

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 2018



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**INDOT Research Program Benefit Cost Analysis—Return on Investment
for Projects Completed in FY 2018**

(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

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Research Impacting the INDOT Strategic Plan

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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 2018. 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 2018 analysis is completed in calendar 2019. 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. Qualitative benefits are highlighted in the companion annual IMPACT report (<https://www.in.gov/indot/files/Research Program Impact Report.pdf>).

In 2019, 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. Mapping of ongoing research projects to the Strategic Plan revealed 99% of the projects directly impact the Strategic Plan, Strategic Objectives. Going forward, 33% of new 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 2018 completed projects were reviewed to determine if they were a viable candidate 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 only SPR-3832 reported RUC and SC savings. A separate B/C ratio is calculated for Agency Savings and Safety/RUC Savings. As Safety and RUC savings are often related, these savings were combined into the same category.

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 15-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 2018 dollars by combining costs and benefit cash flows. Individual project analyses are included in the Appendix. Backup documentation describing calculations and analysis for qualifying 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 the Appendix. 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.
- **Not Successfully Implemented** - For various reasons the project outcomes could not be currently implemented. Common reasons are management, logistical, technical, or legal issues.

Individual Project Analysis

Table 1 is the list of the three projects where benefits (NPV 2018\$ - NPV of future cash flows in 2018 dollars) could be quantified and their individual analysis is found in the Appendix. Table 4, in the Appendix, is a complete list of all 22 projects completed in FY 2018.

Table 1. Quantitative Benefits Project List

No	FY 18 Completed & Implemented SPR Projects	Title	Project Cost (\$1000)	Benefit Type	Analysis Period	NPV Project Benefit (\$1000) 2018\$
1	3832	Friction Surface Treatment Selection: Aggregate Properties, Surface Characteristics, Alternative Treatments, and Safety Effects	\$95	Quantitative(User Savings)	5 Years	\$2,696
2	3903	Fog Seal Performance on Asphalt Mixture Longitudinal Joints	\$120	Quantitative (Agency Savings)	15 Years	\$34,029
3	4156	Capital Program Cost Optimization through Contract Aggregation Process	\$98	Quantitative (Agency Savings)	5 Years	\$5,881

Total Benefits \$42,606,000
Agency Benefits \$39,910,000
Road User Benefits \$ 2,696,000

Two of the projects (3832 and 4156) have a five-year analysis period and the third (3903) 15 years, one with road user savings (3832) and the other two (3903 and 4156) producing agency savings. Project 3832 evaluated long-term friction improvement for different pavement preservation treatments that resulted in reduced crashes. Project 3903 predicts that fog sealing the longitudinal joint every five years on asphalt pavements will eliminate one joint replacement during a 15 year period resulting in reduced maintenance costs. Project 4156 evaluated unit cost data that indicates bundling certain project types generates lower costs for bridge projects, traffic, miscellaneous, and smaller structure work.

Agency Savings

The total quantifiable savings from the two projects resulting in agency savings, during their analysis or impact period, was calculated at \$39,910,000 (in 2018\$). The total research program cost in FY 2018 was \$3,927,000. Therefore, the agency savings BCA for FY 2018 is: $\$39,910,000/\$3,927,000 = 10$, or 10 dollars in agency savings for every research dollar expended.

User Savings

The total quantifiable savings from the one project (3832) resulting in safety/RUC savings, during the analysis or impact period was calculated at \$2,696,441 (in 2018\$). The total research program cost in FY 2018 was \$3,927,000. Therefore, the safety/RUC savings BCA for FY 2018 is: $\$2,696,441/\$3,927,000 = 0.7$, or 70 cents in safety/RUC savings to our customers for every research dollar expended.

A table for each savings category was created, two projects cash flows classified as Agency Savings (Table 2) and one project (3832) produced RUC Savings (Table 3). A condensed version of the tables are shown. The expanded version of each table is included in the Appendix with the project write-ups.

Table 2. Agency Savings Projects

Project Description	FY2018	FY2019	FY2020	FY2021	FY2022
3903 – Annual Benefit (15 Year impact)*	0	0	0	0	0
Research and Implementation cost	-120,000	0	0	0	-3,612,568
Net Benefit	-120,000	321,875	331,531	341,477	351,722
NPV FY 2018	34,029,373				
4156- Annual Benefit (5 year impact)*#	-\$98,000				
Research and Implementation cost	\$1,305,000	\$1,305,000	\$1,305,000	\$1,305,000	\$1,305,000
Net Benefit	\$1,207,000	\$1,305,000	\$1,305,000	\$1,305,000	\$1,305,000
NPV FY 2018	\$5,881,372				
NPV Total 2018	\$39,910,000				
Research Program Cost	\$3,927,000				
Benefit Cost Ratio - ROI	10				
Report Date	12/31/2019				
* Based on 15 year asphalt rehab program ** Based on 5 Year INDOT work program					
The first 5 years of the 15-year cash flows are shown and first fog seal treatment starts in year 5. See supplementary file for the additional cash flows. Savings come from eliminating joint replacement and that starts in year 7.					

