

BENEFITS OF TRANSPORTATION RESEARCH IN UTAH

Prepared For:

Utah Department of Transportation
Research and Innovation Division

**Final Report
May 2020**

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16. Abstract This study was initiated to estimate the benefits of UDOT's research projects over a four-year period, and estimate a benefit-cost ratio for the program. Benefit information gathered in this study indicates that the studies completed during the years 2013 through 2016 by the UDOT research program had an estimated benefit-cost ratio of 19. This included deliverables produced by 63 projects. Each project was also given a grade based on the success of the project and the value of the deliverables. The four-year program received an average grade of 3.1, 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 project managers in improving the implementation of research deliverables and products. Measuring the benefits of transportation research investments is important to justify the expenditure of research funding and to maintain the support of management. Understanding the benefits of research can better establish how future available funds are utilized and maximize how the funding is allocated. A process was developed and outlined for use by the UDOT Research and Innovation Division to gather benefit information related to research projects on an annual basis.			
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LIST OF ACRONYMS

UDOT	Utah Department of Transportation
UTRAC	Utah Transportation Research Advisory Council
TAC	Technical Advisory Committee
PM	Project Manager
PI	Principal Investigator
FHWA	Federal Highway Administration
TOC	Traffic Operations Center
ITS	Intelligent Transportation Systems
B/C	Benefit-Cost Ratio
TBD	To be determined
GPA	Grade point average
MSE	Mechanically Stabilized Earth
ABC	Accelerated Bridge Construction
Info-X	Information Exchange Video Conferencing Program
WASHTO-X	Western Association of States Highway Officials Exchange Videoconferencing
UTA	Utah Transit Authority

EXECUTIVE SUMMARY

This study was initiated to approximate the benefits of research projects conducted by the Utah Department of Transportation (UDOT) over a four-year period. This information was used to estimate a program benefit-cost ratio for the Research and Innovation Division.

Benefit information gathered in this study indicates that the studies completed during the years 2013 through 2016 by the UDOT research program had an estimated benefit-cost ratio of 19. This included deliverables produced by 63 projects.

Each project was also given a grade by end-users based on the success of the project and the value of the deliverables. The four-year program received a “B” grade achieving an average grade of 3.1 based on a 1 to 4 rating system.

The annual Research Workshop (UTRAC) process used to select projects for funding received very positive feedback. Recommendations were provided to aid UDOT research project managers in improving the implementation of research deliverables and products.

A process 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. The process includes tools and data development methods to evaluate the research program on an annual basis.

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

1.0-INTRODUCTION

It is widely understood that transportation agencies and facilities play a vital role in ensuring that our markets and local institutions prosper by the safe and efficient movement of people and goods. Connectivity is vital to the continued success of our state and region. Research programs are essential elements in enhancing these systems and solving problems facing transportation managers, engineers and travelers.

Transportation resources have decreased or remained stagnant resulting in substantial challenges. Our existing systems must not be taken for granted. Engaging in research endeavors to boost efficiency 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 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 by government, academic, and private sector professionals 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. A variety of transportation systems and strategies are being used to accommodate the projected increase in vehicle-miles of travel, more heavy vehicles, and growing congestion.
- 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 lands. UDOT has struggled with finding the correct strategies and funding levels to address the unique needs of each of these areas.
- A wide variety of geographical regions must be considered by the Department, including towering mountainous areas, high open ranges and low elevation deserts. Utah has the highest number of freeze-thaw cycles per year in North America. 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.

- 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.
- Transportation budgets and manpower are inadequate to meet these numerous challenges.

Sufficient assets must be dedicated in the form of funding, personnel and policies. UDOT research initiatives, innovative planning, and technology transfer are the best approaches to addressing these issues. UDOT region experts and central specialists, along with support from academics, consultants, and contractors, can propose solutions to these challenges.

2.0-STUDY OBJECTIVES

- 1- Estimate the benefits of major research projects.
- 2- Compare the observed project benefits with the costs to conduct the studies.
- 3- Calculate a benefit-cost ratio for the UDOT research program as well as for each of the project categories.
- 4- Determine which types of projects produce the highest benefit-cost ratios and which projects are more often unsuccessful or marginal.
- 5- Provide a trend in the benefit-cost ratios over time using the results of past studies.
- 6- Make recommendations concerning the research program and the best types of projects to initiate in the future.

3.0-TASKS

1. Form a TAC for the study made up of managers and stakeholders who are likely to use the findings.
2. Determine the project timeframe for evaluation and the Annual Work Programs that would be meaningful.
3. Compile a list of projects from the selected research programs.
4. List the project title, key champion, project manager, project cost, and all deliverables received for these research projects.
5. Conduct a survey for each project to gather the data needed to complete project objectives.
6. Meet with the key champion and others familiar with the research products, and review the estimates of the study benefits and total costs.
7. Convert all benefits into a dollar value. If this cannot be done the benefits will be listed as “Unknown”, and no benefits will be shown. The project costs will be compiled even if no benefits can be determined.
8. Compile all data and calculate a benefit-cost ratio. This will be done for individual projects, the total four-year time period, and for each project type.
9. Prepare a professionally written publication (Final Report) that will summarize the gathered information, and use the findings to make recommendations concerning the research program, project management procedures, and the research prioritization process (annual Research Workshop, formerly called UTRAC).
10. Create a document that shows the process and template used in the project so that other organizations can have a guide to conduct this work and a final presentation.
11. Create a slide deck explaining the findings and showcasing the results.

4.0-RESEARCH APPROACH

This study was initiated to estimate the benefits of UDOT's major research projects conducted during the years 2013 through 2016, and to make comparisons with the costs expended to conduct the studies. In addition estimates are provided for the benefits of various types of projects, including those related to infrastructure, operations, administration, and policy research.

A survey was distributed to project champions and end-users of the project deliverables. Follow-up interviews were used to aid in completion of the surveys, review the accuracy of the information, and to record other feedback to Research staff.

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 is necessary to allow a period of time between the 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 the 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.

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 percentage. A satisfactory level of involvement was ultimately achieved through follow-up virtual meetings to aid in the completion of surveys and to gather 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

The benefits of research activities can take many forms. For this reason it can be difficult to compile and evaluate these contributions to our transportation programs and operations. Various types of benefits were requested and received in the surveys. The interviews produced understanding of how the projects contributed to transportation state-of-the-practice and knowledge. A more detailed summary of these benefit types is described in Appendix A.

5.1-Benefits in Terms of Dollars

An estimate of the dollar value of the research studies was solicited from the project champions. The financial benefits captured on the project survey typically were entered and compiled as one of the following:

- Enhanced infrastructure (better designs, reduced construction costs, lower maintenance requirements, reduced materials costs, etc.)
- Savings to UDOT operations (reduced manpower, lower bids, lower operational costs, more efficient equipment, etc.)
- Benefits to the public (reduced congestion, improved safety, enhanced environment, etc.)
- Benefits in the form of institutional knowledge
- Zero financial benefits from the deliverables
- Benefits are not known at this time; implementation continues; future benefits may be achieved and are “to be determined” (TBD)

Steps were taken as part of the interview process to ensure that the benefit estimates used in the study remain 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 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 champion, the lower end of the range was used in the calculations.

5.2-Benefits as a Portion of a Program

Research deliverables often result in improvements to a UDOT program. The benefits of research findings may be estimated by assuming that the enhancements represent a “percentage” of the budget of the program or initiative.

The research scope and the resulting deliverables may represent a portion of a significant UDOT-achieved goal. This coordinated approach should be considered when estimating the separate benefits of the research project.

The UDOT programs impacted could be larger initiatives such as the construction program, the design program, safety initiatives, environmental directives, etc. Research project deliverables are often subsets of these programs such as material specifications, pavement design improvements, delineation safety enhancements, improved impact barriers, bridge construction methods, bridge design modifications, advanced geotechnical construction, 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.

Table 5.1-Benefits as Part of a Larger Initiative

Project Rating	Contribution	Estimated Benefit Range
A	Major Impact	10 to 50% of the program
B	Significant Impact	2 to 10% of the program
C	State-of the-Practice	0 to 2% of the program
D	Unclear findings	-0-
E	Objective not met	-0-

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

Example: The use of cable barrier may provide \$50 million in benefits over a ten-year period statewide. A research project aimed at determining where to place the barrier may contribute 10% to UDOT processes and policy on the issue and appropriate implementation of the concept. A \$5 million benefit could then be assigned to the research project.

5.3-Project Grades

The research products were further evaluated to estimate the usefulness of the project findings. Each deliverable was given a grade corresponding to the definitions listed in Table 5.2.

Table 5.2-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 contradictory findings: More study needed
E	Major tasks not completed: Objectives not met

5.4-Benefits Related to Cost Avoidance

Often transportation officials must take actions that increase the cost to the agency, the private sector, or the traveling public. These decisions are made for a number of reasons, but typically have a positive impact in the future. These benefits may be in the form of enhanced safety, reduced user costs, or positive environmental impacts.

But these decisions can also be made to reduce future costs. Cost avoidance is a valid and important engineering process. Cost increases over time are an inevitable aspect of transportation planning and budget preparation.

Deliverables from research projects can and do produce benefits in the form of cost avoidance. 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 cost increases. These costs can be significant over time.

