JOINT TRANSPORTATION
RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION
AND PURDUE UNIVERSITY

INDOT Research Program Benefit Cost Analysis—Return on Investment for Projects Completed in FY 2019

Bob McCullouch

SPR-4225 • Report Number: FHWA/IN/JTRP-2020/27 • DOI: 10.5703/1288284317279

Table of Contents

List of Tables

Introduction

To demonstrate the value of research and its implementation, the Governor's Office requested an annual financial analysis of the INDOT Research Program to determine the return on the research investment (ROI). The current financial analysis is for research projects that completed in FY 2019. Analyses on previous year's projects is necessary primarily due to the time it takes some project outcomes to be implemented, extending into the following year. Therefore, the FY 2019 analysis is completed in calendar 2020. The ROI analysis will supplement the annual IMPACT report by adding a more rigorous quantitative benefit cost analysis (BCA) to the Research Program. Previous financial analyses used the approach of calculating net present values of cash flows to determine a benefit cost ratio and this report uses the same approach. Additionally, an overall program rate of return (ROI) is reported and will be accumulated over time into a rolling 5-year average.

While the quantitative benefit cost analysis (BCA) was rigorous, results are limited to projects where benefits and costs could be quantified, where data is available to perform a quantitative analysis. Qualitative benefits are highlighted in the companion annual IMPACT report (https://www.in.gov/indot/files/Research Program Impact Report.pdf).

In 2018, INDOT unveiled its new Strategic Plan. The Strategic Plan guides the priority research needs of the Research Program and in turn the research results support accomplishing the INDOT Strategic Plan, Strategic Objectives. A new Strategic Objective has been added to the INDOT Strategic Plan addressing Innovation & Technology. Additionally, INDOT created a new Office of Innovation. While the Research Program supports all of INDOT's Strategic Objectives, these new initiatives have further highlighted the importance of research and its role in achieving the Strategic Objectives outlined in the new INDOT Strategic Plan. There has been more emphasis of new research needs related to new technology changes and transformational technologies. This will help position INDOT for future growth, adoption of new technologies and partnering opportunities. These new research projects provide huge qualitative ROI, that are difficult to quantify. Going forward, a growing number of research needs are in the area of 'transformational technologies' and will help position INDOT for future growth, adoption of new technologies and partnering opportunities.

INDOT Strategic Plan Priorities are listed below:

Safety
Ensure road safety for motorists, contractors, and INDOT personnel

Mobility
Enhance end-to-end customer and freight journeys across all modes of transportation

Customer Service
Ensure local engagement, timeliness of service, and quality of responses

Economic Competitiveness
Enhance economic outcomes for Indiana

Asset Sustainability
Enhance ability to manage and maintain assets throughout their life cycle

Organization & Workforce
Provide employees with tools, training, and information to succeed

Innovation & Technology
Harness technology and innovation to develop more effective transportation solutions

Benefit-Cost Analysis Methodology

All FY 2019 completed projects were reviewed to determine if they were a viable candidate (quantifiable data existed) for BCA. Selection was based on 1) can the costs and benefits be quantified on outcomes that impact INDOT operations, 2) what are the implementation costs, and 3) what is the expected impact time period?

The ROI analysis included the following savings components:

- **Agency savings and costs.** This was based on research findings, engineering judgment/estimates from INDOT BO (business owner) and SME (subject matter experts), available data, and projected use of the new product/process.
- **Road User Costs (RUC) Savings.** RUC includes value of time (VOT), and vehicle operating costs (VOC). RUC unit values will be obtained from current INDOT standards which INDOT provided.
- **Safety Costs (SC) Savings.** Safety costs (SC) can include a before and after evaluation or engineering judgement from BO/SMEs to calculate the reduction in crashes (e.g. property damage, fatalities, etc.). SC unit values will be obtained from current INDOT standards which INDOT provided.

Accrued Benefits will be the combination of **Agency savings, RUC cost savings,** and **SC savings**. While Road User Cost (RUC) savings and Safety Cost (SC) savings are a primary goal of INDOT, savings accrued primarily benefit the customer (road user) and may not result in agency cost savings. In this year's analysis no quantifiable projects included RUC and SC savings, rather agency savings. RUC and SC benefits are highlighted in the annual IMPACT report.

Quantitative benefits were calculated for each research project analyzed for the expected impact period where known or planned quantities (estimated in the INDOT Work Program) were available. A five-year analysis period was used on two projects and a 3-year period on the other project. These analysis periods are explained in their individual analysis. Individual project costs are research and implementation costs. Net present value (NPV) for individual projects are calculated to 2019 dollars by combining costs and benefit cash flows. Individual project analyses are included in Appendix B. Backup documentation describing calculations and analysis for quantifiable projects will be kept by the INDOT Research and Development Division and are available for review.

The ROI is expressed as a BCA ratio, which is commonly used by State DOTs and national transportation research agencies when expressing the return on the research investment. This methodology will be used annually to calculate a FY ROI which will be combined with other FY ROIs to create a rolling average over time. The rolling average will accumulate up to a maximum of the five recent years, with FY 2016 being the first year. By using total program costs in the analysis, rather than just the individual project cost, a very conservative BCA ratio is obtained. Interestingly, the quantified cost savings from a single project frequently underwrites the cost of the entire research program in a fiscal year.

