RESEARCH & DEVELOPMENT

Capturing and Communicating the Value of NCDOT Research

Thomas Nicholas II, PhD, PE
Don Chen, PhD
John Hildreth, PhD
Department of Engineering Technology and Construction Management
University of North Carolina at Charlotte

NCDOT Project 2017-21

FHWA/NC/2017-21

February 2018

Capturing and Communicating the Value of NCDOT Research

Final Report

(Report No. FHWA/NC/2017-21)

To North Carolina Department of Transportation
(Research Project No. RP 2017-21)

Submitted by

Thomas Nicholas II, Ph.D., P.E.
Associate Professor
Department of Engineering Technology and Construction Management
University of North Carolina at Charlotte, Charlotte, NC 28223-0001
Phone: (704) 687-5052; Fax: (704) 687-6653; E-mail: tnichola@uncc.edu

Don Chen, Ph.D.
Associate Professor
Department of Engineering Technology and Construction Management
University of North Carolina at Charlotte, Charlotte, NC 28223-0001

John Hildreth, Ph.D.
Associate Professor
Department of Engineering Technology and Construction Management
University of North Carolina at Charlotte, Charlotte, NC 28223-0001

Department of Engineering Technology and Construction Management
University of North Carolina at Charlotte
Charlotte, NC

February 2018

Technical Report Documentation Page

1. Report No. **FHWA/NC/2017-21**	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Capturing and Communicating the Value of NCDOT Research**		5. Report Date **21Feb2018**
		6. Performing Organization Code
7. Author(s) **Thomas Nicholas II, Don Chen, John Hildreth**		8. Performing Organization Report No.
9. Performing Organization Name and Address University of North Carolina at Charlotte 9201 University City BLVD Charlotte, NC 28223		10. Work Unit No. (TRAIS)
12. Sponsoring Agency Name and Address North Carolina Department of Transportation Research and Development Unit 104 Fayetteville Street Raleigh, North Carolina 27601		13. Type of Report and Period Covered Final Report 08/01/2016 to 12/31/2017
		14. Sponsoring Agency Code **#2017-21**

Supplementary Notes:

16. Abstract

The intent in performing applied research is to further the knowledge base or solve a particular problem that is beneficial to society at large. Specifically in transportation research, project outcomes provide society with a safer, more efficient transportation infrastructure. The NCDOT has produced many successful and high value research projects through the Research & Development Unit (R&D). However, relating these successes to NCDOT research stakeholders can be cumbersome without a means to provide objective, accurate accounts of value added. In this study, a new cost benefit analysis methodology was developed to include both quantitative and qualitative benefits. Through a survey and interview process with key NCDOT Research Stakeholders, research success indicators were found to be: Active NCDOT Research Champion, Proposal Quality, Research Need Priority, Researcher Experience with NCDOT and Regular Communication from the PI. These success indicators were used as independent variables in conjunction with the categorical variables of highly successful, successful and moderately successful in an ordinal regression model to predict the probability of project success. This prediction model will assist in identifying potential high value projects. Additionally, a robust communication plan was developed and presented to communicate the value of the transportation research program.

17. Key Words Research Value, Transportation Research, Cost Benefit Analysis of Research	18. Distribution Statement		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 79	22. Price

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

DISCLAIMER

The contents of this report reflect the views of the authors and not necessarily the views of the University. The authors are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of either the North Carolina Department of Transportation or the Federal Highway Administration at the time of publication. This report does not constitute a standard, specification, or regulation.

ACKNOWLEDGMENTS

This research was sponsored by the North Carolina Department of Transportation. The authors gratefully acknowledge the support and assistant from the following individuals:

Research Project Steering and Implementation Committee: Neil Mastin, P.E (Chair), Jamal S. Alavi, P.E., Debra Grist Collins, David B. Harris, P.E., Scott Hidden, P.E., Joseph E. Hummer, Ph.D., P.E., Matthew S. Lauffer, P.E., Christopher A. Peoples, P.E., Jahmal Pullen, P.E., Mike Stanley, P.E., Majed Al-Ghandour, Ph.D., P.E., George Hoops, P.E. (FHWA), Mustan Kadibhai, P.E., John W. Kirby (Project Manager), Kevin Lacy, P.E., CPM, Edward M. Morrison, Jr., Paul C. Worley.

Special Thanks to the NCDOT R&D Unit.

EXECUTIVE SUMMARY

The intent in performing applied research is to further the knowledge base or solve a particular problem that is beneficial to society at large. Specifically in transportation research, project outcomes provide society with a safer, more efficient transportation infrastructure. The NCDOT has produced many successful and high value research projects through the Research & Development Unit (R&D). However, relating these successes to NCDOT research stakeholders can be cumbersome without a means to provide objective, accurate accounts of value added. Currently, the NCDOT R&D Unit does not have a formal methodology for determining success of a research project and therefore requires a research assessment methodology at the program level which includes: determination of the value added (cost-benefit); an implementation plan with pre- and post-measures; identification of future high value projects; and effective communication of results.

Cost benefit analysis normally address tangible research benefits which represent the benefits readily computed in terms of dollars and can take the form of a reduction in material costs, increase in infrastructure life cycle, production increase, etc. The intangible benefits such as quality of life, improved safety measures, level of knowledge, etc. are not easily converted to benefit dollars. The research team developed a CBA methodology that calculates hard cost benefit (tangible), soft cost benefit (quantifiable intangible) and qualitative (non-quantifiable intangible). The introduction of the Impact Constant, *K*, allows the inclusion of the qualitative benefits in the monetary calculations through Impact factors, *IF*.

Through a survey and interview process with key NCDOT Research Stakeholders, research success indicators were developed and are as follows: Active NCDOT Research Champion, Proposal Quality, Research Need Priority, Researcher Experience with NCDOT and Regular Communication from the PI. This list provides a manageable number of variables which were included in the survey to determine level of importance. Utilizing the success indicators and the commercially available program JMP®, an ordinal regression was performed and a prediction model developed. The overall fit of the data to the model is statistically significant with a p-value less than .0001 and the lack of fit result suggests that ordinal regression is the proper model. For this model analysis, both intercepts were statistically significant as is the importance factor, Research Need. Additionally, NCDOT Champion has a 93.4% level of confidence which is very close to the target 95% confidence interval.

Conclusions and recommendations of this study are briefly described as follows:

- An improved applied research model was developed that provides three levels of project assessment and improvements. This new process when implemented will assist with the following:
    - Research need has been identified through this study as a major contributor to project success. Research need can be positively impacted through reviewing

and improving the research needs statements as well as the scope of work at the development level.
    - Communication between the Principal Investigator, Research Champion and StIC (Steering and Implementation Committee) is an indicator of project success. The continuous improvement process during the execution of the research will foster more communication among this group and ensure that direction of research meets the NCDOT needs.
- The climate survey results revealed the following:
    - The majority of respondents found the current quarterly reporting process is valuable and should be retained.
    - Research Engineers play a vital role in promoting communication during the execution of the project. As communication is an indicator of success, there is opportunity in expanding this role.
    - The majority of the respondents define project success as knowledge gained, which is further heightened if a critical need is being met (research need).
- A new Cost Benefit Analysis Methodology was developed and presented. It is recommended that the new CBA tool be used for newly awarded projects. The benefit realized from soft costs (safety, environmental, etc) and qualitative variables (knowledge, dissemination, student exposure, etc) were included.
- A performance prediction model was developed to predict the probability of success in terms of highly successful, successful and moderately successful. The presented models, at current confidence levels for PI Experience should be considered a framework for research prediction. The confidence level of PI Experience is currently well below target level. However, it is readily apparent that PI Experience is an indicator for success and the low confidence level is a function of the small dataset.
- A communication plan and best practices guideline was developed. NCDOT R&D should create a standalone Facebook page. Facebook offers an exceptionally productive forum for NCDOT R&D to communicate the value of its work due to its wide audience reach.
    - The “Research in Motion” tagline should be registered. The research team performed an in-depth review and found no registered trademark; however, this should be professionally researched and registered before implementation.
    - Based on the quality and quantity of research performed, NCDOT Research and Development should utilize a Convention and Expo to further increase visibility to participants, users and stakeholders as well as build community among that same group. UNC Charlotte has volunteered to host.

TABLE OF CONTENTS **Page**

LIST OF FIGURES

LIST OF TABLES

Chapter 1: Introduction

1.1 Problem Statement

The intent in performing applied research is to further the knowledge base or solve a particular problem that is beneficial to society at large. Specifically in transportation research, project outcomes provide society with a safer, more efficient transportation infrastructure. The NCDOT has produced many successful and high value research projects through the Research & Development Unit (R&D). Just in this past year, NCDOT had seven projects recommended as AASHTO high value research projects and the "Improvements to NCDOT's Wetland Prediction Model" was a feature project. However, relating these successes to NCDOT research stakeholders can be cumbersome without a means to provide objective, accurate accounts of value added. Currently, the NCDOT R&D Unit does not have a formal methodology for determining success of a research project and therefore requires a research assessment methodology at the program level which includes: determination of the value added (cost-benefit); an implementation plan with pre- and post-measures; identification of future high value projects; and effective communication of results.

1.2 Background

The sheer volume of transportation research projects currently in motion evidences that, at least conceptually, the value of transportation research is generally understood, and its supply is consistent with a well-established demand. Even more telling, is the increased recognition and appreciation of the role of research specifically in industry growth, as investment in Research & Development (R&D), and more frequently, Research, Development & Technology (RD&T), which presently represents one of the largest influencers of the perpetual evolution of the transportation industry. The President's Budget for Fiscal Year 2017 is exemplary of such acknowledgement, as it emphasizes the importance of enhancing transportation exclusively through R&D, with an investment of $152 billion dollars – a four percent increase from 2016 – of mandatory and discretionary funds in support of transportation's continued advancement.

Nationwide recognition of the value derived from transportation services, which were notably ignored in traditional national economic data analyses, and only recognized for their significance in more recent decades, continues to ensure returns on investment beyond monetary gains; where value of research is easily visible through significant impacts on society, influence on policy and legislation, as well as the very positioning of the United States, and its ability to compete within the global economy. Accordingly, it is the purpose of this paper to reiterate those values, in association with the best tools available for attaining proven benefit potentials, while also distinguishing non-essential endeavors, and ultimately defining the most productive opportunities for implementation.

1.3 Applied Research Process

The applied research process (cradle to grave), is often described as identification, investigation, formulation, reporting and implementation as presented in Figure 1.1. While the

list identifies the process in terms of the responsibility of the individual researcher, it fails to address the needs of a successful research program; namely, the impact of the research project after implementation. Applied research, at its essence, is performed to address a specific need or problem that can influence cost, safety, production, and the like. Thus, seldom can it be labeled as theoretical or basic in nature. To that end, the applied research project should effectively solve a problem if it is to maximize its impact (Hartman, et al., 2001).

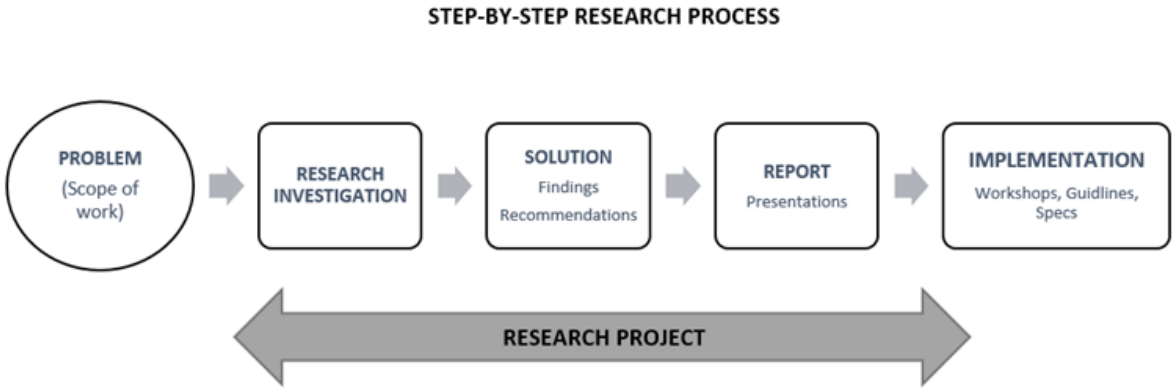

Figure 1.1. Applied Research Process, (adapted from Hartman, et al., 2001)

Ellis, et al. 2003, recognized the need to insure project success by inserting an iterative loop between research investigation and solution. It should be noted that, though the addition of the iterative process does improve the research outcome (solution), it does not necessarily improve overall project success or program level success. This shortcoming in the research process has led both Federal and State Agencies to initiate some form of evaluation process to be executed after the implementation stage.

At the federal agency level, the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), the Department of Defense (DOD) and the Department of Energy (DOE) have implemented a pre and/or post implementation evaluation process. In practice, most federal agencies are selecting pre-implementation evaluation to measure success of the project. Again, this insures success of solution but not necessarily success of the research or research program (Pickrell and Neumann, 2001).

At the state level, transportation departments are renewing their effort to define and quantify research benefit by transportation entities and measure that benefit pre and/or post project implementation (Bikson, et al., 1996). Florida, Minnesota, Texas, Kentucky, and New York have all instituted a formal evaluation process that utilizes Hartman's (2001) research model and adds evaluation and effort to the hierarchy. However, the current political and economic climate is curbing federal spending and investments in transportation research are not at the levels required to meet demand. For a research program to be successful in this new climate, effective communication of research quality, benefit and appropriateness must be established with policy makers and other stakeholders (Guthrie, et al., 2013). Therefore, to produce a successful applied research program, Ellis, et al.'s model will require the addition of evaluation and communication in the hierarchy. The proposed Applied Research Model, Figure 1.2 inserts opportunity at various levels of the research process to improve value of the final Research product.

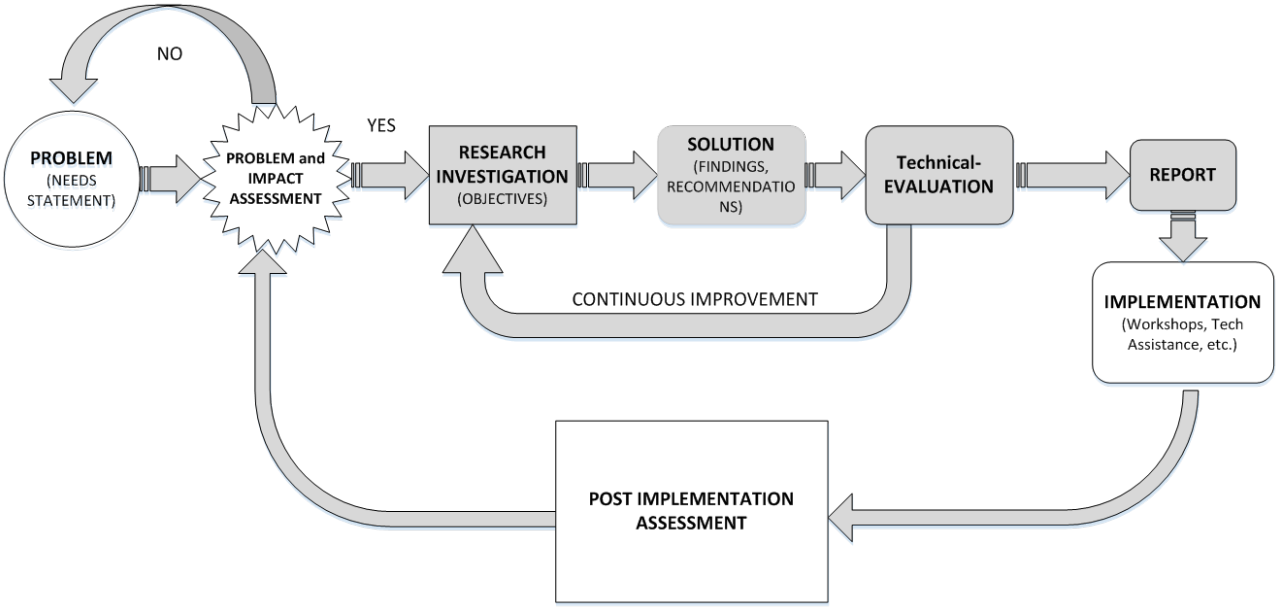

Figure 1.2. Applied Research Model

A continuous improvement process allows for a break in the process, a chance to assess the current direction of the project, correct any area that needs improvement and move forward in a direction that improves product value. The modified research model presented in Figure 1.2 provides three improvement opportunities during the research process. The first opportunity to impact project value occurs during the development of the project needs statement. In determining research project performance indicators, it became readily apparent that project need and accuracy of the scope of work play an important role in the overall success of a project. Secondly, to insure the research products meet the expectations of the stakeholders, timely communication and review must occur between the research team and the NCDOT research champion. This improvement process should occur continuously during the investigation phase of the project. Lastly, the value added by implementing the results of the research should be evaluated and communicated to NCDOT stakeholders.

1.4 Objectives and Scope of Study

In order to better identify and communicate the value of NCDOT research, the following research tasks were performed:

1. Developed a NCDOT research cost benefit analysis methodology;
2. Identified key research performance indicators;
3. Developed a project performance prediction model framework;
4. Developed a research implementation action plan;
5. Developed of a best Practices Guideline for Communicating Research Benefits to NCDOT Stakeholders.

1.5 Organization of Report

The following report consists of seven chapters. In Chapter One, the problem statement is presented, and the scope and objectives of the study are described. In Chapter Two, the

literature review describes the current state of practice for determining cost benefits and communicating results to stakeholders. In Chapter Three, the methodology for the calculations of cost benefits is presented. Chapter Four presents the generation of the ordinal logistic regression model for the prediction of project success. The communication plan is presented in Chapter Five. The conclusion and recommendations of the study are provided in Chapter Six. Chapter Seven presents the implementation plan.

Chapter 2. Literature Review

An extensive literature review was conducted to synthesize past and ongoing research related to the following prominent research components of this research project. An annotated version of the approved literature review is provided in this document for brevity. The full version can be found in Appendix A.

2.1 Introduction

A review of the relevant literature has revealed that a primary hindrance to advancing transportation goals can be attributed to a general failure, and sometimes complete omission, to communicate the true value of research. Although transportation research frequently proves to be a lucrative investment, without effective communication of the particular and potential benefits, even the most useful research can be permanently derailed by an inability to capture interest, further road blocking the likelihood of procuring necessary funds and resources. This harmful investment gap alienates existing funds, while further limiting the ability to gain potential resources required to improve, or simply maintain, the transportation system.

Without the necessary, innovative solutions for identifying the potential impacts of transportation research implementation, R&D objectives will continue to be mired by research projects that ultimately fail to address an issue, advance knowledge, or deliver a solution that benefits the transportation system. Research that fails to add any value is especially detrimental to research that is ultimately deemed successful once its benefits are realized. The ability for a successful research project to get off the ground should not be based in simple luck of the draw or good timing, and it is this retroactive approach to analyzing the value of research that has led to significant waste: wasted time, money, and resources, often at the cost of some of inspiring ideas, all of which could have been dedicated to a research project that had been deemed, within a reasonable level of certainty, as a valuable endeavor prior to its execution.

