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INDOT Research Program Benefit Cost Analysis—Return on Investment for Projects Completed in FY 2020

Bob McCullouch

SPR-4225 • Report Number: FHWA/IN/JTRP-2021/35 • DOI: 10.5703/1288284317265

INDOT Research Program Benefit Cost Analysis—Return on Investment

for Projects Completed in FY 2020

(SPR – 4225)

This Annual Return on Investment (ROI) Report for the INDOT Research Program was prepared at the request of the Governor's Office and INDOT Executive Staff

Bob McCullouch PE, Ph.D.
School of Civil Engineering
Purdue University
December 2021

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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 2020. 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 2020 analysis is completed in calendar 2021. 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 will provide large qualitative ROI, however, are difficult to quantify due to their complexity and newness.

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 2020 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 two quantifiable projects included RUC and SC savings, rather than agency savings. Qualitative 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. The analysis period varied from 1 to 20 years, each one based on impact periods. 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 2020 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 5 recent years, with FY 2016 being the first year. The 2020 analysis marks the fifth year. By using total program costs in the analysis, rather than just the individual project cost, a very conservative BCA ratio is obtained and actual cost savings may be considerably higher.

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, proof of concept, or legal issues.

One project 4233, Implementing the Strut-and-Tie Method for the Design of Bridge Components, is at an early stage of implementation and calculating quantifiable benefits is premature but will occur over time.

Individual Project Analysis

Table 1 is the list of the eleven projects where benefits (NPV 2020$ - NPV of future cash flows in 2020 dollars) could be quantified and their individual analysis is found in Appendix B. Two of the eleven projects will produce RUC savings, the other nine Agency savings. Table 3, in Appendix A, is a complete list of all 39 projects completed in FY 2020 and considered for quantifiable cost analyses.

Table 1. Quantitative Benefits Project List

No	FY 20 Completed & Implemented SPR Projects	Title	Project Cost ($1,000)	Benefit Type	Analysis Period	NPV Project Benefit ($1,000) 2020$
1	3715	CAI/S-BRITE (Steel Bridge Research, Inspection, Training and Education Engineering Center): Preliminary Engineering Design	$472	Quantitative (Agency Savings)	**10 Years**	**$191**
2	3857	Assessment of Pipe Fill Heights	$273	Quantitative (Agency Savings)	**1 year**	**$1,375**
3	4009	Concrete Box Beam Risk Assessment & Mitigation	$290	Quantitative (Agency Savings)	**15 Years**	**$4,046**
4	4103	Developing the Collision Diagram Builder – Phase II	$130	Quantitative (Agency Savings)	**5 Years**	**$194**
5	4107	Subgrade Stabilization Alternatives	$277	Quantitative (Agency Savings)	**5 Years**	**$2,654**
6	4116	Investigation of Design Alternatives for the Subbase of Concrete Pavements	$249	Quantitative (Agency Savings)	**12 Years**	**$1,080**
7	4150	Implementation Proposal for Improve Energy Efficiency of Facilities	$58	Quantitative (Agency Savings)	**15 Years**	**$71**
8	4219	SNIP Light	$119	Road User Costs (User Savings)	**3 Years**	**$22,123**
9	4226	Cost-Effectiveness of Converting Signalized Arterials to Free-Flow Facilities	$168	Road User Costs (User Savings)	**20 Years**	**$28,261**
10 & 11	4353 & 4448	Central HMA Acceptance Lab Process Improvement Project	$60	Quantitative (Agency Savings)	**5 Years**	**$116**

Total Agency Benefits $ 9,727,000

Total User Benefits $ 50,384,000

The analysis periods varied from 1 to 20 years, due to estimated impact period. Project 3857 used a project cost for repairing a pipe failure on the Ronald Reagan Parkway that was performed in 1 year. Projects 4103, 4107, 4353 and 4448 used 5 years based on INDOT work plan. Project 3715 used a 10-year period for training costs averted by using the S-BRITE center. Project 4009 used a 15-year period as this is the estimated box beam bridge deck life gained from its implementation. Project 4116 used a 12-

year period based on estimated concrete pavement patch life extension. Project 4115 15-year period is based on the expected life of the energy efficient systems. Project 4219 will produce user savings and is based on 3 years of comparison data in SNIP projects (2015-2017) projected for an additional 3 years. Project 4226 20-year period is based on converting one signalized corridor to a free flow corridor in the next 20 years and the estimated benefit experienced by the road users.

Agency Savings

The total quantifiable savings from the eight projects (two were combined, 4353 & 4448 due to similarity) resulting in agency savings, during their analysis or impact period, was calculated at $9,727,000 (in 2020$). The total research program cost in FY 2020 was $7,022,000. Therefore, the agency savings BCA for FY 2020, for quantifiable projects, is: **$9,727,000/$7,022,000 = 1.4,** or 1.4 dollars in agency savings for every research dollar expended. **Said another way, the agency savings from these eight projects more than offset the cost of the entire research program for the year.**

Due to the varying impact periods for these eight projects (1 to 15 years) a summary table for agency savings is not practical. Each project write-up in Appendix B contains a summary table of agency savings.

User Savings

Two projects, 4219 and 4226, can produce quantifiable user savings calculated to be $50,384,000. Therefore, the user savings BCA for FY 2020 is: **$50,384,000/$7,022,000 = 7.2**, or 7.2 dollars in user savings for every research dollar expended. Project 4219 has an impact period of 3 years and 4226 of 20 years. To summarize these together in a table is not practical, so individual savings tables are in their project write-ups in Appendix B

Cost Savings Summary

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

3715 – S-BRITE is used as a training center for steel bridge inspection. Four classes are offered on a 2-year cycle which are free to INDOT employees. Calculated savings are based on training cost avoidance calculated from average number of INDOT attending and training costs for these classes paid by consultants.

3857 – This project produced new cover tables for buried pipes to prevent overloading that can cause premature pipe failure. A failed pipe due to improper cover will have cost and driver consequences as in-place replacement will occur and a detour needed. Estimating this cost avoidance by using the new cover tables and the frequency of occurrence on future INDOT projects is challenging. Cost avoidance savings used in the analysis came from costs incurred to fix a failed pipe on the Ronald Reagan Parkway.

4009 - Calculated savings are for the older segment (80) of INDOT's 170 box beam bridges based on delaying replacement through a deck overlay. Greater savings can be achieved if local (county) bridges are included (approximately 4,000).

4103 – Calculated savings is based on time savings achieved by the Office of Traffic Safety using the Corridor Collison Diagram Builder (CCDB) program developed through this project. Each analysis performed with CCDB saves approximately $10,000 in staff or consultant time to assemble this information. The Office of Traffic Safety performs, on average, 4 of these annually.

4107 - The basis for calculated savings is a result of reduced pavement thickness due an improved subgrade. Updating the pavement design with a stronger subgrade was used on an I-65 project in Tippecanoe county resulting in deceasing pavement thickness by ½". This thinner pavement saved INDOT $5,508 per lane mile which is the cost basis in calculating future annual savings

4116 – One outcome of this project was the recommendation to use lean concrete in place of subbase to patch concrete pavements. This substitution extends the patch life by 6 years, from 6 years to 12 years. This is the basis of the cost savings.

4150 – Savings are based on reduced energy usage experienced at the INDOT Division of Research facility after switching to LED interior and exterior lights. Reduced energy costs are accumulated for the expected life span of LED lights, 15 years. Energy savings at other INDOT facilities is expected with this switch in lighting technology.

4353 and 4448 - Savings come from two lab improvements; reduced personnel time to process tests and a reduction in re-tests or testing error results. Estimated annual savings is $24,000 projected for a 5-year work plan period. This estimated savings will likely increase with the passage of the Federal Infrastructure Bill which increases lab testing and paperwork workloads.

Two projects **4219** and **4226**, will produce quantifiable user savings. A summary of these user savings is described below.