Benefit-Cost Analysis Results

Project outcomes were classified as either Quantitative, Qualitative, or Not Successfully Implemented.

- **Quantitative** - Implementation produces benefits that are measurable and quantifiable and where data exists. Each of these projects has an individual analysis performed and is included in Appendix B. The analysis, or impact period, is the time period benefits were available and calculated.
- **Qualitative** - Implementation is successful and benefits occur but cannot be quantified with certainty due to data not being available or easily discoverable. Examples of qualitative benefits could include a specification revision, a new test method, a proof-of-concept study, a synthesis study that produces a summary of options and best practices, manuals or guidelines, or where cost comparison data is unavailable. Qualitative benefits are highlighted in the companion annual IMPACT report.
- **Not Successfully Implemented** - For various reasons the project outcomes could not be currently implemented. Common reasons are management, logistical, technical, or legal issues. In this year’s analysis 1 in 35 projects were not successfully implemented.

Individual Project Analysis

Table 1 is the list of the three projects where benefits (NPV 2019$ - NPV of future cash flows in 2019 dollars) could be quantified and their individual analysis is found in Appendix B. Table 4, in Appendix A, is a complete list of all 35 projects completed in FY 2019.

Table 1. Quantitative Benefits Project List

No	FY 19 Completed & Implemented SPR Projects	Title	Project Cost ($1000)	Benefit Type	Analysis Period	NPV Project Benefit ($1000) 2019$
1	3821	Automated Estimation of Winter Driving Conditions	$2,871	Quantitative (Agency Savings)	**5 Years**	**$1,037**
2	4120	Strength Assessment of Older Continuous Slab and T-Beam Reinforced Concrete Bridges	$230	Quantitative (Agency Savings)	**3 Years**	**$23,038**
3	4229	Cost Effectiveness of Constructing Minimal Shelter to Store INDOT Equipment (Weather Protection)	$50	Quantitative (Agency Savings)	**5 Years**	**$11,593**

Total Agency Benefits $35,668,000

Two of the projects (3821 and 4229) have a five-year analysis period where the implementation is incorporated into the INDOT 5-year work plan, and the third (4120) 3 years due to a work schedule needed for accelerated bridge rehabilitation. All three projects resulted in agency savings. Project 3821 evaluated the use of probe data in travel time calculations thereby eliminating the need for radar and microloop sites to provide this information. Project 4120 developed a method to improve the accuracy of load rating continuous slab and T-beam bridges thereby reducing a number of these bridges from replacement and saving INDOT this expense. Project 4229 calculated maintenance and operation cost savings by housing the INDOT maintenance truck fleet in protective shelters.

Agency Savings

The total quantifiable savings from the three projects resulting in agency savings, during their analysis or impact period, was calculated at $35,668,000 (in 2019$). The total research program cost in FY 2019 was $8,314,040. Therefore, the agency savings BCA for FY 2019, for quantifiable projects, is: **$35,668,000/$8,314,040 = 4,** or 4 dollars in agency savings for every research dollar expended. **Said another way, the agency savings from these three projects more than offset the cost of the entire research program for the year.**

A summary table for agency savings was created for the three projects and the condensed versions are shown in Table 2. The expanded version of each table is included in Appendix B with the project write-ups.

Table 2. Agency Savings Projects

Project Description	FY2019	FY2020	FY2021	FY2022	FY2023
3821 – Annual Benefit (5 Year impact) *					
Research and Implementation cost	$2,871,556				
Net Benefit	-$2,124,537	$789,650	$835,949	$883,954	$933,728
NPV FY 2019	**$1,037,499**				
4120 - Annual Benefit (3 year impact)**					
Research and Implementation cost	$5,926,790	$4,967,454	$5,887,934		
Net Benefit	$6,173,375	$7,172,221	$11,238,083		
NPV FY 2019	**$23,038,511**				
4229 - Annual Benefit (5 year implementation , 50 year benefit)*					
Research and Implementation cost	$14,850,000	$15,244,000	$15,701,320	$15,735,269	$16,207,327
Net Benefit	-$14,847,981	-$14,837,000	-$14,862,900	-$14477,639	-$14,530,487
NPV FY 2019	**11,593,609**				
NPV Total 2019	**$35,668,000**				
Research Program Cost	$8,314,040				
Benefit Cost Ratio - ROI	**4**				
Report Date	12/31/2020				
* Based on 5 Year INDOT work program ** Based on 3 year implementation					

Cost Savings Summary

As previously noted, the three projects produce quantifiable benefits that resulted in agency savings. A summary of these cost savings is described below.

3821 - Savings come from using INRIX probe data for travel time calculations which allow elimination of roadside urban monitoring sites (134) that INDOT has used and eliminating their associated electrical costs. Annual maintenance costs are unknown, which would result in additional savings. Rural sites (303) elimination are not included in the cost savings calculation, which if included is a significant additional saving. Rural roadside monitoring sites are not required due the availability of probe data.

