RESEARCH

UDOT Keeping Utah Moving

Utah Department of Transportation - Research Division
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Report No. UT-23.07

MEASURING TRANSPORTATION RESEARCH BENEFITS IN UTAH

Prepared For:

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Research and Innovation Division

Final Report
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16. Abstract

Research benefits information was compiled to estimate the effectiveness of UDOT's research program. Project benefits were gathered through survey responses submitted by the end users of the project deliverables. Using project costs, an estimate of the benefit-cost ratio for the program was determined.

This information gathered for 57 research projects completed during the years 2017, 2018 and 2019 indicates:

- A total estimate of benefits of $111,790,000.
- This indicates that the benefit-cost ratio for these projects is 26.

Each project was also given a grade based on the success of the project and the value of the deliverables. The three-year program received an average grade of 2.5 or a B-grade based on a 1 to 4 rating system. The UTRAC process used to select projects for funding received very positive feedback.

Recommendations were provided to aid UDOT research managers in improving the conduct, management, and implementation of research deliverables and products.

Continuous measurement of the benefits of transportation research is important to justify the expenditure of research funding and maintain the support of management. Knowledge related to the benefits of research can optimize the allocation of future available funds.

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LIST OF ACRONYMS

B/C	Benefit-Cost Ratio
FHWA	Federal Highway Administration
GPA	Grade Point Average
ITS	Intelligent Transportation Systems
PI	Principal Investigator
PM	Project Manager
RPMs	Research Project Management System Database
TAC	Technical Advisory Committee
UDOT	Utah Department of Transportation
UTRAC	Utah Transportation Research Advisory Council

EXECUTIVE SUMMARY

Measuring the benefits of transportation research investments is important to justify the expenditure of research funding and maintain the support of stakeholders. Understanding the benefits of research can better establish how future available funds are utilized and maximize how the funding is allocated.

The main goal of this research study was to gather information on past research projects conducted through the Utah Department of Transportation (UDOT) Research Program. The study surveyed end users of the research products to determine the benefits in terms of improvements in UDOT practices and the estimated dollars related to these benefits.

This feedback from surveys and conversations was used to estimate a program benefit-cost ratio for the Research and Innovation Division. Information was gathered in this study for 57 research studies completed during the years 2017, 2018 and 2019. A total of 50 surveys were returned for a 68% return rate. Results indicate that the UDOT research program had an estimated $111.794 million in benefits and a benefit-cost ratio of 26 for the three years studied. This included 73 deliverables produced by the 57 projects.

The 73 deliverables were also given a grade by end users based on the success of the project and the value of the deliverables. The three-year program received a B- grade, achieving an average grade of 2.5 based on a 1 to 4 rating system.

The Utah Transportation Research Advisory Council (UTRAC) Process used to select projects for funding received very positive feedback. Recommendations were provided to aid UDOT research managers in improving the implementation of research deliverables and products.

A Process Guide was developed and published in a separate document for use by the UDOT Research and Innovation Division to gather benefit information related to research projects in the future. The process includes tools and data development methods to evaluate the research program on an annual basis.

1.0 INTRODUCTION AND PURPOSE

Connecting cities, towns, factories, farming communities, tourist destinations, and other trip generators are essential to the continued success of our state and region. Transportation research programs are important elements in enhancing these systems and solving problems facing transportation managers, engineers and travelers.

Transportation and transit agencies play a vital role in ensuring that our markets and local institutions prosper by the safe and efficient movement of people and goods. Transportation resources are crucial to meet the many current challenges. Engaging in research endeavors to boost efficiency, enhance facility maintenance, and better plan new construction is the best strategy for making transportation budgets and manpower go further.

Evaluating transportation research activities by determining the direct benefits of this research allows key stakeholders to determine which methods and investment types are the most effective. This aids transportation leaders to apply the limited research budgets in the most effective way. Funding can be dedicated to meet the strategic goals of agencies and address the state's most pressing interests.

Research initiatives have been undertaken over the years on nearly every aspect of transportation. Advancements have been introduced that have enhanced the safety, efficiency and cost effectiveness of transportation networks. Innovation within these institutions must be continued to maintain our productivity and standard of living.

Utah faces a unique set of transportation-related challenges that must be addressed to meet the short- and long-term goals of the state:

- Utah's population is one of the fastest growing in the country both from in-state expansion and new residents from out-of-state communities.
- The economy in Utah is among the fastest growing in the nation. There are significant impacts on Utah's highway corridors. Support for the mining industry, energy development, and national long-haul traffic are key aspects that impact Utah's transportation systems.
- Utah's geological location is crucial to the transportation needs of the country. Known as the "Crossroads of the West," Utah supports some of the most critical connections from both east/west and north/south corridors.
- The state is made up of a combination of high-density cities, sprawling suburbs, and vast regions of rural communities.
- A wide variety of geographical regions must be considered by the department, including towering mountainous areas, high open ranges and low elevation deserts. These factors must be considered when generating designs, maintenance strategies and safety standards.

- Utah is blessed with unique but delicate environmental regions and species. Protection of these special assets must be considered in all aspects of every transportation initiative.

Research initiatives, innovative planning, and technology transfer are the best approaches to addressing these challenges and issues. UDOT region experts and central specialists, along with support from universities, consultants and contractors, can propose and develop solutions to these issues.

This study was conducted to justify and validate the expenditure of UDOT funding on research-related activities. It provides an estimate of the return on investment for these budgets. Also evaluated were the types of projects that are more successful and which are less beneficial. The process utilized was aimed at gathering feedback from end users of research products and recommending improvements to the program.

2.0 STUDY OBJECTIVES

Leaders from the Research and Innovation Division prepared a contract to evaluate the research program through a survey used to gather feedback from their end users and stakeholders. Objectives were prepared as listed below:

1. Calculate a benefit-cost ratio for the UDOT research program during the period of study (2017, 2018, and 2019).
2. Estimate the benefits of major research projects and compare them with the costs expended on the studies.
3. Identify which types of projects produce the highest benefit-cost ratios.
4. Identify trends apparent over time by comparing the results with previous benefit-cost studies both for the general program and for the various types of projects.
5. Develop a process to track research benefits as they are implemented.

3.0 STUDY TASKS

The following tasks required to meet the objectives and complete the contract were prepared:

1. For each project task, identify the principal investigator(s) responsible for its completion.
2. Form a Technical Advisory Committee (TAC) for the study made up of research managers and others who are likely to use the findings.
3. Conduct a thorough literature search to determine how other agencies measure research benefits, promote implementation of deliverables, and evaluate those who conduct the research.
4. Modify the research approach of this study based on methods used by other agencies as needed and recommended by the TAC.
5. Obtain 2017-2019 research project information from UDOT.
6. The UDOT Research Staff will supply needed information including: Project number and title, PIC#, project manager, principal investigator, start and end dates, contract costs, original champion, current champion, and all deliverables received.
7. Submit survey questions to TAC for review prior to sending to champions.
8. Survey and/or meet with the key champion and others familiar with the research

products and outline a plan to obtain a good estimation of the study benefits and total costs.

9. Convert project benefits into a dollar value where possible. If this cannot be done the benefits will be listed as "unknown," and no benefits will be shown. The project costs will be included in the analysis even if no benefits can be determined.

10. Develop a grading metric for evaluating projects.

11. Compile all data and calculate a benefit-cost ratio. This will be done for individual projects, the total three-year time period, and for each project type.

12. If implementation actions were unsuccessful on individual projects, gather information from the champions and end users on how the deliverables could have been better utilized or promoted for use.

13. Identify and analyze any trends observed in the information by comparing the new project findings with the results of the studies done in previous years.

14. Propose improvements to the research program, project management procedures, implementation efforts, and the UTRAC project selection process.

15. Recommend how the research database (RPMs) could support benefits of research efforts, including identification of specific data points in the database.

16. Make recommendations concerning the research program including the types of research projects that are likely to produce significant benefits, topics to avoid, and implementation strategies for adoption.

17. Develop a process that can be used to measure research benefits on an ongoing basis. This will include procedures for use on both the project and program levels. The process will include tools such as:
    a. Forms and surveys to gather research benefits as they are identified
    b. A matrix to apply to every project
    c. Questions that could lead to better projects
    d. Individuals responsible to complete each task
    e. The timeframe and interval for each task to be carried out

18. Provide a detailed description of best practices identified for use in conducting benefit-cost projects of this type. This will be in a form for use by UDOT or consultants that may be performing these studies in the future. Update the current Process Guide for conducting benefit-cost analyses.

19. Provide project ratio data from current and past reports.

20. Verify groupings of subject categories with research data groupings.

21. Develop outline of presentation material (slides, images, relevant data).

4.0 RESEARCH APPROACH

To meet the goals and objectives of the study, a formal and thorough data gathering effort was required. This was done through project-level surveys and through follow-up interviews with the project champions and product end users.

The survey questions were reviewed and approved by the TAC and converted into Google Forms format by Joni DeMille, UDOT's Librarian. This allowed the survey responses to be stored in usable formats for quick and accurate processing.

The survey used in the study is provided in Appendix A. The methods recommended for use in the survey are described in Section 5.

Benefits were expressed as:

- Written description of benefits, and
- Recorded estimates in terms of dollar values.

Project cost information was obtained using:

- Awarded contract amount,
- Average project management costs, and
- Estimated TAC member costs.

The interviews were used to:

- Aid in completion of the surveys,
- Evaluate the data and methods used to estimate the benefits,
- Review the accuracy of the information,
- Ensure that the estimates were conservative, and
- Record other feedback for use by Research staff.

In this way, estimates of the benefits of the overall program were obtained. Also, various types of projects were evaluated separately.

4.1 Research Project Deliverables

The assembling of research benefits, especially financial benefits, enables UDOT leaders to evaluate the research program in terms of "outcomes" as opposed to simple "output." It allows end users of research deliverables to convey how these products enhance the way the traveler is benefited and how UDOT experts change the way they do business. The study findings provide an indication of the "worth" of research investments and make comparisons with program costs.

4.2 Data Gathering Schedule and Execution

Some research initiatives are not fully implemented immediately after the project is completed. For this reason, it may be necessary to allow a period of time between project completion and the assessment of the benefits derived from the deliverables. By allowing this time period, end users of the research products have had sufficient time to determine if a concept

will really work as reported and a better estimation of the benefits has emerged. This approach has worked well in past benefit-cost studies.

4.3 Future Data Gathering

During this project, however, it became obvious that the gap between project completion and a benefits review does not always result in optimum feedback. Many project champions have retired, left UDOT for other employment, or changed positions resulting in a relatively low survey completion. A satisfactory level of involvement was ultimately achieved through follow-up virtual meetings to aid in the completion of surveys and gathering information remotely.

In future studies of this type, data gathering should begin as the project is completed and should continue until a more complete implementation of the findings is achieved. In this way, the best of both strategies is attained by acquiring the information over a longer period of time.

Although some end users may feel that the process is burdensome, a better account of the project implementation is accomplished. The project managers can reduce the burden of the feedback tasks by aiding significantly in the process and by using simplified forms and surveys.

5.0 BENEFIT MEASURES, METHODS AND RATINGS

There are a number of ways that benefits can be achieved through transportation research, and these benefits can take many forms. A wide variety of different methods are needed to compile and evaluate the various contributions to transportation programs and operations.

Benefits resulting from transportation research often go beyond financial enhancements. The various types of benefits were requested through the distributed surveys. Interviews further produced understanding of how the projects contributed to transportation state of the practice and knowledge.

The following sections describe the benefits of successfully completed research. These are included in surveys sent to end users to aid in estimating project benefits.

A list of the UDOT research projects completed in the years 2017, 2018 and 2019 are summarized in Appendix B.

5.1 Conversion of Benefits to Dollars

Most of the benefits listed in the previous sections can be converted into dollars by using conversion methods and factors. This should be done as much as possible to allow more direct comparisons between benefit types.

Facility improvements can be analyzed to reflect monetary benefits. Savings to UDOT staff can be based on wages and hours saved. Average crash costs have been assigned for various levels of crash severity. Property damage, injury crashes and fatal crashes are averaged over time using five severity levels. Lost time due to congestion can be assigned a dollar value based on an average hourly rate.

Again, steps should be taken as part of the process to ensure that the benefit estimates used remain conservative and can be justified.

5.2 Benefits as Part of a Larger Initiative

Many research projects are conducted as part of an existing UDOT program or initiative. The deliverables from these projects may be a percentage of a significant UDOT achieved goal. This coordinated approach should be considered when estimating the separate benefits of the completed research project.

The UDOT programs impacted could be a construction program, a design program, safety initiatives, environmental directives, etc. Research project deliverables are often subsets of these programs such as material specifications, pavement design methods, delineation safety enhancements, improved impact barriers, bridge construction, bridge design, geotechnical construction, geotechnical design, etc. The budgets for these programs can be used to estimate the benefits of a related research project.

It is helpful to note that past research has shown that research projects contribute to UDOT programs based on the estimated ranges shown in Table 5.1. These estimates are only general in nature and may vary from one project to another.

Table 5.1 Benefits as Part of a Larger Initiative

Contribution	Estimated Benefit Range
Major Impact	5 to 50% of the program
Significant Impact	2 to 10% of the program
State of the Practice	0 to 2% of the program
Unclear Findings	-0-
Objectives Not Met	-0-

5.2.1 *Example: Cable Barrier Implementation*

The use of cable barrier may provide $50 million in benefits over a ten-year period. A research project aimed at determining the appropriate implementation of the concept and where to place the barrier may contribute 10% to the overall benefits from the program. A $5 million benefit could then be assigned to the research project as part of the overall initiative.

5.2.2 *Example: Pile Design Enhancements*

The use of new pile cap design may improve the foundation design methods by 1%. Using a three-year program budget of $20 million the estimated benefit of the research is $200,000.

5.2.3 *Example: Pavement Design Modifications*

A research project results in improved pavement design methods. If the program spent $80 million over five years on design, a conservative estimate of benefits for the research project may be 1% improvement or $0.8 million.

5.3 Benefits Related to Cost Avoidance

Transportation functions and activities often lead to actions that increase the cost to the agency, the private sector, and/or the traveling public. These cost increases take a number of forms, and are often necessary. Deliverables from research projects can and do produce benefits in the form of cost avoidance. Benefits related to cost avoidance may be in the form of enhanced safety, reduced user costs, or positive environmental impacts.

Cost avoidance is a very valid and important engineering practice. Cost increases over time are an inevitable aspect of transportation programs, planning and budget preparation.

The trends shown in Figure 5.1 illustrate the costs that may result if no action is taken. Policies, specifications, or other products from research projects can defer excessive cost increases. These costs can be considerable and multiply over time.

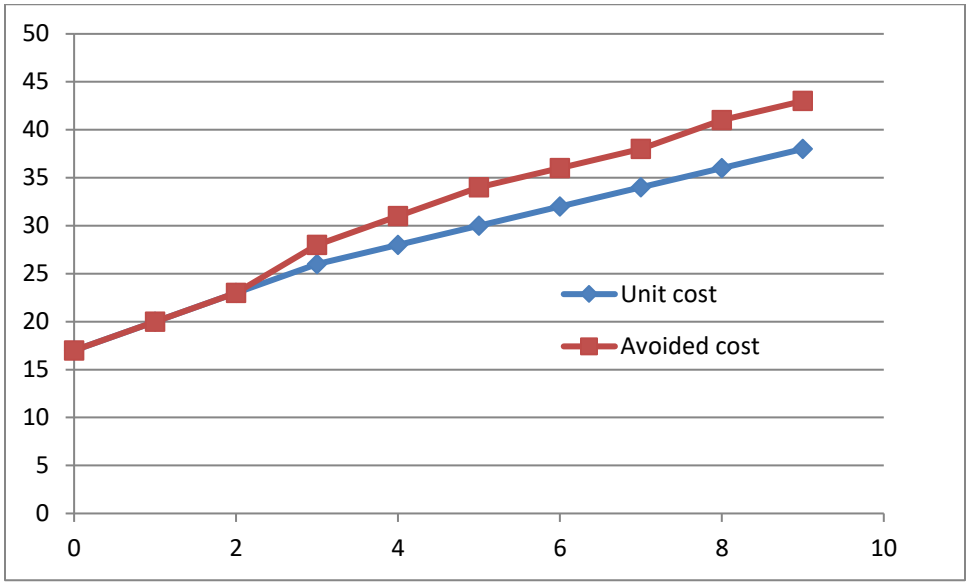

Figure 5.1- Benefits of Avoided Costs
Unit Cost Changes Over Time

5.3.1 *Example of Cost Avoidance: Non-Consent Towing*

A current example of cost avoidance was observed in the research project report, "Non-Consent Towing Cost Study in Utah." A significant increase in the charges allowed for towing companies to remove a disabled vehicle from an accident site was proposed by towing companies and their association.

A research team analyzed various towing company operations and expenses. The authors recommended that increases should be based on national business inflation trends, not random increases. As a result, increases were allowed over time, but excessive towing cost increases were avoided.

5.4 Improved Life and Performance of Transportation Facilities

Enhancement to UDOT facilities is a fundamental aspect of the Research Program and UDOT goals. Improving how the department plans, designs, constructs, and maintains Utah's transportation facilities can have a huge impact on the economy, environment, and tourism.

Examples of how research enhances these facilities are:

- Pavement and bridge life extension
- Improved rehabilitation and maintenance methods

- Highway design advancements
- Traffic control enhancements

5.5 Cost Savings to UDOT and Transportation Users

The most direct benefit that may be measured is related to cost reductions realized by UDOT staff, operations, or the traveling public. The main types of cost information are in the form of direct savings in manpower, savings in the form of user costs, and benefits to key partners.

