Post-Construction Analysis of Major, Mega and Regionally Significant Projects

Final Report

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16. Abstract

WisDOT has invested billions of dollars in Major, Mega, and Regionally Significant transportation projects to save lives, reduce travel time delays, and maintain highway pavements and bridges in a good state-of-repair. These projects undergo extensive planning and analysis as they advance from a concept to a funded project. While existing performance management practices track system-level outcomes, they provide limited insight into whether individual projects achieve their intended benefits after construction. This study develops a practical, repeatable framework for Post-Construction Analysis (PCA) to address that gap. PCA is a structured, data-driven approach that compares pre- and post-construction conditions to evaluate project outcomes and "close the loop" between planning, delivery, and observed performance. The objective of this research was to create an implementation-ready PCA framework tailored to WisDOT's data environment and workflows. The approach combined national best practices with WisDOT-specific data and processes. The resulting framework includes an enterprise-level structure for program implementation, a project-level workflow aligned with the project development lifecycle, and a step-by-step evaluation methodology for conducting before-and-after analyses.

The framework leverages existing WisDOT data systems, with Meta-Manager serving as the primary analytical backbone. A core set of performance measures was identified across safety, mobility, and preservation to support consistent evaluation. The methodology was applied to three completed WisDOT projects, demonstrating that PCA can be conducted using available data and producing meaningful insights into project performance. The applications also highlighted challenges related to changing roadway segmentation, data completeness, and attribution of outcomes.

This research demonstrates that a scalable PCA program is feasible within WisDOT using existing tools and data. Recommended next steps include piloting PCA on select projects, building a library of evaluations, and improving efficiency through standardization and automation. Implementing PCA will enhance WisDOT's ability to evaluate project outcomes, improve future investment decisions, and support a culture of continuous improvement.

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EXECUTIVE SUMMARY

Why PCA Matters

WisDOT has invested billions of dollars in Major, Mega, and Regionally Significant transportation projects to save lives, reduce travel time delays, and maintain highway pavements and bridges in a good state-of-repair. While these investments significantly contribute to the system-level performance outcomes observed in Mobility, Accountability, Preservation, Safety, Service (MAPSS) Performance Improvement program and Federal Highway Administration (FHWA) Transportation Performance Management (TPM) reports, their individual return-on-investment is unclear. Having a better sense of whether individual projects actually deliver their intended benefits once construction is complete can provide important data points to improve future decisions.

Post-Construction Analysis (PCA) addresses this gap by providing a structured, data-driven approach for evaluating real-world project outcomes. It creates a feedback loop between project delivery and observed performance, strengthening accountability, improving transparency, and supporting continuous improvement in planning, design, and forecasting. This is particularly important for high-cost investments, where understanding realized benefits is critical to validating decisions and refining future strategies. At its core, PCA is a framework for answering three questions:

- What changed after the project was completed?
- Why did those changes occur?
- Did the project deliver expected benefits?

Rather than a single model or metric, PCA integrates data, performance measures, and analytical methods into a consistent evaluation approach that complements existing statewide performance reporting with project-level insight. To that end, the purpose of this study was to develop a practical, repeatable PCA framework that enables WisDOT to evaluate the performance of completed Major, Mega, and Regionally Significant projects using existing data systems. The framework is designed to be scalable, consistent, and directly applicable to WisDOT workflows. This was achieved through the following multi-step research process grounded in national best practices and WisDOT-specific data system:

- Review of national literature, including previous work done as part of National Cooperative Highway Research Program (NCHRP) Project 08-170: *Closing the Loop: Post-Implementation Evaluation of Transportation Projects* (being published as NCHRP Report 1184);
- Supplemental review of peer agency PCA practices;

- Development of enterprise- and project-level PCA workflows;
- Identification of available WisDOT datasets and integration of Meta-Manager as the primary analytical backbone;
- Development of performance measures aligned with observable and reproducible data;
- Design of a structured evaluation methodology for before-and-after analysis; and
- Application of the framework to three WisDOT projects as a proof-of-concept demonstration of PCA.

How the Framework Works

Effectively conducting and realizing the benefits of a PCA requires broader organizational support and the ability to capture, store, and analyze performance data over time. To ensure the usefulness of the evaluation methodology, the research team has developed enterprise- and project-level frameworks that encompass the entire PCA workflow – from making the case to invest resources in embarking on a PCA to how analytical findings can be implemented to improve business processes.

Enterprise-Level Framework

The enterprise framework defines how PCA is established and sustained across WisDOT. This structure ensures PCA is not treated as a one-time analytical exercise but as an institutional capability embedded in decision-making processes. It focuses on building organizational readiness and consistency through a staged implementation approach:

1) Making the case for PCA and gaining leadership buy-in
2) Recruiting support for PCA and building a team
3) Defining the problem PCA is intended to solve/answer
4) Establishing the evaluation parameters to be used in PCA
5) Building the library of data to be used for PCA
6) Selecting and conducting the analyses
7) Communicating the results of PCA
8) Implementing enhancements back into the PCA framework

Project-Level Workflow

The project-level workflow translates PCA into a repeatable sequence of steps applied to individual projects. The workflow intentionally includes decision points where PCA may be scaled, deferred, or not pursued depending on data availability, project relevance, and analytical feasibility. It spans:

1) Planning and project identification
2) Pre-construction and PCA scoping
3) Construction and documentation
4) Post-construction data collection
5) Analysis and interpretation
6) Communication and integration
7) Institutional learning

Evaluation Methodology

The analytical process follows a structured sequence designed to ensure consistency across projects. This approach enables consistent corridor-level evaluation while accounting for real-world complexities such as overlapping projects and changing network definitions. The key steps include:

1) Selecting a general approach
2) Screening projects
3) Identifying project influence areas
4) Joining dataset to the project influence area
5) Apportioning benefits from overlapping projects
6) Calculating changes between before and after performance
7) Adjusting performance changes for noise
8) Reporting metrics

More details on each of these framework elements can be found in this report.

Data, Performance Measures, and Challenges

PCA relies on existing WisDOT data systems, with Meta-Manager serving as the primary analytical foundation. It is supplemented by traffic counts, crash records, project data, travel time data, and the National Bridge Inventory (NBI). Together, these datasets support evaluation across safety, mobility, and preservation metrics. However, a key implementation challenge is that roadway segmentation in Meta-Manager changes over time, preventing direct longitudinal tracking of fixed segments. As a result, the developed PCA framework relies on a corridor-based approach that reconstructs project influence areas for each year and aggregates performance using length-weighted methods. Additional challenges include rolling multi-year safety reporting, incomplete or missing data, limited availability of modeled "expected performance" baselines, and variability in data definitions and system updates over time.

Despite these limitations, the framework demonstrates that meaningful and consistent project-level evaluation is achievable using existing data systems. Based on data availability, interpretability, and alignment with project intent, a core set of twelve performance measures was identified across three domains (Table 1).

Table 1. Performance Metrics Analyzed Post-Construction as part of this Research Effort

Metric	Description
Safety	
Total Crashes	Total crash frequency (5-year)
Fatal and Serious Injury Crashes	Fatal + serious injury crashes (5-year)
Annual Crashes	Total crashes (1-year)
Crash Rate	Crashes per 100 million vehicle miles traveled (5-year rolling)
Preservation	
Pavement Condition Index (PCI)	Overall pavement condition (0–100 index)
International Roughness Index (IRI)	Pavement smoothness (in/mi)
Bridge State of Repair Percent Deck Area	Percent of deck area within project area that is good, fair, and poor
Mobility	
Level-of-Service (LOS)	Traffic operating conditions (1-6 index)
Annual Average Daily Traffic (AADT)	Traffic demand / throughput (vehicles/day)
Median Travel Time	Corridor travel time (minutes) per trip
Peak Travel Time	Peak-period travel time (minutes) per trip (AM & PM)
Delay	Additional travel time above free-flow conditions (minutes) per trip

Insights from Sample Evaluations

The PCA framework was applied to the following three WisDOT projects as a proof-of-concept to test feasibility and demonstrate real-world application:

- I-94 North/South Corridor Expansion
- US 51 Two-Way Left Turn Lane (TWLTL) Conversion
- I-41 & US 10 Interchange reconstruction

Across these case studies, the framework successfully supported before-and-after analysis using existing WisDOT data systems. High-level results showed that the projects made progress toward their primary performance objective, but sometimes at a tradeoff to other performance measures. Conducting more PCA in an institutionalized manner can help WisDOT to better understand what a similar project is likely to accomplish under similar circumstances and to take credit for its effective stewardship through strategic communications. Importantly, the value of PCA is less about perfect analysis precision in every instance and more about establishing directionally correct trends in a structured, transparent process that lends to learning from completed investments over time. The evaluations further demonstrate that meaningful project-level performance insights can be generated using existing data systems, even with limitations in data completeness and segmentation consistency.

Key Takeaways and Next Steps

This study demonstrated that WisDOT can implement a scalable PCA program using existing data systems, established analytical methods, and a structured workflow. The framework provides a practical mechanism for closing the loop between project delivery and realized performance outcomes. To move from framework to practice, the following steps are recommended:

1) **Establish enterprise-level PCA governance**
    a) Define purpose, scope, and decision-making authority
    b) Secure leadership alignment and cross-divisional coordination

2) **Start with pilot PCA applications**
    a) Conduct ad-hoc analyses on select "lower complexity" projects
    b) Focus on learning, not standardization in early stages

3) **Build a growing PCA knowledge base**
    a) Document methods, assumptions, and outcomes across projects

b) Identify recurring data issues and methodological refinements

4) **Improve efficiency through standardization and automation**
   a) Develop reusable scripts for data extraction, spatial joins, and metric calculation
   b) Automate data pipelines from systems such as Meta-Manager and NBI
   c) Create standardized visualization and reporting templates

5) **Transition toward scalable implementation**
   a) Reduce manual processing through repeatable workflows
   b) Improve consistency across analysts and project types
   c) Gradually integrate PCA outputs into planning, programming, and asset management processes

From a staffing perspective, PCA can be implemented with a small interdisciplinary team combining data analysis, GIS, and subject matter expertise. However, long-term scalability will depend heavily on automation, standardized workflows, and improved data integration.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

WHY PCA MATTERS TO WISDOT

WisDOT has invested billions of dollars in Major, Mega, and Regionally Significant transportation projects to save lives, reduce travel time delays, and maintain highway pavements and bridges in a good state-of-repair. Post-Construction Analysis (PCA) provides a structured way to evaluate whether those intended outcomes are realized in practice. By examining actual conditions after project completion, PCA creates a feedback loop that strengthens accountability, improves transparency, and supports continuous improvement in how future investments are planned, designed, and delivered.

While WisDOT already maintains strong performance management systems through MAPSS and the Highway Performance Monitoring System (HPMS), those frameworks primarily focus on system-level or aggregated measures. PCA complements these efforts by focusing on project-level outcomes, helping answer not just how the system is performing, but how specific investments are contributing to that performance. This added level of insight is particularly valuable for high-cost projects, where understanding realized benefits is critical to validating investment decisions and refining future strategies.

What is PCA?

Post-Construction Analysis (PCA) is a structured, data-driven approach for evaluating the real-world outcomes of completed transportation projects. It compares conditions before and after construction to assess whether a project delivered its intended benefits, such as improvements in safety, mobility, asset condition, or operational performance. In doing so, PCA helps "close the loop" between project planning, delivery, and observed performance outcomes.

PCA is not a single metric or model, but a framework that combines performance measures, data sources, and analytical methods to answer a set of core questions: What changed? Why did it change? And did the project perform as expected? It can be applied at multiple scales, from individual projects to program-level evaluations, and supports both internal learning and external accountability.

Project Overview

This report develops a practical, repeatable framework for conducting PCA on WisDOT's Major, Mega, and Regionally Significant projects. The framework is designed to be implementation-ready, leveraging existing WisDOT data systems and aligning with established performance management practices. It provides a structured process for defining evaluation questions, selecting appropriate metrics, assembling and processing data, conducting before-and-after analysis, and communicating results to technical staff, leadership, and external stakeholders.

The approach builds on national best practices, including insights from NCHRP Project 08-170: *Closing the Loop: Post-Implementation Evaluation of Transportation Projects* (publication expected in Summer 2026), as well as WisDOT-specific data environments and prior analytical efforts. It is intended not only to support initial PCA implementation, but also to establish a foundation for long-term institutional learning and continuous improvement in project delivery.

WHAT WE LEARNED FROM THE LITERATURE

The literature review presented herein is intended to provide a solid foundational understanding of the state-of-the-practice for developing a practical, repeatable framework to evaluate post-construction outcomes of Major, Mega, and Regionally Significant projects. The review focused on statistical methodologies and organizational frameworks that could be readily adapted and applied by WisDOT staff to support post-construction analysis (PCA).

> *"You can't really know where you are going until you know where you have been."*
>
> *-Maya Angelou*

The research team had recently completed a literature review for National Cooperative Highway Research Program (NCHRP) Project 08-170 on post-implementation evaluation (PIE). As such, this review provides key insights from that study while layering on WisDOT-specific research and other recent PCA studies.

From the NCHRP 08-170 Literature Review

For NCHRP 08-170, the research team's literature search encompassed past NCHRP reports, industry and academic journals, magazines, websites, publications from many state university research centers, public agency guidance, and existing public agency evaluations. The research strategy focused on casting a wide net and extracting representative samples of publications across topic areas. This search showed that 'post-implementation' is a concept that goes by many names, such as 'before and after', 'audit', and 'ex-post'.

To avoid missing potential innovations, the research team reviewed cross-industrial sectors using the Sage Publications suite of library products. In applying the keywords to these broader industries, PIE/PCA frameworks were discovered in i) accounting, auditing, and finance, ii) economics, iii) education and behavioral science, iv) energy, v) medicine and public health, and vi) social impact sectors. When reviewing sources, the team looked for:

- Prior PIEs/PCAs and their approaches
- Evaluated metrics, categorical groupings, and explanatory factors, and

- Relevant takeaways

Research spanned both technical and organizational approaches. Across the 169 works cited, PCA most commonly followed one of the following two approaches: “With vs. Without” and “Before vs. After” (Figure 1). Table 2 covers the key takeaways from the different research focus areas of the NCHRP 08-170 literature review. The full list of sources, organized by focus area, can be found in References.