4120 - This project developed a refined load rating methodology that more accurately calculates load carrying capacity of older continuous slab and T-beam concrete bridges which number 1,303. With more accurate load ratings, some of these bridges can be kept in service through a deck overlay and rehabilitation to other components eliminating bridge replacement and saving INDOT these costs.

4229- Providing sheltered storage of INDOT's maintenance truck fleet (approximately 1100) provides benefits and cost savings. Cost savings come from lower fuel costs due to less morning warmup time and corresponding labor cost for the driver that occur during winter events. Some regular maintenance activities can be performed more efficiently. A total of 183 shelters are needed to house the entire fleet.

Summary

The aggregate benefit of all agency savings is significant, resulting in more than $35 million (2019$). Direct agency savings of over $35 million is a return of $4 for every $1 spent in research. The basis for the numbers used in the BCA came from INDOT databases, subject matter experts (SMEs), and research results. These are described in detail in the individual analyses located in Appendix B.

A ROI of 4 to 1 is considered a significant agency return on research investment, which is indicative of other State DOT Research Programs. While the ROI is significant, a review of the individual project analysis shows a conservative approach was taken in any assumption made and in the calculations; therefore, actual savings may be higher. This analysis indicates that INDOT continues to receive a significant return on its research investment which will continue to grow due to recently passed legislation (HB 1002), authorizing more funding for construction, re-construction, and preservation, as more projects will be impacted.

For 32 projects completed in FY 2019, quantifiable benefits could not be calculated or data was not available, however other qualitative benefits resulted that brought significant value to the Agency and Road Users and are highlighted in the companion annual IMPACT report. A complete listing of all research projects completed in FY 2019 is shown in Table 4 in Appendix A.

Rolling Average BCA

Annual BCA provide an assessment of INDOT's investment in Research on an annual basis. For the last four years, 2016, 2017, 2018, and 2019 the investment indicates positive returns during the life of individual projects implemented. While a majority of the projects in the last four years, 99 out of 123 total research projects benefits are not quantifiable, due to the unavailability of quantifiable data, qualitative benefits were identified and are highlighted in the companion annual IMPACT report. 20 projects where benefits were quantified, produced significant agency savings and 4 projects produced significant road user cost savings. For the combined years of 2016 through 2019 the Agency and Road User BCA are:

BCA (2016 - 2019) Agency Savings = $341,727,000/$22,629,040 = 15 to 1

BCA (2016 - 2019) Road User Savings = $304,959,799/$22,629,040 = 13 to 1

BCA Rolling Average – 2016-2019

Table 3 compiles the estimated agency savings and road user savings for the last four analysis years. BCA averages are calculated from the four-year totals for research expenditures, estimated agency savings, and road user savings.

Table 3. BCA Rolling Average

Year	Research Investment	Estimated Agency Savings	Estimated Road User Savings	BCA Ratio Agency Savings	BCA Ratio Road User Savings	Total B/C
2016	$6,264,000	$76,481,000	$290,743,799	12	46	58
2017	$4,124,000	$189,668,000	$11,247,000	46	3	49
2018	$3,927,000	$39,910,000	$2,696,000	10	0.7	10.7
2019	$8,314,040	$35,668,000	0	4	-	4
Totals	$22,629,040	$341,727,000	$304,959,799	15 avg.	13 avg.	28 avg

Appendix A

Table 4. – Complete Research Project List – FY 2019

No	FY 19 Completed & Implemented SPR Projects	Project Title	Project Cost ($ 1000)	Quantitative Benefits, Qualitative Benefits or Not Successfully Implemented	Project Benefits ($1000)
1	3708	Toward Performance Related Specifications for Concrete Pavements	350	This project stopped prematurely	0
2	3807	Investigating the Need for HMA Drainage Layers	170.258	This project triggers the I-69 demonstration project, no results yet	0
3	3808	Synthesis - Accelerating the Implementation of Research Findings to Reduce the Potential for Concrete Pavement Joint Deterioration	80	Qualitative	0
4	3815	Establishing Modeling Standards for Bridges and Culverts	183.714	Qualitative	0
5	3821	Real Time Traffic Mobility Measures	2871.56	Quantitative	0
6	3852	Transportation Research Board (TRB) Annual Meeting Activities	135.692	Qualitative	0
7	3904	Tack Coat Installation Performance Guidelines	276	Qualitative	0
8	3905	Concrete Patching Materials And Techniques and Guidelines for Hot Weather Concreting	240	Qualitative	0
9	3912	Economic Development Impact of Corridor Improvements and Preservation Projects	520.742	Qualitative	0