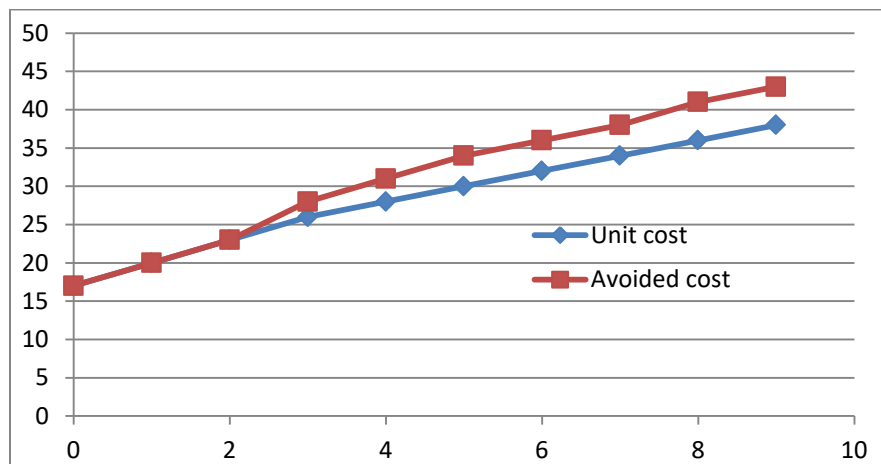


Figure 5.1-Benefits of Avoided Costs-Unit Cost Changes over Time

6.0-PROJECTS AND DELIVERABLES EVALUATED

A list of the reports documenting the research deliverables completed in 2013, 2014, 2015 and 2016 by the UDOT research program is provided in Table 6.1.

Table 6.1-Research Projects Evaluated

Number	Title	Benefits X 1,000	Grade
1301	Project canceled	--	--
1302	2013 UTRAC Proceedings	\$1.2	C
1303	Skid Correction Program - User's Manual	\$5,200	A
1304	Lateral Resistance of Piles Near Vertical MSE Abutment Walls	\$1,500	A
1305	Evaluating the Safety Effects of Signal Improvements	\$500	A
1306	Temporal and Spatial Variability of Base Materials Treated with Asphalt Emulsion: Redwood Road near Saratoga Springs, Utah	NR	--
1307	Compositional and Structural Properties of Emulsion-Treated Base Material: 7800 South in West Jordan, Utah	NR	--
1308	Frost Susceptibility of Base Materials Treated with Asphalt Emulsion	NR	--
1309	Physical and Chemical Effects of Deicers on Concrete Pavement: Literature Review	TBD	C
1310	Maintenance Program Decision-Making Utilizing Crash Data	\$710	C
1311	Reducing Highway Litter	0	B
1312	Behavior and Analysis of an Integral Abutment Bridge	TBD	C
1313a	Evaluating the Feasibility of Incorporating Mobility-Based Work Zone Traffic Control Performance Measures in Highway Construction Project Specifications: Volume I. Feasibility of Continuous Monitoring of Performance Measures	0	C
1313b	Evaluating the Feasibility of Incorporating Mobility-Based Work Zone Traffic Control Performance Measures in Highway Construction Project Specifications: Volume II. Developing Guidelines for Mobility-Based Performance Specifications	R1313a	--
1314	Monitoring of Duromaxx Pipes Installed on Manhead Road in Richfield County, Utah	NR	--
1315	Hot Spot Identification and Analysis Methodology	R1510	--
1316	Lessons Learned-Pavement Marking Warranty Contract	\$350	B

1317	Utah Department of Transportation - Asset Opportunities Study, Phase I	0	B
1318	UDOT 2012 Research Peer Exchange	0	B
1401	Comparison of Winter Temperature Profiles in Asphalt and Concrete Pavements	TBD	C
1402	Deicer Usage on Concrete and Asphalt Pavements in Utah	0	C
1403	Comparison of Wintertime Asphalt and Concrete Pavement Surface Temperature on US Route 40 Near Heber, Utah	NR	--
1404	Water Vapor Movement in Freezing Aggregate Base Materials	NR	--
1405	I-15 Express Lanes, Phase I	R1503	--
1406	Identifying Potential Technological and Service Improvements for UDOT Traffic Operations Center	\$8,400	A
1407	400 South Corridor Assessment	NR	--
1408	Cold In-Place Recycle Phase III, Mix Design	R1604	--
1409	Seismic Evaluation of Grouted Splice Sleeve Connections for Precast RC Bridge Piers in ABC	TBD	C
1501	Non-Consent Towing Cost Study in Utah	\$24.3	A
1502	Comparison of Conventional and Internally Cured Concrete Bridge Decks in Utah	NR	--
1503	I-15 Express Lanes Phase II	\$250	A
1504	Rock Stream Stability Structures in the Vicinity of Bridges	NR	--
1505	Data-Driven Freeway Performance Evaluation Framework for Prioritization and Decision-making	NR	--
1506	Impact of High-Efficiency Vehicles on Future Fuel Tax Revenues in Utah	\$981.7	A
1507	Project canceled	--	--
1508	Cold In-Place Recycle Phase III, Supplemental-Field Protocol: Short-Term Field Stability	R1604	--
1509	Simplified Web-Based Decision Support Method for Traffic Management and Work Zone Analysis	NR	--
1510	Use of Roadway Attributes in Hot Spot Identification and Analysis	\$2,430	A
1511	Identifying Characteristics of High Risk Intersections for Pedestrians & Cyclists: Phase 2	NR	--
1512	Crash Prediction Modeling for Curved Segments of Rural Two-Lane Two-Way Highways in Utah	R1510	--

1513	Development of Performance Matrices for Evaluating Innovative Intersections and Interchanges	NR	--
1514	Calibration of Automatic Performance Measures – Speed and Volume Data: Volume 1. Evaluation of the Accuracy of Traffic Volume Counts Collected by Microwave Sensors	\$350	A
1515	Scan Tour of Safety-Related Intelligent Transportation Systems across the United States	NR	--
1516	Roadmap for Evolution of the UDOT Business Culture: Research Conducted September 2013 through July 2014 (UDOT INTERNAL DOCUMENT ONLY)	NR	--
1517	Utah Department of Transportation - Culture Research Study: Supplemental Report, Phase 2 Research Conducted April through October 2015 (UDOT INTERNAL DOCUMENT ONLY)	NR	--
1601	Impact of Bicycle Corridors on Travel Demand in Utah	NR	--
1602	Developing a Rubric and Best Practices for Conducting Bicycle Counts	NR	--
1603	Correlation of Laboratory and Field Friction Measurements to Optimize Utilization of Bituminous Surface Aggregates	NR	--
1604	Cold In-Place Recycling Using Solventless Emulsion - Phase 4 (Emulsion Qualification and Long-Term Field Performance)	\$5,050	B
1605	Calibration of Automatic Performance Measures - Speed and Volume Data: Volume 2, Evaluation of the Accuracy of Volume Counts & Speeds from Microwave Sensors	\$2,100	A
1606	Snowplow Operator Driving Time: Survey of State and Local Practices	TBD	B
1607	Investing in Utah Transportation Research	\$453.5	A
1608	Process to Measure Research Benefits and Track Implementation, Manual of Instruction	0	B
1609	Using the Bending Beam Rheometer for Low-Temperature Testing of Asphalt Materials	0	B
1610	Evaluation of Pavement Markings Under Wet-Night Road Conditions	0	C
1611	Investigation of Laboratory Tests for Assessing Structural Capacity of Geogrid-Reinforced Aggregate Base Materials	0	C
1612	Laboratory Resilient Modulus Measurements of Aggregate Base Materials in Utah	\$30,000	B
1613	Roadway Safety Analysis Methodology for Utah (Traffic & Safety Project with Scott Jones)	R1510	--
1614	Examining the Characteristics of Fatal Pedestrian Crashes	0	C
1615	Life-Cycle Benefit-Cost Analysis of Safety-Related Improvements on Roadways (Companion to "Roadway Safety Analysis")	R1510	--

1616	Simplified Standard Penetration Test Performance-Based Assessment of Liquefaction and Effects	\$410	A
1617	Review and Specification for Shrinkage Cracks of Bridge Decks	0	E
1618	Project canceled	--	--
1619	Probabilistic Liquefaction Potential and Lateral Spread Hazard Maps for Utah County, Utah: Collaborative Research Brigham Young University and Oregon State University	NR	--
1620	Investigation of Structural Capacity of Geogrid-Reinforced Aggregate Base Materials in Flexible Pavements	TBD	A
1621	Accuracy of In-Situ Water-to-Cement Meters for Concrete	0	C
	Total	\$58,711	

TBD - To be determined

NR - Survey not returned

R - Refer to

7.0-PROGRAM BENEFIT-COST RATIO

The surveys and follow-up interviews with project champions produced a dollar estimate of the value of the deliverables for the 42 surveys returned. A summary of the methods and calculations used are provided in the following sections.

This analysis provides an indication of the worth or value of the deliverables relative to the investment dedicated through research funding and other resources. Again all data utilized in the calculations were conservative based on both the methods recommended for use, 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 of the 63 deliverables was \$58,710,700.

These benefits are shown in Table 6.1.

7.2-Cost of Research Estimates:

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

(Note: Program cost estimates included all project costs even for projects where benefits could not be identified)

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 author.

❖ **Total Contract Amount Cost (4 years) = \$2,155,000**

7.2.2-Technical Advisory Committee (TAC) Investment

A Technical Advisory Committee (TAC) provides oversight, data, information, deliverable reviews, and discussions in meetings. 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 hourly wage of \$40 with 50% overhead was assumed.

$$\diamond \text{ TAC Costs} = 6 \text{ members} \times \$60 / \text{hr} \times 3 \text{ hrs} \times 5 \text{ meetings} \times 63 \text{ projects} = \$340,200$$

7.2.3-Project Management (PM) Costs

Average PM cost estimate = \$9,000 per project.

A high level of project management costs were 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.

$$\diamond \text{ PM Costs} = 63 \times \$9,000 = \$567,000$$

The total cost of the 63 projects is estimated at \$3,062,200.