An effective research assessment methodology can also facilitate better communication of the overall importance and particular impacts of a given research project, which will present information in a more easily understood fashion, help to cater to broader audiences, assist to determine the specific costs and benefits of a transportation research project, allow for assessment at the program level, and ultimately help to facilitate a more expeditious, cost-effective decision making process (TRB, 2013). More importantly, such a methodology will enable transportation agencies to dedicate more resources to high priority projects. By being able to more frequently communicate explicit research needs, research sponsors will help to foster innovation in the areas of the transportation system where such information and guidance is most critical. Accordingly, transportation agencies require the ability to answer the question of whether a transportation research project unambiguously enhances an aspect or feature of the transportation system early on in the process, and well before implementation.

2.2 Value of Research

The necessity to include considerations of research audience is more obvious and intuitive than some of the other elements required for developing a standard research assessment methodology. At least since the days before smart phones became a social standard, and times when significant technological advances were still a new and profound experience,

witnessed only by select facets of society, a valuable idea has become scarcely less obvious on its face. In light of the current economic and social climate, there are increasingly fewer opportunities where an "obvious need" can be addressed by an "obvious solution". In light of social media and increasingly accepted forms of information consumption, where information frequently comes "packaged" in unrelated, mixed, and over-stimulating messages, the value of certain information is simply much less obvious than it used to be. In order to address this challenge, transportation research needs to be presented in a way that aligns its message with its applicable audience (Rue, 2010).

The point cannot be stressed enough that the ability to accurately communicate the value of research is key, and must be held to the same priority levels of other functions of research already regarded as essential. An accurate conveyance of the value of research informs the ability for interested and invested parties to assess, and thereby appreciate the value of such research. Truly, it is a form of advocacy, and requires its own, unique analysis in order to be exercised successfully.

This fundamental gap in the ability of transportation agencies to carry out the goals of their research, due to an arguably simple failure to launch a project that, had stakeholders and relevant authorities been provided the proper and necessary information, would have proven to be, for all intents and purposes, a success, can be filled by a proper evaluation tool. Thus, before the value of research can be effectively communicated, it must first be identified. While there is a wealth of literature available to support the importance of identifying the value of transportation research, the mechanism by which this can be achieved remains open, and only to the continued detriment of those positioned to benefit from it; which, of course, is everyone (Harichandran, 2008).

This lacuna in research-related planning has been scrutinized throughout much of the existing literature, and has been commonly attributed to the apparent fact that transportation agencies, throughout all levels of the industry, including State Departments of Transportation (DOTs), lack a proper evaluation tool that aids to establish the actual impact a potential research project has on a facet of transportation. Notably, the literature also reiterates that the task of creating such a tool is a unique and complicated task that must be founded on well-established knowledge, some of which has never been within the purview of transportation, as well as open consumption of the new and unknown (TRB, 2016). Current industry trends and strategies being embraced by various transportation agencies have offered important guidance in this pursuit.

2.3 Cost-Benefit Analyses as a Value of Research Tool

The systematic process of cost-benefit analysis ("CBA"), or similarly, benefit-cost analysis ("BCA"), has long been relied on as a useful tool whenever seeking to determine the tangible value of a project or program (Sullivan, 2008). There are various approaches within the CBA toolbox that allow for value to be determined at the onset of a project. Although the literature search revealed that CBA has been consistently criticized for insolvable limitations, these limitations are often perceived in practice and, contrary to those sources, there is authoritative literature supporting the effective use of CBA, and affirming the ability of this

research to address those limitations with a solid methodology. As noted in Senate Report 113-182,

> *"Benefit-cost analysis is an important economic tool that can help State and local governments target their transportation funding to the most effective investments. Using benefit cost analysis, a State or local government would compare the monetary value of all benefits and costs that accrue during the life of a project. This process forces the government to evaluate the value of all of the project's benefits, recognize the full cost of the project, and acknowledge whether or not the benefits outweigh the costs."*

In response to Senate Report 113-182, the Federal Highway Administration (FHWA) conducted a qualitative study that established important considerations around the use of BCA at the State level (White and VanLandingham, 2015). The FHWA (FHWA, 2017) study recognized that a majority of State DOTs employing BCA are typically focused on "impact areas with relatively straightforward data, methodologies, and monetization factors," with quantification of safety impacts being the most common. Case study analysis of nine State DOTs, and results of a questionnaire completed by forty-six FHWA Division Offices, the report addressed the four key questions:

1) The extent to which State departments of transportation use benefit cost analysis when making decisions and setting priorities;
2) The quality of such analysis;
3) Challenges that State departments of transportation face when trying to use benefit cost analysis; and
4) Strategies for addressing those challenges.

Regarding the extent to which State DOTs use BCA, the study found that its use significantly varies between State DOTs, with approximately five to six using BCA regularly for the specific purpose of informing decision-making. While this information affirmed that BCA is only being employed as an exception for certain kinds of projects, rather than as an industry standard, and only methodically applied when funding requires it, it also highlighted advantages of BCA. For example, BCA is particularly appealing in an effort to establish an effective research assessment methodology, as it provides an essential tool for calculating project benefits and costs that can be rendered into consistent units of measurement (dollars), allowing for a more comprehensive prioritization framework that goes across project and program categories, rather than simply within them (Gunasekera, 2014).

Additionally, the questionnaire revealed a pattern regarding the frequency with which BCA is used by State DOTs, suggesting that "BCA may be viewed as more useful for larger projects, for which more stakeholder scrutiny may be expected, but also that analytical challenges may play a role, since safety projects tend to be more readily quantifiable in their impacts than asset preservation or bike-pedestrian projects." While this much may be true, a standard research assessment methodology includes an approach that may involve stakeholders much earlier on in the research implementation process to make this type of scrutiny something

that can be readily addressed, most especially at the stage of conception, where these deliberations are fundamental in choosing whether the research is even worth the pursuit.

According to the FHWA study, experts within the transportation economics community have defined a high-quality BCA as one that possesses a majority of the following characteristics:

- Comprehensiveness (i.e., that all societal impacts are included, but only once);
- High reliability of the data and forecasts used to generate estimates;
- Appropriate monetization factors, discount rate, and analytical timeframe;
- Comparison against credible baseline;
- Inclusion of sensitivity analysis or other treatment of uncertainty; and
- Overall transparency and replicability of the analysis.

Although the FHWA did not assess whether any of the State DOTs' BCA products or processes include any and/or all of the aforementioned characteristics, it did find that, despite the substantial variation in which BCA is used, differing "from State to State and project to project," many States' BCA share common defects, such as lack of comprehensiveness; "erroneously including economic development impacts or construction costs as benefits; double-counting benefits; omitting certain categories of impacts; not discounting future values correctly; using unrealistic base cases; and failing to include reference to other viable alternatives." These key issues concerning State DOTs about the general quality of BCA also include "improper baselines, speculative benefits, including transfers of benefits, and a general lack of transparency and reproducibility." Finally, the FHWA report highlighted a need for State DOTs enhance documentation efforts and formalize treatment of uncertainties, which can be aided by regular reviews of prior forecasts and estimates that are necessary to ensure the accuracy of forecasts, like traffic demand, and evaluate assumptions against existing, actual conditions.

2.4 Utilizing Qualitative Analysis in CBA

In a periodical published by the Harvard Graduate School of Education, Professor James Edwin Kee discussed the strengths and limitations of benefit-cost and cost-effectiveness analyses, as part of an examination of their application in program evaluation. Professor Kee accurately described the very challenge of identifying and measuring costs – and the biggest challenge under this type of analysis – which requires, "quantifying and placing a dollar value on the benefits." Despite the challenges recognized in conventional usage of CBA, there are several disciplines that have developed guidelines that provide researchers and practitioners with ways to enhance the already invaluable utility of CBA (Kee, 2011). Moreover, CBA is consistently identified as being one of the most significant forms of value assessment available to members of any sector seeking to invest in a project or program. In a comparison of various analytical approaches, the MITRE Corporation illustrated the broad usefulness of CBA across different agencies in Table 1.

As identified throughout the literature review, and in recognition of a growing trend both within and outside of the transportation industry, the CBA approach proposed by this research will include the development of a standard system for evaluating the costs and benefits of research that specifically quantifies non-numerical values. This section of the literature review seeks to highlight some of those findings in order to determine the best approach for including unconventional calculations, such as "soft benefits," as part of the proposed methodology.

In line with addressing some of the seemingly inherent biases that certain members of the industry have toward CBA, the prescribed methodology could rely on standard monetization values that conform to common industry practice, such as that of the U.S. Department of Transportation. Conveniently, some of these values have been incorporated into a BCA Resource Guide, as a part of the "2015 Benefit-Cost Analysis Guidance for TIGER Grant Applicants," and serve to greatly assist with converting "soft costs" where numerical data is traditionally unidentified. For example, in order to assess the value of injuries, the TIGER BCA Research Guide accounts for several factors, including an Abbreviated Injury Scale (AIS) level, the level of injury severity, the fraction of the Value of Statistical Life (VSL), and assigns a unit value accordingly, as demonstrated by Table 2 (USDOT, 2015).

Table 2.1. MITRE Cost Benefit Analysis

Element	Alternatives Analysis	AoA	BCA	CBA	EA
To address a gap, should I invest or not?		X	X		
I'm going to invest to address a gap. So, how should I invest?	X	X	X	X	X
Operational Effectiveness		X	X	X	X
LCCE	X	X	X	X	X
Qualitative Cost Assessment		X	X	X	X
Quantitative Benefits Assessment	X		X	X	X
Qualitative Benefits Assessment			X	X	X
ROI Calculation	X		X	X	X
Uncertainty Analysis	X		X	X	X
Risk Analysis		X	X	X	X
Sensitivity Analysis			X	X	X
Implementation Description		X	X		

Table 2.2. Value of Statistical Life

AIS Level	Severity	Fraction of VSL	Unit value (2013)
AIS 1	Minor	0.003	$ 28,200
AIS 2	Moderate	0.047	$ 441,800
AIS 3	Serious	0.105	$ 987,000
AIS 4	Severe	0.266	$ 2,500,400
AIS 5	Critical	0.593	$ 5,574,200
AIS 6	Not survivable	1.000	$ 9,400,000

Chapter 3: Development of a Cost Benefit Analysis Methodology

3.1 Determining the Value of Research

It is not enough for the research itself to be considered anecdotally valuable, but its value must also be expressly communicated in a way that inspires decision-making powers to fully consider its implementation. As history has shown that even valuable, high-impact research - especially in transportation - does not necessarily speak for itself. Due to the very nature of transportation research in application, which results in widespread impacts to users and non-users alike, an effective assessment methodology must offer an approach that expansively defines the research possibilities and impact considerations, laid out in a manner that associates the costs and/or benefits according to individual value profiles. For that reason, in addition to creating an all-encompassing value assessment mechanism, the literature also calls for significant deference to be paid toward understanding the research audience(s).

3.2 Development of a Cost Benefit Analysis Methodology

Value added by a research project can be defined through a cost-benefit analysis (ratio) which generally can be defined as (Ellis, et al., 2003):

$$B/C = \frac{N \times K \times NB}{RC + IC} \tag{3.1}$$

Where:

B/C = the benefit-cost ratio for a research and implementation effort

N = the number of "highway units" or "implementation units" for which the research results are implemented

K = an adjustment factor to account for the staged implementation of the project

NB = the net benefit per "highway unit" or "implementation units" for which the research results are implemented

RC = the cost of the research project

IC = the cost for implementation the results of the research project, which can be estimated as a given percent of RC

Tangible benefits represent the benefits readily computed in terms of dollars and can take the form of a reduction in material costs, increase in infrastructure life cycle, production increase, etc. These benefits can be directly calculated and accounted for in the benefit methodology. The intangible benefits such as quality of life, improved safety measures, level of knowledge, etc. are not easily converted to benefit dollars and are not addressed by Ellis's model. During the interview process, a NCDOT Research Benefit Tree was developed and is presented in Figure 3.1.

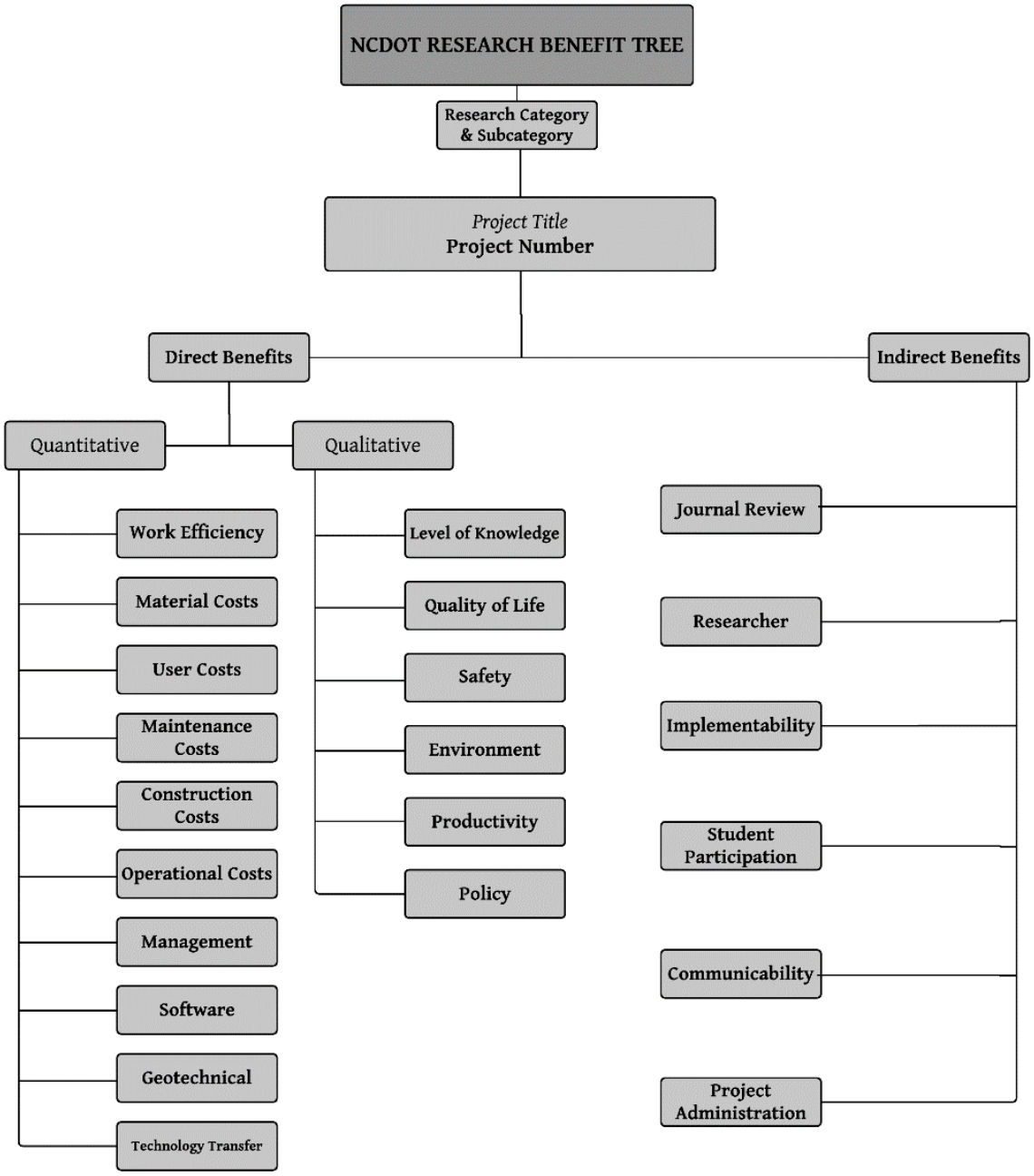

Figure 3.1. NCDOT Research Benefit Tree

In order to address both qualitative and quantitative benefits, the previous Cost-Benefit Analysis model has been amended and is given by the following equation:

$$B/C = \frac{K \times (HB + SB)}{RC + IC} \tag{3.2}$$

Where:

B/C = the benefit-cost ratio for a research and implementation effort

K = Impact Constant ($K = 1 + IF$)

HB = "Hard" Benefits based on per year calculation

SB = "Soft" Benefits based on per year calculation

RC = the cost of the research project

The introduction of the Impact Constant, *K*, allows the inclusion of the indirect benefits in the monetary calculations. Based on survey feedback from NCDOT research stakeholders the following qualitative benefits were identified as beneficial and deemed qualitative impact factors, *IF*:

- Level of Knowledge Gained – development of standards, policies, specifications, changes to operations, etc., K_i
- Implementation of Research Products, IR_i
- Experience Gained between the NCDOT and Researcher (PI), E_i
- Student Participation and Exposure, GS_i
- Positive Visibility of NCDOT, V_i
- Publications, Peer Reviewed (conferences, journals), PC_i

Using Analytical Hierarchy Process (AHP), weighting factors, w_i, were determined for the calculation of *IF*. The Analytical Hierarchy Process (AHP), uses a system of hierarchies to compare alternatives through a pair-wise comparison matrix shown in Figure 3.2. The AHP is similar to the weighted sum method (WSM), however each alternative criteria is normalized by dividing its score by the sum score for that criteria (eigenvector).

$$\begin{matrix} a_{11}/\sum_1^m a_{i1} & a_{12}/\sum_1^m a_{i2} & \cdots & a_{1n}/\sum_1^m a_{in} \\ a_{21}/\sum_1^m a_{i1} & a_{22}/\sum_1^m a_{i2} & \cdots & a_{2n}/\sum_1^m a_{in} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1}/\sum_1^m a_{i1} & a_{m2}/\sum_1^m a_{i2} & \cdots & a_{mn}/\sum_1^m a_{in} \end{matrix}$$

Figure 3.2. Pair-wise Comparison Matrix for AHP

The AHP is a popular method due to its application in single and multi-dimensional decision making, and the ease as to which it is implemented. The decision making methodology derives priorities among alternatives resulting in a ranking of alternatives, e.g. the alternative weighting factor, w_i. The impact factor, *IF* can then be calculated as follows:

$$IF = w_K(K_i) + w_{IR}(IR_i) + w_E(E_i) + w_{GS}(GS_i) + w_V(V_i) + w_{PC}(PC_i) \le 1 \qquad (3.3)$$

And *K* is then given by the following equation:

$$K = 1 + IF \qquad (3.4)$$

In order to effectively deploy AHP, the input (survey data) must elicit the respondent to compare variables and respond to which variable is deemed more important and to what degree is its importance. This requires that the pair wise comparisons have increasing and decreasing degrees of importance past the midpoint (average) assessment. The standard five level Likert scale was selected for the pair wise comparison and is as follows:

Strongly Disagree	1
Disagree	2
Undecided	3
Agree	4
Strongly Agree	5

For the survey, respondents were asked to compare each qualitative variable and provide feedback as it pertains to which was more important and to what degree. For example comparing knowledge gained to research implementation, if the respondent deemed knowledge gained as more important than research implementation the result would be a four on the Likert scale. Conversely, if the respondent deemed research implementation to be of more importance the result would be a two on the Likert scale. In the survey (Appendix A), respondents were asked to compare all qualitative variables. The raw, average ratio results from the survey are given by Table 3.1 (upper triangular matrix) and their reciprocals are represented in the lower triangular matrix. The input matrix is given by Table 3.2 after adjustment due to pivot in the Likert scale being three instead of the usual pivot of one. At this point, the comparison matrix is normalized to produce weighting vectors (factors) totaling to one hundred percent as given by Table 3.3.