Table 3. Safety/RUC Savings Project - 3832

Project Benefits and Costs \$	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Research Cost	-\$95,000					-\$95,000	
Annual User Cost Benefit	\$642,075	\$600,000	\$600,000	\$600,000	\$600,000	\$642,075	\$600,000
Net Benefit-Cost	\$547,075	\$600,000	\$600,000	\$600,000	\$600,000	\$547,075	\$600,000
NPV 2018	\$2,696,441					\$2,696,441	
Research Program Costs	\$3,927,000						
Benefit Cost Ratio - ROI	0.7						

Cost Savings Summary

As previously noted, two projects produce quantifiable benefits that resulted in agency savings. One project produced road user cost (RUC) savings. A summary of these cost savings are described below.

3903 - Benefit cost analysis period is 15 years based on asphalt pavement life period. Fog seals will occur at the five and ten year time intervals, eliminating a joint replacement that typically occurs at the 7 year time interval. The analysis considers two fog seal treatments as investments to eliminate the cost for a joint replacement.

4156 - Annual savings is based on the difference between engineer’s estimates and award amounts. A lower bound on the number of projects annually bundled is used so actual savings could vary with this approach. The researchers evaluated unit cost differences between unbundled and bundled projects to establish project characteristics (e.g. type, size, number of projects, activities) to identify how to bundle projects. To determine overall project savings through unit costs comparisons and analysis is difficult because of variability in the factors that influence unit costs between projects. The approach taken in comparing engineer estimates and award amounts has been used by INDOT to measure bundling effectiveness.

3832- The implementation of project findings has already produced verified road user savings validated through a 2019 summer study on the effectiveness of high friction surface treatments. The cost benefits are based on a five-year safety improvement program adopted by INDOT’s Office of Traffic Safety.

Summary

The aggregate benefit of all project savings is significant, resulting in more than \$40 million in savings over the projected service lives (in 2018\$). The aggregate benefit combines expected agency savings and expected savings for users of the INDOT network. Direct agency savings of over \$39 million is a return of \$10 for every \$1 spent in research. For users, the return is 0.7 to 1 through lower user costs. The basis for the numbers used in the BCA came from INDOT personnel and researchers. These are described in detail in the individual analyses located in the Appendix.

A ROI of 10 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, and actual savings may be higher. This analysis indicates that INDOT is receiving 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 19 projects completed in FY 2018, quantifiable benefits could not be calculated or data was not available, however other qualitative benefits resulted that brought significant value to the Department and are highlighted in the annual IMPACT report. A complete listing of all research projects completed in FY 2018 is shown in Table 4 in the Appendix.

Rolling Average BCA

Annual BCA provide an assessment of INDOT’s investment in Research on an annual basis. For the last three years, 2016, 2017, and 2018 the investment indicates positive returns during the life of individual projects implemented. The majority of the projects in the last three years, 67 out of 88 total research projects benefits are not quantifiable due to the unavailability of quantifiable data, but provide documented qualitative benefits. 17 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 2018 the Agency and Road User BCA are:

BCA (2016 - 2018) Agency Savings = \$306,059,000/\$14,315,000 = 21 to 1

BCA (2016 - 2018) User Savings = \$304,686,799/\$14,315,000 = 21 to 1

BCA Rolling Average – 2016-2018

Year	Research Investment	Agency Savings	User Savings
2016	\$6,264,000	\$76,481,000	\$290,743,799
2017	\$4,124,000	\$189,668,000	\$11,247,000
2018	\$3,927,000	\$39,910,000	\$2,696,000
Totals	\$14,315,000	\$306,059,000	\$304,686,799

Appendix

Table 4. – Complete Research Project List – FY 2018

No	FY 18 Completed & Implemented SPR Projects	Project Title	Project Cost (\$ 1000)	Quantitative Benefits, Qualitative Benefits or Not Successfully Implemented	Project Benefits (\$1000)
1	3307	Efficient Pavement Thickness Design for Indiana	\$238	Qualitative	0
2	3407	Pile Driving Analysis for Pile Design and Quality Assurance	\$240	Qualitative	0
3	3709	Intelligent Compaction of Soils-Data Interpretation and Role in QA/QC Specifications	\$213	Qualitative	0
4	3710	Correlation between Resilience Modulus (MR) of Soil, Light Weight Deflectometer, and Falling Weight Deflectometer (FWD)	\$519	Qualitative	0
5	3803	Integration and Evaluation of Automated Pavement Data	\$200	No Implementation	0
6	3816	Bridge Load Rating	\$251	Qualitative	0
7	3827	Strategic Scheduling of Infrastructure Maintenance and Rehabilitation	\$335	Qualitative	0
8	3832	Friction Surface Treatment Selection: Aggregate Properties, Surface Characteristics, Alternative Treatments, and Safety Effects	\$95	Quantitative	
9	3903	Fog Seal Performance on Asphalt Mixture Longitudinal Joints	\$120	Quantitative	0

