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INDIANA DEPARTMENT OF TRANSPORTATION
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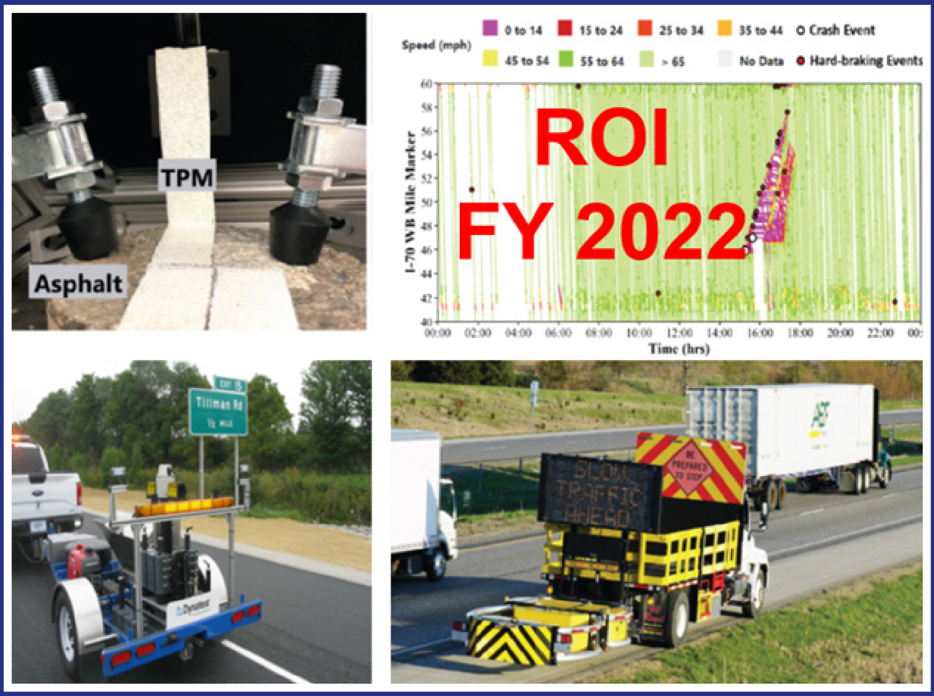
INDOT Research Program Benefit Cost Analysis—Return on Investment for Projects Completed in FY 2022



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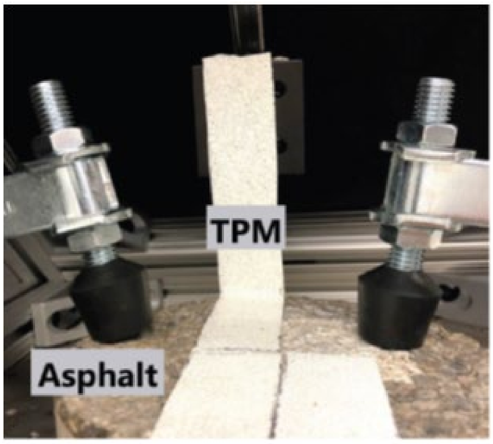
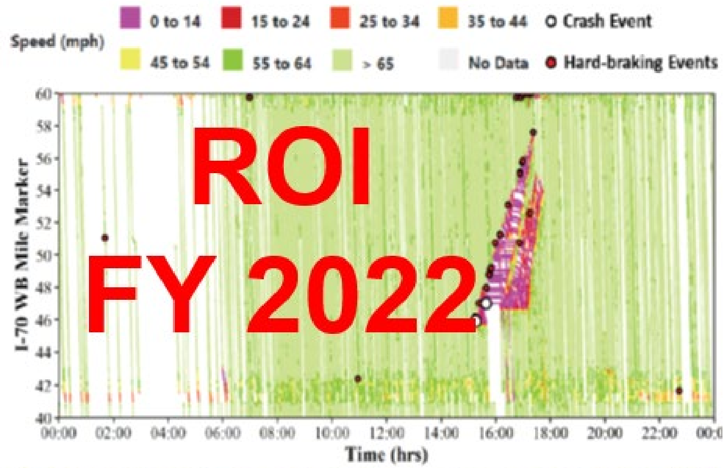
(SPR – 4225)





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 initially requested an annual financial analysis of the INDOT Research Program to determine the return on the research investment (ROI). The INDOT Research & Development (R&D) has continued to publish an annual Return on Investment report. The current financial analysis is for research projects that completed in FY 2022. Analyses on previous year's projects is necessary primarily due to the time it takes some project outcomes to be implemented and verifiable data generated, extending into the following year. Therefore, the FY 2023 analysis is completed research projects in calendar 2022. 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, a seven-year period.