7.3-Benefit-Cost Ratio Calculations:

$$\color{blue}{+} \text{ Benefit/Cost} = (\text{Number} \times \text{Value} \times \text{Percentage}) / (\text{Contract} + \text{TAC} + \text{PM costs})$$

$$\text{Benefit/Cost} = 58.7107\text{M} / 3.062\text{M} = 19.2 \quad \text{Use } \underline{19}$$

Table 7.1- Benefit/Cost Summary of Four-Year Program

	Number	Amount	Total
Benefits	63 projects		<u>\$58,710,700</u>
Contracts	63 projects		\$2,155,000
TAC Costs	6 members x 3 hrs x 5 meetings x 63 projects	\$60 per hour	\$340,000
PM Costs	63 projects	\$9,000 per project	\$567,000
Costs			<u>\$3,062,000</u>
Benefit/Cost			<u>19</u>

7.4-Benefit-Cost Ratio for the Research Program

The estimated B/C for the UDOT Research Program from 2013 to 2016 is 19.

This benefit-cost estimate indicates that every dollar invested in research projects results in a return of \$19 in transportation enhancements and advancements.

The benefits estimated in this study are considered to be somewhat lower than the actual values. This is due to the relatively poor response to the surveys (67%) distributed to the project champions.

This low response was due to a number of factors including:

- Position turnover within UDOT
- A large number of employee retirements
- End-users feel that they are too busy to respond

Many of the champions completing surveys did not feel knowledgeable enough to include benefit estimates in the form of dollars and left that part of the survey blank. Meetings with these project champions were quite successful in many cases due to significant effort on the part of the project manager. Without these meetings the percentage of surveys returned would likely have been much lower.

7.5-Benefit-Cost Ratios for Project Types

The projects were separated into project types as shown in [Table 7.2](#).

7.5.1-Infrastructure Related Projects

These projects included those related to pavements, materials, structures, geotechnical, and construction. A higher benefit-cost ratio was observed for this group. This would be expected due to the high value of infrastructure facilities and the high cost to maintain these features.

7.5.2-Operations Related Projects

Projects considered to be Operations in nature are safety, traffic, and intelligent transportation systems (ITS). These projects also show a high benefit-cost ratio. Crash-related costs have been decreasing over the last few decades due to improvements in vehicle enhancements and highway improvements. Although the number of crashes has increased as traffic volumes have grown, crash rates and severity of incidents has declined. Efficiencies have been achieved through vehicle safety improvements, ITS advancements, and various efficient highway applications.

7.5.3-Administration Related Projects

A review of the four administration-related projects reveals that these projects were successful and provided valuable insights. They contributed to the expertise of key UDOT leaders. A lower benefit-cost ratio was observed here as may be expected.

7.5.4-Policy-Related Research

The five policy-related projects conducted were shown to provide valuable information. Although no dollar benefits were provided for four of the projects through the surveys, these projects were instructive to policymakers in UDOT. The one project related to fuel tax revenue produced a benefit of nearly \$1 million and resulted in a benefit-cost ratio of 5 for this group.

**Table 7.2-Benefit-Cost Ratios for Project Types
2013 - 2016**

Project Type	Contracts x 1,000	TAC Costs x 1,000	PM Costs x 1,000	Total Cost x 1,000	Benefits x 1,000	Benefit/Cost
Infrastructure	\$1,110	\$146	\$244	\$1,500	\$37,310	25
Operations	\$840	\$145	\$242	\$1,227	\$19,964	16
Policy Research	\$140	\$27	\$45	\$212	\$982	5
Administration	\$65	\$22	\$36	\$123	\$455	4
Totals/Average	\$2,155	\$340	\$567	\$3,062	\$58,711	19

8.0-TRENDS IN BENEFITS-COST RATIOS

The estimated benefit-cost ratios from previous studies were compared with the estimate from this study. A general increase is observed in the ratios over time, although the limited data cannot be considered to be statistically significant. Table 8.1 and Figure 8.1 illustrate this information.

Table 8.1-Benefit-Cost Ratios from Previous Studies

Year Reported	Years Evaluated	Number of Projects	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

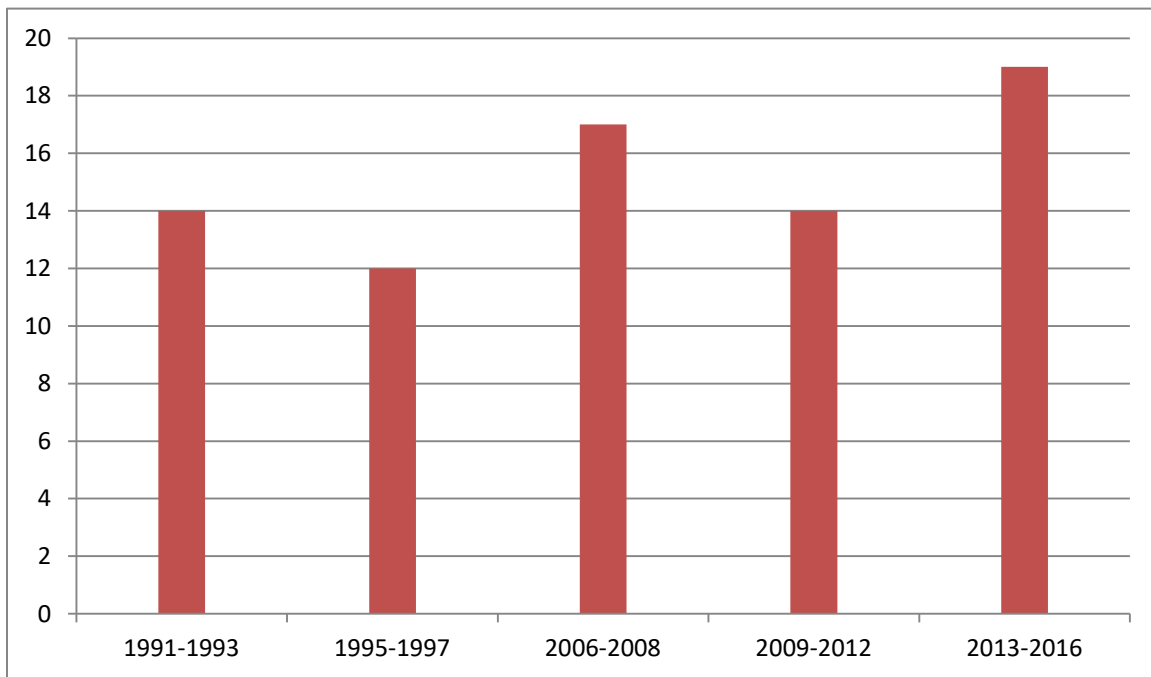


Figure 8.1-Trend in Benefit-Cost Ratio

Similar benefit-cost ratios were estimated for the five benefits-related studies that have been completed over the last 25 years. The values range from 12 to 19. All five of these studies produced benefit values that are considered to be conservative and on the low side.

The benefit-cost ratio of 14 reported in 2016 for the years from 2009 to 2012 is considered to be under-reported. This may be a result of the lower percentage of surveys (37%) returned in that study.

Possible factors leading to a higher benefit-cost ratio for projects conducted in the years 2013 to 2016 are:

- Better project selection through the research prioritization process (Research Workshop)
- Quality project work by consultants
- Improved project management methods utilized by Research staff
- Follow-up interviews, emails, and telephone conversations were used to promote responses to the surveys.

9.0-PROJECT GRADE SCORES

Each study was given a grade by the project champions based on the definitions listed previously in Table 5.1. This information is summarized in Table 9.1.

**Table 9.1-Summary of Project Grades
for Project Types**

Functional Area	A	B	C	D	E	GPA
Construction	-	-	2	-	-	2.0
Materials/Pavement	-	5	3	-	-	2.6
Structures	2	-	-	-	1	2.7
Maintenance	-	4	2	-	-	2.7
Administration	1	2	1	-	-	3.0
Geotechnical	3	-	1	-	-	3.5
Safety/Traffic/ITS	9	-	3	-	-	3.5
Planning/Asset Mgt	2	-	-	-	-	4.0
Policy Research	1	-	-	-	-	4.0
Totals/Average	18	11	12	0	1	3.1

A grade point average of 3.1 (on a 0 to 4 scale) or a B grade was generated from the 41 submitted surveys for the 63 projects evaluated.

An interesting observation is that projects related to the big-ticket aspects of our highway system (structures, construction, pavements, etc.) were given somewhat lower grade-point averages, but had much higher benefit-cost ratios as observed in Table 7.1.

The tendency to give these projects a lower importance is overcome by the higher benefit-cost ratios for these project types. Again the value of these facilities seems to increase the ratios reported.

10.0-PROGRAM BALANCE

It is important for the UDOT research program to engage in all areas of significance within the Department. Program balance should be evaluated annually to review the significance of projects in each functional area.

10.1-Balance in Terms of Project Numbers and Funding Levels

The program balance for the four years observed in this study is illustrated in Table 10.1. Trends in the balance of the research program can be observed by comparing this information with similar records from studies done in previous years.

The overall focus of the research program has changed in many ways over the last 25 years. The top two areas of focus previously were structures and geotechnical-related projects. Safety, traffic and ITS projects were of moderate emphasis.

Significant increases have occurred in the areas related to Operations (safety, congestion, and ITS) and asset preservation (maintenance and asset management). The number of research projects related to structures, geotechnical, and construction issues declined significantly over the last few years.