4219 - SNIP is a key tool used to conduct the annual Network Safety Screening (NSS) process that INDOT's Office of Traffic Safety (OTS) conducts with the six INDOT District Traffic Engineering Offices in order to identify intersections and roadway segments with elevated risk for future crashes. Improved identification has led to safety improvements which have reduced crashes causing property damages, personal injuries, and fatalities. Each of these three outcomes have associated user savings.

4226 – This project developed a decision support tool for the Corridor Development Office (CDO) of the Traffic Engineering Division to evaluate, confirm, and defend both corridor-level and site or intersection specific traffic control strategies for converting signalized arterials to a free-flow corridor. The tool can calculate expected user savings experienced with this conversion.

Summary

The aggregate benefit of all agency savings is slightly less than $10 million ($9.7 million in 2020$). Direct agency savings of $9.7 million is a return of $1.4 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 review of the individual project analysis shows a conservative approach was taken in any assumption made in the calculations, and actual savings may be higher. This analysis indicates that INDOT continues to receive return on its research investment which will continue to grow due to the recently passed Federal Infrastructure Bill, authorizing more funding for construction, re-construction, and preservation, thereby impacting more projects.

For 27 projects completed in FY 2020, 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 2020 is shown in Table 3 in Appendix A.

Rolling Average BCA

Annual BCA provide an assessment of INDOT's investment in Research on an annual basis. For the last 5 years, 2016, 2017, 2018, 2019, and 2020 the investment indicates positive returns during the life of individual projects implemented. While a majority of the projects in the last five years, 127 out of 162 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. 29 projects where benefits were quantified, produced significant agency savings and 6 projects produced significant road user cost savings. For the combined years of 2016 through 2020 the Agency and Road User BCA are:

BCA (2016 - 2020) Agency Savings = $351,454,000/$29,651,040 = 12 to 1

BCA (2016 - 2020) Road User Savings = $355,343,799/$29,651,040 = 12 to 1

BCA Rolling Average – 2016-2020

Table 2 compiles the estimated agency savings and road user savings for the last 5 analysis years. BCA averages are calculated from the 5-year totals for research expenditures, estimated agency savings, and road user savings.

Table 2. 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
2020	$7,022,000	$9,727,000	$50,384,000	1.4	7.2	8.6
Totals	$22,629,040	$341,727,000	$304,959,799	12 avg.	12 avg.	24 avg.

Appendix A

Table 3. – Complete Research Project List – FY 2020

No	FY 20 Completed & Implemented SPR Projects	Project Title	Project Cost ($ 1000)	Quantitative Benefits, Qualitative Benefits or Not Successfully Implemented	Project Benefits ($1000)
1	3711	MEPDG Implementation (Validation/Model Calibration/Acceptable Distress Target/IRI Failure Trigger/Thermal Selection/Binder Selection) and climatic data generation	$231	Qualitative	
2	3715	CAI/S-BRITE (Steel Bridge Research, Inspection, Training and Education Engineering Center): Preliminary Engineering Design	$472	Quantitative	**$191**
3	3820	Probability of Detection (POD) Study for Bridge Inspection Related to Steel Bridges	$364	Qualitative	
4	3857	Assessment of Pipe Fill Heights	$273	Quantitative	**$1,375**
5	3916	Scour Protection Determination for Small Culverts	$176	Qualitative	
6	4003	Improving the Quality of Concrete for INDOT Projects	$370	Qualitative	
7	4004	Development of Subgrade Stabilization and Slab Undersealing Solutions for PCC Pavements Restoration and Repairs	$308	Qualitative	
8	4009	Concrete Box Beam Risk Assessment & Mitigation	$290	**Quantitative**	**$4,046**
9	4042	Quantifying Asphalt Pavement Performance Loss Due to Binder Deficiency in the Design Mix	$500	**Qualitative**	
10	4103	Developing the Collision Diagram Builder – Phase II	$130	**Quantitative**	**$194**

11	4107	Subgrade Stabilization Alternatives	$277	**Quantitative**	**$2,654**
12	4109	Improvement of Stiffness and Strength of Backfill Soils through Optimization of Compaction Procedures and Specifications	$200	**Qualitative**	
13	4112	Best Practices for Patching Composite Pavements	$44	**Qualitative**	
14	4114	Performance Balanced Mix Design for Indiana's Asphalt Pavements	$243	**Qualitative**	
15	4115	Investigation of Delta Tc for Implementation in Indiana	$160	**Qualitative**	
16	4116	Investigation of Design Alternatives for the Subbase of Concrete Pavements	$249	**Quantitative**	**$1,080**
17	4126	Implementation of LiDAR-Based Mobile Mapping System for Lane Width Evaluation and Reporting in Work Zones for INDOT Traffic Management	$394	**Qualitative**	
18	4150	Implementation Proposal for Improve Energy Efficiency of Facilities	$58	**Quantitative**	**$71**
19	4154	Continued Support of the Mobile Infrastructure Materials Testing Laboratory	$15	Qualitative	
20	4160	Programming of Road Projects During The Construction Season Considering Network Connectivity	$196	Qualitative	
21	4162	Incorporating Economic Resilience into INDOT's Transportation Decision-making	$249	Qualitative	
22	4205	Connected Vehicle Corridor Deployment and	$275	Qualitative	

		Performance Measures for Assessment			
23	4210	Determining the Optimal Traffic Opening Timing through an in-situ NDT Method for Concrete Early Age Properties Monitoring	$160	Qualitative	
24	4211	Implementing the Superpave 5 Asphalt Mixture Design Method and Refining the INDOT Ndesign Table, Lift Thickness and Mixture Compactability	$93	Qualitative	
25	4216	Statistical Analysis of Safety Improvements and Integration into Project Design Process	$68	Qualitative	
26	4217	Speed Management in Small Cities and Towns - Guidelines for Indiana	$128	Qualitative	
27	4219	SNIP Light	$119	Quantitative	**$22,123 (User Savings)**
28	4226	Cost-Effectiveness of Converting Signalized Arterials to Free-Flow Facilities	$168	Quantitative	**$28,861(User savings)**
29	4228	Developing a Business Ecosystem around Autonomous Vehicle Infrastructure in Indiana	$80	Qualitative	
30	4233	Implementing the Strut-and-Tie Method for the Design of Bridge Components	$90	Qualitative	
31	4305	Development of Automated Incident Detection System Using Existing ATMS CCTV	$108	Qualitative	

32	4306	Back of Queue Warning and Critical Information Delivery to Motorists	$111	Qualitative	
33	4308	Investigation of Strategic Deployment Opportunities for Unmanned Aerial Systems (UAS)	$89	Qualitative	
34	4318	Installation and Maintenance of Raised Pavement Markers at State Transportation Agencies: Synthesis of Current Practices	$49	Qualitative	
35	4319	Cost/Benefit Analysis of Installing Fiber Optics on INDOT Projects	$100	Qualitative	
36	4321	Evaluation of Our Current and Other Available Anti-Icing/De-Icing Products Under Controlled Environmental Conditions to Test Effectiveness	$100	Qualitative	
37	4353	Central HMA Acceptance Lab Process Improvement Project	$35	Quantitative	**$116 (combined with 4448)**
38	4355	Synthesis Study: Facilities (Enterprise Development, Sponsorship/Privatization)	$25	Qualitative	
39	4448	Central HMA Acceptance Lab Process Improvement Implementation Plan (Phase 2)	$25	Quantitative	**combined with 4353**
			$7,022,000		

Total FY 2019 Research spending is $7,022,000.

Appendix B

Individual Project Analysis

SPR-3715 – CAI/S-BRITE (Steel Bridge Research, Inspection, Training, and Education Engineering Center)

Introduction

Purdue University School of Civil Engineering with the assistance of INDOT has established the **C**enter for **A**ging **I**nfrastructure and the **S**teel **B**ridge **R**esearch, **I**nspection, **T**raining, and **E**ducation Center (CAI/S-BRITE). The center is located on the south campus of Purdue University, see Figures 1 and 2.