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 Strategic Plan. The Strategic Plan is reviewed annually and guides the priority research needs of the Research Program and in turn the research results support accomplishing the INDOT Strategic Plan, Strategic Objectives. A Strategic Objective has been added to the INDOT Strategic Plan addressing Innovation & Technology. Additionally, INDOT created an Office of Innovation. While the Research Program supports all of INDOT's Strategic Objectives, these initiatives have further highlighted the importance of research and its role in achieving the Strategic Objectives outlined in the 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 identify 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 2022 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 or users of the INDOT network, (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), vehicle operating costs (VOC), and crash reduction costs. RUC unit values were obtained from current INDOT standards.
- **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 were obtained from current INDOT and FHWA standards.

Accrued Benefits will be the combination of **Agency savings, RUC 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 one quantifiable project included 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 one to five 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 2022 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 be accumulative of seven 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 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 inconclusive results, logistical, technical difficulties, proof of concept, or legal issues.

Individual Project Analysis

Table 1 is the list of the four projects where benefits (NPV 2022$- NPV of future cash flows in 2022 dollars) could be quantified and their individual analysis is found in Appendix B. One of the four projects will produce SC (safety cost) savings, the other three Agency savings. Table 3, in Appendix A, is a complete list of all 30 projects completed in FY 2022 and considered for quantifiable cost analyses. Qualitative benefits are highlighted in the companion annual IMPACT report.

Table 1. Quantitative Benefits Project List

No	FY 21 Completed & Implemented SPR Projects	Title	Project Cost ($1,000)	Benefit Type	Analysis Period	NPV Project Benefit ($1,000) 2022$
1	4423	Pavement Markings for Asphalt and Concrete Pavements	$201	Quantitative (Agency Savings)	5 Years	$571
2	4447	MEPDG Implementation (Validation/Model Calibration/Acceptable Distress Target/IRI Failure Trigger/Thermal Selection/Binder Selection)	$201	Quantitative (Agency Savings)	3 Years	$5,128
3	4451	Integration of Probe Data Tools into TMC Operations	$200	Quantitative (Agency Savings)	5 Years	$56,952
4	4524	Evaluation of the impact of On Vehicle Digital Communication Alerts to Improve INDOT and Motorist Safety	$83	Quantitative (Safety Savings)	1 Year	$12,739

Total Agency Benefits $62,651,000

Total Safety Benefits $12,739,000

The analysis periods varied from 1 to 5 years, due to the estimated impact period. Projects 4423, 4447 and 4451 analysis periods are based on INDOT Work Plans. Project 4524 used a 1-year period since it did a direct comparison between 2 years of accident data, without and with an on-vehicle, digital alert system. Benefit from 4524 is safety savings.

Agency Savings

The total quantifiable savings from the three projects (4423,4447, 4451) resulting in agency savings, during their analysis or impact period, was calculated at $62,651,000 (in 2022$). The majority of savings come from replacing the interstate camera system with probe data. The *total* research program cost in FY 2022 was $6,243,700. Therefore, the agency savings BCA for FY 2022, for quantifiable projects, is: **$62,651,000/$6,243,700 = 10,** or 10 dollars in agency savings for every research dollar expended. **Said another way, the agency savings from these three projects more than offset the cost of the entire research program for the year.**

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

Safety (User) Savings

One project 4524 produces quantifiable user safety savings calculated to be $12,739,000. Therefore, the user savings BCA for FY 2022 is: **$12,739,000/$6,243,700 = 2**, or 2 dollars in user safety savings for every research dollar expended. Project 4524 savings calculation was based on a 2-year comparison period which translates into a one-year impact. With the adoption of an on-vehicle alert system these savings will continue into the future. A savings table is in the project write-up in Appendix B.