10	3906	Proof Rolling of Foundation Soil and Prepared Subgrade During Construction	\$125	Qualitative	0
11	3911	Evaluating the Impacts of Time-of-Day Tolling on Indiana Roadways	\$239	Qualitative	0
12	3913	The Assessment of Legal and Proposed New Permit Loads on Bridge Rating and Posting Policies to Comply with the Latest AASHTO and MBE Guidelines	\$264	Qualitative	10,930
13	4006	Automated (Image Based) Collection and Measurements for Construction Pay Items	\$210	Qualitative	0
14	4007	Implementation of Risk-Based Bridge Inspection	4007	No Implementation	0
15	4012	Effects of Bridge Surface & Pavement Maintenance Activities on Asset Rating	\$150	Qualitative	0
16	4015	Systemic Safety Countermeasures Decision Guide and Updating the Indiana Crash Reduction Factors	\$155	Qualitative	0
17	4016	Assessment of Alternative Rumble Stripe Construction	\$110	Qualitative	0
18	4044	Evaluating Opportunities to Enhance Hoosier State Train Ridership through a Survey of Riders' Opinions &	\$124	Qualitative	0

		Assessment of Access to the Line			
19	4156	Capital Program Cost Optimization through Contract Aggregation Process	\$98	Quantitative	0
20	4164	Blast Furnace Slag Usage and Guidance for Indiana	\$50	Qualitative	0
21	4167	Synthesis of Autonomous Vehicle Legislation	\$27	Qualitative	0
22	4204	Updating Driveway and General Permit Manuals	\$74	Qualitative	0

\$3,927

Total FY 2018 Research spending is \$3,927,000.

Individual Project Analysis

SPR-3832: Friction Surface Treatment Selection: Aggregate Properties, Surface Characteristics, Alternative Treatments, and Safety Effects

Introduction

This project evaluated long-term friction performance for pavement preservation treatments chip seal, microsurfacing, ultrathin bonded wearing course, and diamond grinding. Crash statistics were evaluated with possible implications to poor friction. This project produced a friction comparison and friction degradation for different surfaces and pavement treatments.

Project results was the impetus for INDOT to implement a new safety improvement program. Implementation resulted in three construction projects that included 22 curves and one approach lane at an intersection where high friction surface treatment (HFST) was applied. Applying high surface friction in these areas did reduce crashes on these roadway segments determined by an INDOT intern study performed during summer 2019.¹ INDOT estimates that into the future annually five curves and an approach lane will have a HFST applied.²

Analysis

ROI analysis is based on estimated crash reductions from applying HFST to the three construction projects described above and future projects directed by the INDOT Office of Traffic Safety

The Office of Traffic Safety uses the RoadHAT software to determine user cost savings through improved safety and corresponding crash reductions. RoadHAT is developed by the Center for Road Safety at Purdue University and assists agencies in evaluating safety at intersections and segments, developing collision and condition diagrams, organizing site investigations, and estimating the economic effectiveness of considered safety improvements.³

ROI analysis is based on estimated user savings from crash reductions experienced on the first project and on future projects which are programmed by the Office of Traffic Safety.

Calculations

The project developed functions for calculating crash reductions per mile by road type; Interstate, State highway, and US highway. Each function calculation is based on friction improvement with an HFST application. The equations developed:

Interstate: $Ln(y_i) = 0.5579 - 0.0456x_i$
 State highway: $Ln(y_i) = 0.4378 - 0.0813x_i$
 US highway: $Ln(y_i) = 1.3781 - 0.1507x_i$

Where y_i is the predicted number of crash per mile per year and x_i is the friction category. Friction categories were developed for friction values ranges and used in the above functions. Friction value ranges before and after treatment typically vary from 30 (category 7) to 70 (category 15). For clarity reasons the next table is a sample of friction categories.

Friction Category	1	...5	6	7	8...	15	16	...20
Friction number range	0-5	20 -25	25-30	30-35	35-40	70-75	75-80	95-100

Based on field measurements from past projects and erring on the conservative side, before and after HFST applications, friction categories go from 7 to a 15. Solving the three functions using these friction categories produces the following crash reductions per mile.

