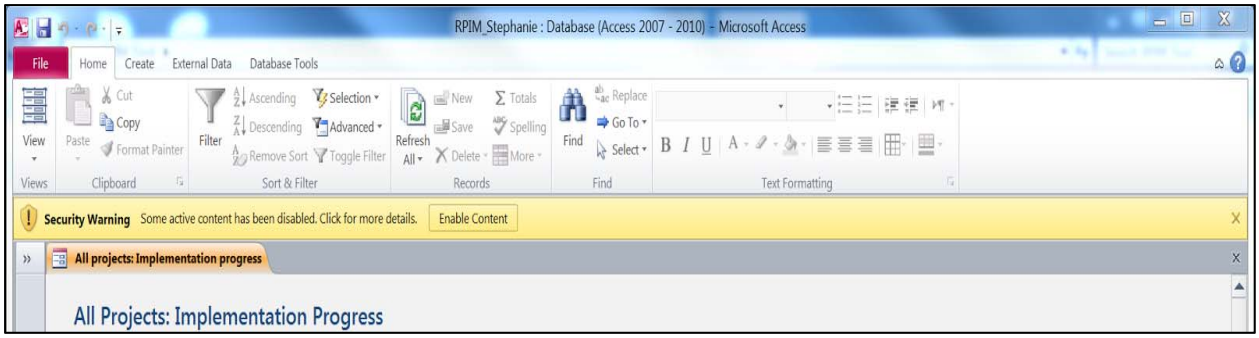

Figure 2 'Enable content'

VI. Make sure the user file is linked to the correct tables using the following steps:

a. Open External Data -> Linked Table Manager (second option from the left in **Figure 3**)

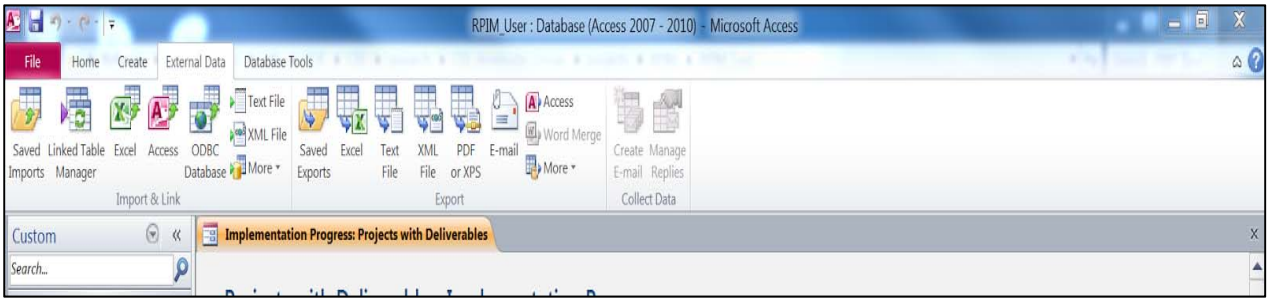

Figure 3 Linked Table Manager (a)

b. Select all tables and check 'Always prompt for new location'. Click 'OK' (**Figure 4**).