Cost Savings Summary

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

4423 – Four testing methods were used to assess current pavement marking products and are recommended to evaluate new pavement markings performance by INDOT's New Product Evaluation Committee (NPEC). These testing methods proved how to improve performance and use of these products in differing weather and pavement conditions. Due to this project, INDOT will be able to improve the selection of these products, reducing their failure rates thereby resulting in cost savings for INDOT.

4447 – INDOT uses MEPDG (Mechanistic Empirical Pavement Design Guide) software to design pavements, the existing version 2.6 increased asphalt base course thickness by 2 to 3 inches. Through this project local coefficient calibrations for the 2.6 version produced results similar to version 2.3 and mirrored pavement deteriorations experienced in the field. With local calibrations compared to global (default) calibrations in version 2.6, designs for full depth HMA are thinner, resulting in savings.

Another qualitative benefit is a more accurate pavement deterioration curve, which allows INDOT's asset/planning department to plan for future pavements and obtain full design life of pavements more accurately. This will generate benefits but will require time to quantify.

4451 – INDOT has investigated the use of probe data in traffic management operations for several years. Applications include analyzing work zones, severe crashes, winter operations, and moving maintenance operations. This study produced tools to visualize interstate queues, identify hard breaking events, and improved management of work zones.

Probe data can be used to replace current camera systems on the interstates, thus substantially reducing TMC capital investments and ongoing maintenance costs with this system. This is one basis for savings that will be generated.

One project **4524**, will produce user safety savings. This savings is described below.

4524 – The Safety Cost (SC) savings come from reducing crash costs in construction and maintenance roadway zones through the use of on-vehicle, digital communications alerts apps operating on cellular devices, for example phones and tablets.

Summary

The aggregate benefit of all agency savings is approximately $62 million in 2022$. Direct agency savings of $62 million is a return of $10 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 26 projects completed in FY 2022, 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 2022 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 seven years, 2016 – 2022, the investment indicates positive returns during the life of individual projects implemented. While many of the projects in the last five years, 177 out of 222 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. Thirty-seven (37) projects where benefits were quantifiable, produced significant agency savings and 8 projects produced significant road user cost savings. For the combined years of 2016 through 2022 the Agency and Road User BCA are:

BCA (2016 – 2022) Agency Savings = $437,925,000/$41,425,740 = 11 to 1

BCA (2016 – 2022) Road User Savings = $327,771,799/$41,425,740 = 8 to 1

BCA Rolling Average – 2016–2022 = 19 to 1

Table 2 compiles the estimated agency savings and road user savings for the last seven analysis years. BCA averages are calculated from the seven-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
2021	$5,531,000	$33,548,000	$20,073,000	6	3.6	9.6

2022	$6,243,700	$62,651,000	$12,739,000	10	2	12
Totals	$41,425,740	$437,925,000	$327,771,799	11 avg.	8 avg.	19 avg

Environmental Benefits

Additionally, 4447, provided environmental benefits in addition to quantifiable agency benefits.

SPR-4447 corrected local coefficient calibrations for the MEPDG pavement design software which results in thinner asphalt base course thickness in full depth asphalt pavements. This correlates to less asphalt pavement quantities which translates to less native materials, asphalt and aggregate, improving the environmental impact of consuming and using these native materials and reducing the carbon footprint.

Appendix A

Table 3. Complete Research Project List – FY 2022

No.	FY 22 Completed & Implemented SPR Projects	Project Title	Project Cost ($1000)	Quantitative Benefits, Qualitative Benefits or Not Successfully Implemented	Project Benefits ($1,000)
1	4102	Building, Evaluating, and Improving LiDAR-based Traffic Scanner Prototypes for Implementation to INDOT Practice	546.6	Qualitative	
2	4108	Development of Comprehensive CPT-Based Geotechnical Design Manual for Indiana Transportation Infrastructure	325.7	Qualitative	
3	4209	Real Life Experience with Major Pavement Types	150.8	Qualitative	
4	4309	Pack Rust -- Mitigation Strategy Effectiveness	185.5	Qualitative	
5	4322	Development of an Intelligent Snowplow Truck that Integrates Telematics Technology, Roadway Sensors, and Connected Vehicle	392.1	Qualitative	
6	4326	Self-healing Cementitious Composites (SHCC) with Ultrahigh Ductility for Pavement and Bridge Construction	367.2	Qualitative	
7	4334	Improved Reliability of FWD Tests Results and Correlation with Resilient Modulus	232.0	Qualitative	
8	4335	Environmentally Tuning Asphalt Pavements Using Phase Change Materials	216.2	Qualitative	
9	4351	Minimizing Blast Furnace Slag (BFS) Leachate Through Improved Product Acceptance Criterion and Siting Considerations	172.1	Qualitative	
10	4413	Assessing the Travel Demand and Mobility Impacts of Transformative	244.1	Qualitative	