Figure 1 – Aerial view of S-BRITE

Figure 2 – Bridge Components

The S-BRITE Center is the first resident center of the Center for Aging Infrastructure (CAI). It focuses specifically on the steel bridge sector of our nation's aging infrastructure. The S-BRITE Center Bridge Component Gallery boasts two full span bridges and a number of sections of bridges taken from service. This rare collection of bridge components provides for a unique training ground.[1]

Analysis

S-BRITE center provides INDOT numerous services through its training program, quick response to emergency bridge issues, and a bridge monitoring program.

Currently there are four training classes offered: 1. Design and inspection of steel bridges for fatigue and fracture, 2. High strength structural bolting, 3. Retrofits on selected steel bridge details, and 4. Inspecting steel bridges for fatigue, and welding. These classes are unique in scope and content and are not offered elsewhere[2]. Classes are offered on a rotation basis averaging between two to three annually with an average attendance of 20 with half the attendees INDOT personnel.

The bridge monitoring services are free to INDOT. The type and frequency of these services vary and their value is difficult to quantify.

INDOT acknowledges the center provides many advantages to the agency such as raising awareness and expertise of INDOT bridge inspectors/engineers who could prevent future problems and save bridge repair and retrofit costs.

A ten-state agency pool fund study provides financial resources and participates in the training classes. The Army Corps of Engineers also utilize the training opportunities.

Potential Savings

Savings is quantified from training costs avoided since INDOT personnel are not charged. Training costs for consultants attending the various classes are:

Design of steel bridges for fatigue and fracture -$700

High strength structural bolting - $550

Retrofits on steel bridges- $2,060

Inspecting steel bridges for fatigue and welding-$550

Training savings are calculated on a bi-annual basis due to the four-class rotation is repeated every 2 years. Class attendance has averaged 20 with half (10) from INDOT. Calculated savings for each class is shown below.[3]

Design of steel bridges for fatigue and fracture -	$700 x 10 (INDOT personnel) =	$7,000
High strength structural bolting -	$550 x 10 =	$5,500
Retrofits on steel bridges-	$2,060 x 10 =	$20,060
Inspecting steel bridges for fatigue and welding-	$550 x 10 =	<u>$5,500</u>
Total bi-annual savings for training costs =		$38,060

Projected annual savings for a 10-year period and a corresponding benefit/cost analysis is shown in Table 1.

Table 1. 3715 Cash Flow Analysis

Cost Analysis of bi-annual training cost savings at S-BRITE center

Years	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029**
Research Cost	($472,000)									
Cost avoidance for training at S-BRITE		$38,060	0	$40,378	0	$42,837	0	$45,446	0	$48,214
NPV Savings	$191,543									
Net Savings*	($280,457)									
B/C	0									

*Net savings = NPV Savings – Research cost

** 2029 is the last year since 2030 projected cost avoidance is 0.

Summary

The BC ratio is **0** due to calculated savings is less than the research cost. Even though calculated savings is less the project cost it did save INDOT training costs, estimated at **$191,543**. Other non-quantifiable benefits are free bridge monitoring services, increased awareness and improved expertise of INDOT bridge inspectors/engineers who could prevent future problems resulting in bridge repair and retrofit costs savings.

These numbers are based on the following:

- Research cost for 3715 is $472,000.
- Annual costs and savings are inflated by 3%.
- 3% cost of capital.
- NPV of future costs and benefits based on 2020$.

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] CAI/S-BRITE website: https://engineering.purdue.edu/CAI/SBRITE.

[2] Robert Conner, Jack and Kay Hockema Professor in Civil Engineering and Director of CAI and S-BRITE.

[3] Pamela Stokes, Senior Planner, Purdue Conferences.

Introduction

Underground or buried pipes are drainage structures used to drain surface water along and away from highways and roadways. They come in different sizes and types and depending on roadway geometry and profiles are placed at various depths, or referred to as cover, below the road surface.

Cover depths, minimum or maximum, influence the selection of pipe needed to support the imposed traffic load and soil cover load. This project developed minimum and maximum cover tables by pipe type and size to provide this design information for INDOT engineers and consultants. Tables were developed for pipe types that INDOT normally uses: Reinforced Concrete pipe, Plastic Pipe (HDPE), Plastic Pipe (PVC), Corrugated Steel pipe, Spiral Steel pipe, Weholite pipe, and Polypropylene Pipe (PP)[1].

Tables 1 and 2 are portions of the minimum and maximum cover depth tables developed for reinforced concrete pipe. Developed cover tables will replace current ones in use. These tables replaced previously ones used by the Pipe Industry[2].

Table 1. Reinforced Concrete Pipe Minimum Cover Requirements

D (in.)	Minimum Cover (ft)				
	Type 1				
	Class I	Class II	Class III	Class IV	Class V
12	1	1	1	1	1
15	1	1	1	1	1
18	1	1	1	1	1
21	1	1	1	1	1
24	1	1	1	1	1
27	1	1	1	1	1
30	1	1	1	1	1
33	0.5	0.5	0.5	0.5	0.5
36	0.5	0.5	0.5	0.5	0.5
42	0.5	0.5	0.5	0.5	0.5
48	0.5	0.5	0.5	0.5	0.5

Table 2. Reinforced Concrete Pipe Maximum Cover Requirements

D (in.)	Maximum Cover (ft)				
	Type 1				
	Class I	Class II	Class III	Class IV	Class V
12	14	16	26	38	54
15	14	16	26	38	54
18	14	16	26	38	54
21	14	16	26	38	54
24	14	16	26	38	54
27	14	16	26	38	54
30	14	16	24	38	54
33	14	16	24	38	54
36	14	16	24	36	54
42	14	16	24	36	54
48	12	16	24	36	54

Potential Savings

Developed cover tables provide guidance to prevent overloading drainage pipes. Calculating the impact these tables have on future construction costs is difficult. A failed pipe due to improper cover will have cost and driver consequences as in-place replacement will occur and a detour needed. This is a significant cost. Estimating this cost avoidance by using the new cover tables developed in this project and the frequency of occurrence on future INDOT projects is challenging.

An example of cost avoidance recently occurred on the Ronald Regan Parkway, contract R-31472[3]. A 365-foot-long 77-inch × 121-inch elliptical pipe failed with a cover height of 25.7 feet. Failure was caused by excessive cover depth. The repair cost was $1,375,000.

With new cover tables this cost could have been avoided. This the only contract where cost avoidance data is available to calculate a benefit/cost analysis.

Summary

Cost of research is $273,000. Cost avoidance from one project is **$1,375,000**.

Benefit Cost ratio = $1,375,000/$273,000 = **5.0** due to cost avoidance through the use of updated cover tables produced by this research. The cost avoidance (savings) are from the one project where cost data was available. If additional project savings were quantifiable, the Benefit/Cost ratio would be significantly higher.

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] Assessment of Pipe Fill Heights, SPR-3857, January 2016.

[2] LRFD Fill Height Tables for Concrete Pipe, American Concrete Pipe Association.

[3] Tommy Nantung, Ph.D., PE, Section Manager, Office of Research and Development, INDOT.

SPR-4009 – Concrete Box Beam Risk Assessment & Mitigation

Introduction

Adjacent pre-stressed box beam bridges account for approximately 25% of Indiana's bridge inventory. In fact, over 4,000 of Indiana's bridges are box beams (Figures 1 and 2). Of these 4,000 box beam bridges, 170 are managed by INDOT and the rest are county bridges.

Unfortunately, adjacent box beams have a history of poor long-term performance, including premature deterioration and failures. Leaking joints between box beams allow chloride-laden water to migrate through the superstructure and initiate corrosion. This leads to uncertainty on bridge condition and capacity. This project developed recommendations for the inspection, load-rating, and design of adjacent box beam bridges.

Recommended inspection and load rating procedures provide INDOT and local agencies an improved basis for making bridge preservation and replacement decisions. The cost analysis is based on these improvements from the research.