10	3914	Life Cycle Cost Analysis of Steel vs. Concrete Bridges	196.298	Qualitative	0
11	3945	Virtual Construction Inspection Technology	200	Qualitative	0
12	4002	Risk-based Specification for Construction	369.555	Qualitative	0
13	4005	Warranty Utility Cut Repair (QC/QA of Utility Cut Repair)	168.004	Qualitative	0
14	4017	Imp. of WIM Data Quality Control and Real-Time Dashboard Development	175	Qualitative	0
15	4040	Experimental Study of the Load Response of Large Diameter Closed-ended and Open-ended Pipe Piles Installed in Alluvial Soils	293.251	Qualitative	0
16	4043	Investigation of Materials from Premature Failures in Pavement and Bridges	27.423	Qualitative	0
17	4100	Maximum Allowable Deflection by Light Weight Deflectometer and Its Calibration and Verification	104.825	Qualitative	0
18	4101	Pavement Materials Testing and Testing Intervals Confidence in Pavement	218.93	Qualitative	0
19	4104	Predicting Impact to Traffic Safety and Mobility of Change in Speed Limits for Indiana Freeways	148.785	Qualitative	0
20	4105	Outsourcing of Laboratory Testing	80.5	Qualitative	0

		and Inspection Activities at State Highway Agencies: Synthesis of Current Practices			
21	4113	Development of a Friction Performance Test for Compacted Asphalt Mixtures	80.404	Qualitative	0
22	4119	Assessment of Bridges Subjected to Vehicular Collision	129.081	Qualitative	0
23	4120	Strength Assessment of Older Continuous Slab and T-Beam Reinforced Concrete Bridges	230	Quantitative	23,038
24	4121	Pack Rust Identification and Mitigation Strategies for Steel Bridges	125	Qualitative	0
25	4123	Strategic and Tactical Guidance for the Connected and Autonomous Vehicle Future	200	Qualitative	0
26	4151	Synthesis Study: Overview of Readily Available Culvert Inspection Technologies	68.527	Qualitative	0

27	**4155**	**Updating Asset Risk and Vulnerability Assessment for INDOT**	**149.637**	**Qualitative**	**0**
28	**4157**	**Quality Assurance Procedures for Chip Seal Operations using Macrotexture Metrics**	**67.39**	**Qualitative**	**0**
29	**4158**	**Implementation of Continuous Improvement for INDOT Maintenance (Training and Tracking Process Improvements)**	**51.581**	**Qualitative**	**0**
30	**4200**	**SPR-4200 Ohio River Bridges East End Crossing, PRB, Project After Action Review of Procurement Models**	**100**	**Qualitative**	**0**
31	**4203**	**Synthesis Study: Facilities Enterprise Development, Sponsorship & Privatization**	**50**	**Qualitative**	**0**
32	**4223**	**Link-Slabs Details and Materials**	**55.675**	**Qualitative**	**0**
33	**4229**	**Cost Effectiveness of Constructing Minimal Shelter to Store INDOT Equipment (Weather Protection)**	**50**	**Quantitative**	**11,593**

34	4236	INDOT Permit Manual Development Project	76.224	No Implementation	
35	4333	Telematics and Utilization Analysis for INDOT Mowing Operations	70	Qualitative	
			$8,314		

Total FY 2019 Research spending is $8,314,000.

Appendix B

Individual Project Analysis

SPR-3821: Automated Estimation of Winter Driving Conditions

Introduction

This project developed an experimental system that utilizes real-time mobility and weather data to estimate winter driving conditions in real-time. This effort is the latest addition to the SPR-3821 umbrella project from a series of projects that started in CY 2014 with the initial project, "Real Time Mobility Measures." This original project was approved for expansion in 2015 to obtain INRIX probe data, which is cell phone time and position data. Another extension was approved in 2015 to expand the implementation of real-time mobility measures and review related maintenance of traffic policies. Then in 2017 a budget expansion was approved to add this project, Automated Estimation of Winter Driving Conditions, to the list of mobility-based projects. With this addition, the total SPR-3821 budget spent on the various phases is $2,871,556. (It should be noted, the associated cost for calculation of travel times is just a subset of the total SPR-3821 budget, but the BCA was based on the total project budget, as has been standard practice when computing project BCAs. Consequently, the calculated BCA for SPR-3821 should be considered very conservative.)

One outcome of SPR-3821 projects, use of probe data, was the development and use of several mobility dashboards that monitor and manage different traffic mobility characteristics[1]. Twelve dashboards were developed by INDOT Traffic Management: Traffic Ticker, Congestion Profiles, Speed Profiles, Delta Speed Map, Delta Speed Profiles, Queuing Heat Map, Segment Travel Time, Segment Ranking, and four dashboards that produce multiyear route-based analysis.

This Benefit Cost analysis focuses on the use of probe data in the calculation of travel times for motorists and quantifiable benefits derived from its use.

Analysis

INDOT use of probe data and its value to highway operations has evolved into multiple projects with INDOT Traffic Operations teams under the parent SPR-3821 project. During this time period, team members worked with probe data provider INRIX to improve data segmentation and increased saturation of probes across the entire network.

One specific project was the utilization of probe data in the calculation of travel times for motorists. Prior to the use of probe data, INDOT was calculating travel times based on speeds captured from roadside equipment that INDOT had to install, operate and maintain. INDOT deployed this equipment approximately every ½ mile along urban interstates. Urban area travel times could be calculated and costs savings calculated by eliminating roadside equipment and associated costs. Similar cost savings would be achieved on rural interstate areas were INDOT able to install roadside equipment along the entire interstate network. With probe data INDOT is now calculating travel times across the entire interstate network even in areas without any roadside field equipment. INDOT is also reviewing the existing inventory of count/speed locations in the urban areas.