		Transportation Technologies in Indiana			
11	4414	Use of Geosynthetics on Subgrade and on Low and Variable Fill Foundations	200.6	Qualitative	
12	4418	Development of In-situ Sensing Method for Monitoring of Water cement(W/C) Values and the Effectiveness of Curing of Concrete	190.7	Qualitative	
13	4419	Superabsorbent Polymers (SAP) for Internally Cured Concrete	187.6	Qualitative	
14	4421	Life Cycle Integration of Infrastructure Information Modeling	131.8	Qualitative	
15	4423	Pavement Markings for Asphalt and Concrete Pavements	200.9	Quantitative	571
16	4429	Use of LRFR Methodology for Load Rating of INDOT Steel Bridges	150.5	Qualitative	
17	4436	Road Condition Detection and Classification from Existing CCTV Fee	226.4	Qualitative	
18	4437	Effective Design and Operation of Pedestrian Crossings	184.1	Qualitative	
19	4440	An Integrated Critical Information Delivery Platform for Smart Segment Dissemination to Road Users	373.7	Qualitative	
20	4447	MEPDG Implementation (Validation/Model Calibration/Acceptable Distress Target/IRI Failure Trigger/Thermal Selection/Binder Selection)	201.1	Quantitative	5,128
21	4451	Integration of Probe Data Tools into TMC Operations	200.0	Quantitative	56,952
22	4502	Heavy Fleet and Facilities Optimization	120.0	Qualitative	
23	4508	Forecasting Freight Logistics needs & INDOT Plans for the Needs	120.0	Qualitative	
24	4509	A Strategic Assessment of Needs and Opportunities for Wider Adoption of Electric Vehicles in Indiana	293.9	Qualitative	

25	4522	Design of Educational Material & Public Awareness Campaigns for Improving Work Zone Driver Safety	138.0	Qualitative	
26	4524	Evaluation of the impact of On Vehicle Digital Communication Alerts to Improve INDOT and Motorist Safety	83.0	Quantitative	12,739
27	4532	Synthesis Study: Repair and Durability of Fire Damaged Prestressed Concrete Bridge Girders	60.0	Qualitative	
28	4542	Alternative Strategies for Roadway Work Zone Safety and Productivity	183.1	Qualitative	
29	4545	Alternate Interchange Signing Study for Indiana Highways	115.1	Qualitative	
30	4546	Implementation Study: Continuous, Wireless Data Collection and Monitoring of the Sagamore Parkway Bridge	51.0	Qualitative	
			$6,243,700		

Total FY 2022 Research spending is $6,243,700

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Appendix B
Individual Project Analysis

SPR-4423: Pavement Markings for Asphalt and Concrete Pavements

Introduction

This project evaluated the properties and performance of temporary and permanent pavement marking materials currently used for asphalt and concrete pavements in Indiana. Research objectives were to (1) design and optimize new testing and analysis methods to characterize the mechanical and adhesive properties of pavement marking materials; and (2) evaluate commercially available pavement marking materials and assess their durability and usability.

Four testing methods were used to assess current pavement marking products and are recommended to evaluate new pavement markings performance by INDOT's New Product Evaluation committee. These testing methods proved how to improve performance and use of these products in differing weather and pavement conditions. Due to this project, INDOT will be able to improve the selection of these products, reducing their failure rates thereby resulting in cost savings for INDOT.

Figure 1. New pavement markings.

Analysis

To determine the possible financial magnitude of project implementation, INDOT's State Construction Engineers office[1] provided Table 1, which contains pavement markings quantities for the years 2021 - 2023.