This is considered to be a fundamental characteristic of transportation research. The Utah Department of Transportation strives to become more efficient and effective in all aspects of the programs and projects under its authority. Excellence is expected from UDOT staff, consultants assisting with the workload, and contractors completing facility construction and maintenance.

Research projects have been shown to be an effective way to accomplish goals, including:

- Reduced construction costs
- Lower operational costs
- Decreased manpower requirements
- More efficient and trained staff
- Reduced materials costs
- More efficient equipment
- Better utilization of existing equipment
- Improved management efficiency

5.6 Safety Benefits

Enhanced safety is one of UDOT's key goals, and is reflected in virtually every aspect of its diverse operations. A "safe arrival" is fundamental to every trip on a daily basis.

Research to produce and implement innovative processes, regulations and products are required to improve safety. Improvements to highway safety can be directly measured in some instances on specific highway sections and estimated on a system basis in other applications.

Safety goals include:

- Crash numbers reduced
- Severity of crashes reduced
- Construction zone safety improved

The benefits related to these safety enhancements or programs can be estimated by projecting the number of crashes prevented and the severity of these crashes. Table 5.2 provides cost estimates of crashes by severity used on a national level.

Table 5.2 Average Cost Per Crash Based on Severity
FHWA Safety Program
(Currently Used by UDOT)

Crash Severity	Crash Cost
5- Fatality (K)	$11,295,400
4- Serious Injury (A)	$655,000
3- Minor Injury (B)	$198,500
2- Possible Injury (C)	$125,600
1- Property Damage Only (O)	$11,900

5.7 Congestion Reduction Benefits

Maintaining efficient traffic flow is a major goal for all UDOT programs. Measurements of travel time and levels of service on major facilities are valuable input related to the effectiveness of adopted innovative processes.

Congestion-related goals include:

- Commuting congestion decreased
- Construction zone delays minimized
- Crash delays reduced
- Multi-modal utilization

5.8 Environmental and Wildlife Benefits

Many of UDOT's programs and facilities have a direct impact on the environment. Often safety improvements are tied to projects, programs and policies other than directly linked to environmental and wildlife initiatives. A significant goal for UDOT is to achieve the benefits listed below. Minimizing these impacts provides a benefit to the general welfare of the public.

- Minimize the footprint of transportation facilities
- Decrease emissions and particulates to improve air quality
- Reduce chemical discharges from pavements and materials
- Avoid existing wetlands when possible and mitigate wetlands that are impacted
- Improve animal migration to reduce conflicts along highways
- Reduce impacts to endangered species and their habitats
- Control noxious weeds on rights-of-way
- Omit or minimize noise to communities

- Avoid flooding through improved hydrological methods

5.9 Decisions To "Not" Do Something

Sound research methods and results can lead to policies and actions by the department to "not" adopt or engage in a new or proposed initiative. These may include:

- Avoid inefficient highway expenditures
- Modify standards to eliminate poor designs
- Replace specifications, guidelines and policies that are unsuccessful
- Reassign staff where they are not productive
- Find alternatives to inferior technologies

5.10 Institutional Knowledge

Some projects provide a direct benefit to transportation experts and managers in the form of institutional knowledge. These have been shown to be:

- Informed staff and stakeholders
- Understanding industry advancements
- Knowledge of future trends and challenges
- Improved awareness of UDOT's goals and focus areas
- Enhanced program to develop management skills
- Identification of training needs

5.11 Project Grades

The research products and deliverables were further evaluated to estimate the success of the project findings using a grading system. Each deliverable received a grade from the end user based on the definitions listed in Table 5.3.

Table 5.3 Grade Definitions

Grade	Definitions
A	Major impact: New or revised specifications, policy, methods, etc.
B	Significant impact: Improved operations, procedures or policies
C	Contributed to state of the practice or institutional knowledge
D	Unclear or contradicting findings: More study needed
E	No contributions: Implementation not recorded

5.12 Conservative Benefit Estimates

Steps were taken as part of the interview and verification process to ensure that the benefit estimates used in the study remained conservative. The following three methods were employed to obtain benefit values that can be justified easily:

1- Each champion was asked to provide minimum benefit values that could be supported with data, methods or other analysis.
2- A percentage was used for some projects where only a portion of the total benefit of the initiative could be attributed to the research project. Other divisions or regions may have contributed significantly to the effort separately from the research project.
3- Where a range was provided by the end user, the lower end of the range was used in the calculations.

5.13 Verifying Survey Responses

The survey input was routinely reviewed and verified to ensure that the information was obtained using valid data and methods. Where no response was provided, attempts were made to aid end users in preparing surveys and help them better understand the survey questions.

The following questions were utilized when interacting with the project champions and end users:

5.13.1 Surveys That Provided Dollar Benefits

- Can you describe the data and methods used to calculate the benefits estimate?
- Were the benefits estimates conservative and justifiable?

5.13.2 Surveys with A or B Grades but No Benefits Provided

- Can you explain why you gave the project an A or B grade but no dollar benefits?
- Was the project successful, but you could not estimate benefits in dollar form?
- Can we provide assistance in estimating dollar benefits related to the project success that accurately represents the value of the deliverables?
- Was the project successful and valuable but not implemented for some reason?
- How can we aid in the implementation of the deliverable(s)?

5.13.3 Surveys Not Returned

- How can we help you understand the survey questions and complete the survey?
- Is there someone else that would be more qualified to complete the survey?
- Are you having problems understanding the project goals, deliverables, or how the results have been utilized?
- How can we aid in resolving these issues?
- Would other experts be able to help you complete the survey?

5.14 Survey Question Feedback

The use of online Google Forms has many advantages. The survey tools allow the researcher to evaluate the appropriateness and effectiveness of each survey question.

The quality of the survey questions, supplementary information, and the survey formats have improved over time. The inclusion of reporting on more types of benefits definitely has enhanced end-user awareness and the quality and quantity of data received.

5.14.1 Survey Question Assessment

Google Forms displays the results in formats that enable the user to better evaluate the input from the survey questions. Some questions initiate a response more often than others, and some are more useful than others.

If a question is rarely answered, the wording of the question may need to be revised to obtain the desired feedback. More explanation of what the question is trying to find out may also be needed.

The survey results summarized in Table 5.4 and illustrated in Figures 5.2 and 5.3 shows how the feedback for each survey question may be evaluated. Poor or confusing responses should indicate that the question may need to be:

- Reworded,
- Eliminated, and/or
- More explanation provided.

Table 5.4 Survey Question Responses for 2017-2019 Completed Research Projects

Survey Question	Responses	Benefits $M	Percent Benefits
Asset Improvement	10	$23.28	20.8%
User Impacts	5	$19.35	17.3%
Safety Impacts	9	$19.50	17.4%
Cost Savings to UDOT	3	$24.29	21.7%
Environmental/Wildlife	-0-	-0-	-0-
Policy/Administration	3	$0.23	0.25
Institutional Knowledge	3	$24.76	22.1%
Other - Peer Exchange	1	$0.34	0.3%
TOTALS	**34**	**$111.79**	100%

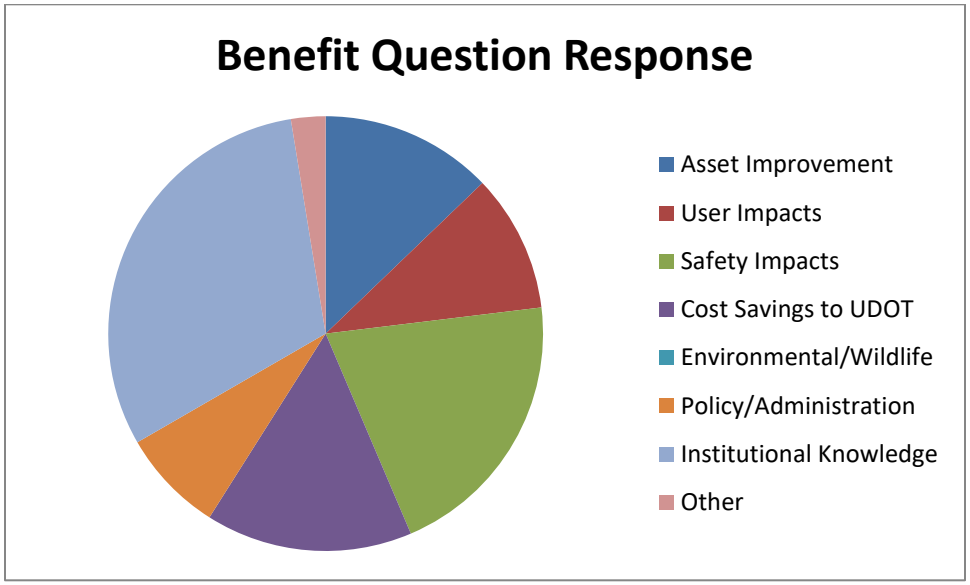

Figure 5.2 Survey Question Response Distribution

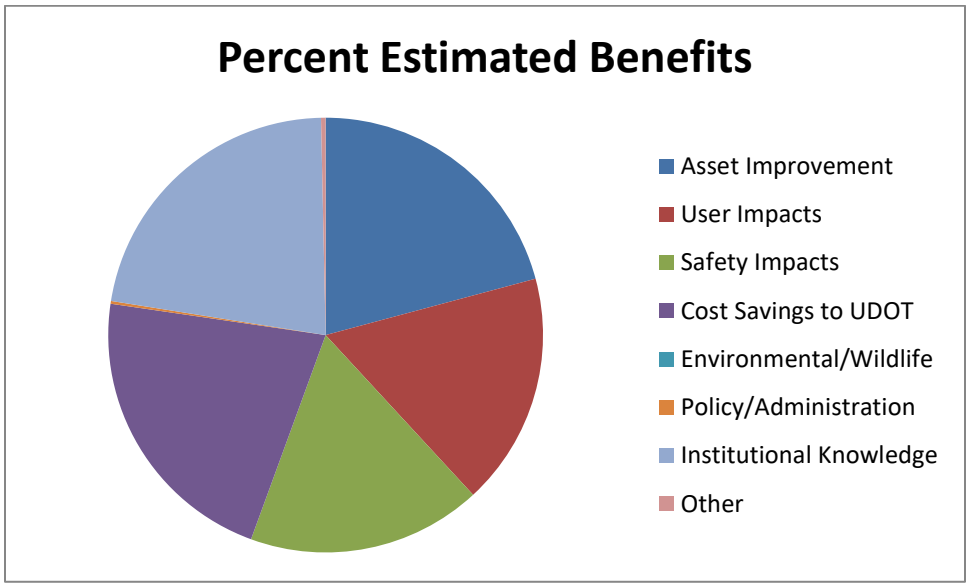

Figure 5.3 Survey Question Benefits Distribution

This feedback indicates that there was a very good distribution of both number of responses and the dollar benefits. Often, an example of how the question has been answered in the past may be useful to the end user completing a survey.

6.0 SUMMARY OF BENEFITS BY PROJECT

The benefits achieved by the UDOT Research and Innovation Division were very significant for the projects completed during 2016, 2017 and 2019. A total of 50 surveys (68%) of the 73 deliverables from 57 research projects were evaluated in this study. An estimated $111,794,000 in benefits was reported through the survey from the implemented products. The following is a summary of these benefits:

6.1 Safety Accomplishments

Project Title: *Driver Compliance at Enhanced Pedestrian Crossings in Utah* (UT-19.03)
Deliverables and Outcomes: Updated guidelines on which pedestrian enhancements are appropriate for certain conditions.
Benefits: $609,816. This study has helped in deciding what pedestrian treatments should be used at crossings statewide. (4% of the crash severity)

Project Title: *Investigation of Utah Highway Speed-Limit Compliance Rates and Evaluation of Speed-Limit Design in Towns Along Highways* (UT-19.26)
Deliverables and Outcomes: We are currently rewriting our speed limit policy.
Benefits: $86,114. This study has provided an estimated safety benefit (1% of the crash severity).

Project Title: *Guidance for Enhanced Pedestrian Treatments Within Reduced-Speed School Zones (RSSZs)* (UT-19.29)
Deliverables and Outcomes: Adjustments to warranting processes and guidelines.
Benefits: $551,856 (4% of the crash severity)

Project Title: *Using a Safety Forecast Model to Calculate Future Safety Metrics* (UT-17.10)
Deliverables and Outcomes: The intended implementation activities were to explore potential changes to how we include safety considerations in planning prioritization.
Benefits: $18,000. This research ended up informing us that using a more rigorous prioritization would cost the Department 120 projects per year x 1 hour x $150 = $18,000 per year.

Project Title: *Left-Turn Signal Warrant Procedures: A Synthesis of Practice* (UT-17.14)
Deliverables and Outcomes: Adjustments to our left-turn warranting process.
Benefits: $1,208,564. This study has provided an estimated safety benefit (2% of the total of the values of crash severity).

Project Title: *An Analysis of Decision Boundaries for Left-Turn Treatments* (UT-19.05)

Deliverables and Outcomes: To understand the safety and mobility characteristics of different types of left turn treatments in order to refine current implementation practices.

Benefits: $1,208,564. This study has provided an estimated safety benefit (2% of the total of the Crash Severity)

Project Title: *Assessment of the Effectiveness of Wrong-Way Driving (WWD) Detection System* (UT-19.13)

Deliverables and Outcomes: It has been determined that radar technology alone is not sufficient to properly detect WWD incidents.

Benefits: $10,000,000 in savings resulted from this research which resulted in UDOT avoiding the expense of trying to use radar alone for WWD incident detection. (estimated # of off-ramps x average cost to deploy a radar unit = 800 x $10,000 = $8,000,000).

Project Title: *Literature Search and Scan Tour of Wrong-Way Driving Mitigation Measures Across the United States* (UT-17.17)

Deliverables and Outcomes: Do a national literature search on WWD mitigation measures, and identify locations for doing a scan tour to observe WWD mitigation implementations.

Benefits: $2,000,000. UDOT is not moving forward with adding or adjusting signage accordingly. Assuming such additions or adjustments would equate to about $2500 in labor and material costs per off-ramp, this equates to a savings of about 800 off-ramps x $2500 per ramp = $2,000,000.

Project Title: *Impacts of Bus Stop Improvements* (UT-18.04)

Deliverables and Outcomes: This research supports a continued effort to improve bus stops.

Benefits: $46,512. Ridership nearly doubled and paratransit was cut in half. This calculation assumes 10 additional riders who pay $129.20 per month (per UTA calculator) to drive 10 miles round trip to work, for 5 years. This is the cost of fuel at 25 mpg and does not account for bus fare (which is negligible compared to other vehicle costs).

6.2 Pavements and Materials Accomplishments

Project Title: *Evaluation of Secondary Consolidation Settlement Associated with Embankment Construction for Fast-Paced Transportation Projects in Utah* (UT-17.22)

Deliverables and Outcomes: A method for designing surcharge fills considering post-construction secondary compression settlement.

Benefits: $32,594,600 in benefits as a result of this project.

Asset Benefit: $7,000,000. A method for designing surcharge considering post construction.

User Impact: $10,000,000. Freeway disruption.

Safety Impacts: $14,594,600. We've probably saved a life from a large bump causing a car to lose control in icy conditions.

Institutional Knowledge: $1,000,000. Simplified surcharge needed for a site.

Project Title: *Evaluation of Curve Fitting Techniques for Estimating End of Primary Consolidation Settlement: Provo Westside Connector Project, Utah* (UT-17.23)

Deliverables and Outcomes: The research evaluated whether there is a better method to determine the end-of-primary settlement than the method being used.

Benefits: $60,000. As a result of this research, we know that the evaluations we have been doing are more efficient than if using the finite difference technique.

Project Title: *Typical and Darkened Portland Cement Concrete Pavement: Temperature, Moisture, and Roughness Analyses* (UT-17.02)

Deliverables and Outcomes: Determine if Darkened Concrete should be used.

Benefits: $1,000,000 in benefits as a result of this research, assuming $1 per square to add pigment that we determined is not needed (cost avoidance) for 1 million sq yds.

Project Title: *Simplified Standard Penetration Test Performance-Based Assessment of Liquefaction and Effects - Updated Liquefaction Parameter Mapping* (UT-18.10 and UT-18.11)

Deliverables and Outcomes: The spreadsheet produced by this research project is required to be used by the Geotechnical Manual of Instruction for all liquefaction designs.

Benefits: $7,500,000. If they mitigate 30 bridges and 10 percent mitigation then 3 bridges x $500,000 cost of mitigation for five years.

Project Title: *Rapid Concrete Repair* (UT-19.08)

Deliverables and Outcomes: Develop a non-proprietary rapid concrete repair specification.

Benefits: $2,500,000 in benefits as a result of this research. 60 percent cost savings on concrete panel replacements $400 per sq yd bid in 2018, $660 per sq yd for precast panels and $225 for rapid-set panels, 2200 sq yds in 2020 and 1600 sq yds in 2021, so $0.5M/yr for 5 years.

6.3 Maintenance & Stormwater

Project Title: *Review of the UDOT Procurement Process - Maintenance Management System* (UT-19.18)

Deliverables and Outcomes: Fully implemented maintenance management system.

Benefits: $300,000.

$100,000. The maintenance management system has been integrated with FINET and the HR system.

$100,000. Policies and HR rules have been programmed into ATOM, which makes it easier for maintenance personnel to understand their policies.

$100,000. Providing this opportunity to other maintenance personnel will expand the knowledge of maintenance assets and activities.

Project Title: *Hotspot and Sampling Analysis for Effective Maintenance and Performance Monitoring* (UT-17.12)

Deliverables and Outcomes: Performance Measures for the UDOT Maintenance Division.

Benefits: $580,000

-Asset Improvement: The original sample size was 100% of all assets. Assuming we spend $500,000 yearly on data collection, reducing the sample size to 16% would save UDOT $80,000.