INDOT currently has 437 roadside detection sites. The plan is to eliminate many of these, leaving only two between each interchange. Instead, probe data will be used in all travel time calculations and the INDOT roadside sites will supplement the probe data and perform QC/QA speed checks and collect traffic count data that is currently not available from probe data. INDOT has identified 134 sites for elimination and is currently retiring these sites. With the cost to install these sites ranging from $35,000 to $45,000 per site to construct, the cost savings in replacements will be significant. Additional savings will occur by eliminating electrical costs, routine maintenance and replacement costs. Below is a breakdown of anticipated savings during the life of these devices, which is estimated at ten years[2].

Potential Savings

The below data was provided by INDOT Traffic Management[3].

Sites to be eliminated and replaced with probe data – 134

Site types: Microloop – 28; Radar - 106

Site cost to install: Microloop - $45,000 each; Radar - $35,000 each

Electrical cost: $50,000 annually

Annual Probe Data cost: $400,000

Potential savings come from not replacing the roadside urban sites (134) and eliminating the electrical costs. Annual maintenance costs are unknown which is an additional saving. Rural sites (303) elimination are not included in the cost savings calculation, which if included is a significant saving.

Phasing out these 134 sites will be performed over a typical five year work plan period which is approximately 26 sites annually. The reductions will be 21 radar sites and 5 (conservative) microloop sites per year. The electrical cost savings is reduced annually ($50,000/5 = $10,000) over the five-year period.

A net present value approach was taken to calculate potential cost savings achieved during the five-year period and shown in Table 1.

A net present value approach was taken to calculate potential cost savings achieved during the five-year period and shown in Table 1.

Table 1. Projected Annual Cash Flows

Years	2019	2020	2021	2022	2023
Research Cost	$ (2,871,556)				
Site replacement Cost Saving[1]	$ 1,135,000	$ 1,169,050	$ 1,204,122	$ 1,240,245	$ 1,277,452
Electrical Savings[2]	$ 10,000	$ 20,600	$ 31,827	$ 43,709	$ 56,275
Probe Data Cost	$ (400,000)	$ (400,000)	$ (400,000)	$ (400,000)	$ (400,000)
Net savings	$ (2,124,537)	$ 789,650	$ 835,949	$ 883,954	$ 933,728
NPV	$ 1,037,499				
B/C	0.4				

[1] Annual replacement saving = 26 (radar) * $35,000 + 5 (microloop)* $45,000 = $1,135,000, increased annually by 3% inflation.

[2] Electrical cost savings increase $10,000 annually for 5 years with a 3% annual inflation added.

Summary

Using the five-year approach to change the 134 roadside sites to probe data, the benefit cost ratio is **0.4.** A quantifiable number that indicates research investment has not resulted in a positive cash flow for INDOT. However, a couple factors not included in the cost analysis will significantly improve the B/C ratio; these are annual site maintenance costs (requested but unknown at this time) and the 303 rural sites that could be phased out like the urban sites, or in this case not required by using the probe data in lieu of installing roadside equipment.

These numbers are based on the following:

- Research cost of $2,871,556.
- 3% cost of capital.
- Annual costs are inflated by 3%.
- NPV of future costs and benefits based on 2019$.

This analysis is only for this project's cost to conduct the research and implementation. In the summary report an overall 2020 benefit cost analysis is based on total program costs.

References

[1] Day, C. M., McNamara, M. L., Li, H., Sakhare, R. S., Desai, J., Cox, E. D., Horton, D. K., & Bullock, D. M. (2016). 2015 Indiana mobility report and performance measure dashboards. West Lafayette, IN: Purdue University. http://dx.doi .org/10.5703/1288284316352.

[2] INDOT Research Division.

[3] Edward D Cox, ITS Engineering Director, INDOT Traffic Management

SPR-4120 – Strength Assessment of Older Continuous Slab and T-beam Reinforced Concrete Bridges

Introduction

INDOT's bridge inventory currently contains 5,750 bridges of these there are 1,303 bridges classified as continuous slab (CS) and T-beam reinforced concrete bridges (TB) (Figures 1 and 2).

Figure 1-Slab Bridge

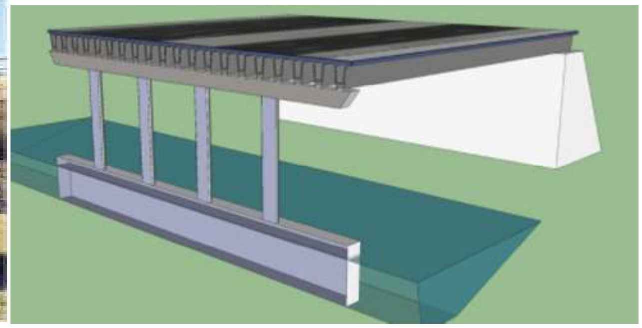

Figure 2 - T-Beam Bridge

All bridges are inspected in a two-year cycle and load ratings evaluated using a conventional load rating (CLR) procedure. CS and TB bridges are load rated using this procedure which is being reported as conservative or underestimating their bridge load capacity. Due to the large number (1,303) of CS and TB bridges, an accurate estimation of load carrying capacity could save INDOT the cost of bridge replacement and extend their life through proper maintenance and repair.