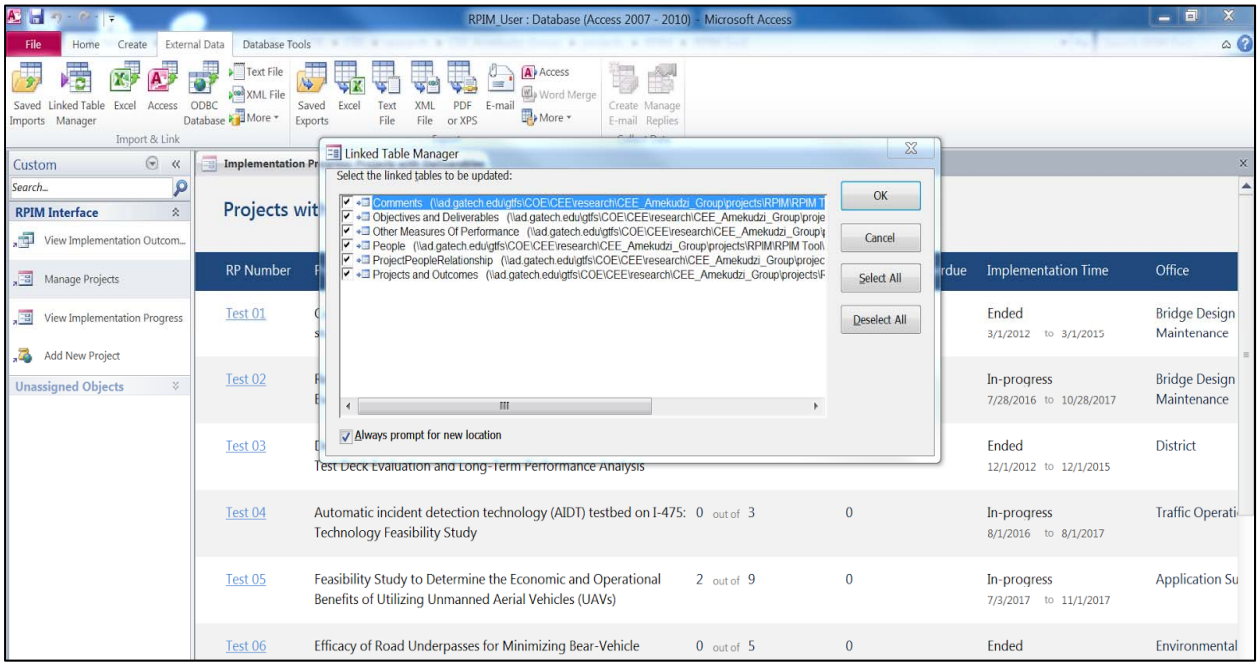

Figure 4 Linked Table Manager (b)

c. Select the RPIM_Common_Tables file in the same folder as the current file (**Figure 5**).