**Table 10.1-Research Program Balance
2013-2016**

Functional Area	Number of Projects	Percent of Projects	Percent of Funding
ITS/Traffic/Safety	16	25	23%
Materials/Pavements	13	21	21%
Planning/Asset Management	8	13	18%
Maintenance	7	11	3%
Administration/Policy	6	10	5%
Geotechnical	5	8	16%
Structures	4	6	8%
Construction	2	3	3%
Hydraulics	2	3	3%
Environmental*	-0-	-0-	-0-

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

These trends appear to be appropriate since new construction has declined and operations and preservation of our corridors have received heightened importance. These trends indicate that the emphasis within the UDOT research program has evolved with the trends in transportation priorities.

Not all functional areas should necessarily be equally represented, but a conscious effort should be made to evaluate and rebalance the research program as needed. This information should be reviewed by key leaders in the Department and feedback to research managers should be provided on this aspect of the research program.

The relative “success” of these functional areas should be considered when making decisions related to program balance. 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.

An effective research program should strive toward focus and balance in a number of ways. These include:

- **High-Value Transportation Aspects** (pavements, bridges, safety, environmental, etc.): Appropriate emphasis should be based on the current needs of these areas, as well as the importance of the aspect. For example, big-ticket items such as pavements and bridges should receive an appropriate portion of the research budget and emphasis. Also safety improvements must be given a high priority.
- **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 that may need only a minor adjustment sufficient chance to succeed. Implementing entirely new technologies too often can also be more costly compared to fine-tuning existing processes and programs.
- **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 expenditures of the transportation budgets, and even modest improvements can be beneficial. 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.
- **National Initiatives vs. Local Issues:** Transportation research is a crucial aspect of our society on 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 the state and local levels generally deal with issues and problems unique to each region or state.

- **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.

When evaluating the benefits of research, these types of issues 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.

11.0-RESEARCH BENEFITS RELATED TO UDOT’S VISION AND GOALS

The UDOT research program must be tailored to stress issues and initiatives identified by key leaders in the Department. UDOT administrators have identified areas of emphasis for UDOT that must in turn be targeted within the research program. 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 a principal consideration when program balance is reviewed.

General guidelines for the research program are highlighted in UDOT’s *Vision* tagline, ***“Keeping Utah Moving”*** and *Mission* statement, ***“Innovating transportation solutions that strengthen Utah’s economy and enhance quality of life”***. The Department’s *Strategic Goals*, *Emphasis Areas*, and *Core Values* provide more focused topics for approval and funding of specific research projects.

Strategic Goals

- Zero Crashes, Injuries, and Fatalities
- Preserve Infrastructure
- Optimize Mobility

Emphasis Areas

- Integrated Transportation
- Innovation
- Collaboration
- Quality
- Education
- Transparency

UDOT’s Core Values

- Trust
- Safety
- Integrity
- Fiscal Responsibility
- Passion
- Public Responsiveness
- Dedication

Observations for the years evaluated show that proper emphasis has been given to the Department’s Vision, Mission, and Strategic Goals when selecting problem statements during the Research Workshop (UTRAC) prioritization method. These concepts have been built into research projects within the Annual Research Work Program funding process. It has been a strong tradition for many years and is being followed well by current Research Managers, to ensure that UDOT’s goals and areas of emphasis are represented in the program balance review.

12.0-RESEARCH WORKSHOP PROCESS ENHANCEMENTS

The annual Research Workshop and prioritization process is a valuable opportunity for UDOT personnel, academic stakeholders, and private-sector partners to set direction for the research program. The main purpose of this 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 is an important aspect of obtaining optimum benefit for the budget expended. The award-winning UTRAC process reliably aligns the available funding with the submitted problem statements.

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

- Problem statements of quality and appropriate concepts
- Project selection methods that are efficient and effective
- Valuable interaction between government, academic, and the private sector resulting in powerful teambuilding in the Utah transportation field
- The workshop propels concepts from an idea to the ideal solution

12.1- Project Deliverables and Products

The survey was utilized to obtain opinions from the project champions on the best products and deliverables to further the implementation of the project findings. The deliverables listed in Table 12.1 were included in the survey.

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	➤ 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 project champions indicated in the surveys that when adequate deliverables are achieved through the projects funded, the program consistently produces successful projects. The surveys ranked the research products and deliverables shown in Table 12.2 as the most valuable in attaining implementation of the project findings. The survey results indicate that hands-on types of products along with a quality report are the most effective in implementing the results of research projects.

Table 12.2-Recommended Products and Deliverables

Ranking	Product/Deliverable	Champions Recommended
1	Training Sessions & Materials	13%
2	Manual of Instruction	12%
3	Report	12%
4	New Product Evaluation	11%
5	Policy & Procedure	10%
6	Specification	9%
7	Peer Exchange	7%
8	State-of-the-Practice Summary	7%
9	Experimental Feature	6%
10	Design Method	4%
11	Scanning Tours & Workshops	3%
12	Laboratory Test	3%
13	Executive Summary	3%

12.2-Implementation Activities at the Research Workshop

The breakout sessions at the annual Research Workshop (UTRAC) are a valuable setting for revisiting the implementation efforts of completed research projects. Each of the six breakout sessions should allocate time to address implementation plans for the top research products recently completed within that group.

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

- New Projects
- Implementation activities of completed projects

Remaining funding not allocated for implementation activities would be used to fund additional new projects.

13.0-REVISIONS TO FORMS TO ENHANCE IMPLEMENTATION

The Research and Innovation Division utilizes five forms during the concept review, project management, implementation of deliverables, and feedback phases of each project. These forms could be modified to better include implementation activities and track project benefits.

Modifications and additions are proposed for each form listed as follows:

13.1-Research Workshop Problem Statement Form

- This 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. The potential deliverables listed in Table 12.1 along with others that may be appropriate should be encouraged.*
- The form could be modified to be more specific to each of the individual breakout session topics. This will require a detailed description of how the project (if funded) would improve operations or reduce costs. A discussion should be required that outlines the *specific benefits* that will be achieved through the deliverables and how they will be implemented.
- *An estimate of the benefit-cost ratio of the project should be included in the form.* The research contact for the breakout session must approve the logic, assumptions, and numbers used on the benefit-cost estimate. 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 in how they would be efficiently engrained in UDOT processes, policies, and business practices.

13.2-Implementation Plan Form

- A section should be added that specifically identifies the benefits resulting from the project and the financial value to the Department that will be achieved.
- This plan is a key part of the research process. For the implementation plan to be effective it must be reviewed and updated throughout the research process. As the plan is updated, each version of the plan should be labeled in the title.
- Each TAC meeting should have an agenda item to review the existing plan and make any needed improvements. If funding is recommended for activities such as training sessions, user’s manuals, or additional products, the TAC should take actions to address this need.

13.3-Research Project Management Checklist

Under the “Project Deliverables” section of this form, provide the same checklist of potential deliverables ([Table 12.1](#)) that could be developed. The contract should include as many of these products as needed to allow for appropriate implementation of the initiative by UDOT.

13.4-Mid-Project Evaluation Form

The review of an ongoing project should include a more detailed evaluation of progress made on the implementation plan. Specific milestones should be evaluated at this point in the project. Special attention should be given to the progress made on the deliverables included in the contract.

13.5-Research Project Evaluation Form

- A section should be included on this form that will provide an estimate of the monetary value of the project deliverables. Briefly describe how these values can be obtained and who should be contacted to determine/verify the estimates.
- The 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.

14.0-IMPLEMENTATION STRATEGIES TO OPTIMIZE BENEFITS

The importance of implementation to a research program cannot be overstated. Achieving all of the steps needed to realize buy-in by end-users is often difficult. The final step in the research process is often the most difficult. Research conferences and national initiatives have been devoted to break down the barriers to implementation for many years.

Some PIs conducting research feel their responsibility is completed when the final report is published. Others feel they aren't given an opportunity to be adequately involved in the implementation process. One of the most important by-products of the annual Research 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 to UDOT operations. Implementation tracking applications such as forms and matrixes 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 to aid in moving the concept into practice is fundamental. Feedback on this phase should include the end-users, TAC members, division and regional key managers, the research project manager, and technology transfer experts.

14.1-Budgeting and Planning for Implementation Initiatives

Funding for implementation activities should be included as part of the research project contract when possible. 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.

A clear vision of what deliverables will be produced is needed. The following questions should be answered at each phase of a research project:

- 1- What implementation-related deliverables will be created?
- 2- What tasks are necessary to achieve implementation?
- 3- Who will be the key personnel during 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?