This project developed a refined load rating methodology using 3D finite element analysis (FEA) that more accurately calculates load carrying capacity by including associated influencing factors of: number of spans, beam spacing, diaphragm effects, and side railing effects. These factors are not fully considered in CLR and will influence load carrying capacity of the bridge.

Analysis

A meeting with INDOT engineers[1] confirmed research implementation has improved the load ratings accuracy of these bridge types.

INDOT engineers[2] provided two data files used in the analysis. One, a current CS and TB bridge inspection data file and the other a calendar 2020 unit cost table for different bridge treatment repairs to extend the life of CS and TB bridges.

The inspection data file contains twenty different load rating categories and if any of these 20 load factor values is less than 1.2, INDOT determined these bridges are not eligible for an overlay due to the extra weight that will be imposed. An overlay with associated repairs to the superstructure and substructure will extend the life of these bridges an additional 15-20 years (INDOT). Consequently, If the load ratings on these bridges are undervalued then unnecessary replacements will occur costing INDOT. Of the 1,303 bridges, 358 had load ratings 1.2 or less. A conservative estimate by INDOT Engineers[2] indicates 5% of the 358 bridges load rating can be moved above the 1.2 threshold through using the FEA method. This equates to 18 bridges. These bridges are whose load ratings are the top 18 in this group.

Cost savings come from eliminating replacement costs but add costs for overlay and superstructure and substructure repairs. Replacement costs and repair unit costs come from data files provided by INDOT[2].

Potential Savings

Table 1 is the list of 18 bridges that by applying an overlay and associated repairs to superstructure and substructure elements, total bridge replacement can be avoided and their life extended 15 years. The table contains estimated unit costs to place rigid deck overlay on non-interstate bridges which includes improvements to superstructure and substructure components. INDOT estimates unit cost increase for both components at 15% each. Unit cost estimates for repair and replacement costs were provided by INDOT.

Table 1 – CS and TB Bridges to be overlaid

	Deck Area(SF)	Bridge Type	Repair Unit Costs /SF[1]	Estimated Replacement Cost($)
1.	3311	2 - Concrete continuous	$227	1,672,055
2.	3069	2 - Concrete continuous	$227	1,549,845
3.	2502	2 - Concrete continuous	$468	2,151,720
4.	2502	1 - Concrete	$468	2,151,720
5.	6716.08	1 - Concrete	$162	2,753,593
6.	3606.4	2 - Concrete continuous	$227	1,821,232
7.	3208.5	2 - Concrete continuous	$227	1,620,293
8.	3676.53	2 - Concrete continuous	$227	1,856,648
9.	2724.45	2 - Concrete continuous	$227	1,375,847
10.	2482.7	2 - Concrete continuous	$468	2,135,122
11.	2997.06	2 - Concrete continuous	$227	1,513,515
12.	4158	2 - Concrete continuous	$227	3,638,250
13.	6907.95	2 - Concrete continuous	$162	2,832,260
14.	3785.6	2 - Concrete continuous	$227	1,911,728
15.	8537.1	2 - Concrete continuous	$130	4,268,550
16.	8537.1	2 - Concrete continuous	$130	4,268,550
17.	6585.6	2 - Concrete continuous	$162	2,700,096
18.	1331.2	2 - Concrete continuous	$468	1,144,832

[1] Unit costs include construction, maintenance of traffic, and approach work increased by 30% to include superstructure and substructure improvements. Unit costs vary by bridge deck areas (economy of scale).

INDOT follows a five-year work plan for their program. In the cost analysis, the 18 bridges are improved over an accelerated three-year span (6 bridges for each year) due to their deteriorated state and are reflected in the ROI calculations. Table 2 is a summary of the benefit cost (BC) analysis. The benefit is avoiding bridge replacement cost while the incurred cost is the expense of repairing these bridges. The BC analysis is for a three-year time period. Table 3 summaries the repair and replacement costs for six bridges in each year period.

Cost Analysis of improving 6 bridges a year for the first 3 years and avoiding replacement.

Table 2 – BC Analysis

Years	2019	2020	2021
Research Cost	$ (230,000)		
Repair Cost for 6 bridges[2]	$ (5,696,790)	$ (4,967,454)	$ (5,887,934)
Replacement Cost avoided[3]	$ 12,100,165	$ 12,139,675	$ 17,126,016
Net Savings	$ 6,173,375	$ 7,172,221	$ 11,238,083
NPV	$ 23,038,511		
B/C	100		