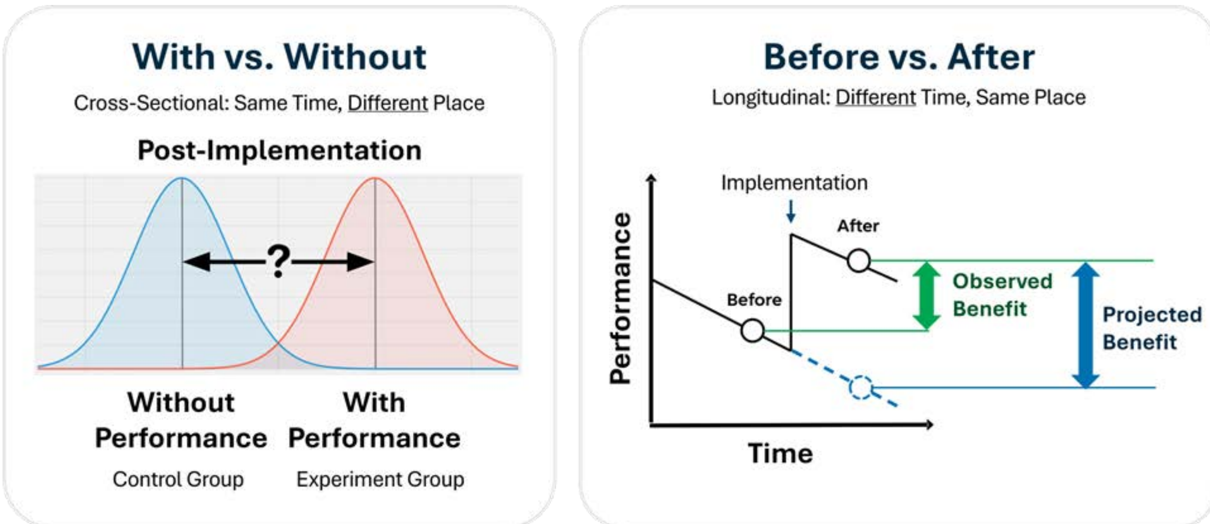

Figure 1. The two general analysis approaches to PCA (Source: NCHRP 08-170 Guidebook)

Table 2. Takeaways from the NCHRP 08-170 Literature Review

Research Focus Area	Takeaways
Highway Safety	**Analysis methods should be tailored to the available data** – if longitudinal data is available, then a before-and-after technique may be appropriate; otherwise, a cross-section with and without the method may be preferred.
	Regression techniques can help isolate the relative impact of improvements relative to other influential external factors – Regression techniques and comparison groups have proven effective in isolating the relative impact of an improvement compared to background noise from confounding factors.
	Building a repository of post-implementation evaluation before and after studies can help others learn from the past and inform future assessments.
Highway Mobility – Capacity	**Capturing the comprehensive impacts of a project may require quantifying before and after data outside of a project’s construction limits** - As demonstrated in Sudheendra Yesantarao & Pulugurtha (2020), establishing a broader influence area may be necessary to capture impacts on other facilities whose performance is affected by the

Research Focus Area	Takeaways
Expansion	project being evaluated.
	Need to isolate 'natural' changes occurring at a project location - As noted in Graham (2017), statistical techniques may be needed to isolate the 'noise' in longitudinal datasets resulting from inherent changes in site conditions rather than a direct impact from constructing a project.
	Use intuitive metrics – some researchers consider monetized travel time savings to be a more straightforward way to communicate the observed benefits of a project to non-transportation experts, as compared to complex travel time indices (Centre for Studies (CSIL) et al. (2020a) and (2020b)).
Highway Mobility – Operations	Both NCHRP Report 551 (Chase et al., 2006) and Report 920 (Harrison et al., 2019) included **recommendations to increase the carefully designed post-implementation evaluations for highway operations.**
	Post-implementation evaluations need not be a timely endeavor –By quickly gathering data before, during, and after a technology is turned on and off, the benefits of operational enhancements can be observed in near 'real-time' (Hoogendoorn et al. (2016).
	Visualizations of performance over time can effectively communicate post-implementation data – heat maps and oblique plots can be practical tools to see apparent deviations in site performance trends during/after implementation of a project (Dutta et al. (2018).
	Program usage and surveyed responses can be data points for assessing post-implementation impacts – As noted in Finke & Schreffler (2004), not all post-implementations require traditional, longitudinal transportation datasets to communicate the benefits of certain project types like transportation demand management strategies. Survey responses can serve as a basis to forecast future mode shifts and travel behavior changes if a sufficient sample size can be realized (Rashedi et al., 2017).
	Post-implementation evaluations can help calibrate simulation software – before and after field data can provide critical data points for estimating how improvements will change user behavior moving forward under similar designs (Lyer et al., 2010).
	Regression to the mean (RTM) can help mitigate the impacts of 'noise' in before-and-after data. Park and Lord (2010) recognized the importance of methods like RTM in traffic data to address temporal biases.
Highway Mobility – Congestion	**Care is needed when defining post-implementation evaluation metrics not to conceal equity issues -** While counterintuitive, Burris & Ashraf (2019) found that increasing tolls was associated with more traffic on tolled roads and revenue. However, frequent managed-lane users decreased their utilization, highlighting the importance of

Research Focus Area	Takeaways
Pricing	disaggregate analysis. Researchers found that existing users were 'priced out' and had to find other routes. This led those willing/able to afford the price to take the suddenly less congested route, only for the system to level off at even more congestion than before the pricing change.
	Isolating impacts due to policy changes is difficult - Willson & Irish (2016) concluded that features related to parking program implementation and local context influence program outcomes counterintuitively, e.g., parking price increments do not generate parking demand reductions. This could be due to underlying 'noise' in site data or a change in the socioeconomics of parking users. Still, some intermediate outcomes, like reduced cruising and better parking use, align with expectations and benefit broader goals like pollution reduction. However, finding the direct connection between price changes and outcomes is challenging and requires innovative data collection and modeling frameworks.
Active & Public Transportation Mobility – Operations	**Use of public surveys to supplement data** – gauging public reactions to service levels can help quickly validate data and directly indicate project success.
	Quick builds indicate the likely post-implementation success of more extensive projects – when feasible, piloting enhancements can give a low-cost way to gauge the likely efficacy of a full reconstruction.
	Considering a broader impact area can help build buy in – ripple effects of projects can create angst among the public as learned in the reviewed SFMTA project. Quantifying tradeoffs of how one road may be improved at the expense of another can help paint a clearer picture for the public to decide on issuing support for an effort.
Active & Public Transportation Mobility – Major Capital Projects	**Operations and Service Define Transit –** many facets of transit operations, such as service hours and headways, can be highly flexible. Transit is also unique in that operation costs are relatively high. Effective before-and-after studies need to consider the specifics of transit operations to ensure accurate comparisons. Furthermore, transit agencies may tweak or modify service frequently to address challenges or performance problems.
	Define Benchmark Points for "Before" and "After" – the transit market is very dynamic and changes to transit ridership are typically not immediate and may take time to come to fruition. Transit service is similarly fluid. Clearly defining appropriate points to collect and evaluate "before" and "after" data will support future evaluations reflecting a mature transit project.
	Use of public surveys to supplement data – gauging public reactions to service levels can help quickly validate data and directly indicate project success. Novel approaches such as the study conducted by Al-Sahar et al. (2024) are available without surveys, but the barrier to distributing surveys is also increasingly low. The rise of companies connecting transit agencies directly with their riders such as the transit app and Swiftly provide an opportunity for reaching riders directly for feedback as the transit app did to

Research Focus Area	Takeaways
	create their 2021 Rider Happiness Benchmarking Report.
Preservation – Pavement	**Pairing longitudinal [historical] inspection data with treatment histories** – the LTPP database for pavement has allowed researchers to conduct asset- and system-level analyses for years. This has enabled researchers to have at least three data points before and after a treatment which helps determine if a trend is consistent and either linear or not. When paired with treatment, a clearer picture emerges as to the typical efficacy of an improvement.
	Setting aside test sections – when feasible, having different stations regularly monitored can help isolate the influence of confounding factors on performance data.
	Field tests are an effective way to test designs – a site-specific field test may be appropriate for very specialized before/after queries.
Preservation – Bridge & Geotechnical Assets	**Need for aligning work histories with longitudinal inspection data** – Longitudinal data is plentiful regarding NBI inspection data. Having historically archived information on what precise treatment was done at what time is less well-known causing researchers to make assumptions based on sudden improvements in condition ratings.
	Comprehensively evaluate projects for both short- and long-term benefits – In some cases, researchers focused more on immediate changes in performance. In contrast, others took a longer-term perspective more focused on the amount of time 'bought' until performance reset to pre-treatment levels. Variations also included when to report a magnitude change vs. just focusing on a consistent end condition and when to report at the component vs. element levels.
	Post-implementation approaches can be tailored to the question being answered – Post-implementation need not be a systemic analysis but can be evaluated through in-situ testing of alternative designs and materials. Findings can then be transferred to broader design guidance for assets under similar conditions and environmental loadings. A more testing-based approach can offset the waiting time to observe asset changes with naturally longer service lives.
Economic Impacts	**Some impacts require a more extended sequence of events to play out** – Transportation projects do not always immediately provoke change but can trigger a more extended sequence of events. For instance, a new highway can inspire development, eventually creating jobs that people will relocate to and generate taxable wages. This can play out over 10 years as noted in EDRG (2012).
	Regression can cut through the noise – Comparing the relative explanatory power of a comprehensive set of factors beyond transportation can help increase confidence in an improvement's actual influence.
Environmental	Evaluating the environmental impacts of transportation projects can be complex,

Research Focus Area	Takeaways
Impacts	however post-implementation evaluations are possible and can utilize methods developed to perform ex-ante predictions (a practice that is generally very robust).
	Direct Monitoring and Evaluation is Most Possible on Regional Scales – For most environmental impacts, direct monitoring of projects impacts is difficult, however when evaluating broader impacts of large projects or programs, regional air quality and water quality monitoring is possible and infrastructure for data collection is most likely already be in place.
	Use Models to Estimate Pollutants Based on Easier to Observe On-road Activities of Mobile Sources – When evaluating project-level impacts, it can be difficult to directly measure them, especially for smaller projects. However, numerous models developed to predict project environmental impacts can be repurposed using observed on-road activities such as vehicle miles traveled, fleet makeup, and vehicle speeds to estimate environmental metrics.
	Experimental Approaches are Possible When Isolating Factors – For projects where the goal of evaluation is to test specific countermeasures (such as green infrastructure mitigations for water or air quality) a more experimental approach may be required, where specific testing infrastructure is put in place to test the countermeasure specifically.
Equity Impacts	**Importance of disaggregate analysis** – A best practice from the literature is to incorporate disaggregate analyses into post-implementation evaluations by breaking before and after results down for different communities and demographic profiles.
	Recognizing that those experiencing a need may not be the ones to realize the benefit of an improvement – Traveler origin/destination analysis post-implementation is increasingly being used by agencies to assess “who benefits” from different facility improvements. It can be beneficial to check that the typical breakdown of road user demographics/socioeconomics does not change before and after a project.
Security	Post-implementation evaluations of technology solutions have the unique ability to be conducted rapidly through with and without testing. **Even transportation agencies' IT functions can benefit from post-implementation evaluation.** For security-related evaluations, this is best done in a simulated setting where the efficacy of cyberattacks can be analyzed with different defensive platforms turned on or off.
Project Delivery – Project Management	**Have clear roles and responsibilities** with widely known levels of authority.
	Provide training and access to on-site supervisors for project managers.
	Keep project managers motivated by incentivizing strong performance.
	Reduce staff time burdens by removing requirements for unnecessary professional

Research Focus Area	Takeaways
	licenses and limiting the extent of simultaneous project commitments.
	Consider project funding mechanisms as they can influence the efficiency of the project delivery process.
Project Delivery – Cost Estimation	**Find measurable leading indicators** that can help proactively mitigate risk, even if the data is a 'proxy' for unknowns.
	Continuously reassess estimation risk throughout the project development cycle.
	Have consistent and standardized training of staff tasked with cost estimation.
	Focus evaluations on larger scale projects as a slight improvement in estimating costs can have a large impact on the overall agency bottom line.
	Recognize that some transportation modes may be more susceptible to more variability in cost estimation.
	Establish contingency strategies to overcome adverse impacts from uncertainties can mitigate risk.
Cross-Industry	**Advanced statistical models could be transferred to transportation analyses** – Private sector, profit-centric industries have developed advanced statistical models that help cut through volatility in longitudinal data to guide future policies. Such pattern recognition could theoretically be applied to 'big' post-implementation datasets.
	We need to understand the benefit timeframe – Benefits can be short- and long-term. Understanding the relative distribution of such benefits over time can help focus post-implementation evaluations. For instance, if the full economic benefits of transportation projects take ten years to realize, maybe an earlier indicator after four years can give a clearer picture of what benefits may be realized later on.
	Performance-based incentives – Some cross-industry researchers have noted that financial awards post-implementation based on performance progress may improve outcomes across the system. It can be tricky in transportation to define what progress means for agencies with different starting points, but recognize that motivating agencies in some way to conduct post-implementation can go a long way.
	Need for standards – Uniformity in how post-implementation evaluations are conducted can go a long way toward providing comparison points. As the CDC has found, ensuring all staff are rowing in the same direction can yield better outcomes.

Supplemental Review for WisDOT

The research team supplemented the NCHRP 08-170 work by reviewing the resources listed in "References: Supplemental Sources for WisDOT". These resources covered PCA studies, data management/governance strategies, and performance management best practices. Various WisDOT-funded research studies were included to better understand the state-of-the-practice within WisDOT. Table 3 covers the key takeaways from the supplemental review.

Table 3. Takeaways from the Supplemental Literature Review for WisDOT

Research Focus Area	Takeaways
Post-Construction Analysis	Technical approaches in the literature consisted of both before/after and with/without analysis: • **'Rigorous' before/after analysis** used in safety has proven effective in mitigating noise and differentiating benefits from a 'natural' reversion to the mean (Claros et al., 2022). • **Comparing pilot (with) and control (without) group** means with T- and chi-squared tests can help determine the statistical significance of the piloted improvements (Tabatabai et al., 2022).
	Qualitative surveys can supplement more objective analyses of before/after data (Tabatabai et al., 2022).
	Random forest type tree models can help **identify correlations with observed outcomes** (Noyce & Song, 2020).
	Post construction **benefits can come in waves** with second-order benefits resulting from the first-order benefits, etc. (Wittwer, 2011).
	Time variant charts/dashboards can visually communicate project impacts (Pande, 2018).
Data Management & Governance	A **vast array of WisDOT data exists** but some are marked sensitive and half lack metadata, meaning the data used for this pilot may require some additional level of effort from WisDOT staff to provide and interpret (Graettinger et al., 2022).
	Clean historical data is key to avoiding propagating analytical errors. Checks can encompass basic missing/outlier checks, spatial/temporal checks for reasonable comparative trends/values, and multivariate checks that the attributes in relation to each other pass the sniff test (Chen et al., 2019).
	Close coordination with IT staff will be needed for PCA data intake requests (Graettinger et al., 2023).