Interstate: $\exp(0.5799-0.0456*7) - \exp(0.5799-0.0456*15) = 0.396$
 State highway: $\exp(0.4378-0.0813*7) - \exp(0.4378-0.0813*15) = 0.419$
 US highway: $\exp(1.3781-0.1507*7) - \exp(1,3781-0.1507*15) = 0.968$

The percentages for fatal, non-fatal injury, and property damage crashes are 0.4%, 15.6%, and 84% respectively in 2017⁵. Using the Federal Highway Administration report⁶ the safety benefit per mile for each road type is calculated below.

Interstate: $0.396*0.4%*\$1,163,947^6 + 0.396*15.6%*\$335,832^6 + 0.396*84%*\$12,108 = \$43,208$ per mile per year

State highway : $0.419*0.4%*\$1,163,947^6 + 0.419*15.6%*\$335,832^6 + 0.419*84%*\$12,108 = \$45,718$ per mile per year

US highway: $0.968 \times 0.4\% \times \$1,163,947^6 + 0.968 \times 15.6\% \times \$335,832^6 + 0.968 \times 84\% \times \$12,108 = \$105,620$ per mile per year

2018 Projects

For the 2018 projects the annual saving calculation using the above method would be:

A total of 25 sites where HFST was deployed. For 24 of the sites the HFST applications took place on opposing travel lanes (2) with an average length of about 1200 feet/lane

There were 5 applications on US Highways: $1200 \text{ feet} \times 2 \text{ lanes} \times 5 \text{ sites} = 12000 \text{ feet}/5280 \text{ feet/mile} = 2.27 \text{ miles}$

The remaining sites were on State highways:

$1200 \text{ feet} \times 2 \text{ lanes} \times 19 \text{ sites} = 45,600 \text{ feet}$, plus one left turn lane with a 900 foot segment = $46,500 \text{ feet}/5280 \text{ feet/mile} = 8.8 \text{ miles}$.

User cost savings for 2018 projects:

US Highway $\$45,718/\text{mile} \times 8.8 \text{ miles} = \$402,318$

State Roads $\$105,620 \times 2.27 \text{ miles} = \$239,757$

Total savings = $\$402,318 + \$239,757 = \$642,075$

Potential Savings

Below is the benefit cost analysis for a five-year work plan with expected user annual savings from applying HFST.⁷ The analysis is based on a known five-year work plan (2017-2022) and a Safety Improvement program utilizing HFST.

Project Benefits and Costs (\$)	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Research Cost	-\$95,000				
Estimated Annual User Savings	\$642,075	\$600,000	\$600,000	\$600,000	\$600,000
Net Benefit-Cost	\$547,075	\$600,000	\$600,000	\$600,000	\$600,000
NPV	\$2,696,441				
Benefits Cost Ratio	28				

Summary

The benefit cost ratio for this project is 28 to 1. This number is based on the following:

- Research cost of \$95,000.
- 3% cost of capital and inflation.
- NPV of future costs and benefits brought to 2018\$.

This analysis is only for this project's cost to execute research and implement. In the summary report an overall 2019 benefit cost analysis is based on total program costs.

References

¹ Analysis of Effectiveness: High Friction Surface Treatment (HFST). Calvin Rizzo, INDOT Summer Intern, August 5, 2019.

²Mike Holowaty (BO) phone conversation, August 19, 2019. Manager Office Traffic Safety at INDOT, Traffic Engineering Division.

³Center for Roadway Safety website.

⁴Luke Zhao, Center for Pavement and Transportation Technology, Department of Civil and Environmental Engineering, University of Waterloo, email message, August 15, 2019.

⁵ Indiana Crash Facts 2017, Indiana University Public Policy Institute.

⁶ Highway Safety Benefit-Cost Analysis, U.S. Department of Transportation Federal Highway Administration, February 2018.

⁷ Five year work plan, Mike Holowaty

SPR-3903: Fog Seal Performance on Asphalt Mixture Longitudinal Joints

Introduction

Due to asphalt pavement construction procedures, the longitudinal joint has lower densities and higher permeability causing this area of the pavement surface to deteriorate faster. This research project determined the use of fog seals on laboratory samples improved their performance with respect to permeability which correlates to improved joint performance. The Greenfield District¹ has tried a fog seal treatment on the longitudinal joint and are experiencing improved durability and performance to the level where it is predicted that one joint replacement treatment will be eliminated in a fifteen year pavement life, which is the time between resurfacing.