Table 3 – Repair and Replacement Cost Summaries

	Deck Area(SF)	Repair Unit Costs /SF	Estimated Replacement Cost[3]	Repair Cost[2]	
1	3311	$227	$1,672,055	$751,597	
2	3069	$227	$1,549,845	$696,663	
3	2502	$468	$2,151,720	$1,170,936	
4	2502	$468	$2,151,720	$1,170,936	
5	6716.08	$162	$2,753,593	$1,088,005	
6	3606.4	$227	$1,821,232	$818,653	
			$12,100,165	$5,696,790	Totals for year 1
7	3208.5	$227	$1,620,293	$728,329.50	
8	3676.53	$227	$1,856,648	$834,572.31	
9	2724.45	$227	$1,375,847	$618,450.15	
10	2482.7	$468	$2,135,122	$1,161,903.60	
11	2997.06	$227	$1,513,515	$680,332.62	
12	4158	$227	$3,638,250	$943,866.00	
			$12,139,675	$4,967,454.18	Totals for year 2
13	6907.95	$162	$2,832,260	$1,119,087.90	
14	3785.6	$227	$1,911,728	$859,331.20	
15	8537.1	$130	$4,268,550	$1,109,823.00	
16	8537.1	$130	$4,268,550	$1,109,823.00	
17	6585.6	$162	$2,700,096	$1,066,867.20	
18	1331.2	$468	$1,144,832	$623,001.60	
			17,126,016	$5,887,933.90	Totals for year 3

Summary

The BC ratio is significant at **100:1** because with improved load ratings these bridges can be properly repaired and kept in service instead of being replaced.

These numbers are based on the following:

- Research cost of $230,000.
- 3% cost of capital.
- Annual costs are inflated by 3%.
- NPV of future costs and benefits based on 2019$.

This project has triggered a follow-up project SPR-4444: Improved Live Load Lateral Distribution Factors for Use in Load Ratings of Older Continuous and T-Beam Reinforced Concrete Bridges. Research results from this research will provide improved load ratings that will further validate load rating analysis using the FEA approach.

This analysis is only for this project's cost to conduct the research and implementation. In the summary report an overall 2020 benefit cost analysis is based on total program costs.

References

[1] Jeremy Hunter PE, INDOT Chief Engineer of Design and Managing Director of Engineering and Jennifer L Hart PE, INDOT Load Rating Engineer.

[2] Erich T Hart PE, INDOT Bridge Asset Engineer and Jennifer L Hart PE, INDOT Load Rating Engineer.

SPR-4229: Cost Effectiveness of Constructing Minimal Shelter to Store INDOT Equipment (Weather Protection)

Introduction

INDOT's maintenance truck fleet, approximately 1100 "dump truck" vehicles statewide, are exposed to year-round weather conditions. This exposure increases maintenance and operating costs for the fleet over providing cover storage facilities, but storage facilities are costly to provide.

This project performed a cost analysis comparison between the current storage being used (exposed vehicles) and covered storage for these vehicles. Providing storage for these vehicles at all INDOT units is an expensive investment but this analysis shows it to be a beneficial investment.

Identified benefits in the research in sheltering equipment include:

- Public Safety
- Employee Safety
- Cost Savings
- Efficient and cost-effective operations
- Protection of equipment
- Environmental impacts

Analysis

Specific quantifiable cost savings are reduced idle time, reduced fuel cost, and reduced labor costs for truck drivers. A payback period cost analysis was performed in the report and updated in this analysis based on investing in building equipment shelters, 183 total.[1] A shelter cost of $400,000 each was provided by INDOT'S Statewide Facilities Director and Statewide Maintenance Director[1].

Financial analysis assumptions:

- 183 shelters required to house the INDOT fleet[1]
- Each shelter cost in 2020 dollars is $400,000.
- Time savings between outside and inside truck startup is 30 minutes, idle time during winter operations.
- Diesel fuel used during 30 minute idle time – 1 gallon
- Diesel fuel cost - $2.50 in 2020 dollars
- Hourly driver rate on snow days, includes overtime, $25.
- Annual number of snow days – 24
- Total number of INDOT snow trucks statewide - 1100

Using the updated facility cost and the report payback analysis approach, if all shelters are built in the same year the initial investment is 183* $400,000 = $73,200,000. The payback period is the time to recover this initial investment through savings in fuel, labor, and maintenance. This annual savings was calculated to be $2,035,073, calculated in Table 1.

Payback period = $73,200,000/$2,035,073 = 36 years

It would take approximately 36 years to recover the initial investment of building 183 equipment shelters.

Potential Savings

A net present value approach was taken to calculate potential cost savings from research implementation and calculate a benefit-cost (B/C) ratio. Savings are based on building protective shelters and two assumptions were used. Assumption 1 builds all shelters in the first year, that cost is $73,200,000. Since this is a significant cost, assumption 2 brings all the shelters on-line over a five-year period. Both investment periods use a 50 year life for these shelters.

<u>Assumption 1 – Build all shelters in one year</u>

Annual user savings come from reduced fuel, driver, and maintenance costs.