Table 3.1 Raw Pair Wise Comparison Input (survey) Matrix (based on pivot value of three)

	Knowledge	Implementation	Experience	Grad Students	Publications	Visibility
Knowledge	3	3.11	3.5	3.722	3.722	3.556
Implementation	0.322	3	3.278	3.556	3.611	3.556
Experience	0.286	0.305	3	3.667	3.444	3.444
Grad Students	0.269	0.281	0.27	3	2.944	2.611
Publications	0.269	0.277	0.29	0.34	3	2.67
Visibility	0.281	0.281	0.29	0.38	0.37	3

Table 3.2 Variable Pair Wise Comparison Matrix

	Knowledge	Implementation	Experience	Grad Students	Publications	Visibility
Knowledge	1.00	1.04	1.17	1.24	1.24	1.19
Implementation	0.96	1.00	1.09	1.19	1.20	1.19
Experience	0.86	0.92	1.00	1.22	1.15	1.15
Grad Students	0.81	0.84	0.82	1.00	0.98	0.87
Publications	0.81	0.83	0.87	1.02	1.00	0.89
Visibility	0.84	0.84	0.87	1.15	1.12	1.00
Total	5.28	5.47	5.82	6.82	6.70	6.28

Table 3.3 Normalized Matrix to Determine Weight Factors

Knowledge	Implementation	Experience	Grad Students	Publications	Visibility	Total	Average	Consistency Measure
0.189	0.190	0.200	0.182	0.185	0.189	1.136	0.189	6.009
0.183	0.183	0.188	0.174	0.180	0.189	1.096	0.183	6.007
0.162	0.167	0.172	0.179	0.171	0.183	1.035	0.173	5.983
0.153	0.154	0.141	0.147	0.147	0.139	0.879	0.147	6.011
0.153	0.152	0.150	0.149	0.149	0.142	0.895	0.149	6.007
0.160	0.154	0.150	0.169	0.168	0.159	0.959	0.160	5.983
								0.000001273
							R. Index	1.24
							C. Ratio	1.02671E-06

With AHP, the weighted vector results are based on the subjective opinion of individual respondents to the survey and therefore, could inject some inconsistent logic into the normalized matrix. AHP acknowledges this fact and accounts for some small level of inconsistency, namely ten percent (0.10). To insure that the inconsistency remains negligible, the consistency ratio is computed as follows:

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{3.5}$$

Where,

CI = Consistency Index

λ_{max} = Average Consistency Measure, CM

n = number of variables

and,

$$CR = \frac{CI}{RI} \tag{3.6}$$

CR = Consistency Ratio

RI = Random Index (1.24 for n = 6)

Based on the resulting calculations in Table 3.3, the consistency ratio is less than ten percent and model logic is considered consistent. The resulting averages or weight vectors are as follows:

- Knowledge 0.19
- Implementation 0.18
- Experience 0.17
- Grad Students 0.15
- Publications 0.15
- Visibility 0.16

Equation 3.3 can then be written as follows:

$$IF = 0.19(K_i) + 0.18(IR_i) + 0.17(E_i) + 0.15(GS_i) + 0.16(V_i) + 0.15(PC_i) \leq 1 \qquad (3.7)$$

The qualitative impact factors are rated based on the values provided by Table 3.4. Through consultation with the NCDOT, the research will rate each impact factor based on the level provided by the research project. For example, if no students were employed to complete the project, the level of impact for *GS* would be zero; however, if two graduate students were employed the level of impact would then be 0.67.

Table 3.4 Individual Impact Factor Values

None	Low Impact	Impacted	High Impact
0	0.33	0.67	1

In summary, the methodology can be defined as follows:

1. Identify and calculate hard costs (quantitative) presented in Figure 3.1.
2. Identify soft costs (qualitative) presented in Figure 3.1 and determine monetary benefits utilizing OHSA, NCDOT, FHWA, etc. databases.
3. Using Equation 3.7 and level of impact (Table 3.4), calculate the impact constant, K.
4. Use Equation 3.2 to calculate the cost benefit ratio.

3.3 Application of the CBA Methodology

Cost Benefit Example: RP 2015-11. Preventive Maintenance Program

The goal of this research project was to monitor oil quality throughout extended drain intervals to determine the type, rate, and magnitude of resulting degradation, and to investigate the potential for extending oil drain intervals. Given the extensive fleet that NCDOT operates and maintains, the recommendation to extend oil change intervals resulted in both hard and soft economic benefits and was therefore selected as the CBA example.

Hard cost calculations (benefits) were performed utilizing an excel spreadsheet:

Table 3.5 Current Annual Cost of Oil Changes

For Regular Interval				
Threshold		Oil Changes per Machine	Annual Cost per vehicle	Annual Cost
value	units			
5,000	miles	2	$ 700.00	$ 114,800.00
5,000	miles	6	$ 900.00	$ 19,800.00
5,000	miles	6	$ 840.00	$ 46,200.00
200	hours	1	$ 270.00	$ 17,280.00
200	hours	2	$ 400.00	$ 21,600.00
200	hours	2	$ 560.00	$ 24,080.00
200	hours	3	$ 750.00	$ 15,000.00
200	hours	2	$ 420.00	$ 23,100.00
			Cost	**$ 281,860.00**
			Benefits	0
			Benefit / Cost Ratio	0

Table 3.6 Annual Cost of Oil Changes using Research Results

from Extended Oil Drain Intervals				
Threshold		Oil Changes per Machine	Annual Cost per vehicle	Annual Cost
value	units			
10,000	miles	1	$ 350.00	$ 57,400.00
5,000	miles	6	$ 900.00	$ 19,800.00
10,000	miles	3	$ 420.00	$ 23,100.00
500	hours	1	$ 270.00	$ 17,280.00
500	hours	1	$ 200.00	$ 10,800.00
500	hours	1	$ 280.00	$ 12,040.00
500	hours	1	$ 250.00	$ 5,000.00
500	hours	1	$ 210.00	$ 11,550.00
			Cost	**$ 156,970.00**

The resulting savings given by Table 3.7 is the difference of $124,890 and 2671 gallons of oil annually. The focus area for soft costs are the reduced time mechanics are exposed to dangers during oil changes. Mechanics are susceptible to eye injuries, slips and falls during the oil changing process. According to the Bureau for Labor Statistics, 2.5 work days are missed per 100 workers per year due to these dangers.

Table 3.7 Annual Estimated Savings

Estimated savings		
Oil Changes per Machine	Annual Cost	Oil (Gallon)
1	$ 57,400.00	1230
0	$ -	0
3	$ 23,100.00	537
0	$ -	0
1	$ 10,800.00	216
1	$ 12,040.00	258
2	$ 10,000.00	210
1	$ 11,550.00	220
	$ 124,890.00	**2671**

Using an average mechanic salary of $42,000/year and 980 mechanics employed by NC, the soft costs can be calculated as follows:

$$SC = .25\ days \times \$168\ per\ day \times 980\ mech \times .443(reduction) = \$18{,}238/year$$

Calculating the *IF* as:

Knowledge	= 1.0 (new knowledge)
Implementation	= 0.33 (has not been fully implemented)
Experience	= 0
Grad Students	= 0.67 (2 MS students funded)
Publications	= 0.67 (3 presentations and a TRB paper)
Visibility	= 0.33 (Small communication about the project)

$$IF = 0.19(1) + 0.18(0.33) + 0.17(0) + 0.15(0.67) + 0.15(0.67) + 0.16(0.33) = 0.50$$

And the CBA can be calculated as follows:

$$B/C = \frac{K \times (HB + SB)}{RC + IC} = \frac{1.50 \times (124{,}890 + 18{,}238)}{121{,}500} = 1.56$$

The resulting cost benefit is 1.56 which is greater than 1.0 based on a per year calculation and would be considered good or of value in a technical sense. It should be noted, the cost of research was also converted to per year basis due to it being a two year project. In this instance, the yearly savings would be better communicated as the project is saving North Carolina taxpayers $187,500/year based on the current implementation level.

Chapter 4: Development of Key Performance Indicators for a Research Success Prediction Model

4.1 Introduction

While there ample previous work in the development of cost benefit analysis post implementation, little, if any previous work has been performed in predicting the cost benefit of future research projects. With the development of a cost benefit analysis methodology and identifying key indicators from that methodology, historical data would then be available to populate a prediction model to assist the NCDOT R&D Unit with a probability of success of similar, future research projects. Through consultation with the NCDOT R&D unit, three levels of success were selected: high, medium and low. These three outputs or probabilities, are corresponding to highly successful, successful, and marginally successful projects, respectively. Since the dependent variable has more than two levels, cumulative ordinal regression was used in this study.

Theoretically, ordinal regression models allow for all variables (indicators) to be added and removed to test their impact on the overall outcome of the model. The caveat to this methodology is each variable must be linked or coupled with a predetermined hierarchy or importance to the prediction. Considering all possible success indicators for all of NCDOT research projects past and present, simply including all indicators to test impact is not feasible for model development.

A number of factors or circumstances can influence a project's success, some significantly, some with little impact to the outcome of the project. Through the interview process with key NCDOT Research Stakeholders, an initial list of twelve possible success indicators were developed and are presented in Table 4.1. This list provides a manageable number of variables which were included in the survey to determine level of importance.

Table 4.1 Success Indicators – Interview Identified

1	Active NCDOT Research Champion
2	Active StIC Participation
3	Detailed Implementation Plan
4	Graduate Student Participation
5	NCDOT Management Support
6	Performing Organization/University
7	Proposal Quality
8	Regular Communication from the PI
9	Research Need Priority
10	Researcher Experience with NCDOT
11	Resulting Publications
12	Routine Engagement with Research Team

It should be noted, the impact of the research engineer was also identified as a success indicator; however, the impact of research engineers is constant across all projects managed by the NCDOT R&D unit. Therefore, the impact of success attributed to research engineers was

removed from consideration. A ranking of identified success indicators was included in the survey and is presented in the following section.

4.2 Development of Controlling Success Indicators and Survey Results

A total of 40 NCDOT research stakeholders out of 110 responded to the survey. To calculate the minimum response rate, *n* given a defined level of confidence, the following equation is used:

$$n = \left(\frac{Z\sigma}{E}\right)^2 = \left(\frac{1.96 \times .96}{.5}\right)^2 = 14.16\ respondents\ or\ a\ 13\%\ response\ rate$$

In the preceding equation, Z is the confidence level (probability of normal distribution), σ represents the standard deviation of responses to the survey, and E is the margin of error for a Likert scale. The resulting number of required respondents to achieve a 95% accuracy is a minimum of fifteen respondents.

In the survey, the indicators were grouped (and respondents asked to rank) based on the categories of NCDOT impact, research engineer impact and researcher impact to the success of a project. The first category, NCDOT impact, indicators illustrated in Figure 4.1 were presented to the respondents who were asked to rank the indicators' contribution to a successful project.

From the list of research indicators described below, please rank each from 1 to 6, according to its overall contribution to the success of a project. 1 represents the indicator as contributing the most to project success, whereas 6 represents the indicator as contributing the least to project success).

	1	2	3	4	5	6
Active NCDOT Research Champion	○	○	○	○	○	○
Research Need Priority	○	○	○	○	○	○
Active StIC Participation	○	○	○	○	○	○
Routine Engagement with Research Team	○	○	○	○	○	○
Detailed Implementation Plan	○	○	○	○	○	○
NCDOT Management Support	○	○	○	○	○	○

Figure 4.1. Research indicator ranking for NCDOT Indicator Category

The aggregate results identify Research Need Priority (Figure 4.2), Active NCDOT Research Champion (Figure 4.3) and Active StIC Participation (Figure 4.4) as the indicators contributing the most to a project's success.

It should be pointed out, that during the interview process these indicators were also the indicators identified as most likely to impact success.

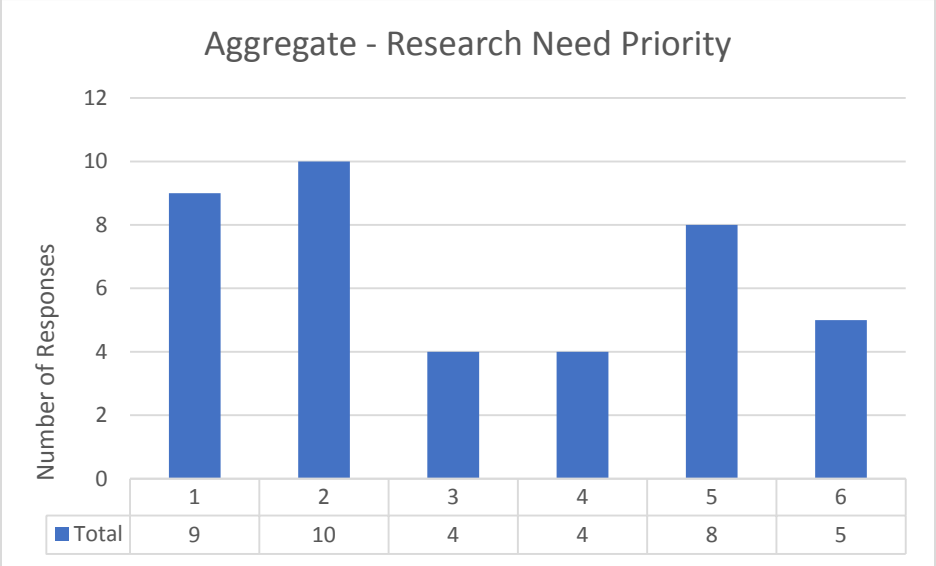

Figure 4.2. Aggregate Preliminary Survey Results for Research Need Priority

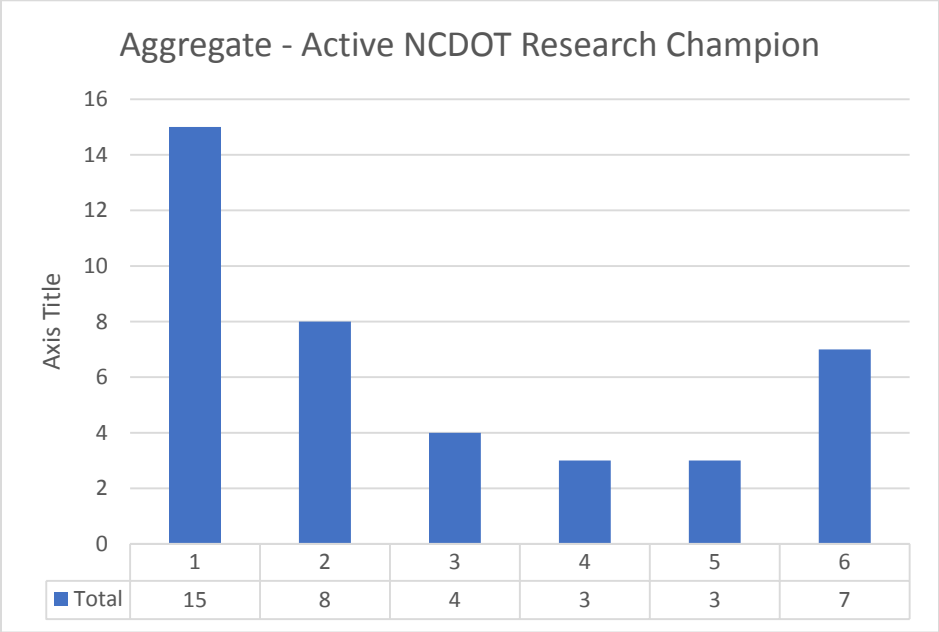

Figure 4.3. Aggregate Preliminary Survey Results for Active NCDOT Research Champion

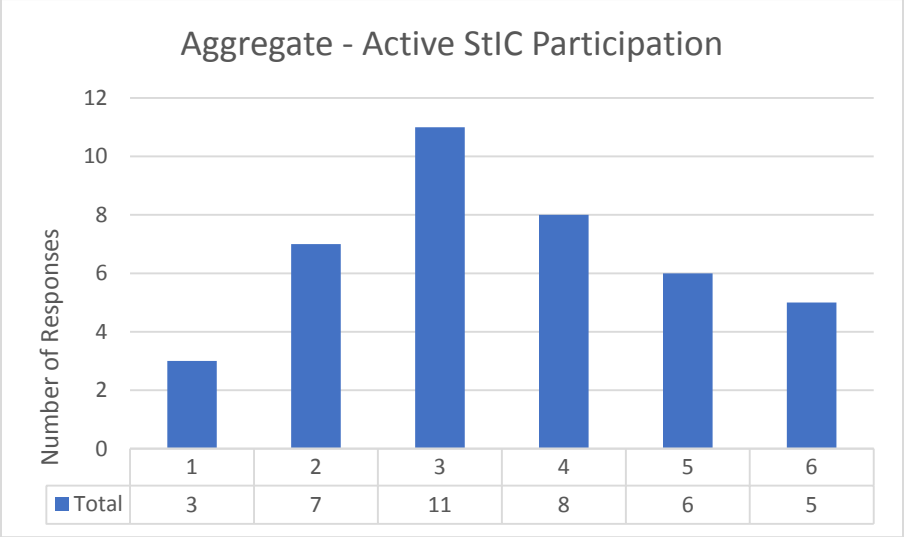

Figure 4.4. Aggregate Preliminary Survey Results for Active StIC Participation

For the second category, Research engineer's impact, indicators illustrated in Figure 4.5 were presented to the respondents who were asked to rank the indicators contribution to a successful project.

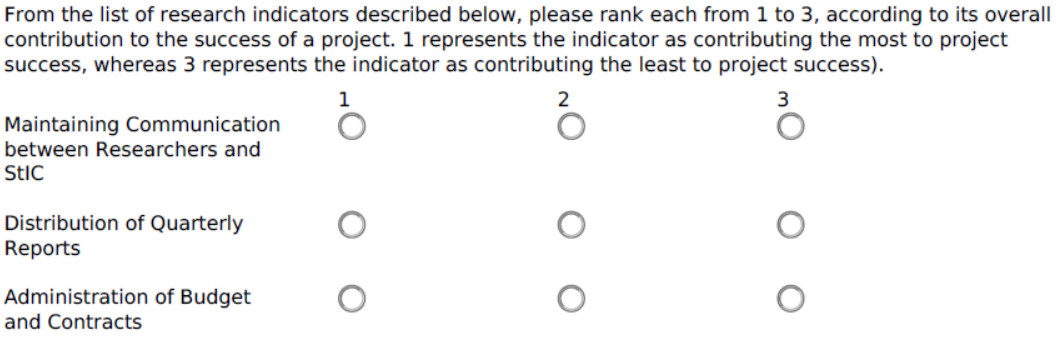

Figure 4.5. Research indicator ranking for NCDOT Research Engineers Indicator Category

The aggregate results identify Maintaining Communication between Researchers and the StIC (Figure 4.6) as the indicator contributing the most to a project's success.