Research Focus Area	Takeaways
	Advanced imaging analysis software has the potential to vastly streamline before/after analyses and increase sample sizes (Faheem et al., 2018).
	Preliminary PCA findings can justify **expanded data collection** programs (Faheem et al., 2018).
	Spatial geometry types should reflect the extent of the project and not just a centroid location if want more precise analyses (Appleyard et al., 2024).
Performance Management	Having **planned recurrence checks** can help determine the duration of observed benefits from a project - essentially, an improvement in service life (Blume et al., 2000).
	Better outcomes come with better planning. The literature recommends: • Proactively focusing on **leading success indicators** before a project can mitigate the risk of poor performance after a project. An evaluation committee structure with technical advisors & oversight from representative leadership can be a model for PCA evaluations (Qin et al., 2022). • Proactively **aligning planned improvements with need** is an important step lest a PCA reveal an inherent flaw in the project development process (Liu et al., 2020).
	Establishing a reporting requirement prior to programming projects can ensure data is available for the before/after analysis (Appleyard et al., 2024).
	PCA results can be **used to identify discussion topics** with staff rather than using outcomes as singular datapoints to report (Schneider et al., 2024).
	Learning modules may be needed to institutionalize PCA knowledge management units (Singh & Qin, 2023).

BUILDING A SUSTAINABLE PCA PROGRAM

To move from insight to action, PCA needs more than one-off analyses: it needs a structure that can be applied consistently while still adapting to the realities of different projects. The framework presented in this section is designed with that balance in mind. It brings together an enterprise-level approach for establishing purpose, governance, and priorities, alongside a project-level workflow that guides how PCA is carried out in practice. Together, these components create a foundation for making PCA a repeatable, scalable part of how WisDOT plans, delivers, and learns from its projects.

At the enterprise-level, the framework focuses on setting direction: clarifying why PCA is being conducted, where it adds the most value, what level of support is needed across the organization, and how the results can be used to improve business processes. At the project-level, it shifts to application, outlining a flexible sequence for scoping, documenting, and interpreting analyses in a way that is meaningful for individual projects. These two perspectives are intentionally complementary: one provides consistency and continuity, while the other allows for variation based on project type, data availability, and staff capacity. Flexibility is a defining feature throughout. The framework emphasizes recommended strategies, decision points, and considerations rather than rigid requirements. This allows the approach to evolve over time and to be tailored to different contexts, whether for Major, Mega, or Regionally Significant projects.

Different users will naturally engage with the framework in different ways. Planning and programming staff may focus on the enterprise-level elements to guide when and why PCA is initiated. Project managers and technical staff are more likely to work within the project-level workflow as they carry out analyses. Executive leadership, in turn, may interact primarily with the outcomes, using PCA insights to understand performance trends, assess investment effectiveness, and inform future decisions.

The sections that follow expand on each part of the framework, outline potential roles, and address common challenges, with the goal of supporting a more consistent and durable approach to PCA across the agency.

An Enterprise-Level Framework

The enterprise-level portion of the framework (Figure 2) establishes the foundational decisions and considerations that guide how PCA is implemented across WisDOT before it is applied within individual project phases. These considerations are made at an organizational level and shape how PCA is governed, supported, and used over time. Specifically, the enterprise-level framework helps inform:

- Which questions PCA is intended to answer?
- How is PCA governed and supported?
- What outcomes are evaluated and how?
- How do PCA efforts scale across project types?

This portion of the framework draws on national best practices, including the NCHRP 08-170 research, and is tailored to WisDOT's existing structure and current state of practice. Several steps within the enterprise-level workflow represent decisions WisDOT will need to address as part of implementing or further standardizing PCA. The sequence of steps reflects a recommended order for effective adoption (for example, establishing internal support and clarity of purpose before developing communication products), but the framework is not intended to prescribe a single implementation path.

Several elements of the enterprise-level framework represent key decision inflection points that benefit from cross-divisional coordination or leadership direction, including:

- Clarifying the primary questions PCA is intended to answer (e.g., accountability, forecast validation, policy learning, or program refinement);
- Determining how PCA will be coordinated, governed, and supported across divisions;
- Identifying priority project types or programs for early or pilot PCA application; and
- Establishing expectations for how PCA results will be communicated and integrated into planning, programming, or asset management processes.

The enterprise-level framework also includes a feedback component, emphasizing that PCA practices should be refined over time as experience is gained and organizational needs evolve.

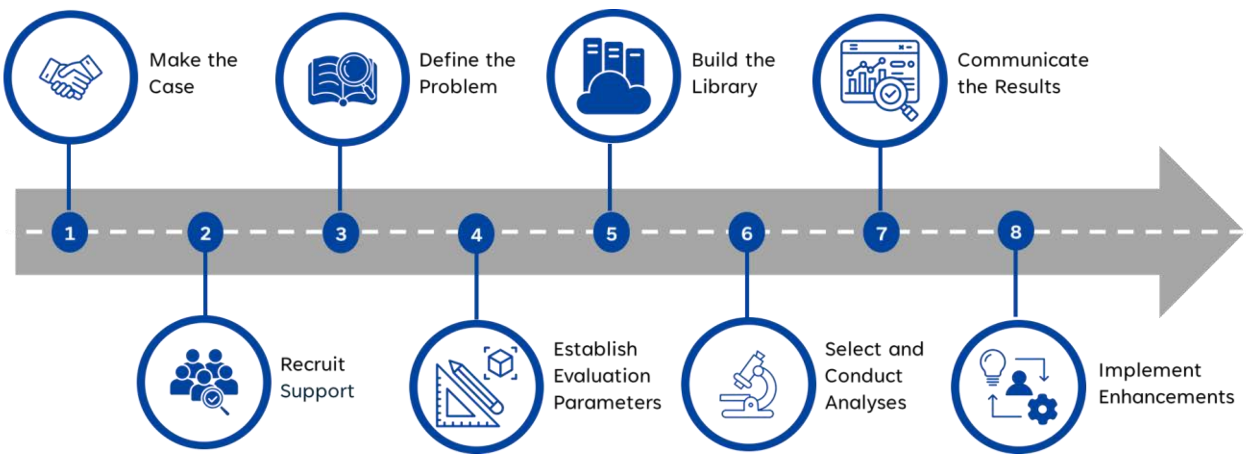

Figure 2. Enterprise-level PCA framework (Source: NCHRP 08-170 Guidebook)

1) Make the Case for PCA

Establishing a sustainable approach to PCA begins with a clear and shared understanding of its purpose. At its core, PCA provides a structured way for WisDOT to understand what its transportation investments are actually delivering once projects are built and in operation. Rather than relying solely on assumptions made during planning and design, PCA creates a feedback loop grounded in observed outcomes. It is vital to gain organizational support by clarifying that a consistent PCA approach will:

- **Connect investment decisions to observed outcomes** to improve decision-making;

- **Improve accountability and transparency** through measured results;
- **Strengthen performance-based planning and programming** by closing the loop between planning, delivery, and outcomes; and
- **Support continuous improvement** by identifying what strategies work best under different conditions.

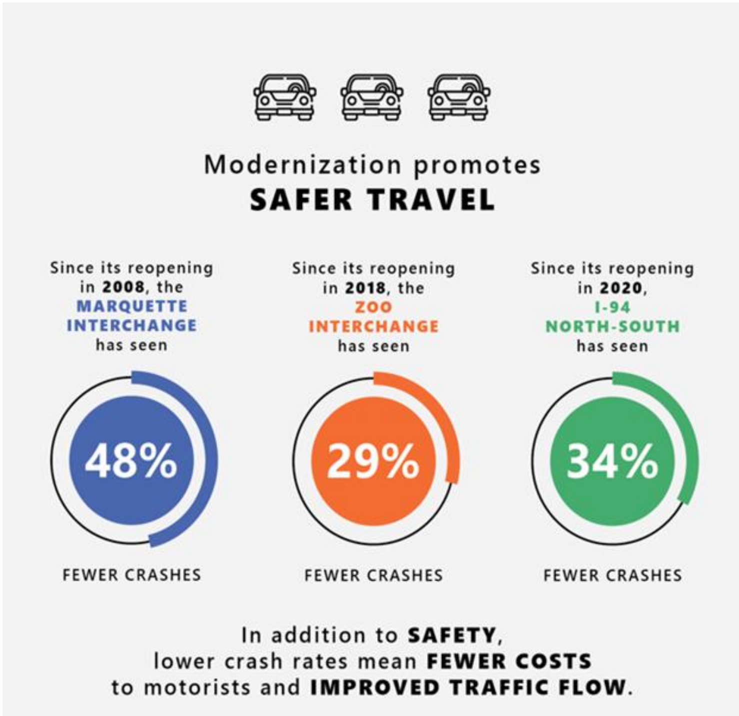

Figure 3. Example PCA application for WisDOT modernization projects (Source: WisDOT)

Positioning PCA effectively also requires clarity about what it is and what it is not. PCA is not intended to evaluate or judge individual projects after the fact, nor is it a tool for assigning blame. Instead, it is a forward-looking process designed to generate insights that can improve future investments. It can also be used to showcase “wins” and standout investments (Figure 3). Framing PCA in this way is essential to building trust, encouraging participation, and fostering a culture that values learning and improvement.

The strategies presented in the following table (Table 4) build on this foundation, outlining practical ways to support adoption and build buy-in across the organization.

Table 4. Common Organizational Challenges to Implementing PCA

Organizational Challenge	Strategy	Framework Step(s)
Limited staff time and competing priorities	Start with targeted, scalable PCA use cases that build on existing TPM, planning, and asset management workflows	Step 3 – Define the Problem
Concern about how results may be perceived	Position PCA as a learning and improvement tool, not a project audit, focusing first on aggregated results and external context	Step 7 – Communicate Results
Need for leadership alignment	Align PCA with WisDOT's stewardship, performance-based planning, and transparency objectives using concise executive-level messaging	Step 1 – Make the Case
Unclear ownership across bureaus	Establish a cross-bureau PCA resource group with a clearly defined PCA lead to coordinate analysis, data, and communication	Step 2 – Recruit Support
Different levels of readiness across programs	Use a readiness-based approach to determine where PCA can add value first and scale over time	Step 2 – Recruit Support Step 3 – Define the Problem

2) Recruit Support

Establishing PCA as a sustainable practice depends on defining how the work is owned, coordinated, and supported across WisDOT. This includes both selecting an organizational model for implementation and identifying how existing roles and offices contribute to PCA over time. At an organizational level, PCA can be structured in several ways (Figure 4), each offering different advantages depending on agency priorities, resources, and maturity. Table 5 compares these structures across key dimensions, including purpose, execution, metrics, and scalability, and is intended to support informed decision-making about how PCA is organized within the agency.

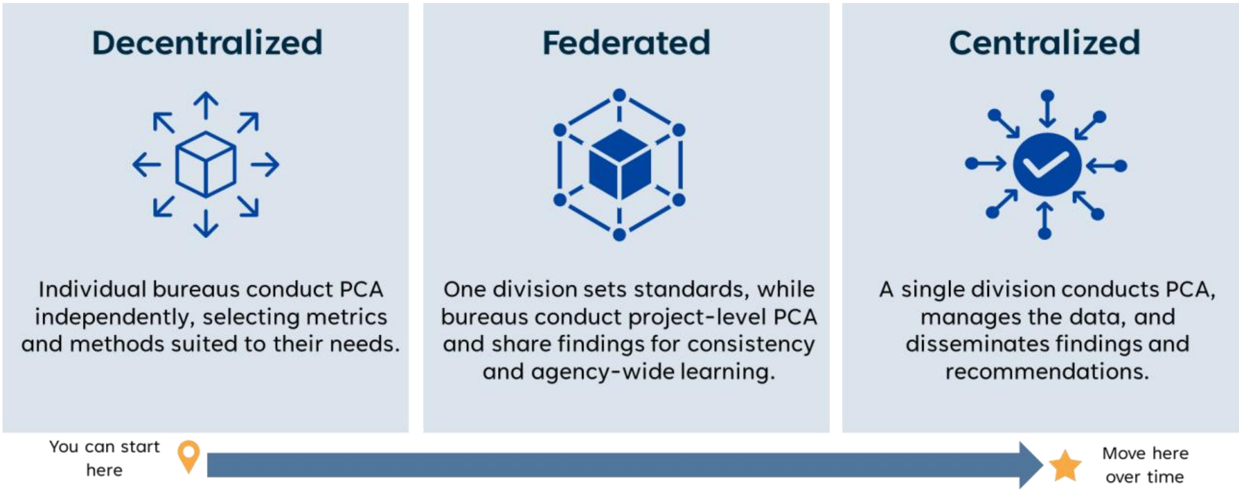

Figure 4. Potential organizational structures for conducting PCA

Table 5. Comparison of Potential PCA Organizational Structures

Dimension	Decentralized	Federated	Centralized
Purpose	Flexibility	Learning & improvement	Consistency & oversight
Framework	Divisional	Central	Central
Execution	Distributed	Distributed	Central
Metrics	Variable	Core + flexible	Fixed
Comparability	Low	High	High
Autonomy	High	Moderate	Low
Scalability	High	High	Moderate
Decision Authority	Local	Shared	Central
Pros	Easy and fast implementation	Balances consistency with flexibility, scalable	Strong consistency, clear ownership, easy comparison
Cons	Limited comparability, inconsistent application	Requires coordination and clear roles	Resource-intensive

Regardless of the organizational model selected, PCA is most effective when it builds on existing roles and responsibilities rather than creating entirely new structures. Across WisDOT, many offices already contribute to activities that align with PCA (Table 6), from project development and performance monitoring to financial tracking and public communication. The goal of this framework is to clarify how these contributions fit together across the PCA lifecycle.