Table 1. Pavement Markings Quantities (2021–2023)

	Markings Quantities (Linear Ft.)	Contract Value ($)
Years 2021-2023	4,644,081	$415,112,711

During this period (2021-2023) contract R-42113 in Seymour District experienced pavement markings failure, which required replacing all the markings, Table 2[2] shows project quantities and costs. This contract was performed in 2022.

Table 2. Contract R-42113 Pavement Markings Quantities and Cost

Description	Unit Price ($/Linear foot)	Quantity (Linear feet)	Total
Line, Preformed Plastic, Solid, White, 6 IN.	5.10	68,426	$348,972
Line, Preformed Plastic, Solid, Yellow, 4 IN.	3.40	3,520	$11,968
Line, Preformed Plastic, Solid, Yellow, 6 IN.	5.10	59,200	$301,920
Line, Preformed Plastic, Broken, White, 5 IN.	4.25	15,240	$64,770
		Total Cost	$727,630

During the three-year period (21-23) one contract R-42113 experienced pavement markings failure; this represents ($727,630/$415,112,711) 0.2% of the pavement markings cost. Implementing results from this project would have saved this expense.

Potential Savings

Potential future annual cost savings are based on the above project data experienced over a three-year period which is $727,630/3 = $242,543. Taking a conservative approach estimated annual savings used in the cash flow analysis is 50% rounded to $120,000. Projected annual savings for a five-year period and a corresponding benefit/cost analysis is shown in Table 3. A five-year period coincides with INDOT's five-year work program project estimates. Estimated annual savings are increased by a 5% inflation factor.

Table 3. 4423 Cash Flow Analysis

Years	2023	2024	2025	2026	2027	2028
Research Cost	$(200,000)					
Analysis savings		$120,000	$126,000	$132,300	$138,915	$145,861
NPV Benefits	$571,429					
Net Savings	$371,429					
B/C	2.9					

NPV – net present value.
Net savings = NPV Savings – Research cost.

Summary

The BC ratio is **2.9 or 3** due to calculated savings is more than the research cost. The savings come from reducing defective pavement markings.

These numbers are based on the following:

- Research cost for 4423 is $200,000.
- Annual costs and savings are inflated by 5%.
- 5% cost of capital.
- NPV of future costs and benefits based on 2023$.

This analysis is *only for this project's* cost to conduct the research and implementation. In the summary report an overall 2022 benefit cost analysis is based on total program costs. If more pavement markings were found to fail, cost savings and the B/C value of using these new test methods would result.

References

[1] Joe Novak, PE, State Construction Engineer, Division of Construction Management and District Support, INDOT.

[2] Gary Kreutzjans, PE , Seymour District Construction Director, INDOT.

Jo, H., Son, H., Rencheck, M., Gohl, J., Madigan, D., Grennan, H., Giroux, M., Thiele-Sardina, T., Davis, C. S., & Erk, K. A. (2021*). Mechanical properties of durable pavement marking materials and adhesion on asphalt surfaces* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2021/29). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284317357

SPR-4447: MEPDG Implementation (Validation/Model Calibration/Acceptable Distress Target/IRI Failure Trigger/Thermal Selection/Binder Selection)

Introduction

The project research team established a local calibration process for Version 2.6 of the AASHTO Pavement ME, referred to as MEPDG, which is software used by the Indiana Department of Transportation (INDOT) in pavement designs. Recommended MEPDG calibration coefficients were produced. The research team arrived at these coefficients by performing more than 30,000 optimization runs in the MEPDG Calibration Assistant Tool, CAT. Based on these results, the research team recommended calibration coefficients for Hot mix asphalt full depth (HMA FD); Hot mix asphalt overlay (HMA OL); and Portland Cement Concrete Pavement (PCCP) on various pavement distress types. Table 1 shows the different pavement types and corresponding distresses where calibration coefficients were developed[1].