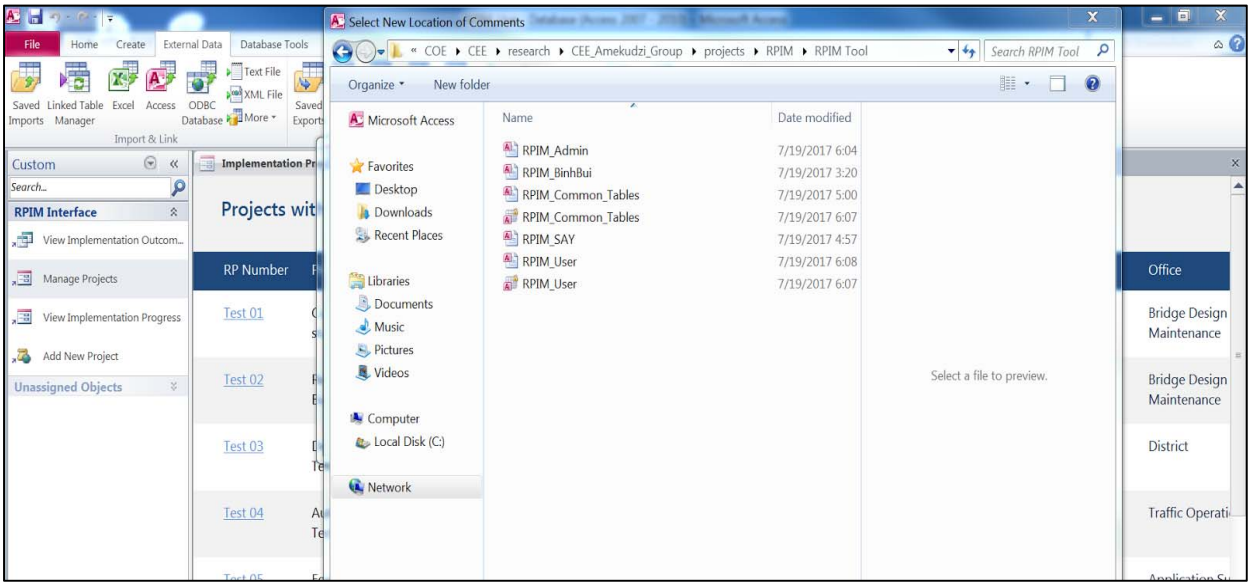

Figure 5 Select RPIM_Common_Tables File

3. Adding a new project

III. To add a new project, do either of the following (**Figure 6**):

a. Double-click on “Add new project” in the left menu, or

b. Double-click on “Manage Projects”, and then click on “Add New Project” button on the top-right

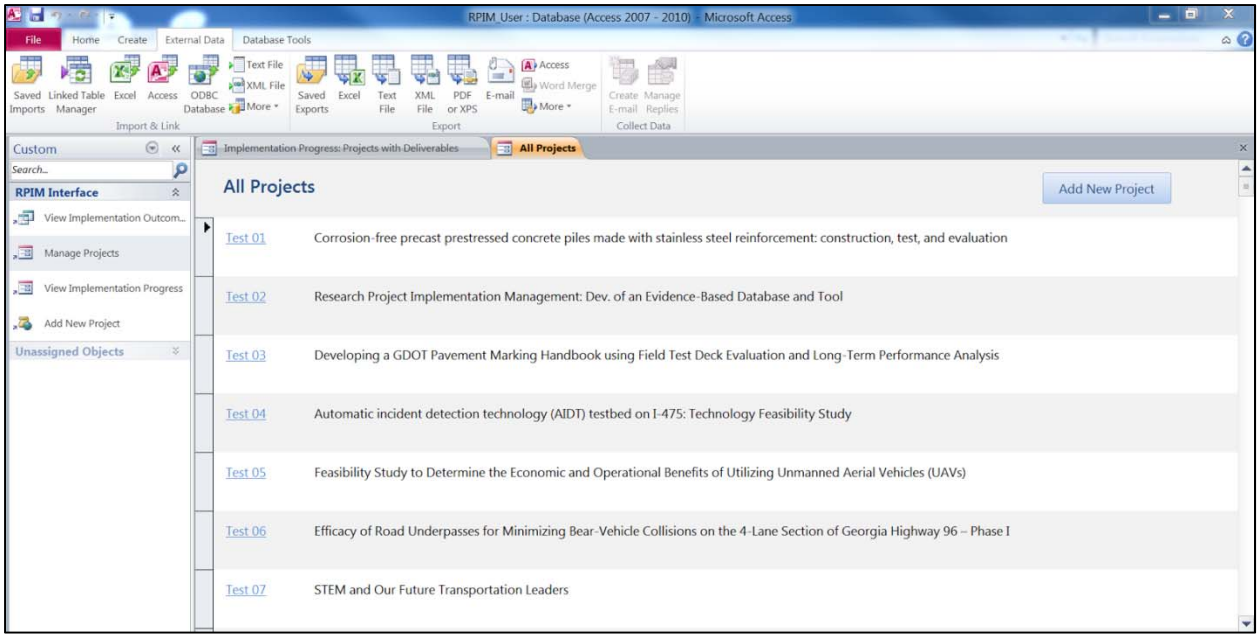

Figure 6 Add new project

IV. Enter all required information (refer to RPIM Tool Specification Table if needed). This form saves as you type. Once you close the form, click on the "Refresh all" button in the Home section of the top-menu (**Figure 7**).