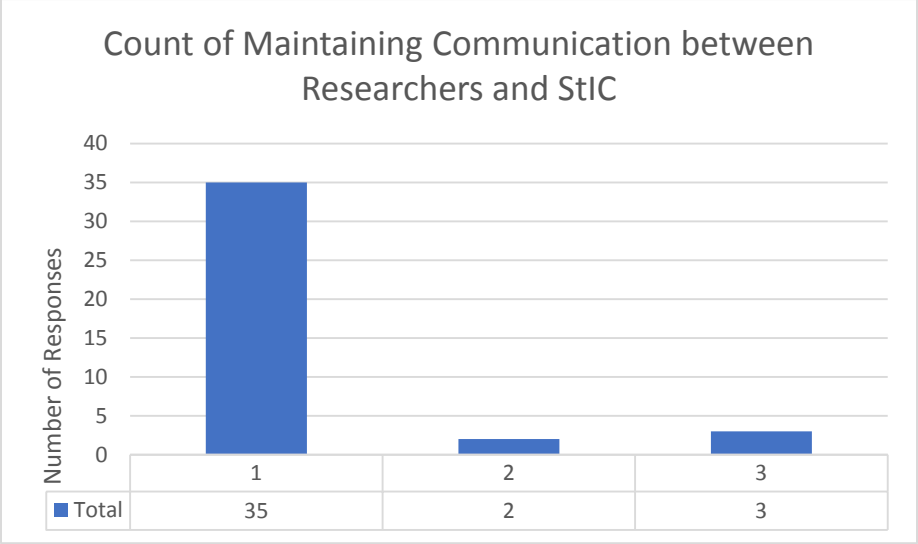

Figure 4.6. Aggregate Preliminary Survey Results for Maintaining Communication between Researchers and the StIC

For the last category, Researcher's impact, indicators illustrated in Figure 4.7 were presented to the respondents who were asked to rank the indicators contribution to a successful project.

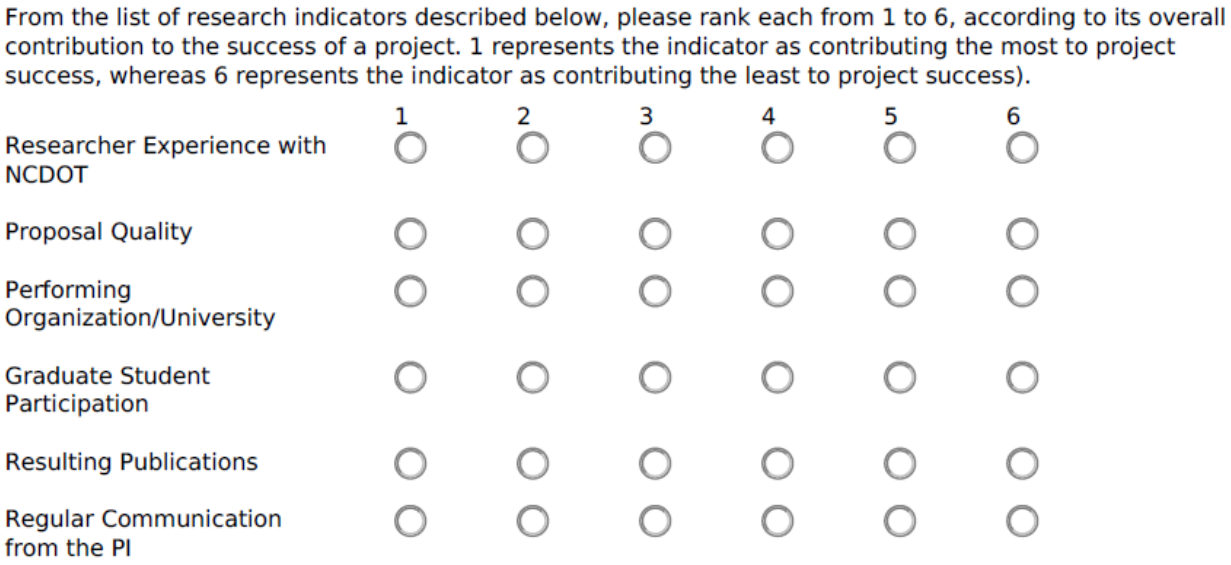

Figure 4.7. Research Indicator Ranking for Researcher and Performing Organization

The aggregate results identify Regular Communication between from the PI (Figure 4.8), Researcher Experience with NCDOT (Figure 4.9) and Proposal Quality (Figure 4.10) as the indicators contributing the most to a project's success.

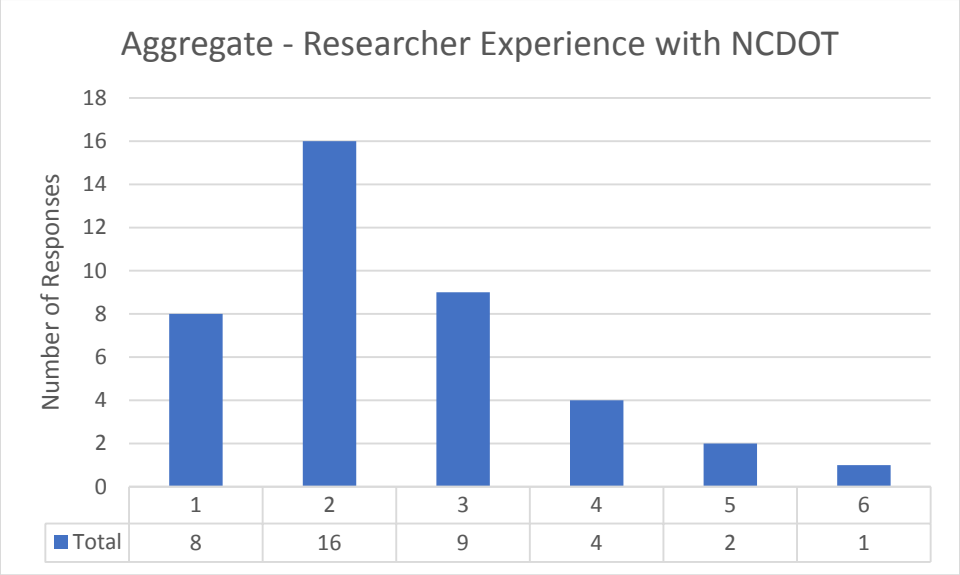

Figure 4.8. Research Indicator Ranking for Researcher Experience with NCDOT

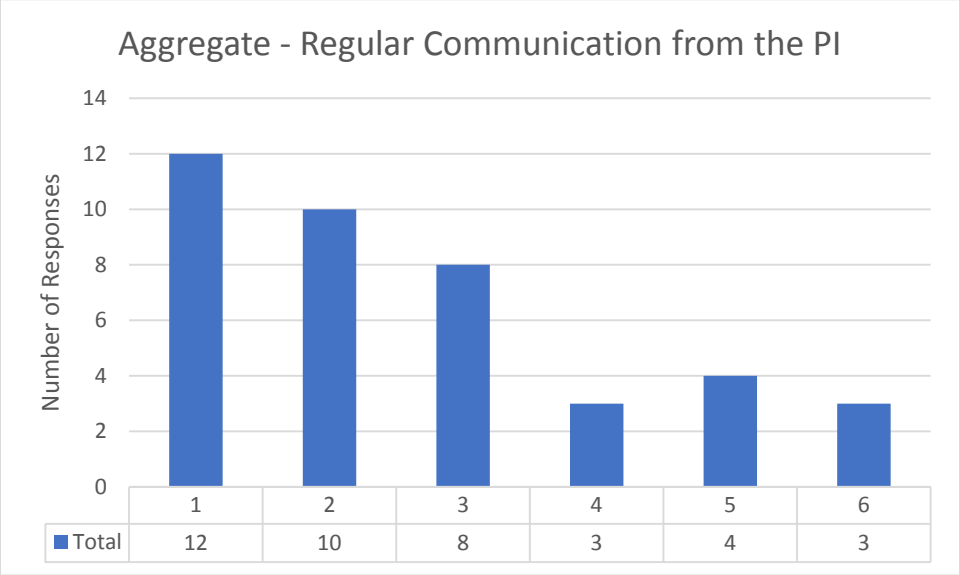

Figure 4.9. Research Indicator Ranking for Regular Communication from the PI

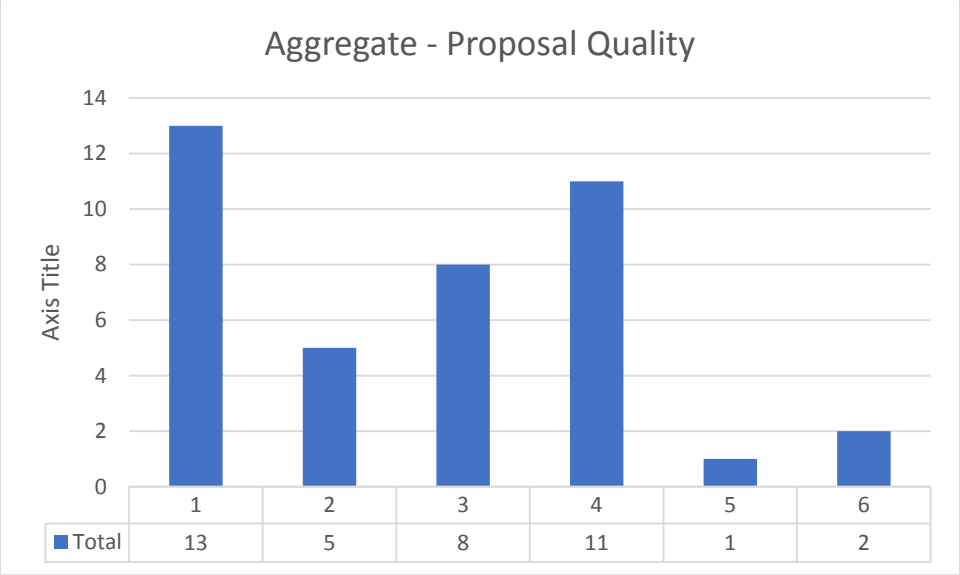

Figure 4.10. Research Indicator Ranking for Proposal Quality

Of concern to the research team is the hierarchy (ranking) of the performance indicator being based on opinion from different stakeholder points of view, e.g., NCDOT, Researcher, Manager, etc. This different perspective on defining project success could bias the model's outcome. At the completion of the survey and with consultation of the NCDOT, bias can be addressed as presented in the following example.

In ranking the graduate student participation indicator (Table 4.2) the aggregate results, a number of respondents ranked this indicator very low in terms of project success. However, a number of respondents (twelve) felt that it was an important aspect of a successful project which was enough to influence its hierarchal position.

Table 4.2. Hierarchal Ranking Results – Aggregate

HIERARCHAL RANK	RESEARCH/ORGANIZATION INDICATORS
1	Regular Communication from the PI
2	Researcher Experience with NCDOT
3	Proposal Quality
4	Graduate Student Participation
5	Resulting Publications
6	Performing Organization/University

In using the respondent categories, such as researcher, engineer, research champion, etc., the data can be subdivided to illustrate respondent perspective. In Table 4.3, the respondents that identified as working for the NCDOT did not view graduate student participation as a key indicator, while researchers viewed the indicator more favorably. At the conclusion of the

survey, the hierarchal rankings were weighted and a final list of indicators developed (Table 4.4).

Table 4.3. Hierarchal Ranking Results – NCDOT

HIERARCHAL RANK	RESEARCH/ORGANIZATION INDICATORS
1	Regular Communication from the PI
2	Researcher Experience with NCDOT
3	Proposal Quality
4	Performing Organization/University
5	Resulting Publications
6	Graduate Student Participation

Table 4.4 Hierarchal Ranking Results – Final

HIERARCHAL RANK	RESEARCH SUCCESS INDICATORS
1	Regular Communication from the PI
2	Researcher Experience with NCDOT
3	NCDOT Research Project Champion
4	Research Need
5	Proposal Quality

In addition to developing the indicator hierarchy, the survey also was developed to gather some general information on the NCDOT research climate for informational purposes. A summary of preliminary results are shown in Table 4.5 on the following page. Referring to the results presented in Table 4.5, respondents rated "knowledge gained" as the most defining characteristic of a successful project. Additionally, respondents generally found the quarterly report to be a valuable tool in assessing direction and progress of a research project. However, Respondents were split on monetary impact as an indicator of a successful project and if a research project results had to be implemented to be considered a success.

Table 4.5. Summary of General Research Climate Questions

QUESTION	RESULT
Definition of a successful Research Project	
Knowledge Gained	31
Detailed Implementation Plan	7
Quality Final Report	2
Cost Benefit Gains	
Strongly Agree	1
Agree	11
Strongly Disagree	2
Disagree	26
Implementation of Research Results	
Strongly Agree	6
Agree	14
Strongly Disagree	1
Disagree	19
Quarterly Reports are Valuable Tools	
Strongly Agree	4
Agree	30
Disagree	6
Quarterly Report Review Time is Adequate	
Strongly Agree	6
Agree	33
Disagree	1
Quarterly Report's Ability to Judge Project Progress	
Strongly Agree	9
Agree	25
Disagree	6

4.3 Development of a Research Performance Prediction Model

4.3.1 Introduction to Ordinal Logistic Regression

Ordinal logistic regression is used to predict an ordinal dependent variable, *Level of Success*, given one or more independent variables, *Success Indicators*. Given three levels of the dependent variable *Level of Success* as Highly Successful, Successful, and Moderately Successful, the ordinal regression model can be generically written as follows:

$$Success = \beta_0 + \sum_{i=1}^{n}\left[\left(\beta_i\right) Indicator_i\right] + error \quad (4.1)$$

Where:

Success is defined categorically as the probability of the project being highly successful, the probability of the project being successful and the probability of the project being moderately successful.

and,

β_0 = model correction factor (y-intercept)

β_i = importance factors (weighting)

$Indicator_i$ = controlling success indicators.

Utilizing ordinal regression,

$$\text{Success } = logit[p(y \leq 1)] = log\left[\frac{p(y\leq 1)}{p(y>1)}\right] = log\left[\frac{p(y=1)}{p(y=2)+p(y=3)}\right] = \exp(\beta_0 + \sum_{i=1}^{n}\left[\left(\beta_i\right) Indicator_i\right])$$

(4.2)

and,

$$Success = logit[p(y \leq 2)] = log\left[\frac{p(y\leq 2)}{p(y>2)}\right] = log\left[\frac{p(y=1)+p(y=2)}{p(y=3)}\right] = \exp(\beta_0 + \sum_{i=1}^{n}\left[\left(\beta_i\right) Indicator_i\right])$$

(4.3)

Due to having three possible levels of success (dependent variables), the need for two independent categorical models becomes necessary as two y-intercepts are produced in the analysis. Equation 4.2 compares the probability that a project will be Highly Successful verses average to moderate level of success. Equation 4.2 should be used to analyze high value, high priority projects in terms of probability for success. Conversely, Equation 4.3 compares the probability of a project being highly successful and successful verses moderately successful. This model should be used during the execution of the research program where risk of a project only being defined as successful is minimized.

4.3.2 Research Prediction Model Data

The methodology to minimize the difference between the predicted and observed requires that projects must be identified using a dummy variable (1, 2, or 3) for highly successful (1), successful (2), and moderately successful (3). Furthermore, these projects must be coupled with a related NCDOT stakeholder's response to the ranking of the performance indicators as shown in Table 4.6. In other words, the survey responses define the indicators to be used in the model, and at what level, while the weighting is determined by the survey responses of those associated with the projects. Currently, eight projects have been identified for the project and ranked as highly successful, successful or moderately successful.

Table 4.6. Data Organization for the Development of the Research Prediction Model

DEFINED PROJECT	NCDOT STAKEHOLDER	INDICATOR#	PROJECT SUCCESS LEVEL
RP 20XX -00	Respondent	RS i	1,2,3

During the interview process, an additional twelve projects were defined as highly successful. However, the data set presented in Table 4.7 utilizes only four highly successful projects to assist in avoiding some bias in the final model. In an effort to allow interviewees some degree of anonymity, the final data set used to develop the model framework removes the actual project number and respondent name.

Table 4.7. Data Organization for the Development of Importance Factors

Project	PI Comm	NCDOT Champ	Research Need	PI Exp	Proposal	Success
1	1	2	2	3	1	1
	3	1	1	2	2	1
	2	1	1	3	2	1
2	2	1	2	1	1	1
	1	1	2	1	2	1
	1	2	1	2	2	1
3	2	1	1	2	2	1
	1	2	1	2	2	1
	1	2	2	2	1	1
4	2	2	2	1	1	1
	2	1	1	1	2	1
	1	1	2	3	2	1
5	1	4	2	3	1	2
	3	1	1	2	2	2
6	5	1	4	3	2	2
	4	1	4	3	1	2
7	5	4	4	3	2	3
	2	4	4	3	1	3
8	5	3	4	3	2	3
	2	3	4	3	1	3

4.3.3 Research Performance Prediction Model

Utilizing a commercially available program JMP®, an ordinal regression was performed using the data presented in Table 4.7. As seen in Figure 4.11, the overall fit of the data to the model is statistically significant with a p-value less than .0001 and the lack of fit suggests (Prob>ChiSq of 1) that ordinal regression is the proper model. However, referring to the parameter estimates (β_i) of the y-intercepts and independent variables, it can be seen that p-value is very high as is the standard error.

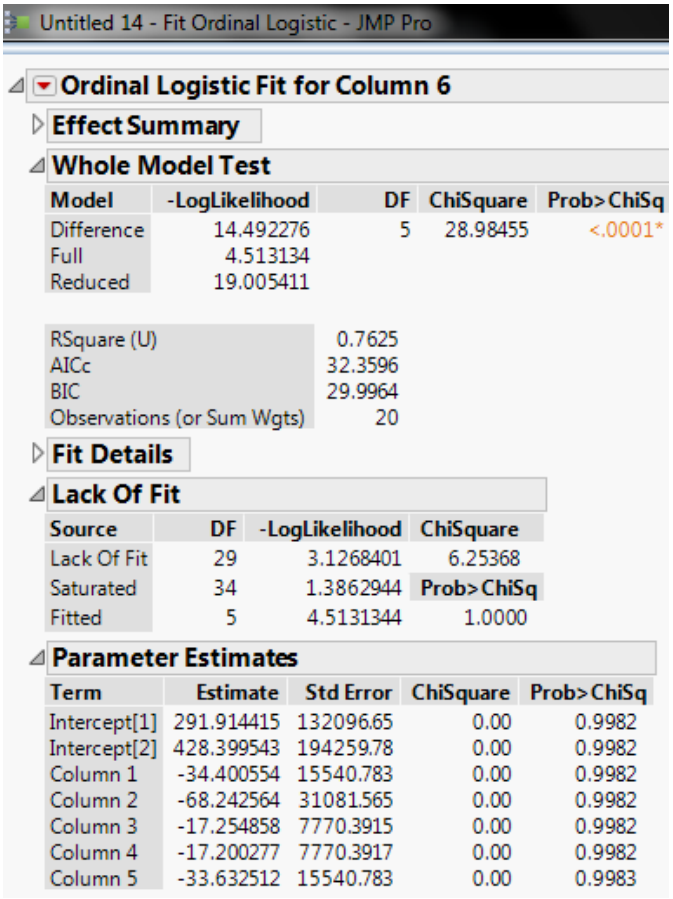

Figure 4.11. Ordinal Logistic Regression Results – Preliminary

In reviewing the interview data (Table 4.7), two importance factors must be investigated for their merits of being included as dependent variables namely, PI Communication and Proposal Quality. In looking at the raw data on proposal quality, it is evident that even for the projects that were rated as moderately successful the proposal quality was very good. This follows the logic that the proposal quality had to be rated high to be selected for funding placing highly rated Proposal Quality as a constant in the data set. As a result, Proposal Quality was removed from the dataset. Secondly, PI communication would be difficult at best to assess during the proposal selection stage unless the reviewer had previous experience with the researcher. The ability to assess communication would therefore be directly related to the importance factor, PI Experience. For this reason, PI communication was removed from the dataset. The resulting dataset is given by Table 4.8.