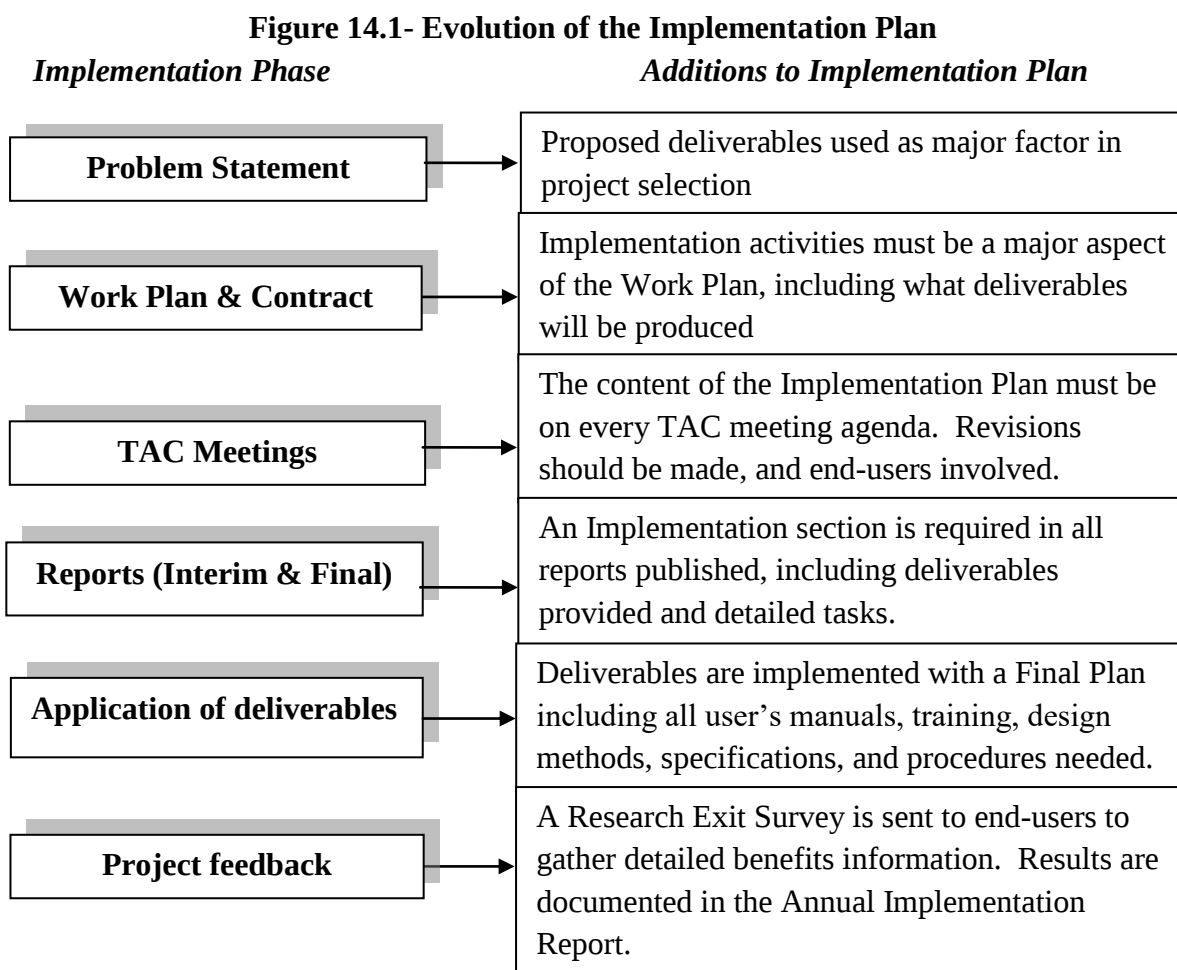
Adoption of more efficient and innovative practices should be a basic underlying philosophy of the entire Department not just the research staff. This culture of adopting new ideas and

processes is a significant investment in resources for the Department, but this commitment has been shown to help the organization work smarter and more efficiently.

14.2-Tools to Track Implementation by Project Phase

All phases of a research project must accurately and effectively address the ultimate implementation of project deliverables. The implementation potential of a project and how it will be achieved should be addressed at each stage.

A high emphasis must be placed on the concept of continuous implementation planning to accomplish this goal. Every phase of a research undertaking should have a link to how the products and outcomes of the project will be used. Figure 14.1 describes how the Implementation Plan can evolve as the project progresses.



The matrix provided in Table 14.1 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 unsuccessful. Time and money can be saved by making decisions as early as possible.

Table 14.1 - 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 annual Research Workshop (UTRAC) -Deliverables and products identified -Used as 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 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

14.3-Technology Transfer Results in High Benefit-Cost Ratios

Distribution of the results of research projects is a deep-seated characteristic of the technology network. Sharing and implementing innovative concepts between agencies and industries carries a very high benefit-cost value. Initiatives such as literature searches, state-of-the-practice studies, scanning tours, experimental features and new product evaluations can provide successful improvements with very modest investments.

Benefits can be achieved from unsuccessful research. This is dreaded by every research stakeholder but it will invariably happen. Processes should be in place to deal with research that does not meet expectations, and reporting of unsuccessful research should *not* be avoided. It is the responsibility of researchers from all aspects of the work to learn from negative research findings. Benefits may be achieved through acquiring knowledge that leads to avoiding inferior concepts or expensive mistakes.

14.4-Region and Division Visits and Interaction

It is valuable for UDOT Research and Innovation Division personnel to have a basic understanding of the problems and challenges facing UDOT engineers, managers, and technicians. The best way to accomplish this goal is to interact with region and division personnel on a recurring basis.

Region and division visits are important to maintain a practical relationship with the operational aspects of the Department. This activity will improve the number and quality of the problem statements submitted to the annual Research Workshop (UTRAC) and will increase the number of special requests submitted for processing.

Attendance at staff meetings is an excellent way to obtain feedback on problems and the needs of UDOT experts. Winter months are especially constructive for meetings since workloads may be lower and the Research Workshop is only a few months away. Participation in the workshop should be encouraged during these interactions. These visits can be used to align UDOT professionals with university and private sector experts to gain the strengths of all three sectors, uniting them in addressing problems and improving efficiency.

14.5-Policy as a Tool for Implementation

The implementation of new and innovative deliverables can be greatly promoted through the use of policies. Using policy to further the use of new design techniques, specifications, testing methods, and new products has not always been 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. The universal use of new design methods, the use of innovative software, the adoption of users' manuals, and other implementation tools should be reviewed and formally promoted by the Department at a high

level. “Good judgment comes from experience. And experience? Well, that comes from poor judgment.” (A.A. Milne)

14.6-Patents and Spin-off Companies

The UDOT Research and Innovation Division should, when appropriate, participate with the private sector in the creation of patents through new product development. 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 grey area in this relationship, but many new products cannot be properly investigated or evaluated without involvement by experts in transportation agencies.

14.6.1-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 to both the traveler 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.

14.6.2-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 indicted which sealers could be used on pavements, and which ones were restricted to vertical concrete surfaces.

14.7-New Products Evaluation

Feedback received indicates that the Research and Innovation Division should have a greater role in the evaluation of new products that are submitted to the Department for consideration. Oversight of this program was formerly managed by Research staff, but was transferred to the Division of Maintenance a few years ago.

Key UDOT leaders should consider moving the New Products Evaluation Program to the Research and Innovation Division once again, or at a minimum, involve Research personnel in the process. This would give the assessment of new products a more broad and formal forum for evaluation. New products should receive one or more of the following recommendations:

- The product meets current standards - Yes or No
- A literature search should be conducted
- It should be used in a field test section
- A scanning tour should be funded

14.8- Videoconferencing

The success of videoconferencing at many levels 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 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 significant costs and time to conduct in-person meetings. Current conditions leading to social distancing further emphasizes this need.

14.8.1- 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. Topics were recommended by state experts and each state was asked to answer questions sent in about how their agency addressed the issue.

14.8.2- WASHTO-X Videoconferencing Program

This technology transfer program was established to conduct virtual, interstate staff meetings. Various groups of experts met over videoconferencing systems to share ideas with their counterparts in other states.

These groups included materials, construction, maintenance, motor carriers, and others, which met on an annual or semi-annual basis. Each group rotated the lead state which would establish agenda items (typically two to five items) sent in for discussion. Session topics included how each state would implement new federal guidelines, best use of equipment and personnel, new problems facing the group, and they would also discuss issues at state borders.

15.0-ADDITIONAL USES FOR BENEFIT-COST INFORMATION

15.1-UDOT Program and Project Decisions: Reverse Engineering

Information related to the benefits and costs of transportation initiatives can be used in the decision-making process for UDOT programs. Although both the benefits and costs of research projects may not directly align with UDOT programs, the information can be very valuable in the types of decisions Region Directors and Division Heads are frequently faced with.

15.1.1-Process

- Determine an acceptable benefit-cost ratio for the program or project feature
- Back-calculate the required benefit by using the B/C 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.

15.1.2-Benefit/Cost Library

UDOT should consider creating and maintaining a Benefit/Cost Library. Values of B/C for various initiatives would be included for use by engineers and planners statewide as follows:

- Traffic and Safety: rumble strip, cable barrier, deer fence, etc.
- Construction: design-build, lane rental, movable barrier, etc.
- Structures and Geotechnical: ABC off-site bridge construction, geofoam foundations, wick drains, etc.
- Materials and Pavements: mechanistic-empirical design, composite pavements, etc.
- Environmental: wetland banking, mitigation methods, noise abatement, etc.

15.1.3-Benefits Entered into the Library

Modifications must be completed to the values gathered through research studies before they can be used in the Benefit/Cost Library. 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 library.

15.1.4-Costs Entered into the Library

The costs related to an initiative are very different than 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.

15.2-Example: Cable Barrier

Assume a value of \$170,000 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) crossover crash occurring during its life-cycle [$\$2,133,100/\$170,000 = 13$].
- Or more than 15 crossover crashes with an “injury” (severity B) occurring during its life-cycle [$(15) \times (\$133,100)/\$170,000 = 12$].
- Or some combination of crash severities and numbers resulting in a B/C of 10 or greater.

15.3-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.

15.4-Media Marketing Program

Communicating innovative activities within UDOT and to external partners has been demonstrated to be a productive activity. The Media Marketing Program can be an important tool in illustrating the benefits of research initiatives and other innovative UDOT activities.

The program involves UDOT personnel at two important levels: communications professionals and technical experts. This team provides information from the researcher to the traveling public. UDOT public relations personnel and media professionals can greatly enhance the message that a research deliverable is of value to the traveling public.

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

15.4.1-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.

15.4.2-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.

15.4.3- Example: Lego 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.

15.4.4-UDOT Uses of Media Marketing Products

Professional video and reporting on these concepts were not just valuable to the media and the public, but UDOT personnel were also able to obtain this video and utilize it for implementation and technology transfer applications. These tools were obtained at no cost from the media by participating in the Media Marketing Program.