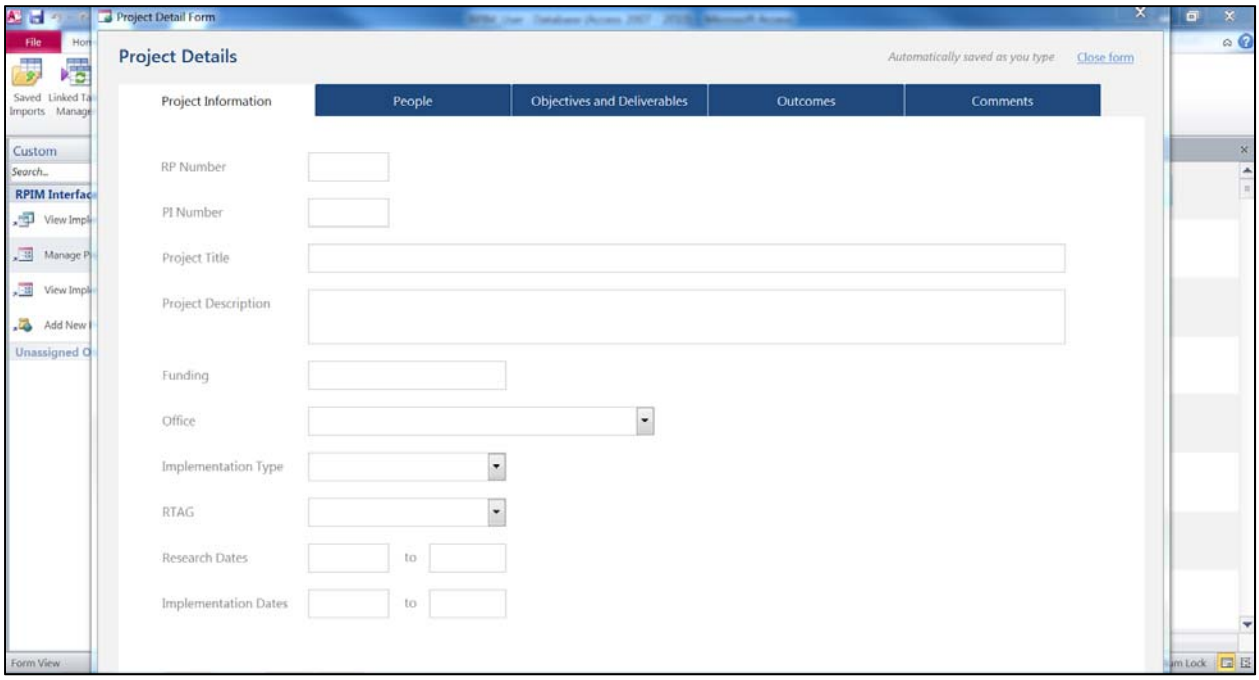

Figure 7 Project details form

Note: If you do not add any deliverables, the project will only show in 'Manage Projects' file.

4. Editing a project

To edit a project, double-click on any of the following three files in the left pane (**Figure 8**):

- View Implementation Outcomes
- View Implementation Progress
- Manage Projects

Then click on the RP number of the project you wish to edit (**Figure 9**).