Figure 1-Box Beam Bridge

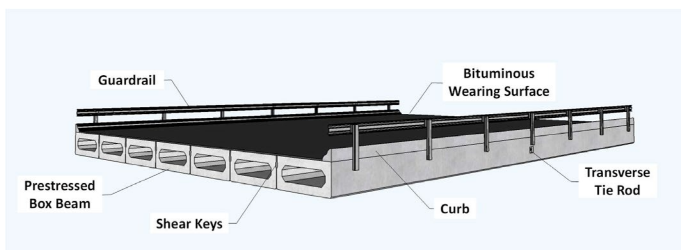


Figure 2 -Typical adjacent box beam bridge

Analysis

Cost analysis uses condition data in INDOT's BIAS (Bridge Inspection Application System) for INDOT's 170 box beam bridges, which INDOT queried[1]. Query results show the highest concentration (80) were built in the 1960s, so the main cluster of box beam bridges are 50 to 60 years old. These bridges are on their second deck overlay.

For the 170 bridges, the average deck area is 710 square feet with average width at 28 feet; the average length is approximately 26 feet, are considered small bridges. These bridges are typically located on non-interstate routes.

Using INDOT's BMS (Bridge Management System), replacement unit cost of $946/square foot, resulting in an average replacement cost of $671,660. Research revealed that damage and condition of these 80 bridges are such that overlays are still possible to extend their life. Whereas beforehand these bridges would be scheduled for replacement.

Cost savings are based on replacement cost avoidance through additional deck overlays. The reasons for using these 80 bridges are BMS forecasts older bridges for replacement and younger bridges for normal preservation activities.

Instead of using deck replacement for all 80 bridges, a conservative approach assumes that half of these bridges (40) will be replaced and the other 40 will have an additional overlay.

Potential Savings

Calculated savings are for INDOT's 170 bridges. Local county bridges number approximately 4,000 so additional savings will occur but are not included in the calculations.

BMS says that each overlay is worth 1/5 of the bridge life or replacement cost.[1] One bridge overlay savings is calculated as $671,660/5 = $134,332. One assumption, all 40 decks will be scheduled for overlay in the 1 year, for analysis purposes that will be in 2022.

Savings are based on delaying replacement through deck overlay. Forty decks are overlaid in 2022, therefore cost savings is 40 x $134,332 = **$5,373,280**. These savings would accrue over a 15-year time period, the expected deck life, making the annual savings $5,373,280/15 = $358,218.

This table shows the cash flow analysis and using Net Present Value (NPV) analysis approach to calculate the Benefit Cost ratio (B/C).

Years	2020	2022	…………………………….	2035
Research Cost	($290,000)			
Annual cost avoidance for replacement through overlay for 40 bridges	$358,218	$358,218		$ 358,218
NPV Savings	$4,046,457			
Net Savings*	$3,756,457			
B/C	13			

*Net savings = NPV Savings – Research cost

Summary

The BC ratio is significant at **13:1** because with improved condition ratings these bridges can be properly repaired and kept in service instead of being replaced. Estimated savings over a 15-year period is **$4,046,457.**

These numbers are based on the following:

- Research cost of $290,000.
- 3% cost of capital.
- NPV of future costs and benefits based on 2020$.

This analysis is only for this project's cost to conduct the research and implementation. In the summary report an overall 2021 benefit cost analysis is based on total program costs.

References

[1] Erich T Hart PE, INDOT Bridge Asset Engineer

SPR-4103 – Collison Diagram Builder: Phase II Corridor Edition

Introduction

The Corridor Collison Diagram Builder (CCDB) has proven to be a useful software tool for investigating safety history and identifying corridor areas for safety improvements. The Office of Traffic Safety is a principal user, but the intent is to provide a tool for any user interested in plotting crash history over an area. Likely users could include planners and scoping engineers concerned with improving the safe operation of roadway corridors[1]. A screen shot of the software tool graphical interface is shown in Figure 1.

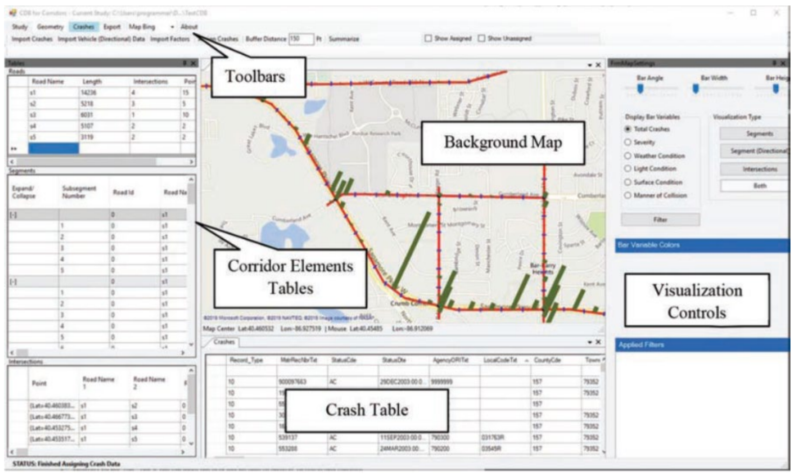


Figure 2-CCDB User Interface

CCDB can visually represent multiyear crash patterns at multiple locations through an aerial view interface. This visual interface saves INDOT safety staff time by understanding where safety hot spots occur while having the ability to see if any infrastructure may be the cause for these crashes or accidents. This is very useful for safety, mobility, and district technical services staff to visualize and display these problem locations and their intensities.

Analysis

Safety improvements will result in reduced crashes lowering the risk of continued property damage, personal injury and fatality impacts and their associated costs; these are difficult to quantify. Because of this difficulty, only the cost savings are calculated for reduced INDOT staff time to perform these analyses. If crash data was quantified, the cost savings would be much higher.

Indiana Local Technical Assistance Program (LTAP) was contacted to determine if CCDB is used at the local agency level[2]. LTAP's safety assistance program is performed through their HELPERS program, Hazard Elimination Program for Existing Roads and Streets, available to all Indiana counties. Currently HELPERS do not utilize CCDB because county road networks are small compared to the INDOT network and these analyses can be performed efficiently through current methods.

Potential Savings

Calculated savings is based on time savings achieved by the Office of Traffic Safety using CCDB. Each analysis performed with CCDB saves approximately $10,000 in staff or consultant time to assemble this information. Office of Traffic Safety performs on average 4 of these annually[1]. This is annual savings of $40,000. INDOT uses a 5-year work plan to schedule projects. Total savings experienced using CCDB during the next 5-year time work period is shown in Table 1.

Table 1. 4103 Cash flow analysis

Years	2020	2021	2022	2023	2024	2025
Research Cost	($130,000)					
CCDB Analysis savings		$ 40,000	$ 41,200	$ 42,436	$ 43,709	$ 45,020
NPV Savings	$ 194,175					
*Net Savings	$ 64,175					
B/C	0.5					

*Net Savings = NPV Savings-Research Cost

Summary

The BC ratio is **0.5:1** due to staff time savings. Estimated savings in staff time for a 5-year period is **$194,175**. On this project the research is yielding a saving of $.50 for each research dollar. If crash data was able to be quantified, the cost savings would be significantly higher.

These numbers are based on the following:

- Research cost of $130,000.
- Annual costs and savings are inflated by 3%.
- 3% cost of capital.
- NPV of future costs and benefits based on 2020$.

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] Michael Holowaty PE, Manager , INDOT Office of Traffic Safety, Traffic Engineering Division

[2] Laura Slusher PE, Traffic Safety Engineer/HELPERS Program Manager Indiana LTAP

SPR-4107 Subgrade Stabilization Alternatives

Introduction

INDOT pavement design is based on the Mechanistic-Empirical Pavement Design Guide (MEPDG) method. This method includes the underlying support level or the subgrade condition and refactors subgrade soils when they are improved through chemical treatment. Chemically treating subgrades, improves this stratum by reducing moisture and temperature effects and improves its stiffness and bearing capacity.

INDOT typically uses Lime Kiln Dust (LKD) and Portland Cement (PC) or their combination to treat subgrades. This project investigated how subgrade soils can be improved by increasing the amount of LKD, PC, and Quick Lime used in treatment. A stronger subgrade will increase pavement life, will increase the in-service pavement performance by reducing the pavement roughness, pavement faulting, pavement fatigue cracks, and will decrease pavement thickness which correlates to savings[1].