-Cost Savings to UDOT: $420,000

-Policy Administration: This is 16% of $500,000 = $80,000

Project Title: *Implementation of Aerial LiDAR Technology to Update Highway Feature Inventory* (UT-17.06)

Deliverables and Outcomes: Cost savings with the yearly LiDAR data collection for UDOT roadway assets and condition.

Benefits: $19,120,000

-Asset Improvement: Using the published costs per mile for both the aerial and mobile LiDAR. Assuming 4000 center lane miles+ $1,190,000 x 5 yrs YTD = $9,520,000.

-Cost Savings to UDOT: Based on information above. Assume 4000 lane miles = $1,200,000 x 8 yrs YTD = $9,600,000.

Project Title: *Update of the Class 8 Truck Study* (UT-19.23)

Deliverables and Outcomes: To get our replacement schedule of plow trucks down to 10 years.

Benefits: $1,680,000. We looked at the maintenance costs of trucks with the longer replacement costs and compared the cost. Implementing a younger fleet saved $.7M per year for 3 years, totaling $1,680,000.

6.4 Cost Savings to UDOT

Project Title: *UDOT Research Peer Exchange, October 12-13, 2016: Implementation, State DOT Library, National Committees, and State Transportation Innovation Council* (UT-17.08)

Deliverables and Outcomes: We improved our implementation ratio as a result of the lessons from the peer exchange focused on this topic.

Benefits: $380,000. There are two parts to this calculation due to topics of the peer exchange: 1) The implementation topic improved our ratio from 2016 (14 to 1) to 2020 (19 to 1). This amounts to $130,000. 2) The national committee topic resulted in at least two funded NCHRP projects worth $1M combined. Assuming the benefit to UDOT is 25%, then the value is $250,000.

Project Title: *Transportation Engineering Project Management: Survey of Practice* (UT-17.03)

Deliverables and Outcomes: Better use of UDOT's scheduling system.

Benefits: $9,750,000 in cost savings annually x 5 yrs. Using 52 (weeks) x 50 (UDOT and Consultant PMs) x 5 (hours in time savings per week) x 150 (loaded rate).

Project Title: *Evaluation of UDOT's Preconstruction Schedule Process* (Internal Document) (UT-18.19)

Deliverables and Outcomes: Better understand how to leverage schedules to improve performance.

Benefits: $2,500.000. Reduce costs with implementation for the next five years. Better inform future procurement of scheduling system. $500,000 x 5 years = $2,500,000.

6.5 Structures and Geotechnical Accomplishments

Project Title: *Lateral Resistance of Piles Behind Walls* (and other related studies - 7 total reports)
(UT-18.12, UT-18.13, UT-18.14, UT-18.15, UT-18.16, UT-18.17, UT-18.18)

Deliverables and Outcomes: Refine design process of piles behind MSE walls.

Benefits: $15,450,000. Benefits as a result of 7 projects.

-Asset Improvements: $5,000,000. There was no objective to save money with this project. The object was to define unknowns in design of piles behind MSE walls. Information was lacking on lateral pressures imparted on MSE walls by pile installed behind them. A major condition where this would happen would be during a major seismic event. Without this research, we would only be making our best assumptions on how far behind MSE walls piles need to be installed to have adequate lateral resistance and to not cause damage to the MSE walls. The cost estimate was made based on the hypothetical condition that without this research 10 bridges and associated MSE walls near the epicenter of a quake would be damaged, and that the repair of each bridge/wall would be $500,000. With this research, those repairs will not be required as that hypothetical damage will not happen.

-User Impacts: $9,200,000. Assume each of the 10 bridges is closed for 1 month. 4 high-volume structures at $1.1M/structure and 6 medium-volume structures at $.8M/structure is a total benefit of $9.2M.

-Safety Impacts: $1,250,000. A possible injury avoided at each bridge site.

Project Title: *Shaking Table Tests to Evaluate Effectiveness of Vertical Drains for Liquefaction Mitigation and Reliability of FEQ Drain for Modeling Performance of Sand Treated with Large Diameter Prefabricated Vertical Drains for Liquefaction Mitigation* (UT 18.20 and UT 18.21)

Deliverables and Outcomes: Determine the effectiveness of vertical EQ drains as a less costly alternative for certain bridge sites to conventional mitigation approaches to mitigate for liquefaction.

Benefits: $2,000,000. Compared mitigation using conventional stone columns vs. EQ drains - site with 2 abutment areas at 100’ by 150’, treatment depth of 30’. Installation unit costs: $100/ft stone columns, $15/ft for ED drains; Installation time: 30 min SCs, 5 min EQDs. Total Estimated Costs: $2.6M for SCs, $600K for EQDs.

6.6 Institutional Knowledge

Project Title: *Surveying Non-Motorized Travel Behavior at At-Crossing Rail Crossings* (UT-19.02)

Deliverables and Outcomes: Possible adjustments to signage at rail crossings.

Benefits: $500,000. Diagnostic teams that make recommendations for rail crossings could have some background information to support decisions of the team. I estimate that this could provide upwards of $100,000 in savings on projects per year over the next 5 years.

Project Title: *Impact of Shared Autonomous Vehicles on Vehicle Miles Traveled in Utah* (UT-19.10)

Deliverables and Outcomes: Industry information and understanding future trends.

Benefits: $50,000. This project provided information to help UDOT staff and stakeholders better understand industry advancements and future trends and challenges. The benefit was estimated as 0.5% of $1,000,000 worth of expenditures.
$50,000. This project helped provide more reliable information to staff and stakeholders regarding transportation investments. Benefit was estimated as 0.5% of $1,000,000 worth of expenditures.

Project Title: *Key Enhancements to the WFRC/MAG Conventional Four-Step Travel Demand Model* (UT-19.14)

Deliverables and Outcomes: Updates or enhancements to the WFRC travel demand model's auto ownership model, non-motorized trip model, and intrazonal trip calculation.

Benefits: $100,000. This project helped advance tools used to plan roadway improvements, thus helping avoid inefficient highway expenditures. Benefit was estimated as 0.5% of $1,000,000 worth of expenditures.

7.0 PROGRAM BENEFIT-COST RATIO

A summary of the methods and calculations used to estimate the benefits, costs and benefit-cost ratios are provided in the following section. Again the data utilized in the calculations were conservative based on both the methods utilized and through individual discussion with the end users completing the surveys.

7.1 Benefit Calculations

Benefits = Number x Value x Percentage

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

➢ **The total estimated benefits from the 73 deliverables are $111,794,000.**

7.2 Cost of Research Estimates

Research Program Three-Year Cost = Contract amount + TAC costs + PM costs

Program cost estimates included all project costs even for projects where benefits could not be identified or when a survey was not returned.

7.2.1 Contract Amounts

The total contract amounts were obtained from the project files and documents for the years included in this study. Members of the project advisory committee spent significant time obtaining precise contract amounts for each project evaluated. This effort is required to obtain accurate information for the benefit/cost estimates, and is greatly appreciated by the authors.

Total Contract Amount Cost (3 years) = $3,459,435

7.2.2 Technical Advisory Committee (TAC) Investment

A project Technical Advisory Committee (TAC) provides project oversight, data, information, deliverable reviews, and discussions in meetings. The TAC costs related to project oversight were estimated by using averages of the number of TAC members, the number of hours committed to the meetings, the number of meetings held per project, and an average loaded project TAC member hourly rate. The factors used in this analysis are summarized in Table 7.1.

It was assumed that an average TAC had six members, met five times, and required three hours of time for each member, including preparation. An average hourly wage of $60 ($40 with 50% overhead) was assumed.

Table 7.1 Recommended Project Factors for Technical Advisory Committees (TAC)

Factor	Recommended
Average Project Management Cost per Project	$9,000
Average Number of Project TAC Members	6 people
Average Hours per Member per Meeting	3 hours
Average TAC Meetings per Project	5 meetings
Average TAC Member Loaded Hourly Rate	$60 per hour

TAC Costs = 6 members x 3 hrs x 5 meetings x $60/hr x 57 projects = $307,800

7.2.3 Project Management (PM) Costs

The cost to provide project management for the projects was estimated using 26% of the average project cost of $34,000. This resulted in an estimated average PM cost per project.

Average PM cost estimate = $9,000 per project

A high level of project management costs was selected to cover expenditures related to implementation of the project products. Future studies should strive to measure implementation costs more accurately, separate from PM costs.

PM Costs = 57 x $9,000 = $513,000

- **The total cost of the 57 projects is estimated at $4,280,235.**

7.3 Benefit-Cost Ratio Calculations

Benefit-Cost Ratio = Total Program Benefits/(Contract + TAC + PM costs)

- **Benefit-Cost Ratio = 111.794M/4.28M = 26.1** **Use 26**

Table 7.2 Benefit-Cost Summary of Three-Year Program

	Number	Amount	Total
Total Benefits			$111,794,000
Contracts	57 projects		$3,459,435
TAC Costs	6 members x 3 hrs x 5 meetings x 57 projects	$60 per hour	$307,800
PM Costs	57 projects	$9,000 per project	$513,000
Total Costs			$4,280,235
Benefit/Cost			26

The benefit-cost estimate determined in this study indicates that every dollar invested in research projects results in a return of $26 in benefits to our transportation system.

This value is considered to be conservative and somewhat lower than the actual benefit-cost estimate. A relatively good survey response of 68% was achieved, but significant benefits of other projects could not be measured.

The response percentage was due to a number of factors including:

- Turnover within UDOT assignments
- A significant number of employee retirements
- End users feel they are too busy to respond
- Lack of knowledge related to the project

For these reasons many of the end users asked to complete surveys did not feel qualified to respond or include benefit estimates in the form of dollars.

7.4 Benefit-Cost Ratios for Project Types

To address a wide scope of transportation needs, research program managers should adjust funding allocations to maintain the optimal level of funding for each research project type. A review of the benefits produced by project type in the survey can be used to observe these levels.

Table 7.4 shows the benefits estimated through the surveys for the specific project types. These are basically the same areas of study determined at the Annual UTRAC Workshop for research prioritization. Breakout session attendees review problem statements and view presentations by experts submitting the topic for funding. UDOT personnel are approved to vote on the problem statements and prioritize them for research funding.

The benefits tabulated in Table 7.4 are compared with the UTRAC project groups. The projects competed in 2017, 2018 and 2019 indicate that the program performed well in the areas of Materials and Pavements, Structures and Geotechnical, and Maintenance. The high benefit-cost ratios observed are significant. The Planning and Traffic & Safety groups also performed well.

Figures 7.1 and 7.2 provide a view of the distribution of benefits by project type, and the benefit-cost ratio by project type. These distributions may be used as feedback to make adjustments to future project funding.

Figure 7.3 illustrates the number of projects in each project type compared with the benefits achieved by each type. Projects conducted on high-value assets such as pavements, structures, and maintenance activities, resulted in higher benefits from fewer project numbers.

Table 7.3 Benefit-Cost Ratios for Project Types
2017-2019

Project Type	Number of Deliverables	Percent of Deliverables	Benefits Estimated (Millions)	Benefit-Cost Ratio
Materials & Pavements	13	18%	$42.65	43.5
Maintenance	7	10%	$22.68	43.1
Structures & Geotechnical	8	11%	$17.45	32.3
Planning	9	12%	$12.25	21.1
Traffic & Safety	26	35%	$15.56	12.8
Public Transportation	10	14%	$1.20	2.8
Aeronautics	-0-	-0-%	$-0-	-0-
Environmental & Wildlife*	-0-	-0-%	$-0-	-0-*
TOTALS	73	100%	$111.79	26