Analysis

The premise for the analysis is fog sealing the centerline longitudinal joint on asphalt pavements every 5 years will eliminate one joint replacement in a 15 year resurfacing cycle. The cost comparison is based on two fog seals will eliminate one joint replacement during a 15 year period. The cost comparison is limited to INDOT's two lane asphalt pavements inventory. The below work activities unit costs are from 2018-2019 INDOT bid tabs provided by INDOT¹.

Fog Seal Activity – 2 each during 15 year time period , one at the five and ten year periods

Fog Seal unit cost is \$0.90/SYS

Seal width is 3 ft.

Fog seal cost per mile = \$0.90/SYS x 3ft./3 ft. x 5280 ft./3 ft. = \$1,584/mile

After fog sealing the centerline pavement stripes reflectivity are diminished so new stripping is needed. Centerline pavement stripes are either solid 4" yellow or broken 4" yellow. Assuming 50% for each one the per mile cost is:

Solid 4" yellow stripe per mile cost = $\$0.77/\text{LFT} \times 5,280 \text{ LFT} \times 0.50$ (50 percent) = \$2,032

Broken 4" yellow stripe per mile cost = $\$1.01/\text{LFT} \times 5,280 \text{ LFT} \times 0.50$ (50 percent) = \$2,666

Fog Seal Operation per mile cost = $\$1,584 + \$2,032 + \$2,666 = \$ 6,282$

Joint Replacement Activities

- a. Milling Joint 1-1/2" depth is \$1.51/SYS, assume a 3 ft. width

Milling cost per mile = $\$1.51 \times 3/3 \times 5,280/3 = \$2,657$

- b. Joint Adhesive - \$0.38/LFT

Joint adhesive cost per mile = $\$0.38 \times 5,280 \text{ ft.} = \$2,006$

- c. HMA Pavement - HMA weighs approximately 110 lbs. per SYS per inch of depth. A 1.5 inch surface course would weigh approximately $(110 \text{ lbs./in-sys}) \times 1.5 \text{ in} = 165 \text{ lb./SYS}$. Asphalt unit cost is \$75/ton.

Assuming a 3 ft. wide width of pavement the asphalt required per mile is :

$165 \text{ lbs./SYS} \times 1 \text{ yard}(3 \text{ ft.}) \times 5,289 \text{ ft./3 ft. (yard)} = 290,400 \# = 145 \text{ tons of asphalt}$

Asphalt cost per mile = $145 \text{ tons} \times \$75/\text{ton} = \$10,875$

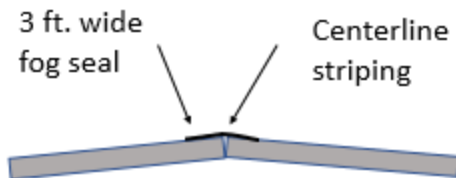
- d. Rumble Strip (Milled HMA Corrugations) is \$0.15/LFT

Rumble strip cost per mile = $\$0.15 \times 5,280 = \792

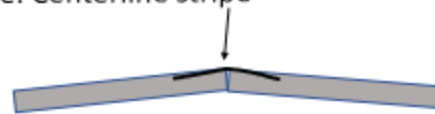
- e. Centerline stripe – See above = $\$2,032 + \$2,666 = \$4,698$

Joint Replacement cost per mile = $\$2,657 + \$2,006 + \$10,875 + \$792 + \$4,698 = \$21,028$

Fog Seal Treatment – 2 each **eliminates** Joint Replacement Treatment – 1 each



- a. 1 – ½ " milled strip
- b. Joint adhesive
- c. Asphalt pavement
- d. Rumble strip
- e. Centerline stripe



Pavement lane miles was provided by INDOT². Assumptions made to arrive at 2 lane asphalt pavements mileage are conservative and based on the following:

- No interstate centerline miles
- US Routes – Eliminated half centerline miles (conservative deduction for concrete)
- All State Roads are asphalt pavements (in reality there are some concrete)

2 lane road centerline miles = 7,267 (State Routes) + 2,718(US Routes) x 0.5 (50% reduction) = 8,626 centerline miles