15.5-Public/Private Partnerships

The Utah Department of Transportation Research and Innovation Division should evaluate the benefits of promoting more public/private partnerships. Many opportunities exist with groups such as motor carrier associations, wildlife advocates, wild-lands experts, construction and design specialists, public authorities, and professional groups.

This strategy has been employed at the annual Research Workshop. The workshop was expanded to include the Utah Transit Authority (UTA) with a Public Transportation breakout session, and an Aeronautics breakout session. These groups provide opportunities to improve UDOT operations that coincide with these agencies.

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

- High-tech advancements
- Cross-industry applications
- Computer-generated products
- Organizational innovations

16.0-PROCESS TO TRACK AND MEASURE FUTURE RESEARCH BENEFITS

The benefits of transportation research initiatives and functions should be evaluated annually by the Research and Innovation Division. A guide was prepared as part of this contract entitled, “Program to Measure Research Benefits and Track Implementation” [10]. This document is intended to aid in benefits measuring at UDOT.

The document includes processes and tools for use in evaluating UDOT’s research program on an annual basis. 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.

A feedback process is outlined for use in evaluating the degree of implementation for each completed project and identifying deliverables needing additional implementation actions. The manual recommends details related to the following aspects of the process:

- Process organization
- Goals of the program
- Personnel requirements
- Information needs
- Examples of benefit/cost
- Meeting schedules
- Program deliverables

Also included is an overview of best practices for use by consultants conducting more comprehensive studies to measure research benefits on a three- to five-year interval.

17.0-CONCLUSIONS

1. Transportation research has been an essential and valuable component of addressing the problems facing our transportation systems. Research initiatives have contributed to the efficient and safe movement of people and goods, and will aid in addressing future demands and challenges for transportation agencies.
2. A total of sixty-three research projects were completed in the years 2013, 2014, 2015, and 2016 by the UDOT research program. Surveys completed by project end-users were used to compile the benefits from the studies. ***This information indicates that the UDOT research program had an estimated \$58.7 million in benefits, and a benefit-cost ratio of 19.*** These estimates are considered to be lower than the actual values due to the conservative methods used to calculate these benefits. Also, a relatively low number of surveys were returned (67%).
3. The current benefit-cost ratio estimate of 19 is similar to values for published studies that were completed in 1995(14), 2000(12), 2010(17), and 2016(14).
4. Completed surveys indicate that the ***UDOT research program had an average grade of 3.1 or a “B” grade*** using a 1 to 4 grading scale.
5. The UDOT research program has been administered professionally, and most projects have been managed in an efficient manner. The investment of resources dedicated to the program is conclusively justified in the form of useable outcomes and products. The program essentially coincides with the Department’s Vision and Strategic Goals. This is reinforced in the balance observed for the various project types.
6. The research prioritization process and annual Research Workshop has been found to be successful in identifying topics related to the most pressing issues facing UDOT and its stakeholders. Improvements in forms used and the balloting process, however, could prioritize problem statements that can produce more usable and implementable deliverables.
7. The consistent implementation of research deliverables will require more focused and dedicated resources. Some valuable products of research have not been fully implemented. A more formal approach to achieving implementation is required. The challenges and barriers to implementation must continuously be addressed and overcome for the research program to realize its maximum potential.
8. The time gap between the publishing of the deliverables and the conduct of this study has been too long. This resulted in problems due to significant turnover of end-users and other factors leading to loss of information related to the projects. The author takes responsibility for this shortcoming by not proposing the study sooner.

9. 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, the cost of various enhancements to corridors and projects can be evaluated for use.

18.0-RECOMMENDATIONS AND IMPLEMENTATION

1. Research, development, and technology transfer programs within the Utah Department of Transportation should be fully funded based on the substantial estimated benefit-cost ratio of 19. This includes research projects, the annual Research Workshop (UTRAC), implementation activities, state-of-the-practice studies, training sessions, scanning tours, videoconferencing information exchanges, and attendance at the TRB Annual Meeting.
2. The UDOT Research and Innovation Division should implement a more formal process to better monitor and manage completed products from research projects. This proposed program is outlined in detail in a document entitled “Program to Measure Research Benefits and Track Implementation” [2]. This process includes the personnel commitments needed, recommended processes, milestones, and performance measures related to implementation.
3. An Annual Implementation Report should be published to measure the benefits of the projects funded. These evaluations indicate which types of research activities are the most effective. Also, it is important to determine if the right level of funding is being dedicated to each aspect of transportation to control program balance. For example, big-ticket items such as pavements and bridges should receive an appropriate portion of the research budget and emphasis. Also, safety improvements must be given a high priority.
4. The Research and Innovation Division should continue to use and improve their annual Workshop. Customers of the research program indicate that the Workshop process produces valuable and effective projects. Some aspects of the Workshop breakout sessions should be expanded in scope. Part of the time should be dedicated to identifying, planning, and funding initiatives to implement recently completed research products into practice.
5. For future studies, benefits 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 project implementation is attained. Project managers can reduce the burden of feedback tasks by aiding significantly in the process, and by using simplified forms and surveys.
6. The research implementation process should be expanded during conduct of the project. This will enhance the quality and scope of project deliverables. These recommended

modifications are in the form of imposing emphasis for implementation on each of the research phases as follows:

- a. **Project Selection (Research Workshop):** The voting process used to select projects should include higher emphasis on projects that propose deliverables that are easily implemented. These include the products listed in [Table 12.1](#). The Problem Statement form should require an estimated benefit-cost ratio for the project. The UDOT sponsor of the Problem Statement should review and verify all data and calculations producing the B/C value.
 - b. **Work Plan Development:** A detailed description of the deliverables should be incorporated in the final work plan and contract documents. This would include the products to be developed, detail on what items will be included, who the target end-users will be, and how the product will be implemented.
 - c. **Conduct of the Research:** All milestones, progress reports, and TAC meetings should address the progress of the end products, and update the implementation plan if needed.
 - d. **Implementation Phase:** The PM should retain the project and related deliverables in a process for a minimum of two years after completion. Quarterly implementation meetings should be held to monitor the progress of the products. Project managers can reduce the burden of feedback tasks by aiding significantly in the process, and by using simplified forms and surveys. Every effort should be made to simplify the feedback process, while obtaining all of the required information.
7. The UDOT Research and Innovation Division should make minor modifications to all five of their standard forms as listed in this report. Improvements to the forms could aid all stakeholders to better require, track, and implement research deliverables.
 8. A Media Marketing Program can be an important tool in illustrating the benefits of research initiatives. This program has been shown in the past to be of value to UDOT, as well as the public. The value is in the form of enhanced tools, news clips, slow-motion video, and high-level professional mediums. These media events help to educate and build support from UDOT partners, stakeholders, the Utah State Legislature, and the public. It is recommended that UDOT reinstate this program.
 9. UDOT leaders should consider taking steps to get Research staff more involved in the New Products Evaluation Program. This would give the assessment of new products a more broad and formal forum for evaluation.

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

APPENDIX A- BENEFITS TYPES

A.1-Improved Transportation Facilities

Enhancement to UDOT facilities is a fundamental aspect of the research program. Improving the way the Department plans, designs, constructs, and maintains Utah's transportation facilities can have a huge impact on the economy, environment, and tourism in the state.

Examples of how research enhances these facilities:

- Pavement and bridge life extension
- Improved rehabilitation and maintenance methods
- Highway design advancements
- Traffic control enhancements

A.2-Cost Savings to UDOT

The most direct and useful benefit that may be measured is related to costs. The main types of cost information are in the form of direct savings to the Department, savings to the traveling public, and benefits to key partners.

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 contributing to the work, and contractors completing facility construction. UDOT managers are committed to interacting with all stakeholders with transportation interests to improve operations. 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 better trained staff
- Reduced materials costs
- More efficient equipment
- Better utilization of existing equipment
- Improved knowledge management practices

A.3-Safety Benefits

Innovative processes, regulations, and products are introduced to the transportation industry on a routine basis to improve safety. Reductions in crash numbers can be directly measured in some instances, and estimated on a systematic basis in other cases. Safety goals include:

- Crash number reduction
- Accident rates decreased
- Severity of crashes reduced
- Construction-zone safety enhanced

A.4-Congestion Reduction Benefits

Efficient track flow is a crucial benefit to the public and a main goal for UDOT. Measurements of travel time and levels of service on major facilities are valuable input related to the effectiveness of innovative processes. Congestion mitigation goals are:

- Commute congestion decreased
- Construction-zone delays minimized
- Crash delays reduced
- Multi-modal programs to reduce highway trips

A.5-Environmental Benefits

Many of UDOT's programs and facilities have a direct impact on the environment. For this reason 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, and is a key goal for the Department.