Table 6. WisDOT Divisions & Bureaus to Potentially Support PCA

<table>
<tr><td colspan="4">Division of Transportation System Development (DTSD)
DTSD leads project development decisions, understands intended outcomes, and is best positioned to interpret outcomes that were achieved. The list below shows how bureaus within DTSD are already conducting PCA-related activities or could become involved in PCA-specific activities:</td></tr>
<tr><td>Bureau of Project Development (BPD)
• Project scoping, alternatives analysis, environmental coordination
• Design oversight and consultant management
• Strong candidate for PCA coordination at the project level</td><td>Bureau of Structures (BOS)
• Bridges and large structures common in Mega projects
• Key source for structural performance, condition, and lifecycle outcomes</td><td>Bureau of Traffic Operations and Safety (BTO)
• Safety performance, operations, traffic management
Core source for safety, reliability, and operational outcomes</td><td>Regional Offices
• Day-to-day project delivery
• Institutional knowledge of construction history, phasing and constraints
• Critical for interpreting post-construction outcomes in context</td></tr>
</table>

<table>
<tr><td colspan="3">Division of Transportation Investment Management (DTIM)
DTIM connects projects to system-level goals, investment decisions, and accountability. The list below shows how bureaus within DTSD are already conducting PCA-related activities or could become involved in PCA-specific activities:</td></tr>
<tr><td>Bureau of State Highway Programs
• Oversees the Major, Mega, Large Bridge, State Highway Rehabilitation(SHR), Highway Safety Improvement Program (HSIP)
• Manages project programming, scheduling, and alignment with funding availability
• Providing critical context for how projects were prioritized and programmed
• Potential managers for PCA methodology</td><td>Bureau of Planning and Economic Development
• Statewide and regional planning, including coordination of TIPs/STIP
• Travel, economic, and land-use impacts
• Key partner for mobility, access, and economic outcome metrics</td><td>Office of Asset and Performance Management (OAPM)
• Bridge between asset management and performance
• Early indicators of asset performance and durability</td></tr>
</table>

Supporting and Enabling Offices and Bureaus			
Outside of the two primary divisions identified above, the following additional office and bureaus could also support and enable PCA within WisDOT. The list below shows how these bureaus/offices are already conducting PCA-related activities or could become involved in PCA-specific activities:			
Division of Budget and Strategic Initiatives (DBSI): Bureau of Performance, Measurement, Research and Strategic Initiatives • Enterprise-level performance measurement and research activities • Supports strategic analysis and evaluation efforts • Could support transition of PCA from research into standard practice, as appropriate	**Division of Business Management (DBM): Bureau of Financial Management** • Cost, funding, and investment tracking • Supports cost effectiveness and delivery metrics • Providing financial context for PCAs	**Office of Public Affairs / Communications** • Public transparency • Could translate PCA findings for external audiences	**Office of the Secretary / Deputy Secretaries** • Oversight of high-visibility projects • Policy alignment and institutional PCA adoption

The roles identified here are aligned with WisDOT's existing organizational structure and were informed by discussions with staff across divisions and bureaus. These roles are intended to clarify how different offices may contribute to PCA delivery and sustainability, without mandating that specific divisions assume fixed responsibilities. To support clarity without over-prescription, roles are further described in Table 7 using a RACI lens that distinguishes who is: **R**esponsible for completing activities, **A**ccountable for outcomes, **C**onsulted for input, and **I**nformed of progress or results.

This approach helps clarify expectations and coordination points across divisions while allowing WisDOT flexibility in assigning specific staff or offices over time. Applying a RACI lens to PCA supports clearer coordination across divisions and helps mitigate common implementation challenges identified in national research, including unclear ownership, reliance on informal institutional knowledge, and difficulty sustaining PCA through staff turnover. Clarifying responsibility and accountability, while allowing flexibility in staffing assignments, supports continuity without requiring new organizational structures.

Table 7. Potential WisDOT PCA Roles and Responsibilities

PCA Function	DTSD / BPD	DTSD/ Regions	DTSD/ BOS	DTSD/ BTO	DTIM	DTIM/ OAPM & DBSI	DBM
Project Screening & PCA Inclusion	A	C	C	C	R	I	I
Define Evaluation Purpose & Scope	A	C	R	R	R	C	I
Document Scope, Design & Context	R	R	C	C	I	I	I
Data Assembly & Metric Development	I	I	R	R	R	A	I
Analysis & Interpretation	C	C	R	R	C	A	I
Communicate Results	C	I	C	C	R	A	I
Institutional Learning & Method Updates	I	I	C	C	R	A	I

3) Define the Problem

With support for PCA established, the next step is to clearly define the problem it is intended to address. PCA is most effective when it is guided by specific questions tied to agency priorities, rather than applied as a general or open-ended evaluation tool. In practice, this means identifying what decisions PCA is meant to inform. Within this context, PCA helps "close the loop" by linking planned outcomes to observed results after projects are constructed and in operation.

As illustrated in Figure 5, PCA can support a range of questions at different stages of the Performance-Based Planning and Programming (PBPP) process. Framing PCA around these types of questions ensures that analyses remain decision-focused and aligned with agency needs.

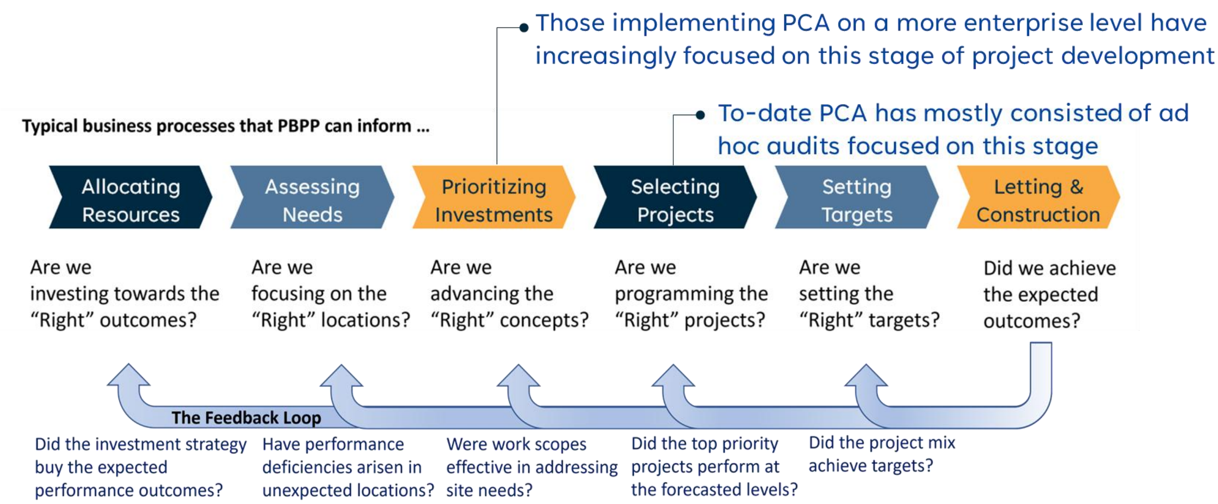

Figure 5. How PCA can Provide Valuable Feedback into Earlier Stages of the PBPP process (Source: NCHRP 08-170 Guidebook)

Defining these use cases is not solely a technical exercise; it is also a strategic one. Involvement from leadership is important at this stage to help prioritize which questions matter most, ensure alignment with agency goals, and reinforce how PCA findings will be used to inform future decisions. Table 8 builds on this foundation by outlining a range of potential PCA use cases and considerations. It is intended to help WisDOT identify which applications are most relevant in the near term, while also providing a framework for expanding PCA over time.

Table 8. How PCA Supports Different PBPP Use Cases

Use Case	Key Questions PCA Helps Answer	Why It's Valuable	Example Outputs
Allocating Resources	Are investments aligned with desired performance outcomes? Are current programs achieving intended results?	Supports system-level decision-making and accountability; focuses on ROI rather than individual projects	Performance return per dollar; effectiveness of spending by program
Assessing Needs	Where do performance gaps persist? Are some locations or populations underserved?	Directs resources to the highest-need areas; supports equity and efficiency	Identification of recurring needs; demonstrated improvement for targeted areas
Prioritizing Investments	Are we advancing the projects and strategies that best support our goals? Is prioritization evidence-based?	Enables transparent, defensible prioritization based on observed benefits	Benefit-based project type rankings; data-driven scope recommendations
Selecting Projects	Do programmed projects meet goals, schedules, and budgets? Are deviations affecting outcomes?	Improves delivery efficiency and risk management	Early detection of cost/schedule overruns; optimized letting schedules
Setting Targets	Are targets realistic, data-driven, and achievable?	Reduces risk of missed targets and strengthens performance management	Confidence that planned investments can meet adopted targets

4) Establish Evaluation Parameters

Once priority use cases have been identified, the next step is to define how project impacts will be measured. Establishing evaluation parameters involves selecting the performance areas, metrics, and comparison approaches that PCA will use to answer the questions identified in the previous step.

PCA can draw from a wide range of potential performance measures, spanning safety, mobility, asset condition, and broader system outcomes. As documented through the literature review conducted for this project, agencies across the country have applied diverse metrics depending on their goals, data availability, and analytical capacity. A comprehensive catalog of these measures is provided in the Appendix, which is intended to serve as a reference point (not a prescribed list) illustrating the breadth of what is possible.

In practice, selecting evaluation parameters requires balancing ambition with feasibility. Not all metrics are equally meaningful or practical in every context. Effective PCA focuses on a core set of measures that:

- Align with the defined use case and decision context,
- Reflect outcomes that can reasonably be influenced by the project,
- Can be supported with available or attainable data, and
- Are interpretable and useful to decision-makers.

For WisDOT, this means prioritizing metrics that support defined goals while ensuring consistency across projects where comparison is desired. Equally important is defining how metrics will be applied. This includes decisions about timeframes (e.g., before/after periods), geographic scope (e.g., project limits vs. corridor influence areas), and normalization (e.g., accounting for traffic volumes in safety analysis). These choices shape how results are interpreted and how comparable they are across projects.

Because PCA is intended to evolve over time, evaluation parameters should not be treated as fixed. Instead, they should be revisited periodically as new data become available, analytical methods improve, and agency priorities shift. Establishing clear (but flexible) parameters at the outset creates a foundation for consistency while allowing refinement over time. Additional details on how performance measures were identified, defined, and applied in this project is provided in The PCA Workflow in Practice section of this report, specifically the *Potential Performance Measures* subsection.

5) Build the Library

With evaluation parameters defined, the next step is to identify and organize the data needed to support PCA. Building a reliable data "library" is essential to making PCA both repeatable and scalable. This step focuses on understanding what datasets already exist, how they can be integrated, and where gaps may need to be addressed.

WisDOT has a strong foundation of data systems that can support PCA. Key among these is Meta-Manager, which integrates information on roadway characteristics, traffic volumes, crash history, pavement condition, and programmed improvements into a common framework. Additional datasets (e.g., traffic counts, detailed crash records, and project-level information) provide further context for understanding project performance. Together, these resources enable analysis across core performance areas such as safety, mobility, and preservation. At a high-level, building the PCA data library involves three key activities:

- **Inventorying available data** to understand what information exists, how it is structured, and how it aligns with desired evaluation parameters;
- **Assessing data quality and completeness**, including identifying missing or inconsistent attributes that may affect analysis; and
- **Identifying gaps and needs**, such as additional years of data, more complete project information, or supplementary datasets to support specific metrics.

This process is not purely technical; it also informs what is feasible in the near term. In this project, the evaluation approach was shaped by the data readily available within WisDOT systems and available to be processed by the research team, with metrics and methods selected to align with those constraints. Over time, as additional datasets become available or are enhanced, the PCA framework can expand to incorporate more advanced or comprehensive analyses. It is also important to recognize that challenges in data integration can influence the applicability of the available data and related evaluation parameters. These topics are explored in greater detail in *The PCA Workflow in Practice* section of this report.

Ultimately, the goal of building the data library is not to create a perfect dataset, but to establish a usable and evolving foundation for PCA. By organizing existing data, documenting limitations, and identifying opportunities for improvement, WisDOT can support a practical, scalable approach to evaluating project outcomes, one that strengthens over time as both data and methods continue to mature.

6) Select and Conduct Analyses

With evaluation parameters defined and the data library in place, the next step is to determine how the analysis will be carried out. As discussed in the *What We Learned from the Literature* section, most PCA efforts fall into two broad categories: **"with vs. without"** and **"before vs. after"** approaches (Figure 1). Each offers a different way of estimating project impacts, and each comes with its own data needs, assumptions, and tradeoffs.

Within these two categories, there is a spectrum of methodological options. The appropriate approach depends largely on the questions PCA is intended to answer, as well as the spatial and temporal characteristics of the available data. For example, some analyses may rely on modeled comparisons to estimate what would have happened in the absence of a project, while others focus on observed changes over time. In all cases, the goal is to isolate, as clearly as possible, the effects of the project from broader system trends.

For WisDOT, a **before-and-after approach** provides the most practical and defensible foundation for

PCA given current data systems and agency priorities. This approach emphasizes observed performance changes over time, supported by several key considerations:

- Defining appropriate project influence areas to capture where impacts are expected to occur,
- Accounting for overlapping or adjacent projects, so that benefits are not double-counted or misattributed, and
- Applying rigorous comparison techniques, such as Empirical Bayes methods, where appropriate.

Together, these elements help strengthen the reliability of findings while maintaining a framework that can be applied consistently across different project types. At the same time, flexibility remains important. Not all projects will support the same level of analytical rigor, and simpler methods may be appropriate in cases with limited data or less complex evaluation needs. The framework is intended to accommodate this range, allowing analyses to scale based on context while still aligning with overall PCA objectives. Detailed guidance on applying the methodology is provided in The PCA Workflow in Practice, specifically the subsection Evaluation Methodology.

7) Communicate the Results

For PCA to be effective, results must be communicated in a way that is credible, useful, and actionable. This requires tailoring how findings are presented based on the audience, recognizing that different users are looking for different levels of detail and different types of insight. A one-size-fits-all approach is unlikely to support decision-making across the agency.

At the executive level, communication should focus on program-level trends and system outcomes, helping answer questions about whether investments are delivering intended performance and where strategies may need to adjust. This is best supported through high-level summaries, a focused set of key performance measures, and clear, intuitive visuals such as dashboards that allow for quick interpretation. For technical staff, the emphasis shifts to project-level context: understanding what worked, under what conditions, and why. This requires more detailed, interactive views that support exploration of before-and-after conditions, peer comparisons, and underlying data.

For external stakeholders and the public, communication should emphasize transparency and stewardship. Clear visuals, plain-language summaries, and selective use of case studies or success stories can help convey what investments have achieved and how the agency is using PCA to improve over time. Across all audiences, the goal is the same: translate analysis into insight, and insight into informed action.

8) Implement Enhancements

The final step in building a sustainable PCA program is moving from analysis to implementation and continuous improvement. This involves developing a structured plan to scale PCA over time, refine methods based on early experience, and embed the process into routine decision-making across WisDOT. Rather than treating PCA as a one-time analytical exercise, the goal is to establish it as an iterative practice that continuously improves. Recommended keys steps for an implementation plan to scale and mature PCA include the following.