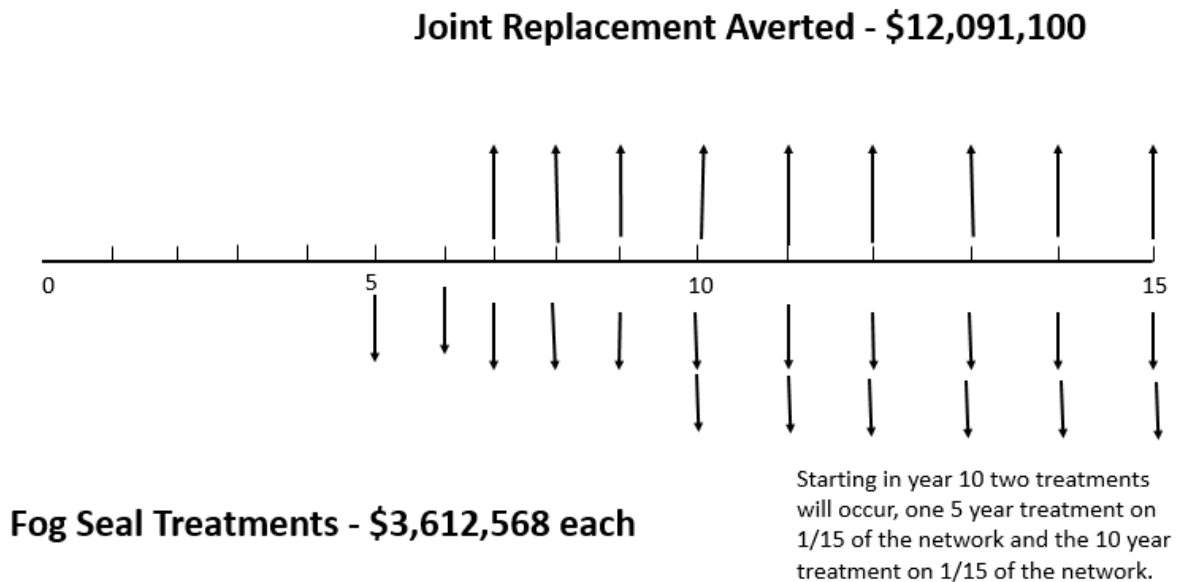
Expected pavement life is 15 years. During this 15 year period two fog seal treatments will replace one joint replacement. So instead of doing two joint replacements there will be one during the expected 15-year pavement life. The benefit cost analysis is based on the following assumptions:

Assumptions:

- Benefit cost analysis period is 15 years based on a pavement life period. This analysis period is conservative if this approach continues on through INDOT's inventory life which is 30 years, the time it takes to overlay all pavement to have a 15-year life.
- Fog seals will occur at the five and ten year time intervals, eliminating a joint replacement at the 7 year time interval. The analysis considers the two fog seal treatments as investments to eliminate the cost for a joint replacement.
- Sequencing the treatments in this manner during a fifteen period, up until year five all pavements resurfaced during will need two fog seals to eliminate one joint replacement.
- Per year fog seal treatment starting in year 5 to year 15 is:
 $1/15 \times 8,626 \text{ (lane miles)} \times \$6,282 = \$3,612,568$
- Joint replacement averted starting in year 7 to year 15 is:
 $1/15 \times 8,626 \text{ (lane miles)} \times \$21,028 = \$12,091,100$

Potential Savings

The below cash flow diagram indicates that starting in year five fog seal treatments will be applied to 1/15 of the pavement mileage which will eliminate one joint replacement starting in year 7 through year 15. And starting in year 10 two fog seal treatments will occur, a five year treatment and a ten year treatment on resurfaced pavement performed in year one of the analysis. Fog seal treatments are considered a cost or expense and joint replacement averted as a savings.



The above diagram cash flows are brought to a net present value in year 2018 with calculations shown in the below table.

Project Benefits and Costs (\$)	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030	FY 2031	FY 2032
Research Cost and fog seal treatment cost	(120)*				(3,612)	(3,612)	(3,612)	(3,612)	(3,612)	(7,225)	(7,225)	(7,225)	(7,225)	(7,225)	(7,225)
Estimated Annual User Savings - Joint treatment averted							12,091	12,091	12,091	12,091	12,091	12,091	12,091	12,091	12,091
Net Benefit-Cost	\$(120)	-	-	-	(3,612)	(3,612)	8,478	8,478	8,478	4,865	4,865	4,865	4,865	4,865	4,865
NPV	34,029														
Benefits Cost Ratio	284														

*Numbers are \$1,000

Summary

The benefit cost ratio for this project is 284 to 1. This number is based on the following:

- Research cost of \$120,000.
- 3% cost of capital.
- NPV of future costs and benefits based on 2018\$.

This analysis is only for this project's cost to conduct the research and implementation. In the summary report an overall 2019 benefit cost analysis is based on total program costs.

References

¹Michael Prather PE, Greenfield Construction Area Engineer.

²Chris Moore PE, Greenfield District Pavement Engineer.

Montgomery, S. R., & Haddock, J. E. (2017). *Fog seal performance on asphalt mixture longitudinal joints* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2017/18). West Lafayette, IN: Purdue University. <https://doi.org/10.5703/1288284316572>

SPR-4156: Capital Program Cost Optimization through Contract Aggregation Process

Introduction

Research analysis of project unit cost data indicates project bundling generates lower unit costs for bridge projects, and most traffic, miscellaneous, and small structure work. The reduction in project unit cost for bridge projects was found to be the most significant. For road projects, however, a slight decrease in unit cost was found only for R3-Patch & Rehab Pavement, R7-Sight Distance Correction and R9-Pavement. For all the other road project types, project bundling seems to lead to a higher unit cost.