Figure 1. Chemically modified subgrade
(courtesy Mintek Resources)

Potential Savings

The basis for calculated savings is reduced pavement thickness. Updating MEPDG design with a stronger subgrade was used on a I-65 project in Tippecanoe county resulting in deceasing pavement thickness by ½". This thinner pavement saved INDOT $5,508 per lane mile which is the cost basis in calculating annual savings[2].

Agency savings is based on lane miles constructed in the future. In 2020, 10.82 lane miles were constructed using this improved subgrade approach. INDOT works off a 5-year construction program, and INDOT pavement design is estimating approximately 100 lane miles a year for the next 5 years[3].

In 2020 the estimated saving is 10.82 (lane miles) * $5,508 = $59,596 (Use $60,000)

For the 1 year in the 5-year program the estimated saving is 100(lane miles) * $5,508 = $550,800

Projected annual savings for a 5-year INDOT work plan and a corresponding benefit/cost analysis is shown in Table 1.

Table 1. 4107 Cash Flow Analysis

Years	2020	2021	2022	2023	2024	2025
Research Cost - 4107	$ (277,000)					
Annual Benefits	$ 60,000	$ 550,800	$567,324	$584,344	$601,874	$619,930
NPV Benefits	$ 2,654,162					
*Net Savings	$ 2,377,162					
B/C	8.6					

*Net Savings = NPV Savings-Research Cost

Summary

The BC ratio is **8.6:1** due to reduced pavement thickness, yielding a saving of $8.60 for each research dollar invested. Estimated savings from a reduced pavement thickness for a 5-year period is **$2,654,162**.

These numbers are based on the following:

- Research cost for this project was $277,000.
- Annual costs and savings are inflated by 3%.
- 3% cost of capital.
- NPV of future costs and benefits based on 2020$.

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] Subgrade Stabilization Alternatives, SPR-4107, Report Number: FHWA/IN/Jtrp-2019/30. DOI 10.5703/1288284317110.

[2] Tommy Nantung, Ph.D., PE, Section Manager, Office of Research and Development, INDOT.

[3] Pankaj G. Patel PE, Pavement Design Engineer, INDOT.

SPR-4116 – Investigation of Design Alternatives for the Subbase of Concrete Pavements

Introduction

Concrete pavement renewal or rehabilitation projects require patching existing pavements. This patching is either partial or full depth. Figure 1 is an image of a full depth concrete patch.

Figure 1. Full Depth Concrete Patch

One outcome of the Research was the recommendation to replace the patch subbase with lean concrete[1]. Lean concrete has lower water level than traditional concrete making it stiffer with a low slump and lower workability. Placing lean concrete is easier and quicker due to the compacting effort required with subbase. Using lean concrete in-lieu of subbase (typically 9" thick) will double the concrete patch life from 6 to 12 years[2].

Analysis

Quantities for full depth concrete patching was obtained from INDOT contracts for the years 2018–2020 and are shown in Table 1[2]. This table has the contract number, contract year, District of the contract, and square yards (SYS) of concrete patching performed. It should be noted that the lean concrete was an alternate option in the contract and was the option used for contracts listed in Table 1. Based on the findings from this study, INDOT is considering requiring lean concrete to be used in lieu of subbase when constructing full depth concrete patches. Consequently, more contracts using the lean concrete will be let, resulting in significant additional savings.

Table 1. Concrete Full Depth Patching (2018–2020)

Contract #	Year	District	Full Depth Concrete Patch Quantity (SYS)
40804	2018	LaPorte	4973
40584	2019	Greenfield	1434
41351	2018	Greenfield	1500
41350	2018	Greenfield	7696
41679	2019	Seymour	535
42652	2020	Crawfordsville	577

Total = 16,715 SYS

Average full depth patching per year for 2018–2020 is 16,715SYS/3 = 5,572 SYS.

A standard INDOT detail of a full depth concrete patch is shown in Figure 2.

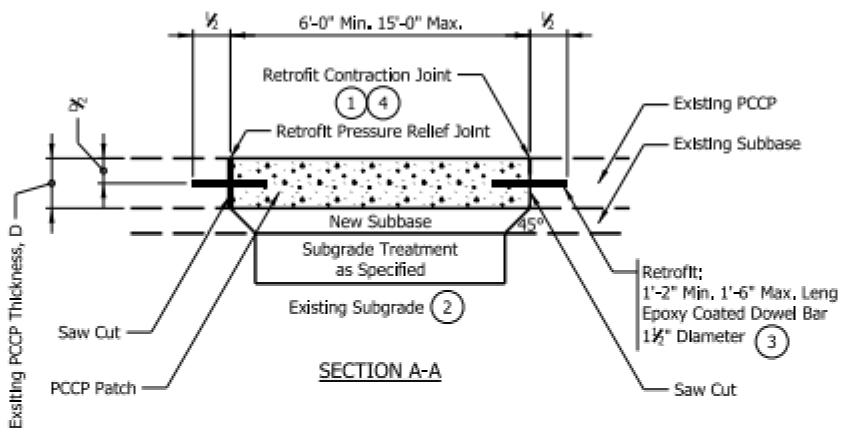


Figure 2. Deep Patch Detail from Contract 42652–Crawfordsville District

Figure 3 illustrates the difference between a full depth patch with subbase or with lean concrete.

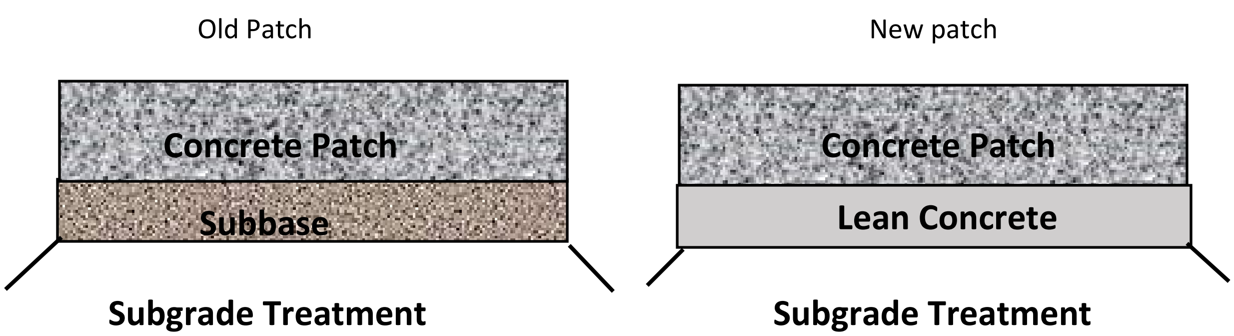


Figure 3. Old versus New Full depth patch

Potential Savings

Savings from the new patch with lean concrete comes by extending the patch life by 6 years, from 6 to 12 years. Using lean concrete instead of subbase makes the patch cost different. The two different patches, illustrated in Figure 3, costs are based on the following INDOT pay items[2]:

Patch concrete = $247.90/SYS

Subbase = $56.72/CYS (Cubic Yards)

Subgrade Treatment = $29.38/SYS

Lean concrete base = $60/SYS

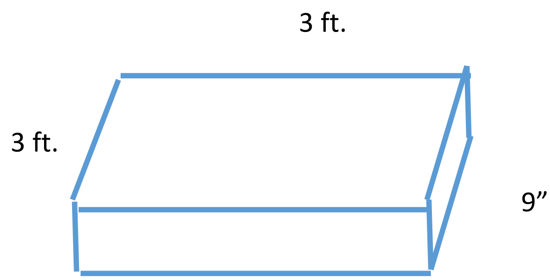
The unit cost for both patch types are calculated in SYS.