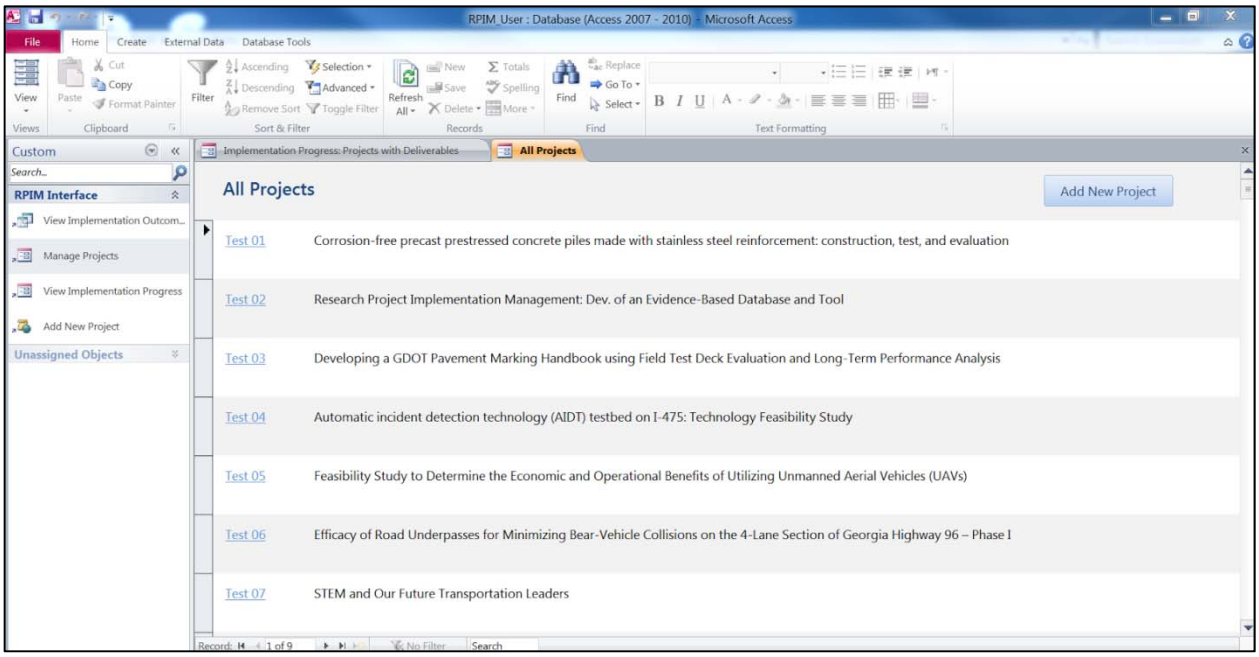

Figure 8 Screenshot showing left pane

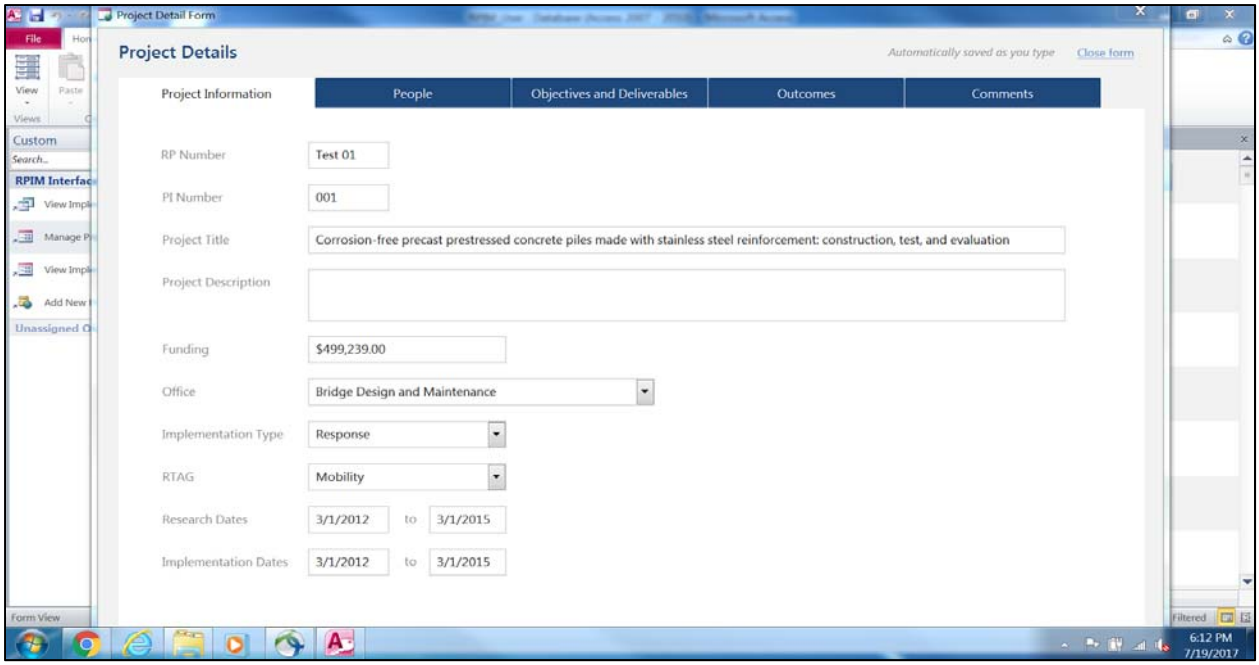

Figure 9 RP Number Test 01 selected for editing

5. Deleting a project

To delete a project (**Figure 10**):

I. Double-click the "Manage Projects" file