Analysis

Bridge Projects

Research data analysis revealed that bundling bridge projects resulted in lower unit costs for different bridge project types: B1 New Bridge, B2 Bridge Replacement, B3 Superstructure replacement, B4 Deck replacement B5 Bridge Widening, B6 Bridge Deck Overlay, B7 Thin deck overlay, and B8 Misc. Bridge Rehab and Repair.

Bridge projects bundled state-wide were analyzed for the years 2017-2019 by utilizing data from SPMS.¹ Three bridge deck contracts bundled a total of 23 projects with cost data shown in the below table. Criteria that defines a bundled project were multiple DES numbers (3 or greater) and a location description that says at various locations within a geographic area or along a corridor.

Contract No	Work Type	No of Des	Est. Amount	Award Amount	Diff
34996	Bridge Deck Reconstruction	6	\$1,833,714.00	\$1,820,699.69	\$13,014
38657	Bridge Deck Reconstruction	11	\$2,540,301.00	\$2,081,968.71	\$458,332
39321	Bridge Deck Reconstruction	6	\$1,616,357.00	\$1,289,184.72	\$327,172
		23			\$798,519

These three contracts bundled 23 individual projects with an estimated cost savings of \$798,519 based on engineering estimates which are not entirely reliable in making accurate comparisons but can indicate potential savings occur through bundling. Average savings per project using this approach is $\$798,519/23 = \$35,000$ approximately.

During the same time frame there were ten bridge rehabilitation and repair contracts that bundled 59 projects with estimated savings shown in the below table.

Contract No	Work Type	No of Des	Est. Amount	Award Amount	Diff
39617	Bridge Rehabilitation And Repair	4	\$1,341,989.38	\$1,350,000.00	-\$8,011
39323	Bridge Rehabilitation And Repair	6	\$1,273,419.00	\$857,434.96	\$415,984
40458	Bridge Rehabilitation And Repair	10	\$560,263.00	\$469,110.00	\$91,153
40866	Bridge Rehabilitation And Repair	11	\$908,790.00	\$592,467.15	\$316,323
39715	Bridge Rehabilitation And Repair	4	\$1,790,071.83	\$2,164,724.04	-\$374,652
40362	Bridge Rehabilitation And Repair	4	\$784,907.00	\$797,817.02	-\$12,910
38553	Bridge Rehabilitation And Repair	10	\$1,460,417.00	\$1,887,182.20	-\$426,765
40054	Bridge Rehabilitation And Repair	4	\$1,550,359.00	\$956,360.00	\$593,999
40057	Bridge Rehabilitation And Repair	3	\$949,056.00	\$564,341.39	\$384,715
40934	Bridge Rehabilitation And Repair	3	\$215,360.00	\$158,741.44	\$56,619
		59			\$1,036,454

Average savings per project is $\$1,036,454/59 = \$18,000$ approximately.

Road Projects

Road projects bundled statewide were analyzed for the years 2017-2019 by utilizing data from SPMS¹. From the data, it appears that small structure replacement projects accrued lower costs when compared to engineer estimates. These contracts are summarized in the below table.

Contract No	Work Type	No of Des	Est. Amount	Award Amount	Diff
35136	Small Structure, Replacement	7	\$2,180,061.00	\$1,737,537.25	\$442,524
35523	Small Structure, Replacement	3	\$3,039,545.00	\$2,531,971.18	\$507,574
35139	Small Structure, Replacement	7	\$1,437,402.00	\$961,591.72	\$475,810
36124	Small Structure, Replacement	7	\$1,183,951.00	\$1,095,842.00	\$88,109
34935	Small Structure, Replacement	10	\$2,889,204.00	\$2,399,699.99	\$489,504
		34			\$2,014,521

Average savings per project is $\$2,014,521/34 = \$59,000$ (Approximately)

Another road work type that appears to benefit from bundling is 3R/4R road rehab projects. One contract was in the Seymour District:

Contract No	Work Type	No of Des	Est. Amount	Award Amount	Diff
39226	Road Rehab (3R/4R Standards)	5	\$78,187,542.00	\$60,837,501.99	\$17,350,040

This significant difference indicates that bundling may be appropriate for these types of contracts but since there was only one data point it was not used in the ROI calculations.

Three other work types were evaluated: patch and rehab, pavement repair or rehabilitation, and resurfacing. Analysis of the first two types indicate no cost savings through bundling contracts. However, bundling resurfacing contracts may provide cost savings, and are summarized in the table below.