**Environmental issues were addressed as part of other programs, including maintenance, planning and safety studies*

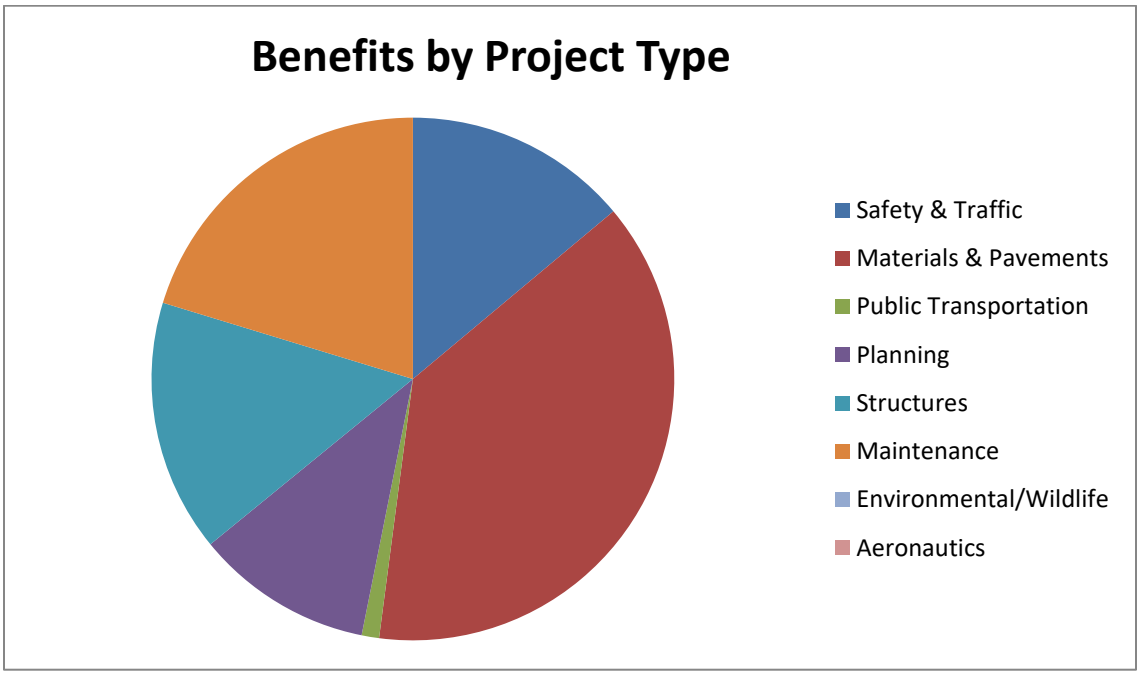

Figure 7.1 Benefit Estimates by Project Type

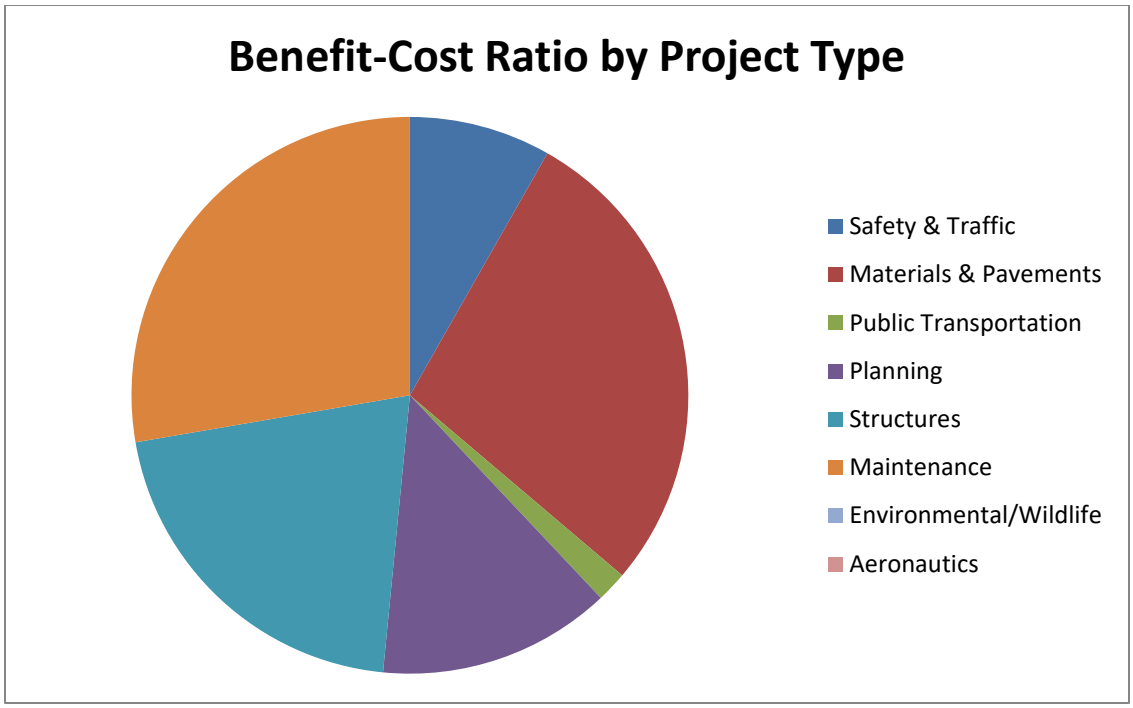

Figure 7.2 Benefit-Cost Ratio by Project Type

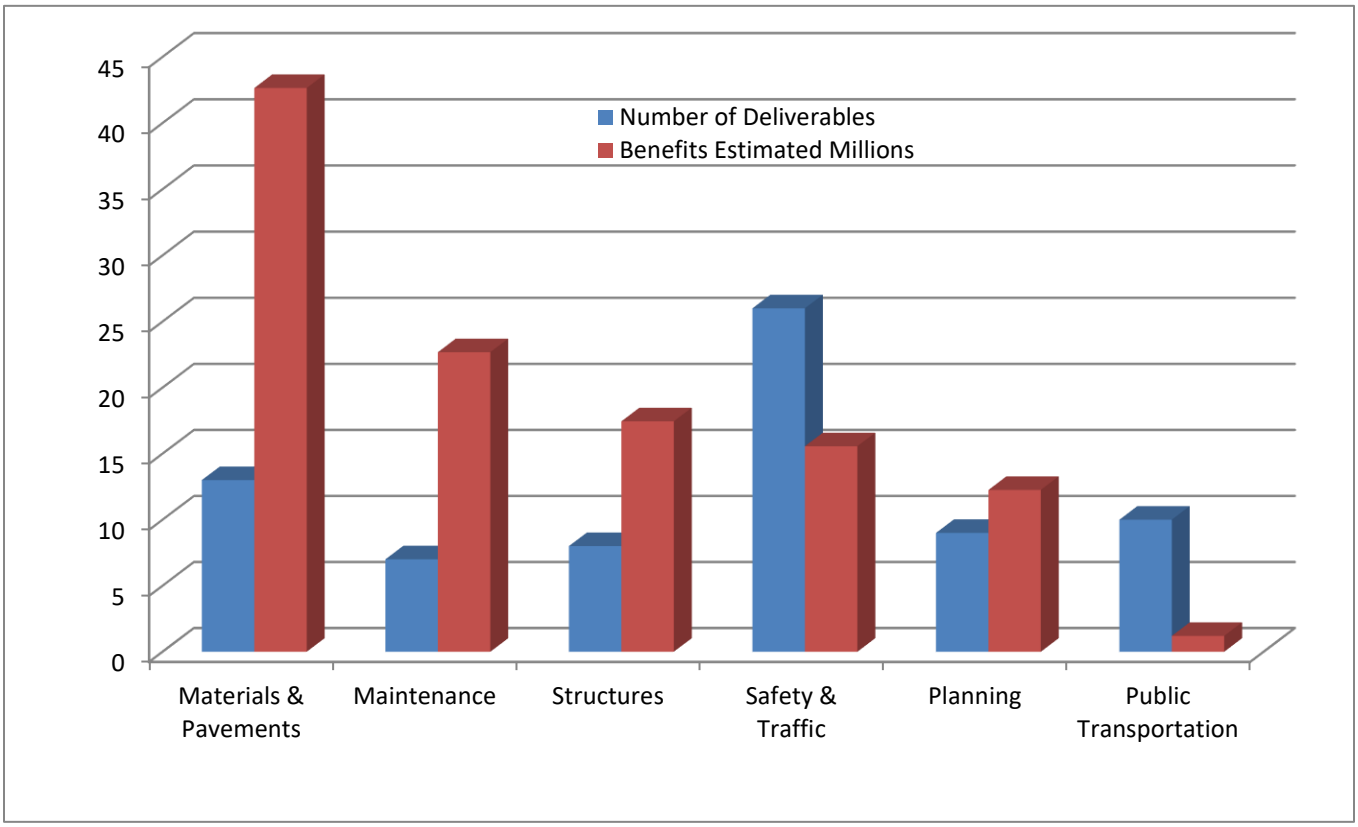

Figure 7.3 Number of Deliverables and Benefits ($Million) by Project Type

8.0 TRENDS IN BENEFIT-COST RATIOS

The trend in benefit-cost ratios from previous studies is illustrated in Table 8.1 and Figure 8.1. A significant increase is observed in the ratios in general over time. This trend is considered to be related to many factors based on the performance of the Research and Innovation Division, survey improvements, and other factors.

Table 8.1 Benefit-Cost Ratios from Previous Studies

Year Reported	Years Evaluated	Number of Deliverables	Percentage of Surveys Returned	Benefit/Cost Estimates
1995	1991-1993	18	--	13-15
2000	1995-1997	22	77%	12
2010	2006-2008	41	78%	17
2016	2009-2012	66	37%	14
2020	2013-2016	63	67%	19
2023	2017-2019	73	68%	26

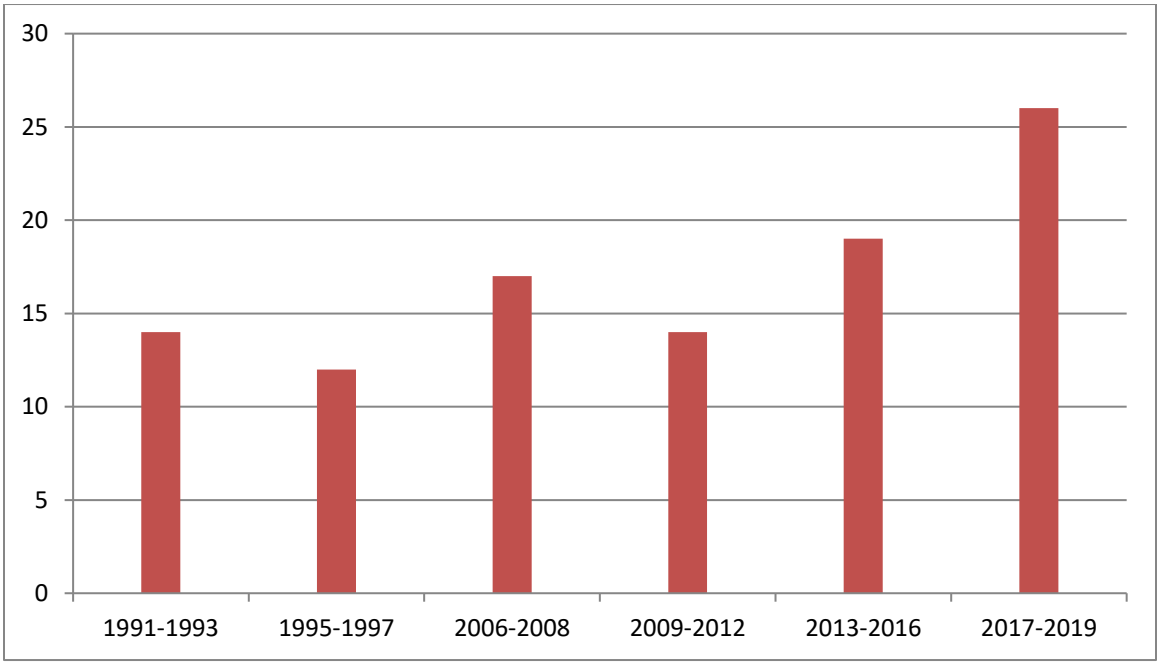

Figure 8.1 Trend in Benefit-Cost Ratios

The benefit-cost ratios shown were estimated in studies that were completed over the last 28 years. All six of these studies produced benefits values that are considered to be conservative and on the low side. Survey response has been as low as 37% (2016).

Possible factors leading to a higher benefit-cost ratio for projects completed in the years 2017, 2018 and 2019 are:

Project-Related Factors:

- Higher quality of Problem Statements submitted to the UTRAC Process
- Better project selection through UTRAC Workshop balloting
- Higher deliverable quality through project conduct standards
  Improved project management methods utilized by UDOT's Research staff

Survey-Related Factors:

- High survey response (68%)
- Improvements in the survey utilized
- Enhanced outreach to end users
- Follow-up interviews, emails, and telephone conversations were used to promote increased response to the surveys
- Improved verification methods to validate benefits reporting

System-Related Factors:

- Increased user costs over time; higher than research project cost increases
- Higher crash costs increasing safety project benefits

9.0 PROJECT GRADE SCORES

Project champions and end users were asked to give each deliverable a grade. The definitions used were listed previously in Table 5.3. The Grade Point Average (GPA) information submitted is summarized in Table 9.1.

Table 9.1- Project Grades by Project Types

Project Type	A	B	C	D	E	GPA
Materials & Pavements	5	1	4	0	0	3.1
Structures & Geotechnical	0	1	7	0	0	2.1
Maintenance	1	3	2	0	1	2.4
Public Transportation	1	2	4	0	0	2.6
Traffic & Safety	1	4	6	0	2	2.2
Planning	1	1	2	0	1	2.2
Totals/Average	9	12	25	0	4	**2.5**

An average GPA of 2.5 (on a 0 to 4 scale) was reported for the 50 surveys submitted for the 73 deliverables evaluated. This is a B- grade.

There appeared to be a significantly high range in GPA at the individual project level with 4 failing projects and 9 given an A grade. Each of the project types showed an average range in GPA from 2.1 to 3.1.

A review of three of the four projects with failing grades indicated that some confusion resulted in these scores. Projects that met the objectives should receive a passing grade even if the concept being evaluated was not adopted. Just because the research concept did not prove to be useful does not necessarily mean that the project was a failure. A higher grade would have been appropriate since this was the case. It is recommended that the Grade Definitions be revised in future studies to better explain how to score projects.

The definitions used in this survey should be changed back to previous wording to better define a failing grade for a research project. Evaluating a concept effectively contributes to UDOT's institutional knowledge (C grade).

The E grade definition should be changed from "No contributions: implementation not recorded" to "Major tasks not completed: Objectives not met." The second definition was used in all five of the surveys done in previous years. This definition refers to the "tasks and objectives," not the "contributions and implementation."

10.0 PROGRAM BALANCE

A well-balanced research program is vital to engage in all areas of significance within the department and in statewide transportation needs. The balance of the program should be scrutinized annually to review the impact of projects in each functional area.

Both the number of projects and the portion of the budget dedicated to each type of project should be monitored. Annual review of the program balance enables research managers to set priorities for future projects. This helps to keep each area of study engaged in research initiatives to improve operations in all areas of UDOT's responsibility.

10.1 Balance in Terms of Project Numbers and Funding Levels

The projects funded through the UTRAC process resulted in the balance shown in Table 10.1 for the three years evaluated. Figures 10.1 and 10.2 illustrate the distribution of project numbers and funding.

A review of program balance from previous years is useful to track trends in program balance, and to determine if changes desired have been met.

Table 10.1 Program Balance for Project Types
2017-2019

Project Type	Number of Deliverables	Percent of Projects	Percent of Funding Allocated
Safety & Traffic	26	35%	22%
Materials & Pavements	13	18%	20%
Public Transportation	10	14%	15%
Planning	9	12%	17%
Structures	8	11%	13%
Maintenance	7	10%	12%
Aeronautics	-0-	-0-	-0-
Environment/Wildlife*	-0-	-0-	-0-
TOTAL	**73**	100%	100%

**Environmental issues were addressed as part of other programs, including maintenance, hydraulics, planning, and safety studies*

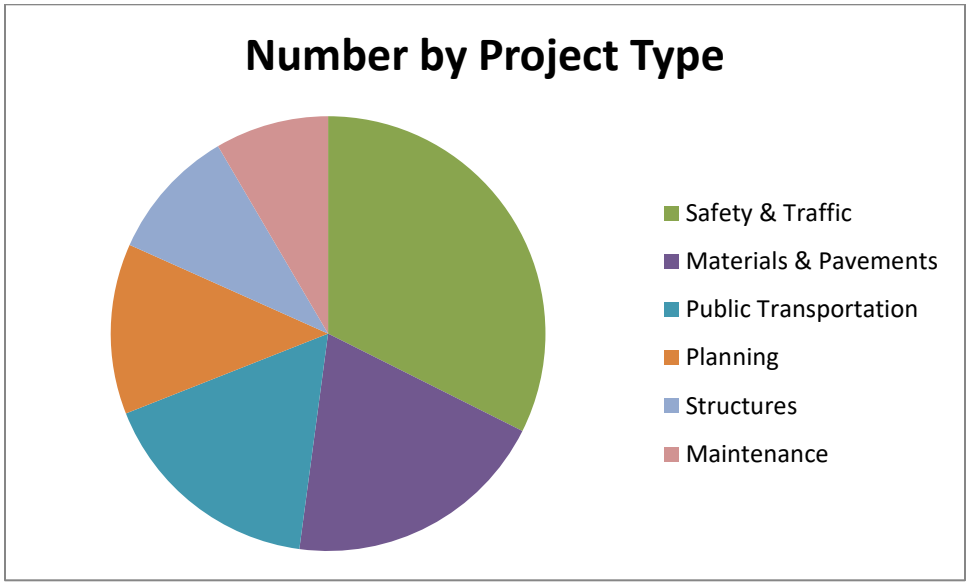

Figure 10.1 Program Balance for Project Types

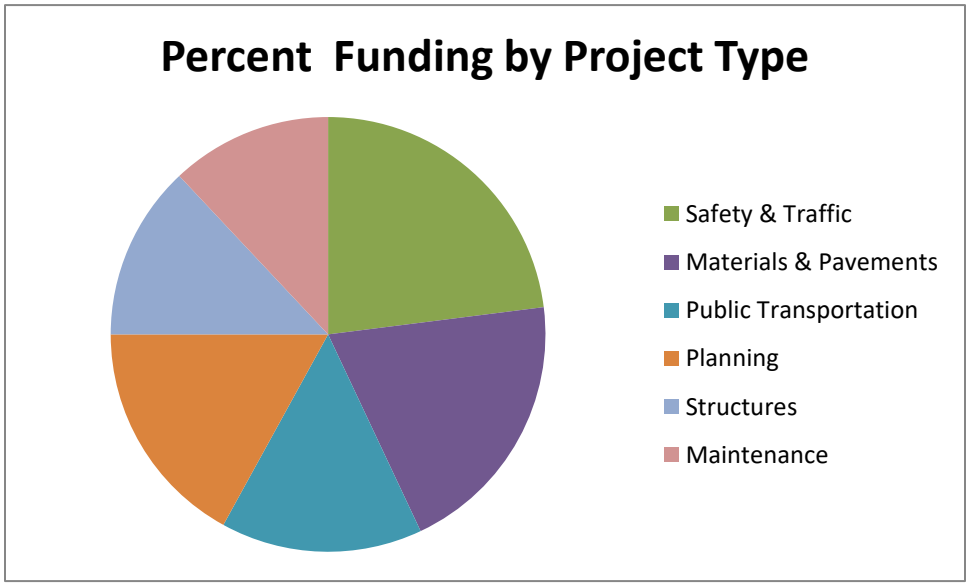

Figure 10.2 Program Balance for Project Spending

Certainly not all project type distributions should be equally represented, but a conscious effort should be made to evaluate and rebalance the research program as needed. The balance information should be reviewed by key leaders in the department, and feedback should be provided to research managers on this aspect of the research program.

Leaders in the Research and Innovation Division may choose to increase the number of projects and/or project funding levels where feedback from end users indicates that project deliverables have high benefits. This could be done through the UTRAC project selection process.

10.2 Additional Factors Related to Balance

A well balanced and effective research program should strive toward focus in a number of ways. When evaluating the outcomes of research, the issues that follow should be considered. The benefits resulting from each of these aspects of research should be used to fine-tune the research program to meet the needs of the organization and public in the best ways possible.

10.2.1 High-Value Transportation Aspects

A greater emphasis should be placed on the current needs of high-value areas. For example, big ticket items such as pavements and bridges should receive an appropriate portion of the research budget and emphasis. Also, safety improvements should be given a high priority.

10.2.2 Problem Solving vs. New Methods

An effective research program should maintain a balance between these two project types. Programs limited to problem solving tend to maintain the status quo. Too much reliance on innovative solutions may fail to give existing technologies sufficient opportunity to be successful. They may need only a minor adjustment to succeed. Implementing entirely new technologies can often be more costly compared to fine-tuning existing processes and programs.

10.2.3 Hard Research vs. Soft Research vs. Policy Research

Each of these types of research initiatives has been shown to produce significant benefit-cost ratios. Hard aspects of transportation receive large allocations from the transportation budget, and even modest improvements can be very beneficial in the long run. Soft research enterprises can result in significant improvements in reducing impacts to the environment, the traveling public, and businesses. Policy research is a crucial piece of any program, and can result in a high benefit for a small investment in program resources.

10.2.4 National Initiatives vs. Local Issues

Transportation research is an important aspect of our society at both national and local levels. State transportation agencies should provide support for both of these levels in the form of funding and technical assistance. Studies performed on a national level provide improvements that all regions of the country can use and on transportation issues requiring consistency from one state to another. Pooled-fund projects can greatly reduce overall costs for research activities.

Research initiatives undertaken at state and local levels generally deal with issues and problems unique to each region or state.

10.2.5 Applied Research vs. Basic Research

Most transportation research programs in the country dedicate a vast majority of their available resources to “applied” research. Basic research initiatives are best left to academic institutions, the private sector and/or specific governmental programs.

11.0 RESEARCH RELATED TO UDOT'S STRATEGIC DIRECTION

The UDOT Research and Innovation Division should review the outcomes of the completed projects and how they correspond with the department's Strategic Direction on an annual basis. The UDOT research program must be tailored to accentuate issues and initiatives identified by key leaders in the department. Figure 11.1 outlines UDOT's current Strategic Direction.

These strategic goals and key areas should be part of the research project selection process and impact significantly on the type of deliverables the projects produce. They should be of principal consideration when program balance is reviewed.

Observations of the Research Program in recent years show that proper emphasis has been given to the department's Strategic Direction. Problem statements selected through the UTRAC Workshop have given proper emphasis to these goals. UDOT's research managers have a strong tradition of ensuring that UDOT goals and areas of emphasis are well represented in the program balance review.

Figure 11.1 UDOT Strategic Direction

UDOT's Strategic Direction is built on the foundation of three Strategic Goals that guide and direct everything we do. The Strategic Direction is data- and performance-driven and is constantly updated to reflect what we are doing to meet these goals.

Zero Crashes, Injuries and Fatalities

UDOT is committed to safety, and we won't rest until we achieve zero crashes, zero injuries and zero fatalities. Zero is the only acceptable goal.

Optimize Mobility

UDOT optimizes traffic mobility by adding roadway capacity and incorporating innovative design and traffic management strategies. We are pioneering technology and project delivery methods.

Preserve Infrastructure

We believe good roads cost less, and through proactive preservation we maximize the value of our infrastructure investment for today and in the future.

12.0 UTRAC PROCESS ENHANCEMENTS

The Research and Innovation Division has sponsored the Utah Transportation Research Advisory Council (UTRAC) workshop and process for many years. The workshop is an extremely valuable asset for UDOT personnel, academic stakeholders and private-sector partners to achieve transportation improvements through the research program. The main purpose of the program is to identify problem-solving activities, initiatives for transportation enhancements, and concepts to address UDOT's most pressing issues.