Table 1. Coefficient Types

Pavement Type	**Distress Type**
HMA FD	Fatigue Cracking, Rutting, Thermal Cracking, Roughness
HMA OL	Fatigue Cracking, Rutting, Thermal Cracking, Roughness
PCCP	Mean Joint Faulting, % Slab, Roughness

Analysis

Going from MEPDG Version 2.3 to 2.6 the update included major changes for new full depth HMA[2]. With version 2.6, full depth HMA design were 2 to 3 inches thicker than the previous version. Through this research project local coefficient calibrations for the 2.6 version produced results similar to version 2.3 and mirrored pavement deteriorations experienced in the field. With local calibrations compared to global calibrations in version 2.6 designs for full depth HMA are thinner.

Another qualitative benefit is a more accurate pavement deterioration curve, which allows INDOT's asset/planning department to plan for future pavements and obtain full design life of pavements more accurately. This will generate benefits but will require time to quantify.

Potential Savings

Using the above outcomes, pavement thickness on HMA FD pavements can be reduced by 1 to 2 inches. Taking a conservative approach, calculated savings will be based on reducing HMA FD pavements base course thickness by 1 inch.

Estimated cost savings from reducing HMA FD pavement base course by 1 inch is:

1 HMA base reduction = ~ 110 lbs./SYS or 0.055 Tons per SYS @ $80 per SYS equals $4.40 savings per SYS.[2]

Table 2 is the estimated quantities of HMA and generated savings for the next three years based on INDOT's work plan.[2]

Table 2. Estimated HMA Full Depth pavement quantities and resulting cost savings

Year	Pavement Area (SYS)	Estimated annual savings
2024	700,000	$4.40 * 700,000 =$3.080,000
2025	150,000	$4.40 * 150,000 = $660,000
2026	420,000	$4.40 * 420,000 = $1,848,000

Table 3 is the estimated cash flows used for the ROI analysis.

Table 3. Cash Flow Analysis

Years	2023	2024	2025	2026
Research Cost	$(201,000)			
Analysis savings		$3,080,000	$660,000	$1,848,000
NPV Benefits	$5,128,345			
Net Savings	$4,927,345			
B/C	25.5			

NPV – net present value.

Net savings = NPV Savings – Research cost.

Summary

The BC ratio is **25.5** due to calculated savings is greater than the research cost. The savings come from reduced asphalt base quantities.

These numbers are based on the following:

- Research cost for 4447 is $201,000.
- Annual costs and savings are inflated by 5%.
- 5% cost of capital.
- NPV of future costs and benefits based on 2023$.

This analysis is *only for this project's* cost to conduct the research and implementation. In the summary report an overall 2023 benefit cost analysis is based on total program costs.

References

[1] Olek, Jan; Lee, Jusang; Mirzahosseine, Mohammadreza. *Procedural Framework for Local Calibration of AASHTO Pavement ME* Version 2.6 using INDOT PMS, December 2021.

[2] Nick Cosenza, P.E. INDOT Pavement Design Engineer.

SPR-4451: Integration of Probe Data Tools into TMC Operations

Introduction

Probe data contains telematics information including geolocation, timestamp, speed and heading attributes collected from cellular phones, other mobile devices (e.g. tablets), or embedded vehicle devices like navigation systems operating on road networks. This data is harvested by Location Based Services and made available to Transportation Agencies at a cost. Figure 1 shows a sample map of probe data generated during a period of 10 seconds for the state of Indiana.

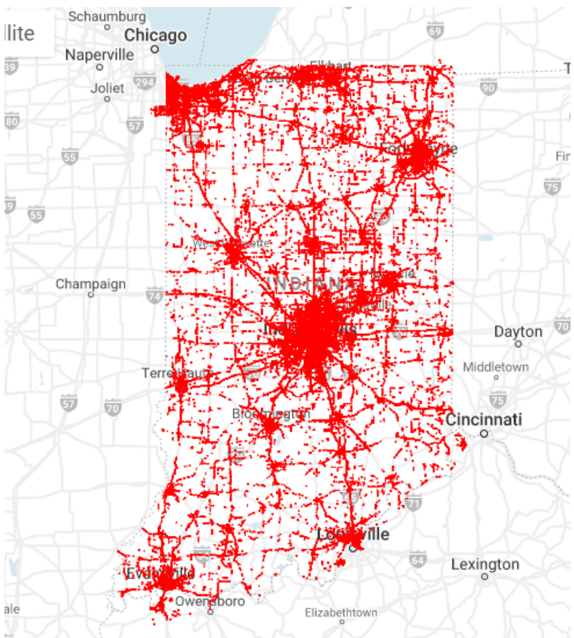

Figure 1. Sample probe data for a period of 10 seconds in the state of Indiana.