1. **Define Purpose and Use Cases:** Clarify how PCA will support WisDOT decision-making, such as informing investment strategies, refining project scoping, and strengthening performance-based planning.
2. **Establish Governance and Roles:** Designate a PCA lead and define roles across planning, technical bureaus, data/GIS, and communications to ensure clear ownership and coordination.
3. **Pilot PCA:** Apply PCA to a small set of projects or programs to test evaluation parameters, data availability, and analytical methods while building internal familiarity.
4. **Build a Roadmap and Set Milestones:** Define clear goals, timelines, and decision points for expanding PCA beyond pilots, informed by early lessons learned.
5. **Monitor Progress and Test Adjustments:** Use recurring check-ins to review results, identify challenges, and test targeted adjustments within selected programs before broader rollout.
6. **Iterate, Scale, and Institutionalize:** Refine methods based on pilot and early implementation results, scale successful practices agency-wide, and use retrospectives to document lessons learned and embed PCA into standard business processes.

A critical part of this stage is ensuring that learning is not incidental, but systematic. Table 9 illustrates how PCA results can be translated into actionable improvements through a structured “lessons learned” approach. It connects evaluation outcomes to strategic goals, identifies the insights they generate, and links those insights directly to potential adjustments in practice. It also clarifies which parts of the organization may be responsible for implementing those changes. In this way, the table serves as a bridge between analysis and action, reinforcing PCA’s role as a tool for continuous improvement rather than one-time evaluation.

Table 9. Hypothetical Example Log of Lessons Learned

Evaluation Outcome	**Strategic Goal**	**Actionable Insight**	**Proposed Adjustment**	**Responsible Team (Example)**
Reduction in crash rates by 25%	Improve roadway safety	Intersection upgrades are highly effective at reducing crashes.	Increase funding allocation for intersection improvements.	Bureau of Traffic Operations and Safety
Transit ridership fell short by 15%	Expand access to transit	Fare policies and service frequency affect usage in low-income areas.	Revise fare policies; expand service during peak hours.	Bureau of Transit, Local Roads, Railroads & Harbors
Pavement conditions deteriorated faster than expected	Preserve infrastructure assets	Current pavement materials are insufficient for high-traffic corridors.	Update design requirements or deterioration models.	Office of Asset & Performance Management
Emissions reduction target exceeded	Enhance environmental sustainability	Mode shift policies are driving emissions reductions in urban areas.	Expand bike lane and pedestrian infrastructure programs.	Bureau of Planning & Economic Development

The Project-Level Workflow

With key enterprise-level decisions in place, PCA can be applied more consistently across the project development lifecycle. The project-level workflow (Figure 6) illustrates how PCA activities align with planning, design, construction, and post-construction phases. It identifies:

- When PCA activities occur by project phase and
- Key decision points and responsibilities assignments.

While the project-level workflow is presented in a generally linear manner, it intentionally includes decision points or “exit ramps” where PCA may be deferred, scaled back, or not pursued. These exit points recognize that PCA is not appropriate or feasible for all projects and that early determination can help conserve staff time, analytical resources, and organizational goodwill. Not all projects are expected to undergo PCA, and the framework is designed to support informed decision-making about when and how PCA is applied.

Consistent with the framework's learning-oriented intent, the project-level workflow includes formal decision or "pause points," particularly prior to analysis, where staff can assess whether sufficient data and contextual information exist to proceed credibly. These pause points are intended to distinguish data limitations from true performance outcomes and to document lessons learned, even when full analysis does not move forward.

As with the enterprise framework, the project-level workflow includes a feedback mechanism to ensure that lessons learned from completed analyses inform future project scoping, forecasting, and PCA practices.

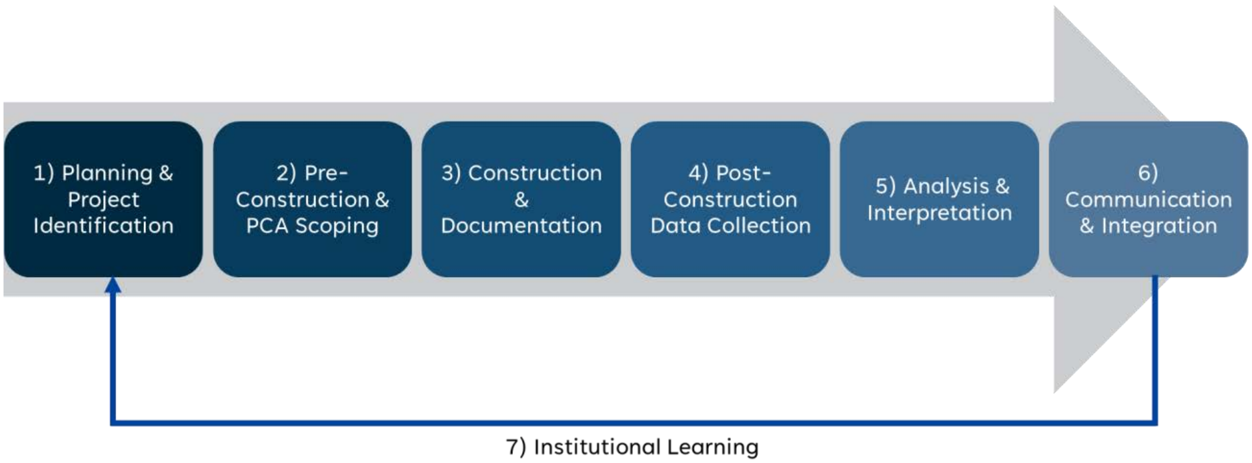

Figure 6. Project-level PCA workflow

1) Planning & Project Identification

The first step in the project-level workflow is determining whether a project should undergo PCA. This stage establishes the initial screening logic and ensures that PCA is applied intentionally rather than retroactively based on data availability. As projects enter the pipeline, they are screened based on their classification (e.g., Major, Mega, Regional, or other categories) and assessed for PCA eligibility. This screening results in one of three outcomes: PCA required, PCA optional, or PCA not recommended. For projects selected for inclusion, a PCA lead is recommended to be assigned and key stakeholders identified to ensure coordination throughout the project lifecycle. This step reflects an important principle identified in the NCHRP 08-170 research: not every project requires PCA. The value of PCA is greatest when projects are selected deliberately and early in the process, rather than added after construction solely because data happens to be available.

2) Pre-Construction & PCA Scoping

Once a project is identified for PCA, the next step is to define what will be evaluated and how the analysis will be structured. This scoping phase establishes the foundation for all downstream work and ensures that the evaluation approach is aligned with decision-making needs. The process begins by clarifying the purpose of the evaluation: whether it is intended to support accountability, validate forecasts, inform policy learning, improve analytical tools, etc. Based on that purpose, the appropriate evaluation approach and performance metrics are selected, spanning areas such as safety, mobility, cost, and asset condition. Relevant datasets are then identified, and key analytical parameters are defined, including baseline conditions, time windows, and comparison groups. Expected project outcomes are also documented at this stage to support later interpretation of results. The NCHRP 08-170 project findings emphasized that clearly defining the evaluation purpose early helps avoid a common pitfall: selecting metrics that are easy to measure but not necessarily meaningful for decision-making.

3) Construction & Documentation

During construction, the focus shifts from planning the evaluation to preserving the context needed to interpret it later. This step ensures that PCA results can be understood not just in terms of outcomes, but also in terms of how and why those outcomes occurred. Key information is documented throughout construction, including final scope details, as-built conditions, design exceptions, scope changes, and cost adjustments. External factors that may influence outcomes (e.g., shifting traffic patterns, policy changes, or major nearby events) are also recorded. At the same time, plans for post-construction data collection are confirmed, including timing, responsible parties, and where analysis materials will be maintained. The NCHRP 08-170 research highlights that these contextual factors often explain more variation in outcomes than the original project design itself, underscoring the importance of systematic documentation during delivery.

4) Post-Construction Data Collection

After construction is complete, the workflow transitions into assembling and validating the data needed for analysis. This step focuses on determining whether the available information is sufficient to support a credible evaluation. Outcome data are collected for the predefined metrics and time periods, followed by a structured validation process to assess completeness, consistency, and comparability. This includes checking whether data collection methods or definitions have changed since the pre-construction phase and confirming that metrics remain aligned across time periods. A key feature of this step is an explicit decision point: whether to proceed with analysis. If data limitations prevent reliable evaluation, those constraints are documented along with lessons learned and potential improvements for future iterations. The NCHRP 08-170 research supports the value of this “pause point,” which helps distinguish true performance outcomes from artifacts of data limitations.

5) Analysis & Interpretation

Once the data are validated, the analysis phase focuses on understanding what happened and why. This step involves applying the selected evaluation approach and comparing outcomes across relevant dimensions, such as pre- versus post-construction conditions, observed versus expected performance, or project performance relative to peers. Equally important is interpretation. Results are evaluated in the context of design and delivery decisions, external influences, and known data limitations. This ensures that findings are not viewed in isolation, but rather as part of a broader system of factors influencing performance. The NCHRP 08-170 findings emphasized that greater analytical complexity does not necessarily lead to better decision-making outcomes. In many cases, clarity and interpretability are more valuable than methodological sophistication alone. Additional detail on analytical methods is provided in *The PCA Workflow in Practice* section of this report.

6) Communication & Integration

The penultimate step in the project-level workflow is translating findings into decisions and action. This begins with preparing tailored internal briefings that align with the needs of different audiences and reflect the original purpose of the PCA. At this point, a decision is also made regarding external communication (whether or not to do so). At this stage, it is important to ensure that messaging (internal or external) is appropriate and consistent with how results are intended to be used. Findings are then integrated into relevant planning tools, forecasts, and prioritization processes so that PCA directly informs future decision-making rather than remaining a standalone evaluation exercise. The NCHRP 08-170 research reinforces that PCA is most effective when results are framed around the decisions they support, rather than presented solely as performance summaries.

7) Institutional Learning

The final element of the workflow focuses on ensuring that PCA contributes to long-term organizational learning. Rather than treating each project as an isolated evaluation, this step emphasizes the accumulation and application of insights across multiple projects over time. Ongoing practices include maintaining a centralized PCA project library, periodically reviewing and refining metrics and methods, updating guidance and templates, and tracking implementation challenges as they arise. Over time, these activities support the development of best practices that strengthen the overall PCA approach. NCHRP 08-170 findings highlight a key principle: the primary long-term value of PCA is not individual project results, but institutional learning that improves how future projects are planned, delivered, and evaluated.

Addressing Common Barriers & Risks

Experience from WisDOT and national research (NCHRP 08-170) suggests that the primary challenges to implementing PCA are organizational rather than technical. In many cases, the underlying data, analytical tools, and methods needed to support PCA already exist. However, conducting PCA consistently requires dedicated time, coordination across divisions, and staff capacity to assemble, interpret, and communicate results. Without intentional effort, PCA can remain an ad hoc activity rather than an institutionalized practice.

Much of this risk can be mitigated through early attention to the “Make the Case” and “Recruit Support” components of the enterprise-level framework. Establishing a clear purpose for PCA, identifying priority use cases, and securing leadership and staff buy-in can help ensure that PCA is viewed as a value-added activity rather than an additional burden. The implementation framework also includes strategies for adoption and buy-in that are intended to help WisDOT integrate PCA into existing workflows and decision-making processes. Additional guidance and resources are expected through the forthcoming NCHRP 08-170 final deliverables (expected in Summer 2026), which will provide further examples, tools, and lessons learned from agencies across the country. WisDOT may also draw from peer agency practices, such as Minnesota DOT’s Corridors of Commerce program or Virginia’s Office of Intermodal Planning and Investment (OIPI) Smart Scale process, which demonstrates more standardized, non-ad hoc approaches to PCA.

Beyond organizational buy-in, several additional risks may affect PCA implementation over the life of a project or program, including the following.

- **Changing priorities.** Administrative, policy, or political priorities may shift between project planning, construction, and post-construction evaluation. These changes can affect the relevance of originally defined PCA objectives or the willingness to dedicate resources to analysis. Clear documentation of evaluation intent and periodic check-ins can help maintain alignment or appropriately recalibrate expectations.
- **Changes in data collection practices.** Modifications to what data are collected, how they are collected, or when they are collected can complicate baseline comparisons and trend analysis. The framework emphasizes early identification of data sources and documentation of assumptions so that changes in data practices can be acknowledged and addressed transparently.
- **Staff turnover and expertise.** PCA often relies on institutional knowledge related to project context, data systems, and analytical methods. Staff turnover can disrupt continuity if processes and assumptions are not well documented. The framework encourages the use of standardized documentation, templates, and clear role definitions, as well as training and knowledge-sharing practices, to reduce reliance on individual staff members.

- **Resource constraints.** Limited staff time and analytical capacity may restrict the scope or depth of PCA, particularly for smaller projects. The framework is intentionally designed to support proportional application, allowing PCA scope to be scaled based on project significance and available resources.
- **Inconsistent project documentation.** Variability in how project scope, assumptions, and external factors are recorded can limit comparability across projects and over time. Emphasizing structured documentation of as-built conditions and contextual factors can help mitigate this risk.
- **External or extenuating circumstances.** Events such as economic shifts, major network changes, or public health emergencies (e.g., COVID-19) may affect observed outcomes or delay post-construction data collection. The framework recognizes these limitations and emphasizes documenting context and uncertainty rather than excluding such projects from analysis entirely.

Overall, the PCA framework (enterprise- and project-level) is designed to acknowledge these risks upfront, and to provide practical mechanisms for managing them. By emphasizing transparency, flexibility, and documentation, the framework supports meaningful evaluation even when conditions are less than ideal.

Applying the Framework Retroactively

While the enterprise-level components of the PCA framework are intended to guide prospective implementation, elements of the project-level workflow can still be applied to projects that have already been completed or that were initiated prior to adoption of the framework. For these projects, PCA activities will necessarily be retrospective and adapted to existing conditions rather than fully integrated into the project development process.

Retroactive application of the framework focuses primarily on clarifying the purpose of the PCA, such as identifying the questions to be answered, the outcomes of interest, and the intended use of results, and aligning available data to those objectives. Several project-level steps, including scoping the analysis, defining baselines, documenting context, and interpreting outcomes, can still be applied in a structured manner even when data collection was not planned in advance.

The scope and rigor of retroactive PCA will be constrained by the availability, quality, and comparability of existing data, particularly for pre-construction conditions and early post-construction periods. In these cases, the framework emphasizes transparency regarding data limitations and encourages the use of proxy measures or qualitative context where appropriate, rather than attempting to recreate unavailable information. Examples of retroactive application of the PCA framework are detailed in Insights from Sample Evaluations. These examples are intended to demonstrate how the framework can be used pragmatically with existing datasets while also highlighting opportunities to improve data readiness and documentation for future projects.