Selection of the most appropriate topics for study plays a crucial role in obtaining optimum benefit for the budget expended. Asking the right question is essential for getting a usable answer. The UTRAC process reliably aligns the available funding with the submitted problem statements.

The UTRAC Workshop has a strong history of providing the following:

- Problem Statements related to pressing transportation problems and needs
- Project selection methods that are efficient and effective
- Significant interaction between government, academia, and the private sector, resulting in powerful team building in the Utah transportation sector
- The annual workshop and process takes concepts from ideas to usable solutions

12.1 Project Deliverables and Products

A survey question was included to obtain opinions from project champions on the best products and deliverables to further implementation activities. The deliverables listed in Table 12.1 were included in the survey for prioritization.

Table 12.1 Project Deliverables to Promote Implementation

▪ Training Session & Materials	▪ Executive Summary
▪ Policy & Procedures	▪ State-of-the-Practice Summary
▪ Specifications	▪ Experimental Feature
▪ Design Methods	▪ Peer Exchange
▪ Software or App	▪ Demonstration Project
▪ User's Manual	▪ Laboratory Tests
▪ Workshop	▪ Performance Measures
▪ Scanning Tours & Workshops	▪ New Product Evaluation
▪ Web Page/Web Site	▪ Final and Interim Reports
▪ Presentation Slide Deck	▪ Videos

The UTRAC annual research prioritization process should strive to select and fund projects that produce the types of deliverables that are the most practical and beneficial to end users. These consumers of the project deliverables indicated in the surveys that implementation is more often achieved when specific deliverable types are produced.

The surveys ranked the research products and deliverables shown in Table 12.2 as the most valuable in attaining implementation of the project findings. Survey results indicate that products and deliverables unique to the project, along with a quality final report are effective in implementing the results of research projects.

Table 12.2 Recommended Products and Deliverables

Ranking	Product/Deliverable	Percentage
1	Report	65
2	State-of-the-Practice Summary	63
3	Policy & Procedure	56
4	Specification	49
5	Manual of Instruction or Guide	44
6	Design Method	40
7	New Product Evaluation	35
8	Training Session & Materials	28
9	Executive Summary	26
10	Peer Exchange	19
11	Scanning Tour & Workshop	16
12	Experimental Feature	12
13	Laboratory Test	9
14	Software or App	7
15	Other	7

12.2 Implementation Activities at UTRAC

The main purpose of UTRAC Workshop breakout sessions is to select new projects from the list of submitted Problem Statements. A secondary purpose of the breakout sessions should be to revisit the implementation efforts of completed research projects. Each of the breakout sessions should allow time to address implementation plans for the top research products recently completed within that group.

The voting members of the breakout session could choose to fund an implementation plan for a previous project to compete for research funding against new projects. Another strategy would be to allocate two separate funding sources within each breakout session:

1) New projects from Problem Statements 2) Implementation activities of completed projects

13.0 Benefits Input to the Research Project Management (RPMs) Database

The UDOT Research and Innovation Division utilizes the Research Project Management (RPMs) database to monitor and document project information. This system includes key information needed to prepare proper project work plans, program annual reports, budget documents and benefit-cost studies. The benefits achieved through the implementation of all research deliverables should be documented in RPMs.

13.1 Benefits Calculations and Input to the RPMs Database

It is recommended that three **benefit estimates** be input to the Research Project Management (RPMs) database as follows:

- Benefits submitted in the UTRAC Problem Statement form
- Benefits estimated for each proposed deliverable and the Final Report
- Benefits observed and measured related to implemented deliverables

It is also recommended that three **benefit-cost ratio estimates** be input to RPMs as follows:

- Benefit/cost estimate submitted in the UTRAC Problem Statement form
- Benefit/cost estimated for each proposed deliverable and the Final Report
- Benefit/cost observed and measured for implemented deliverables

The process outlined in Table 13.1 describes when the benefits and benefit-cost ratios would be updated. The process indicates who should estimate the values at each stage of the process and who will be responsible to review and approve the information and the methods used to estimate the values.

In this way, the benefit-cost analysis for each project, and ultimately for the program, can be achieved. Ensuring that updates are conducted throughout the life of the project will lead to more accurate, complete and timely information.

Table 13.1 Evolution of Project Benefits and Benefit/Cost Estimates for Input to the Research Project Management (RPMs) Database

Project Phase	Benefit Estimate (Dollars)	Benefit/Cost Estimate	Timing	Responsible Party	Review and Approval
Problem Statement	Estimate of funded project B(ps)	Benefit/Project Cost B/C(ps)	Prior to project funding	Problem Statement champion	UDOT project sponsor
Completed Deliverables	Estimate based on deliverable potential B(d)	Benefit/Project Cost B/C(d)	Part of the Final Report and/or other deliverables	Deliverable author	UDOT end users
Implemented Outcomes	Measured benefits from implemented deliverables B(i)	Benefit/Project Cost B/C(i)	Upon full deliverable adoption	UDOT end users	UDOT Research team

13.1.1 Problem Statement Form - B(ps) and B/C(ps)

A conservative estimate is needed in the Problem Statement of the benefits that are likely to be achieved if the project is successful. A qualified UDOT sponsor should review and approve of this value and the estimate of the project cost. This should be a key factor in the criteria used for project selection.

13.1.2 Deliverables Completed - B(d) and B/C(d)

Each recommended deliverable should be used to update the estimated benefit value and the benefit-cost ratio estimate based on the project results.

13.1.3 Implementation Completion - B(i)

The final measured benefits and benefit-cost ratio should be entered into RPMs based on successful end-user adoption and feedback.

13.2 Personnel Responsibilities and Uses for RPMs input

It is vital that each RPMs input be accurately estimated using appropriate data and methods. This information must be reviewed and validated based on these methods. The following sections recommend the responsibilities of each person in the process:

13.2.1 Principal Investigators

- Experts submitting problem statements into the UTRAC process will be required to estimate the specific benefits resulting from the project deliverables. Further, they should provide an estimate of these benefits expressed in dollars. This results in a benefit-cost ratio using the predicted project budget.
- The researchers will, to some extent be held accountable for the project's benefits as the project progresses and the deliverables are implemented.

13.2.2 Champions and End Users

- Benefit estimates are a key factor in prioritizing the submitted problem statements, and in selecting the proposed projects for funding.
- These values reflected in the RPMs database should encourage UDOT professionals to fully engage in implementation of the project deliverables and findings.
- Over time, the RPMs database should promote the continued commitment to follow through with successful research findings.

13.2.3 Research Division Staff

- These RPMs database input values should enhance the ability of the Research staff in tracking the benefits as each project progresses in an efficient manner.
- These values are essential in evaluating the success of the Research Program through a well-documented benefits tracking methodology.
- Benefits and benefit-cost ratios can be used to evaluate the relative success of each transportation functional area and project type (materials, structures, safety, etc.).

13.2.4 UDOT Key Leaders

- Top leaders and decision-makers in the department can use these values to track the success and benefits contributed by the Research Program.

14.0 RECOMMENDED REVISIONS TO FORMS TO ENHANCE PROJECT SELECTION

Over the years the Research and Innovation Division has modified and improved the annual research prioritization process to solicit and select projects. This evolution of the process has been very successful at rising to meet the changing needs of the department. Additional modifications are recommended for consideration:

14.1 UTRAC Problem Statement Form Modifications

The concept of using the benefit-cost values should be considered early when selecting the problem statements for funding. An estimate of the projected benefits and benefit-cost ratio as proposed in Section 13 should be required in the problem statement form. These estimates should be required in both a form with a description of the project outcomes, as well as a financial estimate of the resulting benefits.

The Problem Statement form should include a list of the deliverables that will be developed as part of the proposed project. Deliverables beyond a final report are preferred. A checklist should be included in the instructions provided to those submitting problem statements.

14.2 UTRAC Problem Statement Instructions

The Problem Statement instructions provided should include how these estimates are calculated, and the method used should be evaluated and approved by the UDOT champion. A discussion should be required that outlines the specific benefits that will be achieved through the deliverables and how they will be implemented.

The potential deliverables listed in Table 12.1 along with others that may be appropriate should be encouraged. This will require significant staff time but should make a positive impact on producing more valuable research products.

UDOT experts that are eligible to vote should be instructed to give preference to Problem Statements that include deliverables that lend themselves to implementation of the findings, not just a report. Instructions should include rules for voting to give higher weight on the ballot to problem statements producing more usable deliverables. Research product "worth" should be measured not in just achieving quality deliverables, but also in how they would be efficiently engrained in UDOT processes, policies and business practices.

14.3 Research Problem Statement Tutorial

Consideration of a formal tutorial to aid in the preparation of the UTRAC Problem Statement is proposed. This application would aid in the preparation of information needed in the Problem Statement. The application could be downloaded by submitters and reviewers of Problem Statements in various forms (pdf, app, etc.).

14.4 Research Project Evaluation Form

A section should be included on this form that will provide an estimate of the benefits in dollars projected from the project deliverables. Briefly describe how these values can be obtained and who should be contacted to determine/verify the estimates. This information should be supplied by one or more of the following stakeholders:

- Project Champion
- A key TAC member
- A Region Director that has or will use the results
- A Division Head who has or will use the results

The dollar amounts listed should be conservative. Ranges may be recommended where clear estimates are not yet known.

Place a higher emphasis on evaluating the "outcomes" of the project and less on aspects such as scope, schedule and budget. Conducting the project in compliance with UDOT guidelines is important, but implementation of the end products is by far the most essential issue.

14.5 Relationships with End Users, Stakeholders and Champions

An ongoing relationship with research product users is crucial to obtain feedback related to research projects. Information related to research benefits will improve in quantity and quality if these relationships are fostered over time. Communication and interaction with these stakeholders are fundamental.

In-person opportunities include:

- Division and Region staff meetings to update users on project status and promote UTRAC participation
- UTRAC planning meetings
- Sessions at the Annual UTRAC Workshop
- Detailed feedback at TAC meetings

Methods to obtain benefit information from end users:

- Formal questionnaires related to data concerning implementation success or failure
- Follow-up interviews on questionnaires submitted
- Feedback related to how users may use the products proposed in the Problem Statement
- Commitment from users on how they plan to use the project deliverables

Questionnaire information required:

- Detailed information on the use of the project products
- Description of any benefits achieved
- Cost savings or increases observed

Follow-up interviews:

- Review each submitted item and how the information was calculated by the user
- Verify that the information is accurate, conservative, and defendable
- Emphasize the importance of the information in advancing future studies
- Stress that future research projects may depend on the success of past projects

15.0 RECOMMENDED IMPLEMENTATION STRATEGIES

The implementation of research products is often the most difficult step in achieving optimal research outcomes. Obtaining buy-in by end users is often difficult for many reasons. The importance of implementation to a research program cannot be overstated. For many years research conferences and national initiatives have been devoted to breaking down the barriers to implementation.

Principal Investigators (PIs) conducting the research often feel that their responsibility is completed when the final report is published. Other PIs do not feel that they are given an opportunity to be involved adequately in the implementation process. Too often an "Implementation Gap" is created that becomes a weak link in the process.

15.1 Implementation Priorities

It is very important for the implementation of research products to be considered as early as possible in the research time frame. Every step, in fact, should reevaluate if the implementation plan needs adjustment. Agenda items should be included in every TAC meeting related to implementation needs and strategies.

One of the most important by-products of the Annual UTRAC Workshop is the strengthening of relationships between UDOT, the private sector and academia. The PM should take every step possible to involve the PI in working with end users to take the implementation of project deliverables to completion. One or two more TAC meetings at the project's end may be needed, and the involvement of additional personnel may be required.

It is imperative to utilize a variety of implementation methods to ensure that the end products of the research are applied into UDOT operations. Implementation tracking applications such as forms and matrices are beneficial tools for use in establishing implementation tasks, tracking progress of the plan and measuring the value of each product to the targeted users.

Each project is unique, and selecting the appropriate deliverables (Table 12.1) to aid in moving the concept into practice is fundamental. Feedback on this phase should include the end users, TAC members, division and region key managers, the research project manager and technology transfer experts.

15.2 Budgeting and Planning for Implementation Initiatives

Implementation activities must be funded to achieve the needed project outcome. This funding should be included as part of the research project contract when possible. In those instances when it is not practical to include funding in the original contract, it may be included under a Part 2 of a project contract or other available funding sources.

The following questions should be answered at each phase of a research project:

1- What implementation-related deliverables will be created?

2- What tasks will be needed to achieve implementation?
3- Who will be the key personnel during the implementation activities?
4- What funding and other resources will be needed for implementation?
5- Will products such as training sessions, user's manuals, software, demonstrations, improved equipment, modified policies, revised specifications, new testing methods or performance measures be needed?
6- What is the estimated benefit-cost ratio for each product proposed? Overall project?

UDOT leaders should strive to create a department-wide culture at every level for adopting new ideas and processes. This can be a significant investment in resources for the department, but this commitment has been shown to help organizations work smarter and more efficiently.

15.3 Using the Research Project Management (RPMs) Database to Track Implementation

Steps should be planned and accomplished at every phase of a research project. Each phase must accurately and effectively address the ultimate implementation of the project deliverables. The implementation potential of the project and how it will be achieved should be addressed at each stage.

The PM and TAC members should agree on concepts and decision points that support continuous implementation planning to accomplish this goal. Figure 15.1 describes how the Implementation Plan can evolve as the project progresses.

Key implementation goals and data estimates should be included in the Research Project Management (RPMs) database. The chart presented in Table 15.1 aids in task monitoring and allows for the project stakeholders to track required investments, estimated benefits, and a projected benefit-cost ratio for the applications.

These monitoring tools will also aid in decisions to end a project in a timely manner when a project is completed or determined to be unsuccessful. Time and money can be saved by making these decisions as early as possible.

The RPMs database can be used to avoid an implementation gap on research projects. By routinely entering the required information into the database, and referring to the data at critical times during the project timeline, implementation can be enhanced. Issues leading to implementation failures are listed below. These may be avoided or minimized by identifying the problems early in the process.

Personnel Issues

- Turnover of key UDOT experts assigned to the adoption of the deliverables
- Loss of support by PIs to aid in training or other needs
- Lack of time or priority for the implementation tasks

Funding Deficiencies

- Implementation of the findings are too expensive
- The contract does not included funding for implementation tasks

Management and Administrative Decisions

- Implementation of the findings are too uncertain
- Findings conflict with state policies or goals

Maintaining valid information in the RPMs database may be used to overcome these issues and shortcomings. Improved communication with all stakeholders is enhanced through this process.

Figure 15.1 Evolution of the Implementation Plan

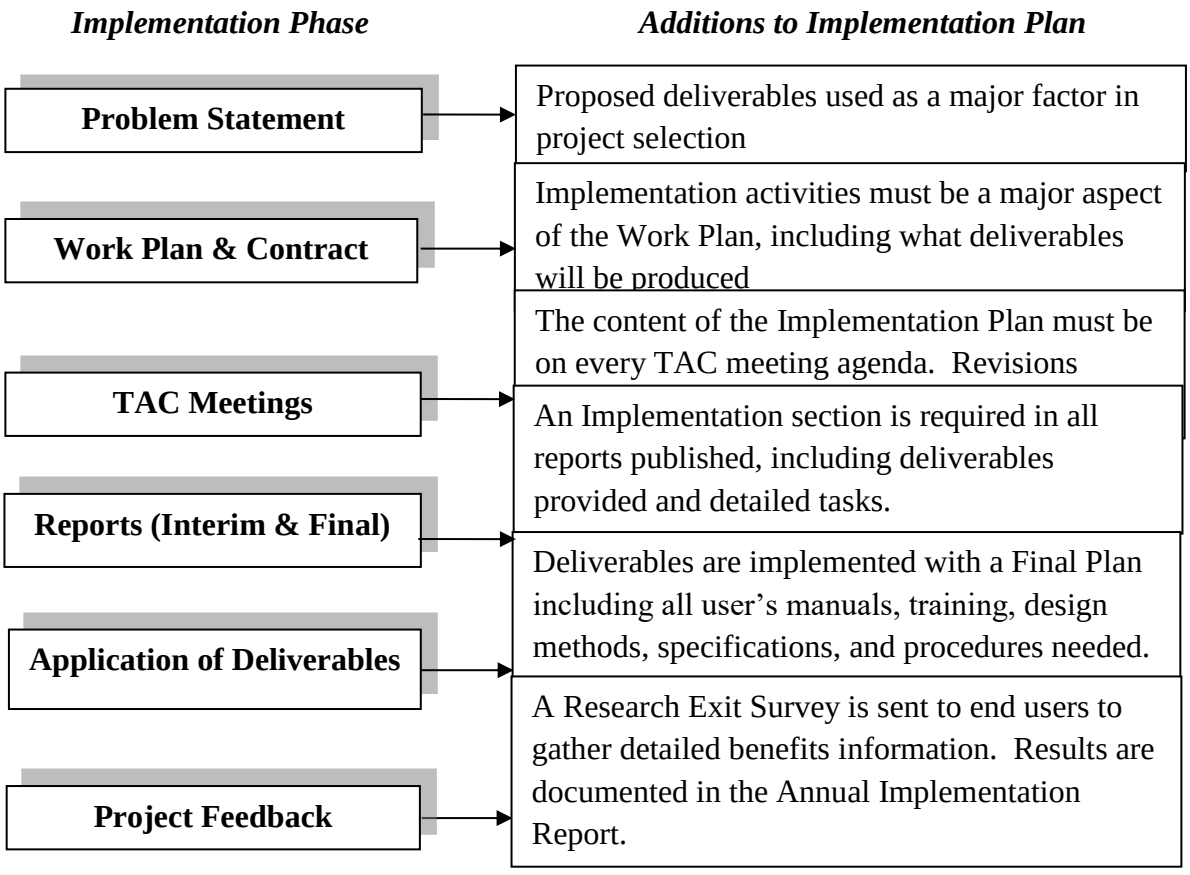

Table 15.1 Matrix to Track Implementation Tasks and Product Value by Project Phase

Project Phase	Activities	Personnel	Estimated Investment	Estimate Benefit Value	Projected Benefit/Cost
Problem Statement	-Required at the UTRAC Workshop -Deliverables and products identified -Used as a major factor in project selection	PI and UDOT reviewer	Initial cost estimate	Benefits in dollars & other	Educated rough estimate
Work Plan & Contract	-Major aspect of Work Plan -More detail on deliverables -List manuals, training, etc.	PI, PM and TAC members	Project budget	Benefits in dollars & other	Refined estimate
TAC Meetings	-Ideal time to plan with end users -Implementation on every TAC agenda	All stakeholders	Track expenditures	Benefits in dollars & other	Refined estimate
Progress Reports	-Implementation section required in Progress Report	All stakeholders	Track expenditures	Revised benefits	Refined estimate
Final Report	-Major section in Final Report -Plan with detailed tasks -Revisit products (manuals, training sessions, etc.)	All stakeholders	Total investment estimate	Detailed benefits in dollars	Calculated estimate for project
Deliverables & Products	-Each deliverable is provided with an implementation plan and budget	All stakeholders	Investment for each product	Estimate value of each product	Calculated estimate for deliverable
Project Feedback	-Key end users are sent a Research Exit Survey -Benefits, B/C estimates, and problems are documented	All stakeholders	Investment for each product	Benefit of each product and B/C	Refine estimate for deliverable

15.4 Policy as a Tool for Implementation

Although UDOT does not formally promote the use of policies, many functions within the divisions and regions should maintain policies to enhance their operations. The use of policy to further the use of new design techniques, specifications, testing methods and new products has not been always fully utilized by UDOT managers and leaders.