INDOT has investigated the use of probe data in traffic management operations at their Traffic Management Center (TMC) for several years. Applications include analyzing work zones, severe crashes, winter operations, and moving maintenance operations. This study produced tools to visualize interstate queues, identify hard breaking events, improved management of work zones, and evaluate traffic signal performance.

Probe data can be used to replace side fire radar, in-ground loop detectors and augment gaps in camera coverage on the interstate (Figure 2), thus substantially reducing TMC capital investments and ongoing maintenance costs. This is the basis for Return on Investment (ROI) cost benefit analysis derived from project implementation.

(a) At 3:15 PM (t1)   (b) At 3:18 PM (t2)

Figure 2. Camera images showing queued traffic.

Analysis

INDOT currently operates an extensive interstate sensor network. Figure 3 shows the sensor and camera network for interstate and state highway routes.

Figure 3. INDOT Statewide Camera Network.

Table 1, developed by the JTRP Office[1] and INDOT[2], contains the numbers and estimated life cycle expense of the statewide camera and sensor network on interstates. Estimated life cycle is five years.

Table 1. 5-Year Life Cycle Cost of Statewide Camera Network

System Unit Costs	Total Cameras on Interstate Network	Cost per Camera Site	Total Cost
System Hardware	407	$97,000	$39.4 Million
5-Year Maintenance Cost		$50,000	$20.4 Million
Total Cost			$59.8 Million

Annual probe data cost is $450,000.

Potential Savings

Potential future cost savings are based on replacing the sensor network with probe data for a five-year life cycle time period. Estimated probe data cost is increased by a 5% inflation factor. Table 2 contains the estimated cash flows for a return on investment analysis (ROI) using a net present value (NPV) analysis approach.

Table 2. 4451 Cash Flow Analysis

Years	2024	2025	2026	2027	2028	2029
Research /Probe Data Cost	$(200,000)	$(400,000)	$(420,000)	$(441,000)	$(463,050)	$(486,203)
Life Cycle savings						$59,800,000
NPV Probe Costs	$(1,904,762)					
Total Costs Including Research	$(2,204,762)					
NPV Life Cycle Savings	$56,952,381					
Net Savings	$54,747,619					
B/C	284.7					

NPV – net present value.

Net savings = NPV Savings – Probe data cost + Research cost.

Summary

The BC ratio is **285** due to calculated savings is more than the research and probe data cost. The savings come from using probe data and eliminating the interstate camera network.

These numbers are based on the following:

- Research cost for 4451 is $200,000.
- Annual costs are inflated by 5%.
- 5% cost of capital.
- NPV of future costs and benefits based on 2023$.

This analysis is *only for this project's* cost to conduct the research and implementation. In the summary report an overall 2022 benefit cost analysis is based on total program costs.

References

[1] Mathew J.K. and Bullock, Darcy M., Joint Transportation Research Program (JTRP), Purdue University.

[2]Sturdevant, J and Cox. E, Indiana Department of Transportation.

Mathew, J. K., Li, H., Desai, J., Sakhare, R. S., Saldivar-Carranza, E., Hunter, M., Scholer, B., & Bullock, D. M. (2022). *Integration of probe data tools into TMC operations* (Joint Transportation Research Program Publication No. FHWA/IN/ JTRP-2022/01). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284317363

SPR-4524: Evaluation of the impact of on Vehicle Digital Communication Alerts to Improve INDOT and Motorist Safety

Introduction

In an attempt to improve work zone safety for the traveling public and construction and maintenance personnel; INDOT has analyzed and implemented various approaches, primarily through a combination of fixed and variable message signs. Through this project INDOT investigated using in-vehicle connectivity in work zones to improve the messaging, its visibility and effectiveness. The use of in-vehicle connectivity has quickly expanded through interfaces like GPS maps (e.g. Apple car play) and “Waze” type applications.

The objective of this study was to conduct trial deployments on INDOT queue vehicles, see Figure 1; evaluate the impact of in-vehicle digital communication alerts and begin a dialog with private sector partners about what information INDOT can share that will create a safer roadway in work zones.