THE PCA WORKFLOW IN PRACTICE

In this section, the project-level workflow is translated into an applied, step-by-step process for evaluating project outcomes using WisDOT's existing data environment. It brings together the available data sources, recommended performance measures, and evaluation methods into a coherent workflow that can be consistently applied across Major, Mega, and Regionally Significant projects. Rather than introducing new systems or overly complex procedures, this section focuses on how existing tools and datasets can be structured and used to generate meaningful, comparable before-and-after insights that support decision-making and continuous improvement.

Data Foundation for PCA

PCA at WisDOT is supported by a broad set of existing datasets that collectively describe system conditions, project delivery, and performance outcomes over time. These data are distributed across multiple systems rather than housed in a single platform, with Meta-Manager serving as the primary data backbone. It integrates information on roadway characteristics, traffic, safety, pavement, and programmed improvements within a common segmentation framework. This is supplemented by additional sources, including traffic counts, detailed crash records, project-level data, probe-based travel time data (NPMRDS), and national bridge condition data (NBI). Together, these datasets provide a multimodal view of performance across safety, mobility, and asset condition, enabling before-and-after comparisons at the corridor level. A summarized list of key datasets and their roles in PCA is provided below (Table 10).

Table 10. Key Data Sources Supporting PCA at WisDOT

Data Source	**Time-frame**	**Primary Content**	**Role in PCA**
Meta-Manager	2013-current	Integrated roadway, traffic, safety, pavement, bridge, and project data by segment (PDP_ID)	Core analytical dataset; supports safety, mobility, and preservation metrics and corridor-level aggregation
Traffic Counts	Ongoing	Continuous and short-duration counts (AADT, hourly volumes)	Supports traffic exposure, throughput, and validation of modeled volumes
Crash	2013-	Detailed crash records (location, severity, conditions, contributing	Underlies safety performance metrics and supports validation beyond aggregated

Data Source	Time-frame	Primary Content	Role in PCA
Data	2024	factors)	summaries
Project Data	2015-present	Project scope, cost, schedule, geometry, and delivery information	Defines project limits, timing, and context for interpreting outcomes
NPMRDS	2017-2025	Probe-based travel speeds and travel times (15-minute intervals)	Supports corridor-level mobility and reliability metrics (travel time, delay, peak performance)
NBI	1993-2025	Bridge condition ratings, characteristics, and inspection data	Provides consistent and comprehensive bridge condition metrics for preservation analysis

While the available data are robust, they are not immediately analysis-ready. A key challenge is that Meta-Manager segmentation changes over time, making it difficult to track individual roadway segments longitudinally. As a result, PCA relies on a corridor-based approach, where project influence areas are spatially defined and reconstructed independently for each year of analysis. In practice, this involves identifying relevant segments within a project corridor, extracting corresponding data for each year, and aggregating results using length-weighted averages. This approach ensures consistency over time despite evolving network definitions and data structures. For mobility analysis, probe-based travel time data (NPMRDS) are similarly aggregated to the corridor level, allowing for consistent evaluation of travel time, delay, and reliability.

Several data limitations should be considered when interpreting PCA results. First, completeness varies across datasets; for example, certain pavement, bridge, and mobility attributes contain nontrivial gaps depending on location and asset type. Second, safety data in Meta-Manager are reported using rolling multi-year windows, which can complicate year-to-year comparisons and limit the ability to isolate short-term effects unless the underlying by-year data is extracted and analyzed. Additionally, some inputs required for more rigorous evaluation methods, such as safety performance function (SPF) projections, are not currently available in Meta-Manager and may require proxies or supplemental data. Finally, differences in segmentation, data definitions, and processing methods over time can introduce variability that is not directly attributable to project performance.

These considerations reinforce the importance of interpreting PCA results within context and documenting assumptions, data limitations, and methodological choices. More detailed guidance on dataset-specific limitations and processing steps is provided in subsequent sections and supporting appendices.

Potential Performance Measures

Per the literature review, a wide variety of performance measures have been evaluated before/after construction. Of those reviewed PCA metrics, available WisDOT performance data would currently enable the calculation of twelve performance measures for most PCAs. Table 11 summarizes a set of metrics that are readily calculable today using currently available WisDOT attributes and data sources, along with their data sources and desired direction of performance.

It should be noted that this list reflects the current state of practice and the data attributes available at the time of writing this report; it is not intended as a fixed or exclusive set. WisDOT is continually advancing its performance measurement practices, and several of the metrics shown here are expected to evolve in the near term. For example, WisDOT is transitioning from crash-rate-based safety measures toward Safety Performance Functions (SPFs) and other predictive methods, and from PCI/IRI toward a composite Pavement Quality Index (PQI) as WisDOT's Geospatial Asset Management Application (GAMA) and other systems mature. The PCA framework described in this report is intentionally metric-agnostic: the workflow, screening logic, project-influence-area construction, apportionment, and noise adjustment steps do not depend on any specific performance measure, so new or replacement metrics can be substituted as they become available without disrupting the framework itself.

Table 11. Potential Set of Metrics for WisDOT PCA

Metric	What it Measures	Data Source	Desired Direction
Total Crashes	Total crash frequency (5-year)	Meta-Manager (Safety)	Lower
Fatal and Serious Injury Crashes	Fatal + serious injury crashes (5-year)	Meta-Manager (Safety)	Lower
Annual Crashes	Total crashes (1-year)	Meta-Manager (Safety)	Lower
Crash Rate	Crashes per 100 million vehicle miles traveled (5-year rolling)	Meta-Manager (Safety)	Lower
PCI	Overall pavement condition (0–100 index)	Meta-Manager (Pavement)	Higher
IRI	Pavement smoothness (in/mi)	Meta-Manager (Pavement)	Lower
Bridge State of Repair Percent Deck Area	Percent of deck area within project area that is good, fair, and poor	NBI	Higher (Percent Good)
LOS	Traffic operating conditions (1-6 index)	Meta-Manager (Mobility)	Lower
AADT	Traffic demand / throughput (vehicles/day)	Meta-Manager (Roadway)	Context-dependent
Median Travel Time	Corridor travel time (minutes) per trip	NPMRDS	Lower

Peak Travel Time	Peak-period travel time (minutes) per trip (AM & PM)	NPMRDS	Lower
Delay	Additional travel time above free-flow conditions (minutes) per trip	NPMRDS	Lower

While these core metrics provide a strong foundation for evaluating project outcomes, stakeholder discussions during this study highlighted additional areas of interest that are not yet fully supported by existing statewide datasets. In particular, WisDOT staff expressed interest in understanding environmental outcomes, especially changes in air quality or emissions associated with transportation investments.

Direct measurement of corridor-level emissions is not currently part of WisDOT's standard data environment, and air quality monitoring data are typically sparse, geographically aggregated, or not directly attributable to individual roadway projects. However, emissions can be reasonably estimated using established relationships between vehicle operating conditions (particularly speed, volume, and vehicle mix) and emission rates derived from national modeling tools (e.g., MOVES-based rate structures). In practice, emissions-based PCA metrics can be approximated by combining:

- Traffic demand and exposure data (e.g., AADT, vehicle miles traveled),
- Operating conditions (e.g., speed profiles derived from NPMRDS or modeled travel times),
- Vehicle composition assumptions (e.g., proportion of heavy-duty trucks), and
- Emission rate functions by speed and vehicle type.

A corridor-based application of this approach can be used to estimate changes in pollutants (e.g., NOx, PM2.5) and greenhouse gas emissions (CO_2) between pre- and post-construction conditions. The general method involves estimating vehicle activity over time, translating operating speeds into emission rates, and aggregating total emissions over a defined post-construction analysis period. This type of approach was successfully applied in comparable work in other states (e.g., Connecticut DOT), where emissions were estimated by integrating roadway performance data with speed-dependent emission factors. The resulting outputs provide approximate but policy-relevant indicators of environmental change associated with transportation investments.

Within WisDOT's PCA framework, emissions estimation should be considered an **optional or supplemental performance dimension**, rather than a core metric category at this time. It is best suited for:

- High-impact capacity projects with expected system-wide traffic shifts.
- Projects with strong public or environmental interest, and
- Corridor-level analyses where speed and volume changes are substantial and well-documented.

Importantly, these estimates should be interpreted as model-based approximations, not direct measurements of air quality conditions. Their primary value lies in supporting directional comparisons (e.g., relative increases or decreases in emissions due to changes in congestion, speed, or travel demand), rather than precise quantification of environmental exposure. As WisDOT's data infrastructure and modeling capabilities evolve, particularly with improved integration of speed, traffic, and vehicle classification data, emissions-based PCA metrics could be formalized into a more standardized and automated component of the framework.

Evaluation Methodology

This section outlines the step-by-step process used to translate raw data into consistent before-and-after performance insights. Figure 7 illustrates the overall process, from selecting the general approach and projects to conducting the analysis and interpreting results. The subsections that follow walk through each step in detail, providing practical guidance on how to apply the methodology in a repeatable and transparent manner across projects.

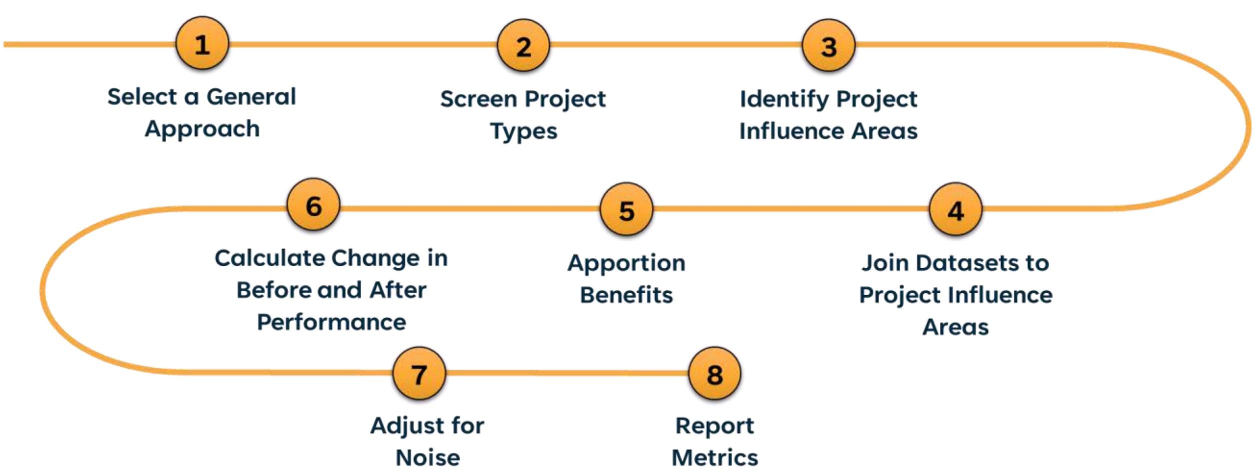

Figure 7. Evaluation methodology flowchart

1) Select a General Approach

Based on the literature review, there are two general approaches to evaluating performance post-construction (Figure 1):

- **With vs. Without:** This involves comparing two sets of data (a control group and an experimental group) with similar characteristics except for the historical improvement being investigated. This method can use cross-sectional (snapshot-in-time) data spanning multiple locations.
- **Before and After:** This approach assesses performance before and after improvement. It uses longitudinal (time-varying) data tracked for a defined location.

With longitudinal data available for Mega, Major, and Regionally Significant projects, the before and after general approach is recommended.

2) Screen Projects

Not all project types will impact all metrics. As such, it is important to evaluate project types only for those metrics for which a benefit or disbenefit could reasonably be expected. This step helps to distinguish causation from correlation. For example, a pavement reconstruction without adding capacity should not be given credit for reducing delays. Such a change may be the result of other projects or external noise from demographic/land use changes. It should also be noted that project impacts may not always be beneficial across all metrics. Oftentimes, there are inherent tradeoffs. For example,

- Added lanes could increase speeds that could correlate to more severe crash events.
- Reducing through lanes could reduce crashes, but as a tradeoff, could increase delay.

3) Identify Project Influence Areas

Project impacts can be far-reaching. In particular, project types that influence route and/or mode choices may have impacts that extend beyond their construction limits. This includes defining influence areas based on:

- **Upstream/Downstream effects -** removing a bottleneck can reduce queueing upstream of the improved area, and/or potentially increase queuing at a downstream bottleneck.
- **Impacted alternative routes** – alternative paths serving the primary origin-destination pairs flowing through the project limits can be impacted due to routing changes brought about by construction.

However, the final influence areas must also be adjusted to align with available roadway segmentation in Meta-Manager, coverage of any supplemental datasets, and consistency of data across analysis years. This will likely result in influence areas that prioritize data consistency and analytical feasibility over theoretical completeness. While this approach may underrepresent some broader network effects, it ensures that calculated metrics are comparable across time. The need for this refinement highlights a key consideration for future PCA applications: influence areas must balance conceptual accuracy with data availability and consistency.

4) Join Datasets to the Project Influence Area

To be able to calculate before and after performance measures for the projects being evaluated under PCA, the prerequisite data must be joined to the project influence areas, either tabularly or spatially.

- **Tabular** joins match records from different data sources based on one or more conditions. The simplest tabular joins rely on matching the values in a single data field, such as the segment IDs within Meta-Manager.
- **Spatial** joins match records from different spatial data sources based on their locations relative to one another. There are some common ways to spatially join data:
  - **Intersect:** Joins features that share any portion of space (e.g., a roadway segment overlapping with a project influence area).
  - **Contain/Within:** Joins features where one feature fully contains or is contained by another (e.g., a crash point within a project influence area).
  - **Nearest:** Joins each feature to the closest feature from another layer based on distance (e.g., assigning a roadway segment to the nearest traffic count station).
  - **Touch/Boundary:** Joins features that share a boundary or edge (e.g., connecting adjacent Traffic Analysis Zones).

There are other methods of spatially joining datasets, including combining methods or customizing with buffers, limits, etc.

Additionally, joins can produce different types of relationships between records depending on how the data aligns:

- **One-to-one:** Each record in one dataset matches with only one record in the other (e.g., linking project IDs to unique project attributes).
- **One-to-many:** A single record in one dataset matches multiple records in another (e.g., one roadway segment linked to several crash records).
- **Many-to-many:** Multiple records in each dataset match with multiple records in the other (e.g., roadway segments that intersect multiple projects, with projects spanning multiple roadway segments).

Datasets within Meta-Manager can be tabularly joined based on matching segment ID (within the same year only). Many of these tabular joins will result in one-to-one relationships. However, project data and bridge data from NBI must be spatially joined. Care must be taken to reconcile any differences in linear referencing systems between datasets or historically over time when tabularly joining datasets. For spatial joins, care must be taken when snapping data around overpasses and underpasses or other access-controlled intersecting linework.