<u>Patch Options</u>

Based on a typical INDOT detail the subbase is 9” thick. Converting to SYS cost,

Volume of subbase material in 1 SYS = 3 ft. x 3 ft. x 9”/12” = 6.75 Cubic feet = 0.25 CYS

Subbase cost = 0.25 x $56.72 = $14.18/SYS



Old patch SYS cost = $247.90 + $14.18 + $29.38 (subgrade treatment) = $291.46 SYS

New patch SYS cost = $247.90 + $60 (Lean concrete) + $29.38 = $337.28 SYS

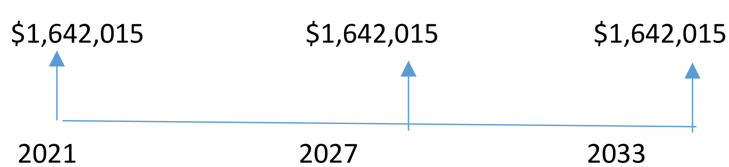
The basis of the benefit cost analysis with the new patch is the elimination of a patch at the 6 year interval for an annual full depth patch quantity of 5,572 SYS.

Old patch annual cost = 5,572 x $291.46 = $1,642,015

New patch annual cost = 5572 x $337.28 = $1,879,324

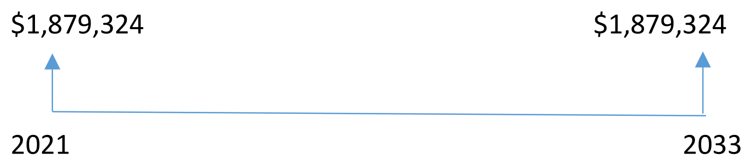
Cash flow diagrams for 1 year of implementation for using the two patch options looks like the below.

Old patch cash flows -



The net present value (NPV) for the cash flows is $4,783,961.

New patch cash flows -



A net present value (NPV) analysis for the cash flows is $3,703,910.

Net savings with the new patch option is $4,783,961 - $3,703,910 = $1,080,051

As noted, this is for 1 year of implementation. As INDOT migrates to requiring and using more lean concrete when constructing full depth concrete patches, significant additional savings will be realized by extending this analysis over multiple contracts and multiple years.

The cost of research is $249,000. Benefit /Cost ratio = $1,080,051/$249,000 = 4.3

Summary

The BC ratio is **4.3:1** due to concrete pavement patch costs savings. Research is yielding a saving of $4.30 for each research dollar. The estimated savings from eliminating one cycle of concrete patching in a 12-year interval is **$1,080,051**.

These numbers are based on the following:

- Research cost for 4116 is $249,000.
- 3% cost of capital.
- NPV of future costs and benefits based on 2020$.

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] Investigation of Design Alternatives for Subbase of Concrete Pavements, SPR-4116. Report Number: FHWA/IN/Jtrp-2020/03. DOI 10.5703/1288284317114.

[2] Pankaj Patel PE, Pavement Design Engineer, Indiana Department of Transportation.

SPR-4150 – Implementation Proposal for Improve Energy Efficiency of Facilities

Introduction

SPR-3946 – Improving Energy Efficiency of Facilities, performed energy assessments of six INDOT facilities, one being Research and Development (R&D) in West Lafayette. The other five were: Crawfordsville administration building, Fall City Sub-district building, Greensburg Unit Building, Frankfort Sub-District Building and Central Materials and Testing building in Indianapolis. Many energy efficiency measures were identified that would reduce annual energy costs.

SPR- 4150 was an implementation project of the SPR-3946 lighting recommendations at the Research and Development facility. Implementation consisted of retrofitting the buildings and parking areas with LED lights. This resulted in energy savings at this facility and is the basis for this cost savings analysis.

Figure 1. INDOT Research and Development Facility in West Lafayette

Analysis

An energy analysis consisted of comparing a 2-year time period before and after the installation of the LED lights. Research and Development facility consists of: a main administration building consisting of R&D staff offices, training rooms, and a garage and shop area; an attached laboratory building; and a detached Accelerated Pavement Testing building.

The LED light project consisted of replacing lighting fixtures within the R&D facility which included office, labs, hallway, outside parking and security lighting. The replacement of inside lighting was performed by INDOT personnel over approximately a two-month time period. Exterior parking lot lighting was installed by a contractor, due to the height of the light poles and requirement for a bucket truck. Interior lighting fixtures within the office, lab and exterior garages were converted to LED through a combination of methods including:

- Fixture removal and replacement,
- Rewiring and removing fluorescent ballasts, and
- Simple bulb replacement, with ballast compatible LED bulbs

Exterior lighting consisted of pole mounted parking lot lighting and building mounted security lighting. These fixtures were all removed and replaced with LED fixtures.

Potential Savings

The cost for the LED retrofit consists of $57,857 for the LED light fixtures and $4,175 for a contractor to install the exterior fixtures. The interior lighting was installed by INDOT personnel. INDOT applied for energy saving incentive to Duke Energy and received $12,615, which offsets the retrofit cost. The net cost for the retrofit is:

LED light fixtures - $57,857
Contractor - $4,175
Duke Energy Incentive - -$12,615
Net LED retrofit cost = $49,867

Savings are based on energy usage comparing a 2-year period before and after LED installation and are shown in Table 1[1].

Table 1. Energy Usage Pre and Post Retrofit

Energy Consumption	Pre-Retrofit (24 months)	Post-Retrofit (24 months)	Savings
Total electrical cost	$99,651	$89,867	$9,784
Average monthly cost	$4,152	$3,744	$408
Total kWh billed	1,108,400	931,800	176,600
Average monthly kWh	46,183	38,825	7,358
Average cost per kWh	$0.0899	$0.0964	-$0.0065*

*Increase in kWh(kilowatts per hour) cost, which is a 7% increase (65/899).

The average monthly savings is $408 with a 7% increase in electrical (kWh) cost over a 2-year period. Annual energy cost saving = $408 x 12 = $4,896.

LED lighting typically has a 15-year life span before replacement is needed[2]; this is the calculated cost saving analysis time period.

Projected annual savings for a 15-year period and a corresponding benefit/cost analysis is shown in Table 2 (truncated for space reasons).

Table 2. 4150 Cash Flow Analysis

Years	2021	2022	2023	2024	2025	2026	2027	2036
Research Cost	$ (58,000)							
LED Retrofit cost	$ (49,867)							
Annual Energy Savings	$	$4,896	$5,043	$5,194	$ 5,350	$5,510	$ 5,676	$7,406
NPV Savings	$71,301							
Net Savings (Savings-retrofit cost-research cost)	($36,566)							
B/C	0							

Summary

The BC ratio is less than **0** due to net savings (energy savings – retrofit cost) is less than the research cost. Even though calculated savings is less the project cost it did save INDOT energy cost. The estimated savings over a 15-year time period of **$71,301** is at one INDOT facility. Expand this conversion to other facilities, similar to those evaluated in SPR-3946, and INDOT will experience significant savings on energy costs.

These numbers are based on the following:

- Research cost for 4150 is $58,000.
- Annual costs and savings are inflated by 3%.
- 3% cost of capital.
- NPV of future costs and benefits based on 2020$.

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] Implementation of Energy Efficiency Improvements for INDOT Research and Development Facilities, Timothy Wells, SPR-4150 Final Report.

[2] Timothy Wells, P.E., Section Manager, INDOT Research and Development.

SPR-4219 SNIP Light

Introduction

The Safety Needs Identification Program, Light version (SNIP Light) is a tool developed by the Center for Road Safety (CRS) at Purdue University. It is the latest version with predecessors SNIP and SNIP2 and is a software tool for identifying roads and areas that require attention for possible safety improvements. SNIP Light supports the following activities: 1. The identification of road segments and intersections that exhibit excessive number of crashes, cost of crashes or proportions of crashes of a type defined by the user; and 2. Visualization of the individual road elements on digital maps[1].

SNIP has been a key tool used to conduct the annual Network Safety Screening (NSS) process that INDOT Office of Traffic Safety (OTS) conducts with the six INDOT District Traffic Engineering Offices in order to identify intersections and roadway segments with elevated risk for future crashes.