Figure 1. INDOT Queue Truck in a Work Zone.

Analysis

Eight INDOT vehicles, primarily consisting of queue trucks and Hoosier helper emergency response vehicles (Figure 2), were equipped with a HAAS alert device (Figure 3).

Figure 2. Hoosier Helper Vehicle Figure 3. HAAS Alert Device

The HAAS device issues alert information that is collected in a "cloud" database, where applications display this information to the traveling public. For example, the Waze app sends notifications to drivers approaching work zones allowing time to respond appropriately and reduce potential accidents from occurring.

Using queue trucks equipped with a HAAS device an accident reduction analysis of seven construction zones on I-65 was performed in 2023. Potential Safety Cost (SC) savings from reduced accidents are calculated and is the Return on Investment (ROI) basis.

Potential Savings

Table 1[1] summarizes the cost of a queue truck system and Table 2[1] calculates the accident reduction that occurred between 2019, without queue trucks, and 2023, with queue trucks equipped with the HAAS system.

Table 1. Queue Trucks System Costs

Cost Items	**Cost**
Queue Trucks [a]	$350,655
HAAS Digital Alert [b]	$9,518
Total Cost	$360,173

[a] 2023 annual INDOT cost for queue truck deployment on I-65

[b] 2023 annual cost for HAAS Alert devices

Table 2. Estimated Crash Reductions

Year 2019 (2,210 hours) [c]			**Year 2023 (1,238 hours)**		
Crash Type [e]	**Total Crashes**	**Rate (accident/hour)**	**Total Crashes**	**Expected [d] Crashes**	**Crashes Reduced**
PDO	61	0.0276	13	34	21
PI	5	0.0023	3	3	0
F	2	0.009	0	1	1

[c] Hours of operation estimated using the heatmap tool for rural highways; Crash rate was estimated as different hours in 2023 compared to 2019.

[d] 2023 Expected crashes = Rate (2019) * hours (2023).

[e] PDO – Property Damage Only, PI – Personal Injury, F – Fatal.

Table 3 contains the expected SC savings calculated from crash reduction and their corresponding unit costs. Unit costs by crash type were obtained from a FHWA on-line publication.[2]

Table 3. Expected Crash Reduction Savings

	Crashes Reduced [f]	Unit Cost [g]	Expected Cost Reductions
Property Damage Only (PDO)	21	$68,750	$1,443750
Personal Injury (PI)	0	$426,750	$0
Fatal (F)	1	$11,295,400	$11,295,400
Total Savings			$12,739,150

[f] From Table 2.

[g] KABCO severity scale equivalency: K – F; Avg.(A&B) – PI; Avg.(C&O) – PDO.

Table 4 summarizes the SC savings, the research cost and queue truck deployment cost, and calculates a benefit cost ratio (B/C) for a one-year comparison period.

Table 4. B/C Calculation

Years	2023
Research Cost (C)	$83,000
Queue Truck and HAAS Costs (Table 1)	$360,173
Total Costs	$443,173
Crash Reduction Savings (B)	$12,739,150
B/C	153.5(153)

Summary

The B/C ratio is **153,** due to calculated crash savings is more than the research cost. The SC savings come from reducing crash costs in construction and maintenance roadway zones. This B/C ratio is a conservative number because it is based on seven construction zones on the I-65 corridor for a one-year time period. Additional interstate corridors, construction and maintenance zones over multiple years will increase the B/C number and the ROI.

This analysis is *only for this project's* cost to conduct the research and implementation. In the summary report an overall 2022 benefit cost analysis is based on total program costs.

References

[1] Sakhare, Rahul. and Bullock, Darcy M., Joint Transportation Research Program (JTRP), Purdue University.

[2] FHWA, https://safety.fhwa.dot.gov/hsip/docs/fhwasa17071.pdf.

Sakhare, R. S., Desai, J., Mathew, J. K., Kim, W., Mahlberg, J., Li, H., & Bullock, D. M. (2021). *Evaluating the impact of vehicle digital communication alerts on vehicles* (Joint Transportation Research Program Publication No. FHWA/IN/ JTRP-2021/19). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284317324

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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