- Minimize the footprint of transportation facilities
- Decrease emissions and particulates into the air
- Reduce chemical discharges from pavement placement and maintenance
- Mitigate wetlands that are impacted
- Reduce impacts to endangered species and their habitats
- Control noxious weeds on right-of-ways and neighboring lands
- Reduce or minimize noise to communities

A.6-Decisions to "Not" Do Something

Sound research methods and conclusions can lead to policies and actions by the Department to *not* adopt or engage in a new initiative. These may include:

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

A.7-Institutional Knowledge

Some research projects provide a direct benefit to transportation experts and managers in the form of institutional knowledge. These include:

- Informed staff and stakeholders
- Understanding industry advancements
- Knowledge of future trends and challenges
- Improved knowledge of UDOT's goals and focus areas
- Enhanced program management skills

APPENDIX B- COMMENTS AND FEEDBACK SURVEYS WITH BENEFITS

Report Number	Title	Benefit Reported x 1,000	End-User Comments	Author Comments
1612	Laboratory Resilient Modulus Measurements of Aggregate Base Materials in Utah	\$30,000	This research resulted in UDOT changing the UTBC modulus value in our pavement design from 40k to 25k. To evaluate this change a typical rural interstate was run using both values. The lower modulus value resulted in needing an extra ½ inch of HMA. Up-front cost of \$14,000 per lane mile.	This is a significant benefit, but is considered to be conservative
1406	Identifying Potential Technology and Service Improvements for UDOT Traffic Operations Center	\$8,400	Steered the TOC to a modified purchasing strategy of \$6M on ATMS operating system. Also a savings of \$2.4M was realized on the TOC video wall.	The TOC is a valuable asset to the public and the user savings are substantial.
1303	Skid Correction Program- User's Manual	\$5,200	This program saved numerous crashes on a slippery section of Redwood Road in SLC. A strategy was quickly identified and Region forces acted on it. Other sections around the state were part of the program but not evaluated for crash reduction.	This benefit is based on only one project. Other benefits were part of the program but not included.
1604	Cold In-Place Recycling, Phases 1, 2, 3, and 4	\$5,050	The previous cold in-place recycling mix design was simplified. The mix design supports recycling most materials. Better long-term performance is expected. A shorter time period to open to traffic was achieved. A 30% reduction in cost has been observed.	These benefits are considered to be low compared to the program overall.

1510 1315 1512 1613 1615	Use of Roadway Attributes in Hot Spot Identification and Analysis- Report Series	\$2,430	Human capital costs for each crash are about 28% of the total crash cost. If these hot-spot mitigations can reduce 5% of the crashes on the State's managed facilities the benefit would be \$243 million per year. It is assumed that this is conservative because hot-spot analysis methods are focused on areas where the crash count or severity is disproportionately high compared to the average. Implementation of safety efforts would INCREASE the costs to UDOT. However, because the model is focused on hot-spot locations, the expenditures are more likely to have a positive benefit-cost ratio. Reduction in crashes would result in less user delay and increased air quality. Part of the modeling effort has led to development in other fact sheets and support websites explaining the impacts and safety improvements (raised median website). The crash "hot-spot" summary reports are provided to Region personnel to help them consider safety improvements that they may not have considered at that location. These reports document the development of the statewide predictive model.	With this wide scope of benefits from these projects the values are likely to be much higher. Crash avoidance and delay reduction result in very high benefits to the traveling public.
1605	Calibration Measures - Speed and Volume Data: Volume 2, Evaluation of the Accuracy of Microwave Sensors	\$2,100	Reduction of having to install permanent count stations into the pavement. Having automated count data has helped in setting green times and improving operations overall, thus reducing delay. Safer intersections with improved signal timing reduce overall crashes. Don't need to manual count cars like we have in years past.	These benefit estimates are considered to be significantly lower than expected from the implementation of these findings.
1304	Lateral Resistance of Piles Near Vertical MSE Abutment Walls	\$1,500	Bridge non-collapse or savings on repair during seismic events. Bridge remains in service following a seismic event. Fewer lives lost. Arriving at the correct answer to a question we didn't know the answer to. Excellent design policy for UDOT and National Design Code Changes.	Good enhancements to the program.

1506	Impact of High-Efficiency Vehicles on Future Fuel Tax Revenues in Utah	\$981.7	This project provided direction for the state of Utah to initiate fees and a road usage charge for alternative fuel vehicles. The financial benefit was calculated by multiplying the number of EVs, PHEV, and gas hybrids by their annual fuel using 2019 data.	This is a conservative estimate based on the impact on fuel tax policies.
1310	Maintenance Program Decision-Making Utilizing Crash Data	\$710	This report suggests the use of crash data to aid maintenance personnel to focus on better snow removal, wild animal crashes, and friction enhancement. Enhanced snow removal (CMF 0.92 for crashes during snowing, or hail) benefit: \$16 million. Wildlife fencing (CMF 0.30 for wild animal crashes) benefit: \$55 million. Total potential benefit is \$71 million. This program has an impact on this benefit at about 1% improvement or \$710,000.	The percentage used to estimate the project portion of the benefits seems too low. More than 1% of the overall program depends on the process developed in the project.
1305	Evaluating the Safety Effects of Signal Improvements	\$500	The crash modification factors have helped to improve the process and reduce costs. We have been able to modify our approach to the CMF's.	This estimate is conservative.
1607	Investing in Utah Transportation Research	\$453.5	This report provides clear justification and support for funding research projects, not just by the Research Division but also other UDOT divisions. In 2019, other UDOT divisions have provided \$453,500 for research (both matching or fully funded).	

1616	Simplified Standard Penetration Test Performance-Based Assessment of Liquefaction and Effects	\$410	We have incorporated the use of the simplified SPT performance-based assessment of liquefaction into our GMOI as a required procedure for all projects. Since it is a full probabilistic analysis, it is more accurate than the pseudo-probabilistic analyses methods that we have been using. It is of liquefaction triggering and it is difficult to know how much money it has saved us so far since it has not been used on that many projects. But results have been more accurate, and no unnecessary ground improvement has occurred since this procedure has recently been installed. This new procedure has an easy-to-use spreadsheet, and there have been some minimal design cost savings. This new performance-based procedure has contributed greatly to UDOT's institutional knowledge. We are now performing liquefaction analysis and determining ground deformations much more accurately. It has been a tremendous addition to our analysis.	This estimate is conservative.
1514	Calibration of Automatic Performance Measures – Speed and Volume Data: Evaluation of the Accuracy of Traffic Volume Counts Collected by Microwave Sensors	\$350	Manual speed studies have been avoided that take time and equipment to perform. We don't have to set up temporary count stations as often and instead can use the automated data. The automated speed data is used to better align speed limits with the 85%-tile speed, thus improving overall safety and reducing crashes. Don't need to pay for manual data collection or equipment.	This estimate is conservative.

1503	I-15 Express Lanes- Phase I and II	\$250	This research tested a process to collect data on Express Lanes users more accurately using the “Carousel Method.” This technique has been a tremendous benefit to the Department as we’ve been able to expand the areas in which we collect information about violations rates. This informs the policies we create for Express Lanes. The additional data will likely encourage Express Lanes to implement violation-reducing strategies 5 years earlier than if the data had not been collected. At about \$1,000,000/year and assuming the study contributed about 5% to this decision, the value of this research to UDOT is about \$250,000.	Good analysis and estimate.
1501	Non-Consent Towing Cost Study in Utah	\$24	Benefits to the tow industry. Less red tape and lower verification effort. Streamlined operations. \$30/hr x 27 hrs/yr x 3 people x 10 years. CPI controls rates for non-consent towing. There was scope creep on this study. The tow industry did not think this was appropriate.	The end-users refused to consider the deferred costs of non-consent towing. The value used by the towing industry has increased, but at a much lower rate due to the study recommendations .
1302	2013 UTRAC Proceedings	\$1.2	This effort captured the results of the 2013 Research Workshop. Without this document many hours would be needed to find this information.	
Total		\$58,711		

APPENDIX C- COMMENTS AND FEEDBACK SURVEYS WITH NO BENEFITS

“Absence of evidence is not evidence of absence.” --Martin Rees

Report Number	Title	Survey Comment	Author Comment
1309	Physical and Chemical Effects of Deicers on Concrete Pavement: Literature Review	The results of this report do give some recommendations on deicer type and usage. However parts of this report contradict other studies performed about this subject and the effects on assets. This report alludes to the damage that is done to users by the use of deicers. This topic could have been further discussed in detail. The report recommends using less deicer and less high-performance deicers which will save money. The reduced use of deicers as per the report implies that there will be a benefit to the environment. This report lends some credibility to the knowledge that deicers hurt the assets of UDOT. There are financial benefits to using less deicer. The benefits are in Assets, Users, and Environmental noticeably.	The benefits provided in the survey comments certainly have financial benefits to the traveling public. None were listed.
1311	Reducing Highway Litter	The research showed that getting out early and often to address littering can possibly decrease littering in the future. Less damage to vehicles if less litter is on the roadway with larger objects. Roadways that lead to dumps normally have larger object litter from untied-down loads. That means in these roadways we should spend extra time on cleaning, helping to reduce the chances of accidents caused by litter. Unclear if spending money on advertising would really reduce UDOT's efforts. If we can reduce litter it would improve our environment and water quality from our drainage systems. No effects on policy from the research; need more data to adjust. If areas receive more litter it can possibly be reduced by cleaning up the area more frequently to help people reduce the desire to add to the littered area.	