II. Click on the left grey bar which is the record selector and then press "Delete" or "Backspace" on your keyboard.

Note: You might have a problem in deleting if other people have their files open. You will all have to close files to be able to delete a project.

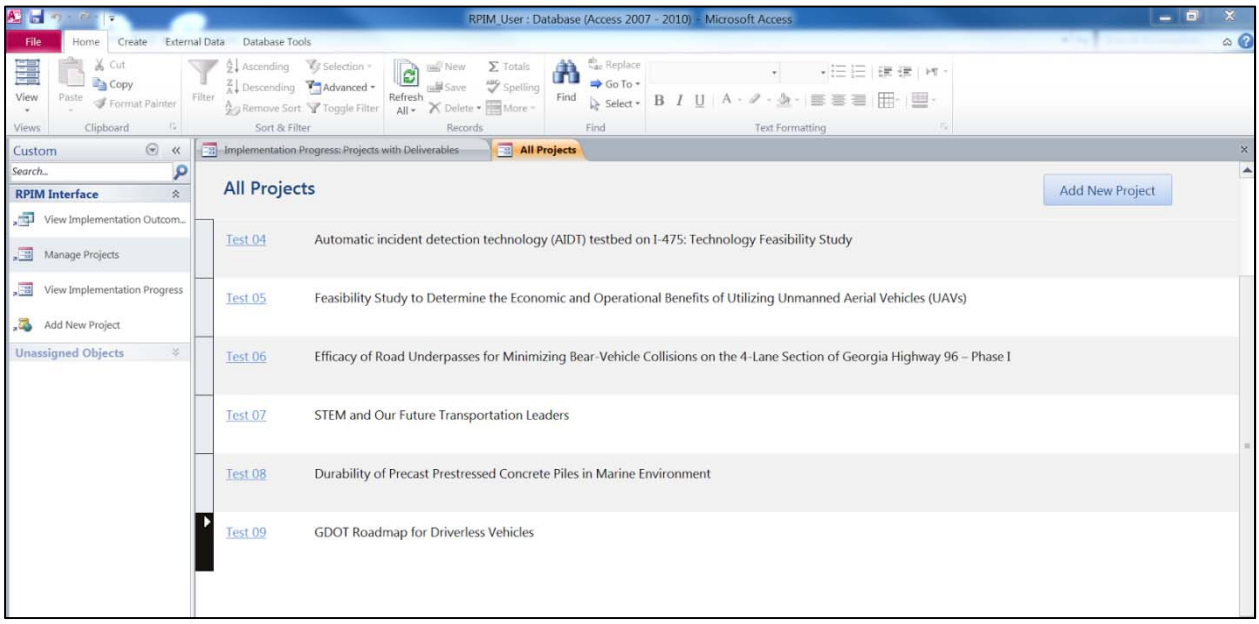

Figure 10 Deleting a project record (a)