Contract No	Work Type	No of Des	Est. Amount	Award Amount	Diff
35134	Resurface	8	\$3,767,701.00	\$2,953,909.61	\$813,791
37295	Resurface	7	\$9,215,166.00	\$10,240,508.23	-\$1,025,342
38655	Resurface	9	\$11,865,768.79	\$11,240,000.01	\$625,769
35102	Resurface	4	\$3,834,999.00	\$3,557,340.93	\$277,658

38668	Resurface	3	\$2,280,954.34	\$2,048,273.68	\$232,681
40520	Resurface	5	\$4,150,897.00	\$3,423,198.69	\$727,698
40908	Resurface	3	\$7,346,679.00	\$6,897,804.00	\$448,875
40027	Resurface	3	\$694,368.00	\$820,133.44	-\$125,765
39394	Resurface	4	\$7,563,224.00	\$8,390,860.00	-\$827,636
40944	Resurface	5	\$11,688,681.00	\$10,191,029.14	\$1,497,652
		51			\$2,645,380

There were ten contracts that bundled 51 projects. The average project savings was $\$2,645,380/51 = \$18,000$ (approximately).

Traffic Projects

Reviewing the same SPMS data set for Traffic contracts showed one lighting contract in the LaPorte district where bundling occurred.

Contract No	Work Type	No of Des	Est. Amount	Award Amount	Diff
39767	Lighting	7	\$248,272.00	\$218,567.36	\$29,705

The difference in this contract indicates that bundling lighting projects may provide savings but since this is only one contract it was not used in the ROI analysis.

Potential Savings

Based on estimated cost savings from various work types for bridge and road projects between 2017 to 2019 the overall estimated savings from bundling contracts is calculated and projected for the years 2020 to 2023 (five year work plan 2018-2022).

Bridge projects

Deck reconstruction bundling indicates an average project saving of \$35,000. Over the three-year period, 2017-2019, 23 projects were bundled, annually averaging approximately seven projects. Taking a conservative approach, five projects will be bundled annually creating an estimated savings of $5 \times \$35,000 = \$175,000$.

Rehabilitation and repair bundling indicates average project savings of \$18,000. Using the same approach used in deck reconstruction, 59 projects were bundled for an annual average of approximately 20 projects. Using an annual conservative number of 15, annual estimated cost savings are $15 \times \$18,000 = \$270,000$.

Road Projects

Small structure replacement bundling indicates average project savings of \$59,000. Using the same approach, 34 projects were bundled for an annual average of approximately 11 projects. Using a conservative number of 10, annual estimated cost savings are $10 \times \$59,000 = \$590,000$.

Resurfacing bundling indicates annual project savings of \$18,000. Continuing with the same approach, 51 projects were bundled for an annual average of approximately 17 projects. Using a conservative number of 15, annual estimated cost savings are $15 \times \$18,000 = \$270,000$.

Combining annual estimated cost savings from bundling bridge and road projects the total estimated savings are:

Deck reconstruction -	\$175,000
Bridge rehabilitation and repair -	\$270,000
Small structure replacement -	\$590,000
Resurfacing -	<u>\$270,000</u>
Total annual estimated savings =	\$1,305,000

As noted the annual savings is based on the difference between engineer's estimates and award amounts. A lower bound on the number of projects annually bundled is used so actual savings could vary with this approach. The researchers evaluated unit cost differences between unbundled and bundled projects to establish project characteristics (e.g. type, size, activities) that help to identify how to group projects. To determine overall project savings through unit costs comparisons and analysis is difficult because of variability in the factors that influence unit costs between projects. The approach taken in comparing engineer estimates and award amounts has been used by INDOT to determine bundling effectiveness.

Below is the benefit cost analysis for a five-year work plan with expected agency annual savings from bundling.

Project Benefits and Costs (\$)	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Research Cost	-\$98,000				
Estimated Annual User Savings	\$1,305,000	\$1,305,000	\$1,305,000	\$1,305,000	\$1,305,000
Net Benefit-Cost	\$1,207,000	\$1,305,000	\$1,305,000	\$1,305,000	\$1,305,000
NPV	\$5,881,372				
Benefits Cost Ratio	60				

Summary

The benefit cost ratio for this project is 60 to 1. This number is based on the following:

- Research cost of \$98,000.
- 3% cost of capital and inflation.

- NPV of future costs and benefits based on 2018\$.

This analysis is only for this project's cost to conduct the research and implementation. In the summary report an overall 2019 benefit cost analysis is based on total program costs.

References

¹Maan Omran, INDOT Business Systems Consultant, provided SPMS data.

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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>.

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