1312	Behavior and Analysis of an Integral Abutment Bridge	Tough to quantify the financial benefit. This project builds on the cost-effective practice of using integral abutments wherever feasible. No real impact to users, but integral construction should result in lower lifetime maintenance. No real impact to safety, but integral construction should result in lower lifetime maintenance, and therefore less time working in traffic. Advances integral construction to more complicated geometric locations.	Benefits were listed in the survey comments and should have financial benefits... None were listed.
1313a 1313b	Evaluating the Feasibility of Incorporating Mobility-Based Work Zone Traffic Control Performance Measures in Highway Construction Project Specifications: Volume I. Feasibility of Continuous Monitoring of Performance Measures	Implementation needed. Zero info on specific products that can make this happen.	
1316	Lessons Learned-Pavement Marking Warranty Contract	Materials used to meet warranty are more robust and last longer than UDOT's conventional latex paint. By having material last more than one year less impact is felt to the traveling public with repainting operations of the roadway. Also the user gets a visible line guaranteed to meet through the winter. From the research you can see how a benefit is available by having visible lines but was not quantified as a reduction in crashes by having said lines. UDOT benefits are that the paint crew no longer has a segment to worry about painting every year allowing them to complete painting of other roadways that	1401

		may not normally get painted every year. Also it frees up Code 1 funding by using the Interstate Maintenance Fund. From this study UDOT created the Pavement Marking Warranties Specification. From doing warranties UDOT has been able to see how long pavement marking materials can last, proper installation procedures, and how to refresh different material types.	
1317	Utah Department of Transportation - Asset Opportunities Study, Phase I	Nothing from this study was implemented or proposed major changes to our current system for pavements and bridges. We are also in the process of refining our data-management integration practices. This study may have helped to identify the need for this to happen. Bundle packages of maintenance activities are being explored but are not expected to save costs on the proposed amount. UDOT is very inexpensive and efficient and the expectation is that we would end up paying more for these services but could get a potential for a higher level of service on specific maintenance activities. Very broad study with limited set of recommendations.	
1318	UDOT 2012 Research Peer Exchange	This peer exchange improved the Research Division program and processes through interactive learning from other state research managers.	This result seems appropriate
1401	Comparison of Winter Temperature Profiles in Asphalt and Concrete Pavements	Understanding use of salt does not need to be in greater quantities for concrete would help with pavement deterioration. Less deicing material can be used on concrete than what was thought in the past. Less salt is better for the environment. Adjustments to applications rate guidance based on material is removed. Experts still disagree with findings of the report.	Benefits listed in the survey comments have financial benefits. None were listed.

1402	Deicer Usage on Concrete and Asphalt Pavements in Utah	Gave knowledge that UDOT has not treated asphalt vs. concrete different to that date. Policy on application rates may have adjusted. The knowledge of what crews are doing on roadways was beneficial to see changes made off report.	
1409	Seismic Evaluation of Grouted Splice Sleeve Connections for Precast RC Bridge Piers in ABC	This project builds on the practice of using ABC when it adds value. Combined with other tools, this too can contribute to significant user savings. ABC saves user cost and also keeps contractors away from traffic, thus improving safety for both workers and travelers. Pretty small tool in the overall ABC program.	The benefits listed in the survey comments have financial benefits to the ABC program. None were listed.
1606	Snowplow Operator Driving Time: Survey of State and Local Practices	Less hours and fatigue means less damage to equipment, along with less chance of damage to asset items on the roadway. Users can have decreased level of service due to limits of drivers. Safety is increased by not having tired snow plow drivers but can be decreased by the level of service they are able to provide. If equipment is not damaged would have a reduced cost based off driver fatigue. Letter of Instruction was updated based off of the research on length of plow drivers and required breaks. We will look to rewrite the policy again based off new responses of UDOT survey.	The benefits certainly have financial benefits to the traveling public. None were listed.
1608	Process to Measure Research Benefits and Track Implementation, Manual of Instruction	This Manual of Instruction provided guidance to improve the value capture of research projects. It also helped select more implementable projects.	
1609	Using the Bending Beam Rheometer for Low-Temperature Testing of Asphalt Materials	This project promotes a cracking performance test for HMA. I gave it a C because it has the potential to improve the HMA but has not done it yet. If this performance test improves cracking resistance then we will have fewer projects to impact the public. The potential savings is huge but not proven.	

1610	Evaluation of Pavement Markings Under Wet-Night Road Conditions	The completed research allowed for a better understanding on what impacts the life cycle of pavement marking and noted what areas the Department needs to improve in. Brings up adding user impact as part of the evaluation of striping not just cost of placing material. Used other studies to show the impact wet reflective striping can have on reduced crashes. Improved products and quality will reduce crashes and improve in public perception is the cost savings but it's not quantifiable. Redo Guidelines on striping selection and where more guidance needs to be given. This information has led to identifying more research to be done in grooving and wet reflective elements.	
1611	Investigation of Laboratory Test Procedures for Assessing the Capacity of Geogrid-Reinforced Aggregate Base	None. See email	
1614	Examining the Characteristics of Fatal Pedestrian Crashes	This research focused more on procedural efforts than crash mitigation efforts. While the research was valuable to enhance tracking of pedestrian crashes, it does not suggest mitigations that can lead to quantified benefits. Pedestrian crashes have a higher severity distribution than most types of crashes so mitigation of pedestrian crashes can lead to large benefits. Providing enhanced information for pedestrian crashes can help UDOT better analyze, explain, and reduce high-profile crashes. There seems to be too few "experts" in UDOT about alternative transportation methods and how to incorporate safety into our facilities. There are even fewer design experts that understand how our current standards impact alternative transportation methods. For the experts that were involved on the TAC for this study, the institutional knowledge was improved.	

1617	Review and Specification for Shrinkage Cracks of Bridge Decks	Research objectives of this project were not achieved. Equipment was never fully or effectively evaluated. (E grade)	
1620	Investigation of Structural Capacity of Geogrid-Reinforced Aggregate Base Materials in Flexible Pavements	None. See email. "A" grade?	The benefits provided in the survey comments have financial benefits. None were listed.
1621	Accuracy of In-Situ Water-to-Cement Meters for Concrete	Research determined that this equipment was ineffectual for the intended use.	

APPENDIX D- 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.

The 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 the 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 projects and aid in implementation.

The “Illinois DOT Implementation Worksheet” is used to plan 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 options approach enhances the decision-making process so that it does not consist merely of a choice of whether or not 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, policymakers, 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 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 values systems should be considered. Table C1 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 government 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 reports 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 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: FREIGHT Economic Changes Driving Future Freight Transportation. Explore and plan for the future of freight with a scenario planning toolkit

VOLUME 2: CLIMATE CHANGE Climate Change and the Highway System: Impacts and Adaptation. How to prepare for extreme weather events.

VOLUME 3: TECHNOLOGY Expediting Future Technologies for Enhancing Transportation System Performance. Select the right technology investments at the right time.

VOLUME 4: SUSTAINABILITY Sustainability as an Organizing Principle for Transportation Agencies. Organize transportation agencies to support a sustainable society.

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

VOLUME 6: SOCIO-DEMOGRAPHICS 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.

APPENDIX E- RECOMMENDED SURVEY FOR FUTURE STUDIES

Figure E1- Research Exit Survey

Project Title: _____ **Control #:** _____
Champion/End-User: _____ **Email:** _____
Principal Investigator: _____ **Project Manager:** _____

Implementation Status	
What is the implementation status of the deliverables from this project? ☐ Implementation is underway - continue to monitor. ☐ All potential implementation has been completed. ☐ Implementation has not been successful – revise plan.	
Recommended changes to the implementation plan:	
Benefits Category	Grade
A-Asset Improvement (pavements, bridges, walls, etc.) List benefits that have contributed to the life or management of UDOT’s assets: Financial Benefit: \$_____. (Could be savings related to enhanced life or performance. Also benefits from <i>not</i> doing unneeded or expensive activities, e.g. cost avoidance) Explain:	
B-User Impacts List benefits that have reduced impacts to the traveling public: Financial Benefit: \$_____. (Could be savings related to shorter construction time or enhanced life. Also benefits from <i>not</i> doing unneeded and expensive activities, e.g. cost avoidance) Explain:	
C-Safety List benefits that have contributed to the safety of the traveling public, UDOT’s employees, and/or contracted employees: Financial Benefit: \$_____. (Could be savings related to improved traffic control or reduced exposure of employees to traffic. Savings in the form of reduced property damage, injuries, or fatalities.) Explain:	

D- Cost Savings to UDOT List benefits in the form of savings to UDOT practices and functions: Financial Benefit: \$ _____. (Could be benefits related to manpower reduction, materials savings, fewer needed contracts, etc.) Explain:	
E-Environmental List benefits that have contributed to environmental aspects of the state: Financial Benefit: \$ _____. (Could be benefits related to wetlands, air quality, water impacts, endangered or noxious plants, etc.) Explain:	
F-Policy and Administrative Issues List benefits that have contributed to enhanced policies and administration of the Department: Financial Benefit: \$ _____. (Could be benefits related to improved management and policies impacting our customers. Also benefits from <i>not</i> doing unneeded and expensive activities, e.g. cost avoidance) Explain:	
G-Institutional Knowledge List benefits that have contributed to the level of knowledge of UDOT experts: Financial Benefit: \$ _____. (Could be savings related to <i>not</i> doing unneeded or expensive activities, e.g. cost avoidance) Explain:	
H-Other _____. List other benefits that have contributed to this category: Financial Benefit: \$ _____. Explain:	
I-Percentage of Larger Initiative (Example: UDOT goal benefits = \$10 million, research project provided 1% to the goal, project benefit = \$100,000) If the research project provided only a percentage of the overall benefits of a UDOT goal, please provide the contributing percentage _____.% Financial Benefit: \$ _____. Explain:	
Overall Grade of the Project	
Total Financial Benefits	\$

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

1- How can the implementation of research products be enhanced? _____

(Use additional sheets if necessary)

2- What do you think are the most valuable products and deliverables that the Research Division can produce? (Rank the top five products from 1 to 5)

- | | |
|-----------------------------------|-----------------------------------|
| ___ Report | ___ Policy & procedure |
| ___ Training sessions & materials | ___ Scanning tours & workshops |
| ___ Manual of instruction | ___ Experimental feature |
| ___ Design method | ___ New products evaluation |
| ___ Specification | ___ Software |
| ___ Laboratory test | ___ Peer exchange |
| ___ Executive summary | ___ State-of-the-practice summary |
| ___ Presentation Slide Deck | ___ Videos |

Survey Return Information

Consultant or research staff

Contact information