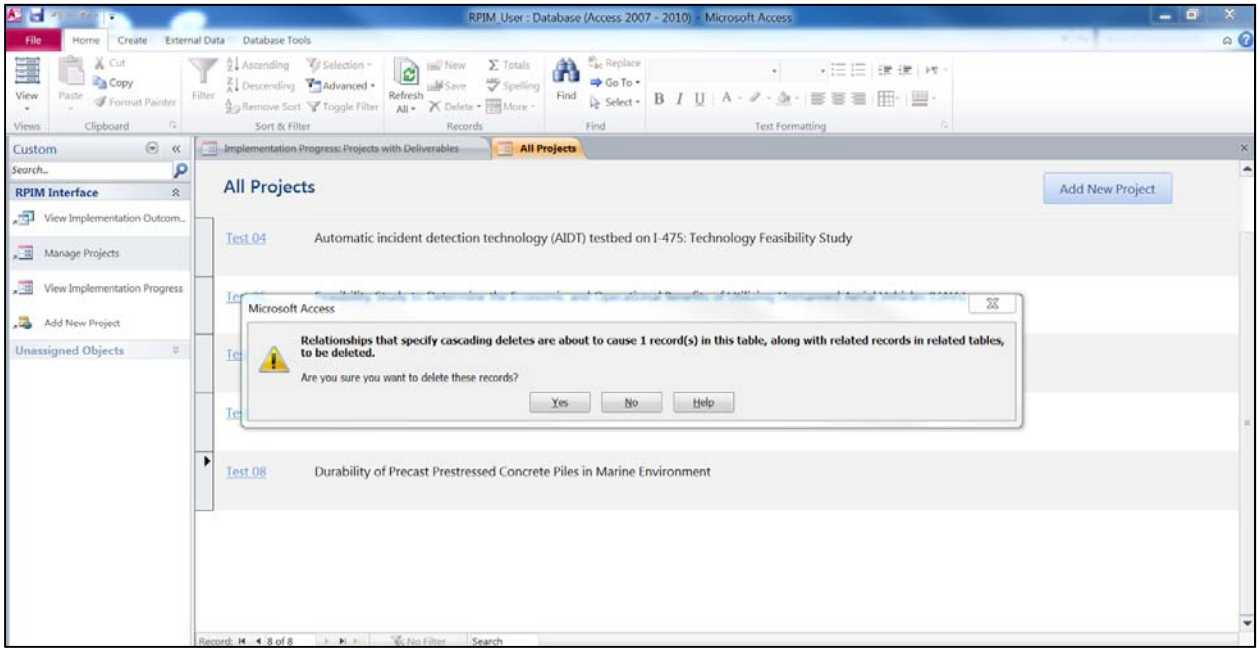

Figure 10 Deleting a project record (b)

6. Search and Filter

I. To search in the document: In the Home section of the top-menu, click on Find. Select the options appropriate to what you are looking for (**Figure 11**).

II. To filter based on a column:

a. Click on any field of the column you want to filter.

b. In the Home section of the top-menu, click on Filter.

c. Select the options appropriate to what you are looking for. You can also use other features that are listed next to the Filter button.

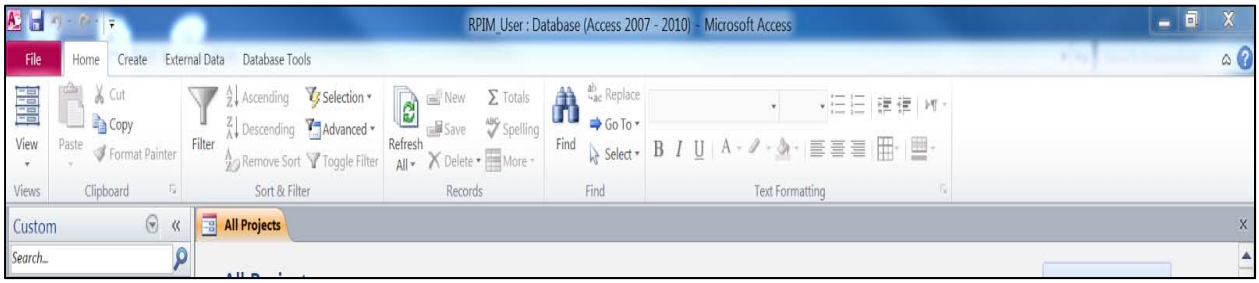

Figure 11 Filtering a column

7. Relational Database Table Relationships

Figure 12 shows the tables along with the table name, the fields and the relationships between different tables. The 1 to ∞ means a one-to-many relationships. For example, a one-to-many relationship between Projects and Outcomes and Comments means there are more than one comments for one project. The connecting field in this case is RPNumber to ProjectRPNumber.