5) Apportion Benefits

When multiple project influence areas overlap, benefits need to be split proportionally based on each project's relative influence. Many Mega, Major, and Regionally Significant projects are part of a larger suite of projects in the same region over a long period of time. These other projects need to be identified so that benefits can be apportioned specifically to the project being evaluated. With this in mind, isolating the benefits of each overlapping project can be a challenge. However, this can be done by i) imputing the expected impacts of each overlapping project, then ii) applying ratios of those imputed impacts to apportion benefits to the individual projects:

- **Handling Partial Spatial Overlaps** (Figure 8):
    - **Segments:** Use a distance-weighted average of the benefits to the k nearest neighboring segments (for example the 3-nearest non-overlapping segments). Nearer segments can be assigned a greater weight through an inverse-distanced-squared function.
    - **Intersections/Interchanges:** Use an average benefit per entering vehicle across the (non-overlapping) legs of the intersection/interchange.
    - Apply the ratio of the imputed values above to the observed benefit of the overlapping area.
- **Handling Temporal Overlaps:**
    - **Not built in the same year** (Figure 9): Carry forward the relative proportions observed in the prior year to impute the benefits in the overlap year.
    - **Built in the same year:** Use the ratio of imputed values from the spatial overlap method directly.
- **Handling Complete Overlaps:** If one project is entirely overlapped by another, segment ratios and spatial methods can't be used. Instead, apply the ratio of project-type averages from the broader system—using locations where no overlaps occurred—to apportion benefits fairly. This

would require results from past PCAs of those project types, hence the importance of continuously building a library of projects and data.

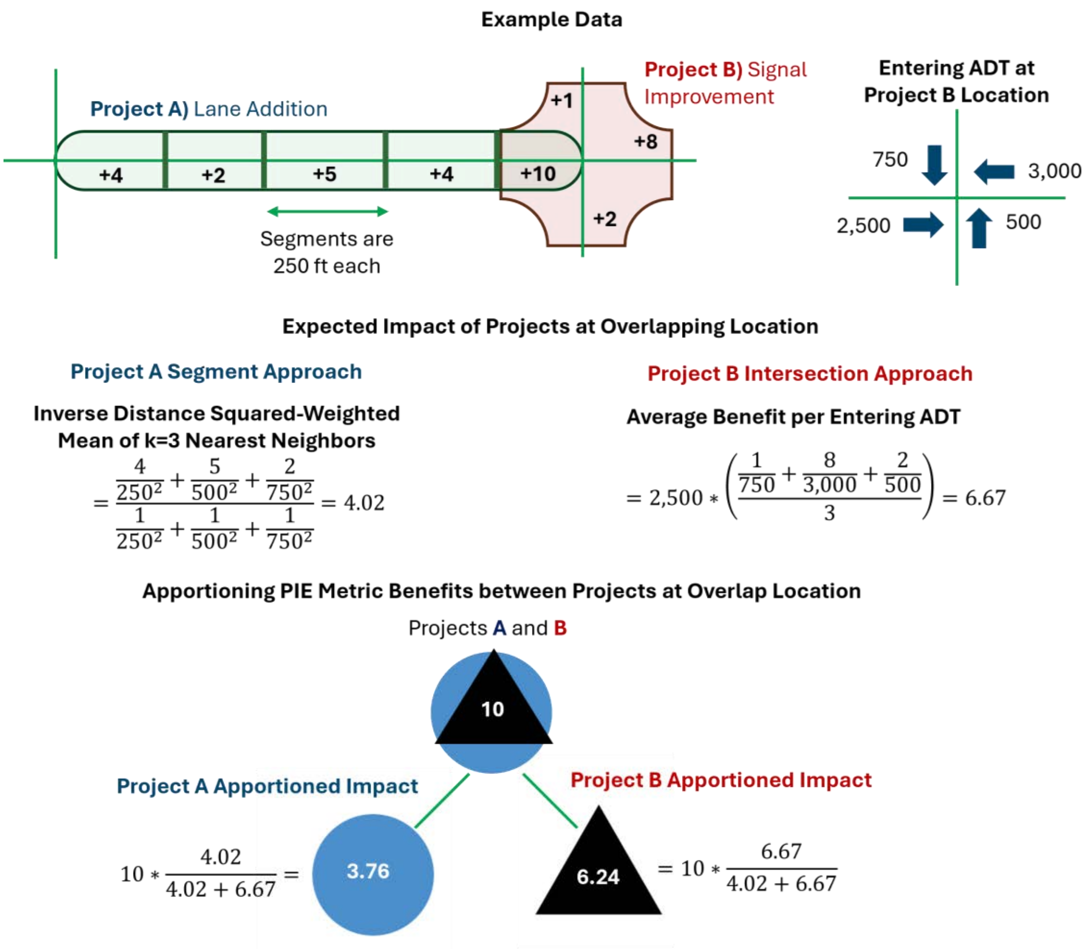

Figure 8. Example apportionment of benefits at overlapping project influence area location (Source: NCHRP 08-170 Guidebook)

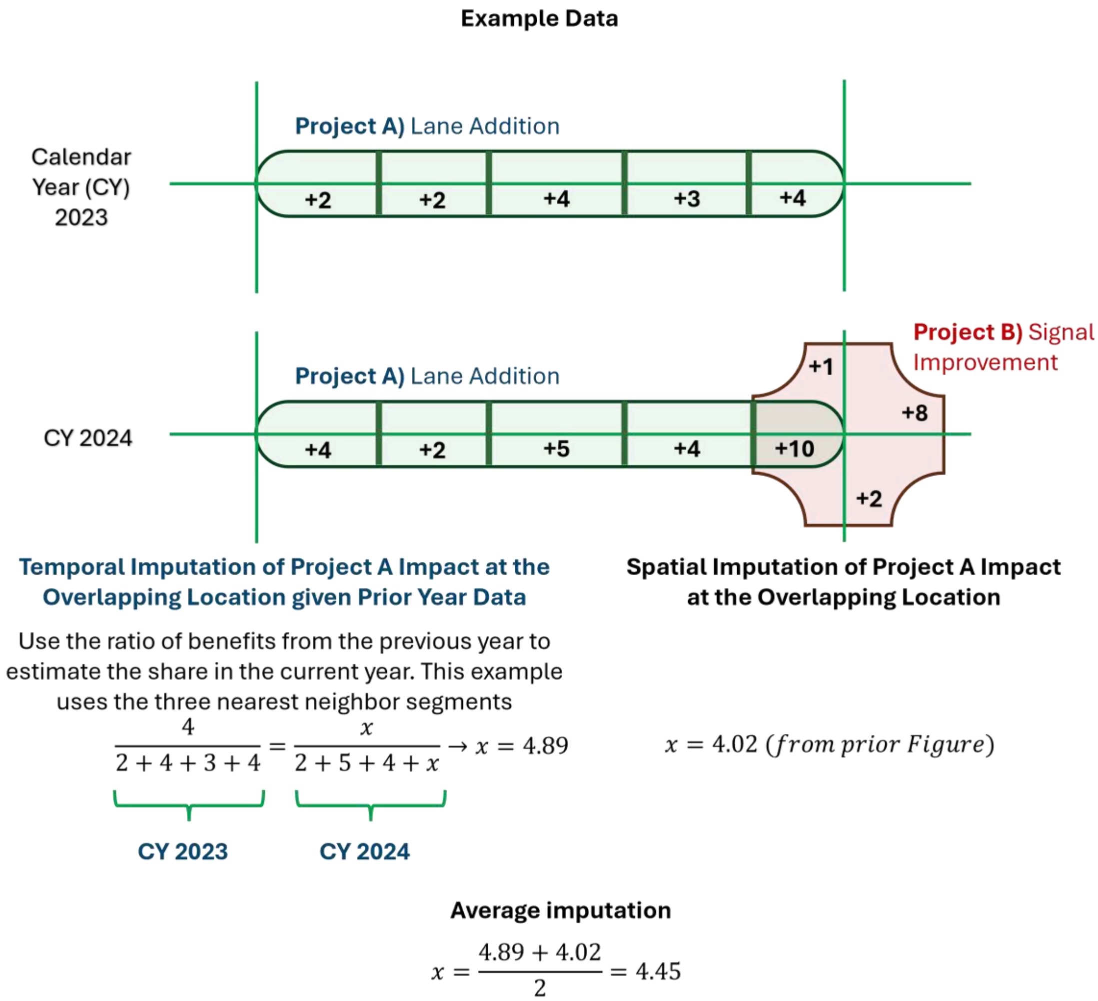

Figure 9. Example blending temporal/spatial imputation of values to guide apportionment (Source: NCHRP 08-170 Guidebook)

In some cases, screening of overlapping projects can be used to streamline or avoid detailed apportionment calculations. Projects that fall outside the defined before-and-after analysis window can be excluded from consideration, as they are unlikely to influence observed outcomes. Similarly, overlapping projects that do not affect the same performance measures as the project being evaluated may also be reasonably excluded. For example, a pavement resurfacing project with no expected mobility impacts may overlap spatially with a lane reconfiguration project that primarily affects traffic operations. Although these projects occur in the same location, their impacts do not meaningfully overlap, allowing them to be evaluated independently without additional adjustment.

6) Calculate Change Before and After Performance

Simple before and after values can be reported on a year-by-year basis and/or cumulatively over the benefit accrual window of a project post-construction via any of the following transformations:

- **Absolute Change:** The direct difference between before-and-after values (e.g., travel time reduced by 2.5 minutes).
- **Percent Change:** The proportional difference relative to the before values (e.g., a 15% reduction in delay).
- **Rate of Change:** The average annual rate of improvement or decline over the analysis period (e.g., the average pavement deterioration rate).
- **Index/Ratio:** The ratio of after to before values, showing relative improvement (e.g., 0.85 indicates a 15% improvement).
- **Normalized Change:** The change per unit of exposure or activity (e.g., reduction in crashes per lane-mile of rumble strip installation).

Selecting an appropriate reporting style for change is important for comparison with other projects and contextualization. For further clarity, this change may be directly reported with the context of any external 'noise.' Or additional steps can be taken to report a noise-adjusted change in performance (see next section). For initial PCA efforts, simple before-and-after transformations can be explored and used as data points for communicating how a project's influence area changed over time. However, it is recommended to adjust for noise for a more accurate portrayal of a project's true influence.

7) Adjust for Noise

Regardless of the methodology used, it is important to isolate the true impact of an investment by properly accounting for the influence of external factors. Three different types of 'noise cancellation' are most commonly used (adapted from NCHRP Project 08-170):

Regression Analysis – External factors that influence performance outcomes can be introduced as explanatory variables in a regression (or panel regression for multi-year datasets) model to support benefit attribution. The relative ratio of coefficients between the 'noise' term and the investment-related variable can explain the relative impact attributed to a type of project. This same ratio can be used to adjust observed project outcomes by proportionately 'backing out' the effect of an external factor. This apportionment is particularly critical when the 'noise' term works in the opposite direction of the investment. In some cases, external noise may adversely 'drown out' the effect of an investment, resulting in an observed net negative outcome. Yet this does not mean the investment did not have a positive effect from a counterfactual perspective (i.e., compared to how much worse performance would have been without the investment).

Comparative Analysis – Another way to control for noise is to group projects into categories that reflect the type of external conditions they experienced. By placing before-and-after results into “buckets” such as significant decline, slight decline, slight increase, or significant increase, it becomes easier to see how much outside factors—like a change in VMT from population growth—may have shaped the observed outcomes. Larger sample sizes strengthen confidence in these comparisons. These samples would come from the library of projects and data.

Such statistics can also be used for simple corrections. For example, if a pavement preservation project happened to occur in a corridor with significantly increasing VMT, its measured effectiveness might appear lower than expected. By comparing it to projects in more stable conditions, we can estimate that its performance would likely have been about 12 units higher had traffic volumes not been rising so rapidly (Figure 10).

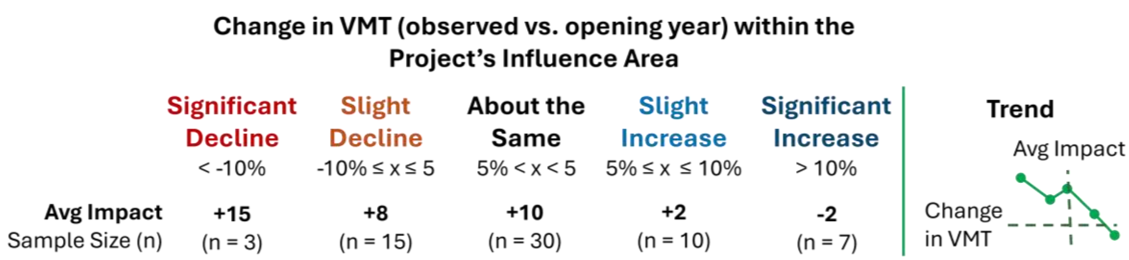

Figure 10. Representative example of comparative before/after data (Source: NCHRP 08-170 Guidebook)

Bayesian Methods – The **rigorous before-and-after analysis** method commonly applied for calibrating crash modification factors is both the most complex and most accurate way to capture a project’s true impact. This Empirical Bayes (EB) approach helps mitigate the potential bias introduced by a location reverting to the mean post-implementation—that is, an observed impact may be due to a natural tendency toward an average state rather than the true impact of an intervention. For instance, imagine a baseball player struggling at the plate decides to try new batting gloves and all of a sudden sees immediate improvement. Was this improvement due to the gloves or just a natural movement toward a mean, as their cold streak was never going to last forever? By accounting for such variability, a more accurate before-and-after project evaluation can be made.

For WisDOT, the latter noise cancellation technique is recommended. The EB Method (i.e., rigorous before and after analysis) controls for noise by comparing predictions as a function of external factors before and after a project via the steps detailed below. The following data inputs are necessary:

- $Predicted_{Before}$ = model-estimated performance during the before period

- $Predicted_{After}$ = model-estimated performance during the after period, assuming a no-build scenario
- w = a goodness-of-fit-based weight for the prediction model. Note that when combining multiple facility types, the weight calculation needs to be adjusted by taking the sum-product of overdispersion parameters and squared before predictions, then average the resulting weight factors with a correlation term.
- $Observed_{Before}$ = observed/measured performance during the before period
- $Observed_{After}$ = observed/measured performance during the after period

Step 1) Establish a *noise adjustment ratio* to account for variations between the before and after periods.

Equation 1

$$Noise\ Adjustment\ Ratio = \frac{Predicted_{After}}{Predicted_{Before}}$$

Step 2) Calculate *expected before and after* outcomes by blending predictions with observed outcomes.