Again, utilizing the commercially available program JMP®, an ordinal regression was performed using the data presented in Table 4.8. As seen in Figure 4.12, the overall fit of the data to the model is statistically significant with a p-value less than .0001 and the lack of fit suggests (Prob>ChiSq of 1) that ordinal regression is the proper model. For this model analysis, both intercepts are now statistically significant as is the importance factor, Research Need. Additionally, NCDOT Champion has a 93.4% level of confidence which is very close to the target 95% confidence interval.

Table 4.8. Importance Factor Data - Final

Project	NCDOT Champ	Research Need	PI Exp	Success
1	2	2	3	1
	1	1	2	1
	1	1	3	1
2	1	2	1	1
	1	2	1	1
	2	1	2	1
3	1	1	2	1
	2	1	2	1
	2	2	2	1
4	2	2	1	1
	1	1	1	1
	1	2	3	1
5	4	2	3	2
	1	1	2	2
6	1	4	3	2
	1	4	3	2
7	4	4	3	3
	4	4	3	3
8	3	4	3	3
	3	4	3	3

The importance factor, PI Experience has a confidence level of 38.6% which is well below the target of 95%. Substituting the results from the ordinal regression analysis, the models can now be written as follows:

$$\text{Success} = log\left[\frac{p(y=1)}{p(y=2)+p(y=3)}\right] = \exp\left(9.08 - 1.41\text{NCDOT}_{\text{Champ}} - 2.06\text{Research}_{\text{Need}} - 0.61\text{PI}_{\text{Exp}}\right) \quad (4.4)$$

and,

$$Success = log\left[\frac{p(y=1)+p(y=2)}{p(y=3)}\right] = \exp(13.1 - 1.41\text{NCDOT}_{\text{Champ}} - 2.06\text{Research}_{\text{Need}} - 0.61\text{PI}_{\text{Exp}}) \quad (4.5)$$

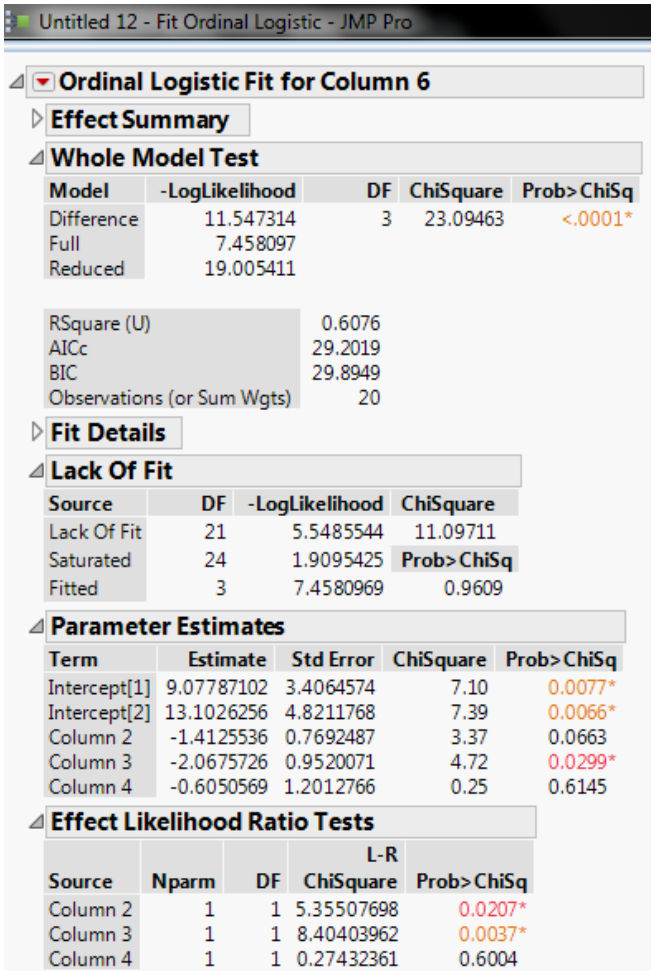

Figure 4.12. Ordinal Logistic Regression Results – Final

Interpreting the model results for Equation 4.4:

- NCDOT Champion – a one unit increase in importance factor rating (going from 5 to 4, 4 to 3, etc) the odds of being highly successful versus the combined successful and moderately successful are 4 times greater given all of the other importance factors are held constant.
- Research Need – a one unit increase in importance factor rating (going from 5 to 4, 4 to 3, etc) the odds of being highly successful versus the combined successful and moderately successful are 7.85 times greater given all of the other importance factors are held constant.
- PI Experience – a one unit increase in importance factor rating (going from 5 to 4, 4 to 3, etc) the odds of being highly successful versus the combined successful and moderately successful are 1.83 times greater given all of the other importance factors are held constant.

Note: Model Results for Equation 4.5 the odds remain the same and the comparison becomes: highly successful and successful versus moderately successful.

The presented models, at current confidence levels should be considered a framework for research prediction success due to the following limitations:

1. The current dataset is biased towards highly successful projects. The model should be amended as moderately successful project data becomes more available.
2. The confidence level of PI Experience is currently well below target level. However, it is readily apparent that PI Experience is an indicator for success and the low confidence level is a function of the small dataset.
3. Due to the dataset size, outliers cannot be properly addressed/removed and are affecting the model accuracy.

Chapter 5: "Research in Motion" - Communication Plan

5.1 Introduction

The ability to communicate the importance and impact of research in an innovative transportation program is essential in the current climate of competitive transportation budgetary dollars. Historically, dissemination of research findings occurred through journal articles and conference papers. While this is still an important and effective means of presenting research throughout the transportation community, budget and planning decisions are made now, not after a peer review process. Referring to NCHRP 610, effective communication of research benefits requires understanding of the target audience, demonstrating a tangible benefit, building relationships and reaching out to stakeholders through multiple communication channels.

According to "The Economic Value of Medical Research," the research was motivated by the same investment incentive problems transportation research is facing, and sought a solution by taking the same into account, while illustrating that improvements in a given subject area are complementary of other valued improvements. Though healthcare research relies on heavily documented empirical evidence, much of which may not be readily available, it more importantly elaborates on the need to assign numerical values to those features of progress that are specifically attributable to research advances (Peipert, 2002). In an analogous cost-benefit scenario developed around medical research, the analysis relied on an economic framework to assess the social benefits of medical research and aid in communicating that value. These points of consideration and evaluation will additionally help to:

1. Address strategic themes and policy issues, not just operational problems
2. Focus on the medium and longer term, not just the short term
3. Be programmatic rather than exclusively project-based
4. Inform policy formulation rather than simply monitoring policy implementation
5. Be prospective rather than retrospective
6. Feed findings regularly back into the policymaking process
7. Provide an interdisciplinary and inter-organizational focus
8. Foster a dialogue between policymakers, practitioners, and academics

5.2 Communication Plan – "Research in Motion"

In Chapter 3 of this report, a methodology was presented to determine a cost benefit (CBA) ratio to establish the value of a transportation research project. The CBA ratio is very useful for establishing the level of impact, or value, at the planning level; however, for some communication targets (general public, legislature) the ratio will fall short. It is recommended that monetary value be the communication subject to these audiences which are listed in Table 5.1. How this value is communicated, is of course, dependent on the audience. Therefore, the "Research in Motion" plan provides multiple communication outlets and best practices for each outlet is presented with an example in the following sections.

Table 5.1 Communication Target Audiences

Research in Motion - Target Audience	
Communication Tool	**Target Audience**
NCDOT Newsletter	NCDOT Management
	NCDOT Research End Users
	Researchers
	Industry
Facebook	General Public: Multi-Generational
	Legislature
	NCDOT Management
	NCDOT Research End Users
	Researchers
	Industry
Twitter	General Public: Mainly professionals, schedule constrained
	Legislature
	NCDOT Management
Instagram	General Public: Younger Audience
Transportation Research Convention and Exposition	Legislature (guests, guest speakers)
	NCDOT Management
	NCDOT Research End Users
	Researchers
	Industry

5.2.1 NCDOT Newsletter – RESEARCH IN MOTION

Content Overview:

- Director's Corner (News of the Quarter from Director)
- In this issue… (Table of Contents)
- Research at Work – Implemented research making a difference in NC.
- Meet the RC and/or PI – This can be a Research Engineer, PI, Research end user, etc.
- "Off the Shelf" (Librarian Section)

Proposed Action Items:

- Consider including less content per newsletter, and allow for referenced information to speak more regarding the particular research item highlighted
- Will assist with giving due attention to other media maintenance, and may seek to publish newsletters with more frequency, if and when applicable
- Clean up content and reference materials
    - Should be minimal and interactive (i.e. linked to site offering additional information) → *NOTE INTERACTIVE COVER PAGE OPTION: can include*

an image/icon related to a specific category of research, to keep consistent with each release, that the reader may click on to be taken directly to the relevant work within the document.

- Enhance accessibility to NCDOT R&D Unit Newsletter - from NCDOT primary webpage - by removing subscription requirement to view documents from website banner on primary site (see image below) i.e. make access 1 step process

- Consider webpage format for newsletter (i.e. remove need to create PDFs), to aid in implementing easily formatted tabulations that include a subscription option and/or past issue search
    - In the alternative, may simply include this access within the document; however, most interactive links within the document should be reserved for the material itself
- In general, the option to subscribe is best suited to appear once reader has an opportunity to review material and consider whether to pursue
    - This option can be highlighted on the newsletter itself, and can be easily completed by merely clicking on the requisite link, and allowing a "login" option – similar to creating typical media account – that directly links the newsletter materials to the account of the individual's choosing (i.e. email/Facebook/etc.)
- Regarding release/schedule:
    - Should be consistent and predictable, bi-annually or quarterly.
- Regarding style:
    - Should maintain some of the traditional newsletter aesthetic, and allow the links to additional/optional information to include the more "in your face" content communication forums
    - Want to do this to ensure that less tech-savvy, easily over-stimulated audience members are not deterred (again, do not want to alienate potential supporters)
    - Remove links such as "fast facts" (unappealing) and "return to home" (unnecessary)

5.2.3 Media Outreach

5.2.3.1 Facebook – NCDOT Research and Development

Facebook offers an exceptionally productive forum for NCDOT R&D to communicate the value of its work, and is especially useful due to its ability to reach particular demographics on social media, including multi-generational populations, such as millennials and older

generations. The wealth of existing research provides ample material that can be strategically tailored to highlight the work of NCDOT as shown in Figure 5.1.

- NCDOT R&D should have a Facebook account dedicated solely to R&D.
    - This action is recommended for each media channel proposed in this communication plan
    - NCDOT R&D can better promote research & related works as a distinct, productive body within the NCDOT
    - Communicating NCDOT as a whole is unrealistic for best response/results and has the potential to alienate critical audiences
    - This option also aligns with a key recommendation re: general ease of access and understanding
- Include profile images with relevant research/policy component (i.e. roadway safety/work zone safety/defensive driving/considerate driving/resources/etc.)
- Consider (interactive) to do list for public use (e.g. a real-time, pre-formatted "to-do" list to allow users to contribute constructive criticism and may rely on the same to assist with content development, etc.
    - This is a way to receive user feedback without the negative reviews; consider a survey component for participants to provide feedback + useful data (such as age, location, job position, etc.. if feasible)
        - NCDOT Legal to consider limits of information
- Utilize Facebook to convey messages that are relevant, consistent, and on message
    - Directly communicating the value of SPECIFIC work by clearly and concisely describing research goals, impacts, benefits, etc.
    - Consider an approach similar to public radio when fundraising
        - this is what we do for you and this is how you help/can help
        - make public feel involved - allow them to contribute (again, not via reviews)

5.2.3.2 Twitter - @NCDOT_R&D, #RESEARCHINMOTION

The restrictions that are inherent when using Twitter (such as quantity of characters) presents a unique forum for NCDOT R&D to communicate content in short and simple messages, with the option to provide more in depth materials for those followers seeking to learn more about the particular post. Twitter is additionally useful as a means of communicating to an additional and distinct demographic; particularly, most users appear to be working professionals and academics, with most of the important political figures and financial tycoons having an active presence. Essentially, Twitter consists mainly of people who make an active effort to keep up on current events but, due to their respective time and/or opportunity constraints, consume information that is quick, condensed, and relevant as illustrated by Figure 5.2.

Likewise, NCDOT R&D must endeavor to present such information in an attention-grabbing manner, while also being informative enough to maintain such attention once it is achieved. The following items address some of the aforementioned considerations.

- In general, similar considerations apply here as those mentioned above (re: Facebook), but must be communicated in a condensed, text format (versus visual - i.e. Instagram) that prompts followers to view more informative materials
    - i.e. to have 140 characters that include enough information to prompt readers to pursue links to relevant info
- Is also a suitable platform for connecting with other DOTs/stakeholders/public figures/etc. in a way that also promotes mutual (neutral) messages

5.2.3.3 Instagram- NCDOT_R&D

Similarly to Facebook and Twitter, Instagram allows NCDOT R&D to target essential audiences in order to promote understanding and positivity for its respective work, and for the department as a whole. While each medium allows NCDOT R&D to communicate major events and points of note to the public, Instagram is a forum best suited for those seeking visual representations of information. Specifically, Instagram can help NCDOT R&D to effectively communicate research-related topics to younger members of society. Accordingly, Instagram presents the department with an opportunity to impact the public, and especially the youth, in a more direct, proactive manner, easily achieved through the creation of simple, representative image, with some inclusion of notes of interest.

<u>General considerations:</u>

- Instagram appears most productive for bringing “character” and detail to images and videos
- Is a source best reserved for research materials that are better communicated visually (i.e. pavement and maintenance work may be less interesting on paper to the targeted audience; a video of the research team conducting site studies/etc. may broaden the viewer-base)

Figure 5.1. Facebook Post Example

Figure 5.2. Instagram Post Example

5.2.3.4 Media Caption

The NCDOT R&D should utilize a media banner on its website to highlight high value research projects. A media banner allows for exposure to an already captive audience (they are already visiting the web site) and create interest in the project being highlighted.

Example:

The proposed scope of work for this research effort will provide research on best practices for cost-based estimation, strategies to incorporate the latest construction cost indexes into the analysis of historical data, and methods to forecast the impact of cost trends within estimates.

Figure 5.3. Media Banner Example

5.2.3.5 Transportation Research Convention & Exposition

NCDOT Research and Development should utilize a Convention and Expo to further increase visibility to participants, users and stakeholders. A sample Schedule and agenda is given in Table 5.2. The following should be considered:

1. Keynote address speaker selection should consider if the person is a research stakeholder and if NCDOT would benefit from this person getting a more in-depth look at the impact from the high value research projects.
2. It is recommended that the Convention and Expo rotate hosting among the UNC Universities to keep costs down, at least until sponsorships are cultivated. By hosting at a UNC campus, approximately $3,500 is saved.
3. It is recommended that at least one session be saved for a “research focus group” meeting. This will allow for a sharing of ideas (research ideas) and provide feedback on current trends in each area.
4. A poster session should be used for projects that offer value but were not selected for presentation. This will increase volume, and therefore visibility of the totality of work performed by the NCDOT R&D group.

Table 5.2. Sample Schedule and Agenda:

8:00 am - 9:00 am	Registration
9:00 am - 10:30 am	Plenary Session Welcome/Opening Remarks: Neil Mastin, PE NCDOT Keynote: SOMEONE HERE Closing Remarks: Dean of Engineering, Director at NCDOT, etc.
10:30 am - 10:45 am	Break
10:50 am - 12:00 pm	Session 1
12:00 pm - 1:00 pm	Lunch
1:00 pm - 3:00 pm	Session 2
3:00 pm - 3:30 pm	Break
3:30 pm - 5:00 pm	Session 3
5:00 pm - 6:00 pm	Reception and poster session

Session 1	"From Research to Practice" - three selected presentations
Session 2	"High Value Research Projects" - three selected presentations
Session 3	Research Area Focus Groups

Chapter 6: Conclusions and Recommendations

The NCDOT has produced many successful and high value research projects through the Research & Development Unit (R&D). However, relating these successes to NCDOT research stakeholders can be cumbersome without a means to provide objective, accurate accounts of value added. Currently, the NCDOT R&D Unit does not have a formal methodology for determining success of a research project and therefore requires a research assessment methodology at the program level which includes: determination of the value added (cost-benefit); an implementation plan with pre- and post-measures; identification of future high value projects; and effective communication of results.

Conclusions and recommendations of this study are as follows:

- An improved applied research model was developed that provides three levels of project assessment and improvements. This new process when implemented will assist with the following:
    - Research need has been identified through this study as a major contributor to project success. Research need can be positively impacted through reviewing and improving the research needs statements as well as the scope of work at the development level.
    - Communication between the Principal Investigator, Research Champion and StIC is an indicator of project success. The continuous improvement process during the execution of the research will foster more communication among this group and ensure that direction of research meets the NCDOT needs.
    - The last continuous improvement opportunity will allow for reflection and lessons learned from the project. The lessons learned can be addressed at a programmatic level. At this stage, the level of implementation of the research projects can be properly assessed.
- The climate survey results revealed the following:
    - The majority of respondents found the current quarterly reporting process is valuable and should be retained
    - Research Engineers play a vital role in promoting communication during the execution of the project. As communication is an indicator of success, there is opportunity in expanding this role.
    - The majority of the respondents define project success as knowledge gained, which is further heightened if a critical need is being met (research need).
    - Demographically, most respondents (92%) could be categorized as very experienced for both academic and NCDOT groups as it relates to the NCDOT research program. Clearly, this group was needed due to the data required for analysis. However, an opportunity to engage new members to the transportation research community in NC was missed. It is recommended that an increased respondent list be created which includes NCDOT divisions and all researcher campuses.

- A new Cost Benefit Analysis Methodology was developed and presented. It is recommended that the new CBA tool be used for newly awarded projects. The benefit realized from soft costs (safety, environmental, etc) and qualitative variables (knowledge, dissemination, student exposure, etc) were included.
    - The evaluation of the impact factor, K, relies on a good engineering judgement by the research group as to the level each impact factor was truly engaged.
    - In defining monetary values in the calculation of soft costs, it is recommended that politically neutral references such as the Department of Labor, OSHA, FHWA, etc be used to avoid inflation of monetary benefits.
    - End user costs and global impact costs (e.g. environmental at a global level) should be avoided when calculating soft costs. The resulting monetary benefit is at a level that is not believable and therefore is difficult to communicate.
- A performance prediction model was developed to predict the probability of success in terms of highly successful, successful and moderately successful. The presented models, at current confidence levels should be considered a framework for research prediction.
    - The quality of the proposal or research idea was found to be an indicator for success in PI selection but not an indicator of project success. All proposals regardless of project outcome, were rated as high to very high in quality.
    - The current dataset is biased towards highly successful projects. The levels were adjusted from High, medium and low probability to high, medium and moderate due to the data bias. The model should be amended as unsuccessful project data becomes more available.
    - The confidence level of PI Experience is currently well below target level. However, it is readily apparent that PI Experience is an indicator for success and the low confidence level is a function of the small dataset.
    - Due to the dataset size, outliers cannot be properly addressed/removed and are affecting the model accuracy. The performance prediction model should be redeveloped once more project date becomes available. Ideally, a homogenous dataset for all three success levels of ten or more will result in a more robust ordinal logistic regression model.
    - According to the current model, research need impacts project success four times more than the research champion and six times more than the experience of the principal investigator. Again, utilizing the continuous improvement process at the research needs statement level will improve the probability of project success.
- A communication plan and best practices guideline was developed. Findings for each method of communication is presented in Chapter 5 of this report and for brevity are not included here. However, it should be noted:
    - NCDOT R&D should create a standalone Facebook page. Facebook offers an exceptionally productive forum for NCDOT R&D to communicate the

value of its work, and is especially useful due to its ability to reach particular demographics on social media, including multi-generational populations, such as millennials and older generations.