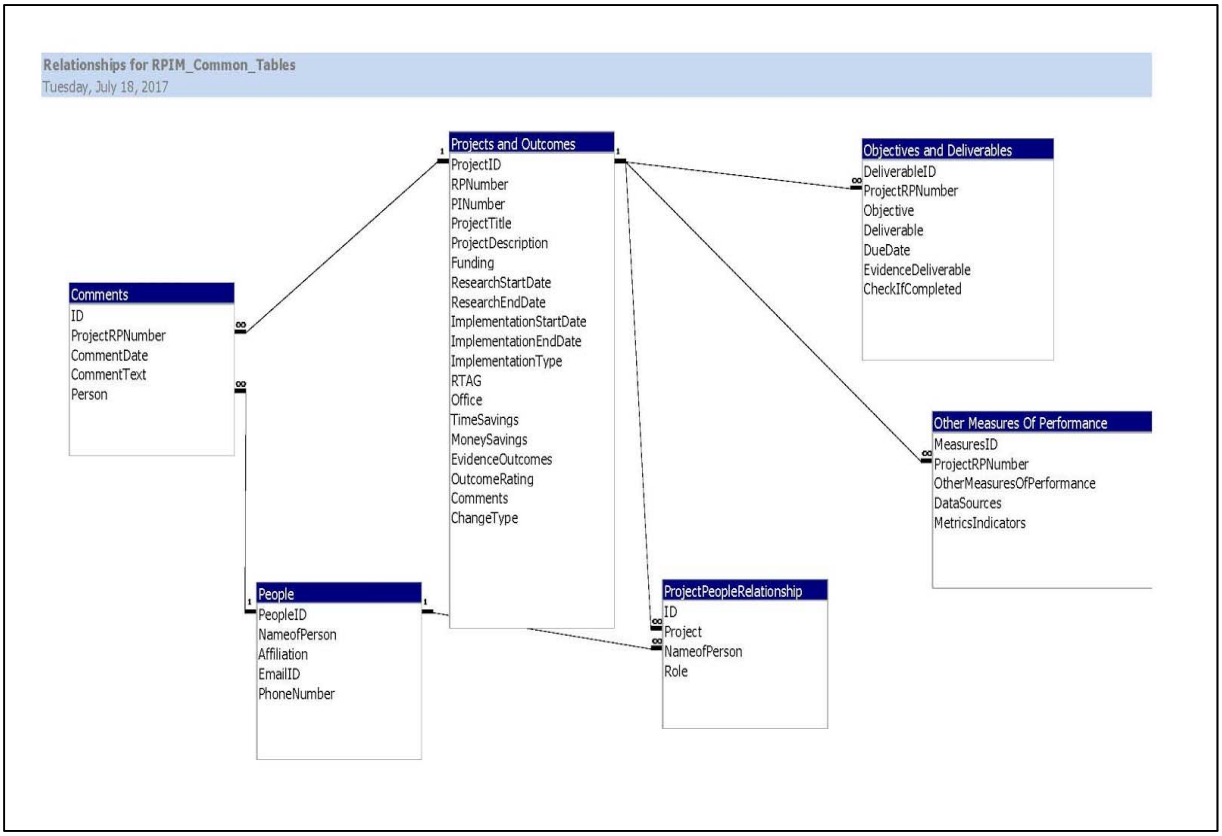

Figure 12 Relational Database Table Relationships