Equation 2

$$Expected_{Before} = w * Predicted_{Before} + (1 - w) * Observed_{Before}$$

The value of *w* reflects how much confidence we place in the prediction model relative to the observed data, based on how well the model has performed in past projects. It is calculated by comparing predicted versus observed outcomes across a library of completed projects of the same type; for example, how closely predicted pavement smoothness improvements matched what was actually measured after construction. If the predictions consistently align with observed results, *w* will be higher, meaning more weight is given to the model's prediction. If past analyses show larger discrepancies, *w* will be lower, giving more influence on the observed data. Building and maintaining a repository of post-construction analyses is therefore critical, as it provides the empirical foundation for estimating w and improving the accuracy of future before-and-after evaluations. In cases where a repository does not yet exist or includes only a small sample of projects, *w* can be estimated for probabilistic models using the overdispersion parameter or approximated using engineering judgment, insights from subject matter experts, or values drawn from past research or similar studies.

Once the expected before value is calculated, the expected after value can be calculated:

Equation 3

$$Expected_{After} = Noise\ Adjustment\ Ratio * Expected_{Before}$$

Step 3) Mitigate the risk of observed outcomes being a 'natural' reversion to the mean by calculating *odds ratios* that reflect the variance of the dataset relative to the prediction.

Equation 4

$$Biased\ Odds\ Ratio = \frac{Observed_{After}}{Expected_{After}}$$

Equation 5

$$Unbiased\ Odds\ Ratio = \frac{Biased\ Odds\ Ratio}{1 + \frac{Noise\ Adjustment\ Ratio^2 * Expected_{Before} * (1-w)}{Expected_{After}{}^2}}$$

Step 4) Report the estimated project impact after correcting for noise and reversion to the mean.

Equation 6

$$\%\ Project\ Impact\ Observed = 100 * (1 - Unbiased\ Odds\ Ratio)$$

In this formulation, the 'After' predictions refer to a no-build state but with updated estimates based on explanatory factors like changes in AADT. More complex formulations are needed for projects that integrate multiple predictive models (e.g., models for different facility types when a project improves multiple facility types). In these cases, it may be desirable to split projects into smaller influence areas.

To implement the rigorous before-and-after approach for WisDOT, pre-implementation predictions would be needed for the evaluation metrics. These can come from predictive models or rely on simplified assumptions. Meta-Manager already includes predictive metrics for mobility and preservation. The benefit of this more rigorous approach is that PCA efforts can more effectively control for any natural regression-to-the-mean.

8) Report Metrics

Results from the PCAs are recommended to be reported and visualized from two perspectives.

- **Raw observations of metrics before-and-after construction:** The exact number of years for the 'after' observations would be based on project type/scope and available data. For instance, larger mobility projects typically need upwards of 3-5 years for impacts to coalesce, and WisDOT prefers to have a minimum of 3 years for safety evaluations. Observed metrics may be reported in tables or graphics, such as a raw change heat map.

- **The change that can be attributed to the project itself after correction for noise and apportionment:** Noise and apportionment corrections, as discussed above, rely on available data. These adjusted results isolate the true effect of the project by removing background trends (such as regional traffic growth or systemwide safety improvements) and distributing overlapping benefits among related projects. The resulting "net impact" provides a more reliable basis for comparing project performance across types, time periods, and locations.

Moving forward with these two perspectives, a dashboard could be prepared to enable exploration of PCA results across regions or projects. It is recommended that results are aggregated by project type so that, as a sufficient sample size of projects grows, typical results by project type can be reported. This would allow for iterative feedback and improvement of prediction models.

Additionally, results could be characterized into buckets (e.g., about the same, slightly better, way better, etc.), rather than reported as exact numbers. Reporting results in broader categories rather than exact figures helps emphasize overall patterns and directional outcomes, rather than small numeric differences that may fall within normal variation. This approach also reduces the risk of misinterpretation by audiences less familiar with the analytical methods, keeping the focus on the scale and consistency of project impacts rather than on precise, but potentially misleading, point estimates.

INSIGHTS FROM SAMPLE EVALUATIONS

The recommended before-and-after approach outlined in the previous section was successfully applied across three sample projects as a proof-of-concept PCA for WisDOT:

1) **I-94 North/South Corridor:** A 22-mile segment between WIS 142 and W College Ave was expanded from six to eight lanes between 2018 and 2020. The project included capacity expansion along with safety and geometric design improvements.

2) **US 51 Two-way-left-turn-lane (TWLTL) in Beloit:** In 2019, this four-lane arterial was reconfigured into a two-lane roadway with a center two-way left turn lane to improve access management and safety.

3) **I-41 & US 10 Interchange Reconstruction:** Completed in 2018, this project reconfigured interchange ramps and introduced a new northbound-to-westbound connection that did not previously exist, improving connectivity and traffic flow.

The availability of longitudinal data within Meta-Manager and NPMRDS supported multi-year trend analysis, allowing performance to be evaluated both prior to and following project completion. The analyses relied on trend-based comparisons over time as well as noise-adjusted comparisons between specific before-and-after years. As none of these sample projects had anticipated bridge condition impacts, the bridge metric was excluded from analysis. Overall successes and challenges from the sample evaluations are summarized in Table 12.

Table 12. Summary of Successes and Challenges from Sample Project Evaluations

Successes	Challenges
Significant mobility gains for the I-94 North/South and I-41/US 10 Interchange projects	**Safety-mobility tradeoffs** seen in both I-94 North/South and US 51 TWLTL projects
Major safety improvements for the US 51 TWLTL and I-41/US 10 Interchange projects	**Attribution complexity across evolving systems** – screening efforts found no overlapping projects likely to materially bias results
Substantial pavement condition recovery post-construction for all three projects	**Data and segmentation constraints** – non-static roadway segmentation required shift from segment-level to corridor-level analysis
Validated PCA methodology across real-world WisDOT data: • Consistent before/after framework successfully applied across all three projects • Trend-based evaluation proved robust despite data complexity	**Influence area and comparability tradeoffs** – boundaries shaped by data availability rather than full theoretical network effects

Because the purpose of the three sample projects was to demonstrate a proof-of-concept for PCA, and not necessarily to provide precise outcomes, the specific analysis details of each evaluation metric are not included herein. Overall, the three sample evaluation projects serve as a basis for further development of PCA for WisDOT. They can be used to help clarify goals, refine analysis methods and metrics, as well as provide examples for recruiting support for future PCA.

RESOURCES, CONSTRAINTS, AND OPPORTUNITIES

Table 1 summarizes the approximate hours required for each step based on the three sample project evaluations. These estimates reflect a largely manual workflow, in which datasets were independently extracted, processed, and analyzed for each project using a combination of tools, including R/RStudio, Excel, and ArcGIS Pro. The hours were also constrained by the consultant research team budget. As such, the reported effort should be interpreted as an approximate baseline. Actual effort for future applications may vary depending on project complexity, data availability, analyst skill level, data familiarity, and the level of process standardization and automation. The times also do not reflect internal communications, meetings, and dissemination that would occur within WisDOT or externally.

Table 13. PCA Time Requirements by Task and Sample Project

Task	**Estimated Time Required for Each Sample Project**			**Total Hours Required**
	I-94 North/South	US 51 TWLTL	I-41 & US 10	
Data acquisition	*This task was performed by WisDOT staff for the research team and was estimated to take 20-40 combined for all three projects.			
Data cleaning	20-40	15-30	15-30	50-100
Metric calculation	25-50	20-40	20-40	65-130
Documentation	15-30	10-20	10-20	35-70

From a staffing perspective, the sample evaluations suggest that PCA can be completed with a relatively small, interdisciplinary team. Recommended roles and responsibilities were outlined in Recruit Support. However, the sample evaluations showed that team skills and capabilities should include:

- Strong analysis skills for managing data processing and metric calculation in a repetitive and reproducible manner (e.g., using R or Python)
- GIS support to define project influence areas and perform spatial data integration
- Subject matter expertise to guide interpretation of results and confirm project intent

The evaluations also highlighted significant opportunities for automation and process improvement. A substantial portion of the effort was associated with repetitive tasks, including data extraction, spatial filtering, and metric calculation. Developing standardized scripts (e.g., in R or Python) for common workflows, such as joining datasets, aggregating corridor-level metrics, and generating outputs, could significantly reduce analysis time and improve consistency across projects. Similarly, establishing automated or semi-automated data pipelines from systems such as Meta-Manager and NPMRDS would streamline data acquisition and reduce manual handling. Prebuilt visualization templates or dashboards could further enhance efficiency by enabling consistent reporting and reducing the need for project-specific graphic development. While the current sample evaluations relied on project-specific scripts and manual processes, transitioning toward a more automated and standardized framework represents a key opportunity to support the scalable implementation of PCA across WisDOT projects.

KEY TAKEAWAYS AND NEXT STEPS

This study demonstrated that a practical, repeatable Post-Construction Analysis (PCA) framework is achievable using WisDOT's existing data systems. While technical challenges remain (particularly around evolving segmentation, data completeness, and attribution of project effects), the sample evaluations show that meaningful before-and-after insights can still be generated with a consistent, corridor-based approach. Importantly, the value of PCA is less about perfect analysis precision in every instance and more about establishing directionally-correct trends in a structured, transparent process that lends to learning from completed investments over time.

A key takeaway from both the analysis and WisDOT staff input is that the primary value of PCA is not just technical precision, but **consistent interpretation and communication of results**. A standardized methodology helps ensure that project outcomes are evaluated in a uniform way, reducing the risk of selective interpretation or "cherry-picked" results. As noted by staff, this consistency supports clearer and more defensible messaging about project performance and reduces ambiguity when communicating outcomes to leadership and the public.

It's also important to emphasize the value of PCA as a **low-cost analytical layer relative to overall project investment**, particularly for Major and Mega projects, where even modest improvements in evaluation consistency can significantly improve accountability. At the same time, PCA offers a way to validate or reconcile "quick estimates" made at the district or regional level, ensuring that informal or preliminary calculations can be reviewed within a consistent, centralized framework.

Another important insight is the value of **time and stability in observed outcomes**. Rather than relying on immediate post-opening impressions, PCA enables performance to be assessed using multi-year datasets, producing a more stable and representative picture of project impacts. While this improves analytical reliability, WisDOT should also recognize a practical challenge: leadership and stakeholders often expect immediate results, which may require careful framing of PCA as a longer-term learning tool rather than an instant reporting mechanism.

From a practical implementation standpoint, it is recommended that WisDOT begin with a phased approach. Early “ad-hoc” PCAs on simpler or well-understood projects can serve as a testing ground to refine data handling procedures, validate assumptions, and identify where analytical workflows are robust versus where they require adjustment. These early applications will also help clarify staffing needs, processing time, and data limitations while building internal familiarity with the process.

As these initial efforts are completed, WisDOT should systematically build a centralized library of PCA studies. This repository will be critical for identifying recurring patterns, improving consistency in methods, and refining performance measures over time. Over multiple iterations, this learning process will support the transition from isolated analyses to a scalable program.

Ultimately, the next step is to **transition from framework development to program development**. By following the enterprise-level PCA structure (starting with organizational alignment and progressing toward standardized metrics, repeatable workflows, and selective automation) WisDOT can incrementally institutionalize PCA as a core component of project delivery and performance management.

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APPENDIX: Catalog of Key Performance Indicators from Past PCAs from Peer Review

This appendix summarizes a wide range of key performance indicators (KPIs) that have been used in PCAs documented in past studies and practice examples. The list is organized into broad categories and subcategories for ease of reference. The KPIs are presented as examples drawn from the peer review; they should not be considered a complete or prescriptive set. The selection of appropriate KPIs for a specific project or program will depend on the project's goals, available data, and agency priorities.

Roads and Highways

Safety

- Change in total [or target] crashes
- Benefit-cost ratio
- Economic effectiveness as measured by cost per crash reduced
- Lives saved, injuries avoided, crashes prevented

Operations

- Hourly speed profiles during peak and off-peak conditions
- Travel time reliability
- Throughput
- Utilization (e.g., of the shoulder as a travel lane)
- Traffic density
- Delay, delay variability, and delay reliability
- Automated Traffic Signal Performance Measures (ATSPMs)
    - Green and red occupancy ratios
    - Arrival on green and arrival on red percentages
    - Split failure (and other failure) rates
- Critical gaps, post-encroachment times, headways, etc.
- Volume, capacity, and level of service

Mobility

- Congestion and traffic volume
- Duration of congestion
- Traffic mix
- Travel speeds
- Buffer time and delay

User Costs

- Travel cost
- In-vehicle and total travel time
- Travel distance

Demand Management

- Toll price changes
- Total trips per roadway type
- Travel mode choice
- Parking space choice
- Vehicle miles traveled
- Search time cruising
- Parking rule compliance
- Parking use efficiency
- GHG emissions reduction
- Program cost recovery
- Parking supply ratio
- Stakeholder perception/support

Active and Public Transportation

- Pedestrian/bicycle level of service
- Transit travel times and delay changes
- Crash rates
- Vehicle speeds
- Pedestrian/bicycle level of comfort
- Corridor automotive travel time
- Neighboring street volume/capacity
- Public support surveys
- Sales tax revenue over time
- Capital costs
- Headways, service hours, speeds
- Operating and maintenance costs
- Ridership
- Land use changes

Economic Development Impacts

- Jobs/job density
- Income
- Gross regional product
- Productivity
- Property values
- Competitiveness
- Quality of life
- Number of industries
- Volume of exported/imported goods
- Total number of annual tourists

- Population density
- Active transportation accessibility to stops
- Minimum travel time/distances to the nearest high-speed rail station
- Number of daily trains/buses
- Number of destinations reachable through direct high-speed rail service
- Change in land prices/valuation as demand grows for locations
- Change in property sales volume and prices as land is purchased for new/more intensive uses
- Change in the amount of construction spending
- Change in employment, associated wages, and total business sales
- Change in public sector tax revenues

Environmental Impacts

- EPA air quality measures (carbon monoxide, ozone, PM2.5, PM10, nitrogen oxides, sulfur dioxide, lead)
- GHG emissions
- Noise
- Water quality (total suspended solids, nitrogen, phosphorus, copper, zinc)

Equity

- Crash outcomes
- Perceptions of safety/comfort
- Sociodemographic profile of transportation users

Preservation

- Deterioration rates
- Pavement distresses
- National Bridge Index or element-level bridge rating data

Security

- Number of attacks (cyber)
- Data transmission rates
- Percent of traffic conflicts that could arise at intersections due to compromised detection

Project Delivery

- Projects per project manager
- Cost escalation pattern (proposed cost, engineer's assessment, design cost, engineer's estimate, letting cost, final cost)
- Number of scope changes