- The “Research in Motion” tagline should be registered. The research team performed an in-depth review and found no registered trademark; however, this should be professionally researched and registered before implementation.
- Based on the quality and quantity of research performed, NCDOT Research and Development should utilize a Convention and Expo to further increase visibility to participants, users and stakeholders as well as build community among that same group. UNC Charlotte has volunteered to host.

Chapter 7: Implementation and Technology Transfer

The outcomes of this study will be disseminated through the following venues:

- The research team can provide a short course or demonstrations to NCDOT personnel on utilizing the implementation plan, prediction model and the cost benefit analysis methodology.
- The research team can provide assistance in setting up and running the Transportation Research Convention & Exposition.
- Generating Research Publications: Research findings will be published in peer reviewed journals, such as ASCE journals and Transportation Research Record (TRR).
- Presenting at National/International Professional Conferences: For example, TRB annual conferences and ASCE conferences.
- The research team can provide review and assessment in the implementation of the communication plan, primarily for the newsletter and Facebook page.

References

Bikson, T.K., et al. (1996) *Facilitating the Implementation of Research Findings: A Summary Report* (NHCRP Report 382). National Academies Press (Washington, D.C.).

Ellis, Robert D., et al. (March 2003) *UF Project #: 4910 45-04-835* (Final Report). Department of Civil and Coastal Engineering, the Florida Department of Transportation (Florida).

Guthrie S, Wamae W, Diepeveen S, Wooding S, Grant J and Europe R (2013) Measuring research: A guide to research evaluation frameworks and tools. RAND Europe: Cambridge, UK.

Gunasekera, K., and I. Hirschman, Cross Mode Project Prioritization, Report on NCHRP Project 08-36, Task 112. Report sponsored by American Association of State Highway & Transportation Officials (AASHTO).

Federal Highway Administration (FHWA), (2017) "Use of Benefit-Cost Analysis by State Departments of Transportation: Report to Congress," Washington, DC.

Hartman, Donald L., "Value of Research: SPR Projects from 1995 to 1999" (2001). Kentucky Transportation Center Research Report. 279.

Harichadndran, R.S (editor), (2008) *Improving Michigan's Transportation System through Research*. MTRB (Michigan).

Kee, James Edwin (2011) At What Price? Benefit-Cost Analysis and Cost-Effectiveness Analysis in Program Evaluation. *The Evaluation Exchange*, Cambridge, M.A., Vol. V (2&3).

National Cooperative Highway Research Program (2009) *Communicating the Value of Transportation Research* (NCHRP Report 610; Project 20-78). Transportation Research Board (Washington, D.C.).

Peirpert, J.F., (2002) "The Economic Value of Medical Research: Is it Worth the Investment," Obstet Gynecol. 2002 Vol. 99 (5 Pt 1):835-40.

Pickrell, S. and Neumann, L. (2001) " Use of Performance Measures in Transportation Decision Making," Conference Proceedings 26, Performance Measures to improve Transportation Systems and Agency Operations, National Academy Press, Washington DC.

Rue, H., McNally, L., Rooney, K., Santalucia, P., Raulerson, M., Lim-Yap, J., Mann, J., and Burden, D., (2010) "Livability in Transportation Guidebook: Planning Approaches that Promote Livability," Federal Highway Administration (FHWA), FHWA-HEP-10-028, Washington, DC.

Transportation Research Board (2013) *Critical Issues in Transportation Research*. National Academies Press (Washington, D.C.).

Transportation Research Board (2016) *Taxonomy and Terms for Stakeholders in Senior Mobility*. National Academies Press, Vol. No. E-C211 (Washington, D.C.).

U.S. Department of Transportation (2015) *TIGER Benefit-Cost Analysis (BCA) Resource Guide.* Federal Highway Administration (FHWA); Federal Register, Notice of Funding Availability (NOFA), 80 FR 18283 (Washington, D.C., April 3, 2015).

White, D. and VanLandingham, G. (2015) Benefit-Cost Analysis in the States: Status, Impact, and Challenges. *Journal of Benefit-Cost Analysis*, Vol. 6, No. 2, pp. 369-399.

Sullivan, E., Joy D., Glen W., and Kazem A. (2008) "Web-Based Guide to Transportation Benefit / Cost Analysis." ASCE Journal of Transportation Engineering, Vol. 134, No. 7, July 2008, pp. 282-286.

Zhao, Xianbo & Bon-Gang, H. (2015) Review of Global Performance Measurement and Benchmarking Initiatives. *International Journal of Construction Management*, Vol. 15 (4), pp. 265-275.

APPENDIX A

Full Literature Review

Chapter 1. Literature Review

1.1 Introduction

The sheer volume of transportation research projects currently in motion evidences that, at least conceptually, the value of transportation research is generally understood, and its supply is consistent with a well-established demand.[1] Even more telling, is the increased recognition and appreciation of the role of research specifically in industry growth, as investment in Research & Development (R&D), and more frequently, Research, Development & Technology (RD&T), which presently represents one of the largest influencers of the perpetual evolution of the transportation industry.[2] The President's Budget for Fiscal Year 2017 is exemplary of such acknowledgement, as it emphasizes the importance of enhancing transportation exclusively through R&D, with an investment of $152 billion dollars – a four percent increase from 2016 – of mandatory and discretionary funds in support of transportation's continued advancement.[3]

Nationwide recognition of the value derived from transportation services, which were notably ignored in traditional national economic data analyses, and only recognized for their significance in more recent decades,[4] continues to ensure returns on investment beyond monetary gains; where value of research is easily visible through significant impacts on society, influence on policy and legislation, as well as the very positioning of the United States, and its ability to compete within the global economy.[5] Accordingly, it is the purpose of this paper to reiterate those values, in association with the best tools available for attaining *proven* benefit potentials, while also distinguishing non-essential endeavors, and ultimately defining the most productive opportunities for implementation. The proceeding literature review demonstrates that this can be achieved with the assistance of a standard evaluation tool, and offers support toward that end, beginning with a preliminary review of the research process.

---

[1] See Example: "An Economic Analysis of Transportation Infrastructure Investment" at https://www.whitehouse.gov/sites/default/files/docs/economic_analysis_of_transportation_investments.pdf

[2] http://www.rita.dot.gov/sites/rita.dot.gov.rdt/files/rdt_strategic_plan_2013.pdf

[3] https://www.whitehouse.gov/omb/budget

[4] http://ntl.bts.gov/lib/13000/13000/13013/ts4r.pdf

[5] http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/transportation_statistics_newsletter/issue_04/entire.html

1.2 Applied Research Process

The applied research process (cradle to grave), is often described as identification, investigation, formulation, reporting and implementation as presented in Figure 1. While the list identifies the process in terms of the responsibility of the individual researcher, it fails to address the needs of a successful research program; namely, the impact of the research project after implementation. Applied research, at its essence, is performed to address a specific need or problem that can influence cost, safety, production, and the like. Thus, seldom can it be labeled as theoretical or basic in nature. To that end, the applied research project should effectively solve a problem if it is to maximize its impact (Hartman, et al., 2001).

Ellis, et al. 2003, recognized the need to insure project success by inserting an iterative loop between research investigation and solution. It should be noted that, though the addition of the iterative process does improve the research outcome (solution), it does not necessarily improve overall project success or program level success. This shortcoming in the research process has led both Federal and State Agencies to initiate some form of evaluation process to be executed after the implementation stage.

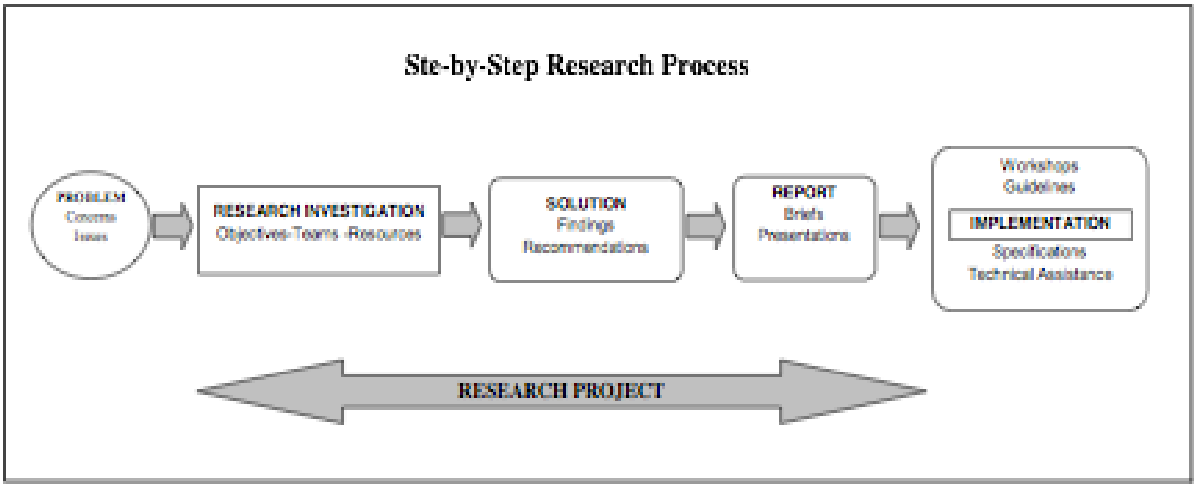

Figure 1. Applied Research Process, (Hartman, et al., 2001)

At the federal agency level, the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), the Department of Defense (DOD) and the Department of Energy (DOE) have implemented a pre and/or post implementation evaluation process. In practice, most federal agencies are selecting pre-implementation evaluation to measure success

of the project. Again, this insures success of solution but not necessarily success of the research or research program (Pickrell and Neumann, 2001).

At the state level, transportation departments are renewing their effort to define and quantify research benefit by transportation entities and measure that benefit pre and/or post project implementation (NCHRP 382). Florida, Minnesota, Texas, Kentucky, and New York have all instituted a formal evaluation process that utilizes Hartman's (2001) research model and adds evaluation and effort to the hierarchy. However, the current political and economic climate is curbing federal spending and investments in transportation research. For a research program to be successful in this new climate, effective communication of research quality, benefit and appropriateness must be established with policy makers and other stakeholders (Guthrie, et al., 2013). Therefore, to produce a successful applied research program, Ellis, et al.'s model will require the addition of evaluation and communication in the hierarchy.

1.2.1 Great Ideas, Imperfectly Laid Plans & the Failure to Launch

A review of the relevant literature has revealed that a primary hindrance to advancing transportation goals can be attributed to a general failure, and sometimes complete omission, to communicate the true value of research. Although transportation research frequently proves to be a lucrative investment, without effective communication of the particular and potential benefits, even the most useful research can be permanently derailed by an inability to capture interest, further road blocking the likelihood of procuring necessary funds and resources. This harmful investment gap alienates existing funds, while further limiting the ability to gain potential resources required to improve, or simply maintain, the transportation system.[6]

Without the necessary, innovative solutions for identifying the potential impacts of transportation research implementation, R&D objectives will continue to be mired by research projects that ultimately fail to address an issue, advance knowledge, or deliver a solution that benefits the transportation system.[7] Research that fails to add any value is especially detrimental to research that is ultimately deemed successful once its benefits are realized. The ability for a successful research project to get off the ground should not be based in simple luck of the draw or good timing, and it is this retroactive approach to analyzing the value of research that has led to significant waste; wasted time, money, and resources, often at the cost of some

[6] http://www.rita.dot.gov/sites/rita.dot.gov.rdt/files/rdt_strategic_plan_2013.pdf

[7] See RITA, etc.

of inspiring ideas, all of which could have been dedicated to a research project that had been deemed, within a reasonable level of certainty, as a valuable endeavor *prior* to its execution.

An effective research assessment methodology can also facilitate better communication of the overall importance and particular impacts of a given research project, which will present information in a more easily understood fashion, help to cater to broader audiences, assist to determine the specific costs and benefits of a transportation research project, allow for assessment at the program level, and ultimately help to facilitate a more expeditious, cost-effective decision making process.[8] More importantly, such a methodology will enable transportation agencies to dedicate more resources to high priority projects. By being able to more frequently communicate explicit research needs, research sponsors will help to foster innovation in the areas of the transportation system where such information and guidance is most critical.[9] Accordingly, transportation agencies require the ability to answer the question of whether a transportation research project unambiguously enhances an aspect or feature of the transportation system early on in the process, and well before implementation.

1.2.2 Proving the Value of Research

It is not enough for the research itself to be valuable, but its value must also be expressly communicated in a way that inspires decision-making powers to fully consider its implementation, as history has shown that even valuable, high-impact research - especially in transportation - does not necessarily speak for itself.[10] Due to the very nature of transportation research in application, which results in widespread impacts to users and non-users alike, an effective assessment methodology must offer an approach that expansively defines the research possibilities and impact considerations, laid out in a manner that associates the costs and/or benefits according to individual value profiles.[11] For that reason, in addition to creating an all-encompassing value assessment mechanism, the literature also calls for significant deference to be paid toward understanding the research audience(s).

---

[8] View tool for consideration re: Critical Issues in Transporation, 2013 Publication by NRC "Harnessing the Will" Paragraph on page 14 http://onlinepubs.trb.org/Onlinepubs/general/criticalissues13.pdf "by employing the most informative, unambiguous approaches available.

[9] See RITA & STC Reports.

[10] http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/transportation_statistics_newsletter/issue_04/entire.html

[11] See details in best practices guide section.

The necessity to include considerations of research audience is more obvious and intuitive than some of the other elements required for developing a standard research assessment methodology. At least since the days before Apple products became a social standard, and times when significant technological advances were still a new and profound experience, witnessed only by select facets of society, a valuable idea has become scarcely less obvious on its face.[12] In light of the current economic and social climate, there are increasingly fewer opportunities where an "obvious need" can be addressed by an "obvious solution".[13] And just as the stated obvious becomes more and more obsolete, the burden of establishing the value of an idea is also becoming that much more difficult. Arguably, save another study altogether, any idea with potentially systemic consequences will face greater obstacles, enhancing the difficulty of establishing value even further. In light of social media and increasingly accepted forms of information consumption, where information frequently comes "packaged" in unrelated, mixed, and over-stimulating messages, the value of certain information is simply much less obvious than it used to be. In order to address this challenge, transportation research needs to be presented in a way that aligns its message with its applicable audience.[14]

Audience is crucial in determining the fate of research because, despite the old adage, many still seem to "judge a book by its cover."[15] As a result, the point cannot be stressed enough that the ability to accurately communicate the value of research is key, and must be held to the same priority levels of other functions of research already regarded as essential. An accurate conveyance of the value of research informs the ability for interested and invested parties to assess, and thereby appreciate the value of such research. Truly, it is a form of advocacy, and requires its own, unique analysis in order to be exercised successfully.[16]

This fundamental gap in the ability of transportation agencies to carry out the goals of their research, due to an arguably simple failure to launch a project that, had stakeholders and

---

[12] In addition to red tape and having to consider an abundance of regulatory implications, people seem to be demanding proof of value before ever witnessing a test or trial….

[13] Note: "Idea" – definitive purpose versus other modes of thought to be discussed – doubting, judging, etc.. http://plato.stanford.edu/entries/descartes-ideas/

[14] http://www.fhwa.dot.gov/livability/case_studies/guidebook/livabilitygb10.pdf "The Livability in Transportation Guidebook's primary purpose is to illustrate how livability principles have been incorporated into transportation planning, programming, and project design, using examples from State, regional, and local sponsors. It is intended to be useful to a diverse audience of transportation agency staff, partners, decision makers, and the general public, and is applicable in urban, suburban, and rural areas." http://www.dot.ca.gov/newtech/researchreports/preliminary_investigations/docs/rural_smart_growth_preliminary_investigation_7-21-10.pdf

[15] Survey results from FHWA support an inference of judgment. Note: BCA notions & anti-use opinions.

[16] Consider: Productive & Profitable; Advocacy, in general.

relevant authorities been provided the proper and necessary information, would have proven to be, for all intents and purposes, a success, can be filled by a proper evaluation tool. Thus, before the value of research can be effectively communicated, it must first be identified. While there is a wealth of literature available to support the importance of identifying the value of transportation research, the mechanism by which this can be achieved remains open, and only to the continued detriment of those positioned to benefit from it; which, of course, is everyone.[17]

This lacuna in research-related planning has been scrutinized throughout much of the existing literature, and has been commonly attributed to the apparent fact that transportation agencies, throughout all levels of the industry, including State Departments of Transportation (DOTs), lack a proper evaluation tool that aids to establish the *actual* impact a potential research project has on a facet of transportation. Notably, the literature also reiterates that the task of creating such a tool is a unique and complicated task that must be founded on well-established knowledge, some of which has never been within the purview of transportation,[18] as well as open consumption of the new and unknown.[19] Current industry trends and strategies being embraced by various transportation agencies have offered important guidance in this pursuit.[20]

1.2.3 Getting a Good Idea off the Ground

The integration of standards in a research project requires a comprehensive view.[21] It is the purpose of this research to create a benefit assessment methodology that removes the fundamental division between quantitative benefits and qualitative benefits,[22] with ancillary costs and benefits to also be factored, such as research service life, or duration of research

[17] Whether infant or adult, pedestrian or bicyclist, investor or researcher, visitor or daily commuter, etc. (Improving Michigan's Transportation System through Research https://www.luminpdf.com/viewer/HB7ek9Y84HZ3HP3aZ; Synthesis of Best Practices for Determining Value of Transportation Research on Safety and Environmental Sustainability https://www.luminpdf.com/viewer/nBWhX6LBxysEMCqw7) Heather Jones TRB 2014 Conference Presentation re: lack of agreement on methodology (page 5).

[18] FHWA Discussing purview of DOTs – zoning, for example.

[19] "In the case of transportation research, identifying the hallmarks of a good literature review is complicated by the wide range of business functions and research subject areas falling under the jurisdiction of federal and state transportation agencies" (Page 19 of TR Circular E-C194: Literature Searches and Literature Reviews for Transportation Research Projects).

[20] RITA & FHWA, as well as medical perspectives in research value studies, etc.