Policies may be used by the organization on centralized or decentralized levels. Decisions related to the use of some research deliverables are best left to region personnel while others should be made at the department level to advocate for consistency. Policies are often an asset during lawsuits against the department showing how decisions were made and guidelines followed.

15.5 Patents and Spin-Off Companies

Public funds and other resources cannot be used to aid in the development of private-sector products, but should assist companies in evaluating if new products or ideas are viable. There is definitely some gray area in this relationship, but many new products cannot be properly investigated or evaluated without involvement by experts in transportation agencies.

15.5.1 *Example: Temporary Markers*

These markers provide delineation on newly surfaced pavements such as aggregate seals and flush coats where traditional pavement markings cannot be placed until curing has occurred. Test sections were placed under the direction of UDOT research by maintenance forces. The delineation was evaluated both in daylight and during nighttime reflectivity.

UDOT was instrumental in showing the advantages of Temporary Markers in improving safety for both travelers and UDOT workers. They also save money by eliminating crews to measure and mark where the new lines are to be placed. Temporary Markers have been used all over the world for more than 25 years as a result of UDOT and private-sector coordination.

15.5.2 *Example: Concrete Surface Sealers*

New concrete sealers were promising, but little was known about their effectiveness and tendency to produce a slippery pavement surface. Test sections were placed on a concrete pavement shoulder in a rural, low-traffic area. Observations and locked-wheel trailer testing indicated which sealers could be used on pavements, and which ones were restricted to vertical concrete surfaces.

15.6 New Products Evaluation

The Research and Innovation Division could have a greater role in the evaluation of new products that are submitted to the department for consideration. Oversight of this program is formally managed by the Maintenance Division, but research initiatives can enhance this program.

New products personnel should coordinate with research on the following:

- Literature search needs
- A field test section may be funded through research
- An Experimental Feature may be promoted
- A Scanning Tour could be organized and funded

15.7 Videoconferencing

The use of videoconferencing has taken a more prominent role in recent years, particularly during the pandemic. It has been shown to be a powerful tool in sharing the results of transportation research and other information. Face-to-face interaction between transportation experts is the most pure form of technology transfer.

The UDOT Research and Innovation Division should take the lead to promote videoconferencing technology transfer. Programs similar to those outlined below should be created to aid the WASHTO states and others in utilizing this powerful face-to-face technology transfer tool. The vast distances between states in the West can result in increased costs and time needed to conduct in-person meetings.

15.7.1 Info-X Videoconferencing Program

For many years this program was utilized by the 17 WASHTO states to conduct technology transfer. Info-X was managed by the Utah Technology Transfer Center at Utah State University to coordinate the results of various programs and agency problems.

A single, pressing issue was selected for each session topic. The topics were recommended by state experts, and each state was asked to answer questions listed about how their agency addressed the issue.

These meetings included materials, construction, maintenance, motor carriers and other experts. Session topics included how each state would implement new federal guidelines, best use of equipment and personnel, new problems facing the group and discussing issues at state borders.

15.7.2 *Examples of Videoconferencing Topics*

- Crack sealing specifications and methods
- Wild animal fence policies
- Snow fence design and maintenance
- Concrete texturing performance
- Automated pavement condition surveys
- Bicycle lane planning and design
- Motor carrier oversize vehicle permitting
- Port-of-entry operations and state line coordination
- Bridge formula enforcement
- Asphalt performance specifications

15.8 State-Level Funding Contributions

In the past, it has been necessary to propose implementation initiatives to the Utah State Legislature or Utah Transportation Commission to gain support for adoption of research findings. This strategy can be a great source to justify these initiatives and provide state-level funding and policy changes.

Programs that may require approval and support from political partners may include initiatives as follows:

- Programs with very large costs
- Long-time commitments to implement
- Multiple state agency buy-in and support
- Programs required by federal mandates

15.8.1 *Example: Wetland Banking Budget*

State-level funding to support wetland banking was needed to meet federal guidelines and protect the state's wetlands and wildlife. A fund was created to meet these goals.

15.8.2 *Example: Corridor Preservation Program Seed Money*

Long delays in completing certain corridors were putting landowners in distress. Examples were Bangerter Highway and Mountain View Corridor.

Owners were required to pay property taxes but could not develop their land. Seed money was provided to buy out landowners who could show a burden due to the preservation designation. The seed money was replenished as extra parcels were sold upon completion of the highway.

15.8.3 *Example: Photolog System Purchase*

Advanced technology was implemented in the new photolog vans by the private sector. Photolog pavement surveys, sign inventory, and other information were possible at highway speeds. This also allows all UDOT personnel to view highways without actually traveling to the site.

Equipment budgets were not funded at the high cost needed to acquire a Photolog van. A document was prepared identifying the cost savings that a van could achieve. The Utah State Legislature gave line-item approval to purchase the van for UDOT's use.

16.0 ADDITIONAL USES FOR BENEFIT-COST INFORMATION

A number of decision-making processes for UDOT programs and projects can be improved through benefit-cost information. The benefits identified through specific research projects may indicate similar benefits when these aspects are applied to other projects or programs.

16.1 UDOT Program and Project Decisions: Reverse Engineering

Using specific benefits information may indicate the value of UDOT applications in the field. Care should be taken to avoid equating research costs with those of construction or maintenance activities. The benefits information can be very valuable in the types of decisions Region Directors and Division Heads frequently face.

16.1.1 Process

- Determine an acceptable benefit-cost ratio for the program or project feature.
- Back-calculate the required benefit by using the benefit-cost ratio and the cost of the feature. This may be accomplished by using traditional methods typically accepted by UDOT divisions, such as crash data, user delay estimates, and construction costs.
- Compare the resulting estimated benefits and the benefit-cost ratio with other potential projects or facility upgrades.
- Recommend an action to include or exclude the initiative from the program or project scope.

16.1.2 Benefit-Cost Database

UDOT should consider creating and maintaining a Benefit-Cost Database. Benefit values for various initiatives would be included for use by engineers and planners statewide as follows:

- Traffic and Safety: rumble strip, cable barrier, access management, etc.
- Construction: design-build, lane rental, movable barrier, etc.
- Structures and Geotechnical: ABC off-site bridge construction, geofoam embankments, wick drains, etc.
- Materials and Pavements: mechanistic-empirical design, composite pavements, etc.
- Maintenance: low-skid correction surface course, deer fence, temporary markers, etc.
- Environmental: wetland banking, mitigation methods, noise abatement, etc.

16.1.3 Benefits Entered into the UDOT Database

Modifications must be completed to the values gathered through research studies before they can be used in the Benefit-Cost Database. Research project-generated benefits will be useful but values may need to be initialized by mile or item. Benefit information by itself can be useful in addition to the benefit-cost ratios monitored in the database.

16.1.4 Costs Entered into the UDOT Database

The costs related to an initiative are very different from the values used to calculate research benefit-cost ratios. The costs included must be related to the design, construction and maintenance of the feature, whereas the research costs are in the form of the contract, management and TAC costs.

16.1.5 *Example: Cable Barrier*

Assume a value of $750,000 per mile has been established for cable barrier installation and maintenance. A minimum Benefit/Cost of 10 is set by UDOT managers.

- Cable barrier should be used where historical crash data shows one or more "fatal" or "incapacitating" (severity K or A) cross-over crash occurring during its life-cycle. **[$11,295,400/$750,000 = 15].**
- Or more than 12 cross-over crashes with an "injury" (severity B) occurring during its life-cycle **[(12) x ($655,000)/$750,000 = 11].**
- Or some combination of crash severities and numbers resulting in a B/C of 10 or greater.

16.1.6 *Example: Fast-Track Construction*

A Benefit/Cost of 15 is set by policy for fast-track construction, and it costs $400,000 over traditional construction methods. User savings in the form of reduced congestion and crash mitigation must be estimated at $6 million or more during the project to justify the innovative construction methods. **$6,000,000/$400,000 = 15**

16.1.7 Legal Aspects of the Benefit-Cost Database

It is essential that UDOT leaders maintain information related to policies that can be used in a court of law. Courts, when ruling on lawsuits filed against transportation agencies, observe two "policy" aspects related to the action:

- Does the agency have a policy related to the issue?
- Did the agency employees follow the policy?

Also, the courts rely on how timely corrective measures must be taken to bring a deficiency up to standards. They observe two time-related aspects as follows:

- Did the agency have "direct knowledge" of the deficiency?
- Did they have "constructive knowledge" of the deficiency? (They should have known.)

Using benefit-cost analysis to make these decisions can be used in court to show that UDOT acted appropriately using sound engineering methods. Decisions to install facilities or not were based on the known benefits of the issue related to the cost to install the item.

16.1.8 *Example: Application of Cable Barrier Not Used at Crash Site*

A lawsuit claims that cable barrier would have prevented a cross-over crash. UDOT shows that barrier was not installed since the location did not meet the policy of a benefit-cost

ratio of 10. No cross-over crashes have occurred at the site based on information from the crash history database.

16.2 Media Marketing Program

The traveling public, business owners, university partners, and private-sector consultants are often asking for information concerning UDOT programs and projects. This is especially true for visible innovative activities in the state.

A Media Marketing Program can be a very important tool in illustrating the benefits of research initiatives and other innovative UDOT activities. The program could provide coordination between technical experts and UDOT's media personnel.

The Media Marketing Program in the past has delivered very useful information in powerful and useful forms. These include enhanced graphics, news clips, slow-motion video and high-level professional mediums that news professionals can supply. These activities can improve relationships with the traveling public, create funding partnerships, and build support from the Utah State Legislature.

16.2.1 *Example: I-15 National Testbed*

The I-15 National Testbed was comprised of 42 research projects conducted as part of the I-15 Reconstruction Project near downtown Salt Lake City. Various innovative techniques were demonstrated to the public through the media. Concepts were reported such as seismic loading of full-scale bridge columns, seismic cyclic loading on bridge decks, geofoam subgrade installations, and carbon wrapping of damaged bridge columns.

16.2.2 *Example: Automated Anti-Icing System*

A specialized sprinkling system was placed on a black-ice vulnerable bridge deck. Conditions were monitored at the bridge with a weather station, and the system was activated automatically to improve traction on the bridge deck surface.

16.2.3 *Example: ABC Bridge Project*

A bridge was constructed on the shoulder of a high-volume corridor by using Automated Bridge Construction (ABC) methods. The bridge was then placed into service in one weekend, and the traffic disruption of the project was greatly reduced.

16.3 Public/Private Partnerships

The Research and Innovation Division should continually be responsive to opportunities to promote public/private partnerships. Many funding sources exist with groups such as motor carrier associations, wildlife advocates, wild-lands experts, construction and design specialists, public authorities, and other professional groups.

These collaborations can produce the following types of solutions to UDOT challenges:

- High-tech advancements
- Computer-generated products
- Cross-industry applications
- Multi-agency laboratories and tools

17.0 PROCESS TO TRACK AND MEASURE FUTURE RESEARCH BENEFITS

The Research and Innovation Division plans to track and measure transportation research benefits on an annual basis. A guide was prepared as part of this contract to aid in this goal entitled, "Process Guide for Measuring the Benefits of UDOT Research" [10].

The guide discusses the types of benefits produced by research projects, benefits measuring methods available and proposed uses of the information. The recommendations in the process include actions needed at both the project and program levels.

The guide describes feedback processes and tools to aid in the implementation of completed projects. Methods are proposed to identify and track deliverables needing additional implementation actions. The guide recommends details related to the following aspects of the process:

- Purpose of the guide
- History of the processes
- Goals of the program
- Information needs
- Benefit types in the survey
- Survey formats and questions
- Response verification
- Personnel requirements and responsibilities
- Uses of the information
- RPMs database input
- Examples of benefit-cost input
- Implementation activities and schedules
- Program deliverables and outcomes

Also included is an overview of best practices for use by consultants conducting more comprehensive studies to measure research benefits on a 3- to 4-year interval. The Process Guide was created for internal use only.

18.0 CONCLUSIONS

1. **The information gathered in this study indicates that the Research and Innovation Division at the Utah Department of Transportation had an estimated $111.794 million in benefits for the 57 projects completed and 73 deliverables produced in 2017, 2018 and 2019.** These estimates were shown to be conservative due to the methods used to gather, review and validate the submitted benefits.

2. **These benefits result in an estimated benefit-cost ratio of 26.** Cost information included contract amounts, project management budgets, and costs related to Technical Advisory Committee (TAC) members from the UDOT staff.

3. **The UDOT research program had an average grade of 2.5 (B- grade)** using a 1 to 4 grading scale. Completed surveys indicated that the program is highly valued by users and stakeholders, and supported by UDOT staff in all areas of expertise.

   Four deliverables were given an "E" grade. Three of these were found to be graded inaccurately. For this reason, the definitions used in the survey appear to be incorrect. These grade responses were not modified in the study results, however.

4. The accomplishments achieved by the UDOT Research and Innovation Division were evident throughout this study in a number of ways. Research division staff, academic partners, and supporting experts were generally effective and efficient in meeting their established objectives.

5. The UDOT Research Program has been conducted in accordance with the goals outlined in UDOT's Strategic Direction. The outcomes and products produced by the program have furthered the short- and long-term objectives of the department. This observation is reinforced in the balance observed for the various project types.

6. The estimated benefit-cost ratio of 26 is significantly higher than values for similar published studies that were completed for UDOT in 1995(14), 2000(12), 2010(17), 2016(14), and 2020(19). This increase is attributed to many factors including a high survey return rate (68%), improvements in the selection and conduct of quality projects, and the user-friendly nature of the survey utilized. Also the higher benefit-cost ratio could be a result of higher user and safety costs that have been inflated faster than the costs tied to research budgets.

7. The annual research prioritization process and workshop was shown to be very successful in selecting research projects for funding. The workshop is beneficial in identifying topics related to the most pressing issues facing UDOT and its stakeholders. The process

fosters a favorable relationship between UDOT experts, academic professionals, and private-sector specialists.

8. Future Problem Statements could be enhanced to provide a more complete estimate of the benefits for the proposed project. This would aid in the prioritization of submitted projects. A review by UDOT personnel of the methods used to calculate these projected benefit levels will be needed to verify accuracy.

9. Thorough implementation of research deliverables is a challenge for most agencies across the country. Improving this process would require more dedicated resources. A few valuable products of research have not been fully implemented. A more formal approach to achieving implementation may be required.

10. The benefits data obtained in this study can be used to make decisions by UDOT engineers and managers. Utilizing target benefit-cost ratios as policy, decision-making related to various enhancements to corridors and projects can be evaluated.

11. The use of Google Forms was found to be very efficient in distributing the survey to research champions and downloading and processing the information.

19.0 RECOMMENDATIONS AND IMPLEMENATION

1. Based on the positive results of this study, the Research and Innovation Division should be fully funded based on the substantial estimated $111.79 million in benefits, and a benefit-cost ratio of 26. This includes research projects, the annual research workshop, implementation activities, state-of-the-practice studies, training sessions, scanning tours, videoconferencing information exchanges, and full attendance at the TRB Annual Meeting.
2. The UDOT Research and Innovation Division should implement a more complete process to better monitor and manage completed products from research projects. This proposed program is outlined in detail in Section 15. This process includes the personnel commitments needed, recommended processes, milestones and performance measures related to implementation. The more complete process would require additional resources beyond the current levels.
3. The annual research Problem Statement prioritization workshop is an essential part of the research process. Some aspects of the workshop breakout sessions should be expanded in scope, if possible. Part of the workshop time should be dedicated to identifying, planning and funding initiatives to implement recently completed research products into practice in addition to selecting new projects.
4. Consideration of a formal tutorial to aid in the preparation of the workshop Problem Statement is proposed for adoption. This application would aid in the preparation of information needed in the Problem Statement form. The application could be downloaded by submitters and reviewers of Problem Statements in various forms (pdf, app, etc.).
5. The Research Project Management (RPMs) database should be expanded as planned by UDOT to aid in the tracking of benefits information during all phases of the research. This will facilitate in the tracking of deliverables and will aid in the implementation process. Benefit information should be estimated in the following project phases:

    a. **Workshop Project Selection**: The voting process used to select projects should include greater emphasis on projects that propose deliverables which produce higher benefits. These include the products listed in Table 12.1.