Table 1 – Annual User Savings – Assumption 1

Time savings between outside and inside truck startup	30 minutes
diesel used during idle time	1 gallon
10 hours work per snow day, overtime hourly rate	$25
trucks used on snow day	1100
snow days per year, average	24
Diesel Fuel cost per gallon	$2.50

Annual Winter Operating Savings- 1100 trucks	
Fuel savings - 1 gallon per morning idle time	$66,000
Driver cost savings	$330,000
Annual winter operation cost savings	$396,000
Annual maintenance cost savings *	$1,639,073
Total savings - winter + maintenance	$2,035,073

*Annual maintenance cost savings based on cost savings with performing maintenance inside versus outside vehicles storage - $1,639,073 for 1100 vehicles. The difference in costs is because of reduced frequency of maintenance visits. and reduced probability of major service. This was calculated through a JaamSim model. The annual maintenance savings per truck is $1,639,073/1100 = $1,490 per truck.

Since the cash flow period is 50 years (shelter life), the cash flow diagram cannot be shown in this document, however it is a part of project documentation saved with this report. A portion of the cash flows is shown below.

Table 2 - Cost Analysis building all shelters in year one and 50-year life of buildings

Project Benefits and Costs ($)	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**..**
Research Cost	$ (50,000)							
Shelter Cost	$ (73,200,000)							
Estimated Annual User Savings		$ 2,035,073	$ 2,096,125	$ 2,159,009	$ 2,223,779	$ 2,290,493	$ 2,359,207	..
Net Benefit-Cost	$ (73,250,000)	$ 2,035,073	$ 2,096,125	$ 2,159,009	$ 2,223,779	$ 2,290,493	$ 2,359,207	..
NPV	$ 22,877,818							
Benefits Cost Ratio - NPV/research cost	458							

The benefit cost ratio is 458: 1 with building all 183 shelters in the first year.

Assumption 2 – Build shelters over a five-year period

INDOT's work program follows a five-year plan that is updated annually. Building 183 shelters is a significant investment and needs to be budgeted for inclusion into the work plan. Using a five-year basis for constructing all 183 shelters, the B/C ratio is calculated through a phase-in increase of shelters. Using this approach 20% of the shelters are built each year for the first five years which translates to 20% additional trucks covered annually so maintenance, labor, and fuel savings are graduated starting at 20% in the first year to 100% in year 5. The annual user savings are based on this approach and summarized in the below table.

Table 3 – Annual User Savings – Assumption 2

Time savings between outside and inside truck startup	30 minutes
diesel used during idle time	1 gallon
10 hours work per snow day, overtime hourly rate	$25
trucks used on snow day	1100
snow days per year, average	24
Diesel Fuel cost per gallon	$2.50
Annual Winter Operating Savings- per truck	
Fuel savings - 1 gallon per morning idle time	$60
Driver cost savings	$300
Annual winter operation cost savings	$360
Annual maintenance cost savings *	$1,490
Total savings - winter + maintenance	$1,850

Since the cash flow period is 50 years (shelter life), the cash flow diagram cannot be shown in this document, however it is a part of project documentation saved with this report. A portion of the cash flows is shown in the below table.

Table 4 - Cost Analysis building 20% of shelters each year over 5 years and 50-year life of buildings

Years	2019	2020	2021	2022	2023	2024	2025	.....
Research Cost	$ (50,000)							
Shelter Cost[1]	$ (14,800,000)	$ (15,244,000)	$ (15,701,320)	$ (15,735,269)	$ (16,207,327)			.....
Labor savings [2]		$ 66,000	$ 135,960	$ 203,940	$ 271,920	$ 339,900	$ 350,097	.....
Fuels Savings [3]		$ 13,200	$ 27,192	$ 40,788	$ 54,384	$ 67,980	$ 70,019	......
Maintenance Savings[4]		$ 327,800	$ 675,268	$ 1,012,902	$ 1,350,536	$ 1,688,170	$ 1,738,815	......
Net savings	$ (14,847,981)	$ (14,837,000)	$ (14,862,900)	$ (14,477,639)	$ (14,530,487)	$ 2,096,050	$ 2,158,932	......
NPV	$ 11,593,609							
B/C	232							

The benefit cost ratio is 232: 1 with building all shelters over a five-year period.

Summary

Based on two financial analyses approaches; payback period (36 years) and benefit cost analysis ratios of 458:1 for building shelters in one year, or 232:1 for building all shelters over a five year period; either option will produce significant savings for INDOT.

The benefit cost ratio for this project is significant regardless of what time period equipment shelters are brought on-line:

183 shelters built in one-year time period – 458:1
183 shelters constructed over a five-year period – 232:1

These numbers are based on the following:

- Research cost of $50,000.
- 3% cost of capital.
- Annual costs are inflated by 3%.
- NPV of future costs and benefits based on 2019$.

This analysis is only for this project's cost to conduct the research and implementation. In the summary report an overall 2020 benefit cost analysis is based on total program costs.

References

[1]Steve McAvoy – INDOT's Statewide Facility Manager, JD Brooks INDOT's Statewide Maintenance Director.

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at http://docs.lib.purdue.edu/jtrp.

Further information about JTRP and its current research program is available at http://www.purdue.edu/jtrp.

About This Report

An open access version of this publication is available online. See the URL in the citation below.

Recommended Citation

McCullouch, B. (2020). *INDOT research program benefit cost analysis—Return on investment for projects completed in FY 2019* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2020/27). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284317279