[21] Some guidance on achieving such integration was offered in a collaborative piece conducted by several European Standards Organizations, "Linking Research and Standardization," which highlighted two fundamental characteristics: 1) standards are consensus-built, and 2) standards can be fast tracked.
http://ec.europa.eu/research/transport/pdf/linkingresearch.pdf

[22] Ellis et al., 2003 – See page 27.

impact.[23] In order to certify that a research assessment methodology can be applied both broadly, and effectively, the literature search included the definitions of what constitutes the necessary elements for establishing a "standard methodology," across multiple disciplines and authorities.[24]

This research is further motivated by the fundamental proposition that NCDOT, as well as other system operators, whether public or private, require a working methodology that can measure the effectiveness of using certain research, and as early on as the conceptual phase of a project; specifically, at the program level. To further the goals of R&D, or RD&T, in such a way as to enhance the transportation system as a whole, a modernized transportation research approach must go beyond data-driven answers and the historical reliance on the primarily quantifiable, to include analysis of more subjective, intangible components.

As a result of the best practices that have been identified throughout this review, the creation of a superior evaluation methodology will, at a minimum, be: flexible; simple and concise; offer good evaluation examples; applied in developing vital training programs;[25] able to address data scarcity issues, including emphasis on determining values not easily quantifiable; imbedded in a platform that facilitates effective communication of its value to broad audiences.[26]

1.3 Standardization & Collaboration – Mechanizing a Methodology

Research, Development and Technology (RD&T) programs serve a particularly central role in establishing models for the entire transportation industry, as these programs are created with the immense responsibility of addressing some of the nation's greatest challenges, including the one posed by this study.[27] The National Cooperative Highway Research Program (NCHRP) has been at the forefront of improving transportation through well-designed research, and its participants recognized early on that in order to address complex issues in

[23] See Task 3 of Proposal Summary.

[24] See http://www.fhwa.dot.gov/policy/otps/policyanalysis.cfm) The U.S. Department of Transportation is also calling for a more standardized approach to RD&T. The September 2013 "Research, Development, and Technology Strategic Plan," offers specific guidance to achieving "a truly multimodal, integrated system" by implementing research in five RD&T priority areas ((http://www.rita.dot.gov/sites/rita.dot.gov.rdt/files/rdt_strategic_plan_2013.pdf)).

[25] http://safety.fhwa.dot.gov/hsm/training/hsmguide.pdf [Flexible Means; Criticisms of length & Complexity; Note to literature pointing to the detrimental lack of training/FAMILIARITY].

[26] Which will arguably be best achieved through enhanced collaboration. See page 10 of STC Report.

[27] See RITA.

transportation, such issues are "best studied through a coordinated program of cooperative research".[28]

"Before the shovel hits the dirt—even before the back-of-the-envelope design calculations are made—transportation projects, programs, and policies all start at the same important place: planning."[29]

In light of the guidance offered from prior works, which include sources of criticism, as well as proven and suggested practices, and the consistent call for a methodology that includes a measurement of the "knowledge benefit of research," this research will expand on those elements identified, and ultimately include them in developing a highly effective research evaluation methodology. As an integral part of creating a methodology that satisfies the needs and demands of the industry, the next section of this review acknowledges some of the relevant perspectives about the cost-benefit approach to be used in this research.

1.3.1 Outlining Agency Perspectives on the Use of Cost-Benefit Analyses

The systematic process of cost-benefit analysis ("CBA"), or similarly, benefit-cost analysis ("BCA"),[30] has long been relied on as a useful tool whenever seeking to determine the tangible value of a project or program.[31] There are various approaches within the CBA toolbox that allow for value to be determined at the onset of a project. Although the literature search revealed that CBA has been consistently criticized for insolvable limitations, these limitations are often perceived in practice and, contrary to those sources, there is authoritative literature supporting the effective use of CBA, and affirming the ability of this research to address those limitations with a solid methodology.[32] As noted in Senate Report 113-182,

"Benefit-cost analysis is an important economic tool that can help State and local governments target their transportation funding to the most effective investments. Using benefit cost analysis, a State or local government would compare the monetary value of all benefits and costs that accrue during the

---

[28] http://onlinepubs.trb.org/onlinepubs/nchrp/impacts/035.pdf CITE NCHRP REPORT 825 (2016)

[29] http://onlinepubs.trb.org/onlinepubs/nchrp/impacts/NCHRPImpacts_08-36.pdf

[30] Note: this paper refers to BCA & CBA interchangeably, according to source use. FHWA Definition: Benefit cost analysis (BCA) was defined in this study as a systematic process by which the impacts of a project (or other action) are forecast and quantified, so that societal benefits can be compared to costs for the project or a range of alternatives. A BCA typically converts estimated impacts into monetary equivalents, and converts future values to present values using a discounting formula. What is CBA - http://www.rms.net/what_is_cba.pdf

[31] (http://bca.transportationeconomics.org/home/when-to-use-benefit-cost-analysis)

[32] (Mouter, N., Annema, J.A. & van Wee, B. Transportation (https://acc.dau.mil/CommunityBrowser.aspx?id=413023 See also Heather Jones submission to TRB 2014, which suggests that proper accounting of RV can aid CBA.

life of a project. This process forces the government to evaluate the value of all of the project's benefits, recognize the full cost of the project, and acknowledge whether or not the benefits outweigh the costs."[33]

In response to Senate Report 113-182,[34] the Federal Highway Administration (FHWA) conducted a qualitative study that established important considerations around the use of BCA at the State level.[35] The FHWA study recognized that a majority of State DOTs employing BCA are typically focused on "impact areas with relatively straightforward data, methodologies, and monetization factors," with quantification of safety impacts being the most common.[36] By way of literature review, case study analysis of nine State DOTs, and results of a questionnaire completed by forty-six FHWA Division Offices,[37] the report addressed the four key questions:

1. The extent to which State departments of transportation use benefit cost analysis when making decisions and setting priorities;
2. The quality of such analysis;
3. Challenges that State departments of transportation face when trying to use benefit cost analysis; and
4. Strategies for addressing those challenges.

Regarding the extent to which State DOTs use BCA, the study found that its use significantly varies between State DOTs, with approximately five to six using BCA regularly for the specific purpose of informing decision-making.[38] While this information affirmed that BCA is only being employed as an exception for certain kinds of projects, rather than as an

[33] See Page 6 of FHWA.

[34] Senate Report 113-182, which requires the U. S. Department of Transportation to "evaluate the use of benefit-cost analysis by State departments of transportation (State DOTs), and to issue a report to the House and Senate Committees on Appropriations."

[35] http://www.fhwa.dot.gov/policy/otps/pubs/bca_report/#conclusions

[36] Page 4 of FHWA Report "More complex areas such as emissions and freight are often excluded, while impacts on quity and the human environment are generally regarded as very challenging to quantify."

[37] Two of the questions presented, regarding overall use and influence, were modeled after questions used in a 2005 GAO (GAO) study, which was conducted in response to questions of States' practices, "to allow for limited comparisons across time." See GAO, Highway and Transit Investments: Options for Improving Information on Projects' Benefits and Costs and Increasing Accountability for Results, Report GAO-05-172, January 2005.

[38] FHWA Report cited Pew-MacArthur Results First Initiative, States' Use of Benefit-Cost Analysis: Improving Results for Taxpayers, July 2013 - A study on use of BCA in State government - showed evidence of increased usage, but that BCA was "not *yet* being mainstreamed into States' decision-making processes," also finding "that other factors are more important than BCA results in making investment decisions."

industry standard, and only methodically applied when funding requires it, it also highlighted advantages of BCA.[39] For example, BCA is particularly appealing in an effort to establish an effective research assessment methodology, as it provides an essential tool for calculating project benefits and costs that can be rendered into consistent units of measurement (dollars), allowing for a more comprehensive prioritization framework that goes across project and program categories, rather than simply within them.[40]

Additionally, the questionnaire revealed a pattern regarding the frequency with which BCA is used by State DOTs, suggesting that "BCA may be viewed as more useful for larger projects, for which more stakeholder scrutiny may be expected, but also that analytical challenges may play a role, since safety projects tend to be more readily quantifiable in their impacts than asset preservation or bike-pedestrian projects."[41] While this much may be true, a standard research assessment methodology includes an approach that may involve stakeholders much earlier on in the research implementation process to make this type of scrutiny something that can be readily addressed, most especially at the stage of conception, where these deliberations are fundamental in choosing whether the research is even worth the pursuit.

According to the FHWA study, experts within the transportation economics community have defined a high-quality BCA as one that possesses a majority of the following characteristics:

- Comprehensiveness (i.e., that all societal impacts are included, but only once);
- High reliability of the data and forecasts used to generate estimates;
- Appropriate monetization factors, discount rate, and analytical timeframe;
- Comparison against credible baseline;
- Inclusion of sensitivity analysis or other treatment of uncertainty; and

[39] Page 3, 8, 9, 15-19 discussing "Extent of Use" FHWA Study - According to the earlier GAO study, Federal requirements significantly affect whether or not State DOTs adopt the use of BCA, especially transit, versus highway, projects (FED FUND REQs). See also Footnote 12: "TIGER (Transportation Investment Generating Economic Recovery) is a competitive grant program operated by USDOT. A benefit-cost analysis has been required as part of the application process in previous competition rounds for the program.

[40] Converse perspective supporting multifactor scoring and weighting approaches - See Gunasekera, K., and I. Hirschman, Cross Mode Project Prioritization, Report on NCHRP Project 08-36, Task 112. Report sponsored by American Association of State Highway & Transportation Officials (AASHTO).

[41] Page 17 of FHWA Report - Also see Page 19: "Table 7 Responses to Question: "Other than BCA, or in addition to BCA, what forms of quantitative analysis does your State DOT typically use for making decisions and setting priorities?" Thirty-six, or 85.7% of the Division Offices responded with cost-effectiveness analysis or life-cycle cost analysis, indicating these methods as the majority practice, consistent with relevant literature on asset management systems.

- Overall transparency and replicability of the analysis.[42]

Although the FHWA did not assess whether any of the State DOTs' BCA products or processes include any and/or all of the aforementioned characteristics, it did find that, despite the substantial variation in which BCA is used, differing "from State to State and project to project," many States' BCA share common defects, such as lack of comprehensiveness; "erroneously including economic development impacts or construction costs as benefits; double-counting benefits; omitting certain categories of impacts; not discounting future values correctly; using unrealistic base cases; and failing to include reference to other viable alternatives."[43] These key issues concerning State DOTs about the general quality of BCA also include "improper baselines, speculative benefits, including transfers of benefits, and a general lack of transparency and reproducibility."[44] Finally, the FHWA report highlighted a need for State DOTs enhance documentation efforts and formalize treatment of uncertainties, which can be aided by regular reviews of prior forecasts and estimates that are necessary to ensure the accuracy of forecasts, like traffic demand, and evaluate assumptions against existing, actual conditions.[45]

The focus of this review will enable the research to address the quality concerns and resource needs surrounding BCA.[46] Unlike the possible failures of prior works, this research seeks to utilize every available resource to inform the creation of an effective research assessment methodology that specifically utilizes a high-quality BCA approach. Those challenges reiterated in the FHWA report, such as "widespread misunderstandings of what BCA is and how it can be used," can be resolved by emphasizing certain aspects offered by a standard methodology, which will promote understanding, trust, and reliance on BCA, and ultimately allow decision makers to defer more frequently to BCA results whenever making policy and program decisions.[47] The FHWA report provided strategies toward resolving the

[42] Page 10 of FHWA - citing example USDOT guidance for the TIGER grant program, LINK.

[43] Page 10 of FHWA citing GAO (2005).

[44] Page 4 of FHWA "Several case studies highlighted that the 'societal' framework of conventional BCA, which focuses on the benefits accruing to all users and non-users and costs borne by society at large, may run counter to State governments' tendency to focus on their own constituents and expenditures, which can bias the results."

[45] Page 4 of FHWA

[46] Page 4 of FHWA "The literature notes resource constraints with BCA, which the questionnaire and case studies confirmed. BCA and its associated data and modeling needs can strain agency budgets, staff time, and other resources; it also requires specialized expertise that may not be present within the organization."

[47] See White, D., and G. VanLandingham, "Benefit-Cost Analysis in the States: Status, Impact, and Challenges," Journal of Benefit-Cost Analysis, Vol.6, No. 2, pp. 369-399 (2015). PAGE 12 of FHWA Report (footnote 23) discussing "BCA results may also be ignored because the analysis of overall long-term outcomes is at variance with decision makers' focus on near-term impacts." The value added by helping agency members become better acquainted with BCA can be enhanced through

limited interest in and understanding of BCA that greatly align with the items proposed by this research, which will:

- Serve to demystify the BCA framework and demonstrate its value to decision makers (like improved outreach to decision makers, as proposed by the Pew-MacArthur study, through briefings for agency officials and legislators);
- Increase the perceived relevance of BCA to decision makers by including key considerations which were not typically considered in conventional BCA, such as distributional or equity impact analyses;
- Present BCA information in a way that is more useful to decision makers, as suggested by the GAO report, with special regard to documentation and discussion of project risks; or as suggested in the Pew-MacArthur study, to include concise summaries of BCA reports, which would make the findings more relevant and useful to decision makers;
- Adopt a replicable BCA model to help improve the timeliness, and ultimate value, or the BCA results;
- Advance technical rigor of BCA and the models that provide data for BCA to yield greater confidence in the results;
- Implement enhanced studies of forecast-versus-actual project impacts and costs;
- Highlight training and outreach sources already being offered, and incentivizing agency utilization to create greater understanding of BCA, including the pros and cons relative to other forms of analysis and decision-support tools; and
- Recommend monetary values and technical approaches where such guidance currently does not exist, and where such practical information is greatly needed.

Apart from using some of the potential strategies suggested throughout the literature to create a high-quality CBA, the CBA offered by this research must also be able to evaluate both

effectively advocating of the overall evaluation methodology, and achieved through proper training and development programs. See also Boardman, A., A. Vining, and W.G. Waters, II. "Costs and Benefits through Bureaucratic Lenses: Example of a Highway Project." Journal of Policy Analysis and Management, Vol. 12, No. 3, (Summer 1993), pp. 532-555. - observed "that practitioners may avoid BCA precisely because those results may be viewed skeptically, both by proponents of a project who are concerned that potentially negative results could undermine its support, and by advocates for limiting public expenditures, who are concerned that consistently positive BCA results could lead to such projects being overfunded. In these situations, BCA may be avoided, or may be subject to claims of bias and partiality that affect the results."

quantitative and qualitative data. While quantitative and qualitative research designs have been completely distinct, a formal methodology for assessing research may offer a merged design in a way that assists in better understanding the aims of the research.[48] Some of the ways in which CBA challenges have been addressed are highlighted in the next section, with particular focus on the measurement of intangibles.

1.3.2 Improving the Characteristics of Qualitative Analysis

In a periodical published by the Harvard Graduate School of Education, Professor James Edwin Kee discussed the strengths and limitations of benefit-cost and cost-effectiveness analyses, as part of an examination of their application in program evaluation.[49] Professor Kee accurately described the very challenge of identifying and measuring costs – and the biggest challenge under this type of analysis – which requires, "quantifying and placing a dollar value on the benefits."[50] Or, as the authors had put it in a submission for the Proceedings of the 8th International Management Conference, "the most challenging part of CBA is to monetize benefits because these are not easy to be identified, involve difficulties to be quantified and require numerous calculations and presumptions in order to associate a monetized value to each piece of benefit."[51]

Despite the challenges recognized in conventional usage of CBA, there are several disciplines that have developed guidelines that provide researchers and practitioners with ways to enhance the already invaluable utility of CBA. Moreover, CBA is consistently identified as being one of the most significant forms of value assessment available to members of any sector seeking to invest in a project or program. In a comparison of various analytical approaches, the

[48] Since it is important to never forget the role of audience, and to proceed in developing an approach that accounts for the scale and diversity of any given audience, effective research plans must foster a deeper analysis of some of the more abstract considerations, such as "soft" benefits, and offer the information necessary to make the value of these findings easily understood; specifically, placing a calculable value on intangible benefits (See Roper, Chapter 8, page 182 re: Definitions, Background, & Applications of Sustainability & Dr. Nicholas's Task 3 Summary).

[49] See discussion of CBA: At What Price? Benefit-Cost Analysis and Cost-Effectiveness Analysis in Program Evaluation [Article] / auth. Kee, James Edwin // The Evaluation Exchange. - Cambridge, MA : Harvard Family Research Project, 2011. - 2 & 3 : Vol. V. "It can be used in evaluations of existing programs to assess their overall success or failure, to help determine whether the programs should be continued or modified, and to assess the probable results of proposed program changes. Benefit- cost analysis consists of three steps: (1) determine the benefits of a proposed or existing program and place a dollar value on those benefits; (2) calculate the total costs of the program; (3) compare the benefits and the costs."

[50] See above at: http://www.hfrp.org/evaluation/the-evaluation-exchange/issue-archive/methodology-15/at-what-price-benefit-cost-analysis-and-cost-effectiveness-analysis-in-program-evaluation

[51] http://conferinta.management.ase.ro/archives/2014/pdf/109.pdf PAGE 1107

MITRE Corporation illustrated the broad usefulness of CBA across different agencies in Table 1. [52]

As identified throughout the literature review, and in recognition of a growing trend both within and outside of the transportation industry,[53] the CBA approach proposed by this research will include the development of a standard system for evaluating the costs and benefits of research that specifically quantifies non-numerical values. This section of the literature review seeks to highlight some of those findings in order to determine the best approach for including unconventional calculations, such as "soft benefits," as part of the proposed methodology.

Table 1. MITRE Cost Benefit Analysis

Element	Alternatives Analysis	AoA	BCA	CBA	EA
To address a gap, should I invest or not?		X	X		
I'm going to invest to address a gap. So, how should I invest?	X	X	X	X	X
Operational Effectiveness		X	X	X	X
LCCE	X	X	X	X	X
Qualitative Cost Assessment		X	X	X	X
Quantitative Benefits Assessment	X		X	X	X
Qualitative Benefits Assessment			X	X	X
ROI Calculation	X		X	X	X
Uncertainty Analysis	X		X	X	X
Risk Analysis		X	X	X	X
Sensitivity Analysis			X	X	X
Implementation Description		X	X		

[52] Note: BCA is distinguishable in the MITRE analysis from this paper's interchangeable use of CBA and BCA. For the purpose of this example, BCA should be understood to refer to "business case analysis." See source for further elaboration regarding the pros and cons of CBA over other forms of analysis, at https://www.mitre.org/publications/systems-engineering-guide/acquisition-systems-engineering/acquisition-program-planning/comparison-of-investment-analyses

[53] See FHWA Report pp. 13-15; Note: overall movement toward performance-based data-driven planning (p. 5); See http://archive.vera.org/sites/default/files/resources/downloads/cost-benefit-analysis-justice-policy-toolkit.pdf re: use of CBA: "We thought there might be reluctance to learn another methodology. Or we might find skepticism about one of CBA's most controversial aspects—the measurement of intangibles, such as the victim costs of crime. But we soon discovered that people in the justice field were eager to acquire and apply these tools, and that many had already gotten started." See also: https://storage.googleapis.com/vera-web-assets/downloads/Publications/using-cost-benefit-analysis-for-justice-policymaking/legacy_downloads/using-cost-benefit-analysis-for-justice-policymaking.pdf which offers added support to the demand for CBA by policy and decision makers, cautions evaluators against "five common pitfalls" to avoid (pages 11-12), and illustrates how some agencies have maximized the value of CBA by including it in a larger decision-making process (pages 14-15) .