    The Problem Statement form should require an estimated benefits and benefit-cost ratio for each proposed project. The UDOT sponsor of the Problem Statement should review and verify all data, methods and calculations. The UDOT review information should be included with the Problem Statement in an attached form.

    b. **Project Work Plan**: An updated estimate of the benefits should be incorporated in the final work plan and contract documents. This would include the value of the products to be developed and how the target end users will utilize the deliverables.

c. **Conduct of the Research**: All milestones, progress reports, and TAC meetings should be utilized to review and update the estimated benefits value of the end products in the RPMs database.

d. **Implementation Phase**: The Project Manager should retain ownership of the project and related deliverables for a minimum of two years after project completion. During this time the actual measured value of the benefits should be determined and loaded into RPMs.

6. UDOT research personnel should continue to implement the concepts outlined in Figure 15.1, "Evolution of the Implementation Plan," and Table 15.1, "Matrix to Track Tasks and Product Values by Project Type." The Research Project Management (RPMs) database can be used to avoid an implementation gap on research projects. By routinely entering the required information into the database, and referring to the data at critical times during the project timeline, implementation can be enhanced.

7. Research managers should continually promote the use of the deliverables prioritized by the end users in Table 12.2. Closely working with Region and Division personnel is necessary when developing the types of research products that produce the desired outcomes.

8. The definitions used in the survey should be changed back to previous wording to better define a failing grade for a research project. Projects that met the objectives should receive a passing grade even if the concept being evaluated was not adopted. Evaluating a concept effectively contributes to UDOT's institutional knowledge ("C" grade).

The definition of an "E" grade should be changed from "No contributions: implementation not recorded" to "Major tasks not completed: Objectives not met." The second definition was used in all five of the surveys done in previous years. This definition refers to the tasks and objectives, not the contributions and implementation.

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2. Crash Costs for Highway Safety Analysis, FHWA Safety Program, Final Report, January 2018.

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6. Concas, S., Reich, S., and Yelds, A., "Valuing the Benefits of Transportation Research: A Matrix Approach," Center for Urban Transportation Research at the University of South Florida, Final Report BC353-24, September 2002.

7. Zmud, J., Paasche, J., 2009, "Communicating the Value of Transportation Research Guidebook," NCHRP 610, TTI.

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12. Anderson, D. I., May 2020, Anderson Transportation Consulting (ATC), "Program to Measure Research Benefits and Track Implementation," Version 2, for the Utah Department of Transportation Research and Innovation Program.

13. Research Program and Project Management for Transportation (RPPM).

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APPENDIX A - SURVEY

2022 UDOT Survey on Benefits of Transportation Research in Utah

Instructions:

1. If you are not familiar with the deliverables and products of the research project, please notify Shana Lindsey (rlindsey@utah.gov), and recommend someone else to respond, if possible.
2. You may also contact Shana for help in estimating the Financial Benefit, and with any other questions about the survey.

Thank you for helping us quantify the value of UDOT's research program and the important work we all share!

atcdoug47@gmail.com Switch account

* Required

Email *

Your email

IMPLEMENTATION STATUS

Project Title: *

Your answer

What implementation activities were intended from the research project?

Your answer

What is the implementation status of the deliverables from this project?

- ◯ All potential implementation has been completed.
- ◯ Implementation is underway and will continue to be monitored.
- ◯ Implementation has not been successful.

What, if any, additional implementation products or activities are planned for this research initiative?

Your answer

What can the Research Division do to enhance the implementation of this research project?

Your answer

If implementation has not been successful, why not?

Your answer

FINANCIAL BENEFITS BY CATEGORY

Please provide a dollar amount for each category that applies to your project. Skip the categories that don't apply. ***Enter amounts in currency format, no $ sign****. (e.g., 3,000,000 and 200,000)*

If this project provided **only a percentage of the overall benefits** to a UDOT improvement, please answer these questions using this example as a guide: *UDOT program benefits = $10 million. Research project provided 1% of these improvements. Project benefit = $100,000.*

Asset Improvement (pavements, bridges, walls, etc.)
These are benefits that have contributed to the life or management of UDOT's assets.

For Asset Improvement, what is the financial benefit, in dollars?
(Could be related to enhanced life or performance, and/or benefits from not doing unneeded or expensive activities, i.e., cost avoidance.)

Your answer

Explain how you calculated that amount.

User Impacts

These are benefits that have reduced impacts to the traveling public.

For User Impacts, what is the financial benefit, in dollars?
(Could be savings related to shorter construction time or enhanced life, and/or benefits from not doing unneeded or expensive activities, i.e., cost avoidance.)

Your answer

Safety Impacts

These are benefits that have contributed to the safety of the traveling public, UDOT's employees, and/or contracted employees.

For Safety Impacts, what is the financial benefit, in dollars?
(Could be savings related to improved traffic control or reduced exposure of employees to traffic, and/or savings in the form of reduced property damage, injuries, or fatalities. The Cost Per Crash Table below may be helpful.)

Your answer

Average Cost Per Crash Based on Severity

FHWA Safety Program

(Currently Used by UDOT)

Crash Severity	Crash Cost
5- Fatality (K)	$ 11,295,400
4- Serious Injury (A)	$ 655,000
3- Minor Injury (B)	$ 198,500
2- Possible Injury (C)	$ 125,600
1-Property Damage Only (O)	$ 11,900

Explain how you calculated that amount.

Your answer

Cost Savings to UDOT

These are benefits in the form of savings to UDOT practices and functions.

For Cost Savings to UDOT, what is the financial benefit, in dollars?
(Could be benefits related to manpower reduction, materials savings, fewer needed contracts, etc.)

Your answer

Explain how you calculated that amount.

Your answer

Environmental and Wildlife Enhancements

These are benefits that have contributed to environmental or wildlife issues.

For Environmental and Wildlife Enhancements, what is the financial benefit, in dollars?
(Could be benefits related to wetlands, air quality, water impacts, endangered or noxious plants, wildlife conservation, etc.)

Your answer

Explain how you calculated that amount.

Your answer

Policy and Administrative Issues

These are benefits that have contributed to enhanced policies and administration of the Department.

For Policy and Administrative Issues, what is the financial benefit, in dollars? *(Could be benefits related to improved management and policies impacting our customers, and/or benefits from not doing unneeded and expensive activities, i.e., cost avoidance.)*

Your answer

Explain how you calculated that amount.

Your answer

Institutional Knowledge

These are benefits that have contributed to the level of knowledge of UDOT experts.

For Institutional Knowledge, what is the financial benefit, in dollars? *(Could be savings related to not doing unneeded or expensive activities, i.e., cost avoidance.)*

Your answer

Explain how you calculated that amount.

Other

This category is for any benefits not previously mentioned that may be relevant to your project.

If you've identified another benefit category, what is it?

Your answer

What is its financial benefit, in dollars?

Your answer

Explain how you calculated that amount.

Your answer

PROJECT GRADE

Please provide an overall grade for the project and all implementation efforts.

Overall, how would you grade this project?

- ◯ A - Major impact (new or revised specifications, policies, or standards).
- ◯ B - Significant impact (improved operations, procedures, or methods).
- ◯ C - Contributed mainly to state-of-the-practice or institutional knowledge.
- ◯ D - Unclear or minimal contributions.
- ◯ E - No contributions; implementation not recorded.

In general, what do you think are the most valuable products research yields? ***(choose five)***

- [ ] Report
- [ ] Training sessions & materials
- [ ] Manual of instruction or guide
- [ ] Specification
- [ ] Design method
- [ ] Laboratory test
- [ ] Executive summary
- [ ] Media article or coverage
- [ ] Policy & procedure
- [ ] Scanning tours & workshops
- [ ] Experimental feature
- [ ] New product evaluation
- [ ] Software or apps
- [ ] Peer exchange
- [ ] State-of-the-practice summary
- [ ] Other

If one of your selections was "Other" in the previous question, please identify that research product.

Your answer

Additional comments or feedback you want to share with the Research & Innovation Division.

Your answer

APPENDIX B - SUMMARY OF PROJECTS

REPORT NUMBER	PIC #	TITLE	PROJECT MANAGER	P.I. / AUTHORS	CURRENT CHAMPION	CONTRACT COST
UT-17.01	UT14.102	Intermediate Temperature Cracking in HMA: Phase I Semi-Circular Bending (SCB) Practicality Evaluation	Kevin Nichol	Kevin VanFrank	Howard Anderson	$62,540
UT-17.02	UT13.201	Typical and Darkened Portland Cement Concrete Pavement: Temperature, Moisture, and Roughness Analyses	Kevin Nichol	W. Spencer Guthrie	Kelly Barrett, Shawn Lambert	$30,000
UT-17.03	UT16.401	Transportation Engineering Project Management: Survey of Practice	Tom Hales	Chris Kline (CTC)	Branden Anderson	$16,540
UT-17.04	-	Intelligent Design and Construction Guidance Document (STIC funded; not R&D)	George Lukes	George Lukes, Jim McDowell (Lochner)	-	-
UT-17.05	UT15.303	Measuring Pedestrian Exposure and Risk in High-Risk Areas	Jason Richins	Shaunna Burbidge	Robert Miles	$50,000
UT-17.06	UT13.206	Implementation of Aerial LiDAR Technology to Update Highway Feature Inventory	Tom Hales, Jason Richins	Ziqi Song	Shawn Lambert	$80,000
UT-17.07	UT14.314	A Comprehensive Safety Assessment Methodology for Innovative Geometric Designs	Kevin Nichol	Ziqi Song	Robert Miles	$40,000
UT-17.08	AM16.06	UDOT Research Peer Exchange, October 12-13, 2016: Implementation, State DOT Library, National Committees, and State Transportation Innovation Council	David Stevens	C.Kergaye, J. Richins, K. Nichol, T. Hales, D. Stevens, J. DeMille, V. Liu	Cameron Kergaye	$11,750
UT-17.09	UT15.306	Utilizing LiDAR Data to Analyze Access Management Criteria in Utah	Kevin Nichol	Grant Schultz, Mitsuru Saito, Marlee Seat, Wyatt Clegg	Robert Miles	$65,000
UT-17.10	UT15.311	Using a Safety Forecast Model to Calculate Future Safety Metrics	Kevin Nichol	Kordel Braley, Chad Worthen	Jeff Lewis	$50,000
UT-17.11	UT15.306	Analysis of Safety Impacts of Access Management Alternatives Using the Surrogate Safety Assessment Model	Kevin Nichol	Grant Schultz, Mitsuru Saito, Kyung Min Kim	Robert Miles	incl. with UT-17.09

UT-17.12	UT15.208	Hotspot and Sampling Analysis for Effective Maintenance and Performance Monitoring	Jason Richins	Xiaoyue Cathy Liu, Zhuo Chen	Shawn Lambert	$50,000
UT-17.13	UT15.501	Reducing Project Delays and Costs Due to Utility Relocations	David Stevens	S. Peterson, P. Romero, M. Watson, A. Watson	Ken Talbot	$50,000
UT-17.14	UT16.304	Left-Turn Signal Warrant Procedures: A Synthesis of Practice	Travis Jensen	Grant Schultz, Joshua Alpers, Mitsuru Saito	Mark Taylor	$15,000
UT-17.15	(Related to UT15.503)	Testing New Technology To Restrict Wildlife Access To Highways: Phase 1	Randall Taylor, Jason Richins	Patricia Cramer, Joseph Flower	Monte Aldridge, Matt Howard	(Region 4) Related to UT-17.16
UT-17.16	UT15.503	Testing New Technology To Restrict Wildlife Access To Highways: Phase 2	Jason Richins	Patricia Cramer, Robert Hamlin	Monte Aldridge, Matt Howard	$35,000
UT-17.17	UT15.307	Literature Search and Scan Tour of Wrong-Way Driving Mitigation Measures Across the United States	Tom Hales, Kevin Nichol	Travis Jensen	Robert Miles, Lisa Zundel	$24,783
UT-17.18	UT16.502	Comparative Case Studies: Trip and Parking Generation at Orenco Station TOD, Portland Region and Station Park TAD, Salt Lake City Region	Kevin Nichol	Reid Ewing, Guang Tian, K. Park, P. Stinger, J. Southgate	Andrea Olson	$36,000
UT-17.19	UT16.605	Coverage vs Frequency: Is Spatial Coverage or Temporal Frequency More Impactful on Transit Ridership?	Kevin Nichol	Torrey Lyons, Reid Ewing, Guang Tian	Shaina Quinn or Jenna Simkins @ UTA	$20,000
UT-17.20	UT16.503	Does Compact Development Increase or Reduce Traffic Congestion?	Kevin Nichol	Reid Ewing, Guang Tian, Torrey Lyons	Andrea Olson	$20,000

UT-17.21	UT15.102	Balanced Asphalt Concrete Mix Performance, Phase II: Analysis of BBR and SCB-IFIT Tests	Kevin Nichol	Pedro Romero, Kevin VanFrank	Howard Anderson	$110,000
UT-17.22	UT11.402	Evaluation of Secondary Consolidation Settlement Associated with Embankment Construction for Fast-paced Transportation Projects in Utah	David Stevens	Steven Bartlett, Evert Lawton, Zach Gibbs	Grant Gummow	$46,812
UT-17.23	UT13.404	Evaluation of Curve Fitting Techniques for Estimating End of Primary Consolidation Settlement: Provo Westside Connector Project, Utah	David Stevens	Clifton Farnsworth, Christopher Pister	Grant Gummow	$15,000
UT-18.01	UT16.310	Risk Assessment of Non-Motorized Access to Rail Transit Stations	Travis Jensen	Shaunna Burbidge	Robert Miles	$95,000
UT-18.02	UT16.302	Developing a Method to Identify Horizontal Curve Segments With High Crash Occurrences Using the HAF Algorithm	Travis Jensen	Mitsuru Saito, Joseph Browning, Grant Schultz	Jeff Lewis	$60,000
UT-18.03	UT15.602	Measuring Systemic Impacts of Bike Infrastructure Projects	Travis Jensen	Shaunna Burbidge	Heidi Goedhart, Stephanie Tomlin	$55,000
UT-18.04	UT16.609	Impacts of Bus Stop Improvements	Kevin Nichol	Ja Young Kim, Keith Bartholomew, Reid Ewing	Shaina Quinn or Jenna Simkins @ UTA	$40,000
UT-18.05	AM17.15	Back-of-Curb Evaluation Study: State Highway Right-of-Way Responsibility and UDOT	David Stevens	William Dye, Ronald Hamilton, Larry Thomas	Zachary Derr	$99,985

UT-18.06	-	Intersection Safety Analysis Methodology for Utah Roadways (T&S-funded; not Research)	Travis Jensen	Grant Schultz; Joshua Gibbons	-	-
UT-18.07	-	Crash Severity Distributions for Life-Cycle Benefit-Cost Analysis of Safety-Related Improvements on Utah Roadways (T&S-funded; not Research)	Travis Jensen	Grant Schultz, Mitsu Saito	-	-
UT-18.08	UT16.316	Streamlined Access Permitting Process	David Stevens	David Bassett, Marlee Seat, Blake Unguren (Avenue)	Zachary Derr	$73,097
UT-18.09	AM17.06	Annual UDOT Workshop on Transportation Research Needs: 2018 Proceedings	Vincent Liu	Vincent Liu, David Stevens	Cameron Kergaye	$4,344
UT-18.10	UT13.407	SPLIQ User's Manual, Version 1.41	David Stevens	Kevin Franke, Lucy Astorga, Braden Error	Darin Sjoblom	($179,500 - incl. with UT-16.16 - already evaluated)
UT-18.11	UT13.407	Simplified Standard Penetration Test Performance-Based Assessment of Liquefaction and Effects - Updated Liquefaction Parameter Mapping - Addendum Report	David Stevens	Kevin Franke	Darin Sjoblom	($179,500 - incl. with UT-16.16 - already evaluated)

UT-18.12	UT11.404	Lateral Resistance of Pipe Piles Adjacent to 15-ft High MSE Wall	David Stevens	Kyle Rollins, Cody Hatch, Jarell Han	Jon Bischoff	incl. with UT-18.16
UT-18.13	UT11.404	Lateral Resistance of Pipe Piles Adjacent to 20-ft High MSE Wall	David Stevens	Kyle Rollins, Jason Besendorfer, Ryan Budd	Jon Bischoff	incl. with UT-18.16
UT-18.14	UT11.404	Lateral Resistance of H-piles and Square Piles Behind an MSE Wall with Ribbed Strip and Welded Wire Reinforcements	David Stevens	Kyle Rollins, Andrew Luna	Jon Bischoff	incl. with UT-18.16
UT-18.15	UT11.404	The Influence of Pile Shape and Pile Sleeves on Lateral Sand Load Resistance	David Stevens	Kyle Rollins, Dalin Russell, Guillermo Bustamante	Jon Bischoff	incl. with UT-18.16
UT-18.16	UT11.404	Lateral Resistance of Abutment Piles Behind Mechanically Stabilized Earth (MSE) Walls [main summary report for pooled fund.	David Stevens	Kyle Rollins, A. Luna, R. Budd, J. Besendorfer, C. Hatch, J. Han, R. Gladstone	Jon Bischoff	$322,000
UT-18.17	UT11.404	The Influence of Pile Shape on Lateral Resistance	David Stevens	Kyle Rollins, D. Russell, G.Bustamante	Jon Bischoff	incl. with UT-18.16
UT-18.18	UT11.404	Lateral Resistance of Piles Within Corrugated Metal Sleeves	David Stevens	Kyle Rollins, Dalin Russell	Jon Bischoff	incl. with UT-18.16
UT-18.19	UT17.501	Evaluation of UDOT's Preconstruction Schedule Process (UDOT INTERNAL DOCUMENT ONLY)	David Stevens	Asia Alvord, JoAnn Williams, Ken Jamison	Branden Anderson, Dave Schwartz	$76,831
UT-18.20	UT07.708	Shaking Table Tests to Evaluate Effectiveness of Vertical Drains for Liquefaction Mitigation	David Stevens	Kyle Rollins, Caleb Oakes	Jim Higbee	$115,000
UT-18.21	UT07.708	Reliability of FEQ Drain for Modeling Performance of Sand Treated with Large Diameter Drains for Liquefaction	David Stevens	Kyle Rollins, Travis Meservy	Jim Higbee	incl. with UT-18.20