Potential Savings

The SNIP tool improves the process of discovering where OTS choses to conduct Road Safety Assessments by producing a ranked list of proposed locations with elevated safety risk for future crashes. After Road Safety Assessment investigations are completed, these proposed projects are then prioritized giving OTS the ability to select for design and construction under the INDOT Asset Management Program where the yearly budget for the safety program is approximately $60 million. SNIP Light's value to OTS is the optimization of this annual budget in selecting safety projects[2].

As part of OTS annual report to FHWA, OTS compares safety performance in terms of numbers of crashes at various severities for a period of 3 years before the projects were constructed to a 3-year period after these projects are completed[2]. The performance results of the constructed safety projects result in reduction in the number of total crash events. The cumulative results are reported by severity level for the years 2015–2017 of safety projects that were constructed and have been analyzed for performance. The use of SNIP allows these results in combination with other actions to mitigate crash occurrences. Since these projects are selected using SNIP some of these benefits can be attributed to its use. OTC suggests that 10% of these reductions occur because of SNIP's use in effectively selecting projects[2]. Table 1 shows the reduced number of crash types for the 3-year period following the construction of the safety improvement projects (SIP).

Table 1. Number of reduced crashes by crash type

Reduction in number of crashes by category	PDO*	Fatal	Injury	Total	Number of Projects
2015	16,768	56	12,901	29,725	49
2016	18,764	161	15,558	34,483	55
2017	28,610	62	14,339	43,011	96
Average	21,381	93	14,266	35,740	67

*Property Damage Only

Table 1 shows the reduction in crashes for a 3-year period before the completion of SIP projects compared to a 3-year period after SIP projects. For example, in 2015 there were 49 SIP projects performed resulting in crash reduction numbers for the time period 2016–2018: Property Damage Only (PDO) – 16,768, fatalities – 56, and Injury 12,901. The same type of numbers is reported for the years 2016 and 2017. Since the numbers vary between the 3 years an average is calculated. The average numbers are the reduction in each crash category due to SIP between 2015-2017.

Crash reductions are traveling public savings or user savings, not agency savings. A reduction in PDO is savings in repairs to vehicles and private or public property damage. A fatality is a value associated with that loss. Injuries are costs associated with medical and follow-up care. The below Tables 2 and 3 are crash costs typically experienced with each type according to Road Hazard Analysis Tool (RoadHAT) software versions 3 and 4. RoadHAT is a software developed by CRS and used by OTS. These costs are lower than what Federal Highway Administration uses so they can be considered conservative. RoadHAT 3 crash costs were developed in 2012 and are lower than RoadHAT 4 costs, and these are used in road user cost savings estimated from using SNIP.

Table 2. RoadHAT 4 Crash Costs

Crash Costs per Event Using RoadHAT 4 **	PDO	Fatal	Injury**	Total
Cost by Severity	$35,600	$1,794,400	$380,400	$2,210,400
Total Cost Savings	$761,163,600	$166,879,200	$5,426,786,400	$6,354,829,200

** Cost from RoadHAT 4 crash cost matrix were calculated using 2019 data that includes medical and repair cost plus an assessment of lifetime perceived value to user for avoiding the event.

Estimated road user savings from average crash reductions for the SIP projects completed during 2015–2017 calculated and shown in Table 1 and using RoadHAT 3 crash costs is shown in Table 3.

Table 3. RoadHAT 3 Crash Costs

Crash Costs per Event Using RoadHAT 3***	PDO	Fatal	Injury**	Total
Cost by Severity	$6,800	$281,200	$34,500	$610,500
Total Cost Savings	$145,390,800	$26,151,600	$492,177,000	$663,719,400

***RoadHAT 3 crash cost for project analysis in the years 2015,2016 and 2017.

**** Costs for fatal and injury events are based on 2012 data for medical and repair costs only and do not reflect value to users.

OTS estimates that using SNIP can be attributed to 10% of these savings which are over a 3-year period. Therefore, annual savings for these crash types from SNIP are shown below.

PDO - $145,390,800/3 years * 0.1(10%) = $4,846,360

Fatal - $26,151,600/3 *0.1 = $871,720

Injury - $492,177,000/3 * 0.1 = $16,405,900

Total annual user savings from using SNIP = $4,846,360+$871,720+$16,405,900 = **$22,123,980**

Overall annual savings for the SIP program is $221,239,800. This is shown in Table 3 total of $663,719,400 (3-year total)/3 = $221,239,800. The SIP is reducing property damage, saving lives, and reducing injuries for Indiana drivers.

The calculated benefit/cost ratio for SNIP is based on 3 years of SNIP projects (2015–2017) because comparison data is available and is the most current since after data was collected in the last year, 2020. The cost of Research was $119,000.

Annual Benefit/Cost ratio = $22,123,980/ $119,000 = **186** for users of the INDOT network.

Summary

The BC ratio is **186:1** due to reduced crashes and is user not agency savings. The research yields a saving of $186 for each research dollar invested.

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] SNIP Light User Manual, SPR-4219, Report Number: FHWA/IN/Jtrp-2019/26. DOI 10.5703/1288284317136.

[2] Michael Holowaty PE, Manager, INDOT Office of Traffic Safety, Traffic Engineering Division.

SPR-4226 – Cost Effectiveness of Converting Signalized Arterials to Free-Flow Facilities

Introduction

This study examined the economic feasibility of converting an existing signalized four-lane divided highway into a free flow corridor, where signalized intersections are removed and redesigned as Reduced Conflict intersections (RCI), or interchanges, or J-turns (Figure 1), or a two-way stop control (TWSC) intersection[1].

Figure 1. INDOT J Turn Intersection

A corridor conversion has costs for INDOT and benefits for users. INDOT must spend construction dollars for these upgrades compared to user savings through improved safety, mobility and reduced congestion. These costs and benefits are sensitive to traffic volume, corridor length, and the distinction of agency cost savings versus user savings.

The research developed a spreadsheet program to be used as a decision support tool for corridor upgrade studies. This tool gives the user ability to assign weights to agency costs and user savings and to adjust factors that influence these decisions.

In the 2019-2020 time period, this decision support tool has been invaluable to INDOT in evaluating, confirming, and defending both corridor-level and site or intersection specific traffic control strategies. Two corridors, one a 60 mile and the other 100 miles, used this tool in their evaluations.

The intent of the spreadsheet program is to evaluate free-flow and freeway alternatives considering safety improvements with known conversion costs for the corridor. The program evaluates the corridor intersections and produces an equivalent agency user cost for the free-flow and freeway treatments. Overall agency safety cost savings can be calculated by comparing the most-cost effective to the least cost-effective option.

The primary user of this study is the Corridor Development Office (CDO) of the Traffic Engineering Division[1].

Potential Savings

In the final report, a Life-Cycle Cost Analysis (LCA) per corridor intersection type was performed. The analysis considers construction and maintenance costs for the different types of corridor improvements and estimated user savings from making these improvements. A total life cycle (20 years) cost was converted to equivalent uniform annual cost (EUAC) for the options Signalized (Keep corridor as is), TWSC, J-turn, and Interchange. Figure 2 shows this EUAC comparison in chart form developed for the final report[1].