In line with addressing some of the seemingly inherent biases that certain members of the industry have toward CBA,[54] the prescribed methodology could rely on standard monetization values that conform to common industry practice, such as that of the U.S. Department of Transportation. Conveniently, some of these values have been incorporated into a BCA Resource Guide, as a part of the "2015 Benefit-Cost Analysis Guidance for TIGER Grant Applicants," and serve to greatly assist with converting "soft costs"[55] where numerical data is traditionally unidentified.[56] For example, in order to assess the value of injuries, the TIGER BCA Research Guide accounts for several factors, including an Abbreviated Injury Scale (AIS) level, the level of injury severity, the fraction of the Value of Statistical Life (VSL),[57] and assigns a unit value accordingly, as demonstrated by Table 2.[58]

Table 2. Value of Statistical Life

AIS Level	Severity	Fraction of VSL	Unit value (2013)
AIS 1	Minor	0.003	$ 28,200
AIS 2	Moderate	0.047	$ 441,800
AIS 3	Serious	0.105	$ 987,000
AIS 4	Severe	0.266	$ 2,500,400
AIS 5	Critical	0.593	$ 5,574,200
AIS 6	Not survivable	1.000	$ 9,400,000

[54] As illustrated with FHWA points to include above.

[55] Define "soft costs."

[56] https://www.transportation.gov/sites/dot.gov/files/docs/Tiger_Benefit-Cost_Analysis_%28BCA%29_Resource_Guide_1.pdf NOTE: FHWA caution re: use of BCAs produced for TIGER grants, which "may not be representative of State DOTs' typical practices, in part because a number of State DOTs only produce full-fledged BCAs where required for TIGER and similar programs, and in part because State DOTs are instructed to use DOT's TIGER program guidance rather than their own methodologies and policies. Homan (2014) also notes that the competitive nature of TIGER grants may create a bias toward showing high net benefits, (FTNT 17-Homan, A.C., "Role of BCA in TIGER Grant Reviews: Common errors and influence on the selection process," Journal of Benefit-Cost Analysis, Vol. 5, No. 1, pp. 111-135, 2014), a factor which may not be present for in-house BCAs.

[57] https://www.transportation.gov/sites/dot.gov/files/docs/VSL2015_0.pdf NOTE: VSL used by DOT analyses to assess the benefits of preventing fatalities, and includes policies for projecting future values and for assigning comparable values to prevention of injuries.

[58] https://www.transportation.gov/sites/dot.gov/files/docs/Tiger_Benefit-Cost_Analysis_%28BCA%29_Resource_Guide_1.pdf

According to "The Economic Value of Medical Research," the research was motivated by the same investment incentive problems transportation research is facing, and sought a solution by taking the same into account, while illustrating that improvements in a given subject area are complementary with other valued improvements.[59] Although healthcare research relies on well-documented empirical evidence that may not be as readily available with respect to transportation research, it elaborates on the need to assign numerical values to those features of progress that are specifically attributable to research advances.[60] In an analogous cost-benefit scenario developed around medical research, the analysis relied on an economic framework to assess the social benefits of medical research, as part of a proposed methodology would additionally:

1. Address strategic themes and policy issues, not just operational problems
2. Focus on the medium and longer term, not just the short term
3. Be programmatic rather than exclusively project-based
4. Inform policy formulation rather than simply monitoring policy implementation
5. Be prospective rather than retrospective
6. Feed findings regularly back into the policymaking process
7. Provide an interdisciplinary and inter-organizational focus
8. Foster a dialogue between policymakers, practitioners, and academics[61]

1.4 Developing a Project Performance Prediction Model

Aligned with traditional forecasting models and their ability to aid companies achieve certain goals, developing a project performance prediction model will similarly aid NCDOT in determining the probability of success of future projects. In general, regression analysis can assist with performance prediction by taking exponential and higher-order mathematical trends, fitting those trends to existing data, and thereby extending them into the future.[62] Where a variable whose value exists on an arbitrary scale in which its placement between different values is its only significance, ordinal regression can be used to predict its ordinal variable.

[59] Page 4 of Economic Value of Medical Research

[60] Page 5 of Economic Value of Medical Research

[61] See page 25 of Ellis, et al., 2003. See also http://faculty.chicagobooth.edu/kevin.murphy/research/murphy&topel.pdf).

[62] See "Strategic Facility Planning" from the Architect's Handbook of Professional Practice, 13th edition, 2000, by the American Institute of Architects). [Transition noting practice importance related to transportation research).

This type of regression analysis will be employed to determine an output in relation to a categorical response based on three success levels: high, medium, and low. These response rates serve to establish the ordinal classification of a research project's value as successful, marginal, and unsuccessful, respectively.[63]

1.5 Developing Best Practice Guidelines for Communicating Research Benefits to NCDOT Stakeholders & the General Public

A publication by the Partnerships for Health Reform (PHR), "Guidelines for Conducting a Stakeholder Analysis," offers a methodology that can be applied to achieve the goals of transportation research.[64] Research, throughout every discipline, serves as a catalyst for debate and, in turn, defines reform. By establishing facts, drawing new conclusions, and offering a view of what those facts and conclusions look like, research can determine the future and fate of its subject by its ultimate ability to "sell" itself. However, just like with any other product, research cannot be sold without first understanding both the "consumer" and "market;" or, in this case, the stakeholders in transportation research, and the bureaucracy in which it exists.

The PHR document confronts the role of "politics" in the decision making process by going straight to the source, and as a result, it developed a framework around the key players who have an investment in proposed reforms. In particular, the paper seeks to help research authorities to "conduct an 'objective' and systematic process for collecting and analyzing data about key health reform stakeholders," while being mindful of the inherent subjectivity within such an analysis.[65] The proposed analysis allows policy makers and managers to predict whether stakeholders might support or block the implementation of health reforms, and offers strategies through supportive actions that can be instituted before an attempt to implement major reform is made. Apart from offering a useful methodology that accounts for consistency where more subjective information requires scrutiny, these guidelines are also applicable when

[63] The goodness-of-fit strategy will be applied to proposed research project in order to determine its suitability for implementation against the widest range of future project scenarios (See "Strategic Facility Planning" from the Architect's Handbook of Professional Practice, 13th edition, 2000, by the American Institute of Architects).

[64] See Schmeer, Kammi. 1999. Guidelines for Conducting a Stakeholder Analysis. November 1999. Bethesda, MD: Partnerships for Health Reform, Abt Associates Inc.

[65] Schmeer, Kammi (November 1999).

an analysis must be performed within strict time constraints, or with little resource availability; two limitations that have restrained exploration of ideas.[66]

[66] Schmeer, Kammi (November 1999). See re: synthesis http://onlinepubs.trb.org/onlinepubs/nchrp/impacts/032.pdf

References

Baabak, Ashuri, et al. (2014) *Southeast Transportation Consortium Synthesis of Best Practices for Determining Value of Research Results* (Final Report 512), Louisiana Transportation Research Center.

Bamberger, Michael (2000) The Evaluation of International Development Programs: A View From the Front. *American Journal of Evaluation*, Vol. 21, pp. 95-102.

Bamberger, Michael, et al. (2003) Shoestring Evaluation: Designing Impact Evaluations Under Budget, Time, and Data Constraints. *American Journal of Evaluation*, Elsevier Inc., Vol. 25, pp 5-37.

Bikson, T.K., et al. (1996) *Facilitating the Implementation of Research Findings: A Summary Report* (NHCRP Report 382). National Academies Press (Washington, D.C.).

Boardman, A., Vining, A., & Waters II, W.G. (1993) Costs and Benefits Through Bureaucratic Lenses: Example of a Highway Project. *Journal of Policy Analysis and Management*, Vol. 12, No. 3, pp. 532-555.

Bureau of Transportation Statistics (April 1998) Economic Importance of Transportation Services: Highlights of the Transportation Satellite Accounts. *Transportation Statistics Newsletter*, Vol. 4, U.S. Department of Transportation (Washington, D.C.).

Committee for Oversight and Assessment of U.S. Department of Energy Project Management (2005) *Measuring Performance and Benchmarking Project Management at the Department of Energy*. National Academies Press (Washington, D.C.).

Costa, Dayana B., et al. (2006) Benchmarking Initiatives in the Construction Industry: Lessons Learned and Improvement Opportunities. *Journal of Management in Engineering*, Vol. 22, (4).

Ellis, Robert D., et al. (March 2003) *UF Project #: 4910 45-04-835* (Final Report). Department of Civil and Coastal Engineering, the Florida Department of Transportation (Florida).

Jones, Heather, et al. (2014) *Transport Infrastructure Evaluation Using Cost-Benefit Analysis: Improvement to Valuing the Asset Through Residual Value; A Case Study*. 93rd Annual Meeting of the Transportation Research Board.

Kee, James Edwin (2011) At What Price? Benefit-Cost Analysis and Cost-Effectiveness Analysis in Program Evaluation. *The Evaluation Exchange*, Cambridge, M.A., Vol. V (2&3).

Krugler, Paul, et al. (2006) *Performance Measurement Tool Box and Reporting System for Research Programs and Projects* (Final Report for NCHRP, Project 20-63). Texas Transportation Institute: Transportation Research Board (College Station, T.X.).

Kumaraswamy, Mohan M. & Ugwu, O. (2007) Critical Success Factors for Construction ICT Projects: Some Empirical Evidence and Lessons for Emerging Economies. *ITCon* (Hong Kong, China), Vol. 12, pp. 231-249.

Lindner, Robert & Raitzer, D.A. (August 2005) *Review of the Returns to ACIAR's Bilateral R&D Investments.* Australian Centre for International Agricultural Research (Australia).

Michigan Transportation Research Board (2008) *Improving Michigan's Transportation System through Research*. MTRB (Michigan).

National Cooperative Highway Research Program (2000) *A Guidebook for Performance-Based Transportation Planning* (Report 446). National Academies Press (Washington, D.C.).

National Cooperative Highway Research Program (2009) *Communicating the Value of Transportation Research* (NCHRP Report 610; Project 20-78). Transportation Research Board (Washington, D.C.).

Price, Andrew D.F., et al. (2004) Empowerment as a Strategy for Improving Construction Performance. *Leadership and Management in Engineering*, American Society of Civil Engineers, pp. 27-37.

Research and Innovative Technology Administration (September 2013) *Research, Development, and Technology Strategic Plan*. U.S. Department of Transportation; RITA (Washington, D.C., Fiscal Year 2013-2018).

Ryan, Nelson R. (2005) Project Retrospectives: Evaluating Project Success, Failure, and Everything Inbetween. *MIS Quarterly Executive*, University of Minnesota (Minnesota), Vol. 4 (3), pp. 361-371.

Schmeer, Kammi (November 1999) *Guidelines for Conducting a Stakeholder Analysis. Partnerships for Health Reform*, ABT Associates Inc. (Bethesda, M.D.).

Shahandashti, M., Ashuri, B., & Tavakolan, M. (2015) *Synthesis of Best Practices for Determining Value of Transportation Research on Safety and Environmental Sustainability*. 51st ASC Annual International Conference Proceedings, April 22-25, 2015 (College Station, T.X.).

Slevin, Dennis P. & Pinto, J.K. (1987) *Critical Success Factors in Effective Project Implementation*.

Transportation Research Board (2013) *Critical Issues in Transportation Research*. National Academies Press (Washington, D.C.).

Transportation Research Board (2016) *Taxonomy and Terms for Stakeholders in Senior Mobility*. National Academies Press, Vol. No. E-C211 (Washington, D.C.).

U.S. Department of Transportation (2015) *TIGER Benefit-Cost Analysis (BCA) Resource Guide.* Federal Highway Administration (FHWA); Federal Register, Notice of Funding Availability (NOFA), 80 FR 18283 (Washington, D.C., April 3, 2015).

White, D., & VanLandingham, G. (2015) Benefit-Cost Analysis in the States: Status, Impact, and Challenges. *Journal of Benefit-Cost Analysis*, Vol. 6, No. 2, pp. 369-399.

Zhao, Xianbo & Bon-Gang, H. (2015) Review of Global Performance Measurement and Benchmarking Initiatives. *International Journal of Construction Management*, Vol. 15 (4), pp. 265-275.

APPENDIX B

Research Performance Indicator Rankings Survey

Research Performance Indicator Rankings

---

1) Please indicate to which role you most identify:

- ○ *NCDOT Research Champion*
- ○ *Steering and Implementation Committee (StIC) Member*
- ○ *Researcher, PI, or Co-PI*
- ○ *NCDOT Management/Executive*
- ○ *User of NCDOT Research Results*
- ○ *Other (Please Identify)*

2) How often have you served as a StIC Chair on a NCDOT research project?

- ○ *0-2*
- ○ *3-5*
- ○ *6+*

3) How often have you served on a NCDOT research StIC?

- ○ *0-2*
- ○ *3-5*
- ○ *6+*

4) How many NCDOT research projects have you participated as a PI?

- ○ *0-2*
- ○ *3-5*
- ○ *6+*

***5)* How many NCDOT research projects have you participated as a Co-PI?**

- ○ *0-2*
- ○ *3-5*
- ○ *6+*

The following questions will ask you to rank a list of research impact indicators starting with the most important to the least important.

Research Impact Indicators (RIIs) are mechanisms that influence (positively or negatively) the outcome of a given research project in terms of success and failure. The following lists represent RIIs that have been identified and grouped into three categories: NCDOT Unit RIIs, NCDOT Research Office RIIs and Research Organizations RIIs. Please take a moment to rank the RIIs in each category.

6) NCDOT Unit Contributions to a Successful Project:

From the list of research indicators described below, please rank each from 1 to 6, according to its overall contribution to the success of a project. 1 represents the indicator as contributing the most to project success, whereas 6 represents the indicator as contributing the least to project success).

	1	*2*	*3*	*4*	*5*	*6*
Active NCDOT Research Champion	○	○	○	○	○	○
Research Need Priority	○	○	○	○	○	○
Active StIC Participation	○	○	○	○	○	○
Routine Engagement with Research Team	○	○	○	○	○	○
Detailed Implementation Plan	○	○	○	○	○	○
NCDOT Management Support	○	○	○	○	○	○

Please provide any other research impact indicators for the NCDOT Unit contributions to a successful project.

7) Research Engineer Contributions to a Successful Project

From the list of research indicators described below, please rank each from 1 to 3, according to its overall contribution to the success of a project. 1 represents the indicator as contributing the most to project success, whereas 3 represents the indicator as contributing the least to project success).

	1	2	3	
Maintaining Communication Researchers and StIC	○	○	○	*between*
Distribution of Quarterly	○	○	○	*Reports*
Administration of Budget Contracts	○	○	○	*and*

Please provide any other research impact indicators for the Research Engineer's contributions to a successful project.

8) Research Organization (University) Contributions to a Successful Project:

From the list of research indicators described below, please rank each from 1 to 6, according to its overall contribution to the success of a project. 1 represents the indicator as contributing the most to project success, whereas 6 represents the indicator as contributing the least to project success).

	1	2	3	4	5	6
Researcher Experience with NCDOT	○	○	○	○	○	○
Proposal Quality	○	○	○	○	○	○
Performing Organization/University	○	○	○	○	○	○
Graduate Student Participation	○	○	○	○	○	○
Resulting Publications	○	○	○	○	○	○
Regular Communication from the PI	○	○	○	○	○	○

Please provide any futher research impact indicators for the Research Organization (University) contributions to a successful project.

9) Based on your personal experience, does project duration impact the success of a project?

- *Yes*
- *No*

10) If your answer in Question 9 is "Yes" please select the project duration you associate as being the most likely to lead to success.

- *1 year*
- *1.5 years*
- *2 years*
- *3 years*
-

For the following questions, please indicate your level of agreement with each statement.

11) Quarterly Reports are valuable tools to track a project's progress.

- *Strongly Disagree*
- *Disagree*
- *Agree*
- *Strongly Agree*

12) The allotted time for Quarterly Report review is adequate.

- *Strongly Disagree*
- *Disagree*
- *Agree*
- *Strongly Agree*

13) The information provided in the Quarterly Report is sufficient to judge project progress.

- *Strongly Disagree*
- *Disagree*
- *Agree*
- *Strongly Agree*

For the following questions, please indicate your level of agreement with each statement.

14) Regular interaction between the StIC and the research team is essential for project success.

- *Strongly Disagree*
- *Disagree*
- *Agree*
- *Strongly Agree*

15) Implementation of research results must occur for a project to be considered successful.

- *Strongly Disagree*
- *Disagree*
- *Agree*
- *Strongly Agree*

16) Success of a research project can be easily measured by the monetary benefit gained through implementing the research results.

- *Strongly Disagree*
- *Disagree*
- *Agree*
- *Strongly Agree*

17) How do you define a successfull Research Project?

- *Knowledge Gained Quality Final Report*
- *Detailed Implementation Plan*
- *Please add any other comments on defining a successful research project.*

18) Please provide any additional comments/experiences you may have on the NCDOT Research Program.

APPENDIX C

Importance Factors Survey

Value of Research - Importance Factors Survey

For this Survey, you will be asked to compare two benefits and provide your opinion as to which is more beneficial. The following are explanations of the benefits that will be covered in the survey:

1. Level of Knowledge: knowledge gained through the development of new standards and specifications, new policies or design directives, and/or administrative (operational) changes.

2. Student Participation: exposing new generations, both graduate and undergraduate, to the engineering and construction of transportation systems.

3. Publications: Dissemination of research results through peer reviewed conferences and journals

4. Visibility of NCDOT: Some research projects can result in positive visibility of the NCDOT to stakeholders and the public at large.

5. Experience of PI: Through the research process, the NCDOT and the research team, namely the PI, build a working relationship that can positively impact current and future projects.

6. Implementation: The ease and/or degree of implementation of the research products.

1) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Level of Knowledge gained is more important than the Resulting Publications? If you feel that they are equally important, please select undecided.

- ○ *Strongly Disagree*
- ○ *Disagree*
- ○ *Undecided*
- ○ *Agree*
- ○ *Strongly Agree*

2) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Level of Knowledge gained is more important than student participation? If you feel that they are equally important, please select undecided.

- ○ *Strongly Disagree*
- ○ *Disagree*
- ○ *Undecided*
- ○ *Agree*
- ○ *Strongly Agree*

3) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Level of Knowledge gained is more important than the experience gained between the PI and NCDOT? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

4) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Level of Knowledge gained is more important than positive visibility of NCDOT? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

5) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Level of Knowledge gained is more important than the ease and/or degree of implementation? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

6) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Ease/degree of implementation is more important than experience gained between NCDOT and the PI? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

7) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Ease/degree of implementation is more important than student participation? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

8) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Ease/degree of implementation is more important than resulting publications? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

9) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Ease/degree of implementation is more important than positive visibility of NCDOT? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

10) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Experience gained between the NCDOT and PI is more important than student participation? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

11) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Experience gained between the NCDOT and PI is more important than positive visibility for NCDOT? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

12) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Experience gained between the NCDOT and PI is more important than resulting publications? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

13) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Student participation is more important than resulting publications? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

14) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Student participation is more important than positive visibility for the NCDOT? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

15) As it pertains to adding value to a research project, to what level would you agree with the following statement:

Resulting Publications are more important than positive visibility for the NCDOT? If you feel that they are equally important, please select undecided.

- *Strongly Disagree*
- *Disagree*
- *Undecided*
- *Agree*
- *Strongly Agree*

APPENDIX D

Media Outreach Examples

Facebook Post Example

Instagram Post Example