UT-19.01	UT17.304	Analysis of Performance Measures of Traffic Incident Management in Utah	Travis Jensen	Grant Schultz, Mitsuru Saito, M. Hadfield, L. Bennett, D. Eggett	John Leonard	$70,000
UT-19.02	UT17.311	Surveying Non-motorized Travel Behavior at At-Grade Rail Crossings	Travis Jensen	Shaunna Burbidge	Jim Golden	$60,000
UT-19.03	UT17.303	Driver Compliance at Enhanced Pedestrian Crossings in Utah	Kevin Nichol	Kiavash Fayyaz, Pablo Galvez de Leon, Grant Schultz	Adam Lough	$50,000
UT-19.04	UT14.315	Safety Effects of Protected and Protected/Permissive Left-Turn Phases	Kevin Nichol	Juan Medina, Scott Shea, Nuzhat Azra	Jeff Lewis	$50,000
UT-19.05	UT17.306	An Analysis of Decision Boundaries for Left-Turn Treatments	Travis Jensen	Grant Schultz, M. Adamson, M. Stevens, M. Saito	Mark Taylor	$70,000
UT-19.06	UT17.305	Pedestrian Walking Speeds at Signalized Intersections in Utah	Kevin Nichol	Grant Schultz, Jordi Berrett, Dennis Eggett	Heidi Goedhart, Stephanie Tomlin	$50,000
UT-19.07	UT16.108	ASTM C-157 Standard Audit for Third Party Shrinkage Testing Laboratories to Improve the Reliability of Results for Concrete Mixes	David Stevens	Avinash Rishi, Pedro Romero	Jason Richins	$30,170
UT-19.08	UT14.104	Rapid Concrete Repair	David Eixenberger, Kevin Nichol	Marc Maguire, Robert Thomas, Ivan Quezada	Jason Simmons	$50,000
UT-19.09	UT15.104	Investigation of Concrete Electrical Resistivity as a Performance-Based Test	David Eixenberger, Kevin Nichol	Marc Maguire, Robert Thomas, Amir Malakooti	Jason Richins	$48,000

UT-19.10	UT17.602	Impact of Shared Autonomous Vehicles on Vehicle Miles Traveled in Utah	Kevin Nichol	Nima Haghighi, Robert Chamberlin, Kiavash Fayyaz, and Cathy Liu	Andrea Olson	$50,000
UT-19.11	UT18.704	Using Pavement Texture to Screen and Target Annual Skid Number Assessment	Vincent Liu	Charles Allen, Tim Peterson	Chris Whipple	$31,804
UT-19.12	UT16.205	A Data Fusion Approach for Extracting Highway Maintenance Features	Vincent Liu	Ziqi Song, Mohammadreza Javanmardi, Xiaojun Qi	Ryan Ferrin	$50,000
UT-19.13	AM17.19	Assessment of the Effectiveness of Wrong-Way Driving (WWD) Detection System	Vincent Liu	Zhao Zhang, Xianfeng Terry Yang,Cathy Liu, Yun Yuan	Robert Miles, Lisa Zundel	$40,000
UT-19.14	UT15.601	Key Enhancements to the WFRC/MAG Conventional Four-Step Travel Demand Model	Kevin Nichol	Reid Ewing, Keunhyun Park, Sadegh Sabouri, Torrey Lyons, Guan Tian	Andrea Olson	$25,000
UT-19.15	UT16.101	Balanced Asphalt Concrete Mix Performance in Utah, Phase III: Evaluation of Field Materials Using BBR and SCB-IFIT Tests	David Stevens	Pedro Romero, Kevin VanFrank	Howard Anderson	$160,000
UT-19.16	UT18.305	Evaluation Criteria for Safe Routes to School Projects	Vincent Liu	Shaunna Burbidge	Travis Evans	$74,967
UT-19.17	UT11.110	Performance Evaluation of Typical UDOT Surface Treatments	Kevin Nichol	Pedro Romero, S. Bao, D. Sudbury	Jason Simmons	$58,960

UT-19.18	AM18.38	Review of the UDOT Procurement Process for a Maintenance Management System	David Stevens, Michelle Lindgren	Rob Zilay (Dye Management Group)	Shawn Lambert	$80,610
UT-19.19	-	U.S. Highway 89 Kanab-Paunsaugunt Wildlife Crossing and Existing Structures Research	Randall Taylor	Patricia Cramer	Monte Aldridge, Matt Howard	(UDOT R4, UDWR, AZGFD)
UT-19.20	UT17.309	Non-Optimal Usage and Perception of a Protected Intersection for Bicycling and Walking, Salt Lake City, UT	Travis Jensen	Torrey Lyons, Dong-ah Choi, S. Hassan Ameli, Keunhyun Park, Reid Ewing	Heidi Goedhart	$10,000
UT-19.21	AM17.07	Travel Time Reliability in Simulation and Planning Models: Utah Case Study (SHRP 2 L04 IAP Round 7)	David Stevens	Xiaoyue Cathy Liu, Nima Haghighi	Kelly Njord	$200,000
UT-19.22	UT18.702	Using ATSPM Data for Traffic Data Analytics	Rukhsana Lindsey	Robert Chamberlin, Kiavash Fayyaz	Nicolas Black	$50,000
UT-19.23	UT17.206	Update of the Class 8 Truck Study	Vincent Liu	Cathy Liu, Zhiyan Yi	Jeff Casper	$35,000
UT-19.24	AM18.28	Annual UDOT Workshop on Transportation Research Needs: 2019 Proceedings	Vincent Liu	Vincent Liu, David Stevens	Cameron Kergaye	$4,099
UT-19.25	UT18.703	HERE Data Validation	Rukhsana Lindsey	Robert Chamberlin, Kiavash Fayyaz, Nima Haghighi	Kelly Njord	$50,000
UT-19.26	AM17.20	Investigation of Utah Highway Speed-Limit Compliance Rates and Evaluation of Speed-Limit Design in Towns along Highways	Vincent Liu	Zhao Zhang, Xianfeng Terry Yang,Cathy Liu, Yun Yuan	Adam Lough	$30,000

UT-19.27	UT18.314	Identification of Wildlife-Vehicle Conflict Hotspots in Utah	Kevin Nichol	Patricia Cramer	Robert Miles, Matt Howard	$65,862
UT-19.28	UT18.314	Hotspot Analysis and Mapping: A Guidebook For Creating Domestic Animal And Wildlife-Vehicle Collision Priority Hotspots Maps Based On Utah Crash And Carcass Data	Kevin Nichol	Patricia Cramer	Robert Miles, Matt Howard	incl. with UT-19.27
UT-19.29	UT18.308	Guidance for Enhanced Pedestrian Treatments within Reduced-Speed School Zones (RSSZs)	Rukhsana Lindsey	Robert Chamberlin, J. Locquaio, S. Petheram, S. Orton	Adam Lough	$24,224

APPENDIX C - LITERATURE SEARCH

Best Practice Guide for Qualifying the Benefits of MnDOT Research - for MnDOT by Athey Creek Consultants, June 2013 [3]

This is a comprehensive evaluation of best practices used to measure the benefits of transportation research by various DOTs around the country. Surveys of all DOTs were conducted through the RAC ListServ. More detailed summaries were documented in the form of case studies of certain DOT programs and practices. These case studies were recorded for Utah, Missouri, Florida, and Louisiana. Additional concepts were recorded from Indiana, Iowa, and Illinois.

The foremost recommendations to MnDOT were to:

1- Increase focus on research benefits by those involved in the research,
2- Encourage implementation and communicate success stories of projects throughout the entire research process.

Missouri DOT has been successful in documenting specific benefits within the deliverables of individual projects. This strategy greatly enhances the chances for implementation of the project findings by directly demonstrating how the changes will benefit the traveling public and the DOT. These benefits are published in the Missouri DOT Tracker.

Florida DOT conducts a "Research Deployment Plan Survey" that is required prior to research contract finalization. A baseline deployment plan is prepared from the information which is updated during the project and used to guide implementation activities and products.

Florida also conducts implementation after completion to document implementation success. They use a form "Florida DOT Implementation Tracker" to compile the needed information.

"Louisiana DOTD Program-Level Performance Measures" are used to measure the success of the research program. They utilize a list of goals and targets to improve performance of their operations, deliver cost-effective products, improve customer service, and effectively manage their financial resources. Louisiana also publishes a project Fact Sheet for each project.

Indiana DOT publishes project findings in the form of a "Research Pays Off" periodical. Iowa DOT publishes a "Research at Work" summary outlining project results. These summaries document the benefits of the projects and aid in implementation.

The "Illinois DOT Implementation Worksheet" is used to plan the implementation activities and needed resources. Potential challenges, the required personnel needed, and the estimated benefits of a successful implementation are recorded and used in the plan.

Valuing Benefits of Transportation Research: A Matrix Approach, Florida 2002 [4]

The results of this study indicate that there is no single method suited to evaluate projects across all proposed categories. Even within a single category different approaches may be appropriate depending on agency constraints and objectives.

This research team developed a matrix approach for categorizing projects as a means of determining the appropriate methods for calculating benefit. In addition to the well-established methods such as Benefit-Cost Analysis and Net Present Value, a Real Options Approach is recommended.

The authors believe that the Real Options Approach is capable of providing a better assessment of transportation research projects whenever there is an element of risk and uncertainty. Transportation research projects have the potential to produce enormous benefits, but they come with risk that actual benefits, costs, and other factors affecting implementation may differ greatly from those predicted.

The option approach enhances the decision-making process so that it does not consist merely of a choice whether to invest in a research project. It also consists of a management perspective that considers a range of possible decisions, with the potential value of each decision measured in terms of its option-creating value. The Real Options Approach is not only a way of estimating expected project benefits, but also is a way of thinking about research programs.

The matrix approach cannot be used to evaluate all project types and therefore should be used along with other methods only when appropriate. It may also be useful in creating an optimal research portfolio geared towards maximizing returns when annual research budgets fluctuate.

Communicating the Value of Transportation Research Guidebook - NCHRP 610, [5]

This guidebook is an excellent resource for research personnel and others participating in the implementation of an innovative practice. It provides strategies for communicating with research partners, stakeholders, and administrators. The guide lists concepts to aid in communicating with specific audiences, such as research program managers, legislators, policy makers, the media, and the public. It also includes case studies from government, academic, and private organizations.

The guide emphasizes the need to convey the value of any research initiative to maintain the support of management and to justify the expenditures of funding. This crucial step is needed for support of existing initiatives as well as investments in research in the future. The guide also promotes the need for illustrating the value of any research undertaking throughout the project. This will help to create buy-in by potential end users and policymakers, leading to enhanced planning, funding, conduct, and deliverables for the project.

Demonstrating research benefits should include facts that show that the deliverables are aimed at the right issue, they portray the right level of importance, and they are being

implemented at the right time. "Communicating value, or worth, is more than providing numbers, as in benefit-cost formulas. Decision makers frequently assess value in terms of how they perceive the importance and worthiness of the research outcomes. The invisible, intangible perceptions they form and will remember can mean the difference between funding a transportation research program and cutting it."

To obtain full benefits from any research product every potential user must be involved in the implementation process. This seems obvious but is overlooked by principal investigators and project managers more often than research officials would like to admit. The guide stresses that: "People can spend a lot of time figuring out exactly what to say without giving much consideration to who should say it." It is very important to identify your implementation targets and then research them so you fully understand your audience and how their key values and interests relate to your research.

"Successfully communicating the value of your research to a targeted audience requires tailoring your communication to resonate with its needs, interests, and backgrounds." Linking your research to tangible benefits for the audience will capture their attention. Members of your audience are more likely to listen to you if they can readily understand why and how the research is important to them.

Many modes are available for communicating your research story, such as websites, advertising, brochures, fact sheets, and reports. These are important to fully portray the value and benefits of the research products. Successful communication sends the right message in the right medium. It also uses the appropriate messenger to deliver the message to the proper audience.

The guide emphasizes that research benefits should be measured and presented in the proper context. The value of a research endeavor is not enough to understand the full benefit. For example, the use of cable barrier prevents nearly 100% of the head-on collisions along a corridor. But a better indication of benefit is that it saves 20 lives per year, which is about 5% of the total fatalities statewide. The use of appropriate context is crucial.

The following concepts are useful for applying context effectively:

- Link current data and messages to long-term trends.
- Interpret the data: Tell the audience what is at stake and what it means to neglect this problem.
- Define the problem so that audience influences and opportunities are apparent— connect the dots, both verbally and in illustrations.
- Focus on how effectively the community/state/nation is addressing this problem.
- Connect the problem to root causes, conditions, and trends with which people are familiar.

Source: FrameWorks Institute, "Framing Public Issues."

Each customer of a research program has a different set of values. For this reason, each end user and stakeholder has a different way of evaluating the benefits of a research project. When calculating and demonstrating the benefits of research initiatives these different value systems should be considered. Table D1 provides a good research tool to prepare for communicating with the various customers of research projects.

Table D1 - Key Audiences for Transportation Research, NCHRP 610 [5]

Audience	Potential Communication Objectives	Benefits of Communication
Research Program Managers	-Ensure continued funding and support. -Communicate technical aspects of research. -Form partnerships for collaboration or coalitions.	-Increases acceptance of the research program across the field. -Increases the ability to leverage existing resources.
Congress, Legislators, and Staff	-Explain the significance of research. -Demonstrate benefits to constituency. -Link spending to research outcomes.	-Introduces legislation that benefits the field. -Increases the potential to gain governmental funding for research.
Policymakers	-Document a real need for research. -Explain the benefits of the research or program. -Demonstrate the success of the program.	-Implements action recommended by the research. -Adopts new products and processes.
Media	-Publicize the need for research. -Publicize the benefits through success stories. -Reach a broad audience.	-Increases exposure for the program. -Puts research on public's "radar." -Highlights a need for change or benefits of a practice or product.
Public	-Explain research findings in non-technical terms. -Show the importance of research to daily life.	-Creates a better-informed public. -Creates community-level support for initiatives.

NCHRP Report 750 Series [6]

These six reports on strategic issues facing transportation summarize the many changes that are projected for the transportation industry. They provide a discussion of how DOTs must work differently in the future. The reports address topics such as freight movement, climate change, technology, sustainability, energy, and socio-demographics.

The UDOT Research & Innovation Division must play a key role as the department transitions to these new transportation aspects. A retreat is recommended with key UDOT leaders to brainstorm how the department can prepare over time to address these issues.

- **Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment**
  Explore and plan for the future of freight with a scenario planning toolkit.

- **Volume 2: Climate Change, Extreme Weather Events and the Highway System: Practitioner's Guide and Research Report**
  How to prepare for extreme weather events.

- **Volume 3: Expediting Future Technologies for Enhancing Transportation System Performance**
  Select the right technology investments at the right time.

- **Volume 4: Sustainability as an Organizing Principle for Transportation Agencies**
  Organize transportation agencies to support a sustainable society.

- **Volume 5: Preparing State Transportation Agencies for an Uncertain Energy Future**
  Identify and assess strategic responses to a variety of future energy scenarios.

- **Volume 6: The Effects of Socio-Demographics on Future Travel Demand**
  Envision and model the transportation impacts of shifting demographics.

Investing in Utah Transportation Research, July 2016 [7]

The UDOT research projects conducted in 2009, 2010, 2011 and 2012 were evaluated. A composite benefit-cost ratio of approximately 14 was estimated for the UDOT research program at that time.

Measuring the Benefits of Transportation Research in Utah - September 2010 [8]

This project estimated the benefit-cost ratio for the program years 2006, 2007 and 2008. Concepts recommended to gather future information on research benefits include:

1- A detailed survey for champions of projects aimed at documenting the benefits in terms of deliverable quality, management performance, implementation successes, and project funding.
2- A table used to accumulate the benefits related to assets, user impacts, safety, quality of life, environmental impacts, knowledge building, and policy input. Each type of benefit is converted to dollars saved or losses prevented, where possible.

Benefits of Research Projects in Utah, May 2000 [9]

A study similar to this project was undertaken in 2000. The UDOT research projects conducted in 1995, 1996, and 1997 were evaluated. A study of this type is recommended on a three- to five-year cycle to determine the current benefits and to consider any recommendations to improve the research program. The lessons learned from the previous study were incorporated into this project to enhance the research methods and results.

Program to Measure Research Benefits and Track Implementation, Manual of Instruction, Version 2, May 2020 [10]

A manual was published to document the processes used to conduct the benefit-cost studies for the Research and Innovation Division at UDOT. A sample survey and data processing methods were included. Examples of B/C projects were provided.

Research Program and Project Management for Transportation (RPPM) [11]

This organization is a good resource to understand research projects, including: planning, funding, conduct, management, implementation, technology transfer and evaluation.

Valuable insight can be shared through collaboration between the states, federal, academic, and private-sector groups.