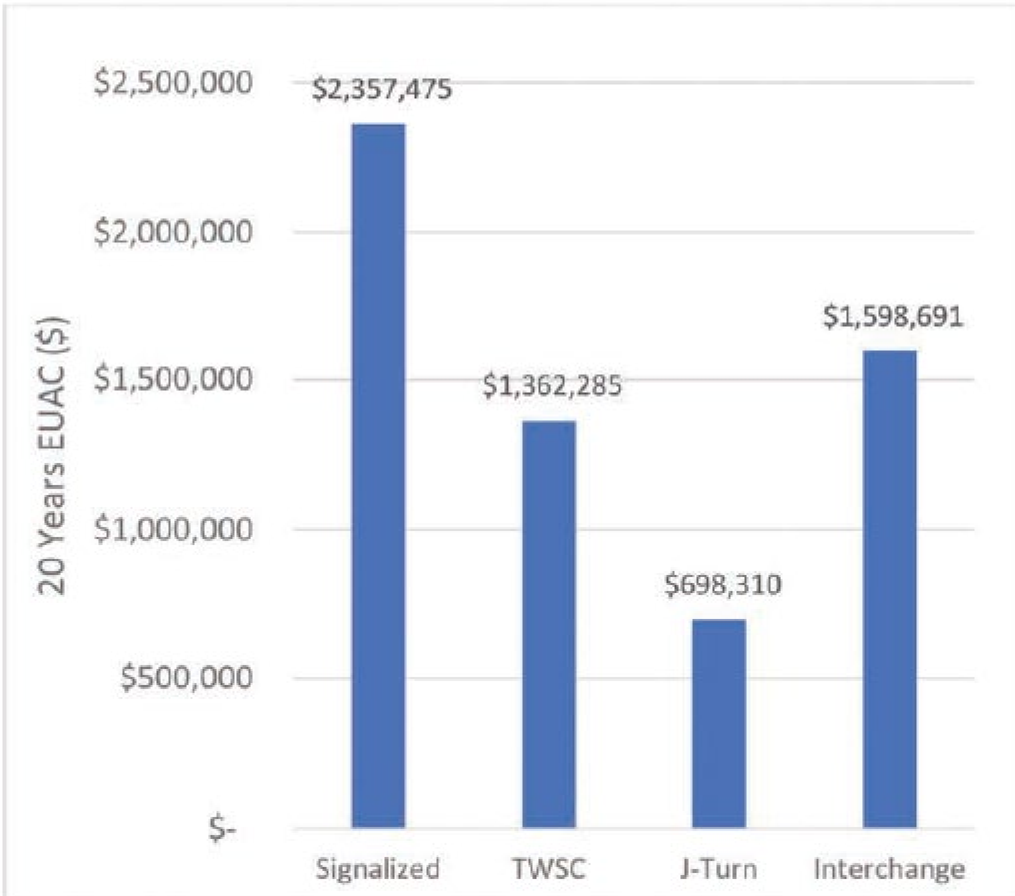


Figure 2. EUAC (20 years) by intersection type

The signalized option is keeping the intersection as is, is considerably higher than the other three options. Below is the EUAC cost saving differences:

Signalized vs. TWSC - $2,357,475 - $1,362,285 = $995,190

Signalized vs. J-Turn - $2,357,475 - $698,310 = $1,659,165

Signalized vs. Interchange - $2,357,475 - $1,598,691 = $758,784

All three intersection options have lower user costs when compared to a signalized one.

CDO performed a life-cycle (20 years) user cost saving analysis for multiple corridors and is summarized in Table 1[2]. Two corridor types are shown, Rural and Urban. Estimated corridor savings are based on an average number of intersections that have occurred on past INDOT conversion projects.

Table 1.

	Rural Setting	Urban/Rural Setting
Total Corridor Savings	$28,681,060	$91,663,032
Per Intersection Savings	$1,195,044	$1,833,261

Both researchers and the CDO independently determined that user savings will occur by converting signalized arterials to free-flowing ones, regardless of the intersection types built. CDO has not reached design development of a corridor because of research implementation as yet, but there will be in the near future[2].

To put user savings in terms of a benefit/cost ratio is difficult for this project as it is dependent on to be determined corridors, their size, type, and number of intersections.

Summary

Corridor conversion savings are predicted and estimated for a 20-year life. These vary by intersection and corridor types.

Intersection savings vary from $758,784 to $1,659,165 each. Corridor savings from $28,681,060 to $91,663,032.

Cost of the research was $168,000.

Currently no possible corridors have reached design stage but CDO is expecting this to occur[1]. For benefit cost analysis a conservative approach is to use a rural corridor user cost savings of **$28,681,060** making the benefit/cost ratio = $28,681,060/$168,000 = **171**.

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] Cost-Effectiveness of Converting Signalized Arterials to Free-Flow Facilities, SPR-4226, Report Number: FHWA/IN/Jtrp-2019/18. DOI 10.5703/1288284317079.

[2] Daniel McCoy PE, Director of Traffic Engineering, INDOT.

SPR-4353 and 4448 – Central HMA Acceptance Lab Process Improvement and Implementation

Introduction

The Indiana Department of Transportation (INDOT) Central Hot Mix Asphalt (HMA) Acceptance lab (Figure 1) is located at the Office of Materials Management (OMM) Facility in Indianapolis. The lab conducts testing of HMA samples from INDOT's Crawfordsville and Greenfield Districts as well as appeals samples from the other four INDOT Districts. SPR-4353 was performed to improve the work processes, organization, and efficiencies of this lab. Suggested implementation predicted a reduced turnaround time for sample tests from 6 days to 4 days. SPR-4448 performed this implementation which resulted in expected time savings and a reduction in sample re-tests, both are the basis for cost savings.

Figure 1

Analysis

SPR-4353 revealed that four issues were affecting productivity[1]:

1. Lack of a structured sample scheduling system.
2. Lack of capacity to meet peak demand.
3. Lack of throughput with the extraction operation.
4. Not getting results the same day testing is completed.

Implementation focused on these four issues generated the following changes to the lab work processes: a work order routing system; use of a resource vs. demand model to facilitate overtime planning; adjust the schedules of lab staff to be able to report end-of-the day test results; and establish a performance for schedule compliance.

Potential Savings

Savings come from two lab improvements; reduced personnel time to process tests and a reduction in re-tests or testing error results. The following lab data was provided by the OMM[2].

Number of samples tested by year:

2018: 1347

2019: 1867

2020: <u>1595</u>
4809 - 3 year total, Average per year = 4809/3 = 1603

Technician cost per test = $142, technician hourly labor rate = $31.50

Estimated number of test errors

Prior to research implementation = 10%

After research implementation = 2%

Results in an 8% reduction in sample retests

Paperwork time savings

Prior to research implementation paperwork time/sample = 10 minutes

After research implementation paperwork time/sample = 3 minutes

Time savings per sample is 10-3 = 7 minutes

Results in cost savings/sample from technician time = 7/60 * $31.50 = $3.67 per sample

<u>Total annual savings</u>

Annual lab savings come from paperwork time savings and a reduction in retests.

Paperwork time savings = $3.67 * 1603 (average number of samples) = $5,883

Retesting savings, Number of reduced retests = 8% * 1603 (average number of samples) = 128 tests

Retest savings = 128 * $142 (technician cost per test) = $18,176

Total estimated annual savings = $5,883 + $18,176 = $24,059, say $24,000.

INDOT uses a 5-year work plan to schedule projects. The estimated number of annual samples is dependent on the number asphalt paving projects. A conservative number is the average used in the above calculations, but this number will likely increase with the passing of a Federal Infrastructure Bill which will generate more savings resulting from this research. Projected annual savings for a 5-year work plan period and a corresponding benefit/cost analysis is shown in Table 1.

Table 1. 4353 and 4448 Cash Flow Analysis

Years	2020	2021	2022	2023	2024	2025
Research Cost - 4353 & 4448	$ (60,000)					
Annual savings		$ 24,000	$ 24,720	$ 25,462	$ 26,225	$ 27,012
NPV Savings	$ 116,505					
*Net Savings	$ 56,505					
B/C	1.9					

*Net Savings = NPV Savings-Research cost

Summary

The BC ratio is **1.9:1** due to lab staff time savings and a reduction in retests. Research is yielding a saving of $1.90 for each research dollar. The estimated savings from paperwork time and reduced retests for a five-year period is **$116,505**.

These numbers are based on the following:

- Research cost for 4353 and 4448 is $60,000.
- Annual costs and savings are inflated by 3%.
- 3% cost of capital.
- NPV of future costs and benefits based on 2020$.

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] Central HMA Acceptance Lab Process Improvement Implementation Plan Project Final Report, SPR-4448, Report Number: FHWA/IN/Jtrp-2020/14. DOI 10.5703/1288284317130.

[2] Matt Beeson PE, Director of Materials and Tests, INDOT Office of Material Management.

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. (2021). *INDOT research program benefit cost analysis—Return on investment for projects completed in FY 2020* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2